Technical Report

Breast Cancer Screening With Mammography: An Updated Decision Analysis for the U.S. Preventive Services Task Force

Prepared for:
Agency for Healthcare Research and Quality
U.S. Department of Health and Human Services
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AHRQ Publication No. 23-05303-EF-2
April 2024

Investigators worked with USPSTF members and Agency for Healthcare Research and Quality (AHRQ) staff to develop the scope, analytic framework, and key questions for this review. AHRQ had no role in study selection, quality assessment, or synthesis. AHRQ staff provided project oversight; reviewed the report to ensure that the analysis met methodological standards; and distributed the draft for peer review. Otherwise, AHRQ had no role in the conduct of the study, or collection, management, analysis, and interpretation of the data. The findings and conclusions in this document are those of the authors and do not reflect the official position of AHRQ, the National Cancer Institute, or the U.S. Department of Health and Human Services.

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Funding

This report is based on research conducted by the CISNET Breast Cancer Working Group under National Cancer Institute grant number U01 CA253911 and contract number HHSA290201500007I, Task Order 2 from AHRQ, U.S. Department of Health and Human Services.

The Breast Cancer Surveillance Consortium and its data collection activities are funded by grants from the National Cancer Institute (P01CA154292, U54CA163303), the Patient-Centered Outcomes Research Institute (PCS-1504-30370), and AHRQ (R01 HS018366-01A1). The collection of cancer and vital status data is supported in part by several state public health departments and cancer registries throughout the United States.

This work was also supported in part by National Cancer Institute grant number P30CA014520 and a Vilas Associates Award to Amy Trentham-Dietz. Jinani Jayasekera was supported by the Division of Intramural Research at the National Institute on Minority Health and Health Disparities of the National Institutes of Health, and the National Institutes of Health Distinguished Scholars Program (Grant Number: N/A).

None of the investigators have any affiliations or financial involvement that conflicts with the material presented in this report.

Acknowledgments

The authors gratefully acknowledge the following individuals for their contributions to this project: Tracy Wolff, MD, MPH, AHRQ Scientific Director for the U.S. Preventive Services Task Force Program; Howard Tracer, MD, AHRQ Medical Officer; Jillian Henderson, Elizabeth Webber, Heidi Nelson, and other members of the Kaiser Permanente EPC; members of the U.S. Preventive Services Task Force who contributed to the decision analysis workplan; Doug Owens, MD, MS (Stanford University), Ya-Chen Tina Shih, PhD (MD Anderson Cancer Center), Jennifer Croswell, MD, MPH (Healthcare Delivery Research Program, National Cancer Institute), Sarah M. Temkin, MD (Office of Research on Women's Health, National Institutes of Health), and an anonymous federal expert for their content expertise and review of the draft report; Julie McGregor, Jennie Martin, and Victoria Foster for project coordination; Linn Abraham and Thomas Lawler for assistance with data; and Amy Knudsen, Claudia Seguin, Barak Davidi, and Hannah Johnson for assistance with graphing.

Author's Contributions

Authors Chapman, Jayasekera, Lowry, and Miglioretti contributed equally to this report.

Suggested Citation

CISNET Breast Cancer Working Group. Breast Cancer Screening With Mammography: An Updated Decision Analysis for the U.S. Preventive Services Task Force. AHRQ Publication No. 23-05303-EF-2. Rockville, MD: Agency for Healthcare Research and Quality; 2024.

Structured Abstract

Importance: The U.S. Preventive Services Task Force (USPSTF) is updating its 2016 guidelines for screening mammography for breast cancer.

Objective: To provide the USPSTF with updated model-based estimates of the benefits and harms of breast cancer screening strategies that vary by the ages to begin and end screening, screening modality, and screening interval. Models estimated outcomes for the overall average-risk population of U.S. female persons and for groups of female persons based on Black race, breast density, elevated relative risk of breast cancer, and level of comorbidity.

Design: Comparative modeling using six microsimulation and analytic models that produce outcomes with and without breast cancer screening in a hypothetical cohort of average-risk U.S. 40-year-old female persons (all races) born in 1980 with no previous breast cancer diagnosis. Analyses were repeated for groups of female persons by Black race, breast density category, elevated risk, and comorbidity level.

Exposures: Screening from ages 40, 45, or 50 years until ages 74 or 79 years with digital mammography (DM) or digital breast tomosynthesis (DBT) annually or biennially or a hybrid combination of the two intervals. Screening strategies using DBT were evaluated in strata according to breast density categories and, separately, for modestly elevated risk levels of breast cancer (relative risk 1.5 and 2.0). Screening strategies with additional stopping ages (69 and 84) were evaluated for female persons older than 65 years according to four levels of comorbidity (none, low, moderate, severe). Full adherence with all screening was assumed, and all cases received immediate treatment regardless of the method of detection according to current treatment dissemination patterns in the United States.

Main Outcome and Measures: Estimated lifetime benefits (breast cancer deaths averted, percent reduction in breast cancer mortality, life-years gained [LYG], quality-adjusted life-years [QALYs] gained), harms (false-positive recalls, benign biopsies, overdiagnosis with overtreatment), number of screening tests, and the stage distribution of breast cancers for a cohort of 1,000 40-year-old female persons screened. Trade-offs of harm and benefit were evaluated through efficiency frontier plots and by calculating harm-to-benefit and benefit-to-harm ratios. Efficient (and near-efficient) strategies were those that required fewer mammograms (or similar) per LYG and per breast cancer mortality reduction relative to other strategies.

Results: Modeling identified five efficient screening strategies resulting in the highest breast cancer mortality reduction and LYG. Efficient strategies involved DBT and biennial screening (ages 50–74, 40–79, or 45–79), annual screening (ages 40–79), and a hybrid combination of intervals (annual at ages 40–49 with biennial at ages 50–79). Across all models for a cohort of 1,000 average-risk 40-year-old female persons including all races, estimated median breast cancer mortality reduction across these five DBT efficient screening strategies compared to no screening ranged from 25.4% to 41.7%, LYG ranged from 120.8 to 229.7, deaths averted ranged from 6.7 to 11.5, lifetime number of mammograms ranged from 11,208 to 34,441, median false-positive recalls ranged from 873 to 2,224, and the number of overdiagnosed cases ranged from 12 to 25.

Four models of breast cancer in Black female persons identified three efficient DBT screening strategies, two with biennial (ages 40–79 or 45–79) and one with annual (ages 40–79) screening. Across the four models for a cohort of 1,000 average-risk Black female persons, estimated median breast cancer mortality reduction across these three efficient screening strategies compared to no screening ranged from 31.2% to 39.6%, LYG ranged from 219.4 to 309.0, deaths averted ranged from 11.7 to 15.5, lifetime number of mammograms ranged from 14,755 to 33,577, false-positive recalls ranged from 1,107 to 2,074, and the number of overdiagnosed cases ranged from 20 to 25. Breast cancer mortality disparities for Black female persons persisted if all female persons obtained mammography with the same screening strategy. More intensive screening for Black female persons (e.g., biennial ages 40 or 45 to 79 with female persons overall screened at ages 50–74) could reduce the elevated disparity in breast cancer mortality rates from 42% to 30%.

Compared with DM, DBT resulted in fewer false-positive recalls, with minimal or modest improvements in mortality for female persons overall and for Black female persons. No DM strategies were efficient or near-efficient in most models for female persons overall or for Black female persons.

When models estimated screening outcomes for female persons with greater breast cancer risk, due to either more dense breast tissue or other risk factors such as a first-degree family history of breast cancer, trade-offs in the benefits and harms of screening improved. Trade-offs were also superior for female persons with a lower comorbidity burden.

Limitations: To isolate the benefits of screening, all modeled scenarios assumed 100% screening adherence and prompt evaluation of abnormal screening results, which may overestimate the benefit of screening compared to real world implementation. Relative performance of compared strategies might change if adherence or evaluation patterns differ by age, race, or screening frequency. We did not consider imaging modalities besides mammography, individuals at high risk of breast cancer due to genetic susceptibility, or potential risk of breast cancer due to screening-related radiation. Model projections were based on a 1980 U.S. birth cohort with current screening performance and treatment effectiveness assumed for breast cancer diagnosed in the future.

Conclusions: This collaborative modeling analysis suggests that several mammography screening strategies reduce breast cancer mortality and increase life expectancy in average-risk female persons. Strategies with biennial screening, start ages at 40 or 45, and cessation age at 79 resulted in greater incremental gains in mortality reduction per mammogram compared with most strategies involving annual screening, start age at 50, and/or cessation age at 74. For some groups of female persons with higher risk of breast cancer and breast cancer death, more intensive screening can maintain similar benefit-to-harm trade-offs and reduce mortality disparities.

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Chapter 1. Introduction

The benefits of screening mammography were first demonstrated over 30 years ago.[1] As breast cancer screening technology and treatment improve, screening guidelines need to reflect currently available evidence for breast cancer screening performance, treatment effectiveness, and the roles of other factors that impact breast cancer risk and survival. Updated screening guidelines hold promise for improving the balance of harms and benefits of breast cancer screening for more individuals.

Mammography has been the standard of care for breast cancer screening in the United States since the 1980s, and mammography technology has continued to evolve since its early adoption. Digital mammography (DM) largely replaced film-screen mammography in the United States in the early 2000s, and in the past decade mammogram modality has been rapidly transitioning from DM to digital breast tomosynthesis (DBT). As of February 1, 2024, 89% (7,900/8,862) of Mammography Quality Standards Act (MQSA)-certified facilities in the United States were accredited to perform DBT.[2] Studies of DBT performance in U.S. screening settings have demonstrated improved recall rates (fewer examinations with recommended additional work-up) and cancer detection rates with DBT versus DM,[3,4] although interval cancer rates are similar.[5,6] Recently, a large cohort study comparing DBT to DM found a lower risk of advanced cancer with DBT among patients with extremely dense breasts and at high risk of breast cancer.[6]

In 2016, the U.S. Preventive Services Task Force (USPSTF) recommended biennial screening mammography at ages 50 to 74 years with clinical recommendations for discussion between patients and their providers about individual risks and preferences for starting screening prior to age 50 years.[7] Many person-level factors are known to impact the benefit and harm trade-offs of screening mammography, and these factors arise during conversations between patients and clinicians. Female persons with a family history of breast cancer or other modest breast cancer risk factors likely experience greater screening benefits than patients without these risk factors. Individuals with dense breasts are known to have greater risk for breast cancer overall and are also at risk for false-negative mammograms due to the masking of cancers by dense breast tissue.[8] At least 38 states now require that mammography facilities include information about breast density in their results letters to patients, and an amendment to MQSA regulations goes into effect September 2024 that specifies a uniform minimum national reporting standard for these letters.[9]

The USPSTF has recently highlighted the need to include "an intentional focus on embedding health equity" into its processes,[10] where race is considered a social construct, not a biological one.[11,12] Despite similar rates of self-reported mammography screening as White female persons, cancer registry data show that Black and African American (hereafter referred to as Black) female persons have experienced long-standing disparities in breast cancer mortality, with rates 40% higher for Black as compared with White female persons.[13] Evidence strongly suggests that racism contributes to differences in risk factor exposures, which impact breast tumor features, for example, obesity and lactation, and to disparities in healthcare access, quality, timeliness, and completeness.[14,15]

Since there are no recent completed U.S. trials of mammography screening and few studies report race-, density-, or risk-specific data, computer models can be utilized to synthesize current observational and trial data and provide evidence for updating screening guidelines. Since 2016, when the USPSTF last commissioned the Cancer Intervention and Surveillance Modeling Network (CISNET) breast cancer modeling teams to evaluate different screening scenarios,[16] the CISNET models have made significant updates to incorporate recent data on age-, period-, and cohort-specific breast cancer risk, screening technology and performance, and treatment effectiveness. The CISNET breast cancer models now include updated estimates for DM and DBT screening performance.[17] The models incorporate breast cancer risk factors, including breast density,[18] and can simulate elevated risk due to factors such as a family history of breast cancer.[19] The models have also updated their treatment parameters to reflect the extension of endocrine therapy for patients with estrogen receptor (ER)-positive cancers from 5 years to 10 years, and to reflect advances from molecularly-targeted therapies.[20] Four of the models have been adapted to model questions related to breast cancer screening for Black female persons.[21,22] CISNET models directly incorporate the differential distributions by race of biological tumor and treatment factors that contribute to race differences in breast cancer mortality and indirectly reflect the effects of racism and other social determinants of health. Our models are therefore well-suited to conduct a decision analysis requested by the USPSTF in conjunction with a systematic review from the Kaiser Permanente Evidence-based Practice Center (EPC) to update its 2016 recommendation statement on breast cancer screening for average-risk female persons overall and groups of female persons based on Black race, breast density, elevated relative risk of breast cancer, and level of comorbidity.

Chapter 2. Methods

Purpose of the Decision Analysis

The purpose of this comparative effectiveness of different breast cancer screening strategies is to inform the USPSTF as it updates the screening recommendations from 2016. Modeling has the advantage of combining evidence from multiple high-quality data sources and simulating exact screening scenarios to quantify the variation of harms and benefits in groups of female persons based on their age, breast density, comorbidity level, race, and risk factor profile. Use of multiple models strengthens the credibility of model projections and provides a range of plausible effects given different modeling approaches and assumptions for representing unobservable phenomena. Decision makers and other stakeholders can gain confidence in collaborative modeling results if all models demonstrate meaningful, qualitatively similar lifetime mortality reductions due to screening despite differences in model assumptions and structures.

Scope of the Decision Analysis

The CISNET Breast Working Group, USPSTF members, EPC review team, and AHRQ Medical Officer defined the scope and questions for the decision analysis. The questions were:

1. Compared with no screening, what are the trade-offs of efficient mammography screening strategies for average-risk, asymptomatic female persons when strategies vary by modality, interval, initiation age, and cessation age?
2. Does the answer to question 1 change when breast cancer in Black female persons is modeled? What screening strategies for Black female persons achieve similar trade-offs as observed for female persons overall and reduce mortality disparities?
3. What are the trade-offs of efficient density-specific DBT screening strategies that vary by starting age, stopping age, and interval once a female person decides on the age to start screening?
4. What are the trade-offs of efficient DBT screening strategies that vary by starting age, stopping age, and interval for female persons with modestly elevated risk (e.g., a family history of breast cancer)?
5. Among female persons screened biennially starting at age 50 with DBT, what are the trade-offs of different stop ages within levels of comorbidity?

The analysis was limited to female persons with no personal history of breast cancer, without a confirmed or suspected genetic mutation known to increase risk of breast cancer (e.g., *BRCA*), and without a personal history of chest radiation therapy at a young age.[23] Models apply to cisgender women and may not accurately reflect breast cancer risk for transgender persons. Model results are driven by sex (i.e., female) rather than gender identity. We use the term "women" herein, while recognizing that not all individuals at risk of breast cancer and eligible for screening self-identify as women.[24]

Overview of the Models and Input Parameters

We used six models of breast cancer: Dana-Farber Cancer Institute (Model D), Erasmus University Medical Center (Model E), Georgetown Lombardi Comprehensive Cancer Center-Albert Einstein College of Medicine (Model GE), University of Texas MD Anderson Cancer Center (Model M), Stanford University (Model S), and University of Wisconsin-Madison-Harvard Pilgrim Health Care (Model W). Detailed descriptions of each model are available in a special issue of *Medical Decision Making*[25-30] and online.[31] We have previously twice provided evidence to inform decisions of the USPSTF for breast cancer screening.[16,32] The six models were independently developed and all replicate breast cancer incidence and mortality in the U.S. female population. The models use common data inputs, but each modeling team makes independent assumptions regarding the natural history of breast cancer and how the data inputs are incorporated into the models; for example, Models E, GE, S, and W are microsimulation models, Model D is an analytic statistical model, and Model M uses a fully Bayesian approach (**Table 1**).

Breast Cancer Natural History Component

All models begin by representing cohorts of individual female persons and their risk of breast cancer in the absence of screening. Individuals enter the models at ages 0 to 25 (depending on the model) since >99% of breast cancers are diagnosed after age 25 and population screening is unlikely to occur prior to that age. Each individual has a risk of symptomatic detection of breast cancer based on an age-period-cohort function using population trend data from the Surveillance, Epidemiology, and End Results (SEER) Program (**Table 2**).[33] Some models use the age-period-cohort function directly, while others use it in calibration or rely on SEER rates from the prescreening era (1975–1979) directly (**Table 1**).

Breast Cancer Screening Component

In all six models, breast cancer is depicted as having a preclinical detectable period or sojourn time, a clinical detection timepoint when symptoms or signs are present (e.g., palpable lump), and a lead time which is the difference of the two (**Figure 1**). When a screening test is administered during the preclinical detectable period, a true positive test leads to earlier detection and initiation of treatment, and potentially a shift to an earlier stage at diagnosis. Some models require a stage shift for screening to have a survival or mortality benefit, while others allow for improved survival when tumors are detected at smaller sizes within the same stage (**Table 1**).

Whether a screening test detects breast cancer during the preclinical period depends on the performance characteristics of the test. For this analysis, updated mammography data were provided by the Breast Cancer Surveillance Consortium (BCSC) for sensitivity of DM and DBT (**Table 3**), the prevalence of breast density by age (**Appendix Table 1**), and density-specific underlying relative risk of breast cancer (**Appendix Table 2**). Mammography sensitivity estimates were stratified by age group, screening interval, breast density, and invasive carcinoma versus ductal carcinoma in situ (DCIS) (**Table 3**). The stage distribution of breast cancer cases

was also provided by the BCSC for screen-detected cases (**Appendix Figure 1**) and interval- and clinically-detected cases (**Appendix Figure 2**).

As required by the Food and Drug Administration, DBT must be accompanied by traditional DM or synthetic DM, which is a two-dimensional image constructed from DBT data; hereafter, references to DBT will imply concurrent use with DM or synthetic DM. Since evidence suggests that DM and synthetic DM contribute comparable benefits when used with DBT,[34-37] synthetic DM is rapidly replacing traditional DM in clinical practice to reduce radiation exposure.[38] For this pragmatic reason, DBT is used in the analysis as the reference modality.

Breast density categories were defined using Breast Imaging Reporting and Data Systems (BI-RADS) lexicon, with dense breasts defined as almost entirely fatty (BI-RADS density "a"), scattered fibroglandular ("b"), heterogeneously dense ("c"), or extremely dense ("d").[39] In the models, each person was assigned a breast density category at age 40 (the earliest age at screening in this analysis), which may decrease twice, at ages 50 and 65, to one less-dense category based on prevalence data in the BCSC (**Appendix Table 1**). BCSC data were also used to estimate the number of false-positive recalls (**Table 3**) and the number of benign biopsies (**Appendix Figure 3**). The followup period for all mammography performance measures (sensitivity, false-positive recalls, benign biopsies) for both annual and biennial screening intervals was 12 months.

Breast Cancer Treatment and Survival

At diagnosis, breast cancer cases were treated according to a stage of disease (AJCC [American Joint Committee on Cancer] anatomic or SEER historical stage) and a subtype based on the estrogen receptor (ER) and human epidermal growth factor receptor 2 (HER2) as observed in the BCSC and SEER (**Appendix Table 3**). Models assumed that all cases diagnosed with breast cancer immediately received local therapy (mastectomy or breast conserving surgery with radiation). The benefit of treatment was based on the combination of treatment assignment and treatment efficacy. According to each stage at diagnosis and subtype, breast cancer cases were assigned a breast cancer–specific survival time with local therapy.[40,41] The probability of breast cancer cases receiving specific types of systemic treatment was based on data from the National Comprehensive Cancer Network and, for newer therapies, expert opinion.[42,43] Treatment efficacy for systemic therapy was based on the most recent published meta-analysis of clinical trials and, for newer therapies, expert opinion.[44,45]

Non-Breast Cancer Death

Modeled individuals were assigned an age- and race-specific life expectancy to capture death from causes other than breast cancer among female persons based on U.S. actuarial data extrapolated to the 1980 birth cohort (**Appendix Figure 4**).[46]

Race-Specific Model Inputs

Some but not all model parameters were updated for separate models of breast cancer outcomes for Black female persons. Model parameters that were assumed to be the same for Black

individuals as for female persons overall included mammography sensitivity (stratified by age, breast density, and screening interval), breast cancer survival in the absence of screening and systemic treatment, treatment assignment, and utility values (**Table 2**). Conversely, race-specific values for Black female persons included the incidence of breast cancer in the absence of screening,[33] the stage distribution of breast cancer cases at diagnosis (**Appendix Figure 1**, **Appendix Figure 2**), the percent of mammograms resulting in a false-positive recall (**Table 3**) and benign biopsy (**Appendix Figure 3**), the prevalence of breast density (**Appendix Table 1**), the distribution of tumor subtype by method of detection (**Appendix Table 3**), breast cancer treatment effectiveness,[22,47] and other cause mortality (**Appendix Figure 4**).[46]

In all analyses, Black individuals received treatment with an efficacy that was lower than for all individuals overall based on an analysis of subtype-specific survival; this decrement in treatment efficacy (28% reduction for treatments for ER-negative tumors and 56% reduction for ER-positive tumors) was based on a published analysis of race-specific breast cancer survival data from >15,000 patients diagnosed during 2000–2007 at eight sites in the National Comprehensive Cancer Network.[47] For ease of modeling, this decrement in treatment benefit was a simplifying assumption that, together with race-specific screening input parameters, was intended to represent the reduced quality of breast cancer early detection and treatment experienced by Black female patients at many points in care, including access, timeliness, and completeness, that affect breast cancer mortality.

Outcomes

Each model aggregated simulation results for all individual persons to provide total counts of screening examinations and health outcomes. Outcomes were tallied from age 40 to death and expressed per 1,000 average-risk female persons who were unscreened and free of diagnosed breast cancer at age 40. Outcomes were presented for the overall U.S. female population and for Black female persons. In additional analyses, outcomes were stratified by breast density category (BI-RADS a, b, c, d), or risk factor group (relative risk values 1.5 and 2.0 [e.g., positive family history of breast cancer]), or level of comorbidity (none, low, moderate, severe).

Benefits

Our primary outcome for screening benefit was estimated percent reduction in breast cancer mortality compared with no screening. (All female patients diagnosed with breast cancer in the models received treatment regardless of method of detection.) Other estimated benefits included breast cancer deaths averted, life-years gained (LYG), and quality-adjusted life-years (QALYs) gained. QALYs were calculated using age-specific utilities for female persons in the general population,[48,49] with disutilities applied to having a mammogram, and, for patients diagnosed with breast cancer, for breast cancer treatment based on the stage at diagnosis (**Appendix Table 4**).[50,51]

Harms

As a routine measure of screening burden, the number of screening tests was considered a harm along with model-estimated false-positive recalls, benign results from biopsies recommended for

findings on screening mammography (hereafter referred to as benign biopsies), and the number of overdiagnosed cases of breast cancer. For these results, overdiagnosis was defined as the excess breast cancer cases that were diagnosed in the presence of screening that would not have been diagnosed in the absence of screening. We recognize that the definition of overdiagnosis can vary across studies, including those conducted using CISNET models. The definition of overdiagnosis used in this project was chosen so that calculations were consistent across all six models. The harm of overtreatment after overdiagnosis was captured by a decrement in utility based on a composite value for undergoing local and systemic therapy without a change in life expectancy.

Trade-Offs

To compare trade-offs of screening harms versus benefits, strategies were plotted on efficiency frontiers. For each figure, the benefits (mortality reduction or LYG) were plotted against the number of mammograms. We considered a strategy more "efficient" than a comparison strategy if it resulted in greater health benefits for a given increase in the number of mammograms. A strategy that entailed more harms but fewer benefits was considered "inferior" to (also referred to as inefficient or dominated by) other strategies. We identified the efficiency frontier as the sequence of strategies that achieved the largest incremental gain in benefits per additional unit of harm (**Figure 2**). Screening strategies that fell on this frontier were considered the most efficient (i.e., no alternative exists that provides more benefit with fewer harms). Because an inferior strategy providing outcomes that are very similar to an efficient strategy may still be considered by decision makers for other reasons (e.g., uncertainty in model estimates, model parameter sampling variation, or for consistency of starting and stopping ages across screening modalities),[52] we also identified "near-efficient" strategies using similar methods as the USPSTF decision analysis for colorectal cancer in 2021.[53] For this analysis, we defined near-efficient a priori as a strategy within 5% of the value for screening biennially during ages 50–74 (the current USPSTF recommendation) with DBT among female persons overall and for Black female persons separately. For plots of the percent reduction in breast cancer mortality, near-efficient strategies included those within 5% of the efficiency frontier on a relative scale, which is equivalent to 1.27 percentage points on an absolute scale for female persons overall and 1.21 percentage points on an absolute scale for Black female persons. For plots of LYG, near-efficient strategies (within 5%) included those within 2.20 days of life gained per person of the efficient frontier for all female persons and 3.15 days of life per Black female person. Strategies that were not efficient or near-efficient were referred to as "inferior."

Incremental Ratios

For each efficient and near-efficient screening strategy, we calculated the incremental number of lifetime mammograms (Δ mammograms) and the incremental LYG (ΔLYG), relative to the next effective or near-effective strategy with fewer mammograms. The ratio for the strategy with the fewest number of mammograms (biennial at ages 50–74) was calculated relative to no screening. We then calculated an "incremental ratio," defined as the incremental number of mammograms required to achieve one additional LYG (Δ mammograms/ΔLYG). The reciprocal of the slope of the efficient frontier between adjacent strategies is the incremental ratio. This ratio is akin to the incremental cost-effectiveness ratio in a cost-effectiveness analysis. As the efficient frontier gets flatter, the incremental ratio increases, indicating

diminishing returns from each additional mammogram performed. Incremental ratios were also calculated using the percent reduction in breast cancer mortality (Δ mammograms/Δ % breast cancer mortality reduction).

To provide additional outcome metrics of screening, we calculated the percentage of breast cancers diagnosed as advanced breast cancer, defined as AJCC version 6 stage IIB or higher (or SEER regional and distant stage). Models also estimated one benefit-to-harm ratio as a measure of the trade-offs of different screening strategies compared with no screening—LYG per 1,000 mammograms—and three ratios of harm-to-benefit: 1) mammograms per breast cancer death averted, 2) false-positive recalls per breast cancer death averted, and 3) mammograms to obtain a 1 percentage point reduction in breast cancer mortality.

Analysis

For this USPSTF decision analysis, each model depicted a contemporary cohort of U.S. average-risk female persons who received modern breast cancer screening and treatment—that is, the 1980 birth cohort of female persons turning 40 in 2020—who were followed until death.

Question 1

Compared with no screening, what are the trade-offs of efficient mammography screening strategies for average-risk, asymptomatic female persons when strategies vary by modality, interval, initiation age, and cessation age?
For analyses of the entire U.S. average-risk asymptomatic female population, we compared model results for mammography screening scenarios that varied by modality (DM, DBT), starting age (40, 45, or 50 years), interval (annual, biennial, or a hybrid of annual and biennial), and cessation age (74 or 79). Three types of hybrid screening scenarios were evaluated: 1) annual starting at 40 then biennial starting at 50; 2) annual starting at 45 then biennial starting at 55; and 3) annual starting at 45 then biennial starting at 50. All six models evaluated DBT and five models evaluated DM (Models D, E, GE, M, and W).

Question 2

Does the answer to question 1 change when breast cancer in Black female persons is modeled? What screening strategies for Black female persons achieve similar trade-offs as observed for female persons overall and reduce mortality disparities?
Based on race-specific inputs, four models for Black female persons (D, GE, M, W) were used to estimate benefits, harms, and the number of mammograms for the same strategies described for Question 1 above. Although individuals of all race and ethnic groups were included in model input data and calibration targets for modeling female persons overall, we did not evaluate screening strategies separately for Hispanic female persons or individuals who were Asian American, American Indian/Alaska Native, Native Hawaiian/Pacific Islander, or multiracial since breast cancer models were unavailable for these populations.

As mentioned above and in accordance with recent statements by the USPSTF, this modeling analysis defines race as a social construct and aimed to provide evidence regarding the trade-offs

of mammography screening strategies for female persons who self-identify as Black as an approach to mitigate health effects of racism.[12] The purpose of this analysis was to 1) identify which screening strategies for Black female persons were efficient, 2) identify which efficient strategies yield benefit-to-harm trade-offs that were similar to (or more favorable than) trade-offs for the strategy recommended for the overall female population, and 3) quantify the breast cancer mortality disparity reduction for pairs of strategies for Black and all female persons.

Question 3

What are the trade-offs of efficient density-specific DBT screening strategies that vary by starting age, stopping age, and interval once a female person decides on the age to start screening?

We did not examine the value of a "baseline" mammogram at age 35 or 40 to determine breast density. Instead, we evaluated the trade-offs of maintaining a screening strategy, and how this varies by breast density at the first mammogram, once a person has already decided on the age at which to begin screening. Five models (Models D, E, GE, M, and W) repeated 18 DBT strategies described for Question 1 four times based on whether female persons had breast tissue described as BI-RADS density a, b, c, or d at age 40, including strategies that varied by starting age (40, 45, 50), stopping age (74, 79), and interval (annual, biennial). All three hybrid scenarios were also evaluated.

Question 4

What are the trade-offs of efficient DBT screening strategies that vary by starting age, stopping age, and interval for female persons with modestly elevated risk (e.g., a family history of breast cancer)?

In all six models, a relative risk of breast cancer associated with elevated risk (either 1.5 or 2.0) was applied to each person's age-specific underlying risk of breast cancer (**Appendix Table 2**). These relative risk values were selected based on a review of studies estimating the risk of breast cancer associated with a first-degree family history of breast cancer.[54-61] Trade-offs of screening were estimated assuming 100% of persons in each analysis had the elevated risk of breast cancer, that is, persons with a family history of breast cancer who receive mammography were compared with persons with a family history who do not receive mammography; results are not shown for a population-level analysis where only a portion of persons have a family history. In the models, elevated relative risk of breast cancer increased risk of a breast cancer diagnosis but did not affect the natural history or the distribution of subtypes of the breast tumors. Results are shown for all breast density groups combined.

This analysis was not intended to address screening for persons who are highly likely to have a strong genetic risk of breast cancer; for example, persons with a family member diagnosed before age 40 or more than two diagnosed family members at any age.

Question 5

Among female persons screened biennially starting at age 50 with DBT, what are the trade-offs of different stop ages within levels of comorbidity?
Two models (Model GE and W) examined the effect of comorbidity on trade-offs of varying ages to stop breast cancer screening by using age- and comorbidity-specific competing mortality.[16,62] Examples of conditions that placed individuals in severe and moderate comorbidity groups included congestive heart failure and diabetes, respectively (**Appendix Table 5**). Comorbidity levels and their associated mortality from causes other than breast cancer were based on published data.[63] We evaluated screening benefits, harms, and numbers of mammograms for female persons screened biennially with DBT from age 50 until age 69, 74, 79, and 84 for each of four comorbidity levels (none, low, moderate, and severe). Within each comorbidity level, biennial DBT screening strategies starting at age 50 with stopping ages 69, 74, 79, and 84 were evaluated. These analyses were limited to persons who survived and were free of breast cancer up until age 65. Within each comorbidity level, biennial screening from ages 50 to 74 was compared with biennial screening from ages 50 to 64. Incremental results for stopping biennial screening at ages 69, 79, and 84 were expressed relative to stopping at age 74.

Sensitivity Analysis

Treatment

In sensitivity analysis, we evaluated the impact on outcomes by varying how treatment is assigned to cases of breast cancer. Primary analyses for the Questions described above assumed that patients received stage- and subtype-specific adjuvant therapy according to empirical data.[41,43] This analysis is intended to represent treatment use as observed in "real world" data. For comparison with previous modeling in 2009 and 2016 for the USPSTF, we repeated analysis of the screening strategies evaluated for Question 1 (limited to cessation age 74) assuming that all patients diagnosed with breast cancer received the single most effective therapy according to stage and subtype. For example, in the base case, among breast cancer cases ages <50 years diagnosed with stage II node-negative ER-negative, HER2-negative breast cancer, 2.41% received local therapy only; the remainder of cases received surgery with or without radiation along with anthracycline with taxane (91.57%), endocrine therapy (1.2%), or anthracycline with taxane and endocrine therapy (4.82%). (Endocrine therapy included tamoxifen, an aromatase inhibitor, or both sequentially). All patients with this diagnosis in the sensitivity analysis received anthracycline with taxane since it was the most effective option (the hazard ratio of breast cancer death is equal to or lower than other options).

Utilities

Although the models calculated QALYs using average disutilities for health states by age, screening, and breast cancer treatment, perceived disutility for these health states varies widely across individual persons. To address this source of variation, we performed sensitivity analyses using the age-specific disutility values for a general population of female persons (all races) derived from the SF-6D[48] as a complement to the values derived from the EQ5D[49] in the base case analysis.

Model Validation

Using dissemination inputs for screening and treatment in all birth cohorts,[20] the models replicated observed patterns of breast cancer incidence (**Figure 3**) and mortality (**Figure 4**) in the United States.

Expert Review and Public Comment

A draft report was reviewed by content experts, representatives of Federal partners, USPSTF members, and AHRQ Medical Officers. The draft report was posted for public comment. Revisions were made based on comments received. Revisions included clarifications to phrasing and ordering in the text, figure titles, and table titles, including definitions of key terms and modeling assumptions. Table 2 was expanded to include more detail on model inputs. Changes were also made due to a recommendation to include overdiagnosis along with the other harms of screening (false-positive recall, benign biopsy) consistently in the tables.

Chapter 3. Results

Probability of a Breast Cancer Diagnosis or Death

For the 1980 birth cohort of all female persons without mammography screening, the models predicted a median 12.7% lifetime probability of a breast cancer diagnosis (range across models, 11.8% to 14.9%). (All analyses assume persons diagnosed with breast cancer received treatment.) Without screening, the median probability of a breast cancer death was 2.73% (range across six models, 2.34% to 3.74%; among models D, GE, M, and W, median 2.83% with the same range). Thus, if a screening strategy leads to a 25.8% reduction in breast cancer mortality (the value for screening biennially during ages 50–74 from the 2016 decision analysis for the USPSTF[16]), the probability of a breast cancer death would be reduced from 2.73% to 2.03%, or 7.1 breast cancer deaths averted per 1,000 female persons screened.

For Black female persons, the models predicted a 11.8% median lifetime probability of a breast cancer diagnosis (range, 11.0% to 14.6%) and a 3.93% median probability of a breast cancer death (range, 3.20% to 4.82%) without screening. Models predicted a median 39% higher breast cancer mortality rate for Black female persons compared to female persons overall in the absence of screening (based on four models). If a screening strategy reduced breast cancer mortality by 25.8%, the models predicted that the probability of a breast cancer death would be reduced from 3.93% to 2.91%, and 10.1 breast cancer deaths would be averted among 1,000 Black female persons.

Question 1: Trade-Offs for Average-Risk Female Persons

Benefits of screening strategies including reductions in breast cancer mortality and gains in life-years, deaths averted, and QALYs increased with increasing numbers of DM (**Table 4**, **Appendix Table 6**) and DBT (**Table 5**, **Appendix Table 7**) examinations. Reductions in breast cancer mortality increased from a median across models of 24.3% for screening biennially at ages 50–74 with DM (range across models, 18.3% to 27.5%) to a median 41.7% reduction for screening annually at ages 40–79 with DM (range, 37.2% to 42.9%) or DBT (range, 39.2% to 43.0%).

When comparing the least-intensive strategy (biennial 50–74) to the most intensive strategy (annual 40–79), the median number of mammograms tripled for both DM (**Table 6**) and DBT (**Table 7**). False-positive recalls increased from 873 (range, 855 to 878) with DBT biennially at ages 50–74 to 2,595 (range, 2,550 to 2,621) with DM annually at ages 40–79. The number of overdiagnosed cases increased from a median of 10 (range, 4 to 29; out of 143 invasive breast cancer cases, data not shown) for biennial 50–74 with DM to 25 (range, 7 to 56; out of 156 invasive breast cancer cases, data not shown) for annual 40–79 with DBT, with a wide range across models and strategies.

Use of DBT instead of DM reduced breast cancer mortality reduction by about 1 percentage point and averted less than 1 additional breast cancer death (**Table 8**), while also reducing false-

positive recall by approximately 150 to 300 per 1,000 persons over their lifetimes, depending on strategy (all with stopping age 74).

Stopping screening at age 79 instead of age 74 generally resulted in an additional 3% to 5% mortality reduction, 1 additional breast cancer death averted, and 64 to 173 additional false-positive recalls per 1,000 persons, depending on strategy (**Table 9**).

The majority of models identified five screening strategies as efficient or near-efficient for *both* primary metrics (percent mortality reduction and LYG), all with DBT, including: biennial (B) 50-74; B45-79; B40-79; B40-49 with annual (A) 50-79; and A40-79 (**Table 10**; table shows strategies efficient or near-efficient for either metric by most models). Compared with less-intensive screening strategies (or no screening), screening with B50-74 and B45-79 required fewer than 150 additional mammograms in most models to increase LYG by 1 life-year (**Figure 5**) and fewer than 1,000 additional mammograms in most models to decrease breast cancer mortality by 1 percentage point more (**Figure 6**). (Note: Considering the reciprocal, 1 LYG/150 mammograms is equal to 2.4 life-days gained per mammogram.) Compared with B 50-74 (the recommendation in 2016), starting screening at age 40 or 45 averted about 2 additional breast cancer deaths while screening annually at ages 40–79 averted about 5 additional breast cancer deaths (**Figure 7**, **Appendix Table 8**).

The percent of invasive breast cancer cases diagnosed in advanced stages generally decreased with more intensive screening (**Figure 8**). For example, the median percentage of advanced cases for annual screening with DBT during ages 40–79 was 12.5% (range across four models, 10.9% to 14.8%, AJCC staging) versus 21.8% for biennial screening during ages 50–74 (range, 19.0% to 23.1%).

Question 2: Trade-Offs of Screening Strategies for Black Female Persons

The analyses described above for female persons of all races were repeated by four models of breast cancer in Black female persons.

Overall Trade-Offs of Screening Strategies for Black Female Persons

Trade-offs between benefits and harms of different screening strategies for Black female persons followed similar patterns as for all female persons combined. However, strategies resulted in more breast cancer deaths averted and LYG for Black female persons compared with the same strategies for female persons overall for DM (**Table 11**, **Appendix Table 9**) and for DBT (**Table 12**, **Appendix Table 10**). For each screening strategy, false-positive recalls, benign biopsies, and the number of overdiagnosed cases were also higher among Black female persons compared with outcomes for female persons overall for both DM (**Table 13**) and DBT (**Table 14**).

Among screening strategies stopping at age 74, median estimates from the models showed that use of DBT instead of DM among Black female persons resulted in less than 1 additional breast cancer death averted, about 9 to 17 additional LYG, and 449 to 1,095 fewer false-positive recalls for 1,000 Black female persons screened, depending on strategy (**Table 15**).

Considering the incremental benefit of stopping screening at age 79 instead of 74, the median additional benefit for Black female persons for percent breast cancer mortality reduction ranged 3.3 to 5.5 percentage points across strategies (**Table 16**). Continuing screening until age 79 added between 72 and 253 false-positive recalls during the lifetimes of 1,000 Black female persons.

Among at least three of four models of breast cancer for Black female persons, seven screening strategies were efficient or near-efficient for LYG (**Figure 9**) or breast cancer mortality reduction (**Figure 10**). These strategies were a subset of those found efficient or near-efficient for female persons overall; three strategies were efficient or near-efficient for both metrics, including B45-79, B40-79, and A40-79 (**Table 17**; table shows strategies efficient or near-efficient for either metric by at least three of four models). Expanding biennial screening from ages 50–74 to ages 40–79 averted 3 additional breast cancer deaths (**Figure 11**; **Appendix Table 11**).

More intensive screening strategies resulted in lower percentages of cases diagnosed in advanced stages. The percentage of cases diagnosed in advanced stages was slightly lower for DBT compared with DM for the same strategy (**Figure 12**); for example, for biennial screening at ages 50–74, 27.4% (range, 26.2% to 31.2%) of Black breast cancer cases were diagnosed in an advanced stage with DM, while 25.4% (range, 25.0% to 29.7%) of cases were advanced at diagnosis with DBT.

Disparities in Outcomes for Black Compared With All Female Persons

Compared to corresponding values for each screening strategy among all female persons, quantities for two harm-to-benefit ratios (false-positive recalls per breast cancer death averted and the number of mammograms per breast cancer death averted) were lower for Black female persons (**Appendix Table 12**). For example, for biennial screening at ages 50–74, models estimated 132.8 (range across models, 95.6 to 166.5) false-positive recalls per breast cancer death averted for all female persons and 90.3 (range, 64.7 to 115.0) for Black female persons. Corresponding results for the number of mammograms per breast cancer death averted (also referred to as the "number needed to screen") were 1,709 (range, 1,228 to 2,137) for all female persons and 1,209 (range, 869 to 1,539) for Black female persons for biennial screening at ages 50–74. Values for the number of mammograms to obtain a 1 percentage point reduction in breast cancer mortality for Black female persons were similar to values for female persons overall for each screening strategy.

Using a fourth ratio—LYG per mammogram (times 1,000)—as a measure of benefit-to-harm showed that two of the four models (D and W) resulted in B50-74 with the highest value of LYG/mammogram among the efficient strategies; all four models found that A40-79 had the lowest values among all efficient strategies (**Figure 13**). All four models estimated higher values for Black female persons as compared with female persons overall for each screening strategy. Thus, several of the efficient strategies resulted in greater values of this ratio for Black female persons than observed for B50-74 as well as B40-74 for all female persons; all four models found greater values of LYG/mammogram for B45-79 and B40-79 among Black female persons compared with the values for B50-74 and B40-74 among female persons overall.

If all female persons receive the same screening strategy (with perfect adherence), models estimate that Black female persons will have 41% to 43% greater breast cancer mortality than the average population (**Table 18**; limited to strategies found to be efficient or near-efficient for female persons overall; see table cells with grey shading). However, if Black female persons are screened with a more-intensive strategy such as B45-79 and female persons overall are screened with B50-74 (both with DBT), then the elevated breast cancer mortality rate for Black female persons would be reduced from 42% to 30% higher than for female persons overall.

Question 3: Trade-Offs of Density-Specific Screening Strategies

Screening strategies were evaluated by five models for separate cohorts of female persons overall and four models for Black female persons assigned one of the four breast density categories at age 40. For all four density levels among female persons overall, two DBT screening strategies were efficient or near-efficient for both primary metrics in most models, including B40-79 and A40-79 (**Table 19, Figure 14, Figure 15**). Additional strategies were efficient or near-efficient for both metrics in most models for density a (B50-79, B45-79), density b (B50-74, B50-79, B45-79, and hybrid A40-49 with B50-79), density c (B50-74, B45-79, and hybrid A40-49 with B50-79), and density d (B50-74). For Black female persons, two screening strategies were efficient or near-efficient for all four density levels (B45-79 and A40-79), with B50-79 efficient for density a and b; B40-79 efficient for density b, c, and d; and A45-79 efficient for density a. Regardless of density level, strategies that started screening at age 40 or included annual screening required more than 1,000 additional mammograms to reduce breast cancer mortality by another 1 percentage point compared to the next less efficient strategy with fewer mammograms.

Since greater breast density across categories a, b, c, and d was associated with greater breast cancer risk and lower mammography sensitivity, screening female persons with more dense breasts was associated with slightly lower percent mortality reduction, more breast cancer deaths averted, up to twice as many LYG, but up to twice as many false-positive recalls (limited to efficient and near-efficient strategies).

Question 4: Trade-Offs of Screening Strategies for Persons With Elevated Risk

Since many female persons have modestly increased risk of breast cancer based on common risk factors, such as a first-degree family history of breast cancer, DBT strategies were evaluated assuming a relative breast cancer risk of 1.5 and 2.0. For the most part, the same DBT strategies were efficient or near-efficient for both relative risk levels (**Table 22**). For female persons overall with relative risk of 1.5, four strategies were efficient or near-efficient for both breast cancer mortality reduction and LYG metrics: B50-74, B45-79, B40-79, and A40-79. For relative risk of 2.0, three of these were also efficient or near-efficient (B50-74, B40-79, and A40-79), along with one hybrid strategy (A40-49 with B50-79) (**Figure 16**). For Black female persons, the same three strategies were efficient or near-efficient for both relative risk levels (B45-79, B40-79, and A40-79) (**Figure 17**).

Models predicted that female persons overall (**Table 23**) and Black female persons (**Table 24**) with elevated relative risk would experience similar percent breast cancer mortality reduction with greater breast cancer deaths averted and more LYG compared to persons with average risk when screened with the same strategy; the number of false-positive recalls was slightly smaller for female persons with elevated risk.

Question 5: Trade-Offs of Stopping Ages According to Comorbidity Level

For 65-year-old female persons who had previously screened biennially during ages 50–65 with DBT and had never been diagnosed with breast cancer, models estimated benefits and harms of continuing with biennial screening until one of four ages (69, 74, 79, and 84) for four comorbidity levels. Model GE predicted that about 1 additional breast cancer death would be averted by biennial screening until age 79 for all four comorbidity levels (range, 1.1 to 1.9, depending on comorbidity level). However, model W estimated that 0.5 to 0.8 additional breast cancer deaths would be averted by biennial screening until 79 instead of 74, depending on comorbidity level.

Sensitivity Analysis

When cases diagnosed with breast cancer received the most effective treatment for their cancer subtype, the percent reduction in breast cancer mortality increased as compared with the scenario where cases received treatment based on dissemination patterns; for example, multiple treatment combinations were possible for cases with the same diagnosis (**Appendix Table 13**). Conversely, breast cancer deaths averted were similar or slightly lower when all cases received the most effective therapy, whereas the difference in LYG and QALYs gained varied by model and screening strategy.

Among all female persons for different DBT screening strategies, using alternate values for age-related disutilities from the SF-6D resulted in QALYs gained that were a median of 3.7 to 6.6 units smaller than QALYs based on the EQ-5D (**Appendix Table 14**). Among Black female persons, QALYs gained across the DBT screening strategies were 5.4 to 9.6 units smaller based on the SF-6D. Screening strategies identified as efficient or near-efficient were the same regardless of which age-related utilities were used to calculate an incremental ratio of the change in mammograms divided by the change in QALYs gained for either female persons overall or for Black female persons. Seven strategies were efficient or near-efficient for all female persons (B50-74; B45-74; B45-79; B40-74; B40-79; A40-49 with B50-79; and A40-79), while six screening strategies were efficient or near-efficient for Black female persons (B50-74; B45-74; B45-79; B40-79; A40-49 with B50-79; and A40-79).

Chapter 4. Discussion

This updated decision analysis for the USPSTF builds upon the prior work conducted in 2009 and 2016 to reflect the most currently available evidence. Important differences from past iterations include consideration of DBT and continuing screening until age 79 versus age 74. Past efforts assumed that all breast cancer cases received the most effective treatment for their age and the stage and subtype of their tumors; here we employed a dissemination model input to reflect the variation in treatment received by patients in the United States. Results remained consistent with previous decision analyses, showing that the underlying model structure—that has remained consistent throughout the history of the CISNET program—affects modeling findings more than incremental changes in model parameters.

In general, the models consistently found the same or slightly increased health benefits and fewer false-positive recalls for DBT as compared with DM. As with previous decision analyses, screening biennially at ages 50–74 was efficient and resulted in about 7 breast cancer deaths averted over the lifetimes of 1,000 female persons screened compared to no screening. One additional death was averted if the starting age was 40, but screening biennially at ages 40–74 was inferior to strategies that screened until age 79 in terms of numbers of mammograms to achieve a reduction in breast cancer mortality or a gain in life-years.

Similar strategies were found to be efficient for female persons overall and those with increased breast cancer risk due to dense breasts or elevated relative risk. However, as breast cancer risk increased, gains with more intensive screening strategies resulted in greater numbers of breast cancer deaths averted and life-years gained. Due to concerns that dense breast tissue can mask detection of breast cancer by a mammogram, the majority of states require that mammography facilities include a note in their letters to patients about breast density that may include information about the presence of dense tissue on the person's mammogram.[64] Given the increased societal awareness of the potential for dense breast tissue to impact breast cancer detection, patients and healthcare professionals are increasingly asking whether more intensive screening is warranted for female persons with dense breasts. Evaluation of supplemental screening for patients with a negative mammogram was beyond the scope of this decision analysis.

Approximately 11% to 16% of female persons have a first-degree family history of breast cancer, defined as having their mother and/or at least one sister and/or daughter diagnosed with breast cancer.[56] Risk of breast cancer has been established to be elevated among female persons with a first-degree family history of breast cancer, if the family member was diagnosed at younger ages, and if multiple family members have been diagnosed.[54,56] Studies of risk associated with a positive family history of breast cancer among Black female persons have found estimates in the 1.5 to 2.0 range, similar to studies of female persons of all races combined or primarily White female persons.[60,61] To examine the balance of benefits and harms of different screening strategies according to different levels of family history of breast cancer, screening strategies were evaluated in the models after applying a relative risk value to the underlying risk of breast cancer for each modeled person's lifetime. The two relative risk values—1.5 and 2.0—represent a range of elevations in risk among female persons with a first-degree family history of breast cancer. This range of elevated risk also captures risk associated with other risk factors,

including obesity, later age at first full-term pregnancy, history of benign breast disease, and frequent alcohol consumption.[18,58,65,66] Models did not incorporate any assumptions about differences in tumor natural history, subtype, or treatment efficacy for female persons with elevated risk.

This report extends findings published in 2021 for one model (GE) that evaluated strategies for reducing breast cancer mortality disparities between Black and White female persons.[22] Our models are intended to generate findings for individuals who self-identify as Black, defining race as a social construct where the social/political environment influences biological processes over the lifecourse.[67-69] Models required a decrement applied to treatment benefits for Black patients to calibrate mortality; this decrement was necessary in addition to racial differences in screening-related model input parameters to reflect the greater mortality in Black as compared with White breast cancer patients.[13] Findings in this report show that, due in part to a higher breast cancer mortality, especially among younger female persons, Black female persons experienced greater LYG per mammogram than those overall when everyone followed the same screening strategy. However, the breast cancer mortality disparity persisted when the same screening strategy was applied to Black female persons and the overall population. More intensive screening—without any changes to the decrement in treatment benefit experienced by Black patients—could potentially reduce the Black/White disparity in breast cancer mortality. As described by Chapman et al[22], intensive screening as a strategy for reducing breast cancer disparities should be viewed as a short-term solution within the control of individual patients until healthcare systems, policy makers, and clinicians remedy treatment disparities. Models were not available to examine screening among race or ethnicity groups other than Black female persons and the overall female population.

Models differ in meaningful ways in structure and assumptions; for example, some models incorporated a benefit to screening due to within-stage shift (Model E, S, and W), while others required a stage shift (Model D and GE) and assigned greater benefit for screen-detected than clinically-detected cases (Model M). Some of the modeling teams modeled tumor growth starting with lesions classified as DCIS (Model E and W), while other models did not explicitly model tumor growth, instead modeling categorical stages of disease (Model D and GE), used a fully Bayesian approach (Model M), or limited tumors to invasive breast cancer (Model S). Some models included tumors with limited malignant potential (Model E, GE, and W), and one model included a small percentage of early-invasive staged cases that grow so slowly that these tumors never lead to death from breast cancer (Model W). These different modeling assumptions allow the CISNET breast cancer modelers to provide policy makers and clinicians with a range of plausible results expected from adopting various screening strategies for different population risk groups about the benefits and harms of detecting and treating tumors with a range of growth features. Overall, using six models to project a range of plausible screening outcomes provides implicit cross-validation, with the range of results from the models as a measure of uncertainty.

Among the five models that included DCIS as well invasive breast cancer, three models found that the overall number of overdiagnosed cases exceeded the number of breast cancer deaths averted (Models E, M, and W). The upper range for all estimates of overdiagnosis was based on results from Model M (MD Anderson Cancer Center) and Model W (Wisconsin-Harvard). Model M generated higher overdiagnosis based on the assumption that incidence in the absence

of screening has essentially remained flat since 1975–1979, with almost all of the increases over time attributable to screening. The other models, including Model W, used some form of an age–period–cohort model for incidence in the absence of screening, where some of the increases in incidence were due to screening and some to changes in risk factors (e.g., use of postmenopausal hormone therapy). While this model structure generated lower rates of overdiagnosis for Models D and GE, Model W had higher rates of overdiagnosis to facilitate calibration to U.S. breast cancer rates during the 1980s, when screening mammography disseminated through the general population and incidence rates dramatically increased. Other sources of variation across models were related to assumptions about the proportions of DCIS cases that never progress to invasive cancer or the number of early invasive cancers that might be nonprogressive. In general, models that assumed higher proportions of nonprogressive DCIS or invasive breast cancer generated higher estimates of overdiagnosis than models that assumed less nonprogressive disease. The underlying incidence in the absence of screening and the proportion and types of tumors that were nonprogressive are unknown and unobservable; therefore, the different results across models based on their respective assumptions provided a range of possible overdiagnosis.

Two sensitivity analyses were conducted to examine the impact of input parameters related to treatment assignment and age-related quality of life disutilities. While other model inputs related to screening performance, for example, relied on rigorous data collected from diverse populations, the inputs for treatment assignment and age-related disutilities relied on data that have greater limitations. Studies report wide variation in quality-of-life experiences related to the impacts of aging and, for patients, breast cancer screening, diagnostic work-up, and treatment.[70,71] This variation was not captured in our base analysis. Although the sensitivity analysis using the SF-6D instead of the EQ-5D for age-related disutilities resulted in lower QALY values, the same screening strategies were efficient. Furthermore, the sensitivity analysis assigning the single most effective breast cancer therapy to all breast cancer patients showed slightly greater percent breast cancer mortality reduction compared with the base analysis that reflected variation in treatment assignment across patients with the same diagnosis. In the scenario where all patients receive the most effective therapy, breast cancer mortality is reduced among those detected through screening as well as those diagnosed clinically. Consequently, little change is observed for breast cancer deaths averted, LYG, and QALYs gained compared to the base analysis. Since our prior modeling work for the USPSTF in 2009[32] and 2016[16] assumed the single most effective therapy assigned to all breast cancer patients, this sensitivity analysis increased confidence that different findings are likely due to changes in other factors such as improved screening performance rather than differences in breast cancer treatment assignment.

Some analyses are based on findings from fewer than six models, which complicated efforts to compare results across topics. Reasons for the inconsistency in the number of models were pragmatic in nature. For example, some models were well-poised to examine certain questions related to racial disparities,[22] breast density,[18] and comorbidities[62] due to programming completed in previous projects; not all models had capacity to complete analyses for all topics.

Conclusion

This collaborative modeling analysis suggests that several mammography screening strategies reduce breast cancer mortality and increase life expectancy in average-risk female persons.

Strategies with biennial screening, start ages at 40 or 45, and cessation age at 79 resulted in greater incremental gains in survival and mortality reduction per mammogram compared with most strategies involving annual screening, start age at 50, and cessation age at 74. More intensive screening for women with greater risk of diagnosis or death can maintain similar benefit-to-harm trade-offs and reduce mortality disparities.

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Table 1. Breast Cancer Model Characteristics, Including a Comparison of Key Model Differences and Similarities

Model Components	D (Dana-Farber)[27]	E (Erasmus)[30]	GE (Georgetown-Einstein)[29]	M (MD Anderson)[26]	S (Stanford)[28]	W (Wisconsin-Harvard)[25]
Type of model	Analytic	Simulation	Simulation	Bayesian	Simulation	Simulation
Natural history structure	State transition	Tumor growth leading to fatal metastasis	State transition	None	Tumor growth with stage shift	Tumor growth with some indolent and aggressive cases
Method of construction	Stochastic process, Time to event	Longitudinal, Likelihood optimization, Stochastic process, Time to event	Time to event	Longitudinal, Likelihood optimization, Stochastic process, Time to event	Longitudinal, Likelihood optimization, Stochastic process, Time to event	Longitudinal, Stochastic process, State transition
Breast cancer incidence without screening	Gangnon 2021 APC Model[33]; used as-is	Age distribution of onset and cohort-specific probabilities estimated based on Holford APC,[72] adjusted based on Gangnon 2021 APC Model[33]; used as a calibration target	Holford APC[72] 1975-2000 adjusted by Gangnon 2021 APC[33] after 2000	Extended 1975 SEER rates; used as a linear model over years with an unknown slope parameter estimated by matching with SEER data	Jointly estimated APC model with postmenopausal hormone therapy effects based on Holford APC Model[72]	Holford APC[72] 1975-2000 adjusted by Gangnon 2021 APC[33] after 2000; APC used as a starting point of calibration to incidence
Breast density	Affects incidence in the absence of screening and mammography performance[a]	Affects incidence in the absence of screening and mammography performance[a]	Affects incidence in the absence of screening and mammography performance[a]	Affects incidence (both in the presence and absence of screening) and mammography performance (specificity)	Not modeled	Affects incidence in the absence of screening and mammography performance[a]
Screening benefit mechanism[a]	Stage shift using stage distribution at diagnosis provided by BCSC	Detection at non-fatal (smaller) size based on screening sensitivity provided by the BCSC, which is a calibration target	Tumor detected in earlier stage and at younger age based on screening sensitivity provided by the BCSC, which is a calibration target	Stage shift and beyond stage shift, defined as better survival for screen-detected cases than clinically detected cases of the same stage	Smaller size, stage shift, age shift based on varying a parameter that quantifies the probability that screening will detect a tumor of a given size	Stage and tumor size shift based on screening sensitivity provided by the BCSC, which is a calibration target

Table 1. Breast Cancer Model Characteristics, Including a Comparison of Key Model Differences and Similarities

					that matches BCSC sensitivity data	
Stage distribution among diagnosed cancers	Assigned based on BCSC data for stage by mode of detection	Stage distribution results from: diameter of clinical detection estimated based on SEER data; threshold diameter of screen detection based on BCSC data; and tumor diameter distribution of invasive tumors linked to AJCC stages	Clinically detected tumors assigned a stage based on BCSC data. Stage of screen-detected tumors determined by Bayes' theorem with BCSC data as prior distribution, likelihood based on stage dwell time distributions, and achieved lead time	Assigned based on BCSC data	Based on tumor growth parameters and diameter of screen detection that are calibrated to BCSC data, diameter of clinical detection based on SEER data	Stage calibrated to SEER incidence with BCSC data as secondary calibration targets for screen-detected cancers
ER/HER2 subtype distribution	Assigned based on BCSC data	Assigned based on BCSC data	Assigned based on BCSC data	Assigned based on BCSC data	Calibrated to BCSC data, then adjusted based on SEER data by stage, tumor size, and calendar year	Assigned based on BCSC data
Treatment benefit mechanism	Hazard reduction	Cure fraction	Hazard reduction; ability to cure	Hazard reduction, cure fraction	Hazard reduction	Cure fraction[b]
Program	Mathcad	Python	C+	C#, R, SAS	Python	C+

Abbreviations: APC, age-period-cohort model; BCSC, Breast Cancer Surveillance Consortium; SEER, Surveillance, Epidemiology, and End Results.

[a] Screening performance includes sensitivity; stage distribution among screen-, interval-, and clinically-detected cases; false-positive recall (specificity); and benign biopsy rates.

[b] Calibrated to mortality for a subset of treatment related parameters after natural history parameters are calibrated to incidence.

Model Profiles are available at https://resources.cisnet.cancer.gov/registry/site-summary/breast/.

Table 2. Common Breast Cancer Model Input Parameters: Description and Data Sources

Input	Description	Updated since 2016	Race-specific	References
Breast cancer incidence without screening	Age-period-cohort model using SEER breast cancer incidence with a period effect for mammography removed	Yes. Recent years added, 1980 instead of 1970 birth cohort.	Yes; incidence varied by race. Same data source.	Gangnon,[33] Holford[72]
Breast density	Prevalence of breast density (BI-RADS a, b, c, d) by age group (40-44, 45-49, 50-64, 65-74, 75-89)	Yes	Yes; density varied by race. Same data source.	BCSC
Mammography performance	Sensitivity and false-positive recall of initial and subsequent mammography by age (40-44, 45-49, 50-64, ≥65) and screening interval (annual, biennial) and density (a,b,c,d) for DM and DBT	Yes	Screening sensitivity did not vary by race. False-positive recall did vary by race. Same data source.	BCSC[6]
Breast cancer stage distribution (AJCC or SEER Summary Stage)	Stage distributions by mode of detection, age group (40-44, 45-49, 50-64, 65-74, 75-89), screening round/interval (first, annual, biennial) for screen-detected cancers, and density (a, b, c, d)	Yes	Yes; stage distributions varied by race. Same data source.	BCSC
ER/HER2 joint distribution	The distribution of ER/HER2 subtypes by age (40-49, 50-74, 75-89) and stage at diagnosis	Yes	Yes; subtype distributions varied by race. Same data source.	BCSC
Survival in the absence of screening and treatment	25-y breast cancer survival before systemic treatment by joint ER/HER2 status, age group, AJCC/SEER stage or tumor size	No	No; base survival did not vary by race.	Munoz,[40] Plevritis[41]
Treatment dissemination	Treatments and rates of use by time period, ER/HER2, stage and age for initial breast cancer diagnosis	Yes	No; treatment assignment did not vary by race.	Caswell-Jin[42], Mandelblatt,[43] Plevritis[41]
Treatment effects	Meta-analyses of clinical trial results by ER/HER2 for initial local therapy. Expert opinion for efficacy of systemic primary and metastatic therapy, and of newer targeted therapies.	Yes	Yes; treatment effectiveness reduced for Black patients based on NCCN data.[47]	Caswell-Jin,[42] Early Breast Cancer Trialists' Collaborative,[44,45,73-76] Plevritis,[41] Warner[47]
Other-cause mortality	Age- and cohort-specific mortality rates from non-breast cancer causes by year and level of comorbidity	Yes	Yes; other-cause mortality rates varied by race. Same data source.	Cho,[77] Gangnon,[46] Lansdorp-Vogelaar[62]
Quality of life	Utility weights for general health and decrements for screening, diagnostic	No	No; utility weights did not vary by race.	de Haes,[50] Hamner,[48,49] Stout[51]

Table 2. Common Breast Cancer Model Input Parameters: Description and Data Sources

	evaluation, and stage-specific treatment	

Abbreviations: AJCC, American Joint Committee on Cancer; BCSC, Breast Cancer Surveillance Consortium; BI-RADS, Breast Imaging Reporting and Data Systems; CISNET, Cancer Intervention and Surveillance Modeling Network; DM, digital mammography; DBT, digital breast tomosynthesis; ER, estrogen receptor; HER2, human epidermal growth factor receptor 2; NCCN, National Comprehensive Cancer Network; SEER, Surveillance, Epidemiology, and End Results.

Table 3. Performance (Sensitivity, False-Positive Recalls) of Digital Mammography and Digital Breast Tomosynthesis for All and Black Female Persons, Breast Cancer Surveillance Consortium

				False-Positive Recall (%)			
			Sensitivity[b]	DM		DBT	
Density	Age	Interval[a]	(%)	All	Black	All	Black
BI-RADS a	40-44	First	90%	13%	10%	11%	6%
		Annual	86%	5%	4%	4%	2%
		Biennial	90%	6%	6%	5%	3%
	45-49	First	93%	14%	11%	12%	7%
		Annual	88%	4%	4%	3%	2%
		Biennial	92%	6%	6%	5%	3%
	50-64	First	97%	16%	14%	13%	8%
		Annual	91%	4%	4%	3%	2%
		Biennial	94%	5%	5%	4%	3%
	65-74	Annual	93%	4%	5%	3%	2%
		Biennial	95%	5%	6%	3%	3%
BI-RADS b	40-44	First	93%	21%	19%	20%	13%
		Annual	85%	9%	9%	8%	6%
		Biennial	89%	11%	11%	10%	8%
	45-49	First	95%	22%	20%	20%	14%
		Annual	88%	8%	9%	7%	5%
		Biennial	91%	10%	11%	8%	7%
	50-64	First	98%	24%	24%	21%	16%
		Annual	91%	7%	8%	5%	5%
		Biennial	93%	8%	10%	7%	6%
	65-74	Annual	93%	6%	8%	4%	5%
		Biennial	94%	7%	10%	6%	6%
BI-RADS c	40-44	First	93%	24%	24%	24%	18%
		Annual	94%	11%	15%	11%	10%
		Biennial	94%	14%	17%	13%	13%
	45-49	First	72%	24%	25%	23%	18%
		Annual	82%	10%	13%	9%	9%
		Biennial	96%	12%	16%	11%	11%
	50-64	First	76%	25%	27%	23%	20%
		Annual	85%	8%	12%	7%	8%
		Biennial	98%	10%	14%	9%	10%
	65-74	Annual	82%	7%	11%	5%	7%
		Biennial	88%	8%	13%	7%	8%
BI-RADS d	40-44	First	85%	16%	16%	17%	12%
		Annual	90%	10%	14%	11%	10%
		Biennial	86%	12%	17%	13%	13%
	45-49	First	90%	16%	16%	17%	12%
		Annual	83%	9%	13%	9%	9%
		Biennial	62%	11%	15%	11%	12%
	50-64	First	76%	16%	17%	16%	13%
		Annual	89%	7%	11%	6%	7%
		Biennial	67%	8%	13%	8%	9%
	65-74	Annual	80%	5%	9%	5%	6%
		Biennial	95%	6%	11%	6%	8%

Abbreviations: a=almost entirely fatty; b= scattered areas of fibroglandular density; BI-RADS=Breast Imaging-Reporting and Data System; c= heterogeneously dense; d=extremely dense; DBT=digital breast tomosynthesis; DM=digital mammography.

[a] Sensitivity and false-positive recall calculations included 12 months of breast cancer followup for both annual and biennial screening intervals.

[b] Values based on predictions for each screening round using data for the calendar year 2018 from a regression model of 1,765,471 mammograms conducted during 2010–2018, adjusted for age (continuous), age-squared,

Table 3. Performance (Sensitivity, False-Positive Recalls) of Digital Mammography and Digital Breast Tomosynthesis for All and Black Female Persons, Breast Cancer Surveillance Consortium

screening interval, breast density category, year of examination, and all two-way interactions except for density by age and interactions with examination year. Sensitivity of digital mammography was not meaningfully different than of digital breast tomosynthesis. Sensitivity was also similar across race and ethnicity. Values shown for all cancers combined (ductal carcinoma in situ and invasive carcinoma).

Table 4. Median Lifetime Benefits (and Range Across Five Models) of Screening Strategies With Digital Mammography for a Cohort of 1,000 40-Year-Old Female Persons Compared With No Screening According to Screening Interval, Starting Age, and Stopping Age

Interval and Age Group[a]	Breast Cancer Mortality Reduction, %	Breast Cancer Deaths Averted	Life-Years Gained	QALYs Gained[b]
Biennial				
50-74	24.3 (18.3-27.5)	6.9 (4.8-8.6)	114.6 (109.8-165.0)	80.7 (72.3-132.4)
45-74	26.4 (20.4-29.3)	7.8 (5.1-9.2)	140.0 (125.0-187.7)	97.5 (82.2-149.5)
40-74	28.4 (22.3-31.7)	8.4 (5.6-10.1)	170.1 (141.2-214.1)	118.8 (91.8-163.8)
Hybrid				
A45-49, B50-74	29.3 (22.4-30.5)	8.6 (5.7-9.6)	151.3 (140.8-194.5)	104.7 (92.4-153.1)
A45-54, B55-74	29.3 (23.0-30.2)	8.8 (5.8-9.4)	159.3 (148.6-195.5)	109.8 (98.3-152.8)
A40-49, B50-74	31.7 (24.4-33.1)	9.3 (6.2-10.7)	178.9 (161.9-234.6)	122.2 (104.4-167.2)
Annual				
50-74	29.4 (24.7-31.7)	9.2 (6.8-9.5)	153.2 (134.0-181.4)	104.2 (89.0-140.3)
45-74	33.4 (29.8-35.4)	10.4 (7.5-11.8)	187.3 (163.6-230.1)	125.0 (108.5-162.2)
40-74	35.2 (31.8-37.6)	11.0 (8.0-13.1)	208.7 (200.7-275.5)	138.0 (133.6-194.0)
Biennial				
50-79	26.9 (22.2-30.2)	7.9 (5.6-9.4)	122.7 (118.5-172.8)	84.7 (77.5-138.9)
45-79	31.7 (24.8-33.3)	8.9 (6.3-11.9)	145.6 (137.8-202.5)	100.6 (90.0-159.2)
40-79	32.9 (25.3-34.9)	9.1 (6.4-12.3)	176.8 (149.8-233.9)	123.2 (97.0-170.3)
Hybrid				
A45-49, B50-79	31.8 (25.4-33.1)	9.4 (6.4-11.7)	156.7 (149.5-209.4)	107.9 (97.7-159.5)
A45-54, B55-79	33.9 (27.5-34.2)	10.0 (6.9-12.4)	168.8 (158.7-217.2)	115.9 (106.1-162.5)
A40-49, B50-79	34.9 (27.4-36.2)	10.1 (6.9-13.1)	187.9 (170.5-257.0)	128.3 (109.6-183.4)
Annual				
50-79	33.7 (32.1-35.8)	10.5 (7.9-12.2)	172.7 (145.8-192.7)	112.4 (96.1-148.7)
45-79	38.1 (35.1-39.5)	11.6 (8.9-14.8)	202.9 (172.0-256.1)	132.0 (113.1-180.0)
40-79	41.7 (37.2-42.9)	12.2 (9.4-16.1)	224.3 (211.4-300.6)	144.2 (140.0-211.2)

Abbreviations: A, annual; B, biennial.

[a] All strategies show results for Models D, E, GE, M, and W.

[b] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

Table 5. Median Lifetime Benefits (and Range Across Six Models) of Screening Strategies With Digital Breast Tomosynthesis for a Cohort of 1,000 40-Year-Old Female Persons Compared With No Screening According to Screening Interval, Starting Age, and Stopping Age

Interval and Age Group[a]	Breast Cancer Mortality Reduction, %	Breast Cancer Deaths Averted	Life-Years Gained	QALYs Gained[b]
Biennial				
50-74	25.4 (18.8-29.4)	6.7 (5.1-9.2)	120.8 (115.1-175.8)	86.1 (77.9-143.0)
45-74	27.5 (21.7-31.2)	7.5 (5.5-9.8)	141.3 (133.9-200.1)	100.4 (89.9-161.3)
40-74	30.0 (24.0-33.7)	8.2 (6.1-10.6)	165.2 (152.4-221.9)	116.8 (101.4-177.0)
Hybrid				
A45-49, B50-74	29.5 (23.9-32.5)	8.0 (6.0-10.2)	153.5 (146.3-207.2)	107.8 (101.3-165.5)
A45-54, B55-74	29.9 (24.4-32.1)	8.2 (6.2-10.0)	161.1 (148.2-207.9)	110.7 (105.2-165.1)
A40-49, B50-74	32.2 (26.1-34.4)	8.8 (6.6-11.0)	181.2 (163.9-240.1)	125.7 (115.5-179.2)
Annual				
50-74	30.6 (24.7-32.8)	8.6 (7.0-10.1)	155.6 (137.1-191.7)	109.0 (93.7-151.4)
45-74	34.1 (31.4-36.5)	9.7 (7.9-11.8)	193.3 (165.7-230.1)	132.0 (112.8-173.8)
40-74	37.0 (33.6-38.9)	10.3 (8.5-13.1)	216.6 (190.1-274.9)	146.1 (132.3-196.5)
Biennial				
50-79	28.0 (23.6-32.2)	7.6 (6.0-10.1)	129.3 (119.6-184.1)	91.7 (83.7-150.1)
45-79	32.1 (26.5-35.5)	8.6 (6.7-12.1)	153.4 (147.7-213.1)	110.2 (98.5-172.1)
40-79	33.3 (27.2-36.5)	8.9 (6.9-12.5)	173.9 (161.7-237.8)	124.2 (107.2-184.2)
Hybrid				
A45-49, B50-79	32.5 (27.2-35.3)	8.9 (6.9-11.9)	160.5 (152.8-215.4)	111.5 (107.1-172.5)
A45-54, B55-79	34.1 (29.2-36.4)	9.2 (7.4-12.6)	172.7 (161.0-220.8)	118.4 (111.6-175.9)
A40-49, B50-79	35.3 (29.4-37.2)	9.5 (7.4-13.3)	188.7 (173.4-260.1)	130.7 (121.4-188.1)
Annual				
50-79	34.5 (32.6-36.9)	9.8 (8.0-12.2)	173.2 (148.2-203.6)	118.4 (102.5-160.8)
45-79	39.1 (37.1-40.8)	10.9 (9.0-14.8)	207.1 (176.1-255.8)	140.8 (119.5-183.2)
40-79	41.7 (39.2-43.0)	11.5 (9.9-16.1)	229.7 (200.4-300.7)	154.3 (139.5-214.6)

Abbreviations: A, annual; B, biennial.

[a] All strategies show results for Models D, E, GE, M, S, and W.

[b] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

Table 6. Median Lifetime Harms (and Range Across Five Models) of Screening Strategies With Digital Mammography for a Cohort of 1,000 40-Year-Old Female Persons Compared With No Screening According to Screening Interval, Starting Age, and Stopping Age

Interval and Age Group[a]	Mammograms	False-Positive Recalls	Benign Biopsies	Overdiagnosed Cases[b]
Biennial				
50-74	11,192 (10,999-11,278)	1,021 (1,003-1,027)	148 (146-149)	10 (4-29)
45-74	13,283 (13,078-13,380)	1,230 (1,212-1,238)	173 (170-174)	11 (4-30)
40-74	16,092 (15,863-16,215)	1,540 (1,520-1,551)	210 (207-212)	12 (4-33)
Hybrid				
A45-49, B50-74	15,992 (15,807-16,164)	1,416 (1,400-1,430)	189 (187-191)	19 (4-33)
A45-54, B55-74	18,006 (17,804-18,197)	1,514 (1,497-1,530)	195 (193-197)	19 (4-33)
A40-49, B50-74	20,898 (20,705-21,133)	1,896 (1,879-1,916)	236 (234-239)	21 (4-35)
Annual				
50-74	21,439 (21,010-21,650)	1,543 (1,513-1,557)	192 (188-194)	16 (5-39)
45-74	26,272 (25,776-26,526)	1,943 (1,907-1,960)	233 (229-235)	18 (5-43)
40-74	31,178 (30,649-31,493)	2,423 (2,385-2,446)	281 (276-283)	19 (5-45)
Biennial				
50-79	12,456 (12,223-12,560)	1,105 (1,084-1,113)	160 (157-161)	12 (6-34)
45-79	15,176 (14,907-15,297)	1,356 (1,333-1,366)	191 (187-192)	14 (6-37)
40-79	17,354 (17,081-17,494)	1,624 (1,601-1,636)	222 (219-223)	14 (6-37)
Hybrid				
A45-49, B50-79	17,242 (17,026-17,443)	1,499 (1,481-1,516)	200 (198-203)	22 (6-37)
A45-54, B55-79	19,876 (19,627-20,112)	1,639 (1,618-1,658)	213 (210-215)	24 (6-40)
A40-49, B50-79	22,150 (21,921-22,412)	1,979 (1,960-2,002)	248 (245-251)	24 (6-40)
Annual				
50-79	24,563 (24,014-24,831)	1,716 (1,678-1,733)	212 (208-214)	19 (7-46)
45-79	29,389 (28,767-29,702)	2,115 (2,072-2,136)	253 (248-256)	21 (7-50)
40-79	34,289 (33,633-34,667)	2,595 (2,550-2,621)	301 (295-304)	23 (7-52)

Abbreviations: A, annual; B, biennial.

[a] All strategies show results for Models D, E, GE, M, and W.

[b] Overdiagnosed cases are in situ and invasive breast cancer cases that would not have been clinically detected in the absence of screening. Overdiagnosis is calculated by subtracting the number of cases detected in the no-screening scenario from the number of cases detected in the screening scenario.

Table 7. Median Lifetime Harms (and Range Across Six Models) of Screening Strategies With Digital Breast Tomosynthesis for a Cohort of 1,000 40-Year-Old Female Persons Compared With No Screening According to Screening Interval, Starting Age, and Stopping Age

Interval and Age Group[a]	Mammograms	False-Positive Recalls	Benign Biopsies	Overdiagnosed Cases[b]
Biennial				
50-74	11,208 (10,976-11,278)	873 (855-878)	136 (133-137)	12 (4-33)
45-74	13,299 (13,051-13,380)	1,080 (1,061-1,086)	164 (161-165)	13 (4-34)
40-74	16,116 (15,826-16,214)	1,376 (1,354-1,384)	201 (198-203)	14 (4-37)
Hybrid				
A45-49, B50-74	16,053 (15,775-16,164)	1,242 (1,221-1,250)	184 (180-185)	19 (4-37)
A45-54, B55-74	18,072 (17,772-18,197)	1,317 (1,296-1,326)	193 (189-194)	20 (4-37)
A40-49, B50-74	20,979 (20,662-21,133)	1,691 (1,667-1,703)	238 (233-240)	21 (4-39)
Annual				
50-74	21,500 (20,963-21,650)	1,277 (1,246-1,285)	186 (182-187)	18 (5-42)
45-74	26,349 (25,716-26,526)	1,647 (1,610-1,657)	234 (229-235)	20 (5-46)
40-74	31,273 (30,572-31,492)	2,096 (2,055-2,110)	288 (283-290)	21 (5-48)
Biennial				
50-79	12,488 (12,193-12,560)	937 (916-943)	144 (141-145)	14 (6-38)
45-79	15,218 (14,871-15,297)	1,176 (1,153-1,183)	176 (173-177)	16 (6-41)
40-79	17,397 (17,037-17,494)	1,440 (1,415-1,449)	210 (206-211)	17 (6-42)
Hybrid				
A45-49, B50-79	17,325 (16,987-17,443)	1,306 (1,282-1,315)	192 (188-193)	22 (6-42)
A45-54, B55-79	19,980 (19,585-20,112)	1,413 (1,387-1,423)	205 (202-207)	24 (6-44)
A40-49, B50-79	22,255 (21,870-22,412)	1,755 (1,728-1,768)	247 (242-248)	24 (6-44)
Annual				
50-79	24,687 (23,953-24,831)	1,405 (1,367-1,417)	202 (197-204)	22 (7-50)
45-79	29,517 (28,692-29,701)	1,774 (1,730-1,789)	250 (244-252)	24 (7-54)
40-79	34,441 (33,538-34,666)	2,224 (2,175-2,240)	304 (298-307)	25 (7-56)

Abbreviations: A, annual; B, biennial.

[a] All strategies show results for Models D, E, GE, M, S, and W.

[b] Overdiagnosed cases are in situ and invasive breast cancer cases that would not have been clinically detected in the absence of screening. Overdiagnosis is calculated by subtracting the number of cases detected in the no-screening scenario from the number of cases detected in the screening scenario. Model S (Stanford University) is excluded because it does not include DCIS.

Table 8. Incremental Benefits and Harms Across Five Models for a Cohort of 1,000 40-Year-Old Female Persons Screened With Digital Breast Tomosynthesis (Median and Range) Compared With Digital Mammography (Median Only) vs. No Screening According to Interval and Start Age With Stop Age 74 Years

	Breast Cancer Mortality Reduction, %		Breast Cancer Deaths Averted		Life-Years Gained		QALYs Gained[b]	
Strategy and Age Group[a]	**DM vs. No Screening**	**DBT vs. DM**	**DM vs. No Screening**	**DBT vs. DM**	**DM vs. No Screening**	**DBT vs. DM**	**DM vs. No Screening**	**DBT vs. DM**
Biennial								
50-74	24.3	+1.0 (0.5-1.8)	6.9	+0.3 (0.2-0.6)	114.6	+5.5 (3.7-10.8)	80.7	+5.6 (4.3-10.5)
45-74	26.4	+1.1 (0.5-1.9)	7.8	+0.3 (0.2-0.6)	140.0	+5.0 (2.7-12.4)	97.5	+4.9 (3.6-11.9)
40-74	28.4	+1.1 (0.5-2.1)	8.4	+0.3 (0.2-0.7)	170.1	+5.8 (3.9-13.8)	118.8	+5.6 (4.7-13.2)
Hybrid								
A45-49, B50-74	29.3	+0.8 (0.4-2.0)	8.6	+0.2 (0.1-0.6)	151.3	+4.9 (3.0-12.6)	104.7	+5.4 (4.0-12.3)
A45-54, B55-74	29.3	+0.8 (0.4-1.9)	8.8	+0.2 (0.1-0.6)	159.3	+3.9 (2.6-12.4)	109.8	+4.8 (3.9-12.3)
A40-49, B50-74	31.7	+0.8 (0.7-2.1)	9.3	+0.2 (0.2-0.7)	178.9	+5.6 (4.0-13.9)	122.2	+6.4 (4.9-13.7)
Annual								
50-74	29.4	+1.1 (0-1.7)	9.2	+0.3 (0-0.5)	153.2	+5.1 (0.4-10.3)	104.2	+5.9 (2.7-11.1)
45-74	33.4	+1.2 (0-1.9)	10.4	+0.3 (0-0.6)	187.3	+5.6 (-0.1-12.2)	125.0	+6.5 (2.6-12.9)
40-74	35.2	+1.3 (-0.1-2)	11.0	+0.4 (0-0.6)	208.7	+6.5 (-1.4-13.5)	138.0	+7.5 (2.1-14.3)

	Mammograms		False-Positive Recalls		Benign Biopsies		Overdiagnosed Cases, n[c]	
Biennial	**DM vs. No Screening**	**DBT vs. DM**	**DM vs. No Screening**	**DBT vs. DM**	**DM vs. No Screening**	**DBT vs. DM**	**DM vs. No Screening**	**DBT vs. DM**
50-74	11,192	0 (-24-0)	1,021	-149 (-150, -148)	148	-12 (-12, -12)	10	0 (0-3)
45-74	13,283	0 (-27-0)	1,230	-152 (-154, -150)	173	-9 (-10, -9)	11	0 (0-3)
40-74	16,092	0 (-37-1)	1,540	-167 (-169, -166)	210	-9 (-10, -9)	12	0 (0-4)
Hybrid								
A45-49, B50-74	15,992	0 (-32-0)	1,416	-180 (-183, -178)	189	-6 (-7, -6)	19	0 (0-4)
A45-54, B55-74	18,006	-1 (-33-0)	1,514	-203 (-206, -201)	195	-3 (-4, -3)	19	0 (0-3)
A40-49, B50-74	20,898	0 (-44-2)	1,896	-212 (-217, -211)	236	+1 (-1, 1)	21	0 (0-4)
Annual								
50-74	21,439	0 (-47-1)	1,543	-271 (-272, -266)	192	-6 (-6, -6)	16	0 (0-3)
45-74	26,272	-1 (-59-0)	1,943	-302 (-304, -297)	233	0 (-1, 0)	18	0 (0-3)
40-74	31,178	0 (-77-2)	2,423	-334 (-337, -330)	281	+7 (5, 7)	19	0 (0-4)

[a] Results summarized over five models (D, E, GE, M, W); model S not included in the table. Range of values for DM shown in **Table 4** and **Table 6**.

[b] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

[c] Overdiagnosed cases are in situ and invasive breast cancer cases that would not have been clinically detected in the absence of screening. Overdiagnosis is calculated by subtracting the number of cases detected in the no-screening scenario from the number of cases detected in the screening scenario.

Table 9. Impact of Screening Continuation to Age 79 (Median and Range Across Models) vs. 74 (Median Across Models) on Screening Benefits and Harms for a Cohort of 1,000 40-Year-Old Female Persons Screened With Digital Breast Tomosynthesis or Digital Mammography vs. No Screening

Strategy and Starting Age[a]	Breast Cancer Mortality Reduction, %		Breast Cancer Deaths Averted		Life-Years Gained		QALYs Gained	
	74 vs. no screening	79 vs. 74	74 vs. no screening	79 vs. 74	74 vs. no screening	79 vs. 74	74 vs. no screening	79 vs. 74
Digital Breast Tomosynthesis								
Biennial								
50	25.4	+2.9 (2.6-6.1)	6.7	+0.8 (0.6-2.3)	120.8	+8.8 (-5.8-20.1)	86.1	+6.5 (-4.3-14.5)
45	27.5	+4.6 (3.8-9.0)	7.5	+1.2 (1.1-3.4)	141.3	+13.4 (9.0-30.1)	100.4	+9.7 (6.0-21.8)
40	30.0	+3.0 (2.6-6.0)	8.2	+0.8 (0.7-2.3)	165.2	+8.8 (6.1-19.8)	116.8	+6.5 (4.0-14.3)
Hybrid								
A45-49, B50	29.5	+3.2 (2.5-6.0)	8.0	+0.8 (0.7-2.3)	153.5	+7.4 (3.2-20.1)	107.8	+5.2 (1.7-14.5)
A45-54, B55	29.9	+4.4 (3.3-9.1)	8.2	+1.2 (0.8-3.4)	161.1	+12.9 (9.5-30.2)	110.7	+8.9 (6.2-21.8)
A40-49, B50	32.2	+2.9 (2.2-6.0)	8.8	+0.8 (0.6-2.3)	181.2	+9.0 (6.5-20.0)	125.7	+6.4 (4.3-14.5)
Annual								
50	30.6	+4.2 (3.6-7.9)	8.6	+1.2 (0.9-3.0)	155.6	+12.7 (-2.7-25.6)	109.0	+9.1 (-2.8-18.0)
45	34.1	+4.4 (4.1-7.9)	9.7	+1.3 (1.0-3.0)	193.3	+11.5 (5.5-25.8)	132.0	+8.2 (3.4-18.1)
40	37.0	+4.3 (4.1-7.9)	10.3	+1.2 (1.0-3.0)	216.6	+13.4 (9.6-25.8)	146.1	+9.6 (5.9-18.1)
Digital Mammography								
Biennial								
50	24.3	+3.2 (2.5-6.0)	6.9	+0.8 (0.7-2.2)	114.6	+7.7 (5.6-19.7)	80.7	+5.3 (3.6-14.0)
45	26.4	+4.6 (3.7-8.9)	7.8	+1.1 (1.1-3.3)	140.0	+12.2 (5.6-29.6)	97.5	+7.8 (3.1-21.1)
40	28.4	+3.1 (2.5-6.0)	8.4	+0.8 (0.7-2.2)	170.1	+7.7 (6.0-19.8)	118.8	+5.2 (3.9-14.1)
Hybrid								
A45-49, B50	29.3	+3.0 (2.5-6.0)	8.6	+0.8 (0.7-2.2)	151.3	+7.7 (5.4-19.7)	104.7	+5.3 (3.3-14.0)
A45-54, B55	29.3	+4.6 (3.9-8.9)	8.8	+1.1 (1.1-3.3)	159.3	+12.2 (9.5-29.6)	109.8	+7.8 (6.0-21.1)
A40-49, B50	31.7	+3.1 (2.6-6.2)	9.3	+0.8 (0.7-2.3)	178.9	+8.6 (6.3-22.4)	122.2	+6.1 (3.9-16.2)
Annual								
50	29.4	+4.8 (4.1-7.8)	9.2	+1.2 (1.0-2.9)	153.2	+11.8 (9.5-25.3)	104.2	+8.4 (5.6-17.3)
45	33.4	+4.9 (4.1-7.9)	10.4	+1.2 (1.0-2.9)	187.3	+11.3 (8.4-25.9)	125.0	+8.4 (4.7-17.9)
40	35.2	+5.0 (4.1-7.8)	11.0	+1.2 (1.1-2.9)	208.7	+11.3 (9.7-25.1)	138.0	+8.4 (5.7-17.2)

Table 9. Impact of Screening Continuation to Age 79 (Median and Range Across Models) vs. 74 (Median Across Models) on Screening Benefits and Harms for a Cohort of 1,000 40-Year-Old Female Persons Screened With Digital Breast Tomosynthesis or Digital Mammography vs. No Screening

	Mammograms		False-Positive Recalls		Benign Biopsies		Overdiagnosed Cases, n[b]	
Digital Breast Tomosynthesis	**74 vs. no screening**	**79 vs. 74**	**74 vs. no screening**	**79 vs. 74**	**74 vs. no screening**	**79 vs. 74**	**74 vs. no screening**	**79 vs. 74**
Biennial								
50	11,208	+1,281 (1,218-1,298)	873	+64 (61-66)	136	+8 (8-9)	12	+2 (1-5)
45	13,299	+1,915 (1,820-1,950)	1,080	+96 (92-99)	164	+13 (12-13)	13	+3 (2-8)
40	16,116	+1,277 (1,211-1,306)	1,376	+64 (61-66)	201	+8 (8-9)	14	+2 (1-5)
Hybrid								
A45-49, B50	16,053	+1,277 (1,212-1,295)	1,242	+64 (61-65)	184	+8 (8-9)	19	+3 (1-5)
A45-54, B55	18,072	+1,912 (1,813-1,947)	1,317	+95 (91-99)	193	+13 (12-13)	20	+4 (2-8)
A40-49, B50	20,979	+1,275 (1,208-1,300)	1,691	+64 (61-66)	238	+8 (8-9)	21	+3 (1-5)
Annual								
50	21,500	+3,177 (2,990-3,233)	1,277	+127 (120-131)	186	+16 (15-16)	18	+4 (2-8)
45	26,349	+3,171 (2,975-3,234)	1,647	+127 (120-131)	234	+16 (15-16)	20	+4 (2-8)
40	31,273	+3,167 (2,966-3,242)	2,096	+127 (119-132)	288	+16 (15-17)	21	+4 (2-8)
Digital Mammography								
Biennial								
50	11,192	+1,279 (1,224-1,294)	1,021	+84 (81-86)	148	+12 (11-12)	10	+2 (1-4)
45	13,283	+1,913 (1,830-1,939)	1,230	+126 (122-129)	173	+18 (17-18)	11	+3 (2-7)
40	16,092	+1,276 (1,219-1,294)	1,540	+84 (81-86)	210	+12 (11-12)	12	+2 (1-4)
Hybrid								
A45-49, B50	15,992	+1,276 (1,219-1,294)	1,416	+84 (81-86)	189	+12 (11-12)	19	+3 (1-4)
A45-54, B55	18,006	+1,907 (1,823-1,939)	1,514	+125 (121-129)	195	+18 (17-18)	19	+4 (2-7)
A40-49, B50	20,898	+1,276 (1,215-1,294)	1,896	+84 (81-86)	236	+12 (11-12)	21	+3 (1-4)
Annual								
50	21,439	+3,172 (3,004-3,214)	1,543	+173 (166-178)	192	+20 (19-21)	16	+4 (2-7)
45	26,272	+3,164 (2,991-3,214)	1,943	+172 (165-178)	233	+20 (19-21)	18	+4 (2-7)
40	31,178	+3,162 (2,984-3,214)	2,423	+172 (165-178)	281	+20 (19-21)	19	+4 (2-7)

[a] Results for DM are summarized over five models (D, E, GE, M, W); DBT results include six models (D, E, GE, M, S, W). Range of values for stopping age 74 shown in **Tables 4–7**.

[b] Overdiagnosed cases are in situ and invasive breast cancer cases that would not have been clinically detected in the absence of screening. Overdiagnosis is calculated by subtracting the number of cases detected in the no-screening scenario from the number of cases detected in the screening scenario. Model S (Stanford University) is excluded because it does not include DCIS.

Table 10. Incremental Ratios for Breast Cancer Mortality (Change in the Number of Mammograms/Change in Percent Breast Cancer Mortality Reduction) and Life-Years Gained (Change in the Number of Mammograms/Change in LYG) From Six Models for a Cohort of 1,000 40-Year-Old Female Persons According to Screening Strategy

		Δ mammograms / Δ % mortality reduction						Δ mammograms / Δ LYG					
Strategy[a]	Screens, n[b]	D	E	GE	M	S	W	D	E	GE	M	S	W
DBT B50-74	11,208	384	441	[c]	426	440	540[d]	64	94	[c]	91	90	95
DBT B50-79	12,448	457	488	[c]	428	507	517	[c]	[c]	[c]	119[d]	[c]	130[d]
DBT B45-74	13,299	[c]	[c]	[c]	[c]	[c]	[c]	87	101	76[d]	102[d]	178[d]	116
DBT B45-79	15,218	813	795	474	621	733	912	148[d]	209[d]	74[d]	[c]	143	132
DBT B40-74	16,116	[c]	[c]	[c]	[c]	[c]	[c]	130	179	74[d]	93	[c]	203[d]
DBT B40-79	17,397	2,142	2,612[d]	1,795	907	1,780	3,110[d]	155	206	73	194	169	154
DBT A40-49, B50-79	22,255	7,236[d]	5,959[d]	2,532[d]	5,527[d]	4,673[d]	[c]	736[d]	215	219	407	725[d]	218[d]
DBT A45-79	29,517	4,310[d]	1,564	2,024[d]	[c]	2,155	1,377	[c]	[c]	[c]	[c]	[c]	222[d]
DBT A40-79	34,441	3,649	2,169	1,816[d]	2,686	2,295	2,218	658	323	302	577	510	217

Abbreviations: A, annual; B, biennial; D, Dana-Farber Cancer Institute; DBT, digital breast tomosynthesis; DM, digital mammography; E, Erasmus Medical Center; GE, Georgetown Lombardi Comprehensive Cancer Center-Albert Einstein College of Medicine; M, University of Texas MD Anderson Cancer Center; S, Stanford University; W, University of Wisconsin-Madison and Harvard Pilgrim Health Care Institute.

[a] Ratios for each strategy are calculated relative to the next efficient or near-efficient strategy with fewer mammograms, not necessarily shown in the table (varied across models). B50-74 is compared with no screening. The ratio for the strategy with the fewest number of mammograms (B50-74) is calculated relative to no screening. DBT strategies are shown that were efficient or near-efficient in 5 or more out of 6 models for either incremental ratio. Zero DM strategies were efficient or near-efficient in 4 or more out of 5 models for either incremental ratio.

[b] Median number of mammograms across models. Strategies are ranked from the least to the most mammograms.

[c] Strategies that are inferior (also referred to as less efficient or dominated) within a specific model; a strategy is classified as such if another strategy results in an equal or higher benefit (percent reduction in breast cancer mortality or life-years gained) with fewer harms (number of screening examinations).

[d] Near-efficient strategy. Strategies were considered near-efficient if they were within 2.2 days per person for LYG and 1.27 percentage points for percent breast cancer mortality reduction of the efficient frontier.

Table 11. Median Lifetime Benefits (and Range Across Four Models) of Screening Strategies With Digital Mammography for a Cohort of 1,000 40-Year-Old Black Female Persons Compared With No Screening According to Screening Interval, Starting Age, and Stopping Age

Interval and Age Group[a]	Breast Cancer Mortality Reduction, %	Breast Cancer Deaths Averted	Life-Years Gained	QALYs Gained[b]
Biennial				
50-74	22.7 (18.5-25.2)	8.5 (6.5-12.2)	163.5 (121.7-211.9)	116.5 (82.6-153.6)
45-74	25.0 (19.1-28.0)	9.0 (7.4-13.5)	183.2 (153.0-262.2)	131.1 (103.2-191.4)
40-74	27.9 (20.8-31.0)	10.0 (8.1-14.9)	214.0 (174.0-297.5)	153.9 (113.6-216.3)
Hybrid				
A45-49, B50-74	26.2 (20.8-30.2)	9.5 (7.9-14.6)	196.5 (153.9-281.7)	138.1 (103.5-204.5)
A45-54, B55-74	26.0 (21.1-29.3)	9.6 (7.8-14.1)	202.7 (159.9-278.7)	141.8 (106.8-200.9)
A40-49, B50-74	28.7 (22.3-32.5)	10.3 (8.7-15.7)	223.0 (195.8-318.4)	156.8 (126.3-228.7)
Annual				
50-74	27.6 (24.2-31.8)	10.8 (7.7-15.4)	211.1 (145.6-266.5)	146.3 (94.2-189.9)
45-74	30.1 (28.3-36.8)	11.8 (9.0-17.8)	243.6 (186.4-336.0)	167.5 (121.8-240.5)
40-74	32.4 (30.4-39.1)	12.4 (10.2-18.9)	266.4 (227.8-373.2)	183.8 (149.9-265.1)
Biennial				
50-79	25.6 (22.4-30.0)	9.9 (7.5-14.5)	176.8 (131.3-233.2)	125.4 (88.9-168.5)
45-79	29.2 (24.4-35.2)	10.8 (8.9-17.0)	202.0 (164.3-294.4)	142.6 (112.1-214.0)
40-79	30.8 (24.6-35.8)	11.0 (9.6-17.3)	225.4 (189.0-318.5)	161.7 (123.1-231.0)
Hybrid				
A45-49, B50-79	28.9 (24.6-35.0)	10.8 (8.8-16.9)	209.5 (166.9-303.1)	146.8 (112.3-219.5)
A45-54, B55-79	30.2 (26.4-36.5)	11.4 (9.2-17.6)	221.5 (172.7-311.1)	154.2 (114.9-223.7)
A40-49, B50-79	31.6 (26.1-37.5)	11.5 (9.9-18.1)	232.6 (210.6-343.5)	163.2 (135.7-246.7)
Annual				
50-79	33.0 (28.3-38.3)	12.9 (9.0-18.5)	232.3 (160.0-295.0)	159.9 (102.9-209.0)
45-79	35.4 (32.3-43.3)	13.9 (10.3-20.9)	264.8 (189.3-364.4)	181.1 (121.7-259.6)
40-79	37.0 (35.9-45.5)	14.5 (11.5-22.0)	287.5 (239.5-401.3)	194.2 (156.5-284.0)

Abbreviations: A, annual; B, biennial.

[a] All strategies show results for Models D, GE, M, and W.

[b] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

Table 12. Median Lifetime Benefits (and Range Across Four Models) of Screening Strategies With Digital Breast Tomosynthesis for a Cohort of 1,000 40-Year-Old Black Female Persons Compared With No Screening According to Screening Interval, Starting Age, and Stopping Age

Interval and Age Group[a]	Breast Cancer Mortality Reduction, %	Breast Cancer Deaths Averted	Life-Years Gained	QALYs Gained[b]
Biennial				
50-74	24.1 (19.8-27.1)	9.2 (7.1-12.6)	176.7 (127.8-219.8)	130.6 (91.3-163.8)
45-74	26.8 (20.5-28.9)	9.7 (8.0-13.9)	199.0 (157.3-270.4)	147.0 (113.2-202.5)
40-74	29.9 (22.4-31.9)	10.7 (8.7-15.4)	228.9 (189-305.7)	171.5 (130.1-228.4)
Hybrid				
A45-49, B50-74	28.1 (22.3-31.1)	10.3 (8.4-15.0)	212.9 (167.3-288.8)	156.3 (119.2-215.6)
A45-54, B55-74	27.9 (22.6-30.1)	10.3 (8.3-14.5)	219.1 (165.4-285.8)	160.5 (117.2-212.5)
A40-49, B50-74	30.9 (24.0-33.6)	11.1 (9.4-16.2)	239.4 (213.1-329.5)	177.0 (146.0-244.6)
Annual				
50-74	29.3 (25.5-32.4)	11.5 (8.2-15.6)	224.7 (154.2-271.3)	163.3 (107.3-200.1)
45-74	32.1 (30.0-37.3)	12.6 (9.6-18.0)	260.8 (196.2-340.3)	188.8 (137.3-251.8)
40-74	34.4 (32.2-39.6)	13.3 (10.7-19.1)	286.2 (243.7-377.7)	205.6 (171.8-278.2)
Biennial				
50-79	27.6 (24.1-31.0)	10.7 (8.0-15.0)	191.2 (142.0-241.7)	140.9 (101.4-179.6)
45-79	31.2 (26.4-36.3)	11.7 (9.3-17.5)	219.4 (172.7-303.6)	161.3 (123.7-226.6)
40-79	33.0 (26.6-36.8)	12 (10.2-17.8)	238.5 (205.4-328.1)	178.5 (141.0-244.6)
Hybrid				
A45-49, B50-79	31.1 (26.5-35.9)	11.7 (9.3-17.3)	227.1 (177.0.-310.7)	166.3 (126.0-231.4)
A45-54, B55-79	32.4 (28.5-37.5)	12.4 (9.7-18.1)	239.6 (180.7-318.7)	174.8 (127.7-236.3)
A40-49, B50-79	33.9 (28.2-38.4)	12.4 (10.5-18.5)	253.1 (225.4-351.4)	185.6 (157.0-260.4)
Annual				
50-79	35.1 (29.7-39.0)	13.8 (9.5-18.8)	247.6 (164.5-300.2)	179.0 (113.7-220.5)
45-79	37.9 (34.0-43.9)	14.9 (10.9-21.2)	283.6 (209.5-369.0)	204.5 (146.0-272.1)
40-79	39.6 (37.9-46.2)	15.5 (12.1-22.3)	309.0 (253.9-406.8)	221.2 (178.1-298.8)

Abbreviations: A, annual; B, biennial.

[a] All strategies show results for Models D, GE, M, and W.

[b] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

Table 13. Lifetime Harms (and Range Across Four Models) of Screening With Digital Mammography Compared With No Screening for a Cohort of 1,000 40-Year-Old Black Female Persons According to Interval, Start Age, and Stop Age

Strategy	Mammograms	False-Positive Recalls	Benign Biopsies	Overdiagnosed Cases[a]
Biennial				
50-74	10,905 (10,834-10,939)	1,263 (1,255-1,265)	188 (187-188)	16 (5-26)
45-74	13,009 (12,937-13,055)	1,517 (1,511-1,524)	218 (217-219)	16 (5-27)
40-74	15,801 (15,706-15,856)	1,880 (1,869-1,887)	262 (261-263)	18 (6-29)
Hybrid				
A45-49, B50-74	15,743 (15,655-15,797)	1,755 (1,748-1,764)	234 (232-234)	18 (5-29)
A45-54, B55-74	17,772 (17,677-17,840)	1,887 (1,879-1,897)	238 (237-240)	18 (5-29)
A40-49, B50-74	20,677 (20,559-20,758)	2,328 (2,315-2,338)	285 (283-286)	18 (6-31)
Annual				
50-74	20,935 (20,733-20,988)	1,960 (1,942-1,964)	231 (229-232)	19 (6-34)
45-74	25,760 (25,524-25,846)	2,452 (2,433-2,462)	277 (274-278)	20 (6-37)
40-74	30,694 (30,409-30,793)	3,024 (2,998-3,036)	328 (325-329)	21 (6-39)
Biennial				
50-79	12,072 (11,978-12,115)	1,387 (1,375-1,387)	206 (204-206)	18 (7-31)
45-79	14,755 (14,650-14,818)	1,703 (1,691-1,705)	245 (243-245)	20 (8-33)
40-79	16,966 (16,847-17,032)	2,004 (1,989-2,007)	280 (278-281)	20 (7-34)
Hybrid				
A45-49, B50-79	16,907 (16,796-16,973)	1,879 (1,868-1,885)	252 (250-252)	20 (7-34)
A45-54, B55-79	19,518 (19,386-19,595)	2,072 (2,059-2,078)	265 (263-266)	22 (8-36)
A40-49, B50-79	21,846 (21,698-21,919)	2,451 (2,434-2,459)	303 (301-304)	21 (7-35)
Annual				
50-79	23,830 (23,548-23,907)	2,216 (2,188-2,218)	260 (257-260)	23 (8-42)
45-79	28,644 (28,329-28,765)	2,707 (2,678-2,715)	305 (302-306)	24 (9-44)
40-79	33,578 (33,209-33,711)	3,280 (3,243-3,287)	357 (353-358)	25 (9-46)

Abbreviations: A, annual; B, biennial.

[a] Overdiagnosed cases are in situ and invasive breast cancer cases that would not have been diagnosed in the absence of screening. Overdiagnosis is calculated by subtracting the number of diagnosed cases detected in the no-screening scenario from the number of diagnosed cases detected in the screening scenario.

Table 14. Lifetime Harms (and Range Across Four Models) of Screening With Digital Breast Tomosynthesis Compared With No Screening for a Cohort of 1,000 40-Year-Old Black Female Persons According to Interval, Start Age, and Stop Age

Strategy	Mammograms	False-Positive Recalls	Benign Biopsies	Overdiagnosed Cases[a]
Biennial				
50-74	10,905 (10,820-10,939)	814 (807-816)	158 (157-159)	16 (5-28)
45-74	13,009 (12,919-13,055)	997 (991-1,002)	189 (188-190)	16 (5-29)
40-74	15,801 (15,681-15,856)	1,253 (1,243-1,257)	233 (231-233)	18 (6-32)
Hybrid				
A45-49, B50-74	15,743 (15,634-15,797)	1,144 (1,138-1,150)	206 (205-207)	18 (5-31)
A45-54, B55-74	17,771 (17,655-17,839)	1,217 (1,211-1,225)	212 (210-213)	18 (5-31)
A40-49, B50-74	20,676 (20,529-20,757)	1,534 (1,523-1,541)	260 (258-261)	18 (6-33)
Annual				
50-74	20,934 (20,702-20,988)	1,209 (1,195-1,211)	200 (198-200)	19 (6-36)
45-74	25,759 (25,482-25,846)	1,538 (1,524-1,546)	247 (245-249)	20 (6-39)
40-74	30,693 (30,354-30,792)	1,929 (1,908-1,936)	302 (299-303)	21 (6-41)
Biennial				
50-79	12,073 (11,961-12,115)	887 (878-888)	171 (169-171)	18 (7-33)
45-79	14,755 (14,625-14,818)	1,107 (1,097-1,109)	208 (206-208)	20 (8-37)
40-79	16,965 (16,817-17,032)	1,326 (1,314-1,329)	245 (243-246)	20 (7-37)
Hybrid				
A45-49, B50-79	16,907 (16,771-16,973)	1,217 (1,208-1,222)	218 (217-219)	20 (7-36)
A45-54, B55-79	19,517 (19,357-19,595)	1,327 (1,317-1,332)	230 (228-231)	22 (8-39)
A40-49, B50-79	21,846 (21,663-21,919)	1,608 (1,593-1,612)	273 (270-273)	21 (7-39)
Annual				
50-79	23,827 (23,506-23,907)	1,353 (1,334-1,355)	221 (218-221)	23 (8-44)
45-79	28,646 (28,276-28,765)	1,683 (1,663-1,688)	268 (265-269)	24 (9-47)
40-79	33,577 (33,141-33,711)	2,074 (2,046-2,077)	323 (318-323)	25 (9-49)

Abbreviations: A, annual; B, biennial.

[a] Overdiagnosed cases are in situ and invasive breast cancer cases that would not have been diagnosed in the absence of screening. Overdiagnosis is calculated by subtracting the number of diagnosed cases detected in the no-screening scenario from the number of diagnosed cases detected in the screening scenario.

Table 15. Change in Benefits and Harms Across Four Models for a Cohort of 1,000 40-Year-Old Black Female Persons Screened With Digital Breast Tomosynthesis (Median and Range[a]) Instead of Digital Mammography (Median) vs. No Screening According to Interval and Start Age With Stop Age 74 Years

	Breast Cancer Mortality Reduction, %		Breast Cancer Deaths Averted		Life-Years Gained		QALYs Gained[b]	
Strategy and Age Group	**DM vs. No Screening**	**DBT vs. DM**	**DM vs. No Screening**	**DBT vs. DM**	**DM vs. No Screening**	**DBT vs. DM**	**DM vs. No Screening**	**DBT Vs. DM**
Biennial								
50-74	22.7	+1.5 (0.9-2.2)	8.5	+0.5 (0.4-0.9)	163.5	+8.9 (6.1-16.5)	116.5	+10.6 (8.6-17.4)
45-74	25.0	+1.4 (0.9-2.4)	9.0	+0.5 (0.4-0.9)	183.2	+10.4 (4.3-18.9)	131.1	+12.4 (8.1-20.0)
40-74	27.9	+1.6 (0.9-2.5)	10.0	+0.6 (0.4-1.0)	214.0	+11.9 (8.2-21.1)	153.9	+14.5 (12.1-22.7)
Hybrid								
A45-49, B50-74	26.2	+1.4 (0.8-2.4)	9.5	+0.5 (0.4-1.0)	196.5	+13.5 (7.1-19.3)	138.1	+15.5 (11.0-21.2)
A45-54, B55-74	26.0	+1.5 (0.8-2.4)	9.6	+0.5 (0.4-0.9)	202.7	+10.5 (5.5-19.0)	141.8	+13.8 (10.4-21.4)
A40-49, B50-74	28.7	+1.8 (1.1-2.6)	10.3	+0.6 (0.5-1.0)	223.0	+14.4 (11.2-21.4)	156.8	+17.9 (15.9-24.4)
Annual								
40-74	27.6	+1.4 (0.5-2.1)	10.8	+0.5 (0.3-0.8)	211.1	+10.0 (4.8-16.0)	146.3	+13.8 (10.2-19.4)
45-74	30.1	+1.7 (0.5-2.3)	11.8	+0.6 (0.2-0.9)	243.6	+12.7 (4.3-18.8)	167.5	+17.4 (11.3-23.2)
40-74	32.4	+1.7 (0.5-2.5)	12.4	+0.6 (0.2-1.0)	266.4	+17.4 (4.5-20.8)	183.8	+21.0 (13.1-23.4)

	Mammograms		False-Positive Recalls		Benign Biopsies		Overdiagnosed Cases[c]	
Biennial	**DM vs No Screening**	**DBT vs DM**	**DM vs No Screening**	**DBT vs DM**	**DM vs No Screening**	**DBT vs DM**	**DM vs No Screening**	**DBT vs DM**
50-74	10,905	0 (-14-0)	1,263	-449 (-450, -448)	188	-30 (-30, -30)	16	0 (0-2)
45-74	13,009	0 (-18-0)	1,517	-520 (-522, -520)	218	-28 (-29, -28)	16	0 (0-2)
40-74	15,801	0 (-24-0)	1,880	-627 (-630, -626)	262	-30 (-30, -29)	18	0 (0-3)
Hybrid								
A45-49, B50-74	15,743	0 (-21-0)	1,755	-611 (-614, -610)	234	-28 (-28, -28)	18	0 (0-2)
A45-54, B55-74	17,772	-1 (-22-0)	1,887	-670 (-673, -668)	238	-27 (-27, -27)	18	0 (0-2)
A40-49, B50-74	20,677	-1 (-31-0)	2,328	-794 (-797, -791)	285	-25 (-25, -25)	18	0 (0-3)
Annual								
40-74	20,935	-1 (-31-0)	1,960	-751 (-753, -746)	231	-31 (-31, -31)	19	0 (0-2)
45-74	25,760	-1 (-42-0)	2,452	-913 (-917, -908)	277	-29 (-29, -29)	20	0 (0-2)
40-74	30,694	-1 (-55-0)	3,024	-1,095 (-1,100, -1,090)	328	-26 (-27, -26)	21	0 (0-3)

[a] Results summarized over four models (D, GE, M, W). Range of values for DM shown in **Table 11** and **Table 13**.

[b] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

[c] Overdiagnosed cases are in situ and invasive breast cancer cases that would not have been clinically detected in the absence of screening. Overdiagnosis is calculated by subtracting the number of cases detected in the no-screening scenario from the number of cases detected in the screening scenario.

Table 16. Changes in Benefits and Harms for a Cohort of 1,000 40-Year-Old Black Female Persons Screened With Digital Breast Tomosynthesis or Digital Mammography vs. No Screening Until Age 79 (Median and Range Across Four Models[a]) Instead of Age 74 (Median Across Four Models)

Type of Mammography, Strategy, and Starting Age[a]	Breast Cancer Mortality Reduction, %		Breast Cancer Deaths Averted		Life-Years Gained		QALYs Gained	
	74 vs. no screening	79 vs. 74	74 vs. no screening	79 vs. 74	74 vs. no screening	79 vs. 74	74 vs. no screening	79 vs. 74
Digital Breast Tomosynthesis								
Biennial								
50	24.1	+3.7 (2.8-4.9)	9.2	+1.4 (0.9-2.4)	176.7	+15.4 (12.4-21.9)	130.6	+10.6 (9.5-15.8)
45	26.8	+5.2 (4.3-7.4)	9.7	+2.0 (1.4-3.6)	199.0	+20.5 (15.3-33.2)	147.0	+14.3 (10.5-24.0)
40	29.9	+3.7 (3.1-4.9)	10.7	+1.4 (1-2.4)	228.9	+14.5 (6.9-22.5)	171.5	+10.2 (4.6-16.2)
Hybrid								
A45-49, B50	28.1	+3.6 (3.0-4.9)	10.3	+1.4 (1.0-2.4)	212.9	+14.1 (9.6-21.9)	156.3	+10.0 (6.8-15.8)
A45-54, B55	27.9	+5.2 (4.4-7.3)	10.3	+2.0 (1.4-3.5)	219.1	+20.4 (15.2-32.9)	160.5	+14.3 (10.5-23.8)
A40-49, B50	30.9	+3.7 (3.0-4.9)	11.1	+1.4 (1.0-2.4)	239.4	+14.4 (10.9-21.9)	177.0	+10.2 (7.7-15.8)
Annual								
50	29.3	+5.4 (4.2-7.5)	11.5	+2.3 (1.3-3.2)	224.7	+22.6 (10.3-29.5)	163.3	+15.7 (6.3-20.4)
45	32.1	+5.4 (4.0-7.4)	12.6	+2.3 (1.3-3.2)	260.8	+22.5 (13.3-29.3)	188.8	+15.7 (8.7-20.3)
40	34.4	+5.5 (4.2-7.4)	13.3	+2.3 (1.4-3.2)	286.2	+22.7 (10.2-29.2)	205.6	+15.6 (6.3-20.6)
Digital Mammography								
Biennial								
50	22.7	+3.4 (2.9-4.8)	8.5	+1.3 (1.0-2.3)	163.5	+13.3 (9.6-21.4)	116.5	+9.0 (6.2-15.0)
45	25.0	+4.8 (4.2-7.2)	9.0	+1.9 (1.3-3.5)	183.2	+18.8 (11.3-32.2)	131.1	+12.5 (7.0-22.6)
40	27.9	+3.4 (2.9-4.8)	10.0	+1.3 (0.9-2.3)	214.0	+13.3 (11.2-21.1)	153.9	+8.9 (7.4-14.7)
Hybrid								
A45-49, B50	26.2	+3.3 (2.6-4.8)	9.5	+1.3 (0.8-2.3)	196.5	+14.0 (10.9-21.4)	138.1	+9.1 (7.8-15.0)
A45-54, B55	26.0	+4.8 (4.2-7.2)	9.6	+1.9 (1.4-3.5)	202.7	+18.8 (12.8-32.4)	141.8	+12.5 (8.1-22.8)
A40-49, B50	28.7	+3.3 (2.9-5.0)	10.3	+1.3 (0.9-2.4)	223.0	+13.2 (7.6-25.1)	156.8	+8.9 (4.6-18.0)
Annual								
50	27.6	+5.3 (3.9-6.9)	10.8	+2.1 (1.3-3.1)	211.1	+21.2 (14.5-28.4)	146.3	+13.6 (8.7-19.1)
45	30.1	+5.2 (3.9-6.9)	11.8	+2.1 (1.3-3.1)	243.6	+21.2 (2.9-28.4)	167.5	+13.6 (-0.1-19.1)
40	32.4	+5.2 (3.9-6.8)	12.4	+2.1 (1.3-3.1)	266.4	+21.1 (11.7-28.1)	183.8	+11.8 (3.6-18.9)

Table 16. Changes in Benefits and Harms for a Cohort of 1,000 40-Year-Old Black Female Persons Screened With Digital Breast Tomosynthesis or Digital Mammography vs. No Screening Until Age 79 (Median and Range Across Four Models[a]) Instead of Age 74 (Median Across Four Models)

	Mammograms		False-Positive Recalls		Benign Biopsies		Overdiagnosed Cases[b]	
Digital Breast Tomosynthesis	**74 vs. no screening**	**79 vs. 74**	**74 vs. no screening**	**79 vs. 74**	**74 vs. no screening**	**79 vs. 74**	**74 vs. no screening**	**79 vs. 74**
Biennial								
50	10,905	+1,164 (1,141-1,183)	814	+72 (71-74)	158	+12 (12-13)	16	+3 (2-5)
45	13,009	+1,744 (1,707-1,767)	997	+108 (106-111)	189	+18 (18-19)	16	+4 (3-8)
40	15,801	+1,163 (1,136-1,177)	1,253	+72 (71-74)	233	+12 (12-13)	18	+3 (2-5)
Hybrid								
A45-49, B50	15,743	+1,163 (1,137-1,178)	1,144	+72 (71-74)	206	+12 (12-13)	18	+2 (2-5)
A45-54, B55	17,771	+1,742 (1,702-1,763)	1,217	+108 (106-110)	212	+18 (18-19)	18	+4 (3-7)
A40-49, B50	20,676	+1,163 (1,134-1,176)	1,534	+72 (70-74)	260	+12 (12-13)	18	+3 (2-5)
Annual								
50	20,934	+2,888 (2,804-2,929)	1,209	+143 (139-146)	200	+20 (20-21)	19	+4 (2-8)
45	25,759	+2,885 (2,794-2,924)	1,538	+143 (138-146)	247	+20 (20-21)	20	+4 (2-8)
40	30,693	+2,883 (2,787-2,919)	1,929	+143 (138-146)	302	+20 (20-21)	21	+4 (2-8)
Digital Mammography								
Biennial								
50	10,905	+1,164 (1,144-1,181)	1,263	+122 (120-125)	188	+18 (18-18)	16	+2 (2-5)
45	13,009	+1,744 (1,713-1,766)	1,517	+183 (180-187)	218	+27 (26-27)	16	+4 (3-7)
40	15,801	+1,163 (1,141-1,178)	1,880	+122 (120-125)	262	+18 (18-18)	18	+3 (2-5)
Hybrid								
A45-49, B50	15,743	+1,163 (1,141-1,178)	1,755	+122 (120-125)	234	+18 (18-18)	18	+3 (2-5)
A45-54, B55	17,772	+1,743 (1,709-1,763)	1,887	+183 (179-187)	238	+27 (26-27)	18	+4 (3-7)
A40-49, B50	20,677	+1,163 (1,139-1,176)	2,328	+122 (120-125)	285	+18 (18-18)	18	+3 (2-5)
Annual								
50	20,935	+2,889 (2,815-2,931)	1,960	+253 (247-259)	231	+29 (28-29)	19	+4 (2-7)
45	25,760	+2,884 (2,806-2,919)	2,452	+253 (246-258)	277	+29 (28-29)	20	+4 (2-7)
40	30,694	+2,883 (2,800-2,919)	3,024	+253 (245-258)	328	+29 (28-29)	21	+4 (2-7)

[a] Results summarized over four models (D, GE, M, W). Range of values for stopping age 74 are shown in **Tables 11–14**.

[b] Overdiagnosed cases are in situ and invasive breast cancer cases that would not have been clinically detected in the absence of screening. Overdiagnosis is calculated by subtracting the number of cases detected in the no-screening scenario from the number of cases detected in the screening scenario.

Table 17. Incremental Ratios From Four Models for Breast Cancer Mortality (Change in the Number of Mammograms/Change in % Mortality Reduction) and Life-Years Gained (Change in the Number of Mammograms/Change in LYG) for a Cohort of 1,000 40-Year-Old Black Female Persons According to Screening Modality, Interval, Start Age, and Stop Age

		Δ mammograms / Δ % mortality reduction				Δ mammograms / Δ LYG			
Strategy (all DBT)[a]	Screens, n[b]	D	GE	M	W	D	GE	M	W
B50-74	10,905	403[d]	[c]	492[d]	[c]	54	50[d]	[c]	75[d]
B50-79	12,073	400	391	484	497	93[d]	[c]	[c]	71
B45-74	13,009	[c]	[c]	[c]	[c]	77	48	[c]	1,507[d]
B45-79	14,755	860	515	632	1,146[d]	95	53	c	114
B40-74	16,116	[c]	[c]	[c]	[c]	165[d]	[c]	77	[c]
B40-79	16,965	2,536	3,919[d]	840	[c]	117	90	171	157[d]
A40-49, B50-74	20,979	[c]	[c]	[c]	[c]	[c]	[c]	960[d]	[c]
A40-49, B50-79	21,846	5,887[d]	[c]	4,526[d]	[c]	476[d]	210	330	[c]
A45-79	28,646	3,356[d]	1,825	[c]	1,969	[c]	[c]	[c]	143
A40-74	31,273	[c]	[c]	[c]	[c]	[c]	[c]	482[d]	[c]
A40-79	33,577	3,159	2,148	2,685	3,074	428	213	412	190

Abbreviations: A, annual; B, biennial; D, Dana-Farber Cancer Institute; DBT, digital breast tomosynthesis; GE, Georgetown Lombardi Comprehensive Cancer Center-Albert Einstein College of Medicine; M, University of Texas MD Anderson Cancer Center; W, University of Wisconsin-Madison and Harvard Pilgrim Health Care Institute.

[a] Ratios for each strategy are calculated relative to the next efficient or near-efficient strategy with fewer mammograms, not necessarily shown in the table (varied across models). B50-74 is compared with no screening. The ratio for the strategy with the fewest number of mammograms (B50-74) is calculated relative to no screening. Ratios shown for strategies that were efficient or near-efficient in 3 or 4 out of 4 models for either incremental ratio. No strategies for digital mammography were efficient in at least 3 models.

[b] Median number of mammograms across models. Strategies are ranked from the least to the most mammograms.

[c] Strategies that are inferior (also referred to as less efficient or dominated) within a specific model; a strategy is classified as such if another strategy results in an equal or higher benefit (percentage of decline in mortality or life-years gained) with fewer harms (number of screening examinations).

[d] Near-efficient strategy. Strategies were considered near-efficient if they were within 3.2 days per person for LYG or 1.21 percentage points for percent breast cancer mortality of the efficiency frontier.

Table 18. Ratios of Breast Cancer Deaths and Life-Years in a Cohort of 1,000 Black Female Persons vs. a Cohort of 1,000 Female Persons Overall by Digital Breast Tomosynthesis Screening Strategy

		Screening Strategies for Black Female Persons								
Screening Strategy[a]	**All Female Persons**	**No screening**	**B50-74[c]**	**B40-74[c]**	**A40-49, B50-74[c]**	**B45-79**	**B40-79**	**A40-49, B50-79[c]**	**A40-74[c]**	**A40-79**
Breast Cancer Deaths		39.3	30.0	28.8	28.3	27.5	27.3	26.8	26.0	23.7
No screening	28.3	**1.39**	1.06	1.02	1.00	0.97	0.97	0.95	0.92	0.84
B50-74	21.1	1.86	**1.42**	1.36	1.34	1.30	1.29	1.27	1.23	1.12
B40-74[b]	20.0	1.97	1.50	**1.44**	1.42	1.38	1.37	1.34	1.30	1.19
A40-49, B50-74[b]	19.6	2.01	1.53	1.47	**1.44**	1.41	1.39	1.37	1.33	1.21
B45-79	19.4	2.03	1.55	1.48	1.46	**1.42**	1.41	1.39	1.34	1.23
B40-79	19.1	2.05	1.57	1.50	1.48	1.44	**1.43**	1.40	1.36	1.24
A40-49, B50-79	18.7	2.10	1.60	1.53	1.51	1.47	1.46	**1.43**	1.39	1.27
A40-74[b]	18.2	2.16	1.65	1.58	1.55	1.51	1.50	1.47	**1.43**	1.30
A40-79	16.9	2.33	1.78	1.71	1.68	1.63	1.62	1.59	1.54	**1.41**
		No screening	**B50-74[c]**	**B45-79**	**B40-74[c]**	**B40-79**	**A40-49, B50-74[c]**	**A40-49, B50-79[c]**	**A40-74[c]**	**A40-79**
	Life-Years	41.783	41.994	42.058	42.063	42.080	42.080	42.097	42.116	42.139
No screening	43.670	**0.957**	0.962	0.963	0.963	0.964	0.964	0.964	0.964	0.965
B50-74	43.789	0.954	**0.959**	0.960	0.961	0.961	0.961	0.961	0.962	0.962
B45-79	43.850	0.953	0.958	**0.959**	0.959	0.960	0.960	0.960	0.960	0.961
B40-74[b]	43.866	0.953	0.957	0.959	**0.959**	0.959	0.959	0.960	0.960	0.961
B40-79	43.879	0.952	0.957	0.959	0.959	**0.959**	0.959	0.959	0.960	0.960
A40-49, B50-74[b]	43.882	0.952	0.957	0.958	0.959	0.959	**0.959**	0.959	0.960	0.960
A40-49, B50-79	43.897	0.952	0.957	0.958	0.958	0.959	0.959	**0.959**	0.959	0.960
A40-74[b]	43.907	0.952	0.956	0.958	0.958	0.958	0.958	0.959	**0.959**	0.960
A40-79	43.927	0.951	0.956	0.957	0.958	0.958	0.958	0.958	0.959	**0.959**

[a] Calculations use the median values for breast cancer deaths from four models (D, GE, M, and W). Strategies limited to efficient and near-efficient strategies for both percent breast cancer mortality reduction and life-years gained versus no screening in most models for all female persons, listed in **Table 10**, along with selected other strategies.

[b] Not efficient or near-efficient for both breast cancer mortality reduction and life-years gained versus no screening in most models for all female persons.

[c] Strategy not efficient nor near-efficient for both breast cancer mortality reduction and life-years gained versus no screening in at least 3 of 4 models for Black female persons, as shown in **Table 17**.

Table 19. Range of Incremental Ratios of Breast Cancer Mortality (Change in the Number of Mammograms/Change in Percent Breast Cancer Mortality Reduction) and Life-Years Gained (Change in the Number of Mammograms/Change in LYG) Across Models for a Cohort of 1,000 40-Year-Old Female Persons According to Efficient Digital Breast Tomosynthesis Screening Strategies and Breast Density

	Δ mammograms / Δ % mortality reduction				Δ mammograms / Δ LYG			
Strategy[a]	Almost entirely fatty	Scattered fibroglandular	Hetero-geneously dense	Extremely dense	Almost entirely fatty	Scattered fibro-glandular	Hetero-geneously dense	Extremely dense
All Female Persons								
DBT B50-74	[b]	374-541	385-532	395-544	108-163	78-115	59-88	50-79
DBT B50-79	390-493	418-513	463-511	481-550	193-326	111-202	[b]	[b]
DBT B45-79	483-1,021	460-881	476-936	487-984	119-331	82-223	71-192	[b]
DBT B40-79	2,426-25,253	1,228-3,867	817-3,283	660-2,787	194-680	95-257	69-2,819	59-325
DBT A40-49, B50-79	[b]	2,733-7,619	2,260-8,922	[b]	371-1,897	250-958	190-644	139-580
DBT A40-79	2,290-3,783	1,875-3,575	1,771-3,644	1,584-3,705	470-1,676	269-817	204-599	166-507
Black Female Persons								
DBT B50-79	354-468	376-493	401-497	406-513	78-140	55-101	[b]	[b]
DBT B45-79	623-1,221	569-1,087	483-1,133	491-1,185	92-220	54-126	52-100	45-88
DBT B40-79	[b]	1,183-8,269	725-2,834	670-2,619	194-330	113-140	74-126	61-249
DBT A45-79	2,077-3,762	1,938-3,317	1,759-3,377	1,559-3,229	283-1,587	[b]	[b]	[b]
DBT A40-79	3,077-4,037	2,583-3,289	1,934-3,125	1,875-3,176	408-857	231-507	161-417	143-327

Abbreviations: A, annual; B, biennial; DBT, digital breast tomosynthesis.

[a] Results shown for five models (D, E, GE, M, and W) for female persons overall and four models (D, GE, M, and W) for Black female persons. DBT strategies are shown that were efficient or near-efficient in at least 4 of 5 models for both incremental ratios within a density category for female persons overall, and at least 3 of 4 models for both incremental ratios within a density category of breast cancer in Black female persons. Density-specific strategies were not evaluated for digital mammography. A strategy is classified as more efficient than a comparison strategy if it resulted in greater health benefits for a given increase in the number of mammograms (or other harm). Strategies were considered near-efficient if they were within 2.2 days per person for LYG and 1.27 percentage points for percent breast cancer mortality reduction of the efficient frontier for all female persons, and within 3.2 days per person for LYG and 1.21 percentage points for percent breast cancer mortality reduction of the efficient frontier for Black female persons. Strategies are ranked from the least to the most mammograms. Ratios for each strategy are calculated relative to the next efficient or near-efficient strategy with fewer mammograms, not necessarily shown in the table (varied across models). The ratio for the strategy with the fewest number of mammograms (B50-74) is calculated relative to no screening.

[b] DBT strategies that were efficient or near-efficient in fewer than 4 of 5 models within a density category for all female persons, or fewer than 3 of 4 models of breast cancer in Black female persons.

Table 20. Median (and Range) of Benefits and Harms Across Five Models of Efficient Screening Strategies With Digital Breast Tomosynthesis for a Cohort of 1,000 40-Year-Old Female Persons According to Breast Density and Screening Strategy

BI-RADS Breast Density	Strategy	Mortality Reduction (%)	Breast Cancer Deaths Averted	Life-Years Gained	QALYs Gained[a]
Almost entirely fatty	B50-74	25.9 (21.6-33.0)	4.9 (3.1-5.7)	82.6 (70.1-107.5)	58.8 (46.1-89.5)
	B50-79	30.8 (25.8-36.5)	5.6 (3.7-6.5)	88.7 (76.9-113.3)	62.8 (50.3-94.7)
	B45-79	34.2 (28.5-39.3)	6.2 (4.1-7.8)	99.7 (87.5-132.1)	70.4 (57.1-104.0)
	B40-79	34.9 (28.8-39.8)	6.4 (4.2-7.9)	108.5 (94.4-143.3)	76.5 (61.4-108.9)
	A40-49, B50-79	35.6 (30.2-40.3)	6.9 (4.4-8.1)	120.3 (103.0-151.0)	84.1 (66.8-109.5)
	A40-79	42.6 (40.1-46.1)	7.6 (5.9-9.7)	143.6 (120.9-173.1)	99.3 (81.3-122.8)
Scattered fibroglandular	B50-74	26.3 (20.5-30.5)	6.7 (4.3-7.7)	106.2 (97.5-146.6)	75.7 (64.7-119.3)
	B50-79	29.2 (24.3-33.6)	7.4 (5.1-8.9)	113.2 (106.0-153.9)	80.0 (70.1-125.7)
	B45-79	33.6 (27.3-36.7)	8.3 (5.7-11.1)	134.2 (125.1-188.7)	94.6 (82.5-141.4)
	B40-79	34.4 (27.9-37.5)	8.6 (5.9-11.3)	150.2 (136.6-211.6)	105.4 (89.7-154.0)
	A40-49, B50-79	36.6 (29.7-38.2)	9.4 (6.3-11.8)	167.8 (152.8-225.6)	116.2 (99.7-162.5)
	A40-79	42.4 (40.0-45.0)	10.7 (8.4-14.2)	200.1 (175.5-259.1)	137.0 (117.5-184)
Hetero-geneously dense	B50-74	25.3 (18.3-29.1)	7.2 (5.6-9.9)	126.6 (114.9-189.8)	90.6 (80.8-154.0)
	B50-79	27.8 (23.6-31.8)	8.7 (6.4-10.8)	135.6 (131.7-198.6)	95.4 (90.6-161.6)
	B45-79	32.0 (26.5-35.4)	9.7 (7.2-12.5)	169.7 (158.1-232.4)	119.9 (106.3-187.4)
	B40-79	33.5 (27.5-36.6)	10.0 (7.5-13.1)	199.8 (169.9-252.5)	141.4 (116.8-201.6)
	A40-49, B50-79	35.6 (29.6-37.3)	10.9 (8.1-14.0)	210.9 (193.5-277.0)	146.6 (132.5-204.1)
	A40-79	42.0 (39.3-43.1)	13.4 (10.4-16.9)	257.5 (234.0-319.3)	170.1 (159.1-227.2)
Extremely dense	B50-74	23.5 (17.7-27.9)	8.3 (6.4-11.4)	143.3 (132.1-218.9)	99.7 (94.2-177.9)
	B50-79	25.7 (22.6-30.4)	9.4 (7.3-12.4)	155.2 (144.9-228.6)	110.9 (104.0-186.2)
	B45-79	30.8 (25.2-33.6)	10.5 (8.2-14.5)	194.3 (171.7-264.6)	139.2 (122.4-214.0)
	B40-79	32.4 (26.1-36.5)	10.8 (8.4-15.2)	241.5 (185.3-292.4)	174.6 (130.9-229.3)
	A40-49, B50-79	34.8 (28.5-37.9)	11.9 (9.2-16.4)	254.6 (213.3-327.4)	181.3 (148.4-239.9)
	A40-79	39.9 (38.0-43.0)	14.6 (12.3-20.2)	297.1 (256.8-385.8)	200.9 (177.1-279.9)
	Strategy	**Screens[b]**	**False-Positive Recalls**	**Benign Biopsies**	**Overdiagnosed Cases[c]**
Almost entirely fatty	B50-74	11,499 (11,410-11,630)	523 (519-528)	84 (84-85)	8 (4-22)
	B50-79	12,849 (12,724-13,004)	568 (563-575)	92 (91-93)	10 (5-26)
	B45-79	15,604 (15,464-15,788)	675 (669-682)	104 (103-105)	11 (5-29)
	B40-79	17,765 (17,634-17,966)	785 (780-793)	116 (115-117)	11 (5-29)
	A40-49, B50-79	22,675 (22,548-22,918)	899 (893-908)	124 (124-126)	16 (5-29)
	A40-79	35,273 (34,914-35,685)	1,130 (1,120-1,143)	148 (146-149)	17 (6-36)
	B50-74	13,391 (13,244-13,533)	788 (780-797)	116 (114-117)	11 (4-27)

Table 20. Median (and Range) of Benefits and Harms Across Five Models of Efficient Screening Strategies With Digital Breast Tomosynthesis for a Cohort of 1,000 40-Year-Old Female Persons According to Breast Density and Screening Strategy

Scattered fibroglandular	B50-79	12,601 (12,430-12,751)	849 (840-859)	124 (122-125)	13 (6-32)
	B45-79	15,324 (15,125-15,508)	1,057 (1,042-1,068)	145 (144-147)	14 (7-35)
	B40-79	17,495 (17,293-17,697)	1,269 (1,255-1,282)	166 (164-167)	15 (6-36)
	A40-49, B50-79	22,370 (22,160-22,630)	1,521 (1,508-1,540)	192 (191-194)	21 (6-37)
	A40-79	34,675 (34,111-35,102)	1,929 (1,907-1,954)	240 (237-243)	22 (7-49)
Hetero-geneously dense	B50-74	11,129 (10,882-11,214)	940 (919-946)	148 (144-148)	13 (5-36)
	B50-79	12,377 (12,081-12,491)	1,007 (983-1,013)	157 (153-157)	15 (6-41)
	B45-79	15,084 (14,751-15,223)	1,282 (1,257-1,291)	195 (191-196)	17 (7-45)
	B40-79	17,261 (16,915-17,408)	1,583 (1,556-1,595)	234 (230-236)	17 (6-46)
	A40-49, B50-79	22,059 (21,730-22,317)	1,946 (1,920-1,967)	278 (275-281)	26 (7-48)
	A40-79	34,070 (33,265-34,481)	2,456 (2,408-2,482)	343 (336-346)	27 (8-61)
Extremely dense	B50-74	10,981 (10,695-11,031)	955 (931-958)	161 (157-162)	14 (5-38)
	B50-79	12,196 (11,851-12,276)	1,024 (994-1,025)	170 (166-170)	17 (7-44)
	B45-79	14,883 (14,489-14,989)	1,257 (1,223-1,276)	208 (203-209)	19 (7-48)
	B40-79	17,059 (16,663-17,180)	1,566 (1,528-1,570)	258 (253-260)	20 (7-49)
	A40-49, B50-79	21,820 (21,445-22,057)	1,915 (1,871-1,921)	300 (295-303)	29 (7-52)
	A40-79	33,623 (32,677-33,989)	2,452 (2,374-2,461)	369 (358-370)	31 (9-66)

Abbreviations: a=almost entirely fatty; A=annual; b= scattered areas of fibroglandular density; B=biennial; BI-RADS=Breast Imaging-Reporting and Data System; c= heterogeneously dense; d=extremely dense.

[a] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

[b] As risk increases, more persons develop and die of breast cancer, therefore the number of lifetime screening mammograms decreases.

[c] Overdiagnosed cases are in situ and invasive breast cancer cases that would not have been clinically detected in the absence of screening. Overdiagnosis is calculated by subtracting the number of cases detected in the no-screening scenario from the number of cases detected in the screening scenario.

Table 21. Median (and Range) of Benefits and Harms Across Four Models of Efficient Screening Strategies With Digital Breast Tomosynthesis for a Cohort of 1,000 40-Year-Old Black Female Persons According to Breast Density and Screening Strategy

BI-RADS Breast Density	Strategy	Mortality Reduction (%)	Breast Cancer Deaths Averted	Life-Years Gained	QALYs Gained[a]
Almost entirely fatty	B50-79	30.7 (26.4-35.2)	7.0 (5.9-10.2)	124.0 (106.6-163.7)	92.9 (75.1-122.5)
	B45-79	34.4 (28.6-38.5)	7.6 (6.6-11.5)	140.2 (120.7-193.4)	105.8 (83.6-145.2)
	B40-79	35.1 (28.5-38.6)	7.8 (6.6-11.5)	150.4 (127.3-202.3)	113.6 (88.1-151.8)
	A45-79	41.5 (35.1-45.4)	9.5 (7.6-13.6)	175.9 (136.9-228.1)	127.8 (97.5-169.4)
	A40-79	42.9 (37.4-47.0)	9.8 (8.1-14.1)	188.1 (156.0-244.3)	136.2 (111.4-181.0)
Scattered fibroglandular	B50-79	29.1 (24.5-32.5)	9.7 (7.4-14.5)	172.6 (133.2-233.4)	127.3 (95.9-174.1)
	B45-79	32.7 (27.0-37.3)	10.6 (8.6-16.6)	196.9 (163.8-283.4)	145.0 (118.1-212.1)
	B40-79	34.0 (27.1-37.5)	10.8 (9.1-16.7)	214.9 (183.2-302.6)	161.3 (126.2-226.2)
	A45-79	39.3 (35.2-44.5)	13.4 (10.0-19.8)	253.6 (186.4-339.3)	183.1 (130.6-250.9)
	A40-79	40.9 (38.3-46.4)	14.0 (10.9-20.7)	274.8 (226.5-368.7)	197.3 (159.8-271.7)
Hetero-geneously dense	B50-79	26.7 (23.8-30.0)	11.7 (8.4-15.6)	209.9 (156.1-252.1)	154.4 (111.4-186.7)
	B45-79	30.6 (26.2-35.6)	12.9 (9.9-18.5)	242.8 (191.2-324.5)	178.2 (136.9-241.5)
	B40-79	32.6 (26.6-36.4)	13.2 (11.0-18.9)	267.0 (229.5-354.3)	199.3 (157.1-263.3)
	A45-79	37.2 (33.5-43.4)	16.3 (11.6-22.6)	313.9 (222.4-398.1)	225.8 (153.9-292.5)
	A40-79	39.0 (37.6-46)	17.1 (13.0-23.9)	343.7 (277.6-443.6)	245.1 (193.8-324.5)
Extremely dense	B50-79	25.6 (22.7-29.1)	13.0 (9.8-18.0)	234.0 (181.1-294.2)	172.9 (129.8-218.6)
	B45-79	29.4 (25.0-34.5)	14.3 (11.7-21.4)	269.1 (225.9-378.4)	198.8 (163.2-283.2)
	B40-79	31.5 (25.3-35.4)	14.7 (12.9-21.9)	304.9 (257.6-414.8)	229.5 (178.0-310.1)
	A45-79	35.2 (33.5-43.3)	18.3 (13.5-26.8)	352.5 (260.0-478.4)	255.4 (181.7-354.4)
	A40-79	38.0 (35.8-45.9)	19.2 (15.4-28.4)	385.4 (336.8-533.4)	277.3 (238.7-394.0)

		Screens[b]	False-Positive Recalls	Benign Biopsies	Overdiagnosed Cases[c]
Almost entirely fatty	B50-79	12,459 (12,363-12,489)	435 (432-437)	105 (104-105)	12 (6-24)
	B45-79	15,189 (15,077-15,229)	510 (506-511)	120 (119-121)	13 (6-26)
	B40-79	17,386 (17,272-17,439)	575 (571-577)	133 (132-133)	13 (6-26)
	A45-79	29,534 (29,265-29,618)	718 (711-720)	137 (135-137)	15 (7-31)
	A40-79	34,486 (34,191-34,592)	833 (825-835)	154 (153-155)	15 (7-32)
Scattered fibroglandular	B50-79	12,206 (12,109-12,217)	776 (773-781)	149 (149-150)	17 (7-29)
	B45-79	14,908 (14,785-14,931)	947 (942-953)	175 (175-177)	18 (7-32)
	B40-79	17,113 (16,979-17,150)	1,107 (1,101-1,114)	200 (199-201)	18 (7-32)
	A45-79	28,955 (28,613-28,997)	1,412 (1,404-1,424)	223 (222-225)	21 (8-43)
	A40-79	33,894 (33,497-33,962)	1,696 (1,685-1,709)	260 (258-262)	22 (9-44)
Hetero-geneously dense	B50-79	11,964 (11,828-12,021)	1,003 (996-1,011)	192 (190-193)	20 (7-38)
	B45-79	14,631 (14,482-14,714)	1,284 (1,264-1,292)	241 (237-242)	22 (8-41)
	B40-79	16,844 (16,671-16,928)	1,561 (1,543-1,570)	289 (285-291)	22 (7-41)
	A45-79	28,390 (27,972-28,553)	1,969 (1,938-1,989)	315 (309-318)	26 (9-52)

Table 21. Median (and Range) of Benefits and Harms Across Four Models of Efficient Screening Strategies With Digital Breast Tomosynthesis for a Cohort of 1,000 40-Year-Old Black Female Persons According to Breast Density and Screening Strategy

	A40-79	33,314 (32,816-33,491)	2,465 (2,434-2,487)	386 (381-390)	27 (9-54)
Extremely dense	B50-79	11,741 (11,633-11,822)	1,105 (1,093-1,126)	207 (205-211)	23 (8-40)
	B45-79	14,385 (14,260-14,498)	1,344 (1,329-1,373)	246 (243-252)	26 (8-44)
	B40-79	16,604 (16,455-16,717)	1,640 (1,620-1,648)	299 (295-301)	26 (8-44)
	A45-79	27,886 (27,489-28,108)	2,114 (2,077-2,150)	318 (313-328)	31 (10-57)
	A40-79	32,800 (32,317-33,037)	2,618 (2,572-2,634)	387 (380-393)	32 (10-60)

Abbreviations: a=almost entirely fatty; A=annual; b= scattered areas of fibroglandular density; B=biennial; BI-RADS=Breast Imaging-Reporting and Data System; c= heterogeneously dense; d=extremely dense.
Results shown from four models (D, GE, M, and W).
[a] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.
[b] As risk increases, more persons develop and die of breast cancer, therefore the number of lifetime screening mammograms decreases.
[c] Overdiagnosed cases are in situ and invasive breast cancer cases that would not have been clinically detected in the absence of screening. Overdiagnosis is calculated by subtracting the number of cases detected in the no-screening scenario from the number of cases detected in the screening scenario.

Table 22. Range of Incremental Ratios for Breast Cancer Mortality (Change in the Number of Mammograms/Change in Percent Breast Cancer Mortality Reduction) and Life-Years Gained (Change in the Number of Mammograms/Change in LYG) Across Six Models for a Cohort of 1,000 40-Year-Old Female Persons According to Efficient Digital Breast Tomosynthesis Screening Strategies and Elevated Relative Risk

	Δ mammograms / Δ % mortality reduction		Δ mammograms / Δ LYG	
DBT Strategy[a]	**RR 1.5**	**RR 2.0**	**RR 1.5**	**RR 2.0**
All Female Persons				
B50-74	374-493	364-454	43-65	32-50
B45-79	455-854	438-832	49-144	[b]
B40-79	821-3,512	921-2,009	49-237	37-118
A40-49, B50-79	[b]	2,285-7,161	143-497	108-377
A40-79	1,740-3,584	1,687-3,518	142-439	106-535
Black Female Persons				
B45-79	497-1,081	481-1,028	36-74	27-55
B40-79	829-3,423	805-2,961	60-99	45-68
A40-79	2,044-3,129	1,958-3,058	125-313	92-216

Abbreviations: A, annual; B, biennial; DBT, digital breast tomosynthesis; RR, relative risk.

[a] Results shown for five models (D, E, GE, M, and W) for female persons overall and four models (D, GE, M, and W) for Black female persons. DBT strategies are shown that were efficient or near-efficient in at least 4 of 5 models for both incremental ratios within a relative risk category for female persons overall, and at least 3 of 4 models for both incremental ratios within a relative risk category of breast cancer in Black female persons. Relative risk-specific strategies were not evaluated for digital mammography. A strategy is classified as more efficient than a comparison strategy if it resulted in greater health benefits for a given increase in the number of mammograms (or other harm). Strategies were considered near-efficient if they were within 2.2 days per person for LYG and 1.27 percentage points for percent breast cancer mortality reduction of the efficient frontier for all female persons, and within 3.2 days per person for LYG and 1.21 percentage points for percent breast cancer mortality reduction of the efficient frontier for Black female persons. Strategies are ranked from the least to the most mammograms. Ratios for each strategy are calculated relative to the next efficient or near-efficient strategy with fewer mammograms, not necessarily shown in the table (varied across models). The ratio for the strategy with the fewest number of mammograms (B50-74) is calculated relative to no screening.

[b] DBT strategies that were efficient or near-efficient in fewer than 4 of 5 models within a relative risk category for all female persons, or fewer than 3 of 4 models within a relative risk category of breast cancer for Black female persons.

Table 23. Median (and Range) of Lifetime Benefits and Harms Across Six Models of Screening With Digital Breast Tomosynthesis vs. No Screening for a Cohort of 1,000 40-Year-Old Female Persons According to Relative Risk Group and Efficient or Near-Efficient Screening Strategy

Relative Risk Group	Strategy	Mortality Reduction (%)	Breast Cancer Deaths Averted	Life-Years Gained	QALYs Gained[a]
1 (average)	B50-74	25.4 (18.8-29.4)	6.7 (5.1-9.2)	120.8 (115.1-175.8)	86.1 (77.9-143.0)
	B45-79	32.1 (26.5-35.5)	8.6 (6.7-12.1)	153.4 (147.7-213.1)	110.2 (98.5-172.1)
	B40-79	33.3 (27.2-36.5)	8.9 (6.9-12.5)	173.9 (161.7-237.8)	124.2 (107.2-184.2)
	A40-49, B50-79	35.3 (29.4-37.2)	9.5 (7.4-13.3)	188.7 (173.4-260.1)	130.7 (121.4-188.1)
	A40-79	41.7 (39.2-43.0)	11.5 (9.9-16.1)	229.7 (200.4-300.7)	154.3 (139.5-214.6)
1.5	B50-74	25.2 (19.2-29.3)	9.2 (7.7-10.5)	172.4 (167.1-256.5)	127.0 (120.5-212.5)
	B45-79	32.2 (27.7-35.4)	12.4 (10.0-17.6)	225.7 (209.0-311.0)	164.0 (152.4-256.6)
	B40-79	33.4 (28.5-37.1)	13.0 (10.3-18.3)	257.4 (218.3-348.7)	185.1 (162.9-275.8)
	A40-49, B50-79	35.8 (30.8-38.2)	13.8 (11.1-19.4)	281.1 (243.2-382.0)	200.0 (179.5-284.5)
	A40-79	42.2 (40.7-43.5)	16.5 (14.7-23.5)	336.5 (290.2-441.2)	237.4 (212.6-325.8)
2.0	B50-74	25.6 (19.5-29.2)	12.5 (10.3-13.4)	220.6 (211.7-332.6)	162.9 (158.8-278.0)
	B45-79	32.4 (28.6-35.4)	15.8 (13.1-22.7)	294.5 (264.3-403.7)	215.4 (197.3-336.4)
	B40-79	33.8 (29.8-37.8)	16.7 (13.7-23.7)	337.9 (292.1-451.4)	248.7 (217.1-362.8)
	A40-49, B50-79	36.4 (32.2-39.2)	17.8 (14.8-25.1)	369.9 (306.5-495.5)	269.3 (231.9-374.6)
	A40-79	43.0 (40.5-44.3)	21.2 (19.3-30.3)	433.2 (363.9-570.9)	313.0 (273.7-428.7)

	Strategy	Screens[b]	False-Positive Recalls	Benign Biopsies	Overdiagnosed Cases[c]
1 (average)	B50-74	11,208 (10,976-11,278)	873 (855-878)	136 (133-137)	12 (4-33)
	B45-79	15,218 (14,871-15,297)	1,176 (1,153-1,183)	176 (173-177)	16 (6-41)
	B40-79	17,397 (17,037-17,494)	1,440 (1,415-1,449)	210 (206-211)	17 (6-42)
	A40-49, B50-79	22,255 (21,870-22,412)	1,755 (1,728-1,768)	247 (242-248)	24 (6-44)
	A40-79	34,441 (33,538-34,666)	2,224 (2,175-2,240)	304 (298-307)	25 (7-56)
1.5	B50-74	10,888 (10,570-10,952)	848 (824-853)	132 (129-133)	14 (2-45)
	B45-79	14,779 (14,306-14,840)	1,145 (1,112-1,152)	172 (167-173)	19 (3-57)
	B40-79	16,963 (16,473-17,051)	1,408 (1,373-1,417)	205 (200-207)	20 (3-58)
	A40-49, B50-79	21,766 (21,243-21,942)	1,719 (1,682-1,734)	242 (236-244)	25 (3-61)
	A40-79	33,482 (32,254-33,716)	2,170 (2,103-2,189)	297 (288-300)	28 (4-77)
2.0	B50-74	10,580 (10,186-10,635)	825 (794-828)	129 (124-129)	19 (3-55)
	B45-79	14,355 (13,775-14,409)	1,115 (1,074-1,120)	168 (162-168)	25 (4-69)
	B40-79	16,547 (15,943-16,621)	1,379 (1,334-1,386)	201 (195-202)	25 (4-70)
	A40-49, B50-79	21,296 (20,651-21,485)	1,686 (1,638-1,702)	237 (230-239)	32 (4-74)
	A40-79	32,590 (31,052-32,768)	2,121 (2,035-2,137)	290 (279-293)	36 (5-93)

Abbreviations: A=annual; B=biennial.

[a] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

[b] As risk increases, more persons develop and die of breast cancer, therefore the number of lifetime screening mammograms decreases.

Table 23. Median (and Range) of Lifetime Benefits and Harms Across Six Models of Screening With Digital Breast Tomosynthesis vs. No Screening for a Cohort of 1,000 40-Year-Old Female Persons According to Relative Risk Group and Efficient or Near-Efficient Screening Strategy

[c] Overdiagnosed cases are in situ and invasive breast cancer cases that would not have been clinically detected in the absence of screening. Overdiagnosis is calculated by subtracting the number of cases detected in the no-screening scenario from the number of cases detected in the screening scenario.

Table 24. Median (and Range) of Lifetime Benefits and Harms Across Four Models of Screening With Digital Breast Tomosynthesis vs. No Screening for a Cohort of 1,000 40-Year-Old Black Female Persons According to Relative Risk Group and Efficient or Near-Efficient Screening Strategy

Relative Risk Group	Strategy	Mortality Reduction (%)	Breast Cancer Deaths Averted	Life-Years Gained	QALYs Gained[a]
1 (average)	B45-79	31.2 (26.4-36.3)	11.7 (9.3-17.5)	219.4 (172.7-303.6)	161.3 (123.7-226.6)
	B40-79	33.0 (26.6-36.8)	12.0 (10.2-17.8)	238.5 (205.4-328.1)	178.5 (141.0-244.6)
	A40-79	39.6 (37.9-46.2)	15.5 (12.1-22.3)	309.0 (253.9-406.8)	221.2 (178.1-298.8)
1.5	B45-79	31.4 (27.5-36.6)	17.1 (14.0-25.4)	321.1 (262.7-443.2)	241.5 (194.4-336.2)
	B40-79	33.2 (27.9-37.3)	17.5 (15.2-25.9)	354.9 (307.1-480.1)	272.1 (218.1-364.3)
	A40-79	40.1 (38.8-46.7)	22.7 (18.1-32.4)	453.7 (375.4-595.2)	335.2 (274.2-447.4)
2.0	B45-79	31.6 (28.4-36.8)	22.2 (18.5-32.6)	419.4 (349.3-572.5)	319.1 (262.5-437.7)
	B40-79	33.5 (29.0-37.6)	22.8 (20.1-33.3)	463.7 (406.7-622.3)	359.8 (293.9-476.4)
	A40-79	41.0 (39.0-47.0)	29.5 (23.8-41.7)	592.6 (499.5-772.0)	444.8 (372.3-587.1)

	Strategy	Screens[b]	False-positive Recalls	Benign Biopsies	Overdiagnosed Cases[c]
1 (average)	B45-79	14,755 (14,625-14,818)	1,107 (1,097-1,109)	208 (206-208)	20 (8-37)
	B40-79	16,965 (16,817-17,032)	1,326 (1,314-1,329)	245 (243-246)	20 (7-37)
	A40-79	33,577 (33,141-33,711)	2,074 (2,046-2,077)	323 (318-323)	25 (9-49)
1.5	B45-79	14,301 (14,170-14,403)	1,072 (1,062-1,075)	202 (200-202)	29 (10-50)
	B40-79	16,523 (16,361-16,629)	1,292 (1,278-1,295)	239 (236-240)	29 (10-51)
	A40-79	32,617 (32,101-32,834)	2,017 (1,983-2,024)	314 (309-315)	35 (12-68)
2.0	B45-79	13,867 (13,737-14,006)	1,039 (1,028-1,044)	196 (194-197)	37 (13-62)
	B40-79	16,098 (15,928-16,243)	1,260 (1,243-1,263)	233 (230-234)	37 (12-63)
	A40-79	31,692 (31,117-31,996)	1,962 (1,924-1,974)	306 (300-307)	45 (15-84)

Abbreviations: A=annual; B=biennial.

[a] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

[b] As risk increases, more persons develop and die of breast cancer, therefore the number of lifetime screening mammograms decreases.

[c] Overdiagnosed cases are in situ and invasive breast cancer cases that would not have been clinically detected in the absence of screening. Overdiagnosis is calculated by subtracting the number of cases detected in the no-screening scenario from the number of cases detected in the screening scenario.

Table 25. Change in Estimated Breast Cancer Screening Outcomes for a Cohort of 1,000 65-Year-Old Female Persons Screened Biennially with Digital Breast Tomosynthesis According to Different Comorbidity Levels and the Age to Stop Screening, Model GE and Model W

Comorbidity Level and Initial Screening Ages[a]	Comparison Stopping Age	Mortality Reduction, %		Breast Cancer Deaths Averted		Life-Years Gained		QALYs Gained	
		GE	W	GE	W	GE	W	GE	W
None									
50-74	69	-14.9	-11.9	-3.5	-1.5	-39.4	-20.4	-29.1	-13.1
50-65	74	25.5	19.3	6.1	2.5	75.6	36.2	56.1	23.4
50-74	79	+8.0	+6.4	+1.9	+0.8	+16.0	+8.6	+11.3	+4.9
50-74	84	+16.1	+12.9	+3.8	+1.7	+28.2	+15.0	+19.6	+8.0
Low									
50-74	69	-14.8	-12.1	-3.1	-1.4	-34.1	-17.3	-24.8	-10.7
50-65	74	26.0	20.0	5.5	2.3	65.8	30.9	48.3	19.4
50-74	79	+7.9	+6.2	+1.7	+0.7	+14.1	+7.1	+9.9	+4.0
50-74	84	+15.8	+12.4	+3.3	+1.4	+24.7	+12.4	+17.1	+6.4
Moderate									
50-74	69	-14.9	-12.1	-2.8	-1.2	-29.7	-15.2	-21.4	-9.2
50-65	74	26.5	20.4	5.0	2.1	58.0	27.4	42.2	16.8
50-74	79	+7.7	+6.1	+1.4	+0.6	+12.2	+6.2	+8.5	+3.4
50-74	84	+15.4	+11.9	+2.9	+1.2	+21.4	+10.8	+14.8	+5.5
Severe									
50-74	69	-14.8	-12.0	-2.1	-1.0	-22.6	-11.5	-16.0	-6.8
50-65	74	26.8	20.8	3.8	1.7	43.6	20.8	31.1	12.1
50-74	79	+7.6	+5.9	+1.1	+0.5	+9.1	+4.7	+6.4	+2.6
50-74	84	+15.3	+11.5	+2.2	+0.9	+16.2	+8.1	+11.1	+4.1
Average									
50-74	69	-14.9	-12.0	-3.2	-1.4	-34.7	-17.4	-25.4	-10.9
50-65	74	26.0	19.8	5.5	2.3	66.9	31.1	49.3	19.6
50-74	79	+7.8	+6.3	+1.7	+0.7	+14.0	+7.2	+9.8	+4.0
50-74	84	+15.8	+12.5	+3.3	+1.4	+24.7	+12.5	+17.1	+6.5

None		Screens, n[b]		False-positive Recalls, n		Benign Biopsies, n		Overdiagnosis, n[c]	
		GE	W	GE	W	GE	W	GE	W
50-74	69	-2,798	-2,741	-155	-152	-21.9	-21.4	-1.3	-10.5
50-65	74	4,778	4,692	266	260	37.5	36.6	1.8	17.3
50-74	79	+1694	+1,653	+85	+83	+11.2	+10.9	+1.7	+6.8
50-74	84	+3789	+3,692	+191	+186	+25.1	+24.4	+5.6	+15.2

Table 25. Change in Estimated Breast Cancer Screening Outcomes for a Cohort of 1,000 65-Year-Old Female Persons Screened Biennially with Digital Breast Tomosynthesis According to Different Comorbidity Levels and the Age to Stop Screening, Model GE and Model W

Low									
50-74	69	-2,674	-2,593	-149	-143	-21.0	-20.2	-2.2	-10.3
50-65	74	4,650	4,530	259	251	36.5	35.4	3.1	17.3
50-74	79	+1520	+1,455	+77	+73	+10.1	+9.6	+2.1	+6.1
50-74	84	+3335	+3,181	+168	+160	+22.1	+21.1	+5.5	+13.3
Moderate									
50-74	69	-2,582	-2,490	-143	-138	-20.2	-19.4	-3.1	-10.2
50-65	74	4,545	4,410	253	244	35.7	34.4	4.2	17.2
50-74	79	+1,376	+1,307	+69	+66	+9.1	+8.7	+2.3	+5.6
50-74	84	+2,955	+2,809	+149	+141	+19.6	+18.6	+5.3	+11.9
Severe									
50-74	69	-2,108	-2,010	-117	-111	-16.5	-15.7	-3.7	-8.5
50-65	74	3,998	3,823	222	212	31.4	29.8	6.5	15.7
50-74	79	+1,028	+975	+52	+49	+6.8	+6.5	+1.7	+4.2
50-74	84	+2,214	+2,103	+111	+106	+14.7	+13.9	+3.9	+8.9
Average									
50-74	69	-2,640	-2,560	-147	-142	-20.7	-20.0	-2.1	-10.1
50-65	74	4,602	4,480	256	248	36.1	35.0	3.1	17.1
50-74	79	+1,517	+1,457	+76	+73	+10.1	+9.7	+1.9	+6.1
50-74	84	+3,353	+3,204	+169	+161	+22.2	+21.2	+5.3	+13.4

[a] Outcomes for biennial screening at ages 50–74 are relative to biennial screening at ages 50–64. Outcomes for stopping biennial screening at ages 69, 79, and 84 are relative to biennial screening during ages 50–74 within each level of comorbidity.

[b] Number of mammograms after age 65.

[c] Overdiagnosed cases are in situ and invasive breast cancer cases that would not have been clinically detected in the absence of screening. Overdiagnosis is calculated by subtracting the number of cases detected in the no-screening scenario from the number of cases detected in the screening scenario.

Figure 1. Graphical Description of When the Timing of Screening in the Models Can Lead to an Earlier Diagnosis Relative to the Timing of the Onset of Symptoms

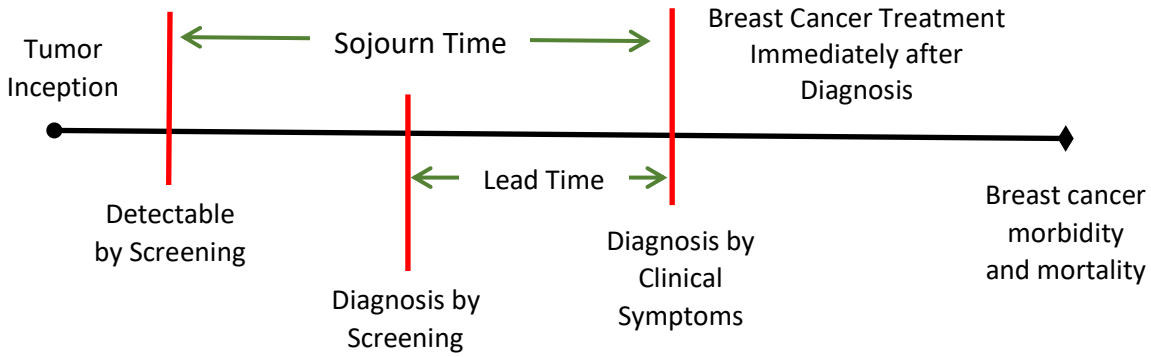


Figure 2. Illustration of the Efficiency Frontier, Efficient Screening Strategies, and an Incremental Ratio (b/a). Adapted From: Knudsen (2021)[53]

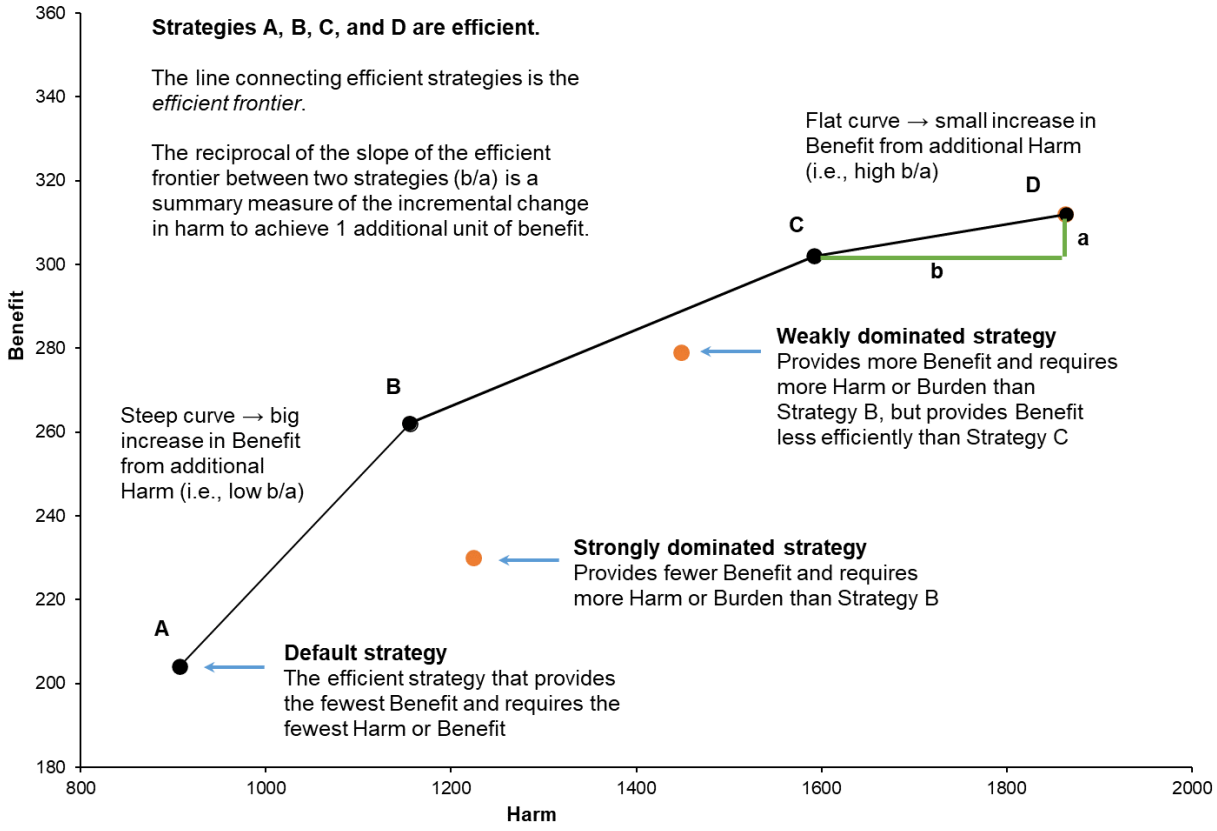


Figure 3. Estimated Age-Adjusted Breast Cancer Incidence per 100,000 Female Persons by Model and From the Surveillance, Epidemiology, and End Results (SEER) Program for 1992–2018, Ages 30–79

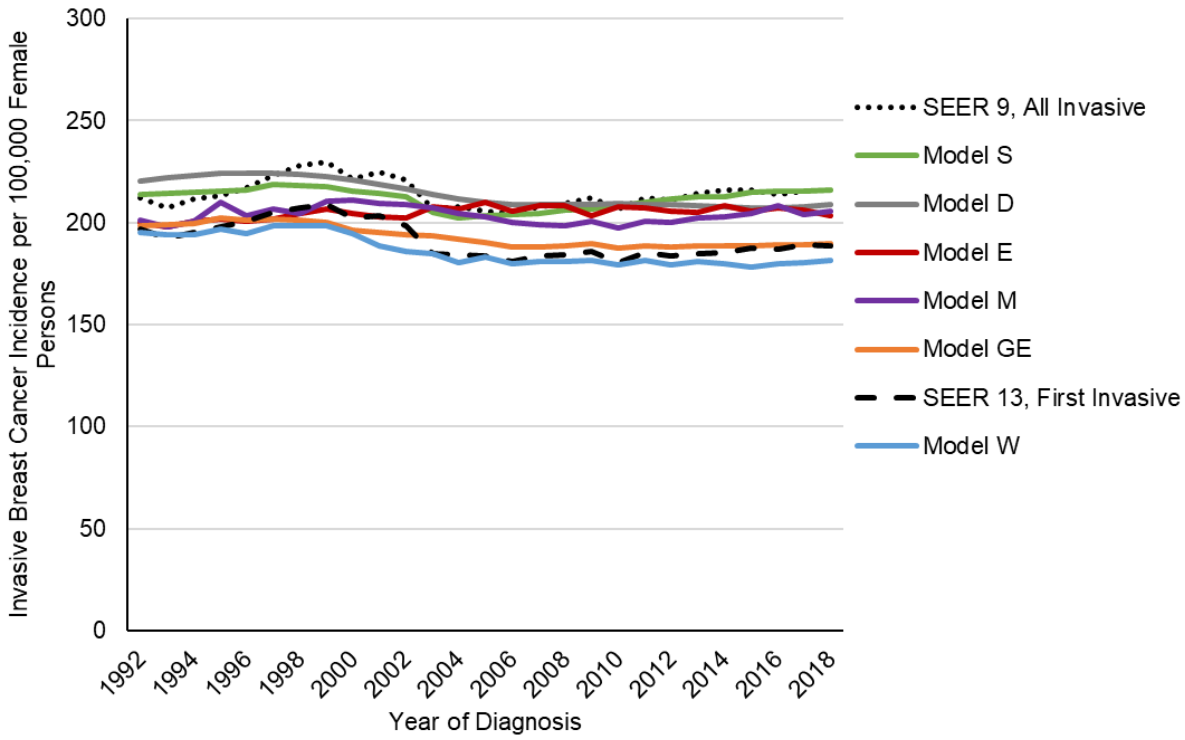
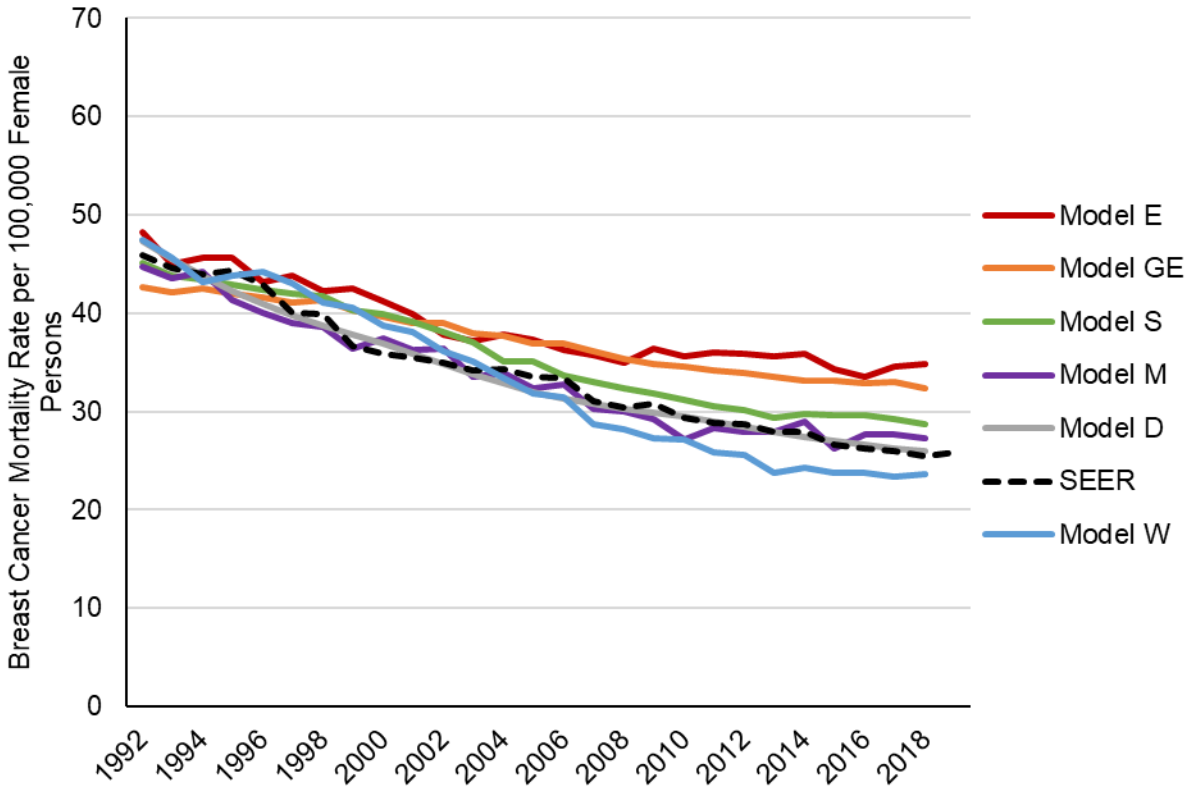


Figure 4. Estimated Age-Adjusted Breast Cancer Mortality per 100,000 Female Persons by Model and From the Surveillance, Epidemiology, and End Results (SEER) Program for 1992–2018, Ages 30–79



Note: For comparison with model results, breast cancer mortality rates from the National Vital Statistics System through SEER*Stat software are shown limited to deaths in the areas covered by the SEER 13 registries ("SEER").

Figure 5. Efficiency Frontiers for the Estimated Lifetime Number of Mammograms and Life-Years Gained for a Cohort of 1,000 Female Persons by Model and Screening Strategy

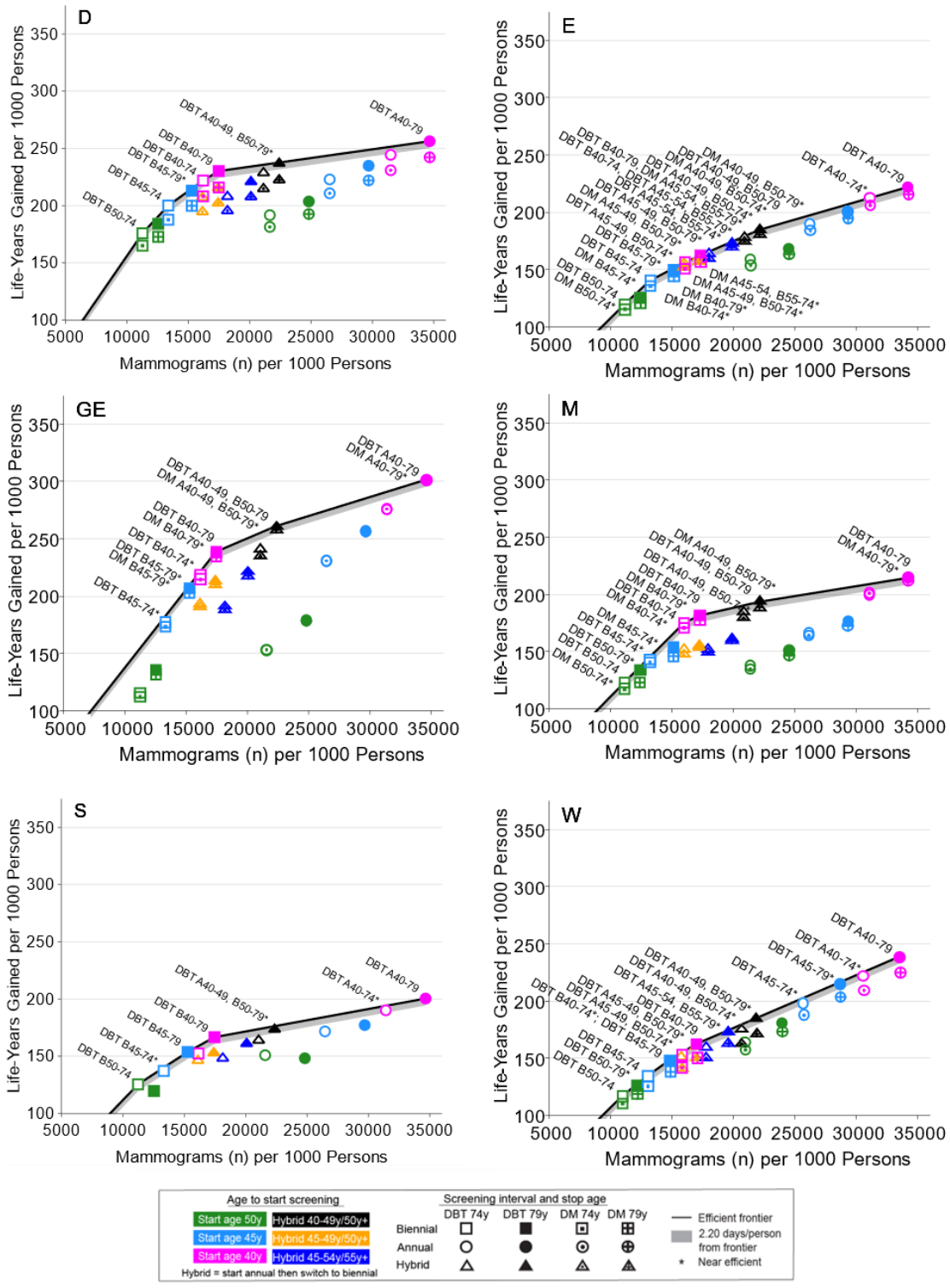


Figure 6. Efficiency Frontiers for the Estimated Lifetime Number of Mammograms and Percent Breast Cancer Mortality Reduction for a Cohort of 1,000 Female Persons by Model and Screening Strategy

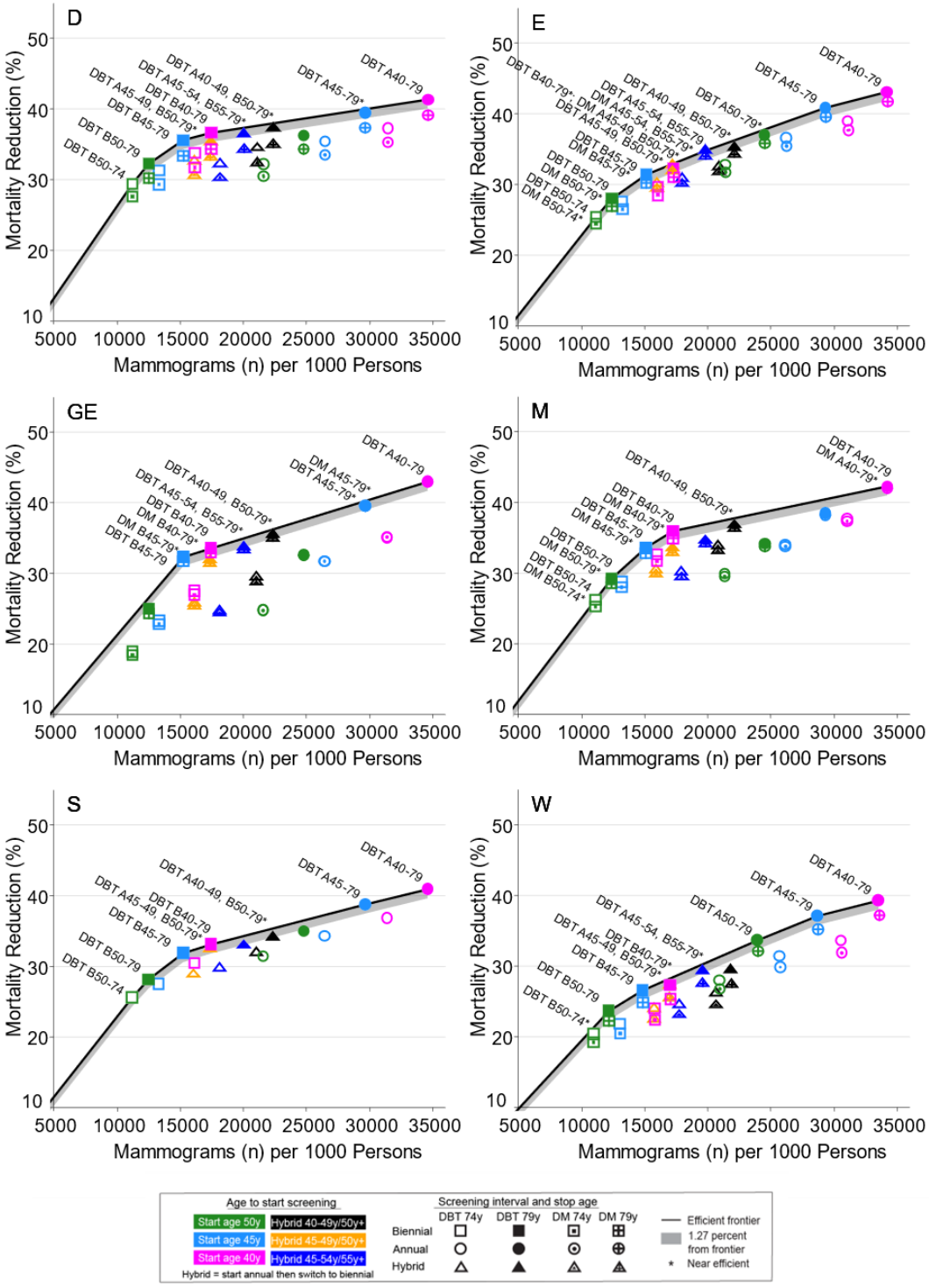
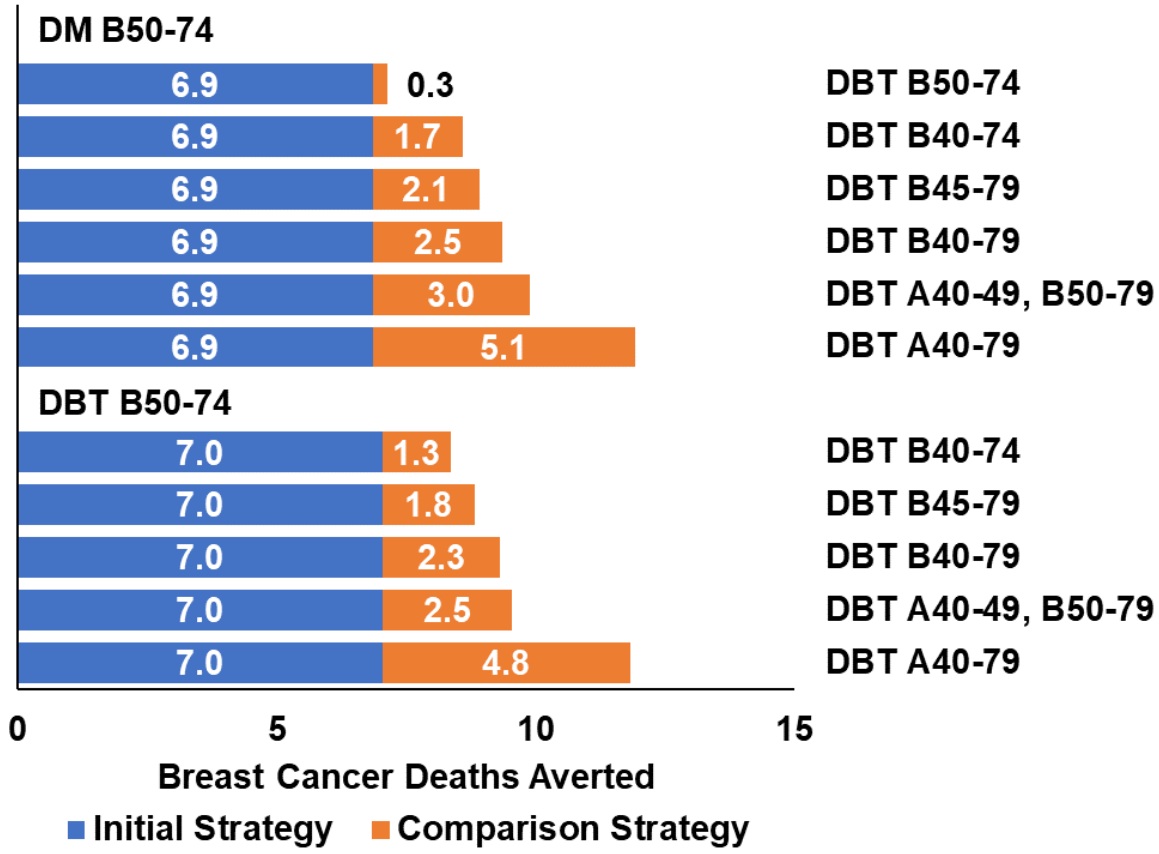
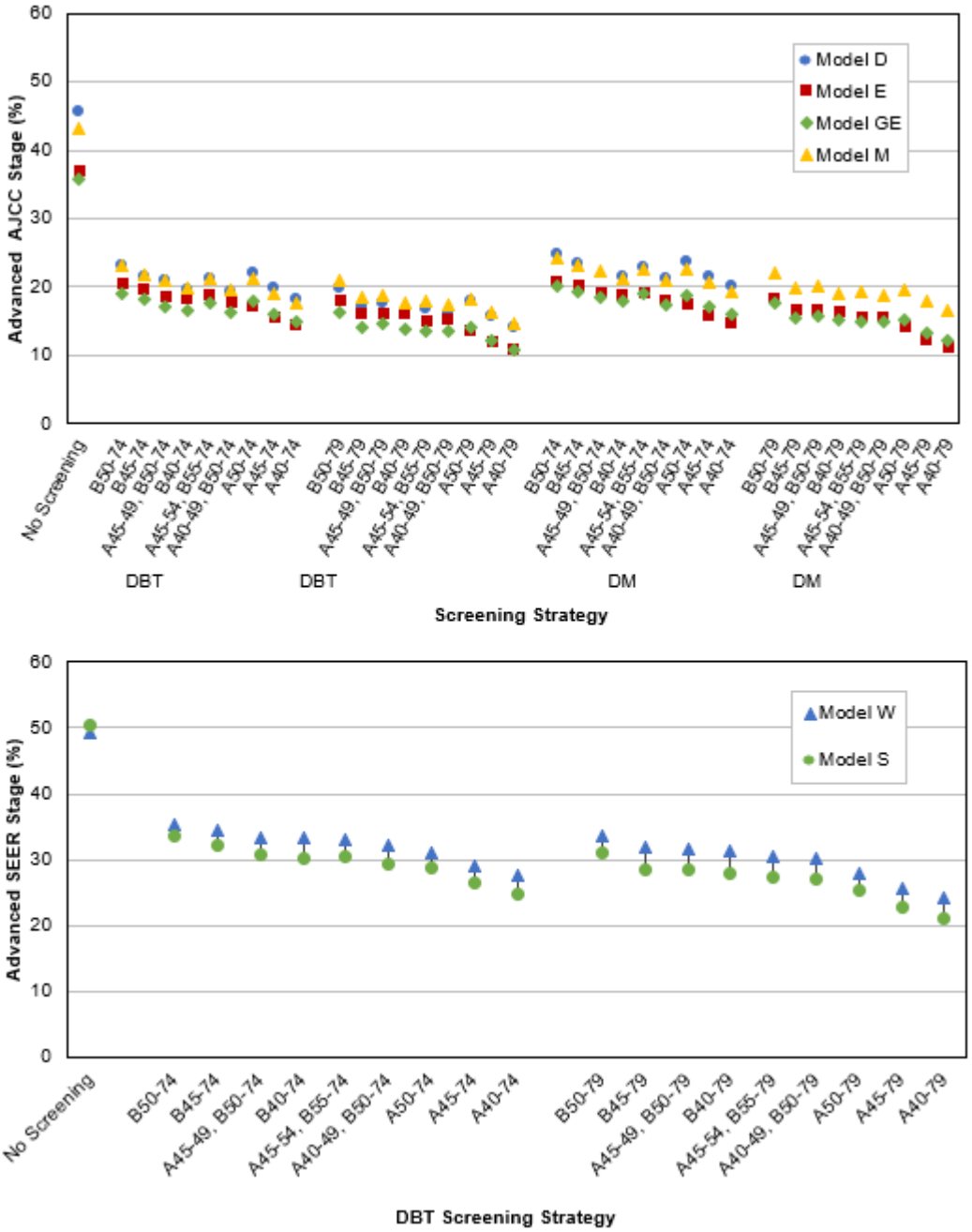


Figure 7. Estimated Median Lifetime Numbers of Breast Cancer Deaths Averted for a Cohort of 1,000 Female Persons Undergoing Screening Across Five Models and Varying Modalities, Screening Intervals, and Ages to Start and Stop Screening



Note: Blue bars represent the initial strategy, with the orange bars showing the incremental gain in breast cancer deaths averted by changing modality, screening more frequently, starting screening earlier, and/or stopping screening later. Comparison strategies limited to efficient and near-efficient screening strategies. Results shown as medians across five models (D, E, GE, M, and W).

Figure 8. Percent of Invasive Breast Cancer Cases Diagnosed in an Advanced Stage According to AJCC Version 6 (IIB or Higher) or SEER Summary (Regional or Distant) Staging Scheme by Model and Mammogram Modality



Abbreviations: AJCC, American Joint Committee on Cancer; DM, digital mammography; DBT, digital breast tomosynthesis; SEER, Surveillance, Epidemiology, and End Results.

Figure 9. Efficiency Frontiers for the Estimated Lifetime Number of Mammograms and Life-Years Gained for a Cohort of 1,000 Black Female Persons by Model and Screening Strategy

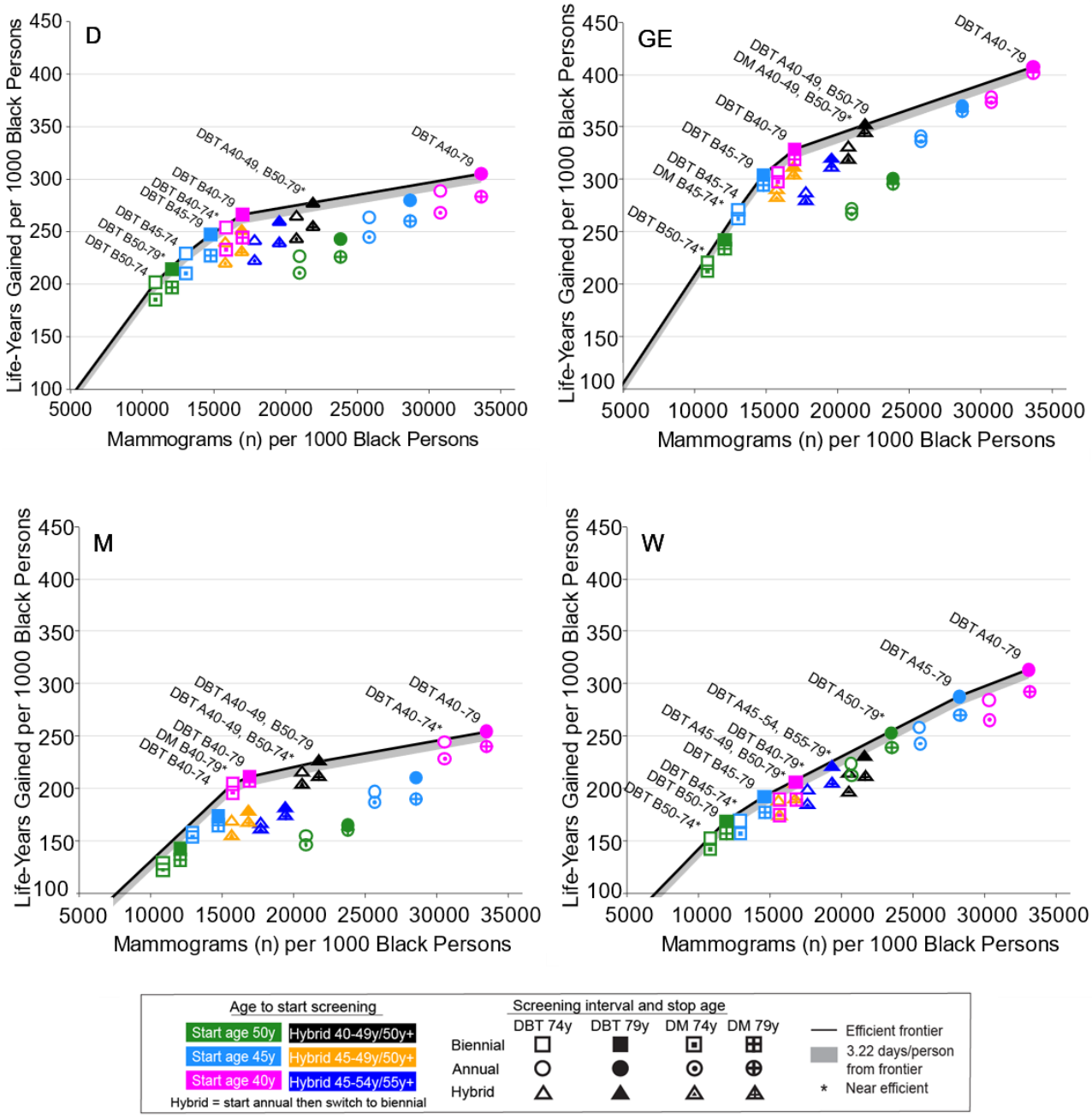


Figure 10. Efficiency Frontiers for the Estimated Lifetime Number of Mammograms and Percent Breast Cancer Mortality Reduction for a Cohort of 1,000 Black Female Persons by Model and Screening Strategy

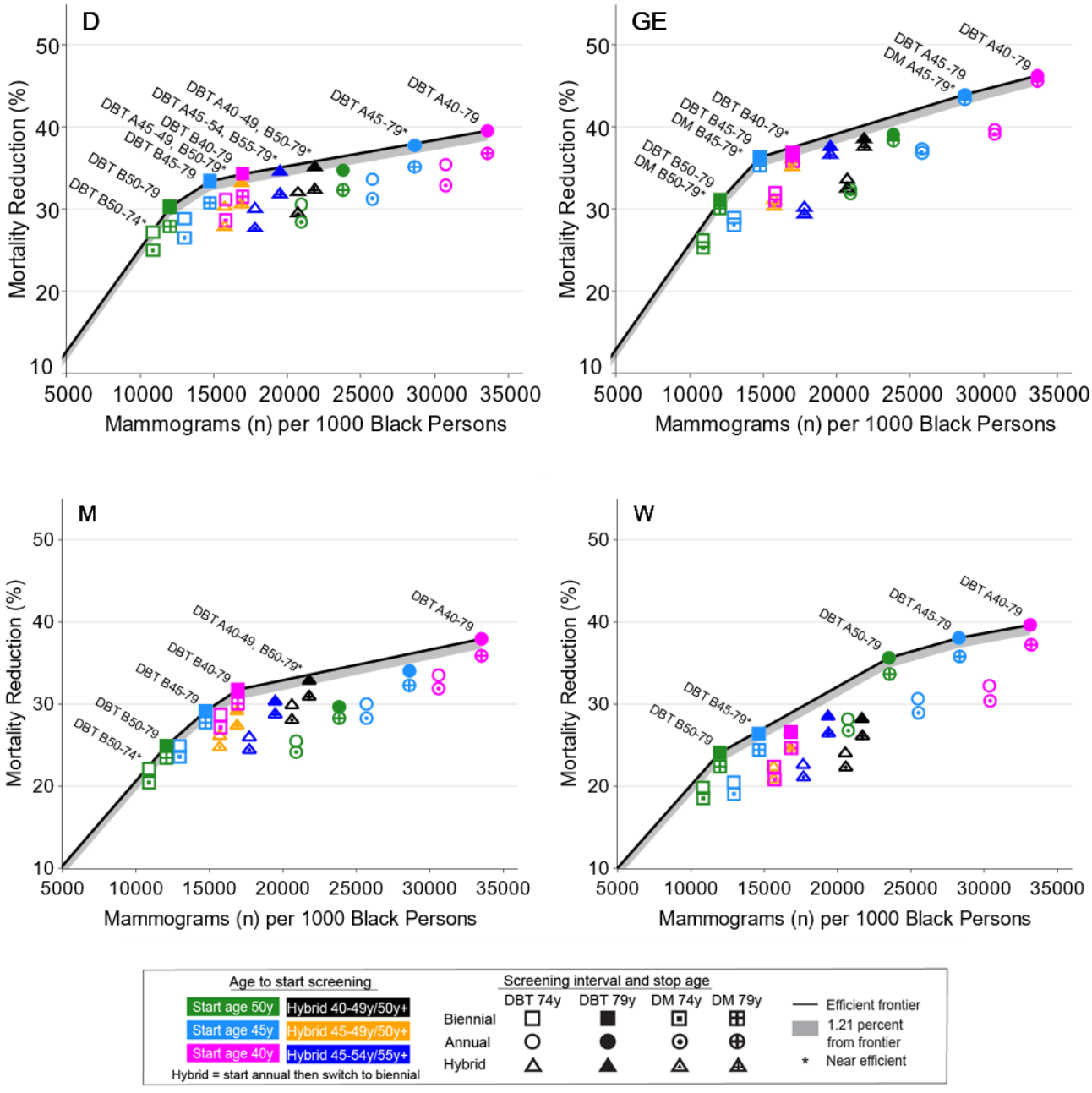
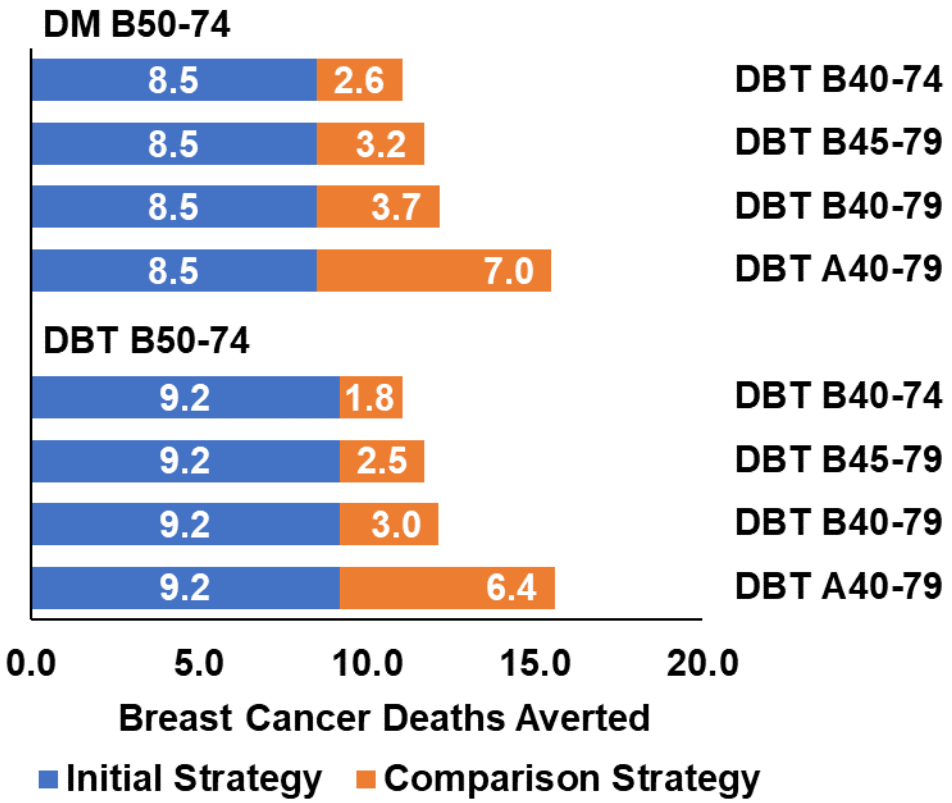


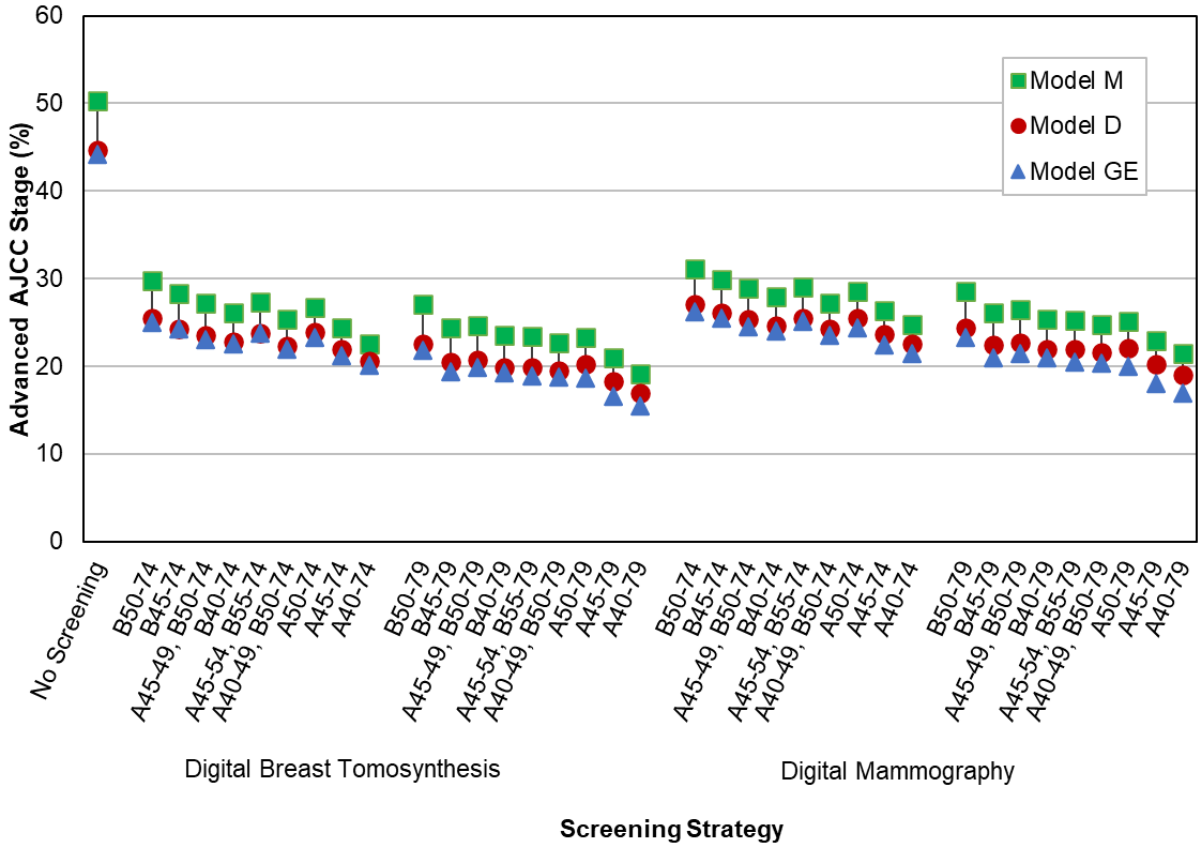
Figure 11. Estimated Median Lifetime Numbers of Breast Cancer Deaths Averted for a Cohort of 1,000 40-Year-Old Black Female Persons Undergoing Screening Across Four Models and Varying Modalities, Screening Intervals, Ages to Start Screening, and Ages to Stop Screening



Abbreviations: DBT, digital breast tomosynthesis; DM, digital mammography.

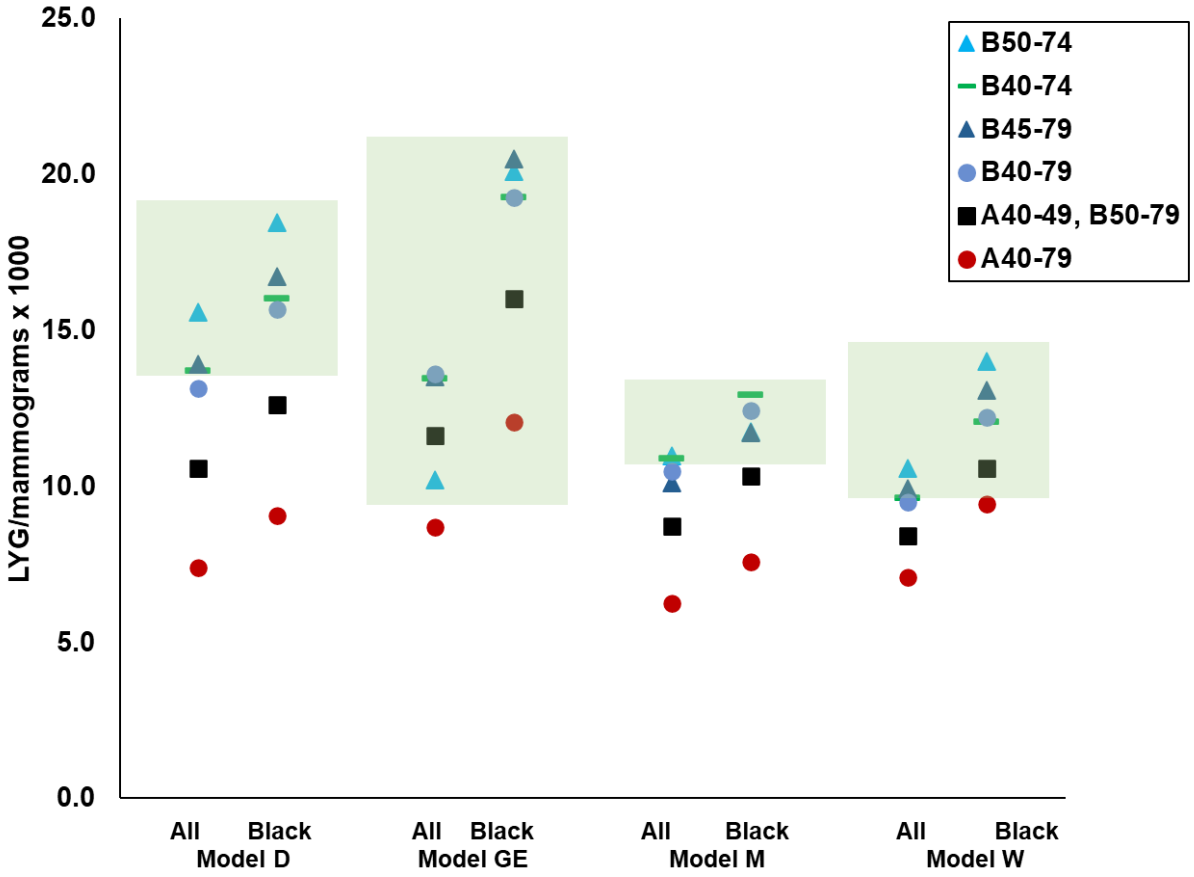
Note: Blue bars represent the initial strategy, with the orange bars showing the incremental gain in breast cancer deaths averted by changing modality, screening more frequently, starting screening earlier, and/or stopping screening later. Comparison strategies limited to efficient and near-efficient screening strategies for Black female persons.

Figure 12. Percent of Invasive Breast Cancer Cases Diagnosed in Advanced AJCC Version 6 Stages IIB, III, and IV Combined for a Cohort of 1,000 40-Year-Old Black Female Persons by Model and Screening Strategy



Note: Figure limited to the three models (D, GE, M) of breast cancer in Black female persons with AJCC stage for breast cancer cases.

Figure 13. Benefit-to-Harm Measured as Life-Years Gained per Mammogram (Times 1,000) From Four Models of All Female Persons and Black Female Persons According to Screening Strategy



Abbreviations: A, annual; B, biennial; LYG, life-years gained.

Note: Limited to efficient or near-efficient strategies among most models along with biennial screening during ages 40–74. All strategies use digital breast tomosynthesis. Green shading indicates strategies for Black female persons with greater values of LYG/mammogram than for biennial screening at ages 40–74 (light blue triangle) or 50–74 (green line) among female persons overall.

Figure 14. Efficiency Frontiers for the Estimated Lifetime Number of Mammograms and Life-Years Gained for a Cohort of 1,000 Female Persons by Breast Density Category and Screening Strategy With Digital Breast Tomosynthesis Using Exemplar Model W

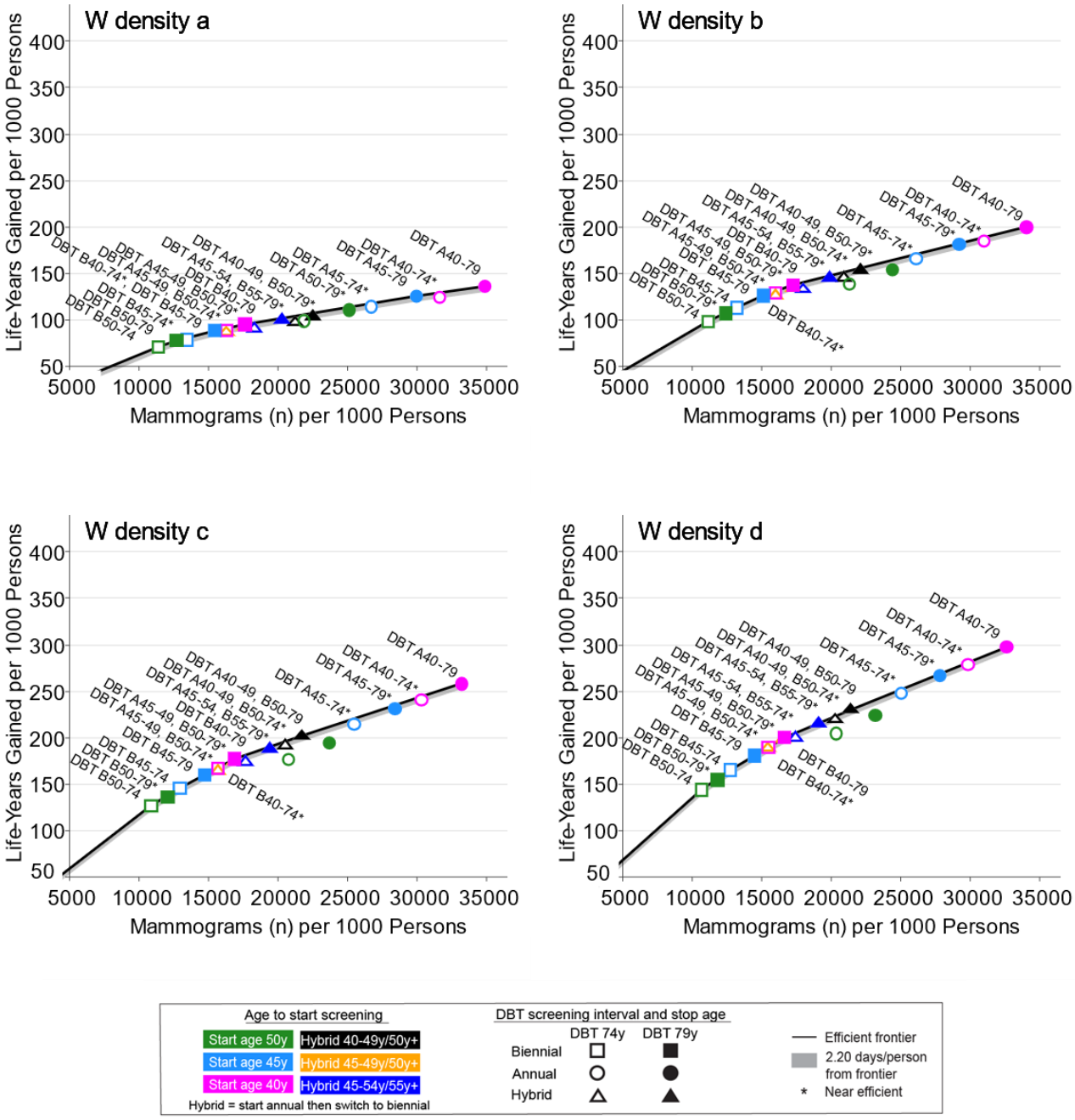


Figure 15. Efficiency Frontiers for the Estimated Lifetime Number of Mammograms and Life-Years Gained for a Cohort of 1,000 Black Female Persons by Breast Density Category and Screening Strategy With Digital Breast Tomosynthesis Using Exemplar Model W

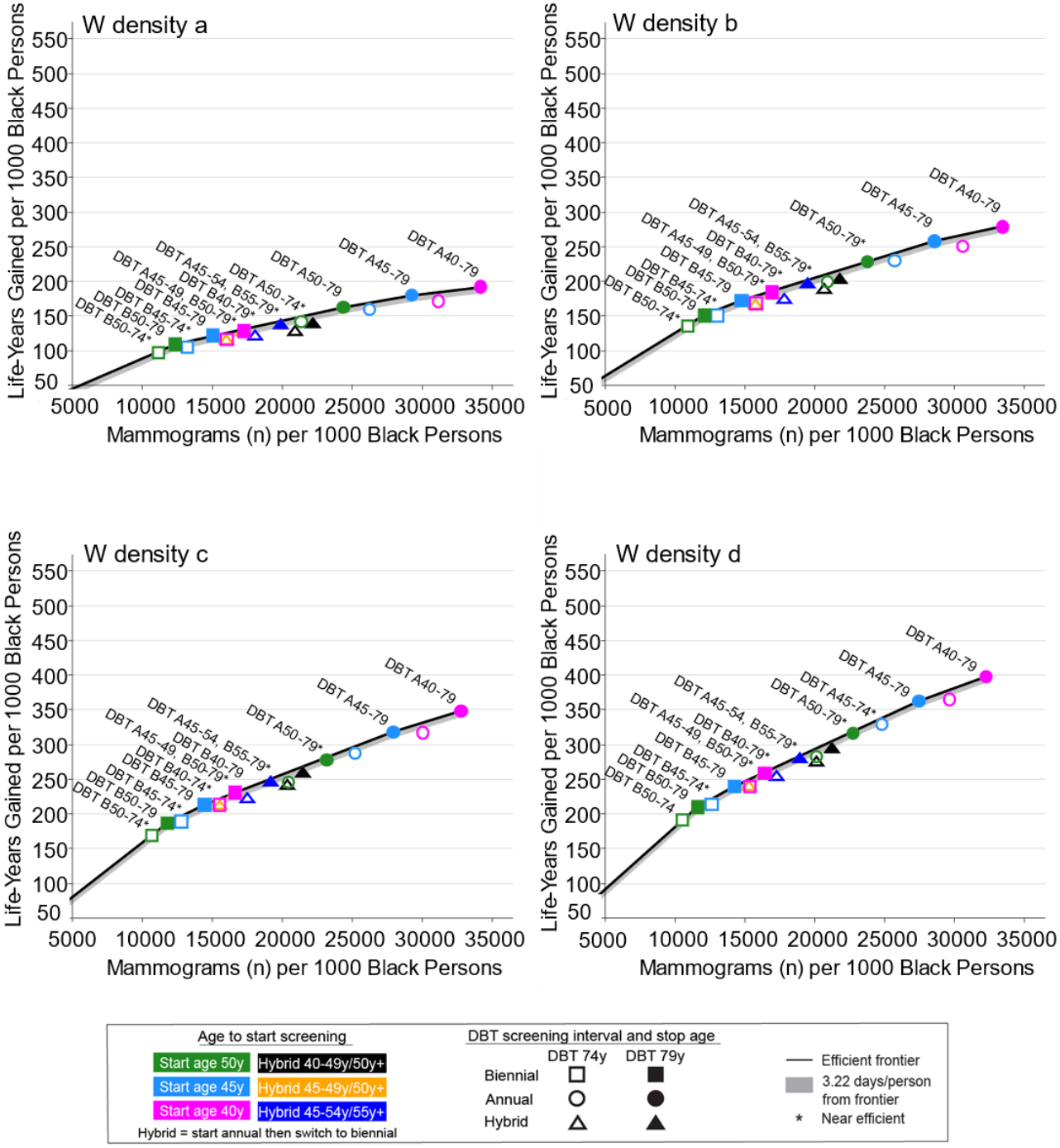


Figure 16. Efficiency Frontiers for the Estimated Lifetime Number of Mammograms and Life-Years Gained for a Cohort of 1,000 Female Persons by Relative Risk (RR) of Breast Cancer and Screening Strategy With Digital Breast Tomosynthesis Using Exemplar Model W

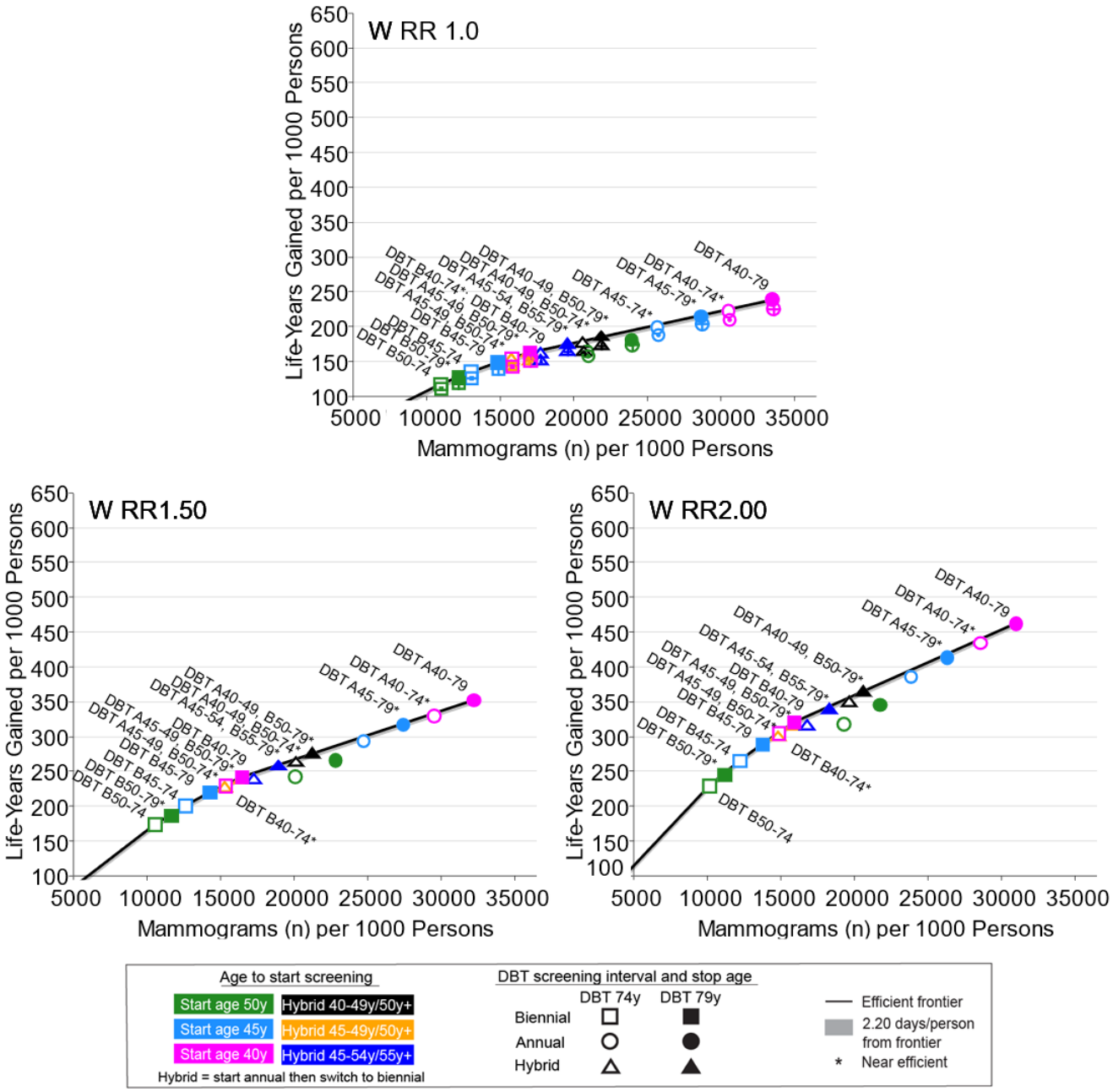
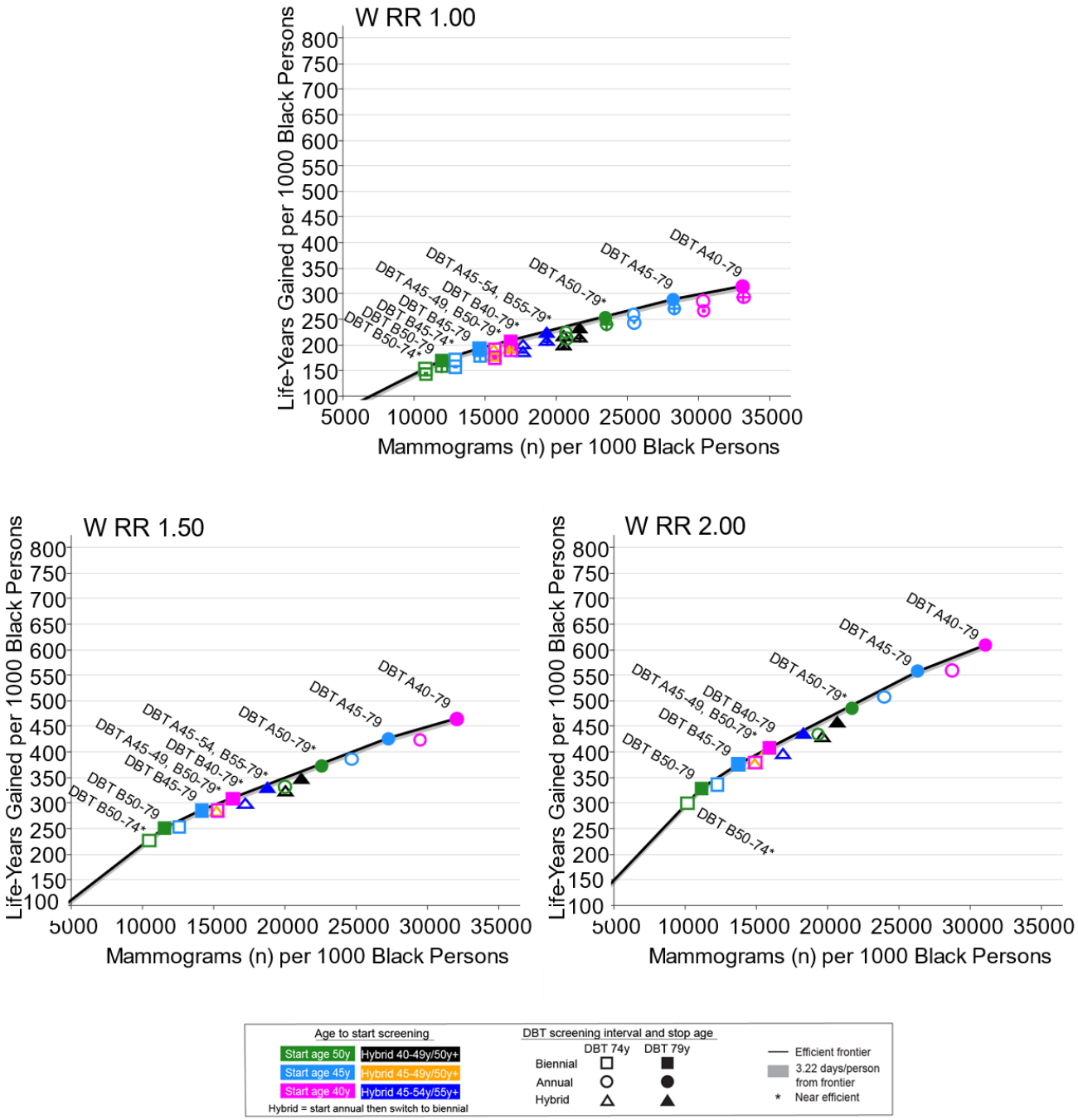


Figure 17. Efficiency Frontiers for the Estimated Lifetime Number of Mammograms and Life-Years Gained for a Cohort of 1,000 Black Female Persons by Relative Risk (RR) of Breast Cancer and Screening Strategy With Digital Breast Tomosynthesis Using Exemplar Model W



Appendix A Table 1. Breast Density Distribution by Age, All and Black Female Persons, Breast Cancer Surveillance Consortium

	BI-RADS Breast Density Category (row percentages[a])			
Age (years)	a Almost entirely fatty	b Scattered areas of fibroglandular density	c Heterogeneously dense	d Extremely dense
All female persons				
All ages	10.7	44.6	37.2	7.4
40-44	5.0	29.7	49.5	15.9
45-49	5.8	33.1	48.0	13.1
50-64	11.0	45.9	36.7	6.5
65-74	14.8	52.8	29.2	3.2
Black female persons				
All ages	10.7	52.5	33.3	3.5
40-44	6.4	37.1	48.1	8.4
45-49	7.2	40.6	46.0	6.2
50-64	11.7	54.5	30.9	2.9
65-74	12.5	58.8	26.9	1.8

Abbreviation: BI-RADS=Breast Imaging-Reporting and Data System.
[a] Prevalence based on 1,765,471 mammograms conducted during 2010–2018. Values shown for all cancers combined (ductal carcinoma in situ and invasive carcinoma).

Appendix A Table 2. Relative Risk of Breast Cancer Associated With Age, Breast Density, and Other Factors Such as a First-Degree Family History of Breast Cancer

Age (yr) and BI-RADS Breast Density	Relative Risk[a] Associated with Factors Other than Breast Density		
	1.0 ("Average" Risk)	1.5	2.0
40-49			
Almost entirely fatty	0.37	0.56	0.75
Scattered areas of fibroglandular density	0.72	1.07	1.43
Heterogeneously dense	1.16	1.74	2.32
Extremely dense	1.46	2.18	2.91
50-64			
Almost entirely fatty	0.50	0.75	1.00
Scattered areas of fibroglandular density	0.84	1.27	1.69
Heterogeneously dense	1.25	1.87	2.50
Extremely dense	1.53	2.30	3.06
65-74			
Almost entirely fatty	0.61	0.92	1.22
Scattered areas of fibroglandular density	0.94	1.41	1.88
Heterogeneously dense	1.28	1.92	2.56
Extremely dense	1.45	2.17	2.90

Abbreviation: BI-RADS=Breast Imaging-Reporting and Data System.

[a] Relative risks are standardized to the average risk in the overall population (RR=1) within each age group.

Appendix A Table 3. Distribution (%) of Subtypes of Breast Cancer by Stage and Method of Detection in All and Black Female Persons, Breast Cancer Surveillance Consortium

AJCC v6 Stage [a]	Subtype	All Screen and Interval Detected	All Clinically Detected	Black Screen and Interval Detected	Black Clinically Detected
I	ER+ HER2+	7.4	8.9	7.0	8.8
	ER+ HER2-	81.1	77.1	74.5	68.0
	ER- HER2+	2.8	4.9	3.2	5.6
	ER- HER2-	8.7	9.2	15.3	17.6
IIA	ER+ HER2+	10.5	10.1	11.7	10.0
	ER+ HER2-	70.0	66.4	54.2	43.8
	ER- HER2+	4.3	5.2	4.5	6.7
	ER- HER2-	15.2	18.2	29.6	39.5
IIB	ER+ HER2+	9.9	11.7	9.5	9.5
	ER+ HER2-	70.3	66.1	54.5	56.2
	ER- HER2+	5.9	7.6	9.5	8.0
	ER- HER2-	13.8	14.5	26.6	26.3
III/IV	ER+ HER2+	12.0	14.0	8.5	13.5
	ER+ HER2-	63.3	59.9	55.9	45.7
	ER- HER2+	8.2	10.4	7.7	11.7
	ER- HER2-	16.5	15.7	27.9	29.1

Abbreviations: AJCC v6, American Joint Commission on Cancer Staging System version 6; ER, estrogen receptor; HER2, human epidermal growth factor receptor 2.

[a] Values are shown in columns by percentages within each stage; based on 18,680 breast cancer cases diagnosed during 2005–2018 among all cancers combined (ductal carcinoma in situ and invasive carcinoma).

Appendix A Table 4. Input Parameter Values for Utilities Associated With Health-Related States

State	Utility	Disutility	Duration	Unit
Age (years)				
40-49	0.863	0.137	1	Year
50-59	0.837	0.163	1	Year
60-69	0.811	0.189	1	Year
70-79	0.771	0.229	1	Year
≥80	0.724	0.276	1	Year
Screening attendance (routine screening)	0.994	0.006	1	Week
Diagnostic phase (evaluation of positive screen)	0.895	0.105	5	Week
Cancer treatment for local or DCIS breast cancer	0.9	0.1	2	Year
Cancer treatment for regional breast cancer	0.75	0.25	2	Year
Cancer treatment for distant breast cancer	0.6	0.4	Until death	

Abbreviation: DCIS, ductal carcinoma in situ.
Source: Hanmer (2006),[49] Stout (2006),[51] and de Haes (1991)[50]

Appendix A Table 5. Comorbidity Levels and Associated Health Conditions

Level	Types of Health Conditions[a]	Prevalence	Remaining Life Expectancy at Age 66 (Years)	Probability of 10-year Survival at Age 66
None	None	69%	17	92%
Low	History of myocardial infarction, acute myocardial infarction, ulcer, rheumatologic disease	2%	15	85%
Moderate	Peripheral vascular disease, cerebrovascular disease, paralysis, diabetes	12%	13	77%
Severe	AIDS, chronic obstructive pulmonary disease, congestive heart failure, moderate or severe liver disease, chronic renal failure, dementia, cirrhosis, and chronic hepatitis	17%	9	57%

Source: Cho (2013),[63] Mandelblatt (2015),[78] and Trentham-Dietz (2021)[79]

[a] Health conditions in the table correspond to separate ICD-9 codes with hazard ratio estimates of death grouped into low (hazard ratios, 1.11 to 1.31), moderate (hazard ratios, 1.44 to 1.52), and severe (hazard ratios, 1.76 to 3.66) levels compared to persons with no comorbidity.

Appendix A Table 6. Lifetime Benefits of Mammography Screening With Digital Mammography vs. No Screening for a Cohort of 1,000 40-Year-Old Female Persons According to Model and Screening Strategy

Strategy	Screens, n[a]	Model					Median
		D	E	GE	M	W	
Stopping age 74		**Reduction in Breast Cancer Mortality per 1,000 Persons Screened vs. No Screening, %[b]**					
B50-74	11,192	27.5	24.3	18.3	25.2	19.2	24.3
B45-74	13,283	29.3	26.4	22.8	28.0	20.4	26.4
A45-49, B50-74	15,992	30.5	29.3	25.3	29.7	22.4	29.3
B40-74	16,092	31.6	28.4	26.9	31.7	22.3	28.4
A45-54, B55-74	18,006	30.2	30.0	24.3	29.3	23.0	29.3
A40-49, B50-74	20,898	32.3	31.7	28.7	33.1	24.4	31.7
A50-74	21,439	30.4	31.7	24.7	29.4	26.7	29.4
A45-74	26,272	33.4	35.4	31.6	33.7	29.8	33.4
A40-74	31,178	35.2	37.6	35.1	37.3	31.8	35.2
Stopping age 79							
B50-79	12,456	30.2	26.9	24.3	28.5	22.2	26.9
B45-79	15,176	33.3	30.2	31.7	32.7	24.8	31.7
A45-49, B50-79	17,242	33.1	31.8	31.3	32.8	25.4	31.8
B40-79	17,354	34.3	31.0	32.9	34.9	25.3	32.9
A45-54, B55-79	19,876	34.2	33.9	33.2	34.1	27.5	33.9
A40-49, B50-79	22,150	34.9	34.2	34.9	36.2	27.4	34.9
A50-79	24,563	34.3	35.8	32.5	33.7	32.1	33.7
A45-79	29,389	37.3	39.5	39.5	38.1	35.1	38.1
A40-79	34,289	39.0	41.7	42.9	41.9	37.2	41.7
Stopping age 74		**Life-Years Gained per 1,000 Persons Screened vs. No Screening**					
B50-74	11,192	165.0	114.6	111.4	116.9	109.8	114.6
B45-74	13,283	187.7	135.1	172.9	140.0	125.0	140.0
A45-49, B50-74	15,992	194.5	151.3	189.7	146.9	140.8	151.3
B40-74	16,092	208.2	150.0	214.1	170.1	141.2	170.1
A45-54, B55-74	18,006	195.5	159.3	187.6	148.6	149.5	159.3
A40-49, B50-74	20,898	214.7	173.8	234.6	178.9	161.9	178.9
A50-74	21,439	181.4	153.2	152.4	134.0	157.0	153.2
A45-74	26,272	210.8	183.5	230.1	163.6	187.3	187.3
A40-74	31,178	230.9	205.5	275.5	200.7	208.7	208.7
Stopping age 79							
B50-79	12,456	172.8	120.3	131.1	122.7	118.5	122.7

Appendix A Table 6. Lifetime Benefits of Mammography Screening With Digital Mammography vs. No Screening for a Cohort of 1,000 40-Year-Old Female Persons According to Model and Screening Strategy

B45-79	15,176	199.8	143.5	202.5	145.6	137.8	145.6
A45-49, B50-79	17,242	202.2	156.7	209.4	153.0	149.5	156.7
B40-79	17,354	215.9	156.0	233.9	176.8	149.8	176.8
A45-54, B55-79	19,876	207.6	168.8	217.2	158.7	162.3	168.8
A40-49, B50-79	22,150	222.4	180.0	257.0	187.9	170.5	187.9
A50-79	24,563	192.7	162.7	177.7	145.8	172.7	172.7
A45-79	29,389	222.1	194.1	256.1	172.0	202.9	202.9
A40-79	34,289	242.2	215.1	300.6	211.4	224.3	224.3
Stopping age 74		**Breast Cancer Deaths Averted per 1'000 Persons Screened vs. No Screening**					
B50-74	11,192	8.6	7.2	6.9	5.9	4.8	6.9
B45-74	13,283	9.2	7.8	8.5	6.6	5.1	7.8
A45-49, B50-74	15,992	9.6	8.6	9.5	7.0	5.7	8.6
B40-74	16,092	9.9	8.4	10.1	7.4	5.6	8.4
A45-54, B55-74	18,006	9.4	8.8	9.1	6.9	5.8	8.8
A40-49, B50-74	20,898	10.1	9.3	10.7	7.7	6.2	9.3
A50-74	21,439	9.5	9.3	9.2	6.9	6.8	9.2
A45-74	26,272	10.5	10.4	11.8	7.9	7.5	10.4
A40-74	31,178	11.0	11.1	13.1	8.7	8.0	11.0
Stopping age 79							
B50-79	12,456	9.4	7.9	9.1	6.7	5.6	7.9
B45-79	15,176	10.4	8.9	11.9	7.7	6.3	8.9
A45-49, B50-79	17,242	10.4	9.4	11.7	7.7	6.4	9.4
B40-79	17,354	10.7	9.1	12.3	8.2	6.4	9.1
A45-54, B55-79	19,876	10.7	10.0	12.4	8.0	6.9	10.0
A40-49, B50-79	22,150	10.9	10.1	13.1	8.5	6.9	10.1
A50-79	24,563	10.7	10.5	12.2	7.9	8.1	10.5
A45-79	29,389	11.7	11.6	14.8	8.9	8.9	11.6
A40-79	34,289	12.2	12.3	16.1	9.8	9.4	12.2
Stopping age 74		**QALYs Gained per 1,000 Persons Screened vs. No Screening[c]**					
B50-74	11,192	132.4	80.7	77.4	81.2	72.3	80.7
B45-74	13,283	149.5	94.9	124.5	97.5	82.2	97.5
A45-49, B50-74	15,992	153.1	104.7	135.8	101.0	92.4	104.7
B40-74	16,092	163.8	103.9	154.5	118.8	91.8	118.8
A45-54, B55-74	18,006	152.8	109.8	133.1	101.3	98.3	109.8
A40-49, B50-74	20,898	165.5	117.8	167.2	122.2	104.4	122.2
A50-74	21,439	140.3	104.9	104.2	89.0	102.9	104.2

Appendix A Table 6. Lifetime Benefits of Mammography Screening With Digital Mammography vs. No Screening for a Cohort of 1,000 40-Year-Old Female Persons According to Model and Screening Strategy

A45-74	26,272	160.9	125.0	162.2	108.5	122.5	125.0
A40-74	31,178	173.3	138.0	194.0	133.6	134.7	138.0
Stopping age 79							
B50-79	12,456	138.9	84.3	91.4	84.7	77.5	84.7
B45-79	15,176	159.2	100.3	145.6	100.6	90.0	100.6
A45-49, B50-79	17,242	159.5	107.9	149.8	104.8	97.7	107.9
B40-79	17,354	170.3	107.8	168.6	123.2	97.0	123.2
A45-54, B55-79	19,876	162.5	115.9	154.3	107.6	106.1	115.9
A40-49, B50-79	22,150	172.0	121.8	183.4	128.3	109.6	128.3
A50-79	24,563	148.7	110.5	121.5	96.1	112.4	112.4
A45-79	29,389	169.3	131.5	180.0	113.1	132.0	132.0
A40-79	34,289	181.7	143.6	211.2	140.0	144.2	144.2

Abbreviations: A, annual; B, biennial; D, Dana-Farber Cancer Institute; E, Erasmus Medical Center; GE, Georgetown Lombardi Comprehensive Cancer Center-Albert Einstein College of Medicine; M, University of Texas MD Anderson Cancer Center; S, Stanford University; W, University of Wisconsin-Madison and Harvard Pilgrim Health Care Institute.

[a] Median number of mammograms across models. Strategies are ranked from the least to the most mammograms. Not all possible mammograms in the age interval are obtained because some people die of other causes before screening would occur.

[b] Without screening, the median probability of dying of breast cancer is 2.73% (range, 2.34%–3.75%). Thus, if a particular screening strategy leads to a 30% reduction in breast cancer mortality, the probability of breast cancer mortality is reduced from 2.73% to 1.91%. This translates into 8.2 deaths averted per 1,000 persons screened.

[c] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

Appendix A Table 7. Lifetime Benefits of Mammography Screening With Digital Breast Tomosynthesis vs. No Screening for a Cohort of 1,000 40-Year-Old Female Persons According to Model and Screening Strategy

		Model						
Strategy	**Screens, n[a]**	**D**	**E**	**GE**	**M**	**S**	**W**	**Median**
Stopping age 74		**Reduction in Breast Cancer Mortality per 1,000 Persons Screened vs. No Screening, %[b]**						
B50-74	11,208	29.4	25.3	18.8	26.1	25.5	20.3	25.4
B45-74	13,299	31.2	27.5	23.2	28.7	27.4	21.7	27.5
A45-49, B50-74	16,053	32.5	30.1	25.8	30.3	28.8	23.9	29.5
B40-74	16,116	33.7	29.6	27.5	32.6	30.4	24.0	30.0
A45-54, B55-74	18,072	32.1	30.8	24.7	30.1	29.6	24.4	29.9
A40-49, B50-74	20,979	34.4	32.5	29.4	33.8	31.9	26.1	32.2
A50-74	21,500	32.1	32.8	24.7	29.8	31.4	27.9	30.6
A45-74	26,349	35.3	36.5	31.6	34.0	34.3	31.4	34.1
A40-74	31,273	37.2	38.9	35.0	37.6	36.8	33.6	37.0
Stopping age 79								
B50-79	12,488	32.2	27.9	24.9	29.1	28.1	23.6	28.0
B45-79	15,218	35.5	31.3	32.3	33.5	31.8	26.5	32.1
A45-49, B50-79	17,325	35.3	32.7	31.8	33.4	32.3	27.2	32.5
B40-79	17,397	36.5	32.2	33.5	35.9	33.1	27.2	33.3
A45-54, B55-79	19,980	36.4	34.7	33.7	34.5	32.9	29.2	34.1
A40-49, B50-79	22,255	37.2	35.1	35.4	36.7	34.1	29.4	35.3
A50-79	24,687	36.2	36.9	32.6	34.1	35.0	33.6	34.5
A45-79	29,517	39.4	40.8	39.5	38.4	38.7	37.1	39.1
A40-79	34,441	41.3	43.0	42.9	42.2	40.9	39.2	41.7
Stopping age 74		**Life-Years Gained per 1,000 Persons Screened vs. No Screening**						
B50-74	11,208	175.8	119.2	115.1	122.4	125.4	116.1	120.8
B45-74	13,299	200.1	140.0	176.4	142.6	137.2	133.9	141.3
A45-49, B50-74	16,053	207.2	155.1	192.6	151.8	146.3	150.9	153.5
B40-74	16,116	221.9	155.7	218.0	174.7	152.4	152.4	165.2
A45-54, B55-74	18,072	207.9	163.2	190.5	151.2	148.2	158.9	161.1
A40-49, B50-74	20,979	228.6	177.8	240.1	184.5	163.9	174.6	181.2
A50-74	21,500	191.7	158.3	152.8	137.1	150.9	163.4	155.6
A45-74	26,349	222.9	189.1	230.1	165.7	171.7	197.5	193.3
A40-74	31,273	244.4	212.0	274.9	199.3	190.1	221.2	216.6
Stopping age 79								
B50-79	12,488	184.1	124.9	135.2	133.1	119.6	125.4	129.3

Appendix A Table 7. Lifetime Benefits of Mammography Screening With Digital Breast Tomosynthesis vs. No Screening for a Cohort of 1,000 40-Year-Old Female Persons According to Model and Screening Strategy

B45-79	15,218	213.1	149.0	206.5	153.1	153.7	147.7	153.4
A45-49, B50-79	17,325	215.4	160.7	212.7	155.0	152.8	160.2	160.5
B40-79	17,397	230.2	161.8	237.8	181.2	166.7	161.7	173.9
A45-54, B55-79	19,980	220.8	172.7	220.6	161.0	161.0	172.6	172.7
A40-49, B50-79	22,255	236.9	184.2	260.1	193.2	173.4	183.9	188.7
A50-79	24,687	203.6	167.9	178.5	150.5	148.2	180.1	173.2
A45-79	29,517	234.9	200.0	255.8	176.1	177.2	214.1	207.1
A40-79	34,441	256.3	221.6	300.7	214.2	200.4	237.8	229.7
Stopping age 74		**Breast Cancer Deaths Averted per 1,000 Persons Screened vs. No Screening**						
B50-74	11,208	9.2	7.5	7.0	6.1	6.4	5.1	6.7
B45-74	13,299	9.8	8.1	8.7	6.7	6.9	5.5	7.5
A45-49, B50-74	16,053	10.2	8.9	9.6	7.1	7.2	6.0	8.0
B40-74	16,116	10.6	8.7	10.3	7.6	7.6	6.1	8.2
A45-54, B55-74	18,072	10.0	9.1	9.2	7.1	7.4	6.2	8.2
A40-49, B50-74	20,979	10.8	9.5	11.0	7.9	8.0	6.6	8.8
A50-74	21,500	10.1	9.6	9.3	7.0	7.9	7.1	8.6
A45-74	26,349	11.0	10.7	11.8	8.0	8.6	7.9	9.7
A40-74	31,273	11.6	11.4	13.1	8.8	9.2	8.5	10.3
Stopping age 79								
B50-79	12,488	10.1	8.2	9.3	6.8	7.0	6.0	7.6
B45-79	15,218	11.1	9.2	12.1	7.8	8.0	6.7	8.6
A45-49, B50-79	17,325	11.1	9.6	11.9	7.8	8.1	6.9	8.9
B40-79	17,397	11.4	9.5	12.5	8.4	8.3	6.9	8.9
A45-54, B55-79	19,980	11.4	10.2	12.6	8.1	8.2	7.4	9.2
A40-49, B50-79	22,255	11.6	10.3	13.3	8.6	8.5	7.4	9.5
A50-79	24,687	11.3	10.9	12.2	8.0	8.8	8.5	9.8
A45-79	29,517	12.3	12.0	14.8	9.0	9.7	9.4	10.9
A40-79	34,441	12.9	12.7	16.1	9.9	10.2	9.9	11.5
Stopping age 74		**QALYs Gained per 1,000 Persons Screened vs. No Screening[c]**						
B50-74	11,208	143.0	85.3	81.7	86.9	92.0	77.9	86.1
B45-74	13,299	161.3	99.8	128.7	101.1	99.6	89.9	100.4
A45-49, B50-74	16,053	165.5	109.2	139.8	106.4	105.8	101.3	107.8
B40-74	16,116	177.0	109.5	159.1	124.0	109.5	101.4	116.8
A45-54, B55-74	18,072	165.1	114.6	137.4	105.2	106.6	106.9	110.7
A40-49, B50-74	20,979	179.2	122.8	173.6	128.6	115.9	115.5	125.7
A50-74	21,500	151.4	110.8	107.0	93.7	108.5	109.6	109.0

Appendix A Table 7. Lifetime Benefits of Mammography Screening With Digital Breast Tomosynthesis vs. No Screening for a Cohort of 1,000 40-Year-Old Female Persons According to Model and Screening Strategy

A45-74	26,349	173.8	131.5	164.8	112.8	121.5	132.5	132.0
A40-74	31,273	187.5	145.5	196.5	135.6	132.3	146.8	146.1
Stopping age 79								
B50-79	12,488	150.1	89.0	96.2	94.4	87.7	83.7	91.7
B45-79	15,218	172.1	105.8	150.5	108.0	112.4	98.5	110.2
A45-49, B50-79	17,325	172.5	112.8	154.3	108.1	110.3	107.1	111.5
B40-79	17,397	184.2	113.6	173.4	128.2	120.2	107.2	124.2
A45-54, B55-79	19,980	175.9	120.8	159.2	111.6	115.9	115.4	118.4
A40-49, B50-79	22,255	186.4	127.0	188.1	134.4	122.8	121.4	130.7
A50-79	24,687	160.8	116.8	125.0	102.5	105.7	120.1	118.4
A45-79	29,517	183.2	138.6	182.9	119.5	124.9	143.0	140.8
A40-79	34,441	196.9	151.4	214.6	145.5	139.5	157.2	154.3

Abbreviations: A, annual; B, biennial; D, Dana-Farber Cancer Institute; E, Erasmus Medical Center; GE, Georgetown Lombardi Comprehensive Cancer Center-Albert Einstein College of Medicine; M, University of Texas MD Anderson Cancer Center; S, Stanford University; W, University of Wisconsin-Madison and Harvard Pilgrim Health Care Institute.

[a] Median number of mammograms across models. Strategies are ranked from the least to the most mammograms by stopping age. Not all possible mammograms in the age interval are obtained because some people die of other causes before screening would occur.

[b] Without screening, the median probability of dying of breast cancer is 2.73% (range, 2.34%–3.75%). Thus, if a particular screening strategy leads to a 30% reduction in breast cancer mortality, the probability of breast cancer mortality is reduced from 2.73% to 1.91%. This translates into 8.2 deaths averted per 1,000 persons screened.

[c] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

Appendix A Table 8. Incremental Changes in Benefits and Harms for a Cohort of 1,000 Screened 40-Year-Old Female Persons: Comparison Strategies Limited to Strategies Efficient or Near-Efficient for Both Percent Breast Cancer Mortality Reduction and Life-Years Gained vs. No Screening in Most Models

Initial Strategy	Comparison Strategy[a]	Added Screens[b]	Change in Value by Model						
			D	E	GE	M	S[c]	W	Median
Breast Cancer Deaths Averted									
DM B50-74	DBT B50-74	0	0.6	0.3	0.2	0.2		0.3	0.3
	DBT B45-79	4,026	2.5	2.1	5.2	1.9		1.9	2.1
	DBT B40-79	6,205	2.8	2.3	5.7	2.5		2.0	2.5
	DBT A40-49, B50-79	11,063	3.0	3.2	6.4	2.7		2.6	3.0
	DBT A40-79	23,249	4.3	5.5	9.2	4.0		5.1	5.1
DBT B50-74	DBT B45-79	4,010	1.9	1.8	5.0	1.7	1.6	1.6	1.7
	DBT B40-79	6,189	2.3	2.0	5.5	2.3	1.9	1.7	2.1
	DBT A40-49, B50-79	11,047	2.5	2.9	6.2	2.5	2.1	2.3	2.5
	DBT A40-79	23,233	3.7	5.2	9.0	3.8	3.9	4.8	4.3
Life-Years Gained									
DM B50-74	DBT B50-74	0	10.8	4.6	3.7	5.5		6.3	5.5
	DBT B45-79	4,026	48.0	34.4	95.1	36.2		37.9	37.9
	DBT B40-79	6,205	65.2	47.2	126.4	64.4		51.9	64.4
	DBT A40-49, B50-79	11,063	71.9	69.6	148.7	76.3		74.1	74.1
	DBT A40-79	23,249	91.3	107.0	189.3	97.3		128.0	107.0
DBT B50-74	DBT B45-79	4,010	37.2	29.8	91.4	30.7	28.3	31.6	31.1
	DBT B40-79	6,189	54.4	42.6	122.7	58.8	41.2	45.7	50.0
	DBT A40-49, B50-79	11,047	61.1	65.0	145.0	70.8	48.0	67.8	66.4
	DBT A40-79	23,233	80.4	102.4	185.6	91.8	75.0	121.7	97.1
False-positive Recalls									
DM B50-74	DBT B50-74	0	-150	-149	-149	-148		-148	-149
	DBT B45-79	4,026	156	153	156	146		150	153
	DBT B40-79	6,205	421	416	421	407		412	416
	DBT A40-49, B50-79	11,063	741	727	738	716		725	727
	DBT A40-79	23,249	1,211	1,194	1,210	1,177		1,172	1,194
DBT B50-74	DBT B45-79	4,010	305	302	305	294	306	298	304
	DBT B40-79	6,189	571	566	569	556	571	560	568
	DBT A40-49, B50-79	11,047	890	877	887	864	889	873	882
	DBT A40-79	23,233	1,361	1,343	1,359	1,325	1,364	1,320	1,351

Appendix A Table 8. Incremental Changes in Benefits and Harms for a Cohort of 1,000 Screened 40-Year-Old Female Persons: Comparison Strategies Limited to Strategies Efficient or Near-Efficient for Both Percent Breast Cancer Mortality Reduction and Life-Years Gained vs. No Screening in Most Models

Benign Biopsies

DM B50-74	DBT B50-74	0	-12	-12	-12	-12		-12	-12
	DBT B45-79	4,026	28	28	28	26		28	28
	DBT B40-79	6,205	62	61	62	59		61	61
	DBT A40-49, B50-79	11,063	99	98	99	94		97	98
	DBT A40-79	23,249	157	155	157	151		152	155
DBT B50-74	DBT B45-79	4,010	41	40	41	38	41	40	41
	DBT B40-79	6,189	74	74	74	71	74	73	74
	DBT A40-49, B50-79	11,047	112	110	111	106	112	109	111
	DBT A40-79	23,233	170	167	169	163	170	164	168

Abbreviations: A, annual; B, biennial; D, Dana-Farber Cancer Institute; E, Erasmus Medical Center; GE, Georgetown Lombardi Comprehensive Cancer Center-Albert Einstein College of Medicine; M, University of Texas MD Anderson Cancer Center; S, Stanford University; W, University of Wisconsin-Madison and Harvard Pilgrim Health Care Institute.

[a] DBT strategies were efficient or near-efficient in 5 or more out of 6 models for either incremental ratio shown in **Table 10**. Zero DM strategies were efficient or near-efficient in 4 or more out of 5 models for either incremental ratio.

[b] Median across six models.

[c] Model S did not evaluate strategies for digital mammography.

Appendix A Table 9. Benefits of Screening With Digital Mammography vs. No Screening for a Cohort of 1,000 40-Year-Old Black Female Persons by Model and Screening Strategy

Strategy	Screens, n[a]	Model				Median
		D	GE	M	W	
		Reduction in Breast Cancer Mortality per 1,000 Black Persons Screened vs. No Screening, %[b]				
Stopping Age 74						
B50-74	10,905	24.9	25.2	20.5	18.5	22.7
B45-74	13,009	26.5	28.0	23.6	19.1	25.0
A45-49, B50-74	15,743	27.7	30.2	24.7	20.8	26.2
B40-74	15,801	28.6	31.0	27.2	20.8	27.9
A45-54, B55-74	17,772	27.5	29.3	24.4	21.1	26.0
A40-49, B50-74	20,677	29.4	32.5	28.1	22.3	28.7
A50-74	20,935	28.4	31.8	24.2	26.8	27.6
A45-74	25,760	31.2	36.8	28.3	28.9	30.1
A40-74	30,694	32.8	39.1	31.9	30.4	32.4
Stopping age 79						
B50-79	12,072	27.8	30.0	23.5	22.4	25.6
B45-79	14,755	30.7	35.2	27.7	24.4	29.2
A45-49, B50-79	16,907	30.5	35.0	27.4	24.6	28.9
B40-79	16,966	31.5	35.8	30.1	24.6	30.8
A45-54, B55-79	19,518	31.8	36.5	28.7	26.4	30.2
A40-49, B50-79	21,846	32.3	37.5	30.9	26.1	31.6
A50-79	23,830	32.3	38.3	28.3	33.7	33.0
A45-79	28,644	35.1	43.3	32.3	35.8	35.4
A40-79	33,578	36.7	45.5	35.9	37.2	37.0
Stopping age 74		**Life-Years Gained per 1,000 Black Persons Screened vs. No Screening**				
B50-74	10,905	185.3	211.9	121.7	141.7	163.5
B45-74	13,009	210.3	262.2	153.0	156.1	183.2
A45-49, B50-74	15,743	219.6	281.7	153.9	173.5	196.5
B40-74	15,801	232.8	297.5	195.1	174.0	214.0
A45-54, B55-74	17,772	222.0	278.7	159.9	183.4	202.7
A40-49, B50-74	20,677	242.8	318.4	203.1	195.8	223.0
A50-74	20,935	210.7	266.5	145.6	211.5	211.1
A45-74	25,760	244.8	336.0	186.4	242.3	243.6
A40-74	30,694	268.0	373.2	227.8	264.8	266.4

Appendix A Table 9. Benefits of Screening With Digital Mammography vs. No Screening for a Cohort of 1,000 40-Year-Old Black Female Persons by Model and Screening Strategy

Stopping age 79						
B50-79	12,072	196.9	233.2	131.3	156.7	176.8
B45-79	14,755	227.2	294.4	164.3	176.8	202.0
A45-49, B50-79	16,907	230.5	303.1	166.9	188.5	209.5
B40-79	16,966	244.4	318.5	206.3	189.0	225.4
A45-54, B55-79	19,518	238.9	311.1	172.7	204.0	221.5
A40-49, B50-79	21,846	254.4	343.5	210.7	210.6	232.6
A50-79	23,830	226.0	295.0	160.0	238.7	232.3
A45-79	28,644	260.1	364.4	189.3	269.4	264.8
A40-79	33,578	283.3	401.3	239.5	291.8	287.5
		Breast Cancer Deaths Averted per 1,000 Black Persons Screened vs. No				
Stopping age 74				**Screening**		
B50-74	10,905	9.9	12.2	6.5	7.2	8.5
B45-74	13,009	10.5	13.5	7.5	7.4	9.0
A45-49, B50-74	15,743	11.0	14.6	7.9	8.1	9.5
B40-74	15,801	11.3	14.9	8.7	8.1	10.0
A45-54, B55-74	17,772	10.9	14.1	7.8	8.2	9.6
A40-49, B50-74	20,677	11.6	15.7	9.0	8.7	10.3
A50-74	20,935	11.2	15.4	7.7	10.4	10.8
A45-74	25,760	12.3	17.8	9.0	11.3	11.8
A40-74	30,694	13.0	18.9	10.2	11.8	12.4
Stopping age 79						
B50-79	12,072	11.0	14.5	7.5	8.7	9.9
B45-79	14,755	12.1	17.0	8.9	9.5	10.8
A45-49, B50-79	16,907	12.1	16.9	8.8	9.6	10.8
B40-79	16,966	12.4	17.3	9.6	9.6	11.0
A45-54, B55-79	19,518	12.6	17.6	9.2	10.3	11.4
A40-49, B50-79	21,846	12.8	18.1	9.9	10.2	11.5
A50-79	23,830	12.8	18.5	9.0	13.1	12.9
A45-79	28,644	13.9	20.9	10.3	14.0	13.9
A40-79	33,578	14.5	22.0	11.5	14.5	14.5
Stopping age 74		**QALYs Gained per 1,000 Black Persons Screened vs. No Screening[c]**				
B50-74	10,905	138.8	153.6	82.6	94.1	116.5
B45- 74	13,009	157.0	191.4	105.1	103.2	131.1
A45-49, B50-74	15,743	162.1	204.5	103.5	114.1	138.1
B40-74	15,801	172.3	216.3	135.5	113.6	153.9

Appendix A Table 9. Benefits of Screening With Digital Mammography vs. No Screening for a Cohort of 1,000 40-Year-Old Black Female Persons by Model and Screening Strategy

A45-54, B55-74	17,772	162.9	200.9	106.8	120.7	141.8
A40-49, B50-74	20,677	176.0	228.7	137.6	126.3	156.8
A50-74	20,935	152.2	189.9	94.2	140.4	146.3
A45-74	25,760	175.5	240.5	121.8	159.6	167.5
A40-74	30,694	195.7	265.1	149.9	171.9	183.8
Stopping age 79						
B50-79	12,072	147.1	168.5	88.9	103.7	125.4
B45-79	14,755	169.0	214.0	112.1	116.2	142.6
A45-49, B50-79	16,907	170.0	219.5	112.3	123.6	146.8
B40-79	16,966	180.6	231.0	142.9	123.1	161.7
A45-54, B55-79	19,518	174.8	223.7	114.9	133.7	154.2
A40-49, B50-79	21,846	184.3	246.7	142.2	135.7	163.2
A50-79	23,830	162.2	209.0	102.9	157.6	159.9
A45-79	28,644	185.5	259.6	121.7	176.8	181.1
A40-79	33,578	199.4	284.0	156.5	189.0	194.2

Abbreviations: A, annual; B, biennial; D, Dana-Farber Cancer Institute; E, Erasmus Medical Center; GE, Georgetown Lombardi Comprehensive Cancer Center-Albert Einstein College of Medicine; M, University of Texas MD Anderson Cancer Center; S, Stanford University; W, University of Wisconsin-Madison and Harvard Pilgrim Health Care Institute.

[a] Median number of mammograms across models. Strategies are ranked from the least to the most mammograms. Not all possible mammograms in the age interval are obtained because some people die of other causes before screening would occur.

[b] Without screening, the median probability of dying of breast cancer is 3.93% (range, 3.20%–4.82%). Thus, if a particular screening strategy leads to a 25.8% reduction in breast cancer mortality, the probability of breast cancer mortality is reduced from 3.93% to 2.91%. This translates into 10.1 deaths averted per 1,000 Black female persons screened.

[c] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

Appendix A Table 10. Benefits of Screening With Digital Breast Tomosynthesis vs. No Screening for a Cohort of 1,000 40-Year-Old Black Female Persons by Model and Screening Strategy

Strategy	Screens, n[a]	Model				Median
		D	GE	M	W	
		Reduction in Breast Cancer Mortality per 1,000 Black Persons Screened vs. No Screening, %[b]				
Stopping Age 74						
B50-74	10,905	27.1	26.1	22.1	19.8	24.1
B45-74	13,009	28.8	28.9	24.9	20.5	26.8
A45-49, B50-74	15,743	30.2	31.1	26.1	22.3	28.1
B40-74	15,801	31.1	31.9	28.7	22.4	29.9
A45-54, B55-74	17,771	29.9	30.1	25.9	22.6	27.9
A40-49, B50-74	20,676	31.9	33.6	29.9	24.0	30.9
A50-74	20,934	30.5	32.4	25.5	28.2	29.3
A45-74	25,759	33.5	37.3	30.0	30.6	32.1
A40-74	30,693	35.3	39.6	33.5	32.2	34.4
Stopping age 79						
B50-79	12,073	30.2	31.0	24.9	24.1	27.6
B45-79	14,755	33.3	36.3	29.2	26.4	31.2
A45-49, B50-79	16,907	33.1	35.9	29.1	26.5	31.1
B40-79	16,965	34.2	36.8	31.8	26.6	33.0
A45-54, B55-79	19,517	34.4	37.5	30.3	28.5	32.4
A40-49, B50-79	21,846	35.1	38.4	32.8	28.2	33.9
A50-79	23,827	34.7	39.0	29.7	35.6	35.1
A45-79	28,646	37.7	43.9	34.0	38.1	37.9
A40-79	33,577	39.5	46.2	37.9	39.6	39.6
Stopping age 74		**Life-Years Gained per 1,000 Black Persons Screened vs. No Screening**				
B50-74	10,905	201.8	219.8	127.8	151.5	176.7
B45-74	13,009	229.2	270.4	157.3	168.7	199.0
A45-49, B50-74	15,743	238.9	288.8	167.3	187.0	212.9
B40-74	15,801	253.9	305.7	203.8	189.0	228.9
A45-54, B55-74	17,771	241.0	285.8	165.4	197.3	219.1
A40-49, B50-74	20,676	264.2	329.5	214.6	213.1	239.4
A50-74	20,934	226.6	271.3	154.2	222.9	224.7
A45-74	25,759	263.6	340.3	196.2	257.9	260.8
A40-74	30,693	288.8	377.7	243.7	283.6	286.2

Appendix A Table 10. Benefits of Screening With Digital Breast Tomosynthesis vs. No Screening for a Cohort of 1,000 40-Year-Old Black Female Persons by Model and Screening Strategy

Stopping age 79						
B50-79	12,073	214.3	241.7	142.0	168.1	191.2
B45-79	14,755	247.4	303.6	172.7	191.5	219.4
A45-49, B50-79	16,907	250.7	310.7	177.0	203.5	227.1
B40-79	16,965	266.3	328.1	210.7	205.4	238.5
A45-54, B55-79	19,517	259.2	318.7	180.7	220.0	239.6
A40-49, B50-79	21,846	276.6	351.4	225.4	229.5	253.1
A50-79	23,827	242.9	300.2	164.5	252.3	247.6
A45-79	28,646	279.9	369.0	209.5	287.2	283.6
A40-79	33,577	305.2	406.8	253.9	312.9	309.0
		Breast Cancer Deaths Averted per 1,000 Black Persons Screened vs. No				
Stopping age 74				**Screening**		
B50-74	10,905	10.7	12.6	7.1	7.7	9.2
B45-74	13,009	11.4	13.9	8.0	8.0	9.7
A45-49, B50-74	15,743	11.9	15.0	8.4	8.7	10.3
B40-74	15,801	12.3	15.4	9.2	8.7	10.7
A45-54, B55-74	17,771	11.8	14.5	8.3	8.8	10.3
A40-49, B50-74	20,676	12.6	16.2	9.6	9.4	11.1
A50-74	20,934	12.1	15.6	8.2	11.0	11.5
A45-74	25,759	13.3	18.0	9.6	11.9	12.6
A40-74	30,693	14.0	19.1	10.7	12.6	13.3
Stopping age 79						
B50-79	12,073	12.0	15.0	8.0	9.4	10.7
B45-79	14,755	13.2	17.5	9.3	10.3	11.7
A45-49, B50-79	16,907	13.1	17.3	9.3	10.3	11.7
B40-79	16,965	13.5	17.8	10.2	10.4	12.0
A45-54, B55-79	19,517	13.6	18.1	9.7	11.1	12.4
A40-49, B50-79	21,846	13.9	18.5	10.5	11.0	12.4
A50-79	23,827	13.7	18.8	9.5	13.9	13.8
A45-79	28,646	14.9	21.2	10.9	14.8	14.9
A40-79	33,577	15.6	22.3	12.1	15.4	15.5
Stopping age 74		**QALYs Gained per 1,000 Black Persons Screened vs. No Screening[c]**				
B50-74	10,905	156.2	163.8	91.3	105.1	130.6
B45- 74	13,009	177.1	202.5	113.2	116.9	147.0
A45-49, B50-74	15,743	183.3	215.6	119.2	129.3	156.3
B40-74	15,801	195.0	228.4	148.0	130.1	171.5

Appendix A Table 10. Benefits of Screening With Digital Breast Tomosynthesis vs. No Screening for a Cohort of 1,000 40-Year-Old Black Female Persons by Model and Screening Strategy

A45-54, B55-74	17,771	184.2	212.5	117.2	136.7	160.5
A40-49, B50-74	20,676	200.4	244.6	153.5	146.0	177.0
A50-74	20,934	171.6	200.1	107.3	155.0	163.3
A45-74	25,759	198.6	251.8	137.3	179.0	188.8
A40-74	30,693	215.8	278.2	171.8	195.3	205.6
Stopping age 79						
B50-79	12,073	165.6	179.6	101.4	116.1	140.9
B45-79	14,755	190.7	226.6	123.7	132.0	161.3
A45-49, B50-79	16,907	192.2	231.4	126.0	140.3	166.3
B40-79	16,965	204.5	244.6	152.6	141.0	178.5
A45-54, B55-79	19,517	197.8	236.3	127.7	151.8	174.8
A40-49, B50-79	21,846	209.9	260.4	161.3	157.0	185.6
A50-79	23,827	183.4	220.5	113.7	174.6	179.0
A45-79	28,646	210.4	272.1	146.0	198.5	204.5
A40-79	33,577	227.5	298.8	178.1	214.9	221.2

Abbreviations: A, annual; B, biennial; D, Dana-Farber Cancer Institute; E, Erasmus Medical Center; GE, Georgetown Lombardi Comprehensive Cancer Center-Albert Einstein College of Medicine; M, University of Texas MD Anderson Cancer Center; S, Stanford University; W, University of Wisconsin-Madison and Harvard Pilgrim Health Care Institute.

[a] Median number of mammograms across models. Strategies are ranked from the least to the most mammograms. Not all possible mammograms in the age interval are obtained because some people die of other causes before screening would occur.

[b] Without screening, the median probability of dying of breast cancer is 3.93% (range, 3.20%–4.82%). Thus, if a particular screening strategy leads to a 25.8% reduction in breast cancer mortality, the probability of breast cancer mortality is reduced from 3.93% to 2.91%. This translates into 10.1 deaths averted per 1,000 Black female persons screened.

[c] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

Appendix A Table 11. Incremental Changes in Benefits and Harms for a Cohort of 1,000 Screened 40-Year-Old Black Female Persons: Comparison Strategies Limited to Strategies Efficient or Near-Efficient for Both Percent Breast Cancer Mortality Reduction and Life-Years Gained vs. No Screening in Most Models of Breast Cancer in Black Female Persons

Initial Strategy	Comparison Strategy[a]	Added Screens[b]	Change in Value by Model				Median
			D	GE	M	W	
Breast Cancer Deaths Averted							
DM B50-74	DBT B45-79	3,850	3.3	5.3	2.8	3.1	3.2
	DBT B40-79	6,060	3.7	5.6	3.6	3.1	3.7
	DBT A40-79	22,672	5.8	10.1	5.6	8.2	7.0
DBT B50-74	DBT B45-79	3,850	2.5	4.9	2.3	2.6	2.5
	DBT B40-79	6,060	2.8	5.2	3.1	2.6	3.0
	DBT A40-79	22,672	4.9	9.7	5.1	7.7	6.4
Life-Years Gained							
DM B50-74	DBT B45-79	3,850	62.1	91.7	50.9	49.8	56.5
	DBT B40-79	6,060	81.0	116.3	89.0	63.7	85.0
	DBT A40-79	22,672	119.9	194.9	132.1	171.2	151.7
DBT B50-74	DBT B45-79	3,850	45.5	83.8	44.8	40.0	45.2
	DBT B40-79	6,060	64.5	108.4	82.9	53.9	73.7
	DBT A40-79	22,672	103.3	187.0	126.1	161.4	143.7
False-positive Recalls							
DM B50-74	DBT B45-79	3,850	-156	-155	-158	-158	-157
	DBT B40-79	6,060	63	63	63	58	63
	DBT A40-79	22,672	812	814	808	791	810
DBT B50-74	DBT B45-79	3,850	293	294	291	290	292
	DBT B40-79	6,060	513	513	512	506	512
	DBT A40-79	22,672	1,262	1,263	1,257	1,238	1,259
Benign Biopsies							
DM B50-74	DBT B45-79	3,850	20	20	20	19	19.80
	DBT B40-79	6,060	57	57	57	56	57.04
	DBT A40-79	22,672	135	135	134	131	134.37
DBT B50-74	DBT B45-79	3,850	50	50	49	49	49.38
	DBT B40-79	6,060	87	87	87	86	86.62
	DBT A40-79	22,672	164	165	164	161	163.95

Abbreviations: A, annual; B, biennial; D, Dana-Farber Cancer Institute; GE, Georgetown Lombardi Comprehensive Cancer Center-Albert Einstein College of Medicine; M, University of Texas MD Anderson Cancer Center; W, University of Wisconsin-Madison and Harvard Pilgrim Health Care Institute.

Appendix A Table 11. Incremental Changes in Benefits and Harms for a Cohort of 1,000 Screened 40-Year-Old Black Female Persons: Comparison Strategies Limited to Strategies Efficient or Near-Efficient for Both Percent Breast Cancer Mortality Reduction and Life-Years Gained vs. No Screening in Most Models of Breast Cancer in Black Female Persons

[a] Comparison strategies were efficient or near-efficient in 3 or more out of 4 models for both incremental ratios shown in **Table 17**. Zero DM strategies were efficient or near-efficient in 3 or more out of 4 models for either incremental ratio.

[b] Median across models.

Appendix A Table 12. Median Values (Range Across Four Models) for Harm-to-Benefit Ratios With Digital Breast Tomosynthesis Compared With No Screening for a Cohort of 1,000 40-Year-Old Female Persons (All Races) and 1,000 40-Year-Old Black Female Persons

Strategy Interval, Start and Stop Age	False-positive Recalls per Breast Cancer Death Averted		Mammograms per Breast Cancer Death Averted		Mammograms to Obtain 1 Percentage Point Reduction in Breast Cancer Mortality	
	All	Black	All	Black	All	Black
Biennial						
B50-74	132.8 (95.6-166.5)	90.3 (64.7-115.0)	1,709 (1,228-2,137)	1,209 (869-1,539)	483 (384-598)	456 (403-546)
B45-74	141.5 (111.3-193.2)	106.0 (71.7-124.9)	1,750 (1,371-2,376)	1,381 (937-1,630)	517 (429-600)	487 (452-631)
B40-74	156.2 (131.1-223.5)	119.2 (81.6-142.5)	1,837 (1,536-2,613)	1,501 (1,031-1,798)	541 (481-660)	529 (497-701)
Hybrid						
A45-49, B50-74	150.7 (122.8-202.0)	113.6 (76.6-136.5)	1,960 (1,588-2,610)	1,560 (1,054-1,879)	576 (497-659)	562 (509-700)
A45-54, B55-74	163.9 (132.0-209.8)	120.5 (84.1-146.1)	2,257 (1,812-2,877)	1,756 (1,227-2,134)	662 (567-736)	640 (592-781)
A40-49, B50-74	184.5 (154.3-252.3)	141.1 (95.0-162.8)	2,301 (1,917-3,127)	1,900 (1,282-2,195)	668 (614-790)	670 (618-855)
Annual						
A50-74	157.6 (127.8-181.3)	104.6 (77.5-148.0)	2,654 (2,153-3,062)	1,812 (1,344-2,562)	734 (674-874)	711 (649-820)
A45-74	176.6 (139.6-203.9)	122.0 (85.8-159.7)	2,822 (2,237-3,288)	2,040 (1,436-2,676)	795 (751-837)	801 (693-856)
A40-74	207.9 (160.5-242.2)	145.2 (101.2-179.5)	3,117 (2,398-3,603)	2,310 (1,613-2,853)	872 (826-910)	892 (778-942)
Biennial						
B50-79	118.5 (93.7-153.7)	83.9 (59.3-111.3)	1,585 (1,249-2,045)	1,143 (810-1,513)	465 (391-517)	442 (391-497)
B45-79	127.2 (97.6-172.0)	95.4 (63.4-118.4)	1,653 (1,266-2,218)	1,271 (847-1,580)	463 (431-561)	474 (409-554)
B40-79	148.0 (115.2-205.7)	112.4 (74.7-130.4)	1,795 (1,394-2,477)	1,439 (959-1,666)	502 (479-626)	515 (463-632)
Hybrid						
A45-49, B50-79	141.6 (110.1-186.8)	105.0 (70.4-130.3)	1,889 (1,464-2,474)	1,457 (979-1,810)	532 (494-625)	545 (472-632)
A45-54, B55-79	148.8 (112.4-187.9)	108.2 (73.6-136.5)	2,111 (1,593-2,653)	1,590 (1,084-2,008)	586 (552-670)	605 (523-680)
A40-49, B50-79	176.4 (132.9-232.6)	130.6 (86.8-152.9)	2,249 (1,687-2,944)	1,775 (1,182-2,074)	617 (602-744)	644 (570-768)
Annual						
A50-79	142.9 (115.6-174.1)	97.4 (72.1-142.6)	2,506 (2,033-3,075)	1,715 (1,272-2,511)	716 (686-761)	674 (614-803)
A45-79	164.9 (120.5-194.3)	112.6 (79.7-154.2)	2,738 (2,007-3,262)	1,915 (1,358-2,627)	759 (751-774)	752 (655-840)
A40-79	196.4 (138.9-221.8)	132.7 (93.2-170.6)	3,034 (2,155-3,468)	2,149 (1,513-2,761)	826 (807-855)	844 (730-883)

Abbreviations: A, annual; B, biennial.

All values presented for four models (D, GE, M, W). Grey shading highlights strategies where median values for Black female persons are greater than values for female persons overall.

Appendix A Table 13. Sensitivity Analysis of Benefits of Screening Strategies Compared With No Screening for a Cohort of 1,000 40-Year-Old Female Persons With Either Population Dissemination Patterns of Treatment Utilization or With All Breast Cancer Cases Receiving the Most Effective Treatment Regimen

Strategy Interval, Start and Stop Age[a]	Reduction in Breast Cancer Mortality, %			Breast Cancer Deaths Averted		
	Treatment Dissemination	Most Effective Treatment	Difference	Treatment Dissemination	Most Effective Treatment	Difference
Biennial						
B50-74	25.3 (18.8-29.4)	30.4 (24.7-33.7)	+4.4 (2.4-13.5)	7.0 (5.1-9.2)	6.8 (3.9-9.3)	0 (-1.3-2.2)
B45-74	27.5 (21.7-31.2)	33.3 (26.7-36.0)	+4.8 (2.6-11.8)	8.1 (5.5-9.8)	7.3 (4.2-10.0)	0 (-1.3-1.4)
B40-74	29.6 (24.0-33.7)	37.5 (30.1-38.9)	+5.1 (3.0-10.2)	8.7 (6.1-10.6)	7.9 (4.7-10.8)	0 (-1.4-0.5)
Hybrid						
A45-54, B55-74	30.1 (24.4-32.1)	34.8 (30.4-37)	+4.9 (2.9-11.7)	9.1 (6.2-10.0)	8.2 (4.8-10.4)	0 (-1.4-1.2)
A40-49, B50-74	32.5 (26.1-34.4)	38.9 (33-39.6)	+5.2 (3.2-9.7)	9.5 (6.6-11.0)	8.7 (5.2-11.2)	0 (-1.4-0.2)
Annual						
A50-74	29.8 (24.7-32.8)	35.7 (32.6-37.4)	+4.6 (2.9-12.6)	9.3 (7.0-10.1)	8.7 (5.1-10.7)	-0.1 (-1.9-1.5)
A45-74	34.0 (31.4-36.5)	40.0 (37.6-42.0)	+5.0 (3.4-10.3)	10.7 (7.9-11.8)	9.7 (5.9-12.0)	-0.1 (-2.0-0.2)
A40-74	37.2 (33.6-38.9)	42.6 (40.8-44.0)	+5.3 (3.9-9.0)	11.4 (8.5-13.1)	10.4 (6.4-12.6)	-0.5 (-2.1-0)

	Life-Years Gained			QALYs Gained[b]		
	Treatment Dissemination	Most Effective Treatment	Difference	Treatment Dissemination	Most Effective Treatment	Difference
Biennial						
B50-74	119.2 (115.1-175.8)	131.8 (100.2-175.3)	-0.6 (-15.9-47.3)	85.3 (77.9-143.0)	94.2 (66.2-144.7)	+1.7 (-11.7-38.3)
B45-74	142.6 (133.9-200.1)	152.7 (115.9-199.9)	-0.2 (-18.0-14.2)	101.1 (89.9-161.3)	108.8 (76.5-163.4)	+2.1 (-13.4-12.0)
B40-74	174.7 (152.4-221.9)	179.7 (134.6-221.7)	-9.3 (-17.8-5.0)	124.0 (101.4-17.07)	128.0 (88.2-179.2)	-6.6 (-13.2-4.0)
Hybrid						
A45-54, B55-74	163.2 (151.2-207.9)	157.9 (138.2-207.2)	-0.6 (-20.7-9.8)	114.6 (105.2-165.1)	110.4 (91.4-166.8)	+1.7 (-15.4-8.6)
A40-49, B50-74	184.5 (174.6-240.1)	191.2 (153.9-228.0)	-12.3 (-20.7-6.7)	128.6 (115.5-179.2)	133.7 (100.1-181.1)	-9.0 (-15.4-5.2)
Annual						
A50-74	158.3 (137.1-191.7)	147.9 (135.4-190.0)	-1.7 (-27.9-34.7)	109.6 (93.7-151.4)	102.2 (88.9-152.3)	+0.9 (-20.7-28.6)
A45-74	197.5 (165.7-230.1)	175.0 (166.4-225.9)	-4.2 (-31.1-8.6)	132.5 (112.8-173.8)	121.3 (109.4-174.7)	-2.1 (-23.1-6.6)
A40-74	221.2 (199.3-274.9)	205.3 (188.9-245.7)	-14.8 (-32.3-6.0)	146.8 (135.6-196.5)	140.2 (122.7-188.6)	-10.8 (-24.1-4.6)

[a] All strategies use digital breast tomosynthesis. Median and range of values across five models (D, GE, E, M, and W) are shown.
[b] Adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

Appendix A Table 14. Comparison of Lifetime QALYs Gained From the Base Case (Using EQ-5D for Age-Specific Utilities) to a Sensitivity Analysis (Using SF-6D) According to Screening Strategy for Cohorts of 1,000 40-Year-Old Female Persons Overall and 1,000 40-Year-Old Black Female Persons

Strategy Interval, Start and Stop Age[a]	QALYs for All Female Persons			QALYs for Black Female Persons		
	Base Case (EQ-5D)[b]	Sensitivity Analysis (SF-6D)	Difference	Base Case (EQ-5D)[c]	Sensitivity Analysis (SF-6D)	Difference
Biennial						
B50-74[d,e]	86.1 (77.9-143.0)	82.4 (74.8-136.6)	3.7 (2.4-6.4)	130.6 (91.3-163.8)	125.0 (87.4-157.0)	5.5 (3.9-7.0)
B45-74[d,e]	100.4 (89.9-161.3)	96.0 (86.2-153.9)	4.4 (3.7-7.4)	147.0 (113.2-202.5)	140.4 (108-193.4)	6.8 (4.9-9.1)
B40-74[d]	116.8 (101.4-177)	111.4 (97.1-168.7)	5.4 (4.2-8.4)	171.5 (130.1-228.4)	163.1 (124.5-217.7)	8.4 (5.5-10.7)
Hybrid						
A45-49, B50-74	107.8 (101.3-165.5)	103.1 (97.0-157.9)	4.7 (4.2-7.6)	156.3 (119.2-215.6)	149.3 (113.8-205.8)	7.0 (5.5-9.8)
A45-54, B55-74	110.7 (105.2-165.1)	106.0 (100.5-157.6)	4.8 (4.5-7.5)	160.5 (117.2-212.5)	153.3 (111.8-202.9)	7.2 (5.4-9.6)
A40-49, B50-74	125.7 (115.5-179.2)	119.9 (110.6-170.9)	5.8 (4.9-8.4)	177.0 (146.0-244.6)	168.3 (139.7-233.0)	8.6 (6.3-11.6)
Annual						
A50-74	109.0 (93.7-151.4)	104.6 (89.7-144.8)	4.4 (3.4-6.6)	163.3 (107.3-200.1)	156.4 (102.8-191.8)	6.9 (4.6-8.2)
A45-74	132.0 (112.8-173.8)	126.5 (107.9-166.0)	5.5 (5.0-7.8)	188.8 (137.3-251.8)	180.5 (131.1-240.6)	8.3 (6.2-11.2)
A40-74	146.1 (132.3-196.5)	139.9 (126.8-187.9)	6.3 (5.5-8.6)	205.6 (171.8-278.2)	196.3 (163.3-265.3)	9.3 (8.3-12.9)

	QALYs for All Female Persons			QALYs for Black Female Persons		
	Base Case (EQ-5D)[b]	Sensitivity Analysis (SF-6D)	Difference	Base Case (EQ-5D)[c]	Sensitivity Analysis (SF-6D)	Difference
Biennial						
B50-79	91.7 (83.7-150.1)	87.8 (80.4-143.5)	3.7 (2.9-6.6)	140.9 (101.4-179.6)	134.9 (97.0-172.3)	6.0 (4.4-7.3)
B45-79[d,e]	110.2 (98.5-172.1)	105.3 (94.6-164.3)	4.9 (4-7.8.0)	161.3 (123.7-226.6)	154.3 (118.1-216.6)	7.2 (5.4-10.0)
B40-79[d,e]	124.2 (107.2-184.2)	118.5 (102.8-175.6)	5.7 (4.4-8.6)	178.5 (141.0-244.6)	169.8 (135.1-233.3)	8.7 (5.9-11.3)
Hybrid						
A45-49, B50-79	111.5 (107.1-172.5)	106.8 (102.7-164.7)	4.8 (4.4-7.8)	166.3 (126.0-231.4)	158.9 (120.3-221.1)	7.3 (5.7-10.3)
A45-54, B55-79	118.4 (111.6-175.9)	113.3 (106.7-167.9)	5.1 (4.8-7.9)	174.8 (127.7-236.3)	167.1 (121.9-225.9)	7.7 (5.8-10.4)
A40-49, B50-79[d,e]	130.7 (121.4-188.1)	124.8 (116.3-179.8)	5.9 (5.1-8.6)	185.6 (157.0-260.4)	176.6 (150.3-248.3)	9.0 (6.7-12.1)
Annual						
A50-79	118.4 (102.5-160.8)	113.7 (98.1-153.8)	4.5 (4.0-6.9)	179.0 (113.7-220.5)	171.5 (108.9-211.5)	7.4 (4.8-8.9)
A45-79	140.8 (119.5-183.2)	135.0 (114.2-175.6)	5.8 (5.0-8.1)	204.5 (146.0-272.1)	195.6 (139.5-260.2)	8.8 (6.5-11.9)
A40-79[d,e]	154.3 (139.5-214.6)	147.8 (133.7-205.4)	6.6 (5.8-9.2)	221.2 (178.1-298.8)	211.4 (169.5-285.2)	9.8 (8.6-13.6)

Abbreviations: A, annual; B, biennial; QALYs, quality-adjusted life-years.

[a] All strategies use digital breast tomosynthesis. QALYs adjusted for general health, mammography screening, breast cancer diagnosis, and breast cancer treatment.

[b] Same as shown in **Table 5**. Results shown for six models (D, GE, E, M, S, and W).

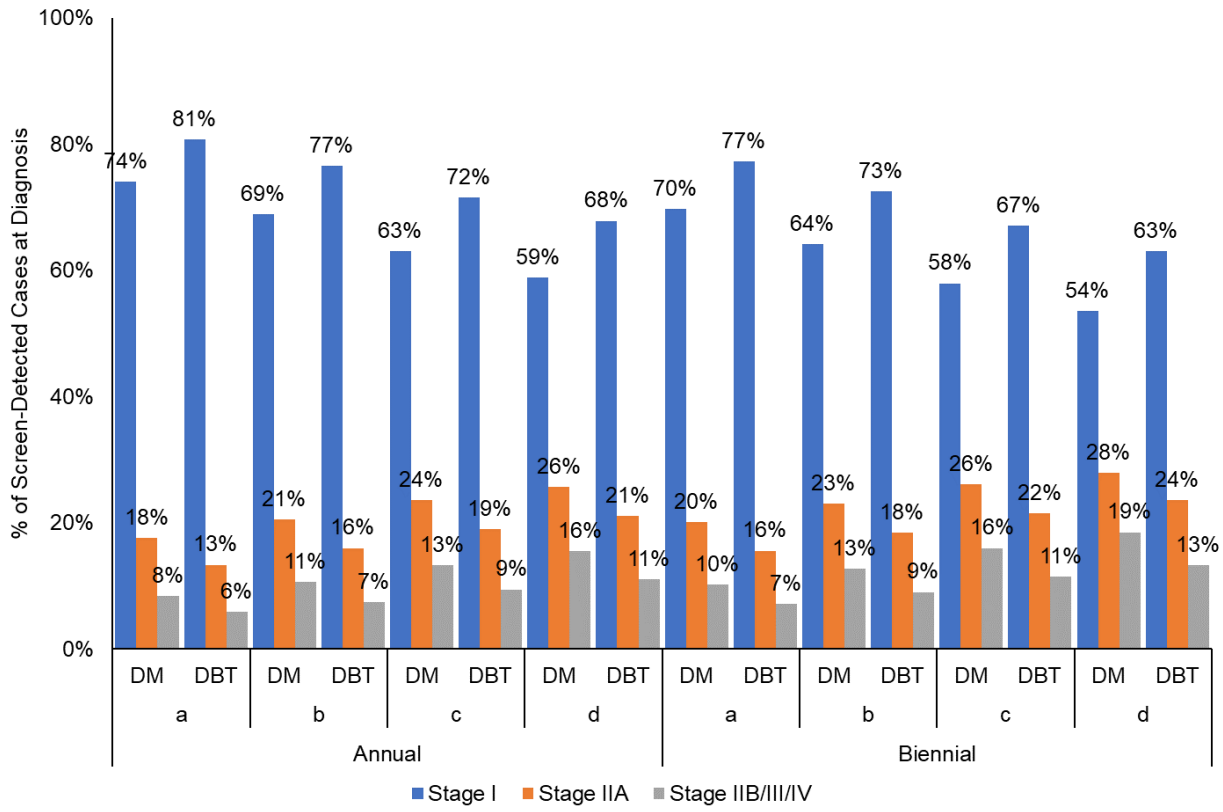
Appendix A Table 14. Comparison of Lifetime QALYs Gained From the Base Case (Using EQ-5D for Age-Specific Utilities) to a Sensitivity Analysis (Using SF-6D) According to Screening Strategy for Cohorts of 1,000 40-Year-Old Female Persons Overall and 1,000 40-Year-Old Black Female Persons

[c] Same as shown in **Table 11**. Results shown for four models (D, GE, M, and W).

[d] Efficient or near-efficient based on an incremental ratio defined as the change in the number of mammograms/change in QALYs gained for female persons overall. Ratios for each strategy were calculated relative to the next efficient or near-efficient strategy with fewer mammograms, not necessarily shown in the order listed in the table (varied across models). DBT strategies are indicated that were efficient or near-efficient in 5 or more out of 6 models. Zero DM strategies were efficient or near-efficient in 4 or more out of 5 models. Strategies were considered near-efficient if they were within 1.57 quality-adjusted days per person of the efficiency frontier for female persons overall.

[e] Efficient or near-efficient based on an incremental ratio defined as the change in the number of mammograms/change in QALYs gained for Black female persons. Ratios for each strategy were calculated relative to the next efficient or near-efficient strategy with fewer mammograms, not necessarily shown in the order listed in the table (varied across models). DBT strategies are indicated that were efficient or near-efficient in 3 or more out of 4 models. Zero DM strategies were efficient or near-efficient in at least 3 models. Strategies were considered near-efficient if they were within 2.33 quality-adjusted days per person of the efficiency frontier for Black female persons.

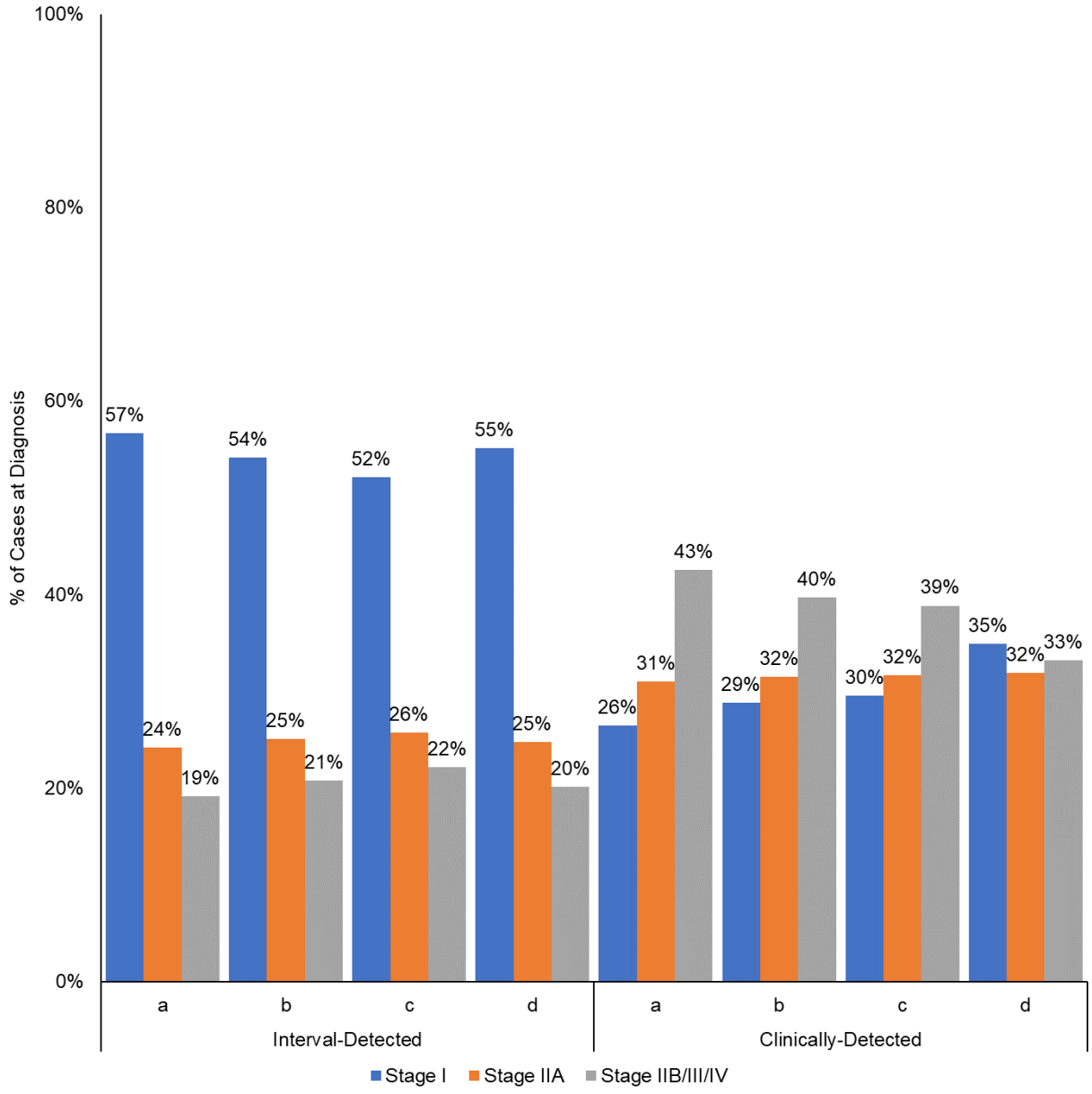
Appendix B Figure 1. AJCC Stage Distribution (%) of Invasive Breast Cancer Cases Diagnosed Through Screening According to Breast Density Category, Screening Interval, and Modality for Female Persons Ages 45–49, Breast Cancer Surveillance Consortium



Abbreviations: a=almost entirely fatty; b= scattered areas of fibroglandular density; c= heterogeneously dense; d=extremely dense; DBT= digital breast tomosynthesis; DM=digital mammography.

Note: Values based on predictions for the calendar year 2018 from a regression model of 18,680 breast cancer cases diagnosed during 2005–2018, adjusted for age, age-squared, screening interval, modality, breast density category, year of diagnosis, and all two-way interactions except for year of diagnosis and screening interval. A single age group is shown as an example of the pattern of the data.

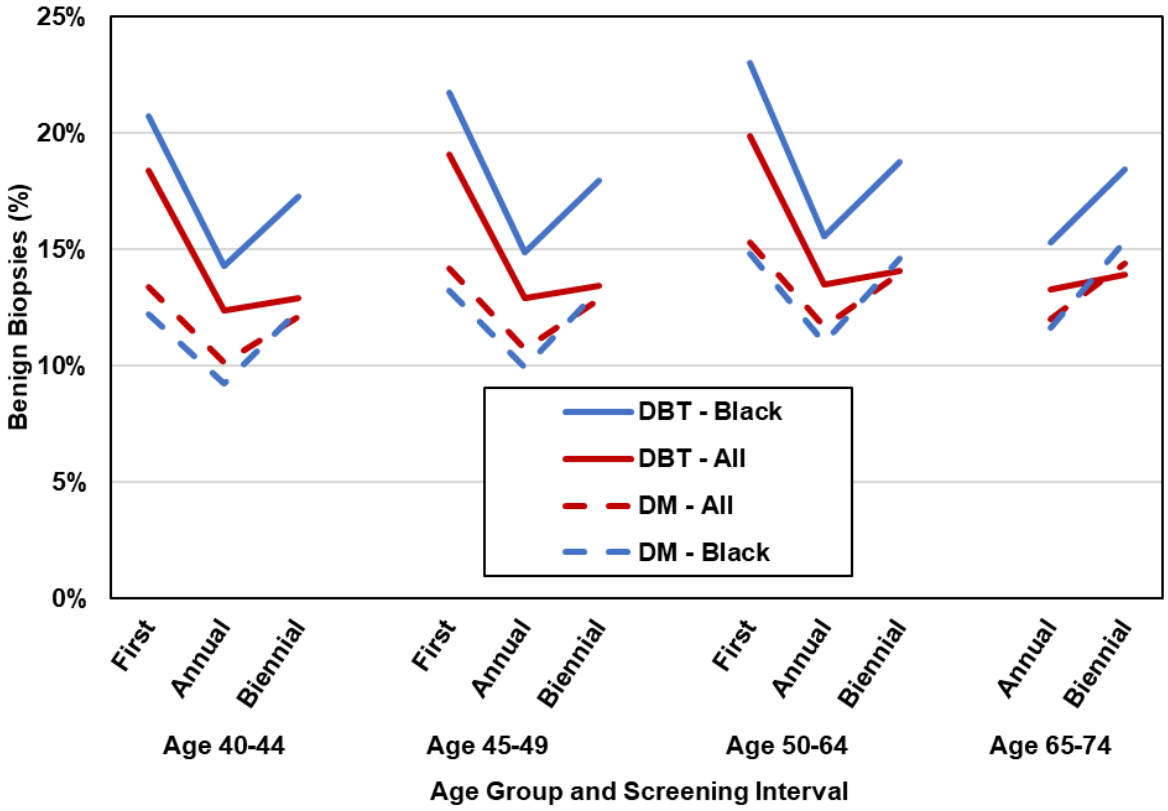
Appendix B Figure 2. AJCC Stage Distribution (%) of All Interval- and Clinically-Detected Invasive Breast Cancer Cases According to Breast Density Category for Female Persons Ages 45–49, Breast Cancer Surveillance Consortium



Abbreviations: a=almost entirely fatty; b= scattered areas of fibroglandular density; c= heterogeneously dense; d=extremely dense.

Note: Values based on predictions for the calendar year 2018 from a regression model of 18,680 breast cancer cases ages 40–89 years diagnosed during 2005–2018, adjusted for age, age-squared, breast density category, and year of diagnosis. A single age group is shown as an example of the pattern of the data.

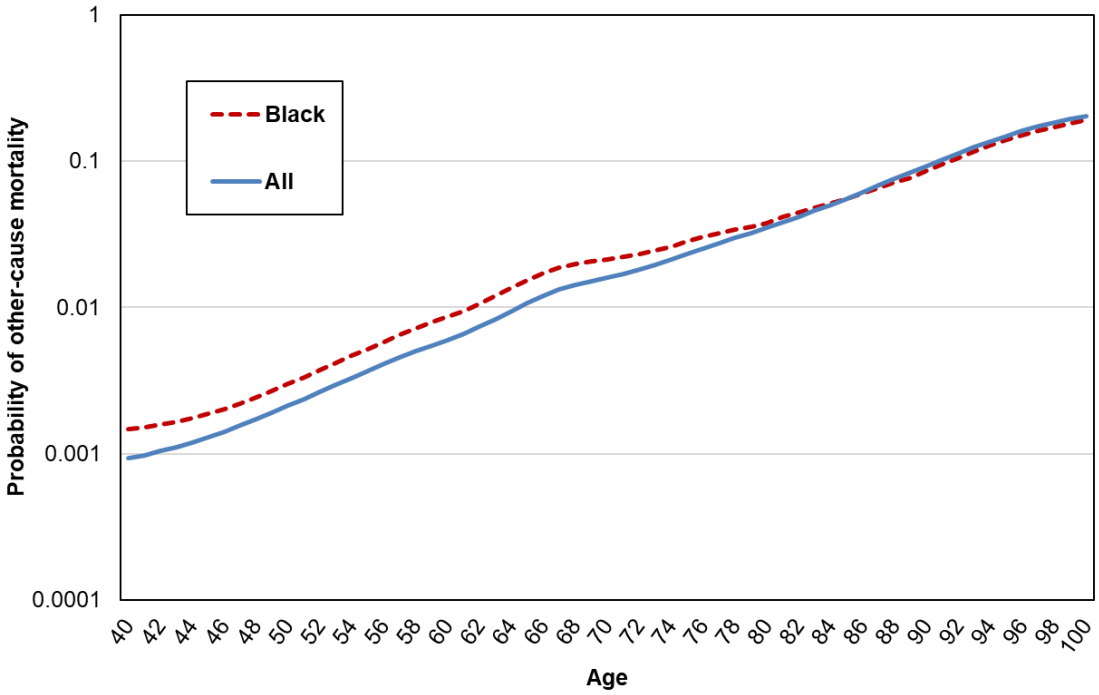
Appendix B Figure 3. Percent of Mammograms With an Initial Positive Result and a Biopsy Recommendation With No Cancer During 12 Months of Followup ("Benign Biopsy") According to Age at Diagnosis, Screening Interval, and Mammogram Modality, for All and Black Female Persons, Breast Cancer Surveillance Consortium



Abbreviations: DBT, digital breast tomosynthesis; DM, digital mammography.

Note: Values based on predictions for the calendar year 2018 from a regression model of 18,680 breast cancer cases ages 40–89 diagnosed during 2005–2018, adjusted for age, age-squared, breast density category, and year of diagnosis.

Appendix Figure 4. Probability of Death From a Cause Other Than Breast Cancer According to Age for All and Black Female Persons Born in 1980



Source: Trentham-Dietz (2021)[79]