Original Article

# Breast Cancer Survivors in the United States

## Geographic Variability and Time Trends, 2005-2015

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**BACKGROUND:** Breast cancer continues to place a significant burden on the healthcare system. Regional prevalence measures are instrumental in the development of cancer control policies. Very few population-based cancer registries are able to provided local, long-term incidence and follow-up information that permits the direct calculation of prevalence. Model-based prevalence estimates are an alternative when this information is lacking or incomplete. The current work represents a comprehensive collection of female breast cancer prevalence from 2005 to 2015 in the United States and the District of Columbia (DC). **METHODS:** Breast cancer prevalence estimates were derived from state-specific cancer mortality and survival data using a statistical package called the Mortality-Incidence Analysis Model or MIAMOD. Cancer survival models were derived from the Surveillance, Epidemiology, and End Results Program data and were adjusted to represent state-specific survival. Comparisons with reported incidence for 39 states and DC had validated estimates. **RESULTS:** By the year 2010, 2.9 million breast cancer survivors are predicted in the US, equaling 1.85% of the female population. Large variability in prevalent percentages was reported between states, ranging from 1.4% to 2.4% in 2010. Geographic variability was reduced when calculating age-standardized prevalence proportions or cancer survivors by disease duration, including 0 to 2 years and 2 to 5 years. The residual variability in age-adjusted prevalence was explained primarily by the state-specific, age-adjusted breast cancer incidence rates. State-specific breast cancer survivors are expected to increase from 16% to 51% in the decennium from 2005 to 2015 and by 31% at the national level. **CONCLUSIONS:** To the authors' knowledge, the current study is the first to provide systematic estimations of breast cancer prevalence in all US states through 2015. The estimated levels and time trends were consistent with the available population-based data on breast cancer incidence, prevalence, and population aging. **Cancer 2009;115:1954–66. © 2009 American Cancer Society.**

**KEY WORDS:** breast neoplasms, prevalence, registries, forecasting, regional health planning.

**Currently,** there are an estimated 2,477,847 breast cancer survivors in the United States, and 65% of these patients have survived for ≥5 years since their initial diagnosis.[1] Breast cancer survivors encompass women who receive initial cancer treatments to women who receive post-treatment, routine follow-up. Increasing prevalence is a result of advances in breast cancer research, which continues to focus on

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developing effective breast cancer screening techniques, minimizing the toxic effects of treatment, and decreasing cancer recurrence. In addition, the aging baby-boom generation and longer life expectancy experienced in the United States also will contribute to the increasing number of breast cancer survivors. Traditionally, US public health programs are developed and disseminated at the state or more local level. This research aids state authorities in making more informed decisions regarding public health programming and allocation of health resources using breast cancer prevalence estimations.

To calculate complete prevalence, a long history of cancer incidence and follow-up data are necessary. To date, only a few US states have collected this type of data, therefore a statistical method was applied to the consistent data available for all states. The Mortality-Incidence Analysis Model (MIAMOD) method uses state-specific mortality (breast cancer and all causes) data and modeled state-specific survival as inputs to derive incidence and complete prevalence estimates and projections. Estimates were validated by comparisons with reported incidence data for 39 states and the District of Columbia (DC) provided by cancer registration programs. For the remaining states that were not covered by cancer registration, MIAMOD incidence estimates were compared with estimates derived from a different methodology: an ecologic regression model of incidence on sociodemographic variables.[2] In this article, we investigated the variability in breast cancer prevalence by state that is correlated with different demographic structure and breast cancer incidence patterns at the state level.

## MATERIALS AND METHODS

### *Mortality and Population Data*

Single age and year state-specific female mortality data for breast cancer and all causes of death from the National Center of Health Statistics and respective populations from the US Census Bureau are available for calendar years from 1969 to 2005 from the Surveillance, Epidemiology, and End Results (SEER)*Stat databases.[3,4] The state population projections from 2006 to 2015 were obtained from the US Census Bureau.[5]

### *State-specific Breast Cancer Survival Model: The Surveillance, Epidemiology, and End Results Baseline Model*

Data from 1975 to 2004 from the 9 initial SEER Program registries (SEER-9)[4] were used to calculate female breast cancer relative survival rates by 3-year period of diagnosis (1975-1977, 1978-1980,..., 2002-2004) and by age at diagnosis (ages 15-44 years, 45-54 years, 55-64 years, 65-74 years, 75-99 years, and $\geq$85 years).[4] Because cancer survival information was needed before 1975 to include all past diagnosis years, we fit the data to a parametric Weibull cure model,[6,7] which is described in detail in a technical report.[8]

### *State-specific Relative Risk of Breast Cancer Death*

We adjusted the SEER baseline survival to represent state-specific survival by applying state-specific relative risks that reflected a greater or smaller risk of breast cancer death in a specific state relative to the SEER-9 areas. The method, which was proposed by Mariotto et al,[9] consists of regressing 5-year breast cancer survival on sociodemographic variables for all counties in the SEER-9 areas. Once the regression model is estimated, state-specific 5-year survival is calculated by extrapolating the model to sociodemographic variables by county at the state level. Data sources on this specific application are described in a technical report.[8]

### *Estimation of Incidence and Prevalence by State: The Mortality-Incidence Analysis Model Method*

State-specific breast cancer prevalence and incidence were estimated from state-specific mortality and population data and from the survival model described above using the MIAMOD method.[10,11] The method is based on equations relating mortality and prevalence for a given cancer to incidence and survival probabilities. The model assumes that survival is known, as estimated above, and that cancer incidence follows an age, period, and cohort (APC) model on the logistic scale. The APC incidence parameters are estimated from a Poisson generalized linear regression model on breast cancer deaths. Once incidence is estimated, prevalence can be calculated from incidence and survival. Further details on the method are given in a technical report.[8]

### Prevalence Projections, 2006 to 2015

MIAMOD prevalence projections from 2006 to 2015 were based on assumptions of future trends of survival, incidence, population, and other causes mortality. It was assumed that *survival* was constant with rates equal to those estimated for the last period of data, 2004. *Incidence* was projected using the previously estimated age and cohort incidence model. This model describes slow changes in incidence, mostly the effect of risk factors, but no period changes. The *population projections* were based on the general assumption that recent state-specific trends in fertility, mortality, domestic migration, and international migration will continue.[5] *Other causes mortality* also was assumed to be constant, as observed in the last years of observed data.

Population denominators were not available for annual ages after age 84 years. Prevalence for ages ≥85 years was estimated by applying prevalence proportions at ages 80 to 84 years to the populations of women aged ≥85 years. The age-adjusted rates were based on the US 2000 standard population.

### Validation of Mortality-Incidence Analysis Model Estimates

MIAMOD estimates of breast cancer incidence cases were compared with reported cases for which data were available. For 9 states participating in the SEER Program, data were available through 2005 with different starting years. An incidence database was obtained through an agreement with the North American Association of Central Cancer Registries (NAACCR). US cancer registries that report data to the NAACCR participate in the SEER Program, or the Centers for Disease Control and Prevention National Program of Cancer Registries (NPCR), or both and receive support from the state, province, or territory where they are located. The NPCR states that participated in this study were those that met NAACCR registry certification standards for providing complete, accurate, and timely data for at least 3 consecutive years during 1995 to 2003 and agreed to release incidence data for this project (30 states and DC).[12] The start and end years of available data varied, and first breast cancers were calculated from the respective database. Table 1 displays the data source and range of years compared for each state. For the remaining 11 states, no reported cases were available, so we compared MIAMOD estimates with independent incidence estimates from ecologic regression analysis at the county level.[2]

Because the MIAMOD estimates represent individual counts rather than tumor counts, we compared the incidence of first breast cancers reported in the respective databases. The determination of first cancers depends on the length of the registration period. For example, a woman who was diagnosed with 2 breast cancers in 1992 and 1998 would be recorded as a case in 1992 if she resided in 1 of the SEER states and in 1998 if she lived in 1 of the NPCR regions.

For each state, we calculated the mean absolute percentage difference (MAPD) between the MIAMOD estimated ($e_y$) and reported ($o_y$) number of breast cancer cases diagnosed up to age 84 years over years $y = y_1, \ldots, y_m$:

$$MAPD = \frac{100 \sum_{y=y_1}^{y_n} |e_y - o_y| / o_y}{(y_n - y_1 + 1)}$$

For the 5 SEER states (Connecticut, New Mexico, Hawaii, Iowa, and Utah) 30-year limited duration prevalent cases from MIAMOD were compared with the corresponding reported values[4] (Table 1).

## RESULTS

For 48 of the 51 states, the estimated number of new breast cases was consistent with reported data within 10% of the MAPD value (Table 1). Larger discrepancies were observed in Utah (10.8%), Arkansas (13.2%), and Wyoming (18.9%); note that the latter had a quite small population and that Arkansas was compared with different estimates,[2] subject to its own sources of errors. Estimated and reported 30-year prevalent cases in 2005 were reasonably close (absolute percentage difference, 1%-8%) in the SEER states, except in Utah, where breast cancer survivors were fairly overestimated (absolute percentage difference, 21.4%).

**Table 1.** Validation of Mortality-Incidence Analysis Model Estimates Against Reported Data From the Surveillance, Epidemiology, and End Results, National Program of Cancer Registries, and Cancer Incidence in North America Databases and From Ecologic Regression Incidence Estimations: Ages 0 to 84 Years*,†

| | | | Incident Cases | | | Survivors at July 2005 | | |
|---|---|---|---|---|---|---|---|---|
| Stage | Data Source for Comparison | Period of Diagnosis | Estimated | Reported‡ | Percentage MAPD (%>MAPD) | Estimated | Reported§ | APD, % |
| Alabama | NPCR | 1998-2003 | 15,979 | 16,645 | 6.8 (50) | | | |
| Alaska | NPCR | 1996-2003 | 2319 | 2489 | 7.8 (38) | | | |
| Arizona | NPCR | 1995-2002 | 23,637 | 23,742 | 3.5 (50) | | | |
| Arkansas | Ecologic | 1995-2003 | 13,453 | 15,485 | 13.2 (63) | | | |
| California | SEER‖ | 1988-2005 | 311,625 | 321,348 | 7.0 (44) | | | |
| Colorado | NPCR | 1995-2003 | 22,487 | 22,721 | 3.8 (44) | | | |
| Connecticut | SEER | 1975-2005 | 63,174 | 65,781 | 7.2 (45) | 28,310 | 30,613 | 7.5 |
| Delaware | NPCR | 1995-2003 | 4933 | 4828 | 5.4 (33) | | | |
| District of Columbia | NPCR | 1999-2003 | 2148 | 1999 | 7.8 (40) | | | |
| Florida | NPCR | 1995-2003 | 110,642 | 105,347 | 6.3 (33) | | | |
| Georgia | NPCR¶ | 1999-2003 | 22,780 | 23,974 | 6.0 (60) | | | |
| Hawaii | SEER | 1975-2005 | 15,558 | 16,670 | 9.3 (45) | 9,466 | 9,794 | 3.3 |
| Idaho | NPCR | 1995-2003 | 6237 | 6700 | 7.5 (56) | | | |
| Illinois | NPCR | 1995-2003 | 70,436 | 71,893 | 5.0 (44) | | | |
| Indiana | NPCR | 1998-2003 | 23,010 | 23,389 | 6.3 (50) | | | |
| Iowa | SEER | 1975-2005 | 51,355 | 51,549 | 5.3 (26) | 22,692 | 22,984 | 1.3 |
| Kansas | Ecologic | 1995-2003 | 15,577 | 15,595 | 3.4 (38) | | | |
| Kentucky | SEER‖ | 1995-2005 | 26,550 | 27,887 | 8.0 (45) | | | |
| Louisiana | SEER‖ | 1995-2005 | 26,843 | 28,453 | 8.9 (55) | | | |
| Maine | NPCR | 1995-2003 | 8041 | 8317 | 4.0 (44) | | | |
| Maryland | Ecologic | 1995-2003 | 32,745 | 32,555 | 4.1 (38) | | | |
| Massachusetts | NPCR | 1997-2003 | 33,570 | 33,495 | 4.6 (43) | | | |
| Michigan | NPCR# | 1995-2003 | 59,631 | 59,320 | 6.0 (33) | | | |
| Minnesota | NPCR | 1995-2003 | 27,149 | 28,545 | 6.1 (56) | | | |
| Mississippi | Ecologic | 1995-2003 | 13,343 | 14,205 | 7.4 (63) | | | |
| Missouri | NPCR | 1998-2003 | 22,595 | 22,561 | 4.2 (50) | | | |
| Montana | NPCR | 1996-2003 | 4996 | 4962 | 6.9 (38) | | | |
| Nebraska | NPCR | 1995-2003 | 10,133 | 9979 | 2.8 (33) | | | |
| Nevada | Ecologic | 1995-2003 | 9508 | 9530 | 4.1 (38) | | | |
| New Hampshire | NPCR | 1999-2003 | 4412 | 4395 | 4.1 (40) | | | |
| New Jersey | SEER‖ | 1979-2005 | 139,468 | 143,487 | 7.6 (48) | | | |
| New Mexico | SEER | 1975-2005 | 22,342 | 21,739 | 6.7 (39) | 12,052 | 11,180 | 7.8 |
| New York | NPCR | 1995-2003 | 110,326 | 115,968 | 6.2 (56) | | | |
| North Carolina | NPCR | 2001-2003 | 16,495 | 15,389 | 7.6 (33) | | | |
| North Dakota | Ecologic | 1995-2003 | 3847 | 4010 | 4.7 (63) | | | |
| Ohio | Ecologic | 1995-2003 | 71,478 | 68,853 | 3.9 (38) | | | |
| Oklahoma | NPCR | 1997-2003 | 16,107 | 16,189 | 4.6 (43) | | | |
| Oregon | NPCR | 1996-2003 | 19,662 | 19,987 | 5.5 (50) | | | |
| Pennsylvania | Ecologic | 1995-2003 | 82,289 | 82,407 | 3.9 (50) | | | |
| Rhode Island | NPCR | 1995-2003 | 6752 | 6695 | 3.4 (33) | | | |
| South Carolina | NPCR | 1997-2003 | 17,323 | 18,103 | 6.2 (43) | | | |
| South Dakota | NPCR | 2001-2003 | 1428 | 1507 | 7.9 (33) | | | |
| Tennessee | Ecologic | 1995-2003 | 31,118 | 31,522 | 4.4 (50) | | | |
| Texas | NPCR | 1995-2003 | 90,909 | 96,524 | 7.2 (56) | | | |
| Utah | SEER | 1975-2005 | 22,854 | 20,532 | 10.8 (35) | 12,816 | 10,557 | 21.4 |
| Vermont | Ecologic | 1995-2003 | 3629 | 3703 | 3.5 (63) | | | |
| Virginia | Ecologic | 1995-2003 | 41,314 | 40,287 | 3.9 (25) | | | |
| Washington | NPCR** | 1995-2003 | 35,988 | 36,524 | 3.6 (33) | | | |
| West Virginia | NPCR | 1995-2003 | 10,557 | 11,223 | 7.9 (56) | | | |
| Wisconsin | NPCR | 1995-2003 | 32,952 | 32,319 | 4.0 (22) | | | |
| Wyoming | NPCR | 1995-2001 | 2262 | 1913 | 18.9 (43) | | | |

MAPD indicates mean absolute percentage difference; APD, absolute percentage difference; NPCR, National Program of Cancer Registries; SEER, Surveillance, Epidemiology, and End Results Program of the National Cancer Institute.

* For SEER data, see SEER Program 2007[4]; for Cancer Incidence in North America data, see North American Association of Central Cancer Registries 2008[12]; and, for ecologic regression incidence estimation data, see Pickle & Su 2002,[13]

† Incidence validation: For the years with incidence data, the total number of estimated and reported first breast cancer cases, the MAPD (in %) between estimated and reported cases over the period of diagnosis, and the percentage of years in which the year-specific APD values exceeded MAPD value (% >MAPD) were calculated. For prevalence validation, the APD was calculated between estimated and reported numbers of first breast cancer survivors on July 1, 2005 (see SEER Program 2007[4]).

‡ See SEER Program 2007,[4] North American Association of Central Cancer Registries 2008,[12] and Pickle & Su 2002.[13]

§ See SEER Program 2007.[4]

‖ These states receive funding from both SEER and NPCR Programs.

¶ The SEER Atlanta Cancer Registry contributes data to the NPCR registry of the state of Georgia.

\# The SEER Detroit Cancer Registry contributes data to the NPCR registry of the state of Michigan.

**The SEER Seattle Cancer Registry contributes data to the NPCR registry of the state of Washington.

We estimate that there were 2.4 million breast cancer survivors in the United States in 2005 (Table 2), a number very similar to the published 2005 prevalence estimate of 2,477,847 survivors.[1] Crude prevalence proportions varied by state, ranging from 1.15% (Alaska) to 2.03% (Florida), because of differences among states in breast cancer incidence, survival, and population age structure. The geographic variability of prevalence also was high among younger women and older women, ranging from 0.55% to 0.94% in women aged <65 years and between 4.7% and 8.3% for patients aged ≥65 years. On average, 17% and 21% of the total 2005 US breast cancer prevalent cases are women diagnosed in the previous 2 years and between 2 and 5 years, respectively. These percentages are quite stable between US states (range, 15%-19% and 19%-23%, respectively). The proportion of short-term survivors is higher in the younger age group (22% within 2 years and 25% between 2 and 5 years) than in the older age group (14% and 18%, respectively). The higher proportion of long-term survivors in the elderly reflects the overall favorable prognosis of breast cancer.

Figure 1 displays the age-adjusted female breast cancer prevalent percentage (Fig. 1A) and its percentage increase from 2005 to 2015 (Fig. 1B) for all US states. The southern states, except Florida, have a lower age-adjusted prevalence compared with the northern states. Conversely, it is predicted that southern states will have a higher increase in age-adjusted prevalence.

Figure 2 displays micromaps of age-adjusted breast cancer prevalence, age-adjusted incidence, crude prevalence proportions, and percentage of the female population aged >65 years by US state in 2010. The maps are ordered by age-adjusted prevalent percentage. After adjusting by age, between-state variability in crude prevalence (1.4%-2.4%) is reduced (1.3%-1.8%). Age-adjusted prevalence clearly is correlated more with incidence (0.83 correlation) than with the elderly population (0.25 correlation), whereas crude prevalence is correlated both with incidence (0.73) and the with population aged ≥65 years (0.80 correlation).

Breast cancer survivors are expected to continue growing from 2005 to 2015 in all US states (Table 3), producing an overall increase of almost 1 million survivors in just a decennium (from 2,403,000 to 3,421,000). The percentage of survivors (among the population) will increase from 1.6% in 2005 to 2.1% in 2015. Although the number of survivors diagnosed within 5 years is expected to increase (by 28% in absolute terms), it is expected to represent a lower proportion of the overall survivors (from 37% in 2005 to 33% in 2015), indicating that prevalence is increasing because of higher numbers of long-term survivors.

A geographic comparison of breast cancer prevalence dynamics from 2005 to 2015 is represented in Figure 3. The corresponding dynamics of incidence and of the elderly female population also are displayed to interpret the geographic variability. Age-adjusted cancer prevalence (Fig. 3, column 1) will increase by a percentage varying from 8% to 32%, whereas the crude prevalence (Fig. 3, column 3) will increase from 16% to 51%, depending on the state. The state ranking of age-adjusted prevalence increase is highly correlated with the ranking of estimated incidence increases (from −3% to 18%) (Fig. 3, column 2). Note that the states with prevalence growth <15% (the first 20 states shown in Fig. 3, column 1) are those in which the age-adjusted incidence is expected to reduce or stabilize (percentage increases <5%) (Fig. 3, column 2). Some of the differences in ranking between the percentage increase in age-adjusted and crude prevalence can be explained by aging (Fig. 3, column 4). For example, in Alaska, for the top value in population aging, the percentage increase of prevalence moves from 49 to 26 when it is adjusted by age.

## DISCUSSION

To our knowledge, this is the first time that the number of women living with breast cancer in the United States has been estimated in a systematic way for all US states. These estimates represent the total breast cancer prevalence, including all women with a past diagnosis of breast cancer. This study includes estimates by age and years since diagnosis as well as cancer prevalence projections up to 2015.

The number of women living with breast cancer in 2005 ranged from 3691 in Alaska to 261,883 in California. Crude prevalence varied between 1.15% in Alaska and 2.03% in Florida. These numbers are influenced by the state population size and the proportion of elderly population. The age-adjusted prevalent percentage is useful for removing discrepancies caused by differences in population age structure and for producing interesting

**Table 2.** State-Specific and Total United States Estimates of Crude Breast Cancer Prevalence in 2005 by Year Since Diagnosis and Age at Prevalence*

| | All Ages | | | | Aged <65 y | | | | Aged ≥65 y | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Percentage of the Population | | | | Percentage of the Population Aged <65 y | | | | Percentage of the Population Aged ≥65 y | | |
| | | Years Since Dx | | | | Years Since Dx | | | | Years Since Dx | | |
| State | Total No. of Survivors (SE) | 0-<2 | 2-<5 | Total | Total No. of Survivors (SE) | 0-<2 | 2-<5 | Total | Total No. of Survivors (SE) | 0-<2 | 2-<5 | Total |
| Alabama | 32,152 (182) | 0.25 | 0.30 | 1.37 | 14,148 (125) | 0.16 | 0.18 | 0.71 | 18,004 (132) | 0.75 | 0.93 | 5.02 |
| Alaska | 3691 (74) | 0.21 | 0.25 | 1.15 | 2040 (57) | 0.15 | 0.18 | 0.68 | 1651 (48) | 0.98 | 1.24 | 7.14 |
| Arizona | 45,364 (250) | 0.26 | 0.32 | 1.52 | 18,136 (156) | 0.15 | 0.18 | 0.71 | 27,228 (196) | 0.89 | 1.16 | 6.43 |
| Arkansas | 19,053 (133) | 0.24 | 0.29 | 1.35 | 8003 (87) | 0.15 | 0.17 | 0.67 | 11,049 (100) | 0.76 | 0.93 | 4.94 |
| California | 261,883 (622) | 0.23 | 0.29 | 1.45 | 110,672 (424) | 0.15 | 0.17 | 0.70 | 151,211 (455) | 0.83 | 1.10 | 6.81 |
| Colorado | 35,092 (240) | 0.26 | 0.31 | 1.52 | 15,623 (169) | 0.16 | 0.19 | 0.76 | 19,469 (171) | 1.01 | 1.28 | 7.40 |
| Connecticut | 34,237 (228) | 0.30 | 0.38 | 1.90 | 13,057 (150) | 0.18 | 0.22 | 0.86 | 21,180 (171) | 0.97 | 1.31 | 7.64 |
| Delaware | 7728 (92) | 0.30 | 0.37 | 1.78 | 2971 (55) | 0.16 | 0.19 | 0.81 | 4757 (74) | 1.09 | 1.36 | 7.41 |
| District of Columbia | 5274 (62) | 0.29 | 0.36 | 1.71 | 2310 (41) | 0.19 | 0.22 | 0.87 | 2,964 (46) | 0.92 | 1.21 | 6.78 |
| Florida | 183,952 (581) | 0.33 | 0.41 | 2.03 | 69,171 (369) | 0.19 | 0.23 | 0.94 | 114,780 (448) | 0.92 | 1.17 | 6.80 |
| Georgia | 55,733 (257) | 0.22 | 0.26 | 1.20 | 27,132 (185) | 0.15 | 0.17 | 0.66 | 28,601 (179) | 0.81 | 1.01 | 5.46 |
| Hawaii | 10,955 (159) | 0.26 | 0.34 | 1.72 | 4724 (108) | 0.18 | 0.21 | 0.88 | 6231 (117) | 0.72 | 1.01 | 6.27 |
| Idaho | 10,296 (106) | 0.23 | 0.29 | 1.45 | 4231 (68) | 0.14 | 0.17 | 0.68 | 6065 (80) | 0.86 | 1.12 | 6.71 |
| Illinois | 104,044 (353) | 0.26 | 0.33 | 1.60 | 41,072 (230) | 0.16 | 0.18 | 0.74 | 62,972 (268) | 0.93 | 1.22 | 6.98 |
| Indiana | 49,490 (248) | 0.26 | 0.32 | 1.56 | 19,433 (159) | 0.15 | 0.18 | 0.71 | 30,056 (190) | 0.89 | 1.16 | 6.58 |
| Iowa | 28,146 (187) | 0.29 | 0.37 | 1.87 | 9648 (110) | 0.16 | 0.19 | 0.77 | 18,498 (152) | 0.93 | 1.24 | 7.25 |
| Kansas | 23,908 (179) | 0.28 | 0.35 | 1.73 | 9001 (115) | 0.17 | 0.19 | 0.76 | 14,907 (138) | 0.96 | 1.24 | 7.18 |
| Kentucky | 30,165 (178) | 0.25 | 0.30 | 1.42 | 12,676 (117) | 0.15 | 0.18 | 0.70 | 17,489 (135) | 0.83 | 1.06 | 5.64 |
| Louisiana | 27,685 (132) | 0.23 | 0.27 | 1.23 | 12,293 (88) | 0.14 | 0.16 | 0.63 | 15,393 (99) | 0.78 | 0.94 | 5.03 |
| Maine | 12,456 (118) | 0.31 | 0.38 | 1.85 | 4844 (75) | 0.18 | 0.21 | 0.86 | 7611 (91) | 0.96 | 1.23 | 6.92 |
| Maryland | 47,170 (230) | 0.29 | 0.35 | 1.63 | 21,063 (154) | 0.18 | 0.21 | 0.84 | 26,108 (171) | 1.01 | 1.27 | 6.96 |
| Massachusetts | 65,116 (315) | 0.31 | 0.39 | 1.96 | 24,172 (203) | 0.18 | 0.21 | 0.86 | 40,943 (241) | 1.04 | 1.37 | 8.04 |
| Michigan | 87,491 (312) | 0.29 | 0.36 | 1.71 | 36,552 (203) | 0.18 | 0.21 | 0.83 | 50,939 (236) | 0.97 | 1.26 | 7.00 |
| Minnesota | 43,482 (244) | 0.27 | 0.34 | 1.69 | 17,123 (156) | 0.16 | 0.19 | 0.77 | 26,359 (188) | 0.92 | 1.23 | 7.37 |
| Mississippi | 18,359 (143) | 0.23 | 0.28 | 1.23 | 8402 (100) | 0.15 | 0.17 | 0.66 | 9957 (102) | 0.71 | 0.91 | 4.70 |
| Missouri | 48,058 (236) | 0.28 | 0.34 | 1.62 | 18,948 (155) | 0.16 | 0.19 | 0.75 | 29,110 (178) | 0.92 | 1.15 | 6.43 |
| Montana | 8661 (113) | 0.30 | 0.37 | 1.85 | 3339 (70) | 0.18 | 0.21 | 0.84 | 5322 (88) | 0.98 | 1.26 | 7.46 |
| Nebraska | 16,376 (141) | 0.28 | 0.36 | 1.85 | 5811 (84) | 0.16 | 0.19 | 0.77 | 10,565 (113) | 0.94 | 1.28 | 7.79 |
| Nevada | 16,408 (134) | 0.22 | 0.28 | 1.38 | 6928 (86) | 0.14 | 0.16 | 0.66 | 9480 (102) | 0.84 | 1.10 | 6.58 |
| New Hampshire | 11,684 (127) | 0.29 | 0.35 | 1.76 | 4650 (82) | 0.17 | 0.20 | 0.81 | 7034 (97) | 1.02 | 1.29 | 7.64 |
| New Jersey | 79,718 (321) | 0.29 | 0.36 | 1.79 | 29,991 (207) | 0.17 | 0.20 | 0.79 | 49,727 (246) | 0.97 | 1.29 | 7.48 |
| New Mexico | 14,001 (134) | 0.24 | 0.30 | 1.43 | 5901 (85) | 0.15 | 0.17 | 0.70 | 8100 (103) | 0.85 | 1.09 | 6.14 |
| New York | 160,915 (429) | 0.27 | 0.33 | 1.62 | 62,243 (287) | 0.16 | 0.18 | 0.73 | 98,672 (319) | 0.91 | 1.15 | 6.61 |
| North Carolina | 66,446 (248) | 0.27 | 0.32 | 1.50 | 29,402 (165) | 0.17 | 0.20 | 0.77 | 37,044 (185) | 0.87 | 1.07 | 5.95 |
| North Dakota | 5844 (78) | 0.31 | 0.37 | 1.85 | 1966 (44) | 0.16 | 0.19 | 0.75 | 3878 (64) | 1.02 | 1.25 | 7.23 |
| Ohio | 105,951 (378) | 0.29 | 0.37 | 1.80 | 40,146 (242) | 0.17 | 0.20 | 0.81 | 65,804 (290) | 0.97 | 1.28 | 7.30 |
| Oklahoma | 29,431 (178) | 0.29 | 0.35 | 1.64 | 11,973 (115) | 0.17 | 0.20 | 0.78 | 17,458 (136) | 0.93 | 1.17 | 6.41 |

*(continued)*

**Table 2.** *(continued)*

| State | All Ages | | | | Aged <65 y | | | | Aged ≥65 y | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Percentage of the Population | | | | Percentage of the Population Aged <65 y | | | | Percentage of the Population Aged ≥65 y | | |
| | | Years Since Dx | | | | Years Since Dx | | | | Years Since Dx | | |
| | Total No. of Survivors (SE) | 0-<2 | 2-<5 | Total | Total No. of Survivors (SE) | 0-<2 | 2-<5 | Total | Total No. of Survivors (SE) | 0-<2 | 2-<5 | Total |
| Oregon | 34,710 (264) | 0.31 | 0.39 | 1.90 | 13,743 (176) | 0.19 | 0.22 | 0.88 | 20,967 (197) | 1.05 | 1.37 | 7.90 |
| Pennsylvania | 123,126 (401) | 0.31 | 0.39 | 1.93 | 42,730 (245) | 0.17 | 0.20 | 0.81 | 80,396 (317) | 0.96 | 1.25 | 7.17 |
| Rhode Island | 10,048 (110) | 0.29 | 0.37 | 1.81 | 3567 (66) | 0.16 | 0.19 | 0.77 | 6481 (88) | 0.98 | 1.28 | 7.27 |
| South Carolina | 31,683 (193) | 0.26 | 0.31 | 1.45 | 14,180 (134) | 0.17 | 0.19 | 0.76 | 17,503 (139) | 0.83 | 1.02 | 5.56 |
| South Dakota | 6573 (80) | 0.27 | 0.33 | 1.69 | 2422 (49) | 0.15 | 0.18 | 0.75 | 4151 (64) | 0.85 | 1.07 | 6.56 |
| Tennessee | 45,007 (244) | 0.26 | 0.32 | 1.48 | 19,482 (165) | 0.17 | 0.19 | 0.75 | 25,525 (180) | 0.84 | 1.07 | 5.76 |
| Texas | 135,608 (416) | 0.21 | 0.25 | 1.18 | 61,177 (293) | 0.13 | 0.15 | 0.60 | 74,431 (296) | 0.81 | 1.02 | 5.66 |
| Utah | 14,879 (155) | 0.21 | 0.25 | 1.20 | 6183 (104) | 0.12 | 0.14 | 0.55 | 8696 (115) | 0.96 | 1.24 | 7.17 |
| Vermont | 5660 (76) | 0.29 | 0.36 | 1.79 | 2277 (50) | 0.18 | 0.21 | 0.85 | 3383 (58) | 0.97 | 1.24 | 7.22 |
| Virginia | 61,561 (279) | 0.28 | 0.34 | 1.60 | 27,456 (193) | 0.18 | 0.21 | 0.82 | 34,106 (202) | 0.96 | 1.22 | 6.75 |
| Washington | 57,580 (339) | 0.30 | 0.37 | 1.82 | 23,790 (229) | 0.18 | 0.22 | 0.87 | 33,790 (251) | 1.09 | 1.41 | 8.29 |
| West Virginia | 14,602 (127) | 0.28 | 0.34 | 1.58 | 5507 (80) | 0.16 | 0.18 | 0.72 | 9095 (98) | 0.84 | 1.06 | 5.62 |
| Wisconsin | 50,948 (247) | 0.30 | 0.38 | 1.83 | 19,617 (156) | 0.18 | 0.21 | 0.83 | 31,332 (192) | 1.02 | 1.35 | 7.56 |
| Wyoming | 4428 (73) | 0.31 | 0.37 | 1.76 | 1723 (44) | 0.17 | 0.20 | 0.79 | 2705 (57) | 1.24 | 1.50 | 7.97 |
| US | 2,402,826 (1791) | 0.27 | 0.33 | 1.60 | 973,647 (1180) | 0.16 | 0.19 | 0.75 | 1,429,179 (1347) | 0.91 | 1.17 | 6.69 |

Dx indicates diagnosis; SE, standard error.

* Listed are the total number of cancer survivors, the SE, and the crude percentage proportion of the population.

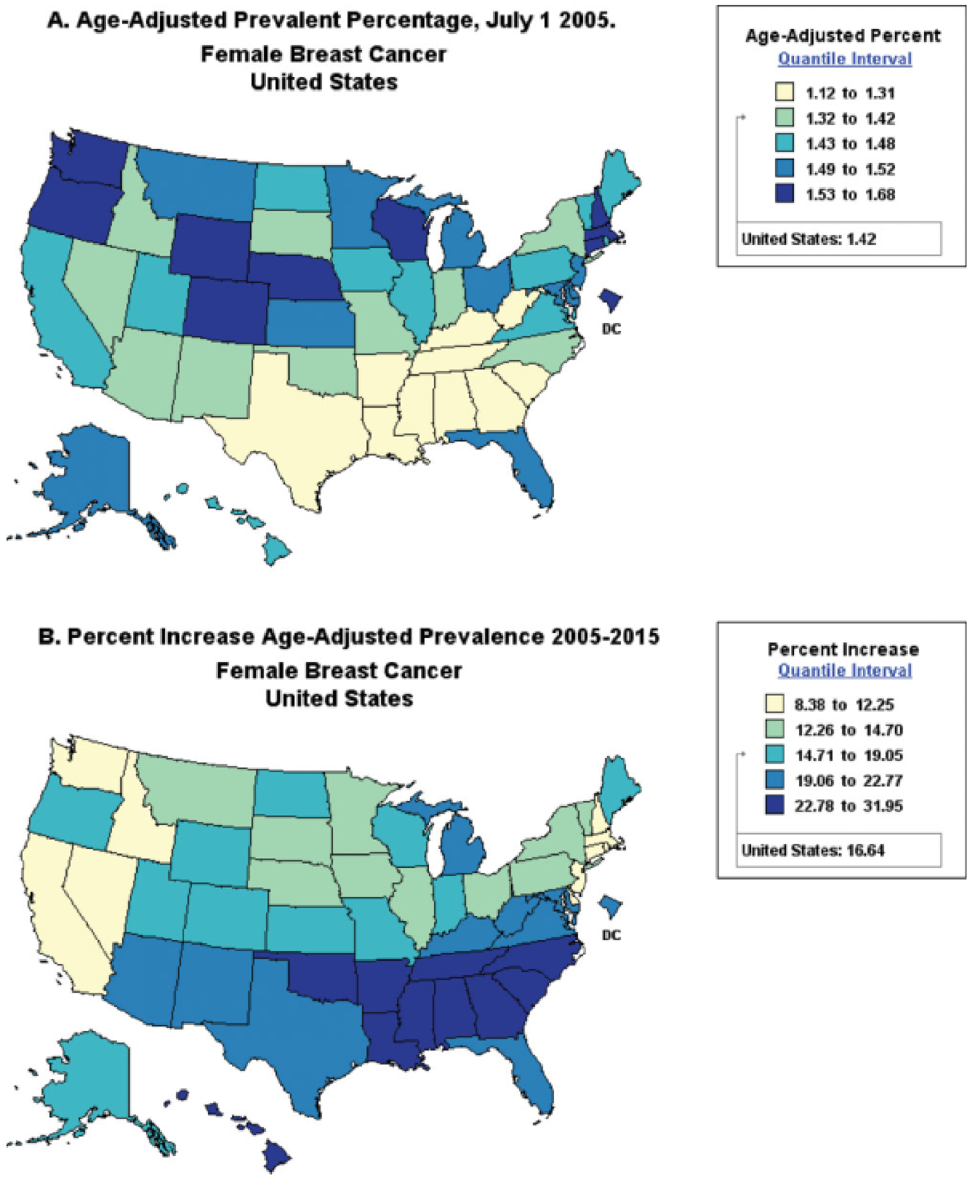


**FIGURE 1.** Female breast cancer age-adjusted prevalent percentage in 2005 (A) and percentage increase of age-adjusted prevalent percentage from 2005 to 2015 (B) by US state.

geographic patterns. The southern states, with the exception of Florida, have lower prevalence compared with the northern states. However, it is predicted that they will have a higher increase in prevalence in the next 10 years compared with the northern states. Studies on risk factors have revealed a positive correlation between patterns of mammography use and income[13,14] that may explain part of the south-north disparity. A variable proportion of breast cancer survivors (range, 35%-42%) had been diagnosed within the previous 5 years. This proportion is lower for the population aged ≥65 years, in which long-term survivors represent the large majority.

The prevalence estimates and projections presented here were based on a statistical method (MIAMOD)[10] that uses state-specific information on cancer mortality and survival. This method was used because it permitted a uniform estimation of breast cancer prevalence across all the US states using available data. When a long series of historic incidence is available, other methods[15-17] can be used. Except for few states that participate in the SEER

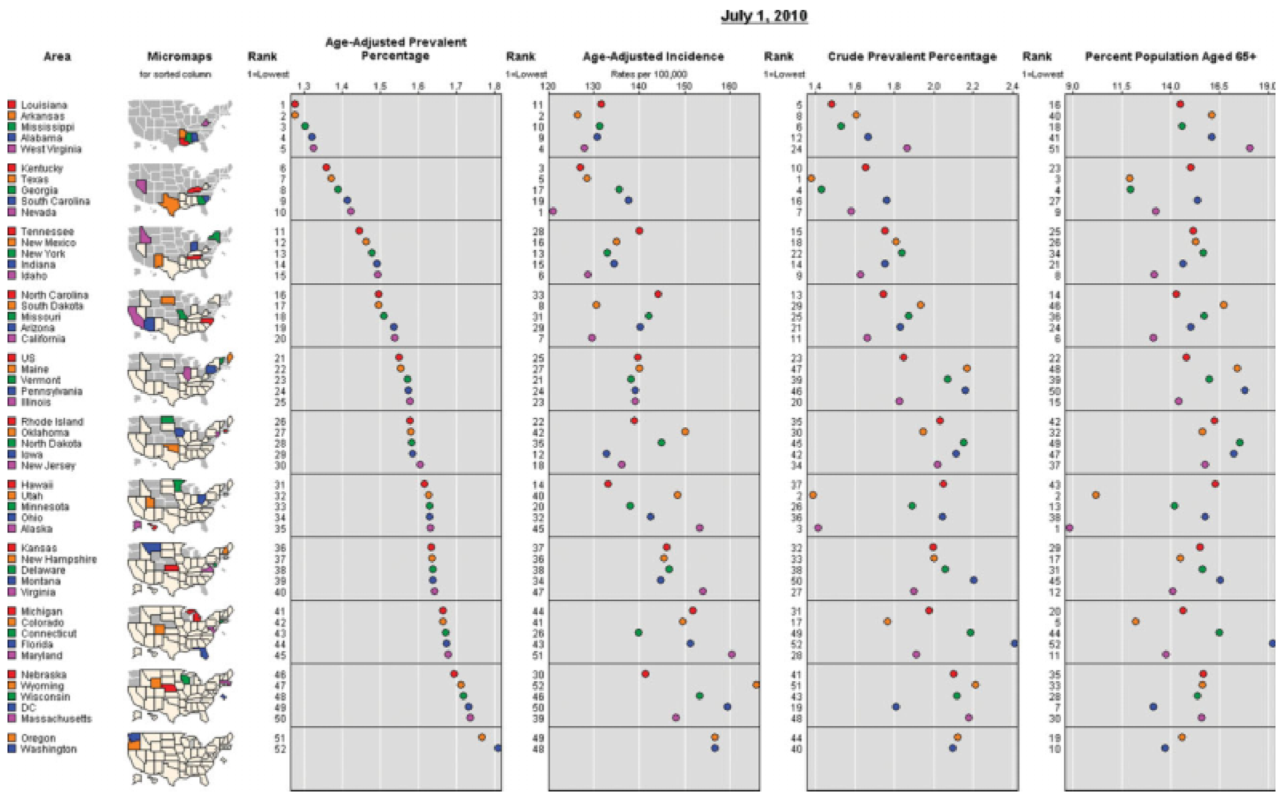


**FIGURE 2.** Geographic comparison of the breast cancer burden in 2010 by US state: Shown are the age-adjusted prevalent percentage (%), the age-adjusted incidence rates per 100,000 population, the crude prevalent percentage (%), and the percentage proportion of the population aged >65 years (%). The micromaps are ranked by age-adjusted prevalent percentage.

Program, the application of these methods is not feasible. However, for most of the US states, a short and varying series of incidence data from either SEER or NPCR is available. The comparison of MIAMOD incidence estimates against the reported incidence series produced similar numbers for most of the states. The exceptions were Utah and Wyoming. Comparable results, except for Arkansas, also were observed for the remaining 11 states compared with independent incidence estimates. Generally, MIAMOD incidence underestimated the reported data. This is consistent with intrinsic limitations of the reported incidence series in determining the first cancers, depending on the length of the registration period.

The 2005 US breast cancer prevalence estimate, which was calculated by summing state estimates, was very similar to a published estimate of 2,477,847.[1] The finding that 2 distinct methods yielded similar estimates is reassuring.

In this work, we defined an individual as a survivor from the moment of diagnosis. Also, the registries data were based on cancer diagnosis. Although this definition is becoming the most prevalent, statistics based on it may not capture all individuals who are affected by cancer, such as family members and caregivers who are impacted by the survivorship experience.[18]

Several limitations are noteworthy. First, the MIAMOD method relies on accurate estimates of mortality and survival. No particular quality problem is reported for breast cancer mortality data by state. However, survival data are not available for the majority of the states and are estimated. The baseline survival model, which reflects SEER survival, has demonstrated a good fit to survival data (results not shown) over a 30-year period of diagnosis and for all age groups. State-specific survival was estimated using relative risks that reflected a higher or smaller risk of breast cancer death compared with SEER. The estimates were obtained through an ecologic regression analysis of breast cancer survival on sociodemographic variables at the county level. Although cross-validation[9] analysis indicated that the survival estimates generally provided a

**Table 3.** Projections 2005 to 2015 of State-specific and Total United States Breast Cancer Prevalence (Absolute Numbers of Survivors and Crude Percentage Proportions of the Population) and the Prevalence of Those Diagnosed in the Previous 5 Years*

| | No. of Survivors | | | | Percentage of the Population | | | | No. of Survivors Diagnosed <5 Years Previously | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| State | 2005 | 2010 | 2015 | Increase 2005-2015, % | 2005 | 2010 | 2015 | Increase 2005-2015, % | 2005 | 2010 | 2015 | Increase 2005-2015, % |
| Alabama | 32,152 | 39,615 | 47,480 | 48 | 1.37 | 1.67 | 1.97 | 44 | 12,783 | 14,798 | 16,708 | 31 |
| Alaska | 3691 | 4805 | 6037 | 64 | 1.15 | 1.41 | 1.67 | 45 | 1496 | 1826 | 2158 | 44 |
| Arizona | 45,364 | 60,596 | 79,589 | 75 | 1.52 | 1.83 | 2.13 | 40 | 17,218 | 21,928 | 27,440 | 59 |
| Arkansas | 19,053 | 23,584 | 28,393 | 49 | 1.35 | 1.61 | 1.88 | 39 | 7594 | 8858 | 10,069 | 33 |
| California | 261,883 | 319,284 | 374,875 | 43 | 1.45 | 1.66 | 1.85 | 28 | 93,610 | 107,884 | 119,724 | 28 |
| Colorado | 35,092 | 42,185 | 49,905 | 42 | 1.52 | 1.76 | 2.00 | 32 | 13,291 | 15,129 | 16,929 | 27 |
| Connecticut | 34,237 | 40,360 | 45,597 | 33 | 1.90 | 2.19 | 2.43 | 27 | 12,352 | 13,707 | 14,646 | 19 |
| Delaware | 7728 | 9418 | 11,176 | 45 | 1.78 | 2.06 | 2.32 | 30 | 2894 | 3347 | 3772 | 30 |
| District of Columbia | 5274 | 5031 | 5264 | 0 | 1.71 | 1.81 | 1.99 | 16 | 2009 | 1820 | 1810 | −10 |
| Florida | 183,952 | 237,226 | 299,105 | 63 | 2.03 | 2.41 | 2.76 | 36 | 66,398 | 81,435 | 97,595 | 47 |
| Georgia | 55,733 | 68,910 | 85,643 | 54 | 1.20 | 1.43 | 1.67 | 39 | 22,552 | 26,245 | 30,847 | 37 |
| Hawaii | 10,955 | 13,734 | 16,749 | 53 | 1.72 | 2.05 | 2.41 | 40 | 3838 | 4564 | 5286 | 38 |
| Idaho | 10,296 | 12,306 | 14,775 | 43 | 1.45 | 1.63 | 1.82 | 25 | 3711 | 4231 | 4834 | 30 |
| Illinois | 104,044 | 119,746 | 135,069 | 30 | 1.60 | 1.83 | 2.03 | 27 | 38,408 | 41,790 | 44,838 | 17 |
| Indiana | 49,490 | 56,796 | 64,343 | 30 | 1.56 | 1.75 | 1.95 | 25 | 18,384 | 19,971 | 21,548 | 17 |
| Iowa | 28,146 | 32,241 | 35,940 | 28 | 1.87 | 2.11 | 2.34 | 25 | 9924 | 10,781 | 11,428 | 15 |
| Kansas | 23,908 | 28,093 | 32,286 | 35 | 1.73 | 2.00 | 2.26 | 31 | 8784 | 9816 | 10,732 | 22 |
| Kentucky | 30,165 | 35,857 | 41,850 | 39 | 1.42 | 1.65 | 1.90 | 34 | 11,763 | 13,113 | 14,395 | 22 |
| Louisiana | 27,685 | 35,053 | 41,692 | 51 | 1.23 | 1.48 | 1.74 | 41 | 11,266 | 13,463 | 15,163 | 35 |
| Maine | 12,456 | 15,113 | 17,741 | 42 | 1.85 | 2.17 | 2.49 | 34 | 4633 | 5330 | 5947 | 28 |
| Maryland | 47,170 | 58,600 | 70,643 | 50 | 1.63 | 1.91 | 2.19 | 34 | 18,594 | 21,748 | 24,861 | 34 |
| Massachusetts | 65,116 | 75,214 | 84,410 | 30 | 1.96 | 2.18 | 2.40 | 22 | 23,332 | 25,552 | 27,219 | 17 |
| Michigan | 87,491 | 104,441 | 121,579 | 39 | 1.71 | 1.98 | 2.27 | 33 | 33,330 | 37,606 | 41,565 | 25 |
| Minnesota | 43,482 | 51,306 | 59,517 | 37 | 1.69 | 1.89 | 2.10 | 25 | 15,562 | 17,437 | 19,229 | 24 |
| Mississippi | 18,359 | 23,316 | 28,796 | 57 | 1.23 | 1.53 | 1.86 | 51 | 7577 | 9064 | 10,566 | 39 |
| Missouri | 48,058 | 56,791 | 65,964 | 37 | 1.62 | 1.87 | 2.13 | 31 | 18,308 | 20,493 | 22,592 | 23 |
| Montana | 8661 | 10,710 | 12,759 | 47 | 1.85 | 2.20 | 2.54 | 37 | 3118 | 3646 | 4108 | 32 |
| Nebraska | 16,376 | 18,760 | 21,078 | 29 | 1.85 | 2.10 | 2.33 | 26 | 5665 | 6184 | 6647 | 17 |
| Nevada | 16,408 | 21,179 | 26,770 | 63 | 1.38 | 1.58 | 1.74 | 26 | 5947 | 7345 | 8859 | 49 |
| New Hampshire | 11,684 | 14,050 | 16,553 | 42 | 1.76 | 2.00 | 2.24 | 27 | 4258 | 4841 | 5384 | 26 |
| New Jersey | 79,718 | 93,457 | 104,940 | 32 | 1.79 | 2.02 | 2.21 | 24 | 28,812 | 31,805 | 33,867 | 18 |
| New Mexico | 14,001 | 18,405 | 22,808 | 63 | 1.43 | 1.81 | 2.17 | 51 | 5293 | 6568 | 7692 | 45 |
| New York | 160,915 | 184,633 | 206,000 | 28 | 1.62 | 1.84 | 2.04 | 26 | 59,739 | 64,486 | 68,006 | 14 |
| North Carolina | 66,446 | 82,561 | 101,280 | 52 | 1.50 | 1.74 | 2.00 | 33 | 25,943 | 30,518 | 35,508 | 37 |
| North Dakota | 5844 | 6814 | 7727 | 32 | 1.85 | 2.15 | 2.45 | 33 | 2133 | 2376 | 2567 | 20 |
| Ohio | 105,951 | 121,128 | 135,202 | 28 | 1.80 | 2.05 | 2.28 | 26 | 38,795 | 41,923 | 44,403 | 14 |
| Oklahoma | 29,431 | 35,420 | 41,790 | 42 | 1.64 | 1.95 | 2.26 | 38 | 11,386 | 12,968 | 14,498 | 27 |
| Oregon | 34,710 | 40,472 | 47,912 | 38 | 1.90 | 2.12 | 2.37 | 25 | 12,798 | 14,216 | 16,049 | 25 |
| Pennsylvania | 123,126 | 140,313 | 155,601 | 26 | 1.93 | 2.16 | 2.37 | 23 | 44,414 | 47,939 | 50,666 | 14 |
| Rhode Island | 10,048 | 11,766 | 13,167 | 31 | 1.81 | 2.03 | 2.23 | 23 | 3642 | 3987 | 4215 | 16 |

*(continued)*

Table 3. *(continued)*

| State | No. of Survivors | | | | Percentage of the Population | | | | No. of Survivors Diagnosed <5 Years Previously | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2010 | 2015 | Increase 2005-2015, % | 2005 | 2010 | 2015 | Increase 2005-2015, % | 2005 | 2010 | 2015 | Increase 2005-2015, % |
| South Carolina | 31,683 | 40,129 | 49,665 | 57 | 1.45 | 1.76 | 2.09 | 44 | 12,532 | 14,932 | 17,385 | 39 |
| South Dakota | 6573 | 7585 | 8680 | 32 | 1.69 | 1.93 | 2.19 | 29 | 2312 | 2546 | 2779 | 20 |
| Tennessee | 45,007 | 56,052 | 68,081 | 51 | 1.48 | 1.75 | 2.04 | 38 | 17,775 | 20,880 | 24,023 | 35 |
| Texas | 135,608 | 170,931 | 210,659 | 55 | 1.18 | 1.38 | 1.57 | 33 | 53,031 | 63,069 | 73,580 | 39 |
| Utah | 14,879 | 17,925 | 22,058 | 48 | 1.20 | 1.38 | 1.59 | 32 | 5633 | 6506 | 7671 | 36 |
| Vermont | 5660 | 6836 | 8022 | 42 | 1.79 | 2.07 | 2.36 | 32 | 2072 | 2365 | 2632 | 27 |
| Virginia | 61,561 | 77,558 | 95,102 | 54 | 1.60 | 1.90 | 2.20 | 38 | 23,946 | 28,448 | 33,098 | 38 |
| Washington | 57,580 | 68,897 | 81,823 | 42 | 1.82 | 2.09 | 2.34 | 28 | 21,091 | 23,887 | 26,826 | 27 |
| West Virginia | 14,602 | 17,398 | 19,968 | 37 | 1.58 | 1.86 | 2.15 | 37 | 5666 | 6364 | 6949 | 23 |
| Wisconsin | 50,948 | 61,265 | 72,035 | 41 | 1.83 | 2.12 | 2.43 | 33 | 19,035 | 21,783 | 24,446 | 28 |
| Wyoming | 4428 | 5736 | 6967 | 57 | 1.76 | 2.21 | 2.64 | 50 | 1719 | 2115 | 2450 | 42 |
| All US states | 2,402,826 | 2,899,601 | 3,421,070 | 42 | 1.60 | 1.85 | 2.09 | 31 | 896,364 | 1,023,636 | 1,146,208 | 28 |

*The percentage increase from 2005 to 2015 is reported for all indicators.

good fit, the ecologic associations inherent in these models may not fit well in every state. Also, it is possible that, for some states, we were not able to capture other differences that may exist between SEER and a specific state[19], however the lack of survival data makes this models a viable option.

Second, prevalence estimates were based on an APC incidence model estimate. Although the APC model is flexible enough to fit a variety of incidence dynamics, it is back-calculated from mortality and survival dynamics. Survival improvements, which are particularly relevant for breast cancer, are captured well in the baseline survival model. The long mortality time series used in this study allowed for the estimation of robust incidence age and cohort effects. However, because of the latency between incidence and mortality, the back-calculation method is not able to capture the recent changes in incidence, like changes associated with the reduced use of hormone-replacement therapy[20] in recent years. Thus, this reduction was not represented in the prevalence projection from 2006 to 2015. For the projections, we assumed no period effect. Nevertheless, a reduction and stabilization of incidence was estimated in 16 states.

Third and finally, the projections were based on several assumptions: flat survival rates after 2004, dynamic population projection, constant other causes mortality, and incidence varying according to the estimated age and cohort effects. This assumption attempts to capture age and risk factor effects on breast cancer incidence, eliminating period effects from the projections, such as screening, because temporal trends are more difficult to forecast.

According to these assumptions, the number of breast cancer survivors is expected to grow in all states at various increasing rates (from 20% to 50% in the decennium 2005-2015). It is estimated that age-adjusted incidence will drop slightly or flatten from 2005 to 2015 in about 20 US States (those with percentage increases <5%) (Fig. 3, column 2), and this partially reduces prevalence growth. These states are located mostly on the eastern and western coast and in northern areas: those with highest breast cancer incidence and prevalence rates and with higher use of mammography screening.[13] We predicted a higher increase in southern states. This may be associated with an increase in the use of screening mammography (because levels were low in the past) and with high obesity and smoking rates,[13] which are known risk

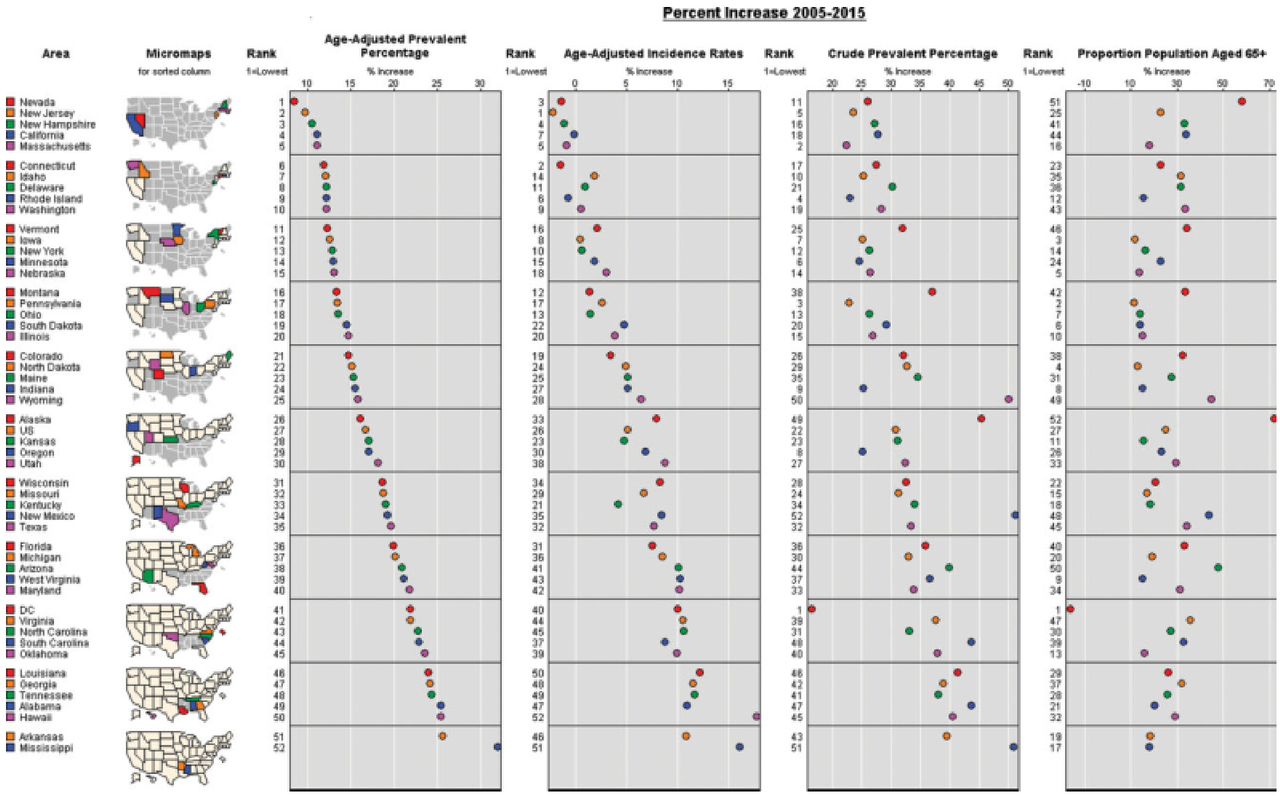


**FIGURE 3.** Geographic comparison of projected breast cancer dynamics in the decennium from 2005 to 2015: Shown are the percentage increases from 2005 to 2015 in the age-adjusted prevalent percentage (%), the age-adjusted incidence rates (%), the crude prevalent percentage (%), and the population aged ≥65 years (%). The micromaps are ranked by the percentage increase in the age-adjusted prevalence proportion.

factors for breast cancer. Breast cancer survivors in 2015 are expected to be older than in 2005 because of population aging and to have a longer disease history, eg, a higher proportion of patients diagnosed >5 years previously (Table 3).

These estimates provide an order of magnitude assessment of the breast cancer burden and can be used by policy makers and health authorities to inform decisions about the allocation of funds, identifying priorities, and planning more targeted cancer control strategies. Given the estimated projections, breast cancer burden will continue to represent a major demand on public health services. Continuing surveillance for breast cancer is needed 5 years postdiagnosis, and prevalence data by disease duration are important for planning research on the quality of life of cancer survivors, because breast cancer is becoming even more a chronic disease.[21] Estimates like those provided in this report support the recommendation by the Institute of Medicine that the National Institutes of Health should strengthen its use of data that estimate the burden of disease in setting its priorities.[22]

## Conflict of Interest Disclosures

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