Published OnlineFirst March 30, 2010; DOI: 10.1158/1055-9965.EPI-09-0966

Research Article

Cancer Epidemiology, Biomarkers & Prevention

Temporal Trends in Geographic Disparities in Small-Area Breast Cancer Incidence and Mortality, 1988 to 2005

Mario Schootman[1,2], Min Lian[1], Anjali D. Deshpande[1,2], Elizabeth A. Baker[3], Sandi L. Pruitt[1], Rebecca Aft[1,2,4], and Donna B. Jeffe[1,2]

Abstract

Background: A goal of Healthy People 2010 was to reduce health disparities. We determined the extent of reductions in geographic disparities in five breast cancer screening indicators.

Methods: We examined the extent of reductions in geographic disparities in five breast cancer screening indicators using data about women ages 40 years and older from 200 counties in the 1988 to 2005 Surveillance, Epidemiology, and End Results Program database. County-level trends in five breast cancer indicators (*in situ*, stage I, lymph node–positive, locally advanced, and mortality) were summarized using the estimated annual percentage change. Observed county rates were smoothed using hierarchical Bayesian spatiotemporal methods to calculate measures of absolute and relative geographic disparity and their changes over time.

Results: For *in situ* breast cancer, absolute disparity increased 93.7% during 1988 to 2005. Relative disparity declined 61.5% during the entire study period. Absolute and relative disparity for stage I breast cancer declined 18.5% and 41.4%, respectively. Absolute disparity for lymph node–positive breast cancer declined 37.9% during the study period, whereas relative disparity declined 17.6%. Absolute disparity for locally advanced breast cancer declined 66.5%, whereas relative disparity declined 17.8% during the study period. Absolute disparity in breast cancer mortality declined 60.5%, whereas relative disparity declined 19.8%.

Conclusions: Absolute and relative geographic disparities narrowed over time for all breast cancer indicators except for *in situ* breast cancer.

Impact: Progress has been made toward reducing geographic disparities in breast cancer outcomes, particularly in advanced-stage breast cancer incidence and mortality rates, although disparities remain. *Cancer Epidemiol Biomarkers Prev; 19(4); 1122–31. ©2010 AACR.*

Introduction

Breast cancer is the most commonly diagnosed cancer and the second leading cause of cancer death among women in the United States with ~40,000 deaths expected in 2009 (1). Mammographic screening for breast cancer reduces the risk of breast cancer mortality (2-5). The proportion of women ages 50 to 64 years who had a mammogram within 2 years more than doubled from 32% in 1987 to 79% in 2000 (6, 7); however, recent studies show that mammography use has reached a plateau or even declined slightly (8).

Authors' Affiliations: [1]Washington University School of Medicine, Departments of Medicine and Pediatrics, Division of Health Behavior Research; [2]Alvin J. Siteman Cancer Center at Barnes-Jewish Hospital and Washington University School of Medicine; [3]Saint Louis University School of Public Health, Department of Community Health; and [4]John Cochran VA Medical Center, Saint Louis, Missouri

Corresponding Author: Mario Schootman, Washington University School of Medicine, Departments of Medicine and Pediatrics, Division of Health Behavior Research, Box 8504, 4444 Forest Park Avenue, Saint Louis, MO 63108. Phone: 314-286-1956; Fax: 314-286-1919. E-mail: mschootm@wustl.edu

doi: 10.1158/1055-9965.EPI-09-0966

Monitoring the effects of breast cancer screening at the population level is vital to maximize its effect, particularly in light of changes in mammography use. Based on data from screening programs implemented in western European countries, the reduction in breast cancer–related mortality among women with screen-detected cancers resulted from a predictable pattern of detection of tumors with smaller mass, at an earlier stage, and before they metastasize to lymph nodes (4, 9-11). In the United States, early-stage breast cancer incidence increased dramatically during the past few decades (12, 13), but declined during 2001 to 2004 (14). In addition, late-stage breast cancer declined over time, as did mortality rates (14).

Although breast cancer incidence and mortality trends are generally monitored at the national level (14), little is known about small-area variation (geographic disparity) in these trends. Reducing disparities, including geographic disparities, is an overarching goal of the Healthy People 2010 initiative and of the National Cancer Institute's (NCI) strategic plan (15, 16). Monitoring disparities in the abovementioned indicators of breast cancer screening at small geographic levels (e.g., the county level) may help facilitate local health planning through interventions aimed at increasing screening and allocation of pertinent screening resources. Extensive geographic disparity in

Published OnlineFirst March 30, 2010; DOI: 10.1158/1055-9965.EPI-09-0966

the effects of breast cancer screening is expected because screening use varies geographically (17-19), but it is unclear if this disparity has changed over time. The purpose of our analysis was to describe temporal changes in geographic disparity and overall rates of five breast cancer screening indicators across 200 counties using population-based breast cancer data during 1988 to 2005.

Materials and Methods

Data source

We used the 1988 to 2005 public-use county-level data from nine population-based Surveillance, Epidemiology, and End Results (SEER) programs to calculate the rate of five breast cancer screening indicators in an ecological study design. We used 1988 as the first year of observation because this is the first year when detailed information about lymph node involvement, American Joint Commission on Cancer tumor-node-metastasis staging, and tumor size are available in the SEER data. The SEER programs collect data about demographics (age, race, marital status, census tract, and county), clinical characteristics of the tumor (stage at diagnosis, tumor biology), treatment (type of surgery, receipt of radiation therapy, and lymph node dissection), and survival. During this time period, the SEER programs at the nine sites included in our study covered 200 counties and about 9% of the United States population. The analyses were based on women age 40 years or older diagnosed with first primary breast cancer or who died from breast cancer from 1988 to 2005.

Breast cancer screening indicators

Indicators of early-stage breast cancer consist of *in situ* breast cancer and invasive breast cancers that were <2 cm at the time of diagnosis (T1 tumors). *In situ* breast cancer was identified from the fifth digit of the histology-behavior code of the SEER data, which is based on the International Classification of Diseases for Oncology. *In situ* and early-stage breast cancer are indicators of reductions in mortality in European studies and correspond to the epidemiology of breast cancer screening (4, 9-11).

The beneficial effect of screening in reducing mortality occurs as a result of identifying tumor early at a reduced tumor size, lower histologic grade, and reduced axillary lymph node involvement (4, 20). We used two indicators of advanced breast cancer: (*a*) the rate of lymph node–positive breast cancers and (*b*) the rate of locally advanced breast cancer (LABC). We define LABC as tumors classified as T3 (tumors >5.0 cm in greatest diameter) or T4 (any size tumor with direct extension to the chest wall or skin, and inflammatory carcinoma; ref. 21). The breast cancer mortality rate was calculated for women who had breast cancer as the underlying cause of death on their death certificate. Women who were previously diagnosed with breast cancer but died from other causes were not included in the breast cancer mortality rate (22).

Statistical analysis

First, we identified changes in overall breast cancer screening indicator rates over time to put in perspective the changes in geographic disparities (23). It is possible for disparities to increase even when overall rates are declining. For example, the racial disparity in breast cancer mortality is growing although overall breast cancer mortality is declining (24). Overall rates were age and race adjusted using the 2000 U.S. standard population. Linear trends in rates from 1988 to 2005 were summarized using the estimated annual percentage change (EAPC). The EAPC was calculated by fitting a linear regression to the natural logarithm of the annual rates, using calendar year as a regression variable. Therefore, the model was

$$\ln(rate) = a^*x + b$$

in which x is the calendar year and EAPC is $100 *(e^a - 1)$. Joinpoint regressions were done to identify significant changes in rates over time. Joinpoint regression is based on permutation tests to identify an inflection point (hereafter called joinpoint) with a significant change in the slope of the trend (25, 26). For our analysis, a maximum of three joinpoints was allowed and a minimum of four points between two joinpoints was required.

Second, we smoothed the observed county rates using hierarchical Bayesian spatiotemporal methods to calculate measures of absolute and relative geographic disparity. Hierarchical Bayesian methods were used because county rates are strongly affected by the annual number of breast cancers in each county and may be very unreliable if based on few breast cancers. Moreover, rates that are close in proximity are not independent of each other (spatial correlation). The smoothed rates are close to the observed rates when based on a large number of breast cancers or population size. However, in counties with lower incidence of breast cancers or with smaller population size, the rates can be strongly affected each year. In this case, the observed rate was smoothed toward the rates of the adjacent counties. Observed county rates were age adjusted using the 2000 U.S. standard population when age-race-county-year–specific data included fewer than five breast cancer cases. Rates were age and race adjusted to this population when age-race-county-year–specific data included at least five breast cancer cases. We used three racial groups: white, black, and other race. Specifically, we used the Knorr-Held model to obtain the yearly, smoothed county rates during 1988 to 2005 (27). This model contained four random terms,

$$\log\theta_{ij} = \beta_0 + \mu_i + v_i + \delta_j + \varphi_{ij}$$

in which θ_{ij} is the county-year–specific rate; β_0 is the intercept; μ_i and v_i are the spatially structured and unstructured random terms, respectively; δj is the temporal random term; and φ_{ij} is the spatiotemporal random term. Specification of the structured spatial random effect was derived from an intrinsic conditional autoregressive model in which adjacent counties were assumed to have

Published OnlineFirst March 30, 2010; DOI: 10.1158/1055-9965.EPI-09-0966

similar disease risk (28). The other three random effects were assumed to be independent of counties and with exchangeable normal priors. Markov Chain Monte Carlo methods were adopted to fit the models. The spatial adjacency matrix was created in ArcGIS (ESRI) using an add-in adjacency tool (29).

Third, we calculated trends in geographic disparity for each of the breast cancer screening indicators. The NCI defines cancer health disparities as adverse differences in cancer incidence (new cases), cancer prevalence (all existing cases), cancer death (mortality), cancer survivorship, and burden of cancer or related health conditions that exist among specific population groups in the United States (30). Geographic disparity can be measured in two different ways, depending on whether one is concerned with measuring the relative or absolute distribution of these indicators across counties. The most frequent method of communicating information about disparities in epidemiology and public health is in relative terms (e.g., relative risk). Risk difference, a measure of absolute disparity, is used less frequently. We used measures of both relative disparity [mean log deviation (MLD)] and absolute disparity (the between-group variance [BGV]) because of potential differences in findings between both measures (23, 31). Whereas many measures of geographic disparity are available, for unordered groups (such as counties, in our instance) the MLD and BGV are recommended (32). This approach uses population-weighted measures that account for changes over time in the underlying distribution of the county populations and measure absolute and relative disparity as differences from the population average (that is, overall rate) for each of the five breast cancer screening indicators. Both measures weight the county rates by their population size and are more sensitive than other measures of absolute and relative disparity to deviations further from the overall rate (31). The BGV is calculated by squaring the differences in county rates from the population average and weighting by population size. The MLD summarizes the disproportionality between county rates and population size (expressed on the natural logarithm scale). Extending the risk difference approach to unordered groups, the yearly absolute disparity of BGV is defined as $\sum_{j=1}^{J} p_j(y_j-\mu)^2$. Extending the relative risk approach to unordered groups, the yearly relative disparity of MLD is written as $\sum_{j=1}^{J} p_j(-\ln r_j)$, in which $r_j = y_j/\mu$, p_j is county j's population fraction, y_j is the county j's age-(race)–adjusted rate, and μ is the overall age-race–adjusted rate across all 200 SEER counties. In the current study, y_j was defined as model-based predicted county-year–specific rates and μ was obtained from a summary after multiplying the smoothed county rate by its population fraction. Theoretically, BGV and MLD are no less than 0 and larger values indicate greater disparities. If there is no disparity, then the BGV and the MLD are 0.

Bayesian spatiotemporal models, including the county-year–specific breast cancer screening indicator rates, year-specific overall breast cancer screening indicator rates, and both measures of geographic disparity, were implemented in WinBUGS (ver.1.4.3, Medical Research Council). After running 20,000 iterations as burn-in, 20,000 more samples were used to obtain parameter estimates, including county-year–specific breast cancer indicator rates and their absolute and relative disparity measures. Model fit was evaluated using the Deviance Information Criteria, with lower values indicating better fit (33).

Fourth, we used joinpoint regressions to identify significant changes in both absolute and relative disparity measures for each of the five breast cancer screening indicators. SEMs of the absolute and relative disparity measures were based on the 95% credible interval obtained from the Bayesian models. Again, the EAPC was calculated for each joinpoint. We also calculated the period change in absolute and relative disparity between 1988 and 2005.

Fifth, we identified priority counties where disparities remained high. Setting priorities was based on concepts developed in other studies (34, 35) and Centers for Disease Control and Prevention's (CDC) state cancer profiles (http://statecancer.profiles.cancer.gov), namely trends over time, 2005 estimated county rate, and precision of the estimate. Specifically, we calculated the difference between the estimated county rate and the age-race–adjusted rate across all 200 counties. In addition, we calculated the ratio of the difference between the estimated 1988 county rate and the estimated 2005 county rate and the difference between the 1988 and the 2005 age-race–adjusted rate across all 200 counties. This ratio describes the change over time of the estimated county rate relative to the change of the rate of all 200 counties. Both the difference measure and the ratio measure were categorized into three groups based on their distribution across the 200 counties, resulting in nine classes of counties. The highest priority counties had an estimated rate that was at least 10 per 100,000 population higher in 2005 than the overall rate and a decline in rate from 1988 to 2005 that was at least twice lower than the overall rate. The lowest priority counties had an estimated rate that was at least 10 per 100,000 population lower than the overall rate in 2005 and a decline in rate from 1988 to 2005 that was at least twice faster than the overall rate. We did not use the measures of absolute disparity and the relative disparity to prioritize counties because they do not indicate if a rate is below or above the overall rate. All data were managed in SAS 9.1 (SAS Institute, Inc.).

Results

Table 1 displays the number of breast cancers and adjusted county rates for each of the five breast cancer indicators. The median and mean numbers of breast cancers per county per year vary because of the skewed distribution. Several counties have a large number of breast cancers.

Published OnlineFirst March 30, 2010; DOI: 10.1158/1055-9965.EPI-09-0966

Table 1. Number of breast cancers and adjusted rates per county per year for five indicators, 1988 to 2005

Breast cancer indicator	Total	No. per county per year				Adjusted rate per county per year (per 100,00 population)			
		Minimum	Median	Mean	Maximum	Minimum	Median	Mean	Maximum
In situ	48,763	0	2	13.5	349	0	31.1	35.2	494.1
Stage I	114,015	0	6	31.7	584	0	101.1	100.9	785.2
Lymph node positive	68,686	0	3	19.1	380	0	62.7	65.1	1,832.7
LABC	25,696	0	1	7.1	187	0	19.8	22.9	1,574.5
Mortality	55,774	0	3	15.5	404	0	49.2	53.2	1,102.1

In situ and stage I breast cancers

From 1988 to 2005, 48,763 *in situ* breast cancers were diagnosed (Table 1). The overall *in situ* rate increased 6.3% per year from 1988 to 2000, after which it remained stable until 2005 (Table 2; Fig. 1). From 1988 to 1993, the absolute disparity for *in situ* breast cancer incidence remained stable (Table 2; Fig. 2), then increased 15.6% per year from 1993 to 1999 and then declined 5.3% per year from 1999 to 2005. Relative disparity declined 5.5% per year during the entire study period. Absolute disparity for *in situ* incidence increased 93.7% from 1988 to 2005, whereas relative disparity declined 61.5%.

From 1988 to 2005, 114,015 stage I breast cancers were diagnosed. The overall stage I rate increased 1.8% per year from 1988 to 2000, after which it declined 4.6% per year. No significant changes were observed in absolute disparity for stage I breast cancer rates on a yearly basis (Table 2; Fig. 3), although there was an 18.5% decline after 1988. Relative disparity declined 6.1% per year from 1988 to 1995 and declined 41.4% over the entire study period.

Lymph node–positive breast cancer, locally advanced breast cancer, and breast cancer mortality

From 1988 to 2005, 68,686 breast cancers were lymph node–positive (Table 1). The overall age-and-race–adjusted lymph node–positive breast cancer rate declined from 1988 to 1996 (2.3% per year), increased from 1996 to 2000 (5.4% per year), and then declined again until 2005 (2.9% per year). The absolute disparity in lymph node–positive breast cancer rate declined 8.9% per year from 1988 to 1993 and remained stable thereafter for an overall

Table 2. Trends (years and EAPC) in five breast cancer indicator rates, absolute disparity (BGV), and relative disparity (MLD), 1988 to 2005

Breast cancer indicator	Trend 1		Trend 2		Trend 3		Percentage of change, 1988-2005	Deviance Information Criterion
Disparity measure	Years	EAPC	Years	EAPC	Years	EAPC		
In situ incidence	1988-2000	6.3*	2000-2005	−1.1				
BGV	1988-1993	2.4	1993-1999	15.6*	1999-2005	−5.3*	93.7	21,819
MLD	1988-2005	−5.5*					61.5	21,819
Stage I incidence	1988-2000	1.8*	2000-2005	−4.6*				
BGV	1988-2005	−1.2					−18.5	29,381
MLD	1988-1995	−6.1*	1995-2005	−0.9			−41.4	29,381
Lymph node positive	1988-1996	−2.3*	1996-2000	5.4*	2000-2005	−2.9*		
BGV	1988-1993	−8.9*	1993-2005	0.1			−37.9	27,184
MLD	1988-2005	−1.1*					−17.6	27,184
LABC incidence	1988-1993	−4.7*	1993-2001	0.9	2001-2005	−6.8*		
BGV	1988-1993	−10.4*	1993-1998	−0.7	1998-2005	−7.0*	−66.5	19,611
MLD	1988-2002	−2.8*	2002-2005	7.1			−17.8	19,611
Mortality rate	1988-2005	−2.0*						
BGV	1988-2005	−5.3*					−60.5	25,907
MLD	1988-2005	−1.3*					−19.8	25,907

*$P < 0.05$; BGV, absolute disparity; MLD, relative disparity. Because BGV and MLD were calculated during the same winBUGS run, the DIC values are from the same model

Published OnlineFirst March 30, 2010; DOI: 10.1158/1055-9965.EPI-09-0966

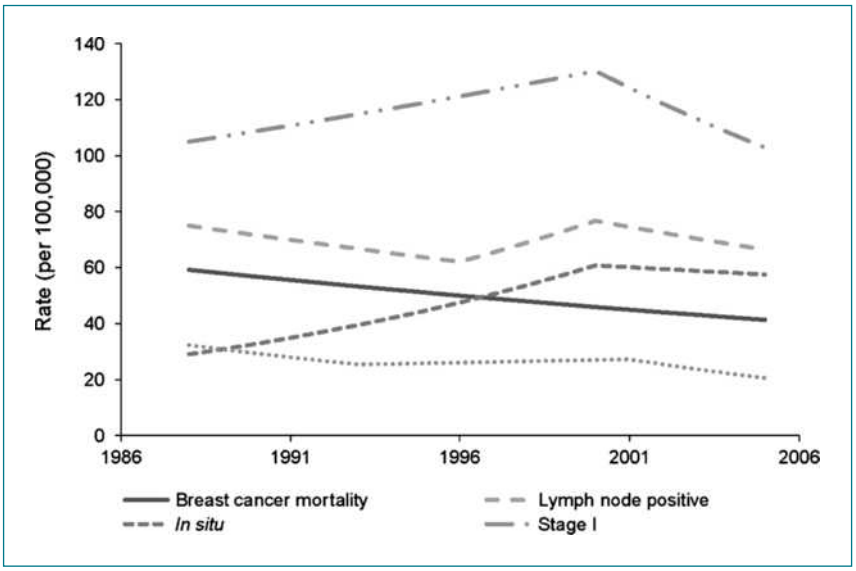

Figure 1. Adjusted, observed breast cancer indicator rates over time based on joinpoint analysis, 1988 to 2005.

decline of 37.9% during the study period (Table 2; Fig. 4). The relative disparity declined by 1.1% per year and 17.6% over the entire study period.

From 1988 to 2005, there were 25,699 LABC cases diagnosed (Table 1). The overall age-and-race–adjusted LABC rate declined 4.7% per year from 1988 to 1993 (Table 2; Fig. 5), after which the LABC rate remained stable and then declined 6.8% per year from 2001 to 2005. The absolute disparity in LABC rates declined 10.4% per year from 1988 to 1993, remained stable from 1993 to 1998, and then further declined 7.0% per year after 1998. Overall, the absolute disparity in LABC rate declined 66.5% from 1988 to 2005. The relative disparity in LABC declined 2.8% per year from 1988 to 2002 and then remained stable after 2002 for an overall decline of 17.8% because 1988.

From 1988 to 2005, there were 55,774 breast cancer deaths (Table 1). During this time period, the overall breast cancer mortality rate decreased 2.0% per year (Table 2; Fig. 6). The absolute disparity in breast cancer mortality declined 5.3% per year for an overall decline of 60.5% since 1988. The relative disparity in breast cancer mortality rates declined 1.3% per year for an overall decline of 19.8% since 1988.

Table 3 displays priority counties for lymph node–positive breast cancer, which was selected because of the lack of change in the absolute disparity measure and the very small change in relative disparity measure over time. The nine classes of counties were based on the 1988 to 2005 changes in the estimated county lymph node–positive breast cancer rate relative to the age-race–adjusted lymph node–positive rate across the 200 counties

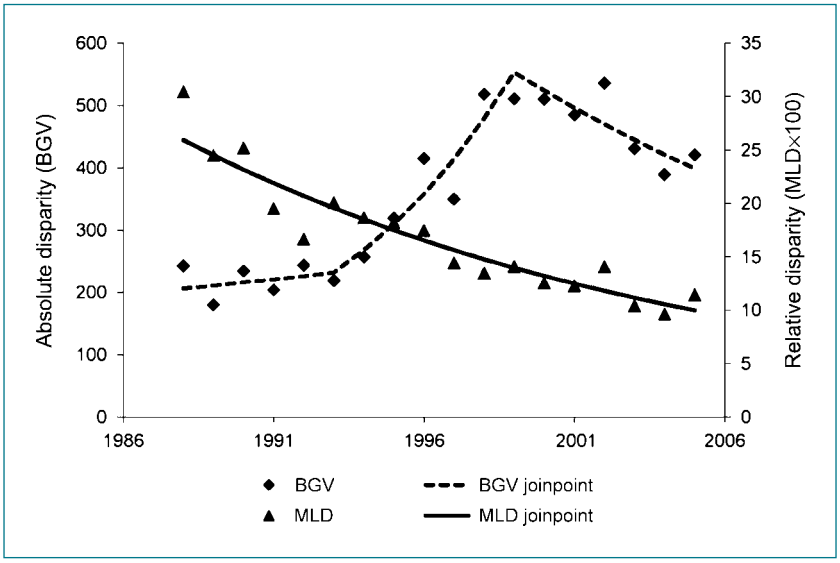

Figure 2. Absolute and relative geographic disparity over time for *in situ* breast cancer, 1988 to 2005.

Published OnlineFirst March 30, 2010; DOI: 10.1158/1055-9965.EPI-09-0966

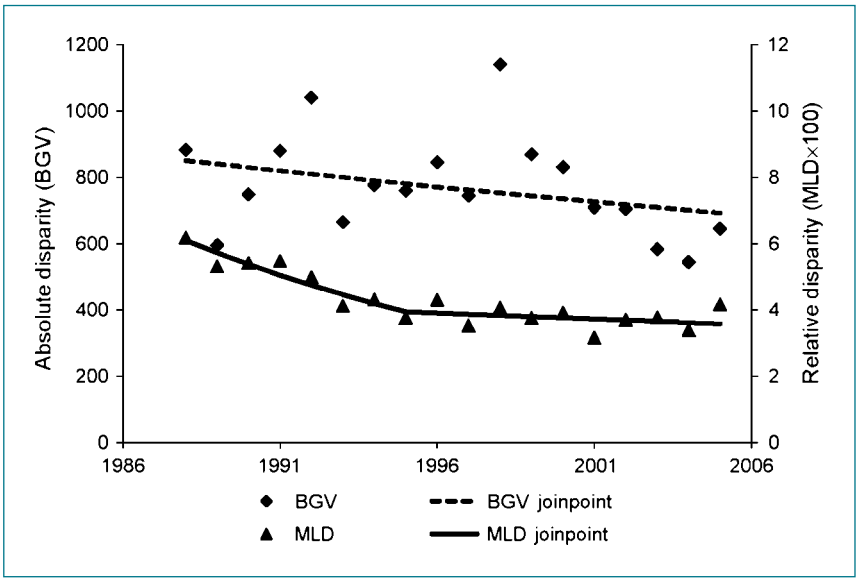

Figure 3. Absolute and relative geographic disparity over time for stage I breast cancer, 1988 to 2005.

and the difference in estimated county rate and the age-race–adjusted lymph node–positive rate across the 200 counties in 2005. Fifty-one counties were classified as hotspots or probable hotspots, which accounted for 25.5% of the 200 counties. Interestingly, there were no counties classified as hotspots or probable hotspots in the Atlanta area, Hawaii, the Detroit area, the San Francisco/Oakland area, and Connecticut. In Iowa, 32 counties (32.3% of 99 Iowa SEER counties) were (probable) hotspots, 8 counties (24.2% of 33 New Mexico counties) were hotspots in New Mexico; 8 counties (27.6% of 29 Utah counties) were hotspots in Utah; and 3 counties (23.1% of 13 area counties) were hotspots in the Seattle/Puget Sound area. The number of (probable) hotspots was overrepresented in the New Mexico, Utah, and Seattle/Puget Sound area based on the number of counties in these areas in SEER. Forty-one counties were considered to be of the lowest priority (Table 3).

Discussion

The purpose of this study was to examine trends over time in absolute and relative geographic disparity in five breast cancer screening indicators using 1988 to 2005 population-based SEER data. Disparities narrowed since 1988 for all indicators except for *in situ* breast cancer. Important progress has been made toward achieving the Healthy People 2010 and NCI strategic objectives for reducing disparities, particularly in LABC incidence and mortality rates. Despite trends over time, geographic

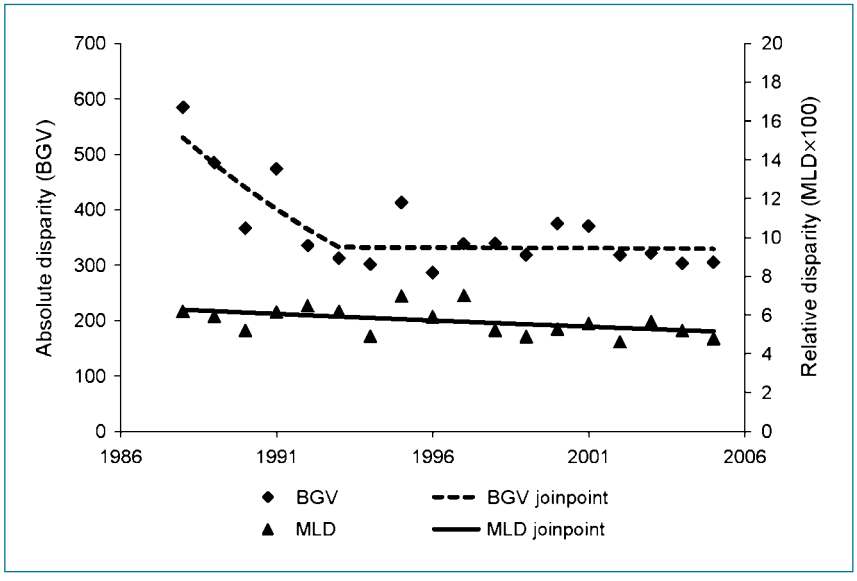

Figure 4. Absolute and relative geographic disparity over time for lymph node–positive breast cancer, 1988 to 2005.

Published OnlineFirst March 30, 2010; DOI: 10.1158/1055-9965.EPI-09-0966

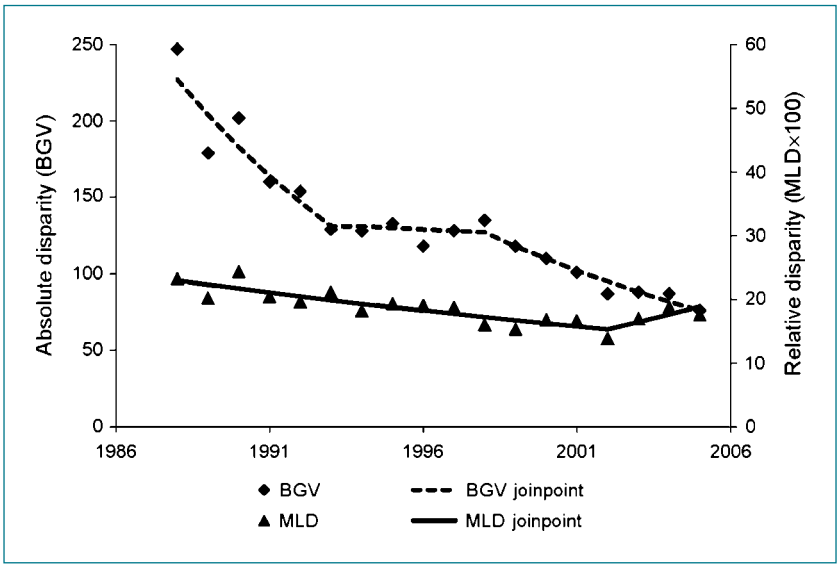

Figure 5. Absolute and relative geographic disparity over time for LABC, 1988 to 2005.

disparities in breast cancer screening indicators remained. This suggests that not all counties studied benefited from early detection of breast cancer.

The age-and-race–adjusted *in situ* breast cancer rate as well as absolute disparity increased dramatically from 1988 to 2000, whereas relative disparity declined during the entire study period. This suggests that the *in situ* breast cancer rate for some counties increased faster, particularly from 1993 to 1999 (15.6% per year), whereas the rates for other counties lagged behind. Increased mammography use likely contributed to the increase in incidence of *in situ* breast cancers from 1988 to 2000 (36). It is also likely that there was geographic variation in mammography adoption during this time period. There was a sudden change in absolute disparity starting in 1999, which may have been related to geographic variation in saturation of mammography use (37, 38) and/or declines in the use of hormone replacement therapy (39). Between 2000 and 2005, nationwide use of screening mammography fell by 4% overall among women ages 40 years or older and by ~7% among women ages 50 to 64 years of age (8). Starting in 1999, both absolute and relative disparity in *in situ* breast cancer rates declined. Continued monitoring of geographic disparities in *in situ* breast cancer rates is warranted in light of recent changes in mammography and hormone replacement therapy use.

For stage I breast cancer, the overall age-and-race–adjusted rate increased until 2000, after which it declined. During the entire study period, absolute and relative disparity declined, suggesting that the stage I incidence rates for some counties changed more rapidly than incidence rates for other counties but that the variation across

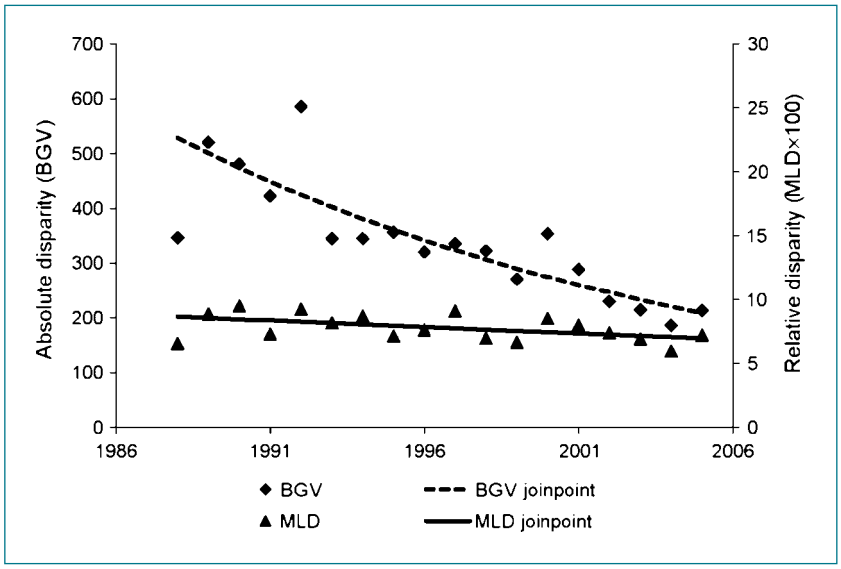

Figure 6. Absolute and relative geographic disparity over time for breast cancer mortality, 1988 to 2005.

Published OnlineFirst March 30, 2010; DOI: 10.1158/1055-9965.EPI-09-0966

Table 3. Nine classes of priority counties based on county-level changes in lymph node–positive breast cancer incidence rates, 1988 to 2005

Classes	Ratio of 1988-2005 changes in county rate vs overall rate*	Difference between county rate and overall rate in 2005	No. of counties
Class 1: definite hotspots	<–2.0	>10/100,000	35
Class 2: probable hotspots	<–2.0	±10/100,000	16
Class 3: moderate priority	<–2.0	<–10/100,000	6
Class 4: moderate priority	±2.0	>10/100,000	13
Class 5: moderate priority	>2.0	>10/100,000	5
Class 6: lower priority	±2.0	±10/100,000	30
Class 7: lower priority	±2.0	<–10/100,000	36
Class 8: lower priority	>2.0	±10/100,000	18
Class 9: lowest priority	>2.0	<–10/100,000	41

*Ratio, <–2.0: the county rate change from 1988 to 2005 was at least twice slower than the overall predicted change during this time period; ratio, >2.0: the county rate change from 1988 to 2005 was at least twice faster than the overall predicted change during this time period

counties diminished over time and became more similar to the overall stage I breast cancer rate.

Overall, declines were observed for lymph node–positive and LABC rates from 1988 to 2005. This is particularly important because both are indicators of reductions in breast cancer mortality (4, 9-11). However, absolute disparity plateaued for lymph node–positive breast cancer and LABC starting in 1993, but then further declined for LABC starting in 1998. Mammography use likely played a role in the changes in both rates over time because early detection is associated with smaller tumor size, lower histologic grade, and lower likelihood of lymph node invasion (4). The changes in disparities over time may be the result, therefore, of increases in county mammography rates similar to overall increases in mammography use, but there was no "catching up" by counties starting out with lower mammography rates in terms of the prevention of lymph node metastasis.

For mortality, the overall rate declined linearly over time as did absolute and relative disparity. This suggests that all SEER counties progressed toward the reduction in the overall age-and-race–adjusted mortality rate, thereby making progress toward the Healthy People 2010 goal and one of the NCI's key strategic objectives (16). It is expected that reductions in disparity in county mammography use and implementation of evidence-based treatment contributed to the reduction in geographic disparity in breast cancer mortality, just as they accounted for changes in the overall breast cancer mortality rate over time (40).

Studies are needed to more fully understand the geographic disparity of the breast cancer indicators examined to replicate the findings. Established risk factors for breast cancer in women include older age, a family history of breast cancer, greater height, adult weight gain, high birth weight, alcohol intake, high mammographic density, postmenopausal hormone use, and certain reproductive factors, including earlier menarche, older age at first pregnancy, shorter duration of breast feeding, lower parity, longer interval between births, and greater body mass index in postmenopausal women (41). Changes in some of these risk factors, such as hormone replacement use, may have contributed to changes in breast cancer incidence at the population level (42). Unfortunately, much less is known if changes in some of these risk factors contributed to changes in geographic disparity in population-based breast cancer rates. The prevalence of these risk factors should vary across space and time to affect changes in geographic disparities in the breast cancer indicators observed. Future research should focus on examining trends in disparities related to breast cancer risk factors, particularly in light of changes in disparities observed in the breast cancer indicators. Moreover, future studies should examine remaining disparities in specific counties that were identified, such as those with lymph node–positive breast cancer rates that changed little over time and remained elevated in 2005.

Our study has some limitations. First, we restricted our data to women ages 40 years and older to focus on the age group that accounts for the majority of breast cancer cases and effectiveness of breast cancer screening. Second, we used county as the smallest geographic entity within a state because it is the smallest geographic unit with the social, political, and legal responsibility for providing a broad range of services, including health-related services. It also is recognized that comparisons across counties presents several challenges in that one county in one state (e.g., San Francisco) is likely to be comparable with several counties in another state (e.g., Iowa) in terms of size and population density. However, a strength of our Bayesian analysis is that we took into account the spatial relationships among counties, which

Published OnlineFirst March 30, 2010; DOI: 10.1158/1055-9965.EPI-09-0966

have been ignored in many ecological analyses. These types of analyses provided many useful features, including the smoothed posterior estimates of the county breast cancer rates we used in the current analysis. Because of our use of the smoothed county rates, disparity measures were less likely affected by extreme rates that were based on few breast cancers or small population size. Consequently, Bayesian methods seem to be more appropriate. Our analysis went beyond describing changes in geographic disparities across the 200 counties to identify also several priority counties.

We recognize that the breast cancer screening indicators are not independent of each other. For example, 53.7% of women diagnosed with LABC had positive lymph nodes and some women (3.3%) who were diagnosed with breast cancer earlier during the study period subsequently died. Regardless of the overlap, we observed important differences across the indicators. Moreover, there are specific biological reasons for focusing on each of the breast cancer indicators (4).

In conclusion, we observed important declines in absolute and relative geographic disparity over time, particularly in LABC incidence and breast cancer mortality rates. This suggests important progress toward achieving Healthy People 2010 and NCI objectives to reduce geographic disparities. However, disparities in county rates remained for *in situ*, stage I, lymph node–positive breast cancer, and breast cancer mortality, indicating a need for continued monitoring and further study to determine where to target efforts to reduce remaining disparities.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

Acknowledgments

We thank the Alvin J. Siteman Cancer Center at Barnes-Jewish Hospital and Washington University School of Medicine in St. Louis, Missouri, for allowing the use of the Health Behavior and Outreach Core.

Grant Support

Grants from the NCI (CA109675, CA91842).
The costs of publication of this article were defrayed in part by the payment of page charges. This article must therefore be hereby marked *advertisement* in accordance with 18 U.S.C. Section 1734 solely to indicate this fact.

Received 09/17/2009; revised 01/11/2010; accepted 01/29/2010; published OnlineFirst 03/30/2010.

References

1. American Cancer Society. Cancer Facts & Figures. Atlanta: American Cancer Society; 2009.
2. Kerlikowske K, Grady D, Rubin SM, Sandrock C, Ernster VL. Efficacy of screening mammography: a meta-analysis. JAMA 1995;273:149–254.
3. van den Akker-van Marle E, de Koning H, Boer R, van der Maas P. Reduction in breast cancer mortality due to the introduction of mass screening in the Netherlands: comparison with the United Kingdom. J Med Screen 1999;6:30–4.
4. Tabar L, Duffy SW, Vitak B, Chen HH, Prevost TC. The natural history of breast carcinoma. What have we learned from screening? Cancer 1999;86:449–62.
5. Feig SA. Effect of service screening mammography on population mortality from breast carcinoma. Cancer 2002;95:451–7.
6. Breen N, Wagener DK, Brown ML, Davis WW, Ballard-Barbash R. Progress in cancer screening over a decade: results of cancer screening from the 1987, 1992, and 1998 National Health Interview Surveys. J Natl Cancer Inst 2001;93:1704–13.
7. Swan J, Breen N, Coates RJ, Rimer BK, Lee NC. Progress in cancer screening practices in the United States: results from the 2000 National Health Interview Survey. Cancer 2003;97:1528–40.
8. Breen N, Cronin K, Meissner H, et al. Reported drop in mammography. Cancer 2007;109:2405–9.
9. Norden T, Thurfjell E, Hasselgren M, et al. Mammographic screening for breast cancer. What cancers do we find? Eur J Cancer 1997;33:624–8.
10. Tabar L, Fagerberg G, Duffy SW, Day NE, Gad A, Grontoft O. Update of the Swedish two-county program of mammographic screening for breast cancer. Radiol Clin North Am 1992;30:187–210.
11. Dongen JA. The usefulness of screening data for studying the biology of breast cancer. Eur J Cancer 1997;33:519–20.
12. Chu KC, Tarone RE, Kessler LG, et al. Recent trends in U.S. breast cancer incidence, survival, and mortality rates. J Natl Cancer Inst 1996;88:1571–9.
13. Edwards BK, Brown ML, Wingo PA, et al. Annual report to the nation on the status of cancer, 1975-2002, featuring population-based trends in cancer treatment. J Natl Cancer Inst 2005;97:1407–27.
14. American Cancer. Breast Cancer Facts & Figures 2007-2008. Atlanta (GA): American Cancer Society; 2007.
15. U.S. Department of Health and Human Services. Healthy People 2010. With Understanding and Improving Health and Objectives for Improving Health. Washington, DC: U.S. Government Printing Office; 2000.
16. National Cancer Institute. The NCI Strategic Plan for Leading the Nation to Eliminate the Suffering and Death Due to Cancer. Washington, DC: National Cancer Institute, US Department of Health and Human Services; 2006.
17. Liff JM, Chow WH, Greenberg RS. Rural-urban differences in stage at diagnosis: possible relationship to cancer screening. Cancer 1991;67:1545–59.
18. Howe HL, Katterhagen JG, Yates J, Lehnherr M. Urban-rural differences in the management of breast cancer. Cancer Causes Control 1992;3:533–9.
19. Schootman M, Jeffe DB, Baker EA, Walker MS. Effect of area poverty rate on cancer screening across US communities. J Epidemiol Community Health 2006;60:202–7.
20. Day NE, Williams DRR, Khaw KT. Breast cancer screening programmes: the development of a monitoring and evaluation system. Br J Cancer 1989;59:954–8.
21. Fleming ID, Cooper JS, Henson DE, et al. AJCC Cancer Staging Manual. 5th ed. Philadelphia: Lippincott-Raven; 1997.
22. Tabar L, Duffy SW, Yen MF, et al. All-cause mortality among breast cancer patients in a screening trial: support for breast cancer mortality as an end point. J Med Screen 2002;9:159–62.
23. Houweling T, Kunst A, Huisman M, Mackenbach J. Using relative and absolute measures for monitoring health inequalities: experiences from cross-national analyses on maternal and child health. Int J Equity Health 2007;6:15.
24. DeSantis C, Jemal A, Ward E, Thun M. Temporal trends in breast cancer mortality by state and race. Cancer Causes Control 2008;19:537–45.
25. Kim H, Fay M, Feuer E, Midthune D. Permutation tests for joinpoint regression with applications to cancer rates. Stat Med 2000;19:335–51.

Published OnlineFirst March 30, 2010; DOI: 10.1158/1055-9965.EPI-09-0966

26. Joinpoint Regression Program, Version 3.2. Bethesda (MD).
27. Knorr-Held L. Bayesian modelling of inseparable space-time variation in disease risk. Stat Med 2000;19:2555–67.
28. Besag J, York J, Mollie A. Bayesian image restoration with two applications in spatial statistics. Ann Inst Stat Math 1991;43:1–59.
29. United Stated Geological Survey. Adjacency for WinBUGS tool. Online at: http://www.umesc.usgs.gov/management/dss/adjacency_tool.html. Last accessed: August 12, 2009.
30. National Cancer Institute. Cancer Health Disparities. Online at: http://www.cancer.gov/cancertopics/factsheet/cancer-health-disparities. 2009. Accessed October 26, 2009.
31. Harper S, Lynch J. Methods for Measuring Cancer Disparities: A Review Using Data Relevant to Healthy People 2010 Cancer-Related Objectives. Washington, DC: National Cancer Institute; 2006.
32. Harper S, Lynch J. Measuring health inequalities. In: Oakes J, Kaufman J, editors. Methods in Social Epidemiology. San Francisco: Jossey-Bass; 2006, p. 134–68.
33. Spiegelhalter D, Best N, Carlin B, van der Linde A. Bayesian measures of model complexity and fit (with discussion). J R Stat Soc Ser B Methodol 2002;64:583–616.
34. Li W, Kelsey JL, Zhang Z, et al. Small-area estimation and prioritizing communities for obesity control in Massachusetts. Am J Public Health 2009;99:511–9.
35. Li W, Land T, Zhang Z, Keithly L, Kelsey JL. Small-area estimation and prioritizing communities for tobacco control efforts in Massachusetts. Am J Public Health 2009;99:470–9.
36. Li CI, Daling JR. Changes in breast cancer incidence rates in the United States by histologic subtype and race/ethnicity, 1995 to 2004. Cancer Epidemiol Biomarkers Prev 2007;16:2773–80.
37. Jemal A, Ward E, Thun M. Recent trends in breast cancer incidence rates by age and tumor characteristics among U.S. women. Breast Cancer Res 2007;9:R28.
38. Schootman M, Aft R. Rural-urban differences in radiation therapy for ductal carcinoma in-situ of the breast. Breast Cancer Res Treat 2001;68:117–25.
39. Hausauer A, Keegan T, Chang E, Glaser S, Howe H, Clarke C. Recent trends in breast cancer incidence in US white women by urban/rural and poverty status. BMC Med 2009;7:31.
40. Blanks RG, Moss SM, McGahan CE, Quinn MJ, Babb PJ. Effect of NHS breast screening programme on mortality from breast cancer in England and Wales, 1990-8: comparison of observed with predicted mortality. Br Med J 2000;321:665–9.
41. Colditz GA, Rosner B. Cumulative risk of breast cancer to age 70 years according to risk factor status: data from the Nurses' Health Study. Am J Epidemiol 2000;152:950–64.
42. Krieger N. Hormone therapy and the rise and perhaps fall of US breast cancer incidence rates: critical reflections. Int J Epidemiol 2008;37:627–37.

Cancer Epidemiology, Biomarkers & Prevention

AACR American Association for Cancer Research

Temporal Trends in Geographic Disparities in Small-Area Breast Cancer Incidence and Mortality, 1988 to 2005

Mario Schootman, Min Lian, Anjali D. Deshpande, et al.

Cancer Epidemiol Biomarkers Prev 2010;19:1122-1131. Published OnlineFirst March 30, 2010.