Medical Advances and Racial/Ethnic Disparities in Cancer Survival

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Abstract

Background: Although advances in early detection and treatment of cancer improve overall population survival, these advances may not benefit all population groups equally and may heighten racial/ethnic differences in survival.

Methods: We identified cancer cases in the Surveillance, Epidemiology and End Results program, who were ages ≥20 years and diagnosed with one invasive cancer in 1995 to 1999 (n = 580,225). We used 5-year relative survival rates to measure the degree to which mortality from each cancer is amenable to medical interventions (amenability index). We used Kaplan-Meier methods and Cox proportional hazards regression to estimate survival differences between each racial/ethnic minority group relative to Whites, by the overall amenability index, and three levels of amenability (nonamenable, partly amenable, and mostly amenable cancers, corresponding to cancers with 5-year relative survival rate <40%, 40-69%, and ≥70%, respectively), adjusting for gender, age, disease stage, and county-level poverty concentration.

Results: As amenability increased, racial/ethnic differences in cancer survival increased for African Americans, American Indians/Native Alaskans, and Hispanics relative to Whites. For example, the hazard ratios (95% confidence intervals) for African Americans versus Whites from nonamenable, partly amenable, and mostly amenable cancers were 1.05 (1.03-1.07), 1.38 (1.34-1.41), and 1.41 (1.37-1.46), respectively. Asians/Pacific Islanders had similar or longer survival relative to Whites across amenability levels; however, several subgroups experienced increasingly poorer survival with increasing amenability.

Conclusions: Cancer survival disparities for most racial/ethnic minority populations widen as cancers become increasingly amenable to medical interventions. Efforts in developing cancer control measures must be coupled with specific strategies for reducing the expected disparities.

(Cancer Epidemiol Biomarkers Prev 2009;18(10):2701–8)

Introduction

In the last several decades, remarkable improvements in cancer survival have been made through advances in early detection and treatment of many cancers (1). However, all segments of the population have not equally benefited and the burden of cancer is disproportionately borne by the socioeconomically disadvantaged and racial/ethnic minorities (2-4). According to data from the Surveillance, Epidemiology and End Results (SEER) registries for cancer cases diagnosed in 1998 to 2000, all racial/ethnic populations, with the exception of Asian/Pacific Islander women, experienced lower survival than non-Hispanic Whites. More long-term data, available only for African American and White cancer cases in the SEER registries, also show that survival disparities have persisted over the last several decades (1).

A growing body of research has identified many factors contributing to cancer survival disparities by race/ethnicity, with the most convincing evidence pointing to the higher distribution of more advanced disease stage at diagnosis, less adequate health care, and greater prevalence of comorbidities among many racial/ethnic minority populations compared to Whites (2, 5-8). This research provides important information about specific factors and pathways involved in disparities, but it has not sought to explain or been able to elucidate why social disparities in cancer vary across cancer sites and time periods. In this article, we propose an explanation as to why disparities exist in some time periods and not others, and why disparities strongly characterize some cancer sites while leaving other cancer sites unaffected. We propose that social disparities emerge in situations where the knowledge, technology, and effective medical interventions for controlling a disease exist, allowing individuals with greater access to important social and economic resources (e.g., knowledge, income, and beneficial social relations) to delay and avoid death from that disease. In contrast, in situations where effective medical interventions are absent or negligible, social and economic resources are of limited utility, and survival differences between the most and the least socially advantaged persons are minimal (9, 10). Applying this line of argument to racial/ethnic disparities in cancer survival, the greater importance of resources for cancers that are amenable to medical interventions would lead to significantly larger survival disparities than what would be observed for cancers with more limited early detection and treatment capacities. We tested this prediction by comparing...
racial/ethnic differences in cancer survival across 53 cancer sites among adult cancer cases in the SEER program, diagnosed in 1995 to 1999 and followed through 2004.

Materials and Methods

Data Source and Population Selection. We obtained de-identified data from population-based registries participating in the National Cancer Institute SEER program. The SEER registries collect information on cancer cases in selected states and metropolitan areas, including information on cancer diagnosis and treatment, patient demographic, vital status, and cause of death. Through linkage with the U.S. Census survey data, socioeconomic data, aggregated at cases’ county of residence, are also available.

Because our primary interest was racial/ethnic differences in cancer-specific survival, we excluded cases who were diagnosed with (a) in situ cancers (International Classification of Diseases, Ninth Revision codes 230-234, 273, and 289); (b) more than one invasive cancer site; (c) ill-defined, unspecified, or unknown cancer site (International Classification of Diseases, Ninth Revision codes 149, 159, 165, 195, 196, 199, 208, 235, 236, 238, and 999); or (d) a cancer that was not microscopically confirmed (e.g., based solely on death certificate, autopsy, or radiologic/imaging information). We further restricted our analysis to cases that were diagnosed between January 1, 1995 and December 31, 1999, with follow-up data through December 31, 2004, to construct a recent cohort of cases with sufficient follow-up time (5-10 years) and a narrow period to minimize significant changes in medical interventions. Additional exclusion criteria included cases ages <20 years (n = 8,434) and those with missing data on cause of death (n = 6,302), race/ethnicity (n = 6,041), or socioeconomic status (SES; n = 1,062). The final sample included 580,225 cases diagnosed with 53 cancers sites, accounting for 96% of all cases in SEER during the specified period. The cases were drawn from the registries for the states of Connecticut, Iowa, New Mexico, Utah, and Hawaii, the metropolitan areas of Atlanta, Detroit, San Francisco/Oakland, and Seattle/Puget Sound, Los Angeles County, and several counties in the San Jose/Monterey area and in rural Georgia.

Variable Definition

Outcome. The study outcome was cancer-specific survival, defined as the time interval (in months) between the dates of diagnosis and death from any cancer when applicable, or the date of last follow-up or death due to noncancer causes. Because cases with multiple cancers were excluded, death from any cancer was most likely due to the cancer site for which cases were selected and was therefore used as the event of interest. Cases that did not die or died of causes other than cancer were censored at the date of death or last follow-up.

Amenability of Cancer Survival. We used relative survival rates (RSR) to develop a measure of the degree to which survival from a specific cancer is amenable to medical interventions (amenability index). The RSR is the ratio of observed survival in a patient cohort and the expected survival of a cohort having the same characteristics as the patient cohort in the general population. Because the main difference between a cohort of cancer cases and a similar cohort in the general population is the presence of cancer in the former, the RSR essentially reflects survival from the underlying cancer after correction for other causes of death present in the population (11). The RSR for a cancer is improved by (a) earlier detection of the cancer and/or (b) increased success of treatment due to earlier detection, timely or effective treatment options. Differences in RSRS across cancer sites within a specified period may therefore provide a reasonable measure of adequacy of early detection and treatment services for one cancer site relative to other cancer sites. Using the National Cancer Institute SEER*Stat software (12), we calculated 5-year RSRS for 53 cancer sites among cases, ages ≥20 years and diagnosed in 1995 to 1999, excluding cases with multiple primary tumors or tumors that were not microscopically confirmed (e.g., identified only through death certificate and autopsy). The final amenability index ranged from 5% for pancreatic cancer to 99% for prostate cancer. We used this index as both a continuous variable and categorized into three levels of nonamenable, partly amenable, and mostly amenable cancers with <40%, 40% to 69%, and ≥70% 5-year RSRS, respectively. These cut points were chosen to divide the index into three categories of roughly equal number of cancer site while at the same time considering breaks in the index values.

Race/Ethnicity. Hispanics of any race were classified as Hispanic; all other cases were defined by their racial/ethnic group as White, African American, Asian/Pacific Islander, and American Indian/Alaska Native. We used additional available information for Hispanics and Asians/Pacific Islanders to create subpopulation groups with at least 1,000 cases, resulting in four Hispanic subgroups of Mexicans (25.2%), Puerto Ricans (2.9%), South or Central Americans excluding Brazil (10.4%), and other Hispanics (59.6% unknown origin, 2.0% Cubans) and eight Asian/Pacific Islander subgroups of Japanese (23.6%), Chinese (23.4%), Filipinos (22.1%), Hawaiians (6.9%), Koreans (6.9%), Vietnamese (5.6%), Asian Indians or Pakistanis (3.2%), and other Asians/Pacific Islanders (4.8% unknown origin and all others <1%).

Covariates. Covariates included age and disease stage at diagnosis, gender, and SES. Disease stage was based on summary staging scheme, classifying cancers into localized, regional, distant, and unstaged by the extent of the spread of cancer from its original site. SES was measured by the percent of persons living below the federally defined poverty threshold in 1999 in the patient’s county of residence and categorized into three levels of <10%, 10% to 19%, and ≥20%.

Data Analysis and Statistical Methods. We used Kaplan-Meier methods to estimate cancer-specific survival rates by racial/ethnic and amenability levels and Cox proportional hazards models to estimate the relative risk of mortality (expressed as hazard ratios [HR]) and their 95% confidence intervals (95% CI) for cancer-specific mortality for each racial/ethnic minority group, with Whites as the reference group, adjusting for age, disease stage, gender, and SES (13). We tested the interaction between race and amenability by including a cross-product of the relevant variables into the Cox models that adjusted for potential confounders and examining the log-likelihood ratio tests between the models with and without the cross-product term. All significance tests were two-sided and conducted at the
Sensitivity Analyses. We conducted additional Cox regression analyses to assess the robustness of the findings. (a) We excluded cases with cancers of lung and bronchus, female breast, prostate, and colon to examine whether survival patterns were primarily influenced by these common cancers. (b) We excluded cases with cancers of prostate and thyroid with long survival periods, which at least partly reflect the slow growth of these tumors and not high amenability to medical interventions. Exclusion of these cancers (previously classified as mostly amenable) was expected to further increase racial/ethnic differences in survival from mostly amenable cancers. (c) We examined racial/ethnic patterns in survival from noncancer causes of death (selected as events while alive status and death to cancer causes were censored at the last follow-up date and death date, respectively) to test whether the amenability measure reflected cancer-directed medical interventions and hence was only specific and predictive of racial/ethnic disparities in death from cancer and not other causes of death.

Results

The median follow-up time after a cancer diagnosis was 5.3 years (range, 0.0-9.9 years). As seen in Table 1, 10.7%, 16.5%, and 21.7% of cancer cases with nonamenable, partly amenable, and mostly amenable cancers were <50 years old, respectively. As expected, majority of cases with mostly amenable cancers were diagnosed with localized stage (72.5%), whereas the proportion of cases with localized stage for partly and nonamenable cancers were

Table 1. Percent distribution of sociodemographic characteristics, vital status, and disease stage by amenability levels in study population, 11 SEER registries, patients ages ≥20 years, diagnosed from 1995 to 1999 with follow-up through 2004

<table>
<thead>
<tr>
<th>Year of diagnosis</th>
<th>Total (n = 580,225)</th>
<th>Nonamenable* (n = 142,488)</th>
<th>Partly amenable† (n = 142,596)</th>
<th>Mostly amenable‡ (n = 295,141)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>19.0</td>
<td>19.5</td>
<td>19.1</td>
<td>18.7</td>
</tr>
<tr>
<td>1996</td>
<td>19.4</td>
<td>19.8</td>
<td>19.5</td>
<td>19.2</td>
</tr>
<tr>
<td>1997</td>
<td>20.1</td>
<td>20.0</td>
<td>20.1</td>
<td>20.1</td>
</tr>
<tr>
<td>1998</td>
<td>20.5</td>
<td>20.4</td>
<td>20.6</td>
<td>20.5</td>
</tr>
<tr>
<td>1999</td>
<td>21.0</td>
<td>20.3</td>
<td>20.7</td>
<td>21.5</td>
</tr>
</tbody>
</table>

Age at diagnosis (y)

- 20-34: 3.8, 1.8, 3.2, 5.1
- 35-49: 13.9, 8.9, 13.3, 16.6
- 50-64: 28.8, 28.2, 27.1, 29.9
- 65-79: 40.1, 46.8, 38.8, 37.4
- ≥80: 13.5, 14.3, 17.7, 11.0

Stage at diagnosis

- Localized: 47.6, 14.2, 29.4, 72.5
- Regional: 21.9, 28.4, 26.6, 16.4
- Distant: 19.1, 44.2, 22.4, 5.4
- Unknown stage: 11.5, 13.2, 21.6, 5.8

Gender

- Male: 50.2, 56.6, 50.1, 47.1
- Female: 49.8, 43.4, 49.9, 52.9

Race/ethnicity

- African American: 9.5, 11.0, 9.2, 9.0
- American Indian/Alaska Native: 0.4, 0.4, 0.4, 0.3
- Asian/Pacific Islander: 7.1, 8.5, 7.7, 6.2
- Hispanic: 7.8, 7.4, 8.0, 7.8
- White: 75.2, 72.8, 74.7, 76.7

Residential county poverty concentration

- Least poor (<10%): 47.1, 45.8, 47.0, 47.7
- Medium poor (10-19%): 51.3, 52.5, 51.3, 50.7
- Poorest (≥20%): 1.6, 1.7, 1.7, 1.6

Vital status (as of December 31, 2004)

- Deceased (cause of death cancer): 36.4, 78.6, 40.0, 14.2
- Deceased (cause of death other than cancer): 13.4, 10.3, 16.4, 13.5
- Alive: 50.2, 11.1, 43.6, 72.3

1Low-amenability cancer sites (International Classification of Diseases, Ninth Revision code) have 5-y RSRs <40% and include pancreas (157), pleura (163), liver and intrahepatic bile ducts (155). Other specified leukemia (207), esophagus (150), trachea, lung and bronchus (162), monocytic leukemia (206), gallbladder and extrahepatic bile ducts (156), stomach (151), brain (191), myeloid leukemia (205), uterus, part unspecified (179), hypopharynx (148), myeloma (203), and retropertioneum and peritoneum (138).

2Medium-amenability cancer sites (International Classification of Diseases, Ninth Revision code) have 5-y RSRs of 40% to 69% and include ovary (183), lymphosarcoma and reticulosarcoma (200), floor of mouth (144), small intestine (152), endocervical glands and related structures excluding thyroid (194), nose, nasal cavities, and middle ear (160), thymus, heart, and mediastinum (164), trachea and oropharynx (146.3-146.9), tonsil (146.0-146.2), tongue (141), mouth excluding gum and floor and including unspecified parts of mouth (145), nasopharynx (147), gum (143), colon excluding rectum (153), larynx (161), rectum, rectosigmoid junction, and anus (154), kidney and other and unspecified urinary organs (189), lymphoid leukemia (204), connective and soft tissue excluding heart (171), and other malignant neoplasms of lymphoid and histiocytic tissue (202).

3High-amenability cancer site (International Classification of Diseases, Ninth Revision code) have 5-y RSR ≥70% and include other non epithelial skin (173), bone and articular cartilage (170), vagina, vulva, and other and unspecified female genital organs (184), nervous system excluding brain and including unspecified parts (192), cervix uteri (180), penis and other male genital organs (187), major salivary glands (142), male breast (175), eye (190), bladder (188), Hodgkin’s lymphoma (201), corpus uteri (182), female breast (174), placenta (181), melanoma of the skin (172), lip (140), testis (186), thyroid (193), and prostate (185).
significantly lower (29.4% and 14.2%, respectively). The proportion of cases dying from cancer was dramatically higher for nonamenable cancers than partly and mostly amenable cancers (78.6%, 40.0% and 14.2%, respectively). Males were overrepresented among the nonamenable cancer cases, but minimal racial/ethnic and socioeconomic differences across amenability levels existed.

Figure 1 displays survival curves for White cases and each of the four minority populations. As seen in Fig. 1 (top, left and right), the survival curves for African Americans and American Indians/Alaska Natives closely resembled the survival curve for Whites for nonamenable cancers, but the racial/ethnic gaps in survival curves quickly widened as amenability level increased from nonamenable to partly and mostly amenable cancers. Hispanics experienced a more favorable survival for nonamenable cancers compared to Whites, but this survival advantage was lost for partly amenable cancers, and their survival trailed behind Whites' survival for mostly amenable cancers (bottom, right). Asians/Pacific Islanders also had better survival than Whites for nonamenable cancers, a pattern that continued for partly amenable cancers until it diminished significantly for mostly amenable cancers (bottom, left).

Figure 2 shows the HR of cancer mortality associated with minority race per unit increase in amenability. Model included age at diagnosis, stage at diagnosis, gender, county-level poverty concentration, each race/ethnicity group, 5-y RSRs (amenability scale), and interaction between each race/ethnicity group and 5-y RSRs. Hispanics, had higher HR than Whites as cancer amenability increased. Differences in cancer survival between Asian/Pacific Islander and White cases did not depend on the amenability of cancer.

We also examined multiplicative interaction between race/ethnicity and categories of cancer amenability,

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Figure 1. Racial/ethnic differences in Kaplan-Meier survival curves by cancer amenability levels.

Figure 2. Change in adjusted HR of cancer-specific mortality associated with minority race per unit increase in amenability. Model included age at diagnosis, stage at diagnosis, gender, county-level poverty concentration, each race/ethnicity group, 5-y RSRs (amenability scale), and interaction between each race/ethnicity group and 5-y RSRs.
adjusting for each covariate one at a time before fitting a fully adjusted model (Table 2). Adjustment for gender did not affect racial/ethnic patterns in cancer survival by amenability, whereas county-level poverty concentration had a modest effect, with the largest influence observed for American Indians/Alaska Natives (≈4.0% reduction in HR). Adjustment for age generally increased the HR for partly and mostly amenable cancers, whereas adjusting for stage primarily reduced the HR for mostly amenable cancers. In fully adjusted models, the HR continued to increase with progressively higher levels of amenability for African American and American Indian/Alaska Native cases relative to White cases. A similar, but less pronounced, pattern was also observed for survival differences between Hispanic and White cases, with no survival differences for nonamenable cancers (HR, 1.01; 95% CI, 0.98-1.03) but poorer survival in Hispanics for partly amenable cancers (HR, 1.17; 95% CI, 1.14-1.21) and mostly amenable cancers (HR, 1.13; 95% CI, 1.09-1.17).

### Racial Subpopulation Groups

Figures 3 and 4 present the results of Cox regression models using Hispanic and Asian/Pacific Islander subgroups. The racial/ethnic differences in cancer survival for Hispanic subgroups compared to the White group became larger as amenability level increased. For example, the HR (95% CI) from nonamenable, partly amenable, and mostly amenable cancers were 0.96 (0.94-0.99), 1.04 (1.01-1.08), and 1.20 (1.16-1.24), respectively, for Mexicans compared to Whites. A similar, but less pronounced, pattern was also observed for survival differences between Hispanic and White cases, with no survival differences for nonamenable cancers (HR, 1.01; 95% CI, 0.98-1.03) but poorer survival in Hispanics for partly amenable cancers (HR, 1.17; 95% CI, 1.14-1.21) and mostly amenable cancers (HR, 1.13; 95% CI, 1.09-1.17).

#### Table 2. Adjusted relative risk and 95% CI of cancer-specific mortality for racial/ethnic minority groups with non-Hispanic Whites as the reference by cancer amenability levels

<table>
<thead>
<tr>
<th>Race/ethnicity</th>
<th>Amenability level</th>
<th>Unadjusted HR (95% CI)</th>
<th>Adjusted for age HR (95% CI)</th>
<th>Adjusted for gender HR (95% CI)</th>
<th>Adjusted for stage HR (95% CI)</th>
<th>Adjusted for poverty HR (95% CI)</th>
<th>Fully adjusted* HR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>African American</td>
<td>Nonamenable</td>
<td>1.05 (1.03-1.07)</td>
<td>1.11 (1.09-1.14)</td>
<td>1.05 (1.03-1.07)</td>
<td>1.00 (0.98-1.02)</td>
<td>1.03 (1.01-1.05)</td>
<td>1.05 (1.03-1.07)</td>
</tr>
<tr>
<td></td>
<td>Partly amenable</td>
<td>1.18 (1.15-1.22)</td>
<td>1.31 (1.27-1.35)</td>
<td>1.18 (1.15-1.22)</td>
<td>1.23 (1.20-1.27)</td>
<td>1.16 (1.12-1.19)</td>
<td>1.38 (1.34-1.41)</td>
</tr>
<tr>
<td></td>
<td>Mostly amenable</td>
<td>1.53 (1.49-1.58)</td>
<td>1.59 (1.54-1.64)</td>
<td>1.54 (1.49-1.58)</td>
<td>1.39 (1.35-1.43)</td>
<td>1.50 (1.45-1.54)</td>
<td>1.41 (1.37-1.46)</td>
</tr>
<tr>
<td>American Indian/Alaska</td>
<td>Nonamenable</td>
<td>1.08 (0.99-1.19)</td>
<td>1.15 (1.05-1.27)</td>
<td>1.08 (0.99-1.19)</td>
<td>1.06 (0.97-1.17)</td>
<td>1.02 (0.93-1.12)</td>
<td>1.10 (1.00-1.21)</td>
</tr>
<tr>
<td>Native</td>
<td>Partly amenable</td>
<td>1.17 (1.03-1.32)</td>
<td>1.36 (1.20-1.54)</td>
<td>1.17 (1.03-1.32)</td>
<td>1.17 (1.03-1.32)</td>
<td>1.10 (0.97-1.25)</td>
<td>1.34 (1.18-1.52)</td>
</tr>
<tr>
<td></td>
<td>Mostly amenable</td>
<td>1.49 (1.29-1.73)</td>
<td>1.69 (1.46-1.96)</td>
<td>1.49 (1.28-1.72)</td>
<td>1.25 (1.07-1.44)</td>
<td>1.41 (1.22-1.64)</td>
<td>1.42 (1.22-1.64)</td>
</tr>
<tr>
<td>Asian/Pacific Islander</td>
<td>Nonamenable</td>
<td>0.87 (0.85-0.89)</td>
<td>0.88 (0.86-0.90)</td>
<td>0.88 (0.86-0.89)</td>
<td>0.91 (0.89-0.93)</td>
<td>0.87 (0.85-0.89)</td>
<td>0.92 (0.90-0.94)</td>
</tr>
<tr>
<td></td>
<td>Partly amenable</td>
<td>0.88 (0.85-0.91)</td>
<td>0.93 (0.90-0.96)</td>
<td>0.88 (0.85-0.91)</td>
<td>0.94 (0.91-0.97)</td>
<td>0.88 (0.85-0.91)</td>
<td>1.01 (0.98-1.05)</td>
</tr>
<tr>
<td></td>
<td>Mostly amenable</td>
<td>0.95 (0.91-0.99)</td>
<td>0.99 (0.95-1.03)</td>
<td>0.95 (0.91-0.99)</td>
<td>0.86 (0.83-0.90)</td>
<td>0.95 (0.91-0.99)</td>
<td>0.90 (0.86-0.94)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>Nonamenable</td>
<td>0.96 (0.94-0.99)</td>
<td>1.05 (1.03-1.08)</td>
<td>0.96 (0.94-0.99)</td>
<td>0.91 (0.89-0.93)</td>
<td>0.94 (0.92-0.96)</td>
<td>1.01 (0.98-1.03)</td>
</tr>
<tr>
<td></td>
<td>Partly amenable</td>
<td>1.04 (1.01-1.08)</td>
<td>1.16 (1.13-1.20)</td>
<td>1.04 (1.01-1.08)</td>
<td>1.04 (1.01-1.08)</td>
<td>1.02 (0.98-1.05)</td>
<td>1.17 (1.14-1.21)</td>
</tr>
<tr>
<td></td>
<td>Mostly amenable</td>
<td>1.20 (1.16-1.24)</td>
<td>1.31 (1.27-1.36)</td>
<td>1.19 (1.15-1.24)</td>
<td>1.02 (0.99-1.06)</td>
<td>1.16 (1.12-1.20)</td>
<td>1.13 (1.09-1.17)</td>
</tr>
</tbody>
</table>

*Adjusted for age, gender, cancer stage, and poverty concentration.

### Figure 3

Adjusted HR of cancer-specific mortality comparing Hispanic subgroups to White racial group by amenability level.

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Cancer Epidemiol Biomarkers Prev 2009;18(10). October 2009
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separately than when using Asian/Pacific Islander as one group. Specifically, Native Hawaiians, Koreans, and Vietnamese had progressively worse survival than Whites with increasing amenability levels, a pattern observed for non–Asian/Pacific Islander racial/ethnic groups. Although Indians and Pakistanis had more favorable survival than Whites, their survival advantage decreased with increasing amenability levels [HR (95% CI) from nonamenable, partly amenable, and mostly amenable cancers were 0.67 (0.57-0.78), 0.69 (0.56-0.86), and 0.95 (0.77-1.16), respectively]. Chinese, Filipinos, Japanese, and other Asian/Pacific Islander had similar or better survival relative to Whites; however, the largest survival advantage for these groups was observed for mostly amenable cancers.

We observed modest racial/ethnic variation in the distribution of cancer sites. Lung and bronchus, female breast, prostate, lung, and colon cancers were the most common cancers in all racial/ethnic populations, accounting for cancer diagnosis in 62% of African American, 46% of American Indian/Alaska Native, 52% of Asian/Pacific Islander, 47% of Hispanic, and 55% of White cancer cases. The same common cancers were also represented within each level of amenability for all racial/ethnic populations as follows: lung and bronchus and stomach for nonamenable cancers, colon and rectum for partly amenable cancers, and female breast and prostate for mostly amenable cancers.

**Sensitivity Analyses.** Excluding cases diagnosed with the four most common cancers (~55% of all cases) did not significantly affect the overall findings, with the largest change observed for mostly amenable cancers in survival differences between American Indian/Alaska Native and Whites (14% reduction in HR from mostly amenable cancers). Removing cases with thyroid and prostate cancers widened the racial/ethnic disparities for mostly amenable cancer, increasing the HR by 18.3% for African Americans, 5.9% for American Indians/Alaska Natives, 10.1% for Asian/Pacific Islander, and 6.1% for Hispanics, all compared to Whites. We explored whether racial/ethnic differences in survival from noncancer causes of death also depended on amenability levels. The results showed that African Americans, American Indians/Alaska Natives, and Hispanics experienced lower survival from noncancer causes of death than Whites for all levels of amenability and the growing disparities, observed for cancer mortality risk, were not found for noncancer mortality risk. As with cancer-specific mortality, Asians/Pacific Islanders had equivalent or more favorable survival than Whites for noncancer causes of death (data not shown).

**Discussion**

We investigated whether racial/ethnic disparities in cancer survival increase as available medical interventions improve overall cancer survival and found clear support of this hypothesis for African Americans, American Indians/Alaska Natives, and Hispanics experienced lower survival from noncancer causes of death than Whites for all levels of amenability and the growing disparities, observed for cancer mortality risk, were not found for noncancer mortality risk. As with cancer-specific mortality, Asians/Pacific Islanders had equivalent or more favorable survival than Whites for noncancer causes of death (data not shown).
with large proportion of immigrants. To reduce the possibility of this bias, we ran our analyses separately for U.S.-born and foreign-born Asian/Pacific Islander and Hispanic cases. Whereas foreign-born cases could arguably have been motivated to return to their country of origin, U.S.-born cases would be unlikely to leave the United States (their birth place) to die in a foreign country (16). Our results conducted with cases with birth place data (76% of Asian/Pacific Islander and 67% of Hispanic cases) did not show materially different patterns for foreign-born and U.S.-born Asian/Pacific Islander cases, but larger survival differences from partly and mostly amenable cancers were observed in the U.S.-born Hispanic than in the foreign-born Hispanic cases, both compared to White cases. A plausible explanation, which is compatible with our proposal regarding the use of social resources for delaying death, is the relatively high SES profile for several Asian/Pacific Islander subgroups compared to other racial/ethnic minority populations. Additional research with more detailed data including socioeconomic data is needed to evaluate this hypothesis.

The observation that survival disadvantage for most racial/ethnic minority populations increases as cancers become more treatable may appear counterintuitive at the first consideration, particularly because substantial survival improvements have been documented for all racial/ethnic populations (1, 3, 17). We propose, however, that it is precisely this enhanced capacity to successfully treat some cancers together with the social disadvantage faced by most racial/ethnic minorities that give rise to cancer survival disparities. Other studies examining social disparities in disease mortality by varying levels of medical amenability have also provided supportive evidence (10, 18-22). For example, Phelan et al. showed steeper socioeconomic gradients in mortality from causes of deaths that were mostly preventable, as determined by expert judgment, than for causes of deaths that were mostly unpreventable in the late 1980s (10). Another recent study reported increasing survival disparities in mortality over time for diseases with the most medical progress as measured by the number of approved therapeutic drugs and improvement in mortality and survival rates (19).

The survival patterns observed in this study also corroborates widely documented R/E differences in survival among cancer cases from population-based databases, health-care plans, and clinical trials (4, 7, 15, 23-26). However, most studies have focused on one or a few specific cancers, such as the most common sites or sites with significant disparities, and provided information to explain cancer site-specific survival disparities. In contrast, we compared racial/ethnic differences in survival across a spectrum of cancers, classified according to how amenable each cancer site is to available medical interventions. In so doing, we have attempted to illustrate the fundamental role that access to valuable social and economic resources, patterned by race/ethnicity, play in shaping survival disparities. If we are correct in our interpretation that racial/ethnic disparities emerge as a result of greater uptake and utilization of available medical interventions by socially advantaged groups, minimizing the relevance of personal resources to obtaining medical care may have the greatest potential for reducing survival disparities. Examples include efforts to reduce complexity of medical procedures, number of visits, and amount of patient time and resource commitment. Increasing the delivery to and utilization of medical care among individuals with limited resources may also promote a more equitable distribution of medical care in the population. An example of such effort is the patient navigation programs designed to reduce racial/ethnic and SES disparities in accessing cancer care (27).

Our study has strengths in using a large racially diverse population-based sample of cancer cases with a wide range of cancers, a relatively long follow-up, and identical data collection systems across racial/ethnic populations. Racial/ethnic data in SEER are drawn from administrative and medical records, which may be different from self-reported data. A recent evaluation of racial/ethnic data in the SEER registries against self-reported data from the National Longitudinal Mortality Study surveys suggested excellent agreement between the two sources for data on racial classification ($\kappa = 0.90$) and moderate to substantial agreement for Hispanic ethnicity ($\kappa = 0.61$; ref. 28). We used a novel quantitative approach to develop a relative measure of the degree to which cancers are amenable to medical interventions. We found substantial agreement between this measure and a previously published measure of preventability of death from 26 cancer sites based on average ratings of two independent experts (Pearson correlation coefficient $= 0.70$; weighted $\kappa = 0.57$; ref. 10). The validity of the study findings was further strengthened by results of several supplemental analyses confirming a priori hypotheses and by adjustment for several key factors associated with cancer survival. It is worth noting that accounting for the disease stage at diagnosis, a powerful prognostic predictor, only partially accounted for survival differences by race/ethnicity. This is consistent with other reports of persistent survival disparities for many cancer sites after adjusting for disease stage as well as within each stage (1, 2). Furthermore, adjustment for stage primarily affected racial/ethnic differences in survival from mostly amenable cancers and, to a lesser degree, for partly amenable cancers. This is consistent with our hypothesis and measurement of amenability index, which suggest a greater variation by racial/ethnic in stage at diagnosis for mostly amenable cancers for which early detection and/or effective treatments are available. We were also able to adjust for an SES indicator, percent of persons living below the poverty level in a county, which is strongly associated with other area-based SES indicators in the United States (4). Data on SES characteristics of individual cases or aggregated at smaller geographic units were unavailable in the SEER data set used for this analysis, limiting our ability to account for differences in individual-level and neighborhood-level SES, which are likely to be present among persons residing in the large geographic unit of the county.

In conclusion, we found evidence that cancer survival disparities for most racial/ethnic minority populations are substantially greater for cancers that can potentially be detected early and treated successfully than cancers with more limited early detection and treatment options. Therefore, medical advances that improve overall absolute survival may not only fail to narrow but also, when combined with existing population-level social inequalities, can contribute to greater relative racial/ethnic disparities in cancer survival. These findings stress the need for considering the effect of emerging cancer
discoveries on social disparities and employing specific strategies for averting the unequal burden of cancer.

**Disclosure of Potential Conflicts of Interest**
No potential conflicts of interest were disclosed.

**Acknowledgments**
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This research was supported by a grant from the Lance Armstrong Foundation Young Investigator Award and a post-doctoral fellowship from the National Cancer Institute to the first author (R25 CA094061).

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