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Journal of Health Disparities Research and Practice

Volume 5 | Issue 2 Article 5

2012

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Abstract

Objective. This population-based study compared cause-specific cancer survival by socioeconomic status using methods to more accurately assign cancer deaths to primary site. Methods. The current study analyzed Idaho data used in the Accuracy of Cancer Mortality Statistics Based on Death Certificates (ACM) study supplemented with additional information to measure cause-specific cancer survival by census tract poverty level. Results. The distribution of cases by primary site group differed significantly by poverty level (chi-square = 265.3, 100 df, p In the life table analyses, for 8 of 24 primary site groups investigated, and all sites combined, there was a significant gradient relating higher poverty with poorer survival. For all sites combined, the absolute difference in 5-year cause-specific survival rate was 13.6% between the lowest and highest poverty levels. Conclusions. This study shows striking disparities in cause-specific cancer survival related to the poverty level of the area a person resides in at the time of diagnosis.

Keywords

Cancer – Patients; Cancer registry; Cancer survival; Census tract; Death certificates; Discrimination in medical care; Idaho; Medical statistics; Poor; Poverty; Social status – Health aspects

Cover Page Footnote

Source of Support: This project was completed by the state cancer registry of Idaho and ICF Macro under contract 200-2002-00574 from the Division of Cancer Prevention and Control at the Centers for Disease Control and Prevention. Financial Disclosures: There are no financial disclosures from any of the authors. Disclaimers: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention. Acknowledgments: The authors wish to thank the following colleagues for assistance with this project: Denise Jozwik, RHIT, CTR; Maryann Sacks, RHIT, CTR; Loretta E. Travers, RHIT, CTR; and Pam Harder, BS.

Journal of Health Disparities Research and Practice
Volume 5, Issue 2, Summer 2012, pp. 45-61

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ABSTRACT

Objective. This population-based study compared cause-specific cancer survival by socioeconomic status using methods to more accurately assign cancer deaths to primary site.

Methods. The current study analyzed Idaho data used in the Accuracy of Cancer Mortality Statistics Based on Death Certificates (ACM) study supplemented with additional information to measure cause-specific cancer survival by census tract poverty level.

Results. The distribution of cases by primary site group differed significantly by poverty level (chi-square = 265.3, 100 df, p In the life table analyses, for 8 of 24 primary site groups investigated, and all sites combined, there was a significant gradient relating higher poverty with poorer survival. For all sites combined, the absolute difference in 5-year cause-specific survival rate was 13.6% between the lowest and highest poverty levels.

Conclusions. This study shows striking disparities in cause-specific cancer survival related to the poverty level of the area a person resides in at the time of diagnosis.

Key words: cancer registry, cancer survival, death certificate, poverty, census tract

INTRODUCTION

Area variations in cancer outcomes, including survival, may be due to differences in public education and culture, extent of disease at diagnosis and access to optimal treatment. Many recent studies have shown social inequities in population health measures of cancer burden, including incidence (Clegg et al., 2009; McCarthy, Dumanovsky, Visvanathan, Kahn, & Schymura, 2010; Singh, Miller, Hankey, & Edwards, 2003; Singh, Miller, Hankey, & Edwards, 2004), mortality (Singh et al., 2003; Singh et al., 2004; Ward et al., 2004), stage distribution (Clegg et al., 2009; Colorado Cancer Coalition, 2002; Hahn et al., 2007; McCarthy et al., 2010; Singh et al., 2003; Singh et al., 2004), and survival (Artinyan et al., 2010; Bradley, Given, & Roberts, 2004; Byers et al., 2008; Colorado Cancer Coalition, 2002; Dalton et al., 2007; Du, Fang, & Meyer, 2008; McCarthy et al., 2010; Meliker, Goovaerts, Jacquez, Avruskin, & Copeland, 2009; Movva et al., 2008; Niu, Pawlish, & Roche, 2010; Schwartz et al., 2009; Simon et al., 2006; Singh et al., 2003; Singh et al., 2004; Yan et al., 2009; Zell et al., 2008).

Recognizing the impact of social inequality on health, Healthy People 2020 and the Idaho Comprehensive Cancer Strategic Plan include goals to measure and eliminate health disparities (Comprehensive Cancer Alliance for Idaho, 2006; U.S. Department of Health and Human Services [USDHHS], 2011a). Unfortunately, socioeconomic data are largely absent from most U.S. public health surveillance systems. Population-based cancer registries collect information on demographic variables including age, sex, race and ethnicity, but do not routinely collect information on patient income or education, for example. An efficient solution to the problem of absent socioeconomic data in population-based cancer registries is to geocode residential addresses and use area-based socioeconomic measures (ABSMs) (Krieger, Chen, Waterman, Rehkopf, & Subramanian, 2003; Krieger et al., 2002; Krieger, Waterman, Chen, Rehkopf, & Subramanian, 2004).

The current study analyzed Idaho data used in the Accuracy of Cancer Mortality Statistics Based on Death Certificates (ACM) study (Fink et al., 2011; German et al., 2011), supplemented with address information of cases at the time of diagnosis to measure cause-specific cancer survival by census tract poverty level. The main objective of the ACM study was to estimate the agreement of primary cancer site between the central cancer registry and death certificate data sources. The methods have been described in detail previously (German et al., 2011). As part of the ACM study, cancer cases and deaths were carefully categorized and matched, resulting in a high quality dataset for accurate causespecific survival analyses.

There are two common measures of net survival from cancer: causespecific survival and relative survival (Brown, 1983; Ederer, Axtell, & Cutler, 1961; Marubini & Valsecchi, 1995). Cause-specific survival requires that choices be made regarding assigning attributable deaths, and both methods may require decisions about excluding some cases (e.g. second or later primary cases) from analysis. Relative survival methods are often used when information on cause of death is unreliable, but require appropriate life tables to calculated expected survival rates (Ederer et al., 1961). Competing causes of death are not distributed equally among socioeconomic classes (in essence, different socioeconomic classes have different life tables). Life tables are generally not available by socioeconomic position, and using expected survival from inappropriate life tables may result in biased estimates of survival from cancer.

We used data from a high quality population-based registry that utilized enhanced methods for matching UCD to primary site group in order to test the hypothesis that cause-specific cancer survival would vary by census tract poverty level. Compared to other

comprehensive population-based studies of cancer survival and socioeconomic status (SES) in the U.S. (Byers et al., 2008; Colorado Cancer Coalition, 2002; Niu et al., 2010; Singh et al., 2003; Ward et al., 2004), this study included more cancer sites, had a longer follow-up period, used results of the ACM study to more accurately assign cancer deaths to primary site, and utilized finer poverty level categories. We included all primaries for individuals with more than one primary cancer (Brenner & Hakulinen, 2007; Ellison, 2010; Rosso et al., 2009) and assigned the cause-specific cancer cause of death to the appropriate primary.

METHODS

In the ACM study, data from central cancer registry records from California, Colorado, and Idaho were linked with death certificates from the corresponding state vital statistics registries and evaluated by demographic and tumor information (Fink et al., 2011; German et al., 2011). Long-term prospective and retrospective concordances of primary site category were measured using ICD-O- 3 codes from the cancer registry and ICD-9 and ICD-10 codes for the underlying cause of death (UCD) from the death certificate (Fritz et al, 2000; World Health Organization [WHO], 1978; WHO, 2007) These states were selected to participate based on several criteria that ensured high-quality death clearance data, including the ability to perform valid linkages between the cancer registry and mortality data. Idaho resident primary invasive cancer cases[a] diagnosed in 1993 through1995 were followed up to 2004 via a combination of ongoing activeatient follow-up, complete manual review of Idaho death certificates for the period 1993 through2000, and linkages with both Idaho death certificates and the National Death Index (NDI) (USDHHS, 2000) covering deaths in 1993 through 2004. We conducted cause-specific survival analyses by poverty level of the census tract in which the case resided at the time of diagnosis.

Cancer Incidence Data

Incidence data on Idaho residents with primary invasive cancer cases diagnosed in 1993 through1995 were obtained from the Cancer Data Registry of Idaho (CDRI), the central cancer registry for the state of Idaho. CDRI has functioned since 1969 and has been population-based since 1971. CDRI has achieved North American Association of Central Cancer Registries (NAACCR) and/or U.S. Centers for Disease Control and Prevention (CDC) National Program of Cancer Registries (NPCR) standards for data completeness, timeliness and quality since 1993 (North American Association of Central Cancer Registries, 2011; USDHHS, 2011c). Audits evaluating data quality and completeness performed by NAACCR in 1996 and by CDC in 2000 and 2007 have shown completeness rates of 98%- 99.6% and error rates lower than the median error rates for central cancer registries (USDHHS, 2011d).

Follow-up Information

CDRI is one of few central cancer registries not part of the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) program to have performed active patient follow-up to ascertain vital status. For patients included in this study, annual follow-up was performed through mailings to the patients' physicians. Official date and cause of death information was obtained via linkages with state vital statistics and the NDI (USDHHS, 1999; USDHHS, 2000).

State Death Certificates

Probabilistic linkages were conducted between the CDRI database encompassing cases from1993 through1995 and death certificate data encompassing deaths in 1993 through 2004 in Idaho using Link Plus software (V2.0, CDC, Atlanta, Georgia). Link Plus computes probabilistic record linkage scores based on the theoretical framework developed by Fellegi and Sunter (1969). Social Security number, birth date, Soundex of last name, Soundex of first name, and Federal Information Processing Standards (FIPS) county code were used as blocking variables and last name, first name, middle name, Social Security number, birth date, FIPS county code, and sex were used as matching variables. Visual review of the linkage results file was used to determine high and low cutpoints for match scores. Records with scores above the high cutpoint were deemed to be true matches. Records with scores below the low cutpoint were deemed to be false matches. Records with intermediate scores were reviewed manually using additional resources including the Social Security Death Index, the full cancer registry record, and the full death certificate.

In addition, during the period 1993 through 2000, Idaho conducted complete manual review of Idaho death certificates for the death clearance process (Johnson, Carson, & Wick, 2004). This process resulted in 55 additional matches between CDRI cases and Idaho death certificates listing cancer as the UCD.

National Death Index

In order to obtain date and cause of death information on persons who were diagnosed with cancer as an Idaho resident during 1993 through1995 and who may have died in another state during the period of 1993 through 2004, records that did not link to an Idaho death certificate were submitted to the National Center for Health Statistics (NCHS) for an NDI search (USDHHS, 2000). The NDI is a national file of identifying death record information compiled from data submitted by State vital statistics offices. NCHS conducts NDI searches and provides the NDI user with an indication that an individual in the user's file has been involved in a possible match with one or more records in the NDI file. CDRI used an algorithm developed by NPCR registries for use in the CONCORD study to determine which potential NDI matches were indeed true matches (Coleman et al., 2008; Johnson, McLaughlin, Copeland, Weir, & NPCRCONCORD Workgroup, 2002);

Underlying Cause of Death

For deaths in Idaho, UCD was obtained from Automated Classification of Medical Entities codes from the NCHS enhanced Mortality Medical Indexing, Classification, and Retrieval system (SuperMICAR) files (USDHHS, 2011b). For deaths in other states, the NDI *Plus* service was used to obtain cause of death information (USDHHS, 1999).

Categorization of Primary Site and Assignment of Cause of Death

We categorized cancer incidence and mortality data using the 25 cancer site groups that are used in the *"United States Cancer Statistics"* publication (USDHHS, 2010) and the ACM study (German et al., 2011). Incidence data were categorized using primary site, histology, and behavior codes converted from ICD-O-2 to ICD-O-3. Deaths were categorized using UCD codes (ICD-9 for deaths in 1993 through1998, ICD-10 for deaths in 1999 through 2004). The Kaposi's sarcoma group is not included in the site-specific results because fewer than 10 cases were available for this analysis.

We attributed cause-specific deaths to individual primary sites for persons in this study. For patients with only one primary cancer listed in the cancer registry data, any cancer UCD was

considered to have arisen from the primary site, including cancer deaths potentially misattributed to metastatic sites. For persons with more than one primary cancer listed in the cancer registry data, the cancer death was attributed to the primary that matched the analysis group of the UCD. For persons with more than one primary cancer, and for whom the cancer cause of death analysis group did not agree with any of the primary sites, the linked incidence/mortality records were reviewed by two Certified Tumor Registrars to assign the UCD to the appropriate primary cancer. If the death grouping was for a site listed as a metastatic site for a particular primary, this was deemed to be a match. For 26 cases it was not possible to match the primary site to the cancer death grouping because the cancer death code was for "multiple primary" cancers, the death certificate text included mention of more than one specific cancer site, and the person had each of the specific cancer primaries. These cases were excluded from all analyses. However, if the person had additional primaries not coded or mentioned in the death certificate, these cases were included in the analysis and censored at date of death. In a few instances, the cancer death code was different from all of the primaries, and could not have been a metastatic site (e.g., potential missed case or not reportable because the cancer occurred while the person resided in another state and no treatment was provided by Idaho hospitals). These cases were included in the analysis and censored at date of death. For persons with more than one cancer of the same primary site and whose cancer death matched the analysis group (41 persons: 19 with colon and rectum cancer, 12 with breast cancer, 7 with lung and bronchus cancer, 1 each of kidney and renal pelvis, non-Hodgkin lymphoma, and oral cavity and pharynx), the cancer death was attributed to each primary. This decision was made because the subsites and/or histology codes varied for each case within a person, the fact of which was masked by categorization into analysis group. We grouped individuals with single and multiple primaries in the same analyses, consistent with recent trends in cancer survival methods (Brenner & Hakulinen, 2007; Ellison, 2010; Rosso et al., 2009). Non-cancer deaths were censored at date of death in the statistical analysis.

Geocoding of Cases and Assignment of 1990 Census Tract Poverty Level

We geocoded cancer incidence records to 1990 census tract based on address of residence at the time of diagnosis (Krieger et al., 2002). A census tract is a subdivision of a county that contains on average about 4,000 persons and boundaries are drawn such that the population covered is relatively homogenous. The percentage of the population with incomes below federal poverty guidelines was calculated by 1990 census tract, and tracts were categorized by poverty status into four groups: 0.0-4.9%, 5.0-9.9%, 10.0-19.9%, and 20.0+ (Krieger et al., 2002; Krieger et al., 2003; Krieger et al., 2004). This measure of socioeconomic inequality was selected based on recommendations by the Public Health Disparities Geocoding Project regarding validity, robustness, and completeness criteria (Krieger et al., 2002).

Statistical Analysis

We calculated cause-specific cancer survival rates by the four census tract poverty levels and overall using the actuarial (life table) method in SEERStat (Berkson & Gage, 1950; USDHHS, 2011e). The study cutoff date was set to December 2004. If the last follow-up date for a person was after the study cutoff, the end date for the person was set to the study cutoff and vital status was set to alive. We excluded cases from analysis if they were reported by autopsy or death certificate only (231 cases), had unknown or missing cause of death (251 cases), had vital status alive but no follow-up time (72 cases), or died due to other causes and had no follow-up time (80 cases). Cases were censored at either the date of death, last follow-up, or study cutoff

and using the rules regarding primary site and death analysis group matches detailed above. We computed the Wilcoxon test for trend and p-values comparing survival functions from the four census tract poverty levels using SAS Proc Lifetest (Version 9.2, Cary, NC: SAS Institute, Inc.). The test for trend compared the null hypothesis that the four population hazard rates were the same versus an ordered alternative: $S_{0.0\text{-}4.9\%}(t) \geq S_{5.0\text{-}9.9\%}(t) \geq S_{10.0\text{-}19.9\%}(t) \geq S_{20.0+}(t)$, with at least one inequality. Trend tests have more power to detect ordered alternatives such as that specified (Klein & Moeschberger, 1997).

We ran Cox proportional hazards models overall and by cancer site to estimate the hazard ratios associated with census tract poverty level as compared to the low poverty group (0.0-4.9% poverty). The Cox models were run in SAS (V9.2) Proc PHREG and adjusted for age at diagnosis, sex, and sequence of cancer (first primary versus subsequent primary). Age at diagnosis and the square of age at diagnosis were included in the models to account for non-linear relationships between age and survival time. Race was not adjusted for in the Cox models because 96.9% of cases were among non-Hispanic whites and the other race and ethnicity data were too sparse. The greatest number of cases for other than whites was 47 cases of breast cancer among Hispanics (2.5% of cases). Most site by race (or ethnicity) counts were less than 10 cases at entry. Ties in failure time were handled using the approximate likelihood of Efron (1977). Cases were censored using the same rules as for the life tables.

Human Subjects Protections

The ACM study received a non-research determination from the CDC. Use of non-identifying data in this study was approved by the Cancer Data Registry of Idaho. To ensure the protection of patient confidentiality, table cells based on five or fewer cases are suppressed in the results.

RESULTS

A total of 12,851 Idaho resident cancer cases diagnosed from 1993 through1995 was included in the statistical analysis, 10,943 of which were the first primary. For 82 cases, census tract was unable to be assigned due to unknown address information besides state of residence; these were excluded from analysis by poverty status. For the survival data censored as of December 2004, cause of death was determined from state death certificates for 7,733 cases and from NDI for 476 cases.

Table 1 shows counts and percentages of incident cases from 1993, 1994, and 1995 that entered into the survival analyses by primary site group and 1990 census tract poverty level. The distribution of cases by primary site group differed significantly by poverty level (chi-square = 265.3, 100 df, $p<0.0001$). There were higher percentages of breast and melanoma of the skin cases, and lower percentages of colon and rectum and lung and bronchus cases in the lowest (0.0-4.9%) poverty level census tracts. For tobacco-related cancers (e.g. esophagus, larynx, lung and bronchus), incidence patterns were consistent with higher smoking rates in areas with higher census tract poverty.

Table 1. Count and Percentage of 1993-1995 Incident Cases Entering into Survival Analysis by Primary Site Group and 1990 Census Tract Poverty Level.

Primary Site Group	1990 Census Tract Poverty Level									
	0.0-4.9%		5.0-9.9%		10.0-19.9%		20.0%+		Total[a]	
All Sites	956	100.0%	3,183	100.0%	7,210	100.0%	1,420	100.0%	12,851	100.0%
Brain and Other Nervous System	24	2.5%	54	1.7%	116	1.6%	25	1.8%	219	1.7%
Breast	169	17.7%	512	16.1%	993	13.8%	189	13.3%	1,864	14.5%
Cervix Uteri	8	0.8%	26	0.8%	73	1.0%	19	1.3%	126	1.0%
Colon and Rectum	82	8.6%	324	10.2%	777	10.8%	154	10.8%	1,337	10.4%
Corpus and Uterus, NOS	29	3.0%	88	2.8%	223	3.1%	46	3.2%	386	3.0%
Esophagus	6	0.6%	40	1.3%	49	0.7%	10	0.7%	106	0.8%
Hodgkin Lymphoma	9	0.9%	32	1.0%	46	0.6%	8	0.6%	95	0.7%
Kidney and Renal Pelvis	13	1.4%	75	2.4%	145	2.0%	24	1.7%	258	2.0%
Larynx	5	0.5%	24	0.8%	62	0.9%	13	0.9%	104	0.8%
Leukemia	21	2.2%	95	3.0%	209	2.9%	42	3.0%	370	2.9%
Liver and Intrahepatic Bile Duct	b	b	16	0.5%	39	0.5%	9	0.6%	67	0.5%
Lung and Bronchus	91	9.5%	351	11.0%	990	13.7%	218	15.4%	1,650	12.8%
Melanoma of the Skin	52	5.4%	143	4.5%	268	3.7%	41	2.9%	514	4.0%
Mesothelioma	b	b	6	0.2%	13	0.2%	b	b	23	0.2%
Myeloma	9	0.9%	42	1.3%	89	1.2%	19	1.3%	160	1.2%
Non-Hodgkin Lymphoma	44	4.6%	129	4.1%	291	4.0%	58	4.1%	524	4.1%
Oral Cavity and Pharynx	31	3.2%	80	2.5%	179	2.5%	46	3.2%	341	2.7%
Ovary	21	2.2%	62	1.9%	138	1.9%	30	2.1%	251	2.0%
Pancreas	26	2.7%	55	1.7%	156	2.2%	49	3.5%	288	2.2%
Prostate	160	16.7%	561	17.6%	1,246	17.3%	222	15.6%	2,230	17.4%
Stomach	10	1.0%	40	1.3%	122	1.7%	16	1.1%	189	1.5%
Testis	9	0.9%	28	0.9%	49	0.7%	8	0.6%	94	0.7%
Thyroid	17	1.8%	49	1.5%	92	1.3%	10	0.7%	168	1.3%
Urinary Bladder	57	6.0%	136	4.3%	364	5.0%	68	4.8%	628	4.9%

[a] Total includes cases for which census tract poverty level is not determined (n=82).
[b] Small cell suppression.

Overall cause-specific cancer survival among Idaho residents diagnosed with primary invasive cancers from 1993 through1995 was 61.2% at 5 years and 54.5% at 10 years. Tables 2 and 3 show 5-year and 10-year cause-specific cancer survival by primary site group and 1990 census tract poverty level. Cause-specific survival at 5 years varied by primary site group from 6.1% for pancreas to 95.0% for thyroid. At 10 years, cause-specific survival varied from 4.9% for pancreas to 92.9% for testis.

For eight primary site groups (breast, esophagus, larynx, leukemia, melanoma of the skin, oral cavity and pharynx, prostate, and urinary bladder) and all sites combined, there were significant differences ($p<0.05$) among poverty levels in cause-specific cancer survival evaluated at either 60 or 120 months. For each primary site group besides breast and larynx, there were monotonic decreases in cause-specific cancer survival with increasing poverty level. For breast cancer, the differences in 60 and 120 month survival between the 0.0-4.9% and 5.0-9.9% poverty levels were not statistically significant, and there were lower survival rates for the remaining higher poverty levels. Data by poverty level were sparse for the larynx group, but the lower two poverty levels had higher survival rates than the higher two poverty levels. For melanoma of the skin and oral cavity and pharynx cancers, the highest poverty level had distinctly poorer survival than the remaining poverty levels. In all of these primary site groups except leukemia, the absolute differences in survival by poverty level increased from the time of diagnosis to 5-years post-diagnosis (data not shown). The differences by poverty level continued to increase from 5 to 10 years for breast and prostate cancers.

Table 2. 5-Year Cause-Specific Cancer Survival (Percent, Standard Error) by Census Tract Poverty Category.

Primary Site Group	1990 Census Tract Poverty Level										Prob[a]	
	0.0-4.9%		5.0-9.9%		10.0-19.9%		20.0%+		Total			
All Sites	68.9	(1.5)	64.5	(0.9)	59.7	(0.6)	55.3	(1.4)	61.2	(0.5)	<.0001	*
Brain and Other Nervous Sys	14.9	(7.8)	34.3	(6.7)	35.8	(4.7)	35.9	(10.0)	33.2	(3.3)	0.1392	
Breast (Females)	84.7	(2.8)	87.7	(1.5)	83.8	(1.2)	80.2	(3.1)	84.6	(0.9)	0.0027	*
Cervix Uteri	75.0	(15.3)	64.0	(10.4)	71.5	(5.6)	70.9	(11.1)	70.1	(4.3)	0.8571	
Colon and Rectum	60.6	(5.7)	62.9	(2.8)	58.3	(1.9)	65.4	(4.1)	60.3	(1.4)	0.7518	
Corpus and Uterus, NOS	85.8	(6.6)	83.8	(4.1)	81.8	(2.7)	89.9	(4.8)	83.4	(2.0)	0.3533	
Esophagus	22.7	(19.3)	14.3	(5.9)	10.2	(4.6)	c	c	11.3	(3.3)	0.0127	*
Hodgkin Lymphoma	63.0	(17.2)	86.5	(6.3)	81.8	(5.8)	87.5	(11.7)	82.2	(4.0)	0.4029	
Kidney and Renal Pelvis	69.2	(12.8)	60.8	(5.8)	52.6	(4.3)	62.2	(10.7)	56.9	(3.2)	0.9618	
Larynx	100.0	0.0	85.4	(7.9)	61.3	(7.1)	71.0	(14.2)	69.6	(5.2)	0.0310	*
Leukemia	60.6	(11.0)	60.5	(5.4)	44.4	(3.6)	31.3	(7.6)	48.0	(2.8)	0.0013	*
Liver and Intrahepatic Bile Duct	b	b	28.4	(11.6)	15.3	(6.1)	20.0	(14.0)	21.3	(5.3)	0.3718	
Lung and Bronchus	26.4	(4.9)	13.8	(2.0)	14.9	(1.3)	10.3	(2.3)	14.7	(1.0)	0.3359	
Melanoma of the Skin	91.2	(4.2)	87.8	(2.9)	85.0	(2.4)	71.2	(7.8)	85.4	(1.7)	0.0582	+
Mesothelioma	b	b	16.7	(15.2)	27.0	(12.8)	b	b	18.9	(8.4)	0.1214	
Myeloma	47.3	(18.7)	27.9	(7.6)	27.2	(5.3)	17.7	(9.2)	27.6	(4.0)	0.3630	
Non-Hodgkin Lymphoma	56.3	(7.8)	56.4	(4.6)	54.0	(3.1)	59.9	(6.7)	55.2	(2.3)	0.6320	
Oral Cavity and Pharynx	89.1	(6.0)	81.4	(4.7)	73.0	(3.6)	57.5	(7.8)	74.6	(2.5)	0.0035	*
Ovary	21.4	(9.3)	35.7	(6.3)	30.7	(4.2)	47.0	(9.5)	33.0	(3.1)	0.7771	
Pancreas	c	c	8.2	(4.0)	7.2	(2.3)	4.1	(2.8)	6.1	(1.5)	0.2471	
Prostate	97.4	(1.3)	90.1	(1.3)	87.7	(1.0)	85.7	(2.6)	88.9	(0.7)	<.0001	*
Stomach	30.9	(16.7)	17.5	(6.2)	21.9	(4.0)	23.5	(11.6)	21.2	(3.2)	0.5862	
Testis	100.0	0.0	100.0	0.0	89.2	(4.6)	80.0	(17.9)	92.9	(2.8)	0.0804	+
Thyroid	94.1	(5.7)	95.4	(3.2)	94.3	(2.5)	100.0	0.0	95.0	(1.7)	0.6743	
Urinary Bladder	92.7	(3.5)	79.1	(3.9)	77.4	(2.4)	76.9	(5.4)	79.3	(1.7)	0.0421	*

* p<0.05, + p<0.10.
[a] Tests for trends evaluated at 60 months.
[b] Small cell suppression.
[c] Not calculable.

Table 3. 10-Year Cause-Specific Cancer Survival (Percent, Standard Error) by Census Tract Poverty Category.

Primary Site Group	1990 Census Tract Poverty Level										Prob[a]	
	0.0-4.9%		5.0-9.9%		10.0-19.9%		20.0%+		Total			
All Sites	63.8	(1.7)	58.9	(0.9)	52.2	(0.7)	48.6	(1.5)	54.5	(0.5)	<.0001	*
Brain and Other Nervous Sys	c	c	30.0	(6.5)	28.6	(4.6)	35.9	(10.0)	27.9	(3.3)	0.1299	
Breast (Females)	78.9	(3.3)	81.8	(1.8)	74.2	(1.5)	70.6	(3.8)	76.4	(1.1)	0.0054	*
Cervix Uteri	75.0	(15.3)	54.9	(12.3)	64.3	(6.4)	70.9	(11.1)	64.1	(4.9)	0.7887	
Colon and Rectum	58.5	(5.8)	54.0	(3.1)	53.1	(2.0)	58.0	(4.5)	54.2	(1.5)	0.7868	
Corpus and Uterus, NOS	85.8	(6.6)	81.0	(4.4)	74.6	(3.3)	76.7	(7.4)	77.3	(2.4)	0.4148	
Esophagus	c	c	c	c	7.7	(4.1)	c	c	8.8	(3.0)	0.0128	*
Hodgkin Lymphoma	63.0	(17.2)	86.5	(6.3)	77.0	(7.2)	87.5	(11.7)	80.2	(4.4)	0.5269	
Kidney and Renal Pelvis	69.2	(12.8)	54.5	(6.3)	43.4	(4.7)	62.2	(10.7)	49.9	(3.5)	0.9244	
Larynx	100.0	0.0	85.4	(7.9)	51.1	(7.6)	71.0	(14.2)	63.1	(5.6)	0.0313	*
Leukemia	53.8	(11.6)	46.8	(6.0)	33.1	(3.8)	25.0	(7.2)	37.1	(2.9)	0.0011	*
Liver and Intrahepatic Bile Duct	b	b	17.0	(11.2)	c	c	c	c	10.0	(4.9)	0.3716	
Lung and Bronchus	16.6	(4.8)	12.2	(1.9)	9.1	(1.2)	7.3	(2.1)	10.1	(0.9)	0.3488	
Melanoma of the Skin	88.1	(5.1)	83.8	(3.4)	81.1	(2.8)	67.5	(8.2)	81.6	(2.0)	0.0453	*
Mesothelioma	b	b	16.7	(15.2)	18.0	(11.3)	b	b	14.2	(7.5)	0.1110	
Myeloma	c	c	18.6	(7.4)	12.6	(5.0)	c	c	12.7	(3.6)	0.3677	
Non-Hodgkin Lymphoma	53.5	(7.9)	43.9	(4.9)	41.9	(3.3)	55.1	(6.9)	44.8	(2.4)	0.5995	
Oral Cavity and Pharynx	84.2	(7.4)	72.8	(5.9)	70.1	(3.8)	57.5	(7.8)	70.2	(2.8)	0.0032	*
Ovary	16.0	(8.4)	30.0	(6.1)	22.1	(4.0)	34.4	(9.4)	25.1	(3.0)	0.7773	
Pancreas	c	c	5.5	(3.5)	6.1	(2.2)	c	c	4.9	(1.4)	0.2473	
Prostate	92.1	(2.4)	83.4	(1.8)	77.1	(1.4)	74.5	(3.7)	79.8	(1.0)	<.0001	*
Stomach	c	c	9.3	(5.5)	19.1	(4.0)	15.7	(10.0)	16.0	(3.0)	0.6089	
Testis	100.0	0.0	100.0	0.0	89.2	(4.6)	80.0	(17.9)	92.9	(2.8)	0.0804	+
Thyroid	94.1	(5.7)	95.4	(3.2)	90.1	(3.4)	100.0	0.0	92.6	(2.2)	0.7245	
Urinary Bladder	84.7	(5.5)	76.5	(4.2)	70.5	(2.8)	69.0	(7.2)	73.1	(2.1)	0.0532	+

* p<0.05, + p<0.10.
[a] Tests for trends evaluated at 120 months.
[b] Small cell suppression.
[c] Not calculable.

For all sites combined, the absolute difference in 5-year cause-specific survival rate was 13.6% between the lowest and highest poverty levels. By primary site group, the survival disparity was 4.5% for breast cancer, 12.5% for esophagus, 29.0% for larynx, 29.3% for leukemia, 20.0% for melanoma of the skin, 31.6% for oral cavity and pharynx, 11.6% for prostate, and 15.8% for urinary bladder.

Table 4 shows 5-year and 10-year cause-specific cancer survival by sex and 1990 census tract poverty level for all sites combined and for each primary site group with ≥ 500 cases (colon and rectum, lung and bronchus, melanoma of the skin, non-Hodgkin lymphoma, and urinary bladder; breast and prostate previously shown). For all sites combined, there were significant differences ($p<0.05$) among poverty levels in cause-specific cancer survival evaluated at 60 and 120 months for both males and females. None of the individual primary site groups had a significant difference ($p<0.05$) among poverty levels in cause-specific cancer survival. Among males, the difference in cause-specific cancer survival by poverty level approached statistical significance ($p<0.10$). For all sites combined, the survival disparity was about twice as high for males as for females, owing mostly to the survival disparity in lung cancer survival.

Table 4. 5 and 10-Year Cause-Specific Cancer Survival (Percent, Standard Error) by Sex and Census Tract Poverty Category for Selected Primary Site Groups.

Primary Site Group	Sex	Years Surv.	1990 Census Tract Poverty Level: 0.0-4.9%		5.0-9.9%		10.0-19.9%		20.0%+		Total		Prob[a]	
All Sites	Male	5	72.5	(2.0)	63.7	(1.2)	58.7	(0.8)	53.3	(1.9)	60.6	(0.6)	<.0001	*
All Sites	Male	10	66.8	(2.3)	58.1	(1.3)	50.9	(0.9)	47.7	(2.1)	53.7	(0.7)	<.0001	*
All Sites	Female	5	65.2	(2.3)	65.5	(1.3)	61.0	(0.9)	57.6	(2.0)	62.1	(0.7)	<.0001	*
All Sites	Female	10	60.9	(2.4)	59.9	(1.4)	53.7	(1.0)	49.7	(2.2)	55.4	(0.7)	<.0001	*
Colon and Rectum	Male	5	61.1	(7.5)	61.0	(4.1)	55.7	(2.5)	69.2	(5.5)	58.7	(1.9)	0.6669	
Colon and Rectum	Male	10	57.2	(8.0)	49.3	(4.4)	49.5	(2.8)	62.3	(6.3)	51.3	(2.1)	0.6586	
Colon and Rectum	Female	5	60.2	(8.6)	64.8	(4.0)	61.5	(2.8)	61.4	(6.0)	62.3	(2.1)	0.3474	
Colon and Rectum	Female	10	60.2	(8.6)	59.1	(4.3)	57.3	(2.9)	53.3	(6.4)	57.5	(2.2)	0.3748	
Lung and Bronchus	Male	5	30.2	(6.6)	11.6	(2.4)	12.0	(1.5)	8.0	(2.7)	12.4	(1.2)	0.8826	
Lung and Bronchus	Male	10	21.2	(6.4)	11.0	(2.3)	7.4	(1.4)	8.0	(2.7)	9.1	(1.1)	0.8864	
Lung and Bronchus	Female	5	20.4	(7.1)	17.0	(3.4)	19.3	(2.2)	13.0	(3.8)	18.0	(1.6)	0.1933	
Lung and Bronchus	Female	10	b	b	14.2	(3.2)	11.6	(2.0)	6.3	(3.0)	11.5	(1.5)	0.2095	
Melanoma of the Skin	Male	5	92.9	(4.8)	86.1	(3.7)	80.0	(3.8)	76.0	(9.5)	83.2	(2.4)	0.0891	+
Melanoma of the Skin	Male	10	87.3	(7.1)	81.6	(4.4)	76.4	(4.1)	76.0	(9.5)	79.4	(2.7)	0.0881	+
Melanoma of the Skin	Female	5	88.7	(7.6)	91.2	(4.2)	90.6	(2.8)	64.6	(12.8)	88.5	(2.4)	0.2421	
Melanoma of the Skin	Female	10	88.7	(7.6)	88.1	(5.1)	86.3	(3.7)	55.4	(13.9)	84.6	(2.9)	0.1768	
Non-Hodgkin Lymphoma	Male	5	64.4	(10.9)	46.7	(6.3)	55.5	(4.2)	61.4	(10.2)	54.1	(3.2)	0.9777	
Non-Hodgkin Lymphoma	Male	10	64.4	(10.9)	36.5	(6.4)	40.3	(4.6)	56.3	(10.5)	42.2	(3.4)	0.9523	
Non-Hodgkin Lymphoma	Female	5	50.0	(10.7)	68.4	(6.4)	52.3	(4.5)	58.7	(8.8)	56.4	(3.3)	0.5683	
Non-Hodgkin Lymphoma	Female	10	45.5	(10.6)	53.6	(7.3)	43.7	(4.7)	54.7	(9.1)	47.5	(3.5)	0.5339	
Urinary Bladder	Male	5	91.4	(4.1)	77.9	(4.5)	77.6	(2.7)	80.9	(6.1)	79.6	(2.0)	0.1560	
Urinary Bladder	Male	10	82.4	(6.2)	77.9	(4.5)	69.5	(3.3)	70.1	(8.9)	72.8	(2.4)	0.1967	
Urinary Bladder	Female	5	100.0	(0.0)	83.1	(7.1)	76.7	(4.8)	68.1	(10.8)	78.4	(3.6)	0.1091	
Urinary Bladder	Female	10	100.0	(0.0)	71.4	(9.8)	73.3	(5.2)	68.1	(10.8)	73.9	(4.0)	0.1029	

* $p<0.05$, + $p<0.10$.
[a] Tests for trends evaluated at 60 and 120 months.
[b] Not calculable.
Sample sizes by primary site group, sex, and poverty category are available upon request from the corresponding author.

Table 5 shows results of the Cox models, adjusting for age at diagnosis, sex, and sequence of cancer. For two primary site groups (female breast and prostate) and all sites combined, there were significant differences among poverty levels in cause-specific cancer survival ($p<0.05$). For an additional three sites (esophagus, leukemias, and oral cavity and pharynx), there were differences among poverty levels in cause-specific cancer survival that approached statistical significance ($p<0.10$). For each of these primary site groups besides breast and leukemias, there were monotonic increases in the hazard ratios compared to the 0.0-4.9%

poverty level with increasing poverty level. For breast cancer, the hazards were similar in the 0.0-4.9% and 5.0-9.9% poverty levels, but there were increased hazards for the remaining higher poverty levels. For leukemias, the poverty level 5.0-9.9% showed essentially the same hazard as the 0.0-4.9% poverty level, but increased hazards for the remaining higher poverty levels.

Table 5. Hazard Ratios (Wald Confidence Intervals) Comparing to Reference Group of 0.0-4.9% Census Tract Poverty, from Cox Regression Models.

Primary Site Group	1990 Census Tract Poverty Level						Prob	
	5.0-9.9%		10.0-19.9%		20.0%+			
All Sites	1.1	(1.0,1.3)	1.3	(1.2,1.5)	1.5	(1.3,1.7)	<.0001	*
Brain and Other Nervous System	0.6	(0.4,1.1)	0.6	(0.4,1.0)	0.7	(0.4,1.4)	0.2386	
Breast (Females)	0.8	(0.6,1.3)	1.3	(0.9,1.8)	1.4	(0.9,2.2)	0.0050	*
Cervix Uteri	1.6	(0.3,7.5)	1.3	(0.3,5.4)	1.4	(0.3,7.4)	0.9047	
Colon and Rectum	1.0	(0.7,1.5)	1.1	(0.8,1.6)	0.9	(0.6,1.4)	0.4916	
Corpus and Uterus NOS	1.1	(0.4,3.3)	1.6	(0.6,4.3)	1.1	(0.3,3.7)	0.5261	
Esophagus	1.1	(0.4,3.1)	1.7	(0.6,5.0)	2.6	(0.8,8.7)	0.0585	+
Hodgkin Lymphoma	0.2	(0.0,0.8)	0.3	(0.1,1.1)	0.3	(0.0,2.5)	0.1588	
Kidney and Renal Pelvis	1.5	(0.5,4.4)	1.8	(0.7,5.0)	1.1	(0.3,3.8)	0.4173	
Larynx	a	a	a	a	a	a	0.1807	
Leukemias	1.0	(0.5,2.0)	1.4	(0.7,2.8)	1.7	(0.8,3.7)	0.0791	+
Liver and Intrahepatic Bile Duct	1.1	(0.2,5.0)	1.8	(0.4,8.7)	1.5	(0.3,8.7)	0.5730	
Lung and Bronchus	1.2	(0.9,1.6)	1.2	(0.9,1.5)	1.3	(1.0,1.8)	0.2395	
Melanoma	1.1	(0.4,2.7)	1.4	(0.6,3.2)	2.6	(1.0,7.0)	0.1032	
Mesothelioma	0.1	(0.0,12.2)	0.1	(0.0,18.8)	b	b	0.6987	
Myeloma	1.3	(0.5,3.2)	0.9	(0.4,2.2)	1.6	(0.6,4.1)	0.1670	
Non-Hodgkin Lymphoma	1.0	(0.6,1.7)	1.1	(0.7,1.7)	0.8	(0.5,1.5)	0.7087	
Oral Cavity and Pharynx	1.8	(0.6,5.4)	2.3	(0.8,6.5)	3.7	(1.2,10.9)	0.0550	+
Ovary	0.6	(0.4,1.1)	0.7	(0.4,1.2)	0.6	(0.3,1.2)	0.4247	
Pancreas	0.9	(0.5,1.4)	0.8	(0.6,1.3)	1.1	(0.7,1.8)	0.3579	
Prostate	2.1	(1.1,4.0)	2.7	(1.5,4.9)	2.9	(1.5,5.7)	0.0039	*
Stomach	1.4	(0.6,3.1)	1.4	(0.6,3.0)	1.1	(0.4,2.8)	0.7875	
Testis	a	a	a	a	a	a	0.9889	
Thyroid	0.1	(0,2.3.0)	0.2	(0.0,3.0)	c	c	0.5795	
Urinary Bladder	1.8	(0.8,4.2)	2.0	(0.9,4.4)	1.8	(0.7,4.3)	0.3515	

* p<0.05, + p<0.10.
[a] Hazard ratios were not estimable for larynx and testis because there were no deaths among persons in the reference poverty category.
[b] Small cell suppression.
[c] Not calculable.

DISCUSSION

This study shows striking disparities by poverty level of the area a person resides in at the time of diagnosis in cause-specific cancer survival. In the life table analyses, for 8 of 24 primary site groups investigated, and all sites combined, there was a significant gradient relating higher poverty with poorer survival.

These results are comparable in direction and magnitude to several other studies that investigated socioeconomic disparities in cancer survival. Using cases diagnosed during 1988 through1994, the SEER program analyzed areabased socioeconomic variation in cancer survival for all sites combined and for six major cancers (lung, colorectal, prostate, breast, cervix, and melanoma of the skin) (Singh et al., 2003; Singh et al., 2004; Ward et al., 2004). SEER used cutpoints of <10%, 10-19.9%, and 20%+ poverty measured at the census tract level of geography. Persons in high poverty census tracts generally had lower rates of cancer survival than those in low poverty census tracts for all cancers combined and the individual cancers considered. For all sites combined, there was a 12.0% absolute difference in 5-year cause-specific survival for males, and 10.3% for females (Singh et al., 2003). This difference was

greater for all sites combined than for individual sites due to differences in site distribution among the SES categories. For individual sites, the absolute differences in 5-year causespecific survival were 4.6% for male lung, 4.4% for female lung, 7.8% for male colorectal, 6.2% for female colorectal, 6.9% for prostate, 8.9% for female breast, 6.5% for cervix, 11.4% for melanoma male, and 7.6% for melanoma female. Not only did the highest poverty areas have lower survival, but there was also a poverty-related survival gradient which generally held across race and ethnicity categories.

The Colorado Cancer Coalition (2002) employed methods similar to those used in the NCI report; they used the same three poverty categories (<10, 10-19, 20+), but assigned poverty based on census block group or ZIP Code instead of census tract. Colorado found lower 5-year cause-specific survival in poorer areas for all sites combined and specific sites. The absolute survival deficit for the highest poverty areas compared to the wealthiest areas was 14.4% for all sites combined, 6.5% for breast cancer, 11.9% for colorectal, 13.8% for melanoma, and 7.9% for prostate cancer.

Results of the Cox models are consistent with previous reports of increased hazard of death associated with lower SES for several cancer sites. In a study conducted using Detroit metropolitan area SEER data, the hazard of breast cancer-specific death was higher among persons residing in census blocks categorized as working poor versus professional (HR=1.32 for localized disease, 1.16 for regional disease), adjusting for race, age, tumor characteristics, and treatment (Simon et al., 2006). The hazard of dying from early stage breast cancer among women aged 65+ in the SEER-Medicare linked database diagnosed in 1992 through1999 and followed for up to 11 years was 7% higher in the highest census tract poverty quartile versus the lowest in a model adjusting for age, marriage status, tumor stage, size, grade, hormone receptor status, comorbidity, year of diagnosis, SEER region, primary surgery and radiotherapy, and chemotherapy (Du et al., 2008). Among women aged younger than 65 years in Michigan diagnosed with cervical cancer in 1996 through1997 and followed up to 1998, the HR of death from cervical cancer for Medicaid-enrolled at diagnosis versus non-Medicaid-insured was 1.77, and the HR for Medicaid-enrolled after diagnosis was 2.40, adjusting for age, race, and stage (Bradley et al., 2004). Melanoma-specific survival was higher among persons residing in census blocks in the highest quintile of SES compared to the lowest (HR=0.68) in a California study that also adjusted for age, sex, race/ethnicity, stage, histologic subtype, anatomic subsite, and therapy (Zell et al., 2008). These results suggest widespread disparities in cause-specific cancer survival by SES, with variations in magnitude by primary site and presence of stage and treatment variables in multivariate models.

Many of the differences in survival among persons living in high and low poverty areas are likely to stem largely from disparities in access to screening (stage shift) and high-quality cancer treatment. The Colorado study found the largest poverty gradient for survival for regional stage cases, which may suggest differences in treatment patterns by poverty level. Treatment delay has been shown to be caused by insufficient clinical investigations by health care providers and a lack of awareness of the potential meaning of symptoms (Pagano et al., 2003). The SEER study found that stage at diagnosis did not fully account for the socioeconomic differences in survival (Singh et al., 2003; Singh et al., 2004; Ward et al., 2004). In a study of a nationwide cohort of breast cancer cases in Denmark, poorer management of comorbid conditions was suggested as a partial explanation of the social inequality in survival (Dalton et al., 2007). In the U.S., lack of health insurance is a critical barrier to receiving recommended preventive care,

cancer screening and treatment (USDHHS, 2006; USDHHS, 2007; Ward et al., 2008). While the U.S. Department of Health and Human Services has an objective to address cancer health disparities through the unbiased access to continuous quality preventive care, early detection, and treatment, evidence in fact suggests that the SES gap is widening in the U.S. and elsewhere (Coleman et al., 2004; Singh et al., 2004; USDHHS, 2004). It was not our intention in this study to differentiate decrements in survival as arising from late screening/stage versus inferior treatment.

The interpretation of differences in cause-specific cancer survival among poverty levels is made more complicated for cancers amenable to screening due to potential lead-time bias. Differences in screening prevalence among different poverty levels is a function of health care access, and may result in cancer diagnosis at earlier stages and at earlier ages among populations with higher screening rates. However, better survival among higher SES groups may reflect earlier diagnosis, not postponement of the date of death. Lead-time bias may occur within a stage, not just between stages, so adjustment for stage in statistical models may not fully account for it (Berrino, Estève, & Coleman, 1995). For prostate cases, in particular, lead-time bias may extend to a long detectable preclinical phase or indolent tumors.

Many studies of the impact of SES on stage distribution and cancer survival sought to disentangle the effects of race/ethnicity from those of SES. Differences in cancer survival by race have been associated with insurance status, screening prevalence, and SES (Du et al, 2008; Hahn et al., 2007; Movva et al., 2008; Ward et al., 2004). Some studies found persistent differences by race/ethnicity after adjusting for SES (McCarthy et al., 2010; Niu et al., 2010; Simon et al., 2006; Zell et al., 2008), others found no significant effects for measures of SES after adjusting for race (Artinyan et al., 2010; Dash et al., 2008), and others found no significant race effects after adjusting for SES (Meliker et al., 2009; Schwartz et al., 2009; Yan et al., 2009). The race distribution in Idaho (94.4% white race in 1990 Census) precluded us from investigating the independent effect of race in this study, yet our results are also unlikely to be confounded by race (U.S. Census Bureau, n.d.).

As cancer survival improves over time, increasing numbers of individuals are diagnosed with multiple primary cancers. The CDRI has been populationbased since 1971, so long-term survivors of cancers diagnosed in the 1970s and 1980s were more able to have been assigned the proper match between cancer death and primary site, reducing a potential source of bias among persons with multiple primaries spanning many years or decades.

Limitations

The relatively low numbers of cancer cases in Idaho mean that there may not have been sufficient power to detect significant differences in cause-specific cancer survival by poverty level for some primary site groups or by sex. Also, the differences in survival may be related to differences in sub-site or histologic type distribution, but could not be analyzed separately due to sparse data (Berrino et al., 1995).

The cases used in this analysis were diagnosed with first or later primary cancers during 1993 through1995 and followed up to the end of 2004. The survival rates presented may be lower than experienced by patients diagnosed in more recent years due to improvements in treatment and changes in risk factor and/or screening prevalence for some cancer sites (e.g. Idaho's Early Detection Program for Breast and Cervical Cancers has increased screening among low income women in certain age groups) (Idaho Department of Health and Welfare, 2011).

A potential criticism of this study is that poverty was measured at the census tract at the time of diagnosis, not the individual level. Data on socioeconomic measures such as education and income are not routinely available in cancer registry records. Nonetheless, Krieger and colleagues have demonstrated that well chosen area-based socioeconomic measures can be used to examine socioeconomic inequalities in health (Subramanian, Chen, Rehkopf, Waterman, & Krieger, 2006a; Rehkopf et al., 2006). Area-based socioeconomic measures need not be thought of as proxies for (unavailable) individual measures, but instead capture components of individual and area-based health influences (Subramanian, Chen, Rehkopf, Waterman, & Krieger, 2006b). The potential risk of using area-based socioeconomic measures when measures on individuals are lacking is to underestimate socioeconomic disparities.

Conclusion

The purpose of this study was to describe cause-specific cancer survival by census tract poverty level using population-based data with high quality death coding. We found significant or suggestive differences in cause-specific survival by poverty level for several individual cancer sites and all sites combined. The results of our study underscore the need for the health disparities objectives promoted by Healthy People 2020 and the Idaho Comprehensive Cancer Strategic Plan (Comprehensive Cancer Alliance for Idaho, 2006; USDHHS, 2011a). We are hopeful that the results of this and other studies can guide programs to achieve these objectives by focusing attention on cancer sites with significant poverty-related survival disparities.

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