Disparities in Cancer Mortality and Incidence Among American Indians and Alaska Natives in the United States

Mary C. White, ScD, David K. Espey, MD, Judith Swan, MHS, Charles L. Wiggins, PhD, MSPH, Christie Eheman, PhD, and Judith S. Kaur, MD

Objectives. We used improved data on American Indian and Alaska Native (AI/AN) ancestry to provide an updated and comprehensive description of cancer mortality and incidence among AI/AN populations from 1990 to 2009.

Methods. We linked the National Death Index and central cancer registry records independently to the Indian Health Service (IHS) patient registration database to improve identification of AI/AN persons in cancer mortality and incidence data, respectively. Analyses were restricted to non-Hispanic persons residing in Contract Health Service Delivery Area counties in 6 geographic regions of the United States. We compared age-adjusted mortality and incidence rates for AI/AN populations with White populations using rate ratios and mortality-to-incidence ratios. Trends were described using joinpoint analysis.

Results. Cancer mortality and incidence rates for AI/AN persons compared with Whites varied by region and type of cancer. Trends in death rates showed that greater progress in cancer control was achieved for White populations compared with AI/AN populations over the last 2 decades.

Conclusions. Spatial variations in mortality and incidence by type of cancer demonstrated both persistent and emerging challenges for cancer control in AI/AN populations. (*Am J Public Health.* 2014;104:S377–S387. doi:10.2105/AJPH.2013.301673)

Cancer has emerged as a leading cause of premature death among American Indian and Alaska Native (AI/AN) populations,[1] and measures of cancer mortality and incidence provide important indicators of health status for AI/AN populations. Previous analyses of cancer mortality among AI/AN populations described substantial geographic variation in death rates.[2,3] The interpretation of results from some earlier analyses were constrained, however, by the existence of racial misclassification on death certificates.[4] In recent years, our ability to examine cancer incidence in AI/AN populations was strengthened by the systematic linkage of records from central cancer registries with patient registration records from the Indian Health Service (IHS). This linkage substantially reduced misclassification of AI/AN ancestry in cancer incidence data.[5] Although imperfect, the improvement in race classification allowed a series of articles to be developed to provide a more accurate, comprehensive overview of cancer incidence among AI/AN populations from 1999 to 2004.[6–8]

At the time that these articles describing cancer incidence among AI/AN populations were published, comparable cancer mortality data that addressed racial misclassification on death certificates were not available. Recent linkages between the IHS patient registration file and the National Death Index (NDI) have resulted in reduced racial misclassification in death records and the opportunity to present comparable cancer mortality and incidence data. Our study took advantage of more accurate data on AI/AN ancestry to provide an updated overview of patterns in cancer mortality across multiple cancer sites among AI/AN populations. Longer-term trends in cancer mortality, from 1990 to 2009, were also examined. In addition, information was provided on cancer incidence to provide an update to the comprehensive overview of cancer incidence among AI/AN populations that was published in 2008.[8] By examining geographic variability and disparities in cancer mortality and incidence rates and changes over time, we identified priorities for action to reduce both cancer mortality and incidence in AI/AN populations.

METHODS

Detailed methods for generating the analytical mortality files are described elsewhere in this supplement.[5]

Population Estimates

We included bridged single-race population estimates developed by the US Census Bureau and the Centers for Disease Control and Prevention (CDC) National Center for Health Statistics (NCHS), adjusted for the population shifts caused by Hurricanes Katrina and Rita in 2005,[9] as denominators in the calculations of death rates.[10] Bridged single-race data made the post-2000 race/ethnicity population estimates comparable with the pre-2000 race/ethnicity estimates and enabled the reporting of a combined rate spanning 2000 as well as trend analyses.

Preliminary analyses revealed that the updated bridged intercensal population estimates significantly overestimated AI/AN individuals of Hispanic origin.[11] To avoid underestimating cancer incidence and death rates in AI/AN persons because of overestimated population denominators, all analyses in this supplement were limited to non-Hispanic AI/AN persons. Non-Hispanic Whites were chosen as the most homogeneous referent group. For conciseness, the term "non-Hispanic" was omitted when discussing both groups.

Mortality Records

Death certificate data are compiled by each state and sent to the NCHS, where they are edited for consistency and stripped of personal identifiers. The NCHS makes this information available to the research community in electronic format as part of the National Vital Statistics System (NVSS), which includes underlying and multiple cause of death fields, state of residence, age, sex, race, and ethnicity.[12] NCHS applies a bridging algorithm nearly identical to the one used by the Census Bureau to assign

a single race to decedents with multiple races reported on the death certificate.[13]

The IHS patient registration database is linked to death certificate data in the NDI to identify AI/AN deaths misclassified as non-Native.[5] Following this linkage, a flag indicating a positive link to IHS was added as an additional indicator of AI/AN ancestry to the NVSS mortality file. This file was combined with the population estimates to create an analytical file in SEER*Stat (version 8.0.2; National Cancer Institute [NCI], Bethesda, MD; AI/AN-US Mortality Database [AMD]) that included all deaths for all races reported to the NCHS from 1990 to 2009. Race for AI/AN deaths in this article was assigned as reported elsewhere in this supplement.[5] In short, it combined race classification by NCHS based on the death certificate and information derived from data linkages between the IHS patient registration database and the NDI.

For 1990 to 1998, the underlying cause of death was coded according to the *International Classification of Diseases, Ninth Revision* (*ICD-9*).[14] For 1999 to 2009, *ICD-10* was used.[15] The Surveillance, Epidemiology, and End Results (SEER) Cause of Death Recode was used for deaths caused by cancer.[16] Cancer death rates for AI/AN persons were compared with those of Whites, a population that provided more homogeneity across regions.

Incidence Records

We identified incident cancer cases diagnosed from 1999 to 2009 from population-based registries that participated in the CDC National Program of Cancer Registries (NPCR) or the NCI SEER Program.[17,18] For this study, participating registries classified tumor histology, tumor behavior, and primary cancer site according to the *International Classification of Diseases for Oncology, Third Edition* (*ICD-O-3*).[19] Detailed descriptions of the data sources and methods used for this analysis were described previously,[6] and data from 1999 to 2004 were described in a previous article.[8]

Incidence rates were presented for all cancer sites combined and for the most common cancer sites among AI/AN populations nationwide; site categories were consistent with prevailing reporting standards.[6,17–19] Lymphomas (*ICD-O-3* histology codes 9590–9729) were presented as 2 separate categories (i.e., Hodgkin and non-Hodgkin lymphoma) and were not included with other tumors of specific anatomic sites. Mesothelioma (*ICD-O-3* histology codes 9050–9055) and Kaposi sarcoma (*ICD-O-3* histology code 9140) were not included with other tumors of specific anatomic sites. In situ and invasive bladder tumors were combined in a single category.[20] Malignant tumors (*ICD-O-3* behavior code 3) were included in this analysis.

To identify AI/AN cancer cases misclassified as other races, central cancer registries worked with the IHS and CDC to link cancer registry records with the same IHS patient registration file used to link with the NDI, as described elsewhere.[5,6]

Geographic Coverage

We restricted analyses to Contract Health Service Delivery Area (CHSDA) counties, which, in general, contain federally recognized tribal lands or are adjacent to tribal lands.[5] CHSDA residence is used by the IHS to determine eligibility for services not directly available within the IHS. Linkage studies indicated more accurate race classification for AI/AN persons in these counties.[5,21] The CHSDA counties also had higher proportions of AI/AN persons in relation to total population than did non-CHSDA counties, with 64% of the US AI/AN population residing in the 637 counties designated as CHSDA (these counties represent 20% of the 3141 counties in the United States). Although less geographically representative, we presented analyses restricted to CHSDA counties for death and incidence rates for the purpose of offering improved accuracy in interpreting mortality and incidence statistics for AI/AN persons. For death and incidence rates restricted to CHSDA counties, we included data from 35 states and 6 regions.

We completed analyses for all regions combined and by the 6 designated IHS regions: Northern Plains, Alaska, Southern Plains, Southwest, Pacific Coast, and East (Table 1).[5] Identical or similar regional analyses were used for other health-related publications focusing on AI/AN persons.[2,8,22]

Statistical Methods

All rates, expressed per 100 000 population, were directly age adjusted, using SEER*Stat software version 8.0.2, to the 2000 US standard population.[23] Age adjustment for death rates utilized 11 age groups in accordance with a 1998 US Department of Health and Human Services recommendation.[24,25] Ranks for cancer deaths were based on number of deaths. Age adjustment for cancer incidence rates was performed using 19 age groups. Ranks in incidence rates were based on the age-adjusted rates.

Using the age-adjusted death and incidence rates, we calculated standardized rate ratios (RRs) for 1999 to 2009 for AI/AN populations using rates in White persons for comparison. RRs calculated by the reader from rounded rates presented in the tables might not correspond to the RRs calculated by SEER*Stat before rounding. Ninety-five percent confidence intervals (CIs) for age-adjusted rates and RR were calculated based on methods described by Tiwari et al.[26] The mortality-to-incidence ratio (MIR) was an indicator of survival and was used to compare cancer fatality by race.[27] MIRs for 1999 to 2009 were calculated as the age-adjusted death rate divided by the age-adjusted incidence rate.[28] We calculated the 95% CIs for the MIRs using the method by Fay.[29] Long-term cancer death trends (1990–2009) were described using joinpoint analysis,[30] including the annual percent change (APC) statistic for each interval. Differences in APCs were tested using the methods described by Kim et al.[31]

RESULTS

For men residing in CHSDA counties, cancer death rates from 1999 to 2009 varied significantly by region for AI/ANs and minimally for Whites (Table 1). Among AI/AN men in CHSDA counties, death rates for all cancer sites combined ranged from 163.8 in the Southwest to 338.1 in the Northern Plains, more than a 2-fold difference. By contrast, the lowest all-site rate for White men was 207.1 in the Southwest, and the highest was 231.7 in the East. Among AI/AN women residing in CHSDA counties, the overall death rate for all cancer sites combined ranged from the lowest value of 125.9 in the Southwest to a high of 246.9 in the Northern Plains. Among White women, total cancer death rates varied slightly, from 149.9 in the Southwest to 164.4 in the Pacific Coast region. For all malignant cancers

TABLE 1—Death Rates, Ranks, and Rate Ratios of the Top 15 Cancers for American Indian/Alaska Native Persons Compared With White Persons, by Indian Health Service Region and Sex: Contract Health Service Delivery Area Counties, United States 1999–2009

	Northern Plains			Alaska			Southern Plains			Southwest			Pacific Coast			East			All United States		
Cancer Sites	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR
Males																					
All malignant cancers		338.1 (223.4)	1.51*		298.7 (207.2)	1.44*		319.8 (244.2)	1.31*		163.8 (207.1)	0.79*		233.8 (223.7)	1.05		192.5 (231.7)	0.83*		248.4 (224.7)	1.11*
Lung and bronchus	1 (1)	113.4 (66.2)	1.71*	1 (1)	89.2 (62.4)	1.43*	1 (1)	102.1 (83.6)	1.22*	1 (1)	20.1 (58.6)	0.34*	1 (1)	62.3 (63.7)	0.98	1 (1)	58.8 (71.7)	0.82*	1 (1)	67.5 (67.0)	1.01
Colon and rectum	2 (3)	38.1 (20.6)	1.84*	2 (2)	39.1 (18.5)	2.12*	2 (2)	33.6 (22.7)	1.48*	3 (3)	13.2 (19.9)	0.66*	2 (3)	28.0 (19.8)	1.41*	2 (3)	18.5 (21.3)	0.87	2 (3)	26.0 (20.6)	1.26*
Prostate	3 (2)	41.2 (26.7)	1.55*	5 (3)	22.7 (24.3)	0.93	3 (3)	31.3 (24.0)	1.30*	2 (2)	22.4 (24.5)	0.92	3 (2)	26.4 (26.9)	0.98	3 (2)	23.0 (23.4)	0.98	3 (2)	27.6 (25.2)	1.09*
Liver and intrahepatic bile duct	4 (10)	14.9 (5.4)	2.75*	6 (7)	12.6 (5.9)	2.12*	5 (9)	13.6 (6.2)	2.18*	5 (8)	13.0 (5.9)	2.19*	4 (9)	13.9 (6.6)	2.11*	4 (8)	9.3 (6.8)	1.38	4 (8)	13.4 (6.3)	2.12*
Kidney and renal pelvis	5 (8)	12.9 (6.2)	2.08*	8 (10)	10.8 (5.4)	1.98*	4 (8)	14.3 (6.8)	2.11*	6 (10)	12.0 (5.2)	2.33*	7 (10)	7.2 (5.8)	1.23	7 (9)	6.7 (5.9)	1.13	5 (10)	11.3 (5.9)	1.92*
Pancreas	6 (4)	11.1 (11.8)	0.94	4 (4)	18.7 (10.9)	1.72*	6 (4)	11.4 (12.1)	0.95	7 (4)	11.3 (11.2)	1.01	5 (4)	12.6 (12.4)	1.02	6 (4)	6.4 (12.8)	0.50*	6 (4)	11.8 (12.2)	0.96
Stomach	8 (13)	10.4 (4.3)	2.44*	3 (11)	17.6 (4.0)	4.43*	9 (14)	7.3 (3.8)	1.92*	4 (14)	15.4 (3.6)	4.31*	9 (14)	6.6 (4.2)	1.57*	5 (11)	7.5 (5.0)	1.50	7 (14)	10.8 (4.3)	2.49*
Esophagus	7 (6)	10.1 (8.2)	1.23	7 (6)	11.7 (7.1)	1.66*	7 (6)	10.9 (7.6)	1.44*	9 (6)	5.7 (7.5)	0.76*	6 (6)	9.7 (8.5)	1.15	9 (6)	4.7 (8.1)	0.58*	8 (6)	8.6 (8.1)	1.06
Non-Hodgkin lymphoma	9 (5)	9.4 (9.8)	0.96	10 (5)	4.4 (9.6)	0.46*	8 (5)	11.6 (9.7)	1.20	8 (5)	5.5 (8.3)	0.66*	8 (5)	7.6 (9.7)	0.79	10 (5)	4.2 (9.3)	0.45*	9 (5)	7.7 (9.4)	0.82*
Brain and other nervous system	11 (9)	4.0 (6.0)	0.67*	13 (8)	2.0 (5.5)	0.36*	10 (10)	5.7 (6.1)	0.93	11 (9)	2.3 (5.6)	0.41*	10 (8)	4.7 (6.8)	0.69*	13 (10)	2.9 (5.8)	0.50*	10 (9)	3.9 (6.1)	0.63*
Myeloma	12 (12)	6.0 (4.7)	1.26	14 (14)	2.0 (3.5)	0.57	13 (13)	6.2 (4.0)	1.54*	10 (12)	5.4 (4.0)	1.38*	12 (13)	4.8 (4.6)	1.04	11 (14)	3.5 (4.2)	0.83	11 (13)	5.3 (4.4)	1.20*
Myeloid and monocytic leukemia	10 (11)	5.1 (4.9)	1.03	9 (13)	4.0 (3.9)	1.03	12 (12)	5.8 (5.1)	1.14	12 (13)	2.3 (3.9)	0.61*	11 (12)	5.1 (5.1)	0.99	12 (13)	2.2 (4.8)	0.45*	12 (12)	4.2 (4.8)	0.88
Urinary bladder	14 (7)	4.7 (8.2)	0.57*	12 (9)	4.4 (8.0)	0.55	11 (7)	8.0 (7.6)	1.05	17 (7)	2.1 (8.0)	0.26*	13 (7)	4.5 (8.5)	0.53*	8 (7)	7.2 (8.4)	0.86	13 (7)	4.7 (8.3)	0.57*
Lymphocytic leukemia	15 (15)	1.8 (3.3)	0.56*	16 (15)	1.4 (3.7)	0.38	14 (15)	3.7 (3.3)	1.11	13 (15)	1.3 (2.7)	0.50*	14 (15)	3.2 (3.3)	0.96	15 (15)	3.1 (2.8)	1.10	14 (15)	2.4 (3.1)	0.79*
Larynx	13 (18)	4.7 (1.8)	2.52*	20 (19)	1.1 (1.4)	0.83	16 (18)	3.1 (2.1)	1.51*	18 (18)	1.5 (1.7)	0.93	15 (18)	2.8 (1.7)	1.60	14 (17)	2.1 (2.2)	0.96	15 (18)	2.6 (1.9)	1.36*
Females																					
All malignant cancers		246.9 (154.4)	1.60*		232.6 (155.5)	1.50*		221.1 (162.1)	1.36*		125.9 (149.9)	0.84*		194.4 (164.4)	1.18*		141.6 (160.5)	0.88*		185.8 (159.1)	1.17*
Lung and bronchus	1 (1)	81.6 (38.7)	2.11*	1 (1)	61.9 (44.9)	1.38*	1 (1)	61.8 (46.2)	1.34*	2 (1)	11.6 (41.0)	0.28*	1 (1)	53.8 (45.5)	1.18*	1 (1)	37.0 (44.5)	0.83*	1 (1)	46.2 (43.4)	1.06*
Breast	2 (2)	25.8 (22.9)	1.13	2 (2)	29.0 (23.0)	1.26*	2 (2)	29.2 (24.7)	1.18*	1 (2)	15.2 (23.8)	0.64*	2 (2)	21.9 (25.0)	0.88	2 (2)	17.0 (24.1)	0.71*	2 (2)	22.2 (24.1)	0.92*
Colon and rectum	3 (3)	23.0 (15.0)	1.53*	3 (3)	31.7 (13.0)	2.43*	3 (3)	25.0 (15.2)	1.64*	3 (3)	10.2 (14.2)	0.72*	3 (3)	20.1 (14.6)	1.38*	3 (3)	19.4 (14.9)	1.30*	3 (3)	19.3 (14.7)	1.31*
Pancreas	4 (4)	10.6 (9.3)	1.14	5 (4)	11.0 (10.3)	1.06	4 (4)	10.5 (8.3)	1.27*	5 (4)	8.6 (8.5)	1.02	4 (5)	11.8 (9.6)	1.23*	4 (4)	9.0 (9.7)	0.93	4 (4)	10.1 (9.3)	1.08
Ovary	6 (5)	8.3 (9.0)	0.92	7 (5)	7.0 (6.5)	1.08	5 (5)	9.7 (8.4)	1.15	4 (5)	9.5 (8.6)	1.10	5 (4)	10.2 (10.1)	1.01	5 (5)	5.4 (8.9)	0.61*	5 (5)	9.0 (9.2)	0.98
Liver and intrahepatic bile duct	7 (12)	8.3 (2.6)	3.25*	6 (10)	8.5 (2.7)	3.14*	7 (11)	7.0 (2.8)	2.54*	6 (9)	8.5 (2.7)	3.14*	6 (10)	8.1 (2.9)	2.84*	6 (10)	4.5 (2.7)	1.67	6 (10)	7.7 (2.7)	2.84*
Non-Hodgkin lymphoma	10 (6)	7.0 (6.4)	1.11	10 (6)	4.5 (6.5)	0.70	6 (6)	8.8 (6.3)	1.40*	9 (6)	5.1 (5.6)	0.91	7 (6)	7.4 (6.1)	1.21	12 (6)	2.8 (5.9)	0.47*	7 (6)	6.4 (6.0)	1.07
Stomach	8 (16)	6.5 (2.0)	3.28*	4 (17)	11.8 (1.7)	7.11*	12 (16)	4.6 (1.9)	2.44*	7 (15)	6.6 (1.8)	3.61*	9 (16)	5.0 (2.0)	2.47*	11 (14)	3.0 (2.5)	1.22	8 (14)	5.9 (2.1)	2.77*
Kidney and renal pelvis	9 (9)	6.1 (3.0)	2.04*	9 (12)	4.6 (2.4)	1.91	8 (9)	5.9 (3.3)	1.81*	8 (11)	5.6 (2.4)	2.36*	10 (12)	4.6 (2.6)	1.78*	7 (13)	4.0 (2.6)	1.56	9 (12)	5.4 (2.7)	2.02*
Cervix uteri	5 (20)	7.3 (1.8)	4.15*	12 (11)	3.5 (1.9)	1.83	9 (13)	4.3 (2.8)	1.58*	10 (17)	4.2 (2.0)	2.05*	13 (19)	2.4 (2.0)	1.20	8 (19)	3.3 (2.0)	1.69	10 (19)	4.2 (2.0)	2.11*

Continued

TABLE 1—Continued

Corpus and uterus, not otherwise specified	11 (7)	5.4 (4.4)	1.22	14 (13)	1.9 (2.2)	0.88	10 (8)	4.5 (3.7)	1.22	13 (8)	3.3 (3.1)	1.06	8 (8)	4.7 (4.0)	1.19	9 (7)	3.6 (3.6)	1	11 (7)	4.0 (3.8)	1.07	
Myeloma	13 (11)	4.1 (2.9)	1.42	11 (8)	3.5 (3.2)	1.08	11 (12)	4.6 (2.4)	1.91*	12 (10)	3.9 (2.4)	1.62*	14 (11)	3.1 (2.7)	1.16	10 (9)	3.8 (2.6)	1.42	12 (11)	3.9 (2.6)	1.46*	
Brain and other nervous system	12 (8)	3.4 (4.1)	0.82	17 (7)	1.2 (4.0)	0.30*	13 (7)	4.2 (4.1)	1.02	14 (7)	1.8 (3.7)	0.47*	11 (7)	3.5 (4.5)	0.77	16 (8)	1.8 (3.8)	0.46*	13 (8)	2.9 (4.1)	0.70*	
Gallbladder	16 (23)	3.2 (0.9)	3.45*	23 (36)	0.9 (0.3)	2.69	18 (24)	1.9 (0.6)	3.04*	11 (25)	4.6 (0.6)	8.32*	18 (23)	1.9 (0.6)	3.09*	19 (24)	1.2 (0.6)	1.85	14 (24)	2.8 (0.7)	4.16*	
Myeloid and monocytic leukemia	14 (10)	3.5 (3.0)	1.15	15 (9)	1.9 (2.7)	0.69	17 (10)	2.3 (3.0)	0.76	16 (13)	1.4 (2.4)	0.61*	12 (9)	3.4 (3.1)	1.08	13 (11)	2.6 (2.8)	0.92	15 (9)	2.4 (2.9)	0.83*	

Note. AI/AN = American Indian/Alaska Native; CHSDA = Contract Health Service Delivery Area; RR = rate ratio. Analyses are limited to persons of non-Hispanic origin. AI/AN race is reported from death certificates or through linkage with the Indian Health Service patient registration database. Rates are per 100 000 persons and are age-adjusted to the 2000 US standard population (11 age groups; Census P25-1130). RRs are calculated in SEER*Stat before rounding of rates and may not equal RRs calculated from rates presented in table. Indian Health Service regions are defined as follows: Alaska[a]; Northern Plains (IL, IN,[a] IA,[a] MI,[a] MN,[a] MT,[a] NE,[a] ND,[a] SD,[a] WI,[a] WY[a]); Southern Plains (OK,[a] KS,[a] TX[a]); Southwest (AZ,[a] CO,[a] NV,[a] NM,[a] UT[a]); Pacific Coast (CA,[a] ID,[a] OR,[a] WA,[a] HI); East (AL,[a] AR, CT,[a] DE, FL,[a] GA, KY, LA,[a] ME,[a] MD, MA,[a] MS,[a] MO, NH, NJ, NY,[a] NC,[a] OH, PA,[a] RI,[a] SC,[a] TN, VT, VA, WV, DC). Percent regional coverage of AI/AN persons in CHSDA counties to AI/AN persons in all counties: Northern Plains = 64.8%; Alaska = 100%; Southern Plains = 76.3%; Southwest = 91.3%; Pacific Coast = 71.3%; East = 18.2%; total US = 64.2%.

Source. AI/AN Mortality Database (AMD 1999–2009).

[a]Identifies states with ≥ 1 county designated as CHSDA.

*$P < .05$.

combined, death rates were significantly higher for AI/AN men and women than for White men and women in the Northern Plains, Alaska, and Southern Plains, significantly higher for AI/AN women than White women in the Pacific Coast, and significantly lower for AI/AN men and women than for White men and women in the East and Southwest.

Death rates for several specific cancers are described in greater detail elsewhere in this supplement.[32–38] Death rates for gallbladder, stomach, liver, and kidney cancers were consistently elevated among AI/AN persons compared with Whites across all 6 regions, although some elevations did not reach statistical significance in all regions. Death rates for gallbladder cancer were particularly higher for AI/AN women in the Southwest, where the rate was more than 8 times the rate for White women. Stomach cancer death rates for AI/AN men and women were highest in Alaska, followed by the Southwest and Northern Plains. Death rates for liver cancer and kidney cancer among AI/AN men and women exceeded the rates for Whites by more than 2-fold in most regions. By contrast, death rates for brain cancer among AI/AN men and women were lower than those for Whites across all regions, except the Southern Plains, and death rates were also lower for urinary bladder cancers among AI/AN men than those for White men across most regions.

Beyond these similarities for a few cancers across regions, distinct patterns were observed in each region for several other cancers. In Alaska, marked elevations were observed in death rates among AI/AN men and women for cancers of the lung, colon, and rectum, and among AI/AN men for cancer of the esophagus compared with Whites. In both the Northern and Southern Plains, death rates for AI/AN men were elevated compared with White men for cancers of the lung, colon or rectum, prostate, and larynx. AI/AN women in the 2 regions also had significantly higher rates of lung, colorectal, and cervical cancers. By contrast, AI/AN persons in the Southwest region had lower death rates than those for Whites for lung, colorectal, brain, esophagus (male), bladder (male), and female breast cancers, but higher death rates than those for Whites for cervical cancers and myeloma. In the East, death rates among AI/AN women were significantly higher than those among White women

TABLE 2—Incidence Rates, Ranks, and Rate Ratios of the Top 15 Cancers for American Indian/Alaska Native Persons Compared With White Persons, by Indian Health Service Region and Sex: Contract Health Service Delivery Area Counties, United States 1999–2009

	Northern Plains			Alaska			Southern Plains			Southwest			Pacific Coast			East			All United States		
Cancer sites	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR	Rank, AI/AN (White)	Rate, AI/AN (White)	AI/AN: White RR
Males																					
All malignant cancers		633.1 (530.6)	1.19*		556.0 (551.3)	1.01		655.4 (547.6)	1.20*		316.6 (491.0)	0.64*		468.2 (549.1)	0.85*		356.1 (580.4)	0.61*		487.8 (546.4)	0.89*
Prostate	1 (1)	164.1 (155.5)	1.06	3 (1)	83.0 (165.4)	0.50*	1 (1)	170.6 (146.2)	1.17*	1 (1)	81.3 (132.1)	0.62*	1 (1)	113.6 (153.9)	0.74*	1 (1)	97.1 (155.8)	0.62*	1 (1)	121.2 (150.8)	0.80*
Lung and bronchus	2 (2)	123.6 (80.4)	1.54*	1 (2)	120.8 (83.4)	1.45*	2 (2)	127.3 (103.2)	1.23*	4 (2)	25.1 (71.8)	0.35*	2 (2)	72.9 (78.2)	0.93	2 (2)	55.3 (91.6)	0.60*	2 (2)	80.2 (83.3)	0.96*
Colon and rectum	3 (3)	83.4 (56.5)	1.48*	2 (3)	105.9 (54.8)	1.93*	3 (3)	78.4 (58.6)	1.34*	2 (3)	33.6 (49.8)	0.68*	3 (3)	56.4 (52.8)	1.07	3 (3)	39.7 (60.4)	0.66*	3 (3)	60.6 (55.6)	1.09*
Kidney and renal pelvis	4 (7)	32.3 (18.3)	1.77*	4 (6)	31.7 (18.9)	1.68*	4 (7)	34.5 (19.2)	1.80*	3 (7)	31.9 (16.8)	1.90*	4 (7)	23.7 (18.3)	1.29*	5 (7)	20.5 (20.2)	1.01	4 (7)	30.2 (18.7)	1.62*
Urinary bladder	5 (4)	26.9 (39.4)	0.68*	6 (4)	22.8 (46.0)	0.49*	5 (4)	30.9 (35.9)	0.86*	10 (4)	8.0 (38.7)	0.21*	5 (4)	22.7 (41.4)	0.55*	4 (4)	21.3 (44.8)	0.48*	5 (4)	20.6 (41.4)	0.50*
Non-Hodgkin lymphoma	7 (5)	19.8 (23.2)	0.85	9 (5)	15.3 (25.8)	0.59*	6 (6)	27.7 (22.6)	1.23*	7 (6)	12.1 (20.5)	0.59*	6 (6)	21.2 (24.5)	0.87	7 (6)	11.2 (24.5)	0.46*	6 (6)	18.6 (23.6)	0.79*
Liver and intrahepatic bile duct	9 (17)	17.6 (5.6)	3.18*	10 (13)	13.4 (8.3)	1.61*	9 (14)	14.9 (7.2)	2.08*	6 (13)	14.7 (6.8)	2.15*	7 (14)	20.4 (7.7)	2.64*	9 (14)	10.3 (8.0)	1.3	7 (14)	16.1 (7.3)	2.21*
Stomach	10 (13)	15.5 (7.9)	1.97*	5 (15)	31.5 (6.9)	4.54*	11 (15)	13.2 (7.0)	1.87*	5 (14)	18.0 (6.5)	2.75*	10 (13)	13.2 (7.9)	1.67*	10 (12)	9.6 (9.4)	1.03	8 (13)	15.9 (8.1)	1.97*
Oral cavity and pharynx	6 (9)	20.9 (15.6)	1.34*	7 (8)	20.8 (16.1)	1.29	8 (8)	19.9 (18.7)	1.06	12 (8)	6.9 (15.0)	0.46*	8 (8)	16.0 (17.3)	0.93	6 (8)	13.6 (17.5)	0.77	9 (9)	15.1 (16.8)	0.90*
Leukemia	8 (8)	17.8 (17.1)	1.04	12 (7)	9.4 (17.1)	0.55*	7 (9)	21.9 (17.9)	1.23*	9 (9)	8.0 (14.5)	0.55*	9 (9)	13.9 (17.0)	0.82*	8 (9)	10.5 (17.5)	0.60*	10 (8)	14.0 (16.9)	0.83*
Pancreas	13 (10)	11.0 (12.1)	0.91	8 (10)	19.5 (11.4)	1.71*	10 (10)	14.1 (12.7)	1.11	8 (10)	10.6 (11.7)	0.9	11 (10)	11.4 (13.1)	0.87	11 (10)	7.5 (13.7)	0.54*	11 (10)	12.1 (12.9)	0.94
Esophagus	11 (11)	13.4 (9.2)	1.45*	11 (11)	11.1 (9.1)	1.23	15 (12)	9.2 (8.0)	1.15	13 (12)	5.8 (8.0)	0.73*	13 (12)	9.3 (8.8)	1.06	14 (11)	6.0 (9.4)	0.64	12 (11)	8.7 (8.9)	0.98
Myeloma	14 (15)	9.7 (6.5)	1.49*	18 (16)	3.5 (6.7)	0.53*	14 (16)	9.5 (6.3)	1.51*	11 (17)	7.3 (5.4)	1.36*	15 (16)	6.1 (6.7)	0.91	16 (16)	4.6 (6.8)	0.68	13 (16)	7.5 (6.5)	1.16*
Melanoma of the skin	15 (6)	6.2 (20.8)	0.30*	19 (9)	2.2 (15.9)	0.14*	12 (5)	12.7 (23.4)	0.54*	16 (5)	3.5 (28.1)	0.13*	12 (5)	10.1 (34.3)	0.30*	13 (5)	6.0 (29.9)	0.20*	14 (5)	7.4 (29.0)	0.25*
Larynx	12 (16)	12.4 (6.2)	1.98*	13 (17)	6.4 (6.1)	1.06	13 (13)	10.0 (7.4)	1.35*	19 (18)	2.6 (5.3)	0.49*	14 (17)	6.4 (5.4)	1.18	12 (15)	6.9 (7.7)	0.9	15 (17)	6.9 (6.4)	1.09
Females																					
All malignant cancers		483.6 (408.5)	1.18*		530.5 (428.5)	1.24*		520.8 (409.7)	1.27*		257.5 (393.2)	0.66*		408.0 (436.6)	0.93*		288.7 (443.1)	0.65*		398.3 (425.7)	0.94*
Breast	1 (1)	112.6 (125.5)	0.90*	1 (1)	141.3 (135.5)	1.04	1 (1)	136.1 (127.7)	1.07*	1 (1)	59.6 (121.0)	0.49*	1 (1)	106.6 (138.7)	0.77*	1 (1)	72.9 (132.9)	0.55*	1 (1)	100.0 (131.3)	0.76*
Lung and bronchus	2 (2)	97.2 (51.8)	1.88*	3 (2)	81.4 (62.7)	1.30*	2 (2)	83.2 (62.7)	1.33*	6 (2)	13.0 (54.9)	0.24*	2 (2)	64.2 (59.8)	1.07	2 (2)	46.5 (63.1)	0.74*	2 (2)	57.6 (59.0)	0.98
Colon and rectum	3 (3)	60.0 (42.8)	1.40*	2 (3)	97.5 (40.0)	2.44*	3 (3)	61.9 (41.7)	1.48*	2 (3)	23.9 (37.1)	0.65*	3 (3)	46.0 (40.1)	1.15*	3 (3)	36.3 (43.9)	0.83*	3 (3)	47.5 (41.4)	1.15*
Corpus and uterus, not otherwise specified	5 (4)	22.9 (26.4)	0.86*	4 (4)	17.1 (23.1)	0.74*	4 (4)	27.0 (20.0)	1.35*	3 (4)	21.5 (19.6)	1.09	4 (5)	23.6 (23.9)	0.99	4 (4)	14.8 (25.2)	0.59*	4 (4)	22.6 (23.8)	0.95*
Kidney and renal pelvis	4 (11)	23.9 (9.7)	2.46*	6 (11)	16.4 (10.5)	1.57*	5 (10)	21.0 (10.3)	2.05*	4 (11)	14.2 (9.0)	1.58*	6 (12)	14.8 (9.1)	1.62*	5 (12)	14.8 (10.2)	1.46*	5 (12)	17.4 (9.6)	1.81*
Non-Hodgkin lymphoma	6 (5)	18.0 (17.0)	1.06	7 (5)	13.5 (19.2)	0.70*	6 (5)	20.8 (16.7)	1.25*	8 (7)	10.7 (14.8)	0.72*	5 (6)	17.0 (16.8)	1.01	7 (6)	9.3 (16.9)	0.55*	6 (6)	15.4 (16.6)	0.93*
Ovary	8 (7)	11.2 (13.7)	0.82*	10 (8)	12.5 (12.1)	1.04	7 (7)	16.8 (13.2)	1.28*	5 (8)	13.5 (13.0)	1.04	7 (7)	12.4 (14.4)	0.86	10 (8)	7.9 (13.9)	0.57*	7 (8)	13.3 (13.8)	0.96
Thyroid	10 (8)	9.7 (13.6)	0.71*	11 (6)	12.4 (15.2)	0.81	10 (8)	12.6 (11.1)	1.13	7 (5)	11.2 (18.0)	0.62*	9 (8)	11.9 (13.4)	0.89	6 (7)	9.5 (16.9)	0.56*	8 (7)	11.4 (15.0)	0.76*
Cervix uteri	7 (13)	13.3 (6.8)	1.97*	9 (13)	13.1 (6.8)	1.94*	8 (11)	15.1 (9.2)	1.64*	10 (13)	8.3 (7.0)	1.19*	11 (13)	9.6 (7.0)	1.36*	9 (13)	8.4 (7.1)	1.18	9 (13)	11.0 (7.1)	1.55*
Pancreas	9 (12)	10.5 (9.2)	1.14	8 (10)	13.3 (11.1)	1.2	11 (12)	11.7 (8.9)	1.32*	9 (10)	9.2 (9.0)	1.02	8 (9)	12.3 (10.2)	1.21	8 (10)	9.3 (10.5)	0.88	10 (11)	10.8 (9.9)	1.10*
Leukemia	11 (9)	9.7 (10.3)	0.94	14 (9)	7.2 (11.2)	0.64*	9 (9)	12.9 (10.9)	1.18*	14 (12)	6.0 (8.9)	0.67*	10 (10)	9.8 (10.2)	0.96	12 (11)	5.5 (10.2)	0.54*	11 (10)	8.9 (10.1)	0.88*
Stomach	12 (17)	8.9 (3.3)	2.72*	5 (19)	17.1 (2.7)	6.36*	15 (17)	7.4 (3.2)	2.32*	11 (17)	8.2 (2.9)	2.82*	14 (17)	6.2 (3.3)	1.90*	16 (16)	3.8 (4.3)	0.89	12 (17)	8.0 (3.5)	2.26*

Continued

TABLE 2—Continued

Liver and intrahepatic bile duct	13 (19)	8.1 (2.3)	3.54*	13 (17)	7.3 (2.9)	2.53*	17 (18)	7.3 (3.0)	2.40*	12 (18)	8.1 (2.5)	3.30*	12 (18)	7.9 (2.8)	2.82*	11 (19)	5.8 (2.5)	2.27*	13 (19)	7.7 (2.6)	2.95*
Myeloma	16 (16)	6.1 (4.1)	1.50*	16 (16)	6.0 (4.1)	1.48	13 (16)	8.0 (4.0)	2.00*	15 (16)	5.8 (3.2)	1.82*	17 (16)	5.3 (3.9)	1.36*	15 (17)	4.0 (4.2)	0.96	14 (16)	6.2 (3.9)	1.57*
Oral cavity and pharynx	14 (14)	7.9 (6.3)	1.25	12 (15)	11.2 (5.4)	2.07*	16 (14)	7.3 (6.5)	1.13	16 (15)	3.0 (5.8)	0.52*	16 (14)	5.3 (6.8)	0.78	14 (14)	4.9 (6.5)	0.74	15 (14)	5.8 (6.4)	0.90*

Note. AI/AN = American Indian/Alaska Native; RR = rate ratio. Analyses are limited to persons of non-Hispanic origin. AI/AN race is reported from death certificates or through linkage with the Indian Health Service patient registration database. Rates are per 100 000 persons and are age-adjusted to the 2000 US standard population (11 age groups: Census P25-1130). Rate ratios are calculated in SEER*Stat before rounding of rates and may not equal rate ratios calculated from rates presented in table. Indian Health Service regions are defined as follows: Alaska[a]; Northern Plains (IL, IN,[a] IA,[a] MI,[a] MN,[a] MT,[a] NE,[a] ND,[a] SD,[a] WI,[a] WY[a]); Southwest (AZ,[a] CO,[a] NV,[a] NM,[a] UT[a]); Pacific Coast (CA,[a] ID,[a] OR,[a] WA,[a] HI); East (AL,[a] AR, CT,[a] DE, FL,[a] GA, KY, LA,[a] ME,[a] MD, MA,[a] MS,[a] MO, NH, NJ, NY,[a] NC,[a] OH, PA,[a] RI,[a] SC,[a] TN, VT, VA, WV, DC). Percent regional coverage of AI/AN persons in CHSDA counties to AI/AN persons in all counties: Northern Plains = 64.8%; Alaska = 100%; Southern Plains = 76.3%; Southwest = 91.3%; Pacific Coast = 71.3%; East = 18.2%; total US = 64.2%. *Source.* Data are from population-based cancer registries that participate in the National Program of Cancer Registries and/or the Surveillance, Epidemiology, and End Results Program, and meet criteria for high data quality. Years of data and registries used: 1999–2009 (43 states): AK, AL, AZ, CA, CO, CT, DE, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MT, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, TX, UT, VT, WA, WV, WY; 1999–2008: WI; 1999–2001 and 2003–2009: DC; 2001–2009: AR, NC, SD; 2002–2009: VA; 2003–2009: MS, TN.

[a]Indicates states with ≥1 county designated as CHSDA.

* $P < .05$.

for cancer of the colon and rectum, but significantly lower for cancers of the breast, lung, and ovary, whereas AI/AN men had lower rates than those for White men for cancers of the lung, pancreas, esophagus, and myeloid or monocytic leukemia. In the Pacific Coast region, rates for AI/AN persons were higher than those for Whites for colorectal cancer (CRC), and higher among AI/AN women for pancreatic cancer.

Incidence and Trends

Overall geographic patterns in cancer incidence from 1999 to 2009 were similar to those observed for cancer mortality. Among AI/AN men in CHSDA counties, the overall cancer incidence rates ranged from 316.6 in the Southwest to 655.4 in the Southern Plains, whereas among White men, the rates ranged from 491.0 in the Southwest to 580.4 in the East (Table 2). For women in CHSDA counties, the incidence rates for all cancer sites combined among AI/AN women were higher than those among Whites in Alaska, the Northern Plains, and the Southern Plains and lower elsewhere. The rates for AI/AN females varied from 257.5 in the Southwest to 530.5 in Alaska, whereas the rates for White females ranged from 393.2 in the Southwest to 443.1 in the East.

Overall cancer death rates increased significantly for AI/AN men and women from 1990 to 2009, whereas overall cancer death rates declined significantly for White men during this period and for White women from 1993 to 1998 and 2001 to 2009 (Table 3). Compared with Whites, deaths for all cancers combined among AI/AN persons were significantly lower from 1990 to 1998, but significantly higher from 1999 to 2009 (data not shown). For lung, CRC, and breast cancers, significant declines in death rates occurred in White populations, whereas the corresponding death rates for AI/AN populations remained unchanged or increased. Death rates for stomach cancer declined among AI/AN men and women, but the magnitude of the decline was substantially less than that for Whites and significant only for AI/AN men and women combined. Death rates declined for prostate cancer for White men and remained stable for AI/AN men. Death rates for liver cancer increased significantly for AI/AN and White populations. Death rates for cervical cancer for AI/AN women declined precipitously in the early 1990s, but after 1993, the APC reflected a modest and not statistically significant decline. In comparison, a significant 2.5% decrease per year was observed for White women over this same period.

Mortality-to-Incidence Ratio

With the exception of liver cancer, the MIRs were consistently higher for AI/AN than for White persons for common cancer sites (Table 4). The magnitude of the difference between MIRs for AI/AN and White persons was generally most pronounced for cancers that were considered amenable to screening and treatment, such as female breast, cervix, CRC, and prostate cancers. By contrast, the smallest differences, as measured by the AI/AN:White ratio, were for highly fatal cancers with MIRs approaching 1.0, such as liver, lung, and pancreas cancers.

DISCUSSION

These new data offered several key findings that could guide cancer control efforts to improve understanding of cancer disparities in AI/AN populations. First, the data extended earlier observations of distinctive geographic patterns in AI/AN cancer mortality and incidence.[2,3,8,39,40] Second, they highlighted substantial cancer disparities between AI/AN and White populations in regional analyses that were masked when rates were aggregated across regions. Third, the substantial progress in reducing cancer death rates experienced over the 2 decades by Whites was not shared by AI/AN persons.

Some of the observed regional differences in cancer could be because of variation in the social and environmental factors that contributed to population differences in obesity, physical inactivity, alcohol consumption, and smoking, as reported by Cobb et al. in this supplement.[41] The prevalence of exposure to multiple infectious and carcinogenic agents at critical periods across the life span might also vary geographically and explain some of these patterns.[42]

Trends in overall cancer mortality were strongly influenced by death rates from lung cancer, which showed little improvement in AI/AN populations compared with Whites.[34] Smoking prevalence estimates in the Behavioral

TABLE 3—Cancer Death Rate Trends With Joinpoint Analyses for Selected Cancers for American Indian/Alaska Native Persons Compared With White Persons, by Sex: Contract Health Service Delivery Area Counties, United States, 1990–2009

	Trend 1		Trend 2		Trend 3		Trend 4	
Race/Ethnicity and Sex	Years	APC[a]	Years	APC[a]	Years	APC[a]	Years	APC[a]
All sites								
AI/AN								
Both sexes	1990–2009	0.7*						
Male	1990–2009	0.7*						
Female	1990–2009	0.8*						
White								
Both sexes	1990–1993	0.1	1993–1998	−1.2*	1998–2001	−0.3	2001–2009	−1.5*
Male	1990–2002	−1.1*	2002–2009	−1.7*				
Female	1990–1993	0.7	1993–1998	−1.2*	1998–2001	−0.0	2001–2009	−1.3*
Lung								
AI/AN								
Both sexes	1990–2009	1.2*						
Male	1990–2009	0.3						
Female	1990–2009	2.4*						
White								
Both sexes	1990–2002	−0.4*	2002–2009	−1.7*				
Male	1990–2003	−1.4*	2003–2009	−2.6*				
Female	1990–1992	3.4	1992–2002	0.7*	2002–2009	−1.1*		
Colorectal cancer								
AI/AN								
Both sexes	1990–2009	0.8						
Male	1990–2009	1.1						
Female	1990–2009	0.6						
White								
Both sexes	1990–1994	−1.2*	1994–1997	−2.9	1997–2000	−0.5	2000–2009	−3.1*
Male	1990–2001	−1.9*	2001–2009	−3.4*				
Female	1990–2000	−1.6*	2000–2009	−2.8*				
Stomach								
AI/AN								
Both sexes	1990–2009	−1.1*						
Male	1990–2009	−1.2						
Female	1990–2009	−1.1						
White								
Both sexes	1990–2009	−3.8*						
Male	1990–2009	−4.0*						
Female	1990–2009	−3.7*						
Breast								
AI/AN								
Female	1990–2009	0.9*						
White								
Female	1990–2009	−2.1*						

Continued

Risk Factor Surveillance System for AI/AN persons varied by region and mirrored regional differences in lung cancer incidence and mortality.[41] Overall, AI/AN populations had the highest prevalence of tobacco use of any population in the United States.[43] A new Government Performance Results Act (GPRA) measure was established in 2006 to track tobacco cessation service delivery among current smokers within the IHS and tribal programs, and this measure progressively improved each year, from the baseline of 12% in 2006 to 35.2% in 2012.[44]

CRC mortality also displayed significant regional variation, with Alaska AI/AN people experiencing a 3-fold greater rate than those in the Southwest. Compared with Whites, AI/AN persons had poor indicators of survival and were diagnosed with later stage disease.[33] Perhaps most concerning, compared with impressive decreases in CRC death rates in Whites, AI/AN persons made no measureable progress. Adding CRC screening as a GPRA measure in 2006 likely contributed to improved screening prevalence and might affect death rates in the next few years.[33,41]

The overall lower death rate for breast cancer in AI/AN women compared with White women contrasted with our findings that among AI/AN women, breast cancer death rates were higher in Alaska and the Southern Plains, no improvement had occurred in breast cancer death rate trends, and the indicator of survival was poorer.[36] A possible contributor to worse breast cancer outcomes was a lower prevalence of mammography use among AI/AN women compared with White women.[41]

Compared with White men, AI/AN men were less likely to develop prostate cancer, but more likely to die from prostate cancer. Regional differences were also observed in both death rates and incidence rates for prostate cancer among AI/AN men. Lower prevalence estimates for prostrate screening antigen testing among AI/AN men could explain some of the differences in incidence rates, especially among younger men, whereas lower health care access could contribute to higher death rates.[38]

Cervical cancer mortality was generally regarded as a great success story of declining death rates because of the emphasis previously given to efforts that targeted AI/AN women to

TABLE 3—*Continued*

Cervical						
AI/AN						
Female	1990–1993	−26.2*	1993–2009	−1.2		
White						
Female	1990–2009	−2.5*				
Prostate						
AI/AN						
Male	1990–2009	−0.4				
White						
Male	1990–2009	−3.0*				
Liver						
AI/AN						
Both sexes	1990–2009	2.4*				
Male	1990–2009	2.3*				
Female	1990–2009	2.3*				
White						
Both sexes	1990–2009	2.5*				
Male	1990–2009	2.5*				
Female	1990–1996	4.3*	1996–2000	−1.2	2000–2009	2.2*

Note. AI/AN = American Indian/Alaska Native; APC = annual percent change. Joinpoint analyses with up to 3 joinpoints are based on rates per 100 000 persons and were age-adjusted to the 2000 US standard population (11 age groups; Census P25-1130); Joinpoint Regression Program, Version 4.0.1. January 2013; Statistical Research and Applications Branch, National Cancer Institute, Bethesda, MD. Analyses are limited to persons of non-Hispanic origin. AI/AN race is reported from death certificates or through linkage with the Indian Health Service patient registration database.
Source. AI/AN Mortality Database (AMD 1990–2009); the following states and years of data are excluded because Hispanic origin was not collected on the death certificate: LA: 1990; NH: 1990–1992; OK: 1990–1996.
[a]APC is based on rates that were age-adjusted to the 2000 US standard population (11 age groups; Census P25-1130).
*2-sided $P < .05$.

improve screening services.[35] Nonetheless, significant disparities persisted across regions where AI/AN women continued to experience greater mortality and incidence and more modest decrements in mortality over time than White women. Continued efforts to improve screening and expand use of HPV vaccines could help improve this picture.

The higher cancer death and incidence rates for liver, stomach, kidney, and gallbladder cancers in AI/AN compared with White populations across multiple regions were consistent with previous reports.[45–48] Kidney cancer is discussed elsewhere in this supplement.[32] Liver, stomach, and gallbladder cancers have a very low 5-year survival.[49] The advent of the hepatitis B vaccine is expected to prevent new cases of liver cancer and diminish mortality in subsequent generations, but more effort is needed to increase vaccination among older adults and the less educated.[50] A dramatic decrease in the incidence of hepatocellular carcinoma was observed after a hepatitis B vaccination program was introduced in Alaska.[51] New treatments are on the horizon for hepatitis C infection that could also reduce liver cancer mortality.[52] Factors that contribute to lower risks for some cancers among AI/AN populations, such as brain cancer and melanoma, were not identified, but also deserve attention.

Results from our investigation indicated that less progress was achieved in reducing cancer deaths over the last 2 decades for AI/AN populations than for White populations. For all cancers combined, death rates declined significantly for White men and women from 2001 to 2009 and increased significantly for AI/AN men and women. In addition, cancer survival, as measured by the MIR, was consistently less favorable for AI/AN compared with White populations for nearly all cancers examined. These disparities in cancer outcomes were consistent with earlier reports,[39,53–55] and likely were related to lower socioeconomic status and lack of health care access. As described previously, several geographic, financial, and bureaucratic barriers are faced by AI/AN populations, resulting in lower access to specialty medical care for the early diagnosis and treatment of cancer.[39]

Cancer control programs were initiated over the past 25 years to increase awareness about cancer control within AI/AN communities and access to quality screening and prevention services, but many areas remain underserved. In the absence of these efforts, the cancer disparities described in this article might be even larger. At the national level, the IHS has provided direct clinical and preventive services through its network of clinics and through its support of tribal health facilities, and the CDC has provided support to both state health departments and tribes for cancer control programs that serve AI/AN populations.[56] Within the National Breast and Cervical Cancer Early Detection Program (NBCCEDP), for example, more than one-third of eligible AI/AN women received NBCCEDP-funded cervical cancer screening services,[57] and nearly half of eligible AI/AN women received mammography services,[58] compared with much smaller percentages for eligible women of other races. The reauthorization of the Indian Health Care Improvement Act[59] has the potential for demonstration projects that could improve mobile clinics for screening CRC and breast cancer. Other organizations focusing on cancer control in AI/AN populations have made important contributions and continue to raise awareness about these disparities. Prominent examples of these include the AI/AN Community Networks Program "Spirit of E.A.G.L.E.S"[60] and the Native American Cancer Research Corporation.[61]

Limitations

Our interpretation of these results was subject to the following limitations. The method of linking records to reduce AI/AN misclassification was based on IHS patient records, and thus, did not address misclassification among AI/ANs who did not receive health care from the IHS. Moreover, there was substantial variation between federally recognized tribes in the proportion native ancestry required for tribal

TABLE 4—Mortality-to-Incidence Ratios for American Indian/Alaska Native Persons Compared With White Persons, by All Cancer Sites Combined and Specific Cancer Sites: Contract Health Service Delivery Area Counties, United States, 1999–2009

Cancer Sites	AI/AN MIR (95% CI)	White MIR (95% CI)	AI/AN:White Ratio[a]
All cancers	0.49 (0.48, 0.50)	0.39 (0.39, 0.39)	1.26
Bladder	0.24 (0.20, 0.27)	0.20 (0.20, 0.20)	1.19
Breast (female)	0.22 (0.21, 0.24)	0.18 (0.18, 0.19)	1.22
Cervical (female)	0.38 (0.33, 0.44)	0.28 (0.27, 0.29)	1.36
Colorectal	0.42 (0.40, 0.44)	0.36 (0.36, 0.36)	1.16
Hodgkin disease	0.21 (0.14, 0.30)	0.15 (0.14, 0.15)	1.40
Kidney and renal pelvis	0.35 (0.32, 0.38)	0.30 (0.29, 0.30)	1.18
Leukemia	0.60 (0.55, 0.67)	0.58 (0.57, 0.58)	1.05
Liver/intrahepatic bile duct	0.91 (0.83, 0.99)	0.91 (0.90, 0.93)	1.00
Lung and bronchus	0.83 (0.80, 0.86)	0.77 (0.77, 0.78)	1.07
Ovary (female)	0.68 (0.61, 0.77)	0.66 (0.65, 0.67)	1.03
Pancreas	0.96 (0.88, 1.05)	0.95 (0.94, 0.96)	1.02
Prostate (male)	0.23 (0.21, 0.25)	0.17 (0.17, 0.17)	1.40
Stomach	0.70 (0.64, 0.78)	0.56 (0.55, 0.57)	1.27
Uterus (female)	0.18 (0.16, 0.21)	0.16 (0.16, 0.16)	1.14

Note. AI/AN = American Indian/Alaska Native; CI = confidence interval; MIR = mortality-to-incidence ratio. Analyses are limited to persons of non-Hispanic origin. AI/AN race is reported from death certificates, by National Program of Cancer Registries and Surveillance, Epidemiology, and End Results cancer registries, or through linkage with the Indian Health Service patient registration database.

Source. For death rates, AI/AN Mortality Database (AMD 1999–2009). For incidence rates, data are from population-based cancer registries that participate in the National Program of Cancer Registries or the Surveillance, Epidemiology, and End Results Program, and meet criteria for high data quality. Years of data and registries used: 1999–2009 (43 states): AK, AL, AZ, CA, CO, CT, DE, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MT, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, TX, UT, VT, WA, WV, WY; 1999–2008: WI; 1999–2001 and 2003–2009: DC; 2001–2009: AR, NC, SD; 2002–2009: VA; 2003–2009: MS, TN.

[a]The AI/AN:White ratio is the MIR for American Indians/Alaska Natives divided by the MIR for Whites.

membership, and therefore, for eligibility for IHS services. Whether and how this discrepancy in tribal membership requirements might influence some of our findings was unclear, although our findings were consistent with previous reports. In addition, the analysis was restricted to non-Hispanic AI/AN residents of CHSDA counties who might not represent AI/AN residents of non-CHSDA counties. Given the diverse makeup of the AI/AN population within CHSDA counties, regional differences might not accurately reflect trends in specific tribes or ethnic groups. The characteristics of AI/ANs who resided in non-CHSDA counties or who did not receive health care from the IHS were not well known, and the potential bias introduced by the record linkage methodology used in this study was not well understood. The restriction of analyses to non-Hispanic AI/ANs was done because of difficulties in obtaining accurate population estimates. Fewer than 5% of cancer cases and deaths were identified as Hispanic AI/ANs. This restriction would not be expected to change the relative ranking of different areas or trends.

Conclusions

This study and the other articles in this supplement provide the most accurate and comprehensive examination of cancer mortality to date in AI/AN populations. Linking IHS data with death records from the NCHS and with case reports from central cancer registries identified AI/AN persons more accurately and aided in recognizing disparities in cancer incidence and mortality within the AI/AN population. The importance of accurate racial data was compounded when assessing differences among AI/AN populations by geographic regions. The ability to link existing data sets was an effective way to approach this problem, but the linkage required technical expertise and could be time and resource intensive.

Disparities in health status and mortality have persisted among AI/AN populations compared with the general population for many generations.[62] These results demonstrated persistent and growing disparities in cancer among AI/AN populations and the need to expand action beyond existing efforts. Regional differences in cancer occurrence among AI/AN populations reflected missed opportunities to identify and address the social, physical, and economic determinants of cancer risk at the community level. A comprehensive and culturally appropriate approach is needed to address the multilevel determinants of cancer risk. In addition, disparities in death rates and proxy measures of survival in AI/AN populations compared with Whites underlined the need for improved access to and utilization of quality health services for cancer screening, diagnosis, and treatment. ■

About the Authors

Mary C. White, David K. Espey, and Christie Eheman are with the Division of Cancer Prevention and Control, Centers for Disease Control and Prevention, Atlanta, GA. Judith Swan is with the Surveillance Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute, Bethesda, MD. Charles L. Wiggins is with the New Mexico Tumor Registry, University of New Mexico Cancer Center, Albuquerque. Judith S. Kaur is with the Native American Programs, Mayo Clinic, Rochester, MN. David K. Espey is also a guest editor for this supplement issue.

Correspondence should be sent to Mary C. White, ScD, Epidemiology and Applied Research Branch, Division of Cancer Prevention and Control, CDC, 4770 Buford Highway NE, F76, Atlanta, GA 30341 (e-mail: mxw5@cdc.gov). Reprints can be ordered at http://www.ajph.org by clicking the "Reprints" link.

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Contributors

M. C. White coordinated the writing team, led the drafting of the article, and contributed to analytical decisions and interpretation of results. D. K. Espey led the development of the linked data files, the methods, and the data analysis plan. J. Swan contributed to the analysis plan and led the drafting of the description of the results. C. L. Wiggins developed the framework for the presentation of findings in the context of previous work and contributed to the analysis plan. C. Eheman provided technical input on utilizing cancer registry data. J. S. Kaur discussed the findings in the larger context of cancer control in AI/AN populations. All authors took part in the conceptualization of the overall study design, drafting of the article, and discussion of

results, critical revision of the article for important intellectual content, and gave final approval of the submitted article.

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CDC and the Indian Health Service determined this project to constitute public health practice and not research; therefore, no formal institutional review board approvals were required.

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