Am J Transl Res 2026;18(6):4897-4909
www.ajtr.org /ISSN:1943-8141/AJTR0171384

Original Article

Affordable care act and 4-year all-cause mortality among U.S. working-age adults with or without cancer: 2000-2015

Iris Z Shen[1,4], Lanjing Zhang[1,2,3]

[1]Department of Chemical Biology, Ernest Mario School of Pharmacy, Rutgers University, Piscataway, NJ, USA; [2]Department of Pathology, Princeton Medical Center, Plainsboro, NJ, USA; [3]Rutgers Cancer Institute of New Jersey, New Brunswick, NJ, USA; [4]The Winsor School, Boston, MA, USA

Received January 11, 2026; Accepted April 8, 2026; Epub June 15, 2026; Published June 30, 2026

Abstract: Background: It is unclear how associations of socioeconomic and behavioral factors with mortality in U.S. working-age adults with cancer changed after implementing the Affordable Care Act (ACA). Therefore, we examined changes in associations of prognostic factors with 4-year mortality risk in working-age American adults after implementing the ACA by cancer status. Methods: We conducted 4 retrospective cohort studies, using the National Health Interview Survey data from 2000 to 2015, linked to the National Death Index through December 2019. The primary outcome was 4-year all-cause mortality. Multivariable logistic regression was used to quantify the associations of various factors with 4-year mortality in each cohort for all, cancer and non-cancer participants. Difference-in-difference analyses were performed to compare adjusted odds ratios (aOR) before and after the ACA implementation. Results: The 4 retrospective cohort studies included ~307 million U.S. working-age adults (aged 18-64 years, with 74-78 million weighted participants in each cohort) who participated in the survey years 2000, 2005, 2010, and 2015. Cancer prevalence among U.S. working-age adults rose 13.0% (5,150 per 100,000 in the 2015 cohort versus 3,970 per 100,000 in the 2000 cohort). Difference-in-difference analyses showed aORs of cancer, sex, age, race, and smoking-status for 4-year all-cause mortality risk remained unchanged throughout the 15 years. However, post-ACA regional gaps widened among cancer patients, with increasing aORs in the South and West versus the Northeast region. Post-ACA age-gaps reduced among non-cancer participants, with decreasing aORs in participants aged 55-64 or 45-54 years (versus 18-34 years). Conclusions: Cancer prevalence among U.S. working-age adults rose significantly during 2000-2015. There were no significant post-ACA changes in associations of key prognostic factors with 4-year mortality in all participants. However, the influences of ACA implementation on socioeconomic disparities differed by cancer status. Further works should focus on its influence by other disease status, including diabetes and cardiovascular disease.

Keywords: Prevalence, mortality, cancer survivorship, health policy, affordable care act

Introduction

The implementation of the Affordable Care Act (ACA) that started in 2010 and completed in 2014 represented the most sweeping U.S. health policy reform in decades and substantially expanded insurance coverage and preventive care access [1, 2]. Insurance coverage and other socioeconomic factors are known to link to all-cause mortality, cancer mortality and cardiovascular disease [1, 3-6]. However, the association of ACA with mortality and its change in U.S. working-age adults with cancer is largely unclear. We therefore aim to focus on this key health policy issue.

Indeed, several related knowledge gaps are yet critical and need urgent actions. First, most of the related studies had major methodological limitations. Nearly all published studies on the association of ACA implementation with mortality had unclear, no, or <4 years of follow-up [7-9], except one (4-year overall survival [OS]) [10]. Some performed only univariable analyses [11-14].

Second, the ACA's association with mortality in U.S. adults with cancer was conflicting among studies. It was associated with a better OS among working-age adults (18/20-62/64

https://doi.org/10.62347/HJWV4203

years) with newly diagnosed specific types of cancer [6, 8, 15-18]. However, it was found not linked to improved OS in working-age adults with cancers in other studies [7, 10, 14, 19], nor with reduced overall mortality of top-10 or all cancers in working-age Americans (aged 30-64 years) [9].

Finally, the impact of the ACA implementation on disparities in cancer mortality is conflicting in studies. The ACA showed improved racial disparities of incidence and mortality in patients with stage IV breast, cervical or colon cancers [20, 21] but not that in rectal or breast cancer [21, 22]. In contrast, gender, socioeconomic and racial/ethnic disparities in OS remained unchanged in young adults with certain cancers after implementing the ACA [8, 18, 19, 21].

To address these knowledge gaps, we leveraged the National Health Interview Survey (NHIS) linked with the National Death Index to examine four population-based cohorts. This study represents the first analysis on the independent association of cancer diagnosis with 4-year all-cause mortality in US working-age adults using NHIS-National Death Index data across multiple decades. We also aimed to examine whether the associations of socioeconomic determinants with 4-year mortality risk in U.S. cancer and non-cancer populations changed in the broader policy environment after the ACA implementation.

Materials and methods

Data source

The NHIS is a large, ongoing cross-sectional household study conducted by the Centers for Disease Control and Prevention [23]. It uses household interviews with a focus on the U.S. civilian non-institutionalized population. Sample weights and stratum were provided at individual level and permit inferences on the U.S.-population based epidemiologic data. The latest National Death Index linked public-use mortality files (released in 2022) were used to determine the vital status of the included individuals and contain the follow-up data through December 2019 [24]. These mortality data were reliably based on death certificate records from the National Death Index and have been used in many prior works [1, 25-29].

Study cohorts

The cutoff year of the ACA implementation varied by studies. Some used 2010 (before versus after 2010, or states with versus without Medicaid expansion) [6, 11, 30-33], while the majority of the studies used 2014 [7, 12, 15, 16, 18, 19, 34-37]. The rest used a washout period of 2-4 years [13, 17, 22, 38]. Therefore, we chose the 2010 and 2015 cohorts as the early and full post-ACA cohorts, respectively, and chose the 2000 and 2005 cohorts as the before-ACA cohorts.

The working age was defined as 18-64 years since a majority of the studies used the age range of 18/20-62/64 years to define working-age adults [6, 15-18, 25]. Individuals were included in the regression analyses only if they responded to the question: “Have you ever been told you had cancer?” (NHIS variable: canev). Key covariates included age, sex, poverty status (above or below the published federal poverty line for a single-person household) [39], race, ethnicity (Latino/Hispanic or non-Latino/Hispanic), citizenship, education (completed a college education or not), current smoking status, insurance status, and region of residence.

Study design

We conducted 4 retrospectively cohort studies, including the work-age U.S. adults participating in the NHIS surveys conducted in 2000, 2005, 2010 and 2015, respectively. The primary outcome of each study was the 4-year all-cause mortality. The secondary outcome was DID in the associations of key factors with 4-year all-cause mortality, that were assessed by comparing adjusted odds ratios (aORs) of multivariable logistic regression analyses (MVA). A 4-year mortality variable was created for each cohort that tracked participant vital status four years after the survey year. The sensitivity analyses using survival models were considered but not performed. Because we were concerned about the data quality and missing data of cancer diagnosis time in cancer patients, and the lack of universally agreed entry time for non-cancer and all participants (e.g., time of interview versus mid-year, versus beginning of the year).

The insurance variable was derived through the NHIS survey questions asking participants whether they had private insurance, military health insurance, Medicaid, Medicare, another state-sponsored health plan, or other government program, respectively. Participants that responded no to all of the questions were classified as not having insurance [2]. All analyses incorporated the survey weights provided by NHIS to produce estimates representative of U.S. working-age adults.

Statistical analyses

Statistical analyses were conducted using Stata (version 18. College Station, TX: StataCorp LLC.), except the DID analyses. All univariate and MVA were conducted by cohort year. Univariable logistic regression was first performed to examine the possible association between individual variable and 4-year mortality. The factors that had a *p*-value <0.1 in univariable regression would be included in the MVA one to exclude potential confounding and biases. Analyses were then repeated by cancer diagnosis status as subgroup analyses. For all MVA models, aORs and their corresponding 95% confidence intervals (CIs) were recorded.

The DID analyses were performed using pairwise comparisons of the aORs to assess possible differences in a factor's associations with 4-year mortality among various cohorts [17, 40, 41]. Briefly, the difference in log aORs was calculated, with standard error (SE) of the difference as sqrt($SE\_a^2 + SE\_b^2$). The test statistic was Z = difference/SE_difference. The *p*-values were then calculated assuming 95% CIs (Z-critical value = 1.96). For each aOR, the SE of the log OR was derived as SE = [ln(upper CI) - ln(lower CI)]/(2 × 1.96). The test statistic was computed as Z = ln(OR)/SE, with the two-tailed *p*-value as 2 × (1 - norm.cdf (|Z|)). The *p* values of comparing the aORs were calculated using the CIs, but not using assessment of Cis' overlaps [42-44]. A *p*-value <0.05% was considered statistically significant for all tests.

Results

Baseline characteristics

Each of the 4 cohorts comprised about 74-78 million of weighted participants aged 19-64 years, totaling 307,657,954 (**Table 1**). There were 33,108 (0.03%) to 82,119 (0.08%) of the participants who refused to answer the CANEV question ("Have you ever been told you had cancer?"), while 33,815 (0.03%) to 48,636 (0.05%) of them answered "don't know" to this question (Supplementary Table 1). Cancer prevalence was 3,970 per 100,000 (3.97%), 4,870 per 100,000 (4.87%), 5,830 per 100,000 (5.83%) and 5,150 per 100,000 (5.15%) in the respondents of the 2000, 2005, 2010 and 2015 cohorts, respectively. It was statistically different cross the years (Chi-squared test, P<0.001 for all sequential comparisons of one cohort versus the next). The weighted 4-year all-cause mortality among cancer patients and non-cancer participants significantly increased in the early and full ACA implementation cohorts, except non-cancer participants in the 2015 cohort (Supplementary Table 2).

Across all survey years, cancer patients were consistently older than non-cancer participants, with the age gap widening in 2010 and 2015. The proportion of younger participants declined across all cohorts, although this decline was more significant among cancer patients (**Table 1**).

White participants were disproportionately represented as cancer patients compared with non-cancer respondents (≥90% vs. ~80%). Hispanics had consistently lower representation among cancer patients (approximately 4-5% vs. 11-14% in non-cancer participants). This pattern persisted across all four survey years.

Socioeconomic attributes of the participants showed mixed patterns. Poverty and education distributions did not differ significantly between cancer and non-cancer participants in later years (2010 and 2015), while insurance coverage was consistently higher among cancer patients than non-cancer participants (87.8-94.8% versus 78.4-87.4%, Supplementary Table 3). While non-smokers comprised a greater proportion in both cancer and non-cancer participants in all cohorts, former smokers were substantially overrepresented in cancer patients compared with those in non-cancer participants (Supplementary Table 3).

Multivariable analyses in all participants

MVA on all participants revealed several factors independently associated with 4-year mortality in the US working-age adults (**Table 2**). Some exceptions were noticed, mostly in the

Table 1. Prevalence of cancer survivors among US working-age adults, 2000-2015

	2000			2005			2010			2015		
	Cancer		*P*	Cancer		*P*	Cancer		*P*	Cancer		*P*
	No	Yes		No	Yes		No	Yes		No	Yes	
Age (y)			<0.001			<0.001			<0.001			<0.001
18-34	27,425,115	404,361		27,263,697	445,852		27,235,694	423,338		27,520,141	314,092	
%	98.55%	1.45%		98.39%	1.61%		98.47%	1.53%		98.87%	1.13%	
35-44	18,929,954	601,419		17,890,563	632,862		15,368,701	601,449		15,728,194	545,324	
%	96.92%	3.08%		96.58%	3.42%		96.23%	3.77%		96.65%	3.35%	
45-54	15,055,073	906,427		16,643,980	1,098,469		16,057,358	1,291,237		15,809,408	1,019,813	
%	94.32%	5.68%		93.81%	6.19%		92.56%	7.44%		93.94%	6.06%	
55-64	9,866,940	1,037,119		12,366,651	1,623,555		13,597,640	2,159,884		15,621,110	2,172,534	
%	90.49%	9.51%		88.40%	11.60%		86.29%	13.71%		87.79%	12.21%	
Sex			<0.001			<0.001			<0.001			<0.001
Male	33,185,619	944,912		34,892,727	1,246,298		34,471,124	1,571,056		35,585,999	1,485,743	
%	97.23%	2.77%		96.55%	3.45%		95.64%	4.36%		95.99%	4.01%	
Female	38,091,463	2,004,414		39,272,164	2,554,440		37,788,269	2,904,852		39,092,854	2,566,020	
%	95.00%	5.00%		93.89%	6.11%		92.86%	7.14%		93.84%	6.16%	
Race			<0.001			<0.001			<0.001			<0.001
White	56,513,126	2,659,206		60,125,796	3,456,861		56,879,735	3,940,670		57,837,181	3,550,990	
%	95.51%	4.49%		94.56%	5.44%		93.52%	6.48%		94.22%	5.78%	
Black	9,168,134	170,532		9,722,645	233,981		10,141,980	359,052		10,268,301	328,236	
%	98.17%	1.83%		97.65%	2.35%		96.58%	3.42%		96.90%	3.10%	
AIAN	515,588	26,626		537,321	15,192		616,826	42,910		724,807	28,966	
%	95.09%	4.91%		97.25%	2.75%		93.50%	6.50%		96.16%	3.84%	
Asian	2,305,242	37,031		2,733,369	60,367		3,328,648	46,405		4,227,267	73,936	
%	98.42%	1.58%		97.84%	2.16%		98.63%	1.37%		98.28%	1.72%	
Ethnicity			<0.001			<0.001			<0.001			<0.001
Non-Hispanic	64,045,187	2,853,105		65,076,640	3,627,370		62,495,352	4,217,481		63,318,600	3,776,559	
%	95.74%	4.26%		94.72%	5.28%		93.68%	6.32%		94.37%	5.63%	
Hispanic	7,231,895	96,221		9,088,251	173,368		9,764,041	258,427		11,360,253	275,204	
%	98.69%	1.31%		98.13%	1.87%		97.42%	2.58%		97.63%	2.37%	
Citizenship			<0.001			<0.001			<0.001			<0.001
US Citizen	5,293,861	43,044		6,050,932	85,079		6,328,007	84,948		6,696,221	95,559	
%	99.19%	0.81%		98.61%	1.39%		98.68%	1.32%		98.59%	1.41%	
Non US Citizen	65,817,334	2,906,282		67,891,196	3,713,784		65,852,314	4,389,581		67,864,227	3,956,204	
%	95.77%	4.23%		94.81%	5.19%		93.75%	6.25%		94.49%	5.51%	
Smoking Status			<0.001			<0.001			<0.001			<0.001
NS	38,568,553	1,212,621		42,542,559	1,663,705		42,734,427	2,062,790		47,845,023	2,088,961	
%	96.95%	3.05%		96.24%	3.76%		95.40%	4.60%		95.82%	4.18%	
FS	13,181,740	821,594		13,200,262	1,118,207		12,831,453	1,262,432		13,217,591	1,161,592	
%	94.13%	5.87%		92.19%	7.81%		91.04%	8.96%		91.92%	8.08%	
CS	18,894,409	903,225		17,761,009	991,953		16,307,115	1,073,890		13,370,179	780,633	
%	95.44%	4.56%		94.71%	5.29%		93.82%	6.18%		94.48%	5.52%	

Region of residence			0.24			0.68			0.42			0.06
Northeast	13,566,601	515,270		12,960,869	682,098		12,119,928	752,713		12,638,875	554,036	
%	96.34%	3.66%		95.00%	5.00%		94.15%	5.85%		95.80%	4.20%	
Midwest	18,296,912	706,735		18,822,602	948,063		17,329,190	1,128,849		17,642,439	992,899	
%	96.28%	3.72%		95.20%	4.80%		93.88%	6.12%		94.67%	5.33%	
South	25,652,120	1,152,937		27,250,315	1,344,418		26,319,573	1,675,161		27,645,278	1,645,817	
%	95.70%	4.30%		95.30%	4.70%		94.02%	5.98%		94.38%	5.62%	
West	13,761,449	574,384		15,131,105	826,159		16,490,702	919,185		16,752,261	859,011	
%	95.99%	4.01%		94.82%	5.18%		94.72%	5.28%		95.12%	4.88%	
Education Status			0.29			0.08			0.06			0.57
Below College	40,103,855	1,716,781		43,609,414	2,358,114		45,352,476	2,935,598		49,743,019	2,744,368	
%	95.89%	4.11%		94.87%	5.13%		93.92%	6.08%		94.77%	5.23%	
College and above	30,589,419	1,215,164		29,880,130	1,423,404		26,684,191	1,528,686		24,666,817	1,300,076	
%	96.18%	3.82%		95.45%	4.55%		94.58%	5.42%		94.99%	5.01%	
Income			0.19			0.93			0.72			<0.001
≥PIT	38,203,772	1,396,712		39,721,029	1,821,811		40,946,720	2,270,720		40,520,372	1,853,485	
%	96.47%	3.53%		95.61%	4.39%		94.75%	5.25%		95.63%	4.37%	
<PIT	7,385,918	315,202		6,798,882	308,321		6,967,568	370,258		9,585,857	273,847	
%	95.91%	4.09%		95.66%	4.34%		94.95%	5.05%		97.22%	2.78%	
Insurance Status			<0.001			<0.001			<0.001			<0.001
Noninsured	13,304,171	350,336		14,019,132	464,536		15,531,850	489,490		9,350,548	210,055	
%	97.43%	2.57%		96.79%	3.21%		96.94%	3.06%		97.80%	2.20%	
Insured	57,599,421	2,598,990		59,847,065	3,327,877		56,483,563	3,979,755		64,919,608	3,830,980	
%	95.68%	4.32%		94.73%	5.27%		93.42%	6.58%		94.43%	5.57%	
Vital status (4-year FU)			<0.001			<0.001			<0.001			<0.001
Alive	66,602,755	2,648,791		67,901,285	3,328,246		70,026,194	4,135,411		72,204,906	3,743,351	
%	96.18%	3.82%		95.33%	4.67%		94.42%	5.58%		95.07%	4.93%	
Dead	956,933	185,317		997,812	223,398		1,083,357	301,072		1,059,579	266,037	
%	83.78%	16.22%		81.71%	18.29%		78.25%	21.75%		79.93%	20.07%	
Total												
Count	71,277,082	2,949,326		74,164,891	3,800,738		72,259,393	4,475,908		74,678,853	4,051,763	
%	96.03%	3.97%		95.13%	4.87%		94.17%	5.83%		94.85%	5.15%	

Notes: AIAN, American Indian/Alaska Native; PIT, poverty income threshold; NS, never smoker; FS, former smoker; CS, current smoker; FU, follow up.

Table 2. Multivariable adjusted odds ratios of 4-year mortality in patients during survey conducted in 2000, 2005, 2010, or 2015

Variable	2000		2005	2010		2015	
	aOR (95% CI)	*P* vs. 2005	aOR (95% CI)	aOR (95% CI)	*P* vs. 2005	aOR (95% CI)	*P* vs. 2005
Cancer diagnosis							
No	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Yes	3.46 (2.56-4.67)^	0.84	3.55 (2.07-6.07)^	2.70 (1.60-4.56)^	0.48	3.05 (2.24-4.14)^	0.63
Sex							
Male	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Female	0.63 (0.50-0.78)^	0.45	0.53 (0.36-0.77)^	0.80 (0.56-1.15)	0.09	0.55 (0.44-0.70)^	0.90
Age (year)							
18-34	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
35-44	2.39 (1.57-3.62)^	0.18	1.31 (0.65-2.62)	1.98 (1.00-3.95)	0.36	1.30 (0.72-2.53)	0.97
45-54	5.40 (3.64-8.02)^	0.74	4.91 (2.71-8.90)^	3.97 (2.15-7.32)^	0.56	3.31 (2.10-5.20)^	0.38
55-64	8.67 (5.91-12.72)^	0.63	10.08 (5.48-18.54)^	5.35 (2.73-10.49)^	0.23	7.92 (5.17-12.17)^	0.54
Race							
White	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Black	1.70 (1.30-2.22)^	0.44	1.56 (0.97-2.50)	1.99 (1.34-2.95)^	0.44	1.78 (1.34-2.36)^	0.64
AI/AN	1.85 (0.79-4.33)		1.42 (0.17-11.94)	*		1.91 (0.89-4.11)	
Asian	1.73 (0.87-3.43)	0.28	0.58 (0.13-2.52)	0.67 (0.24-1.85)	0.86	0.95 (0.56-1.62)	0.42
Ethnicity							
Non-Hispanic	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Hispanic	1.01 (0.67-1.54)	0.47	1.37 (0.76-2.49)	1.36 (0.79-2.31)	0.98	0.79 (0.51-1.22)	0.32
Citizenship Status							
Citizen	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Noncitizen	0.90 (0.54-1.52)	0.81	0.85 (0.43-1.67)	1.73 (0.82-3.68)	0.17	1.38 (0.76-2.51)	0.36
Income							
≥PIT	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
<PIT	n/a		2.05 (1.27-3.31)^	2.00 (1.25-3.20)^	0.94	n/a	
Smoking Status							
NS	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
FS	1.53 (1.15-2.05)^	0.95	1.51 (0.95-2.39)	1.82 (1.21-2.75)^	0.54	1.46 (1.06-2.02)^	0.87
CS	2.63 (1.99-3.49)^	0.95	2.60 (1.63-4.13^	1.51 (0.95-2.40)	0.12	2.86 (2.11-3.89)^	0.69
Education Status							
College and above	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Below college	1.50 (1.18-1.92)^	0.43	1.14 (0.80-1.63)	1.40 (0.97-2.02)	0.43	1.54 (1.20-1.98)^	0.17

Notes: aOR, adjusted odds ratio; CI, confidence intervals; AIAN, American Indian/Alaska Native; PIT, poverty income threshold; NS, never smoker; FS, former smoker; CS, current smoker. ^, P<0.05 in multivariable regression on that year's cohort; *, collinear; n/a, not application because of non-significance in univariable regression analysis; *P* vs. 2005, *p* values for comparing with the respective aOR of the 2005 cohort. Insurance status showed lack of associations in the univariable regression analyses in all cohorts and is omitted here.

2010 cohort. However, DID analyses showed no significant differences in aOR of various factors (**Table 2**).

Cancer diagnosis was consistently and independently associated with increased 4-year mortality (**Table 2**, aOR range, 2.70-3.55 across cohorts, all P<0.001). Its aOR did not differ significantly across cohorts or between pre- and post-ACA periods.

Age was among the most significant prognostic factor of mortality across all cohorts, with progressively higher aORs in each older age stratum (e.g., 55-64 years: aORs ranging from 5.35 to 10.08, all P<0.001). In contrast, sex and smoking status were both associated with 4-year mortality in 2000, 2005, and 2015, except 2010. Black participants experienced higher 4-year mortality than Whites in 2000, 2010, and 2015 (aORs 1.70-1.99, all P≤ 0.001), although this difference did not reach significance in 2005. However, region of residence, insurance status, ethnicity and citizenship were not associated with 4-year mortality in any of the cohorts.

Multivariable regression analyses in cancer patients

Factors associated with 4-year all-cause mortality varied substantially across survey years.

Table 3. Multivariable adjusted odds of 4-year mortality in patients with cancer present during survey conducted in 2000, 2005, 2010, or 2015

Variable	2000		2005	2010		2015	
	aOR (95% CI)	*P* vs. 2005	aOR (95% CI)	aOR (95% CI)	*P* vs. 2005	aOR (95% CI)	*P* vs. 2005
Sex							
Male	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Female	0.63 (0.37-1.09)	0.63	0.48 (0.22-1.06)	0.90 (0.51-1.58)	0.20	0.47 (0.26-0.86)^	0.96
Age (y)							
18-34	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
35-44	0.85 (0.31-2.39)	0.95	0.76 (0.03-18.55	n/a		1.54 (0.20-11.70)	0.72
45-54	1.70 (0.81-3.53)	0.47	3.52 (0.28-45.59)	n/a		9.95 (5.09-19.44)^	0.37
55-64	1.83 (0.81-4.12)	0.63	7.92 (0.70-89.39)	n/a		18.31 (11.87-28.23)^	0.46
Race							
White	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Black	3.78 (2.08-6.87)^		*	n/a		1.22 (0.55-2.73)	
AI/AN	2.25 (0.59-8.61)		*	n/a		*	
Asian	1.53 (0.78-2.98)		*	n/a		2.07 (0.51-8.40)	
Education Status							
College and above	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Below college	n/a		1.41 (0.62-3.22)	1.96 (1.04-3.69)^	0.53	1.86 (1.12-3.11)^	0.57
Income							
≥PIT	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
<PIT	n/a		5.47 (1.78-16.84)^	2.55 (1.40-4.65)^	0.24	n/a	
Region of residence							
Northeast	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Midwest	n/a		0.45 (0.18-1.16)	n/a		1.79 (0.55-5.85)	0.18
South	n/a		0.41 (0.14-1.26)	n/a		3.49 (1.18-10.28)^	0.01
West	n/a		0.24 (0.06-0.86)^	n/a		1.60 (0.50-5.15)	0.03
Smoking status							
NS	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
FS	n/a		0.55 (0.19-1.55)	2.51 (1.34-4.69)^	0.01	n/a	
CS	n/a		1.85 (0.59-5.85)	1.17 (0.48-2.87)	0.54	n/a	

Notes: aOR, adjusted odds ratio; CI, confidence intervals; AIAN, American Indian/Alaska Native; PIT, poverty income threshold; NS, never smoker; FS, former smoker; CS, current smoker. ^, P<0.05 in multivariable regression on that year's cohort; *, collinear; n/a, not application because of non-significance in univariable regression analysis; *P* vs. 2005, *p* values for comparing with the respective aOR of the 2005 cohort. Insurance status showed lack of associations in the univariable regression analyses in all cohorts and is omitted here.

DID analyses could not substantiate that aORs of the potentially interesting factors changed significantly after the ACA implementation, except that the regional gaps in aOR significantly widened (**Table 3**).

Compared with adults aged 18-34 years, older adults (45-54 and 55-64 years, respectively) were independently associated with 4-year mortality in the full ACA cohort (2015) but not in earlier cohorts. However, DID analyses showed no differences in the aORs. Although the aOR of Black (versus White) significantly reduced from 2000 to 2015 (P = 0.03 for aOR comparison of 2000 and 2015), being Black was not associated with 4-year mortality in 2010. Therefore, the post-ACA change cannot be ascertained due to the lack of association/data in the 2005 cohort.

Multivariable regression analyses in non-cancer participants

Age, race and smoking status remained associated with 4-year mortality in all cohort years among non-cancer participants (**Table 4**). Female sex was also consistently associated with better 4-year mortality in all cohort years, except 2010.

Similar to the MVA results of cancer population, some factors associated with 4-year all-cause mortality varied across survey years. Our DID analyses showed that aORs of these associated factors did not change significantly before or after the ACA implementation, except that age-associated aOR (versus 2005 cohort) was decreased (**Table 4**).

Table 4. Multivariable adjusted odds ratios of 4-year mortality in patients without cancer present during survey conducted in 2000, 2005, 2010, or 2015

Variable	2000		2005	2010		2015	
	aOR (95% CI)	*P* vs. 2005	aOR (95% CI)	aOR (95% CI)	*P* vs. 2005	aOR (95% CI)	*P* vs. 2005
Sex							
Male	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Female	0.60 (0.47-0.76)^	0.77	0.57 (0.45-0.73)^	0.74 (0.50-1.09)	0.27	0.57 (0.44-0.74)^	0.99
Age (year)							
18-34	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
35-44	2.66 (1.69-4.16)^	0.64	2.24 (1.29-3.89)^	2.05 (1.01-4.14)	0.85	1.36 (0.75-2.47)	0.23
45-54	6.05 (4.00-9.15)^	0.78	6.62 (4.05-10.81)^	3.55 (1.87-6.75)^	0.13	3.18 (1.99-5.08)^	0.03
55-64	10.92 (7.27-16.41)^	0.17	17.04 (10.44-27.82)^	6.30 (3.20-12.40)^	0.02	7.82 (5.03-12.16)^	0.02
Race							
White	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Black	1.55 (1.19-2.02)^	0.47	1.80 (1.32-2.46)^	1.97 (1.30-2.99)	0.73	1.82 (1.35-2.45)	0.96
AIAN	1.76 (0.76-4.08)	0.93	1.86 (0.81-4.30)	*		2.31 (1.08-4.93)	0.71
Asian	1.73 (0.85-3.53)	0.38	1.07 (0.48-2.40)	0.51 (0.15-1.70)	0.32	0.87 (0.43-1.74)	0.70
Ethnicity							
Non-Hispanic	1 [reference]		1 [reference]	1 [reference]			
Hispanic	0.93 (0.64-1.36)	0.65	1.05 (0.73-1.53)	n/a		0.82 (0.51-1.30)	0.42
Citizenship							
Citizen	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Noncitizen	n/a		1.01 (0.61-1.67)	n/a		1.82 (0.51-1.30)	0.09
Smoking Status							
NS	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
FS	1.37 (0.99-1.90)	0.43	1.65 (1.20-2.28)^	1.56 (0.98-2.49)	0.85	1.38 (0.96-1.98)	0.47
CS	2.85 (2.12-3.84)^	0.64	3.16 (2.30-4.34)^	1.22 (0.77-1.95)	<0.001	3.32 (2.37-4.66)^	0.84
Education Status							
College and above	1 [reference]		1 [reference]	1 [reference]		1 [reference]	
Below college	1.57 (1.20-2.05)^	0.51	1.39 (1.10-1.77)^	1.39 (0.94-2.05)	0.99	1.47 (1.10-1.95)^	0.77

Notes: aOR, adjusted odds ratio; CI, confidence intervals; AIAN, American Indian/Alaska Native; NS, never smoker; FS, former smoker; CS, current smoker. ^, P<0.05 in multivariable regression on that year's cohort; *, collinear; n/a, not application because of non-significance in univariable regression analysis; *P* vs. 2005, *p* values for comparing with the respective aOR of the 2005 cohort. Income and insurance status showed lack of associations in the univariable regression analyses in all cohorts and is omitted here.

Discussion

Cancer prevalence rose 13.0% among U.S. working-age adults (aged 18-64 years) in 4 population-based cohort studies, from 3,970 per 100,000 (3.97%) in 2005 to 5,150 per 100,000 (5.15%) in 2015. In MVA on all participants, cancer diagnosis, sex (except in 2010), age and smoking status were associated with 4-year all-cause mortality. However, DID analyses showed no significant changes of their aORs after the ACA implementation. Among participants with cancer, sex, age, education and region of residence became associated with 4-year all-cause mortality after ACA implementation, but the aOR of region of residence significantly changed after the ACA implementation in DID analyses. Among the participants without cancer, sex and age remained associated with 4-year all-cause mortality after ACA implementation, but only the aORs of age significant changed and were reduced.

There seem to be two key scientific and public-health impacts of our findings. Our DID data highlights that ACA was associated with different changes of disparities in 4-year mortality risk by cancer status, despite few changes in the factors' associations in all participants. It will be interesting to understand whether ACA's influences on the socioeconomic disparities of mortality also differ by statuses of other diseases, such as diabetes and cardiovascular diseases. More works are warranted to investigate the long-term impact of ACA implementation. Additional studies using large, population-data (not national-representative datasets) are also needed to rigorously examine its impact on individual cancer types and resolve the conflicting results of prior studies [6, 7, 14-18].

The widened regional disparities in 4-year mortality risk may be attributable to more states without Medicare expansion in the South region [2, 45, 46] and a smaller insurance coverage rate in the South region and similar insurance coverage rate in the West region than the Northeast region [2]. As supported by the largest aOR of cancer diagnosis for linking to 4-year mortality among all factors, cancer patients' mortality appears more dependent on the ACA and other health policy influencing insurance coverage than that of non-cancer participants. However, we could not incorporate state-level Medicaid expansion status in the analyses due to lacking state-level residence data. Our data showed also no association of insurance status with 4-year mortality in cancer, non-cancer or overall population. Therefore, alternative explanations must be sought, including regional or state-level differences/heterogeneity in cancer mix, health policy, healthcare infrastructure, or baseline mortality trends.

Several strengths of this study appear noteworthy. First, this is the first population-based study on the factors associated with 4-year all-cause mortality risk before versus after the ACA implementation. All published studies had unclear, no, or <4 years of follow-up, except a National Cancer Database-based study on four cancers with 4-year follow-up; however, it did not cover all cancers or any of the other cancers [10]. Moreover, the National Cancer Database is known for its selection bias of limiting to the cancer programs accredited by the Commission on Cancer of the American College of Surgeons and American Cancer Society [47-49].

Second, this is one of the few studies on the association of ACA with 4-year all-cause mortality in working-age Americans using sample weighting and large population datasets (>70 million in each cohort). Nearly all studies on the association of ACA with mortality/survival used the National Cancer Database or Surveillance, Epidemiology, End Results data [9, 19, 21, 38]. Therefore, they had much smaller sample sizes and statistical power than this one, while the only study based on NHIS-linked National Death Index data used unweighted data and had a smaller sample size than ours [50].

Third, we exclusively focused on prevalence-based 4-year mortality and included both cancer survivors and patients with first-time cancer diagnosis. Since nearly all studies on the association of ACA with all-cause mortality in working-age Americans used the National Cancer Database or Surveillance, Epidemiology, End Results data, they exclusively focused on patients with newly diagnosed cancer. Our inclusion of cancer survivor (who had a cancer diagnosis at the time of survey) thus fills a critical knowledge gap in the intermediate-term (e.g., 4 year) mortality of cancer survivors. Indeed, we also showed increasing cancer prevalence through the 15 years. However, cancer survivors and patients with first-time cancer diagnosis have different prognoses [51, 52]. This heterogeneity may dilute or obscure ACA-related effects, but would have little impact on the DID of population-level associations that were examined here.

Fourth, this study has sound statistical methodologies that are rarely combined in past works. Its scientific rigors are strengthened by its aOR-based DID analyses, cohort study design and use of MVA. The DID comparison of aOR in 2000, 2010 and 2015 with those in the 2005 cohort not only examined the influence of ACA implementation in 2010 and beyond (2015), but examined the possible intrinsic changes in aOR before its implementation (2000 vs 2005 cohort). The SE-based calculation of *p* values for comparing aORs is more reliable than detecting overlaps of Cis and has been recommended [42-44].

Finally, it appears more sensible to use early and full ACA implementation periods than just use a simple cutoff as most studies did (see the method section for summary of prior works). A study on California cancer registry used the same year grouping [8], while the similar strategy of using washout period has also been used [13, 17, 22, 38].

Limitations

The retrospective design of this study will inevitably introduce biases. While our cohort study design and MVA method have significantly reduced confounding and biases, prospective cohort studies can further reduce biases and are needed. Moreover, NHIS relied on self-reported cancer diagnosis and socioeconomic statuses that are mostly accurate but still prone to recall biases and missing data. However, our DID analysis has mitigated the influ-

ences of those biases unless, in an unlikely event, the recall biases and missing-data rates changed through the years. Our data indeed showed similar missing-data rates among the cohorts (approximately 0.08-0.12% of the respondents refused to answer or stated "don't know" about the cancer diagnosis told by a doctor). Furthermore, cancer staging, pathology and treatment are all important for cancer survivals [53-56], but are not available in the NHIS dataset. While this intrinsic limitation of NHIS cannot be overcome, caution must be used when interpreting our findings. For example, the observed widening of regional disparities in cancer patients may be primarily driven by certain cancer types that are particularly sensitive to healthcare access barriers, such as advanced-stage cancers. Therefore, studies using local cohorts and cancer registry data are warranted to incorporate these factors. In addition, we chose logistic regression to model 4-year mortality risk, but not Cox proportional hazards model, which may be preferred by some scholars. While Cox regression is more robust in analyzing time-event based mortality, its validity requires sufficient and good data in event times and that survival (time-event) data pass the test of proportional hazards; otherwise, its results may be unreliable if not misleading [57-59]. Future works may use Cox regression, although MVA used here is sufficient to test our scientific hypotheses. This study is also limited by not incorporating state-level Medicaid expansion status, and should be interpreted with caution. Finally, while our findings highlight interactions among poverty, education, and smoking, further work is needed to delineate potential causal relationship in trials or prospective cohort studies.

Conclusion

This population-based retrospective cohort study demonstrates rising cancer prevalence among U.S. working-age adults from 2005 to 2015, with cancer diagnosis, sex, age, race, and smoking status consistently linked to 4-year all-cause mortality. DID analyses reveal no significant post-ACA shifts in these associations for all participants. However, regional disparities significantly increased post-ACA in cancer patients, while age-disparities significantly reduced in non-cancer participants. These results highlight that the influences of ACA implementation on socioeconomic disparities differed by cancer status. Further works should focus on its influence by other disease status, including diabetes and cardiovascular disease. Long-term, population-level studies are also warranted to clarify ACA's impacts on specific cancers and guide equitable policy reforms.

Acknowledgements

This work was supported by the National Cancer Institute, National Institutes of Health (grant number R37CA277812 to LZ). The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit this work for publication.

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Lanjing Zhang, Department of Chemical Biology, Rutgers Ernest Mario School of Pharmacy, 164 Frelinghuysen Road, Piscataway, NJ 08854, USA. Tel: 848-445-8004; Tax: 732-445-0687; E-mail: lanjing.zhang@rutgers.edu

References

[1] Gulati I, Kilian C, Buckley C, Mulia N and Probst C. Socioeconomic disparities in healthcare access and implications for all-cause mortality among US adults: a 2000-2019 record linkage study. Am J Epidemiol 2025; 194: 432-440.

[2] Sanford NN, Lam MB, Butler SS, Ahn C, Beg MS, Aizer AA and Mahal BA. Self-reported reasons and patterns of noninsurance among cancer survivors before and after implementation of the affordable care act, 2000-2017. JAMA Oncol 2019; 5: e191973.

[3] Abdalla SM, Rosenberg SB, Maani N, Melendez Contreras C, Yu S and Galea S. Income, education, and the clustering of risk in cardiovascular disease in the US, 1999-2018: an observational study. Lancet Reg Health Am 2025; 44: 101039.

[4] Zheng Z, Hu X, Banegas MP, Han X, Zhao J, Shi KS and Yabroff KR. Health-related social needs, medical financial hardship, and mortality risk among cancer survivors. Cancer 2024; 130: 2938-2947.

[5] Shiels MS, Graubard BI, McNeel TS, Kahle L and Freedman ND. Trends in smoking-attributable and smoking-unrelated lung cancer death

rates in the United States, 1991-2018. J Natl Cancer Inst 2024; 116: 711-716.
[6] Shi KS, Ji X, Jiang C, Ruddy KJ, Castellino SM, Yabroff KR and Han X. Association of Medicaid expansion with timely receipt of treatment and survival among patients with HR-negative, HER2-positive breast cancer. J Natl Compr Canc Netw 2024; 22: 593-599.
[7] Bhambhvani HP, Hampshire K and Eisenberg ML. The association of Medicaid insurance and affordable care act expansions with survival among patients with testicular cancer. Urol Pract 2021; 8: 440-449.
[8] Abrahao R, Cooley JJP, Maguire FB, Parikh-Patel A, Morris CR, Schwarz EB, Wun T and Keegan THM. Stage at diagnosis and survival among adolescents and young adults with lymphomas following the Affordable Care Act implementation in California. Int J Cancer 2022; 150: 1113-1122.
[9] Semprini J. Explicit inference: a meta-replication of SEER cancer registry research evaluating the Affordable Care Act's Medicaid expansion. J Eval Clin Pract 2024; 30: 1531-1538.
[10] Lam MB, Phelan J, Orav EJ, Jha AK and Keating NL. Medicaid expansion and mortality among patients with breast, lung, and colorectal cancer. JAMA Netw Open 2020; 3: e2024366.
[11] Choi SK, Adams SA, Eberth JM, Brandt HM, Friedman DB, Tucker-Seeley RD, Yip MP and Hebert JR. Medicaid coverage expansion and implications for cancer disparities. Am J Public Health 2015; 105 Suppl 5: S706-712.
[12] Semprini J and Olopade O. Evaluating the effect of medicaid expansion on black/white breast cancer mortality disparities: a difference-in-difference analysis. JCO Glob Oncol 2020; 6: 1178-1183.
[13] Barnes JM, Johnson KJ, Adjei Boakye E, Schapira L, Akinyemiju T, Park EM, Graboyes EM and Osazuwa-Peters N. Early medicaid expansion and cancer mortality. J Natl Cancer Inst 2021; 113: 1714-1722.
[14] Lee G, Dee EC, Orav EJ, Kim DW, Nguyen PL, Wright AA and Lam MB. Association of medicaid expansion and insurance status, cancer stage, treatment and mortality among patients with cervical cancer. Cancer Rep (Hoboken) 2021; 4: e1407.
[15] Akinyemi O, Ogunyankin F, Fasokun M, Abodunrin F, Eze O, Ndebele-Ngwenya P, Geter K, Hughes K and Lawson S. Medicaid expansion and overall mortality among women with cervical cancer. Int J Gynaecol Obstet 2026; 172: 343-350.
[16] Premnath N, Liu Y, Reves H, Pandey U, Nair RG, Anderson J, Afrough A, Anderson LD Jr, Chung SS, Kaur G, Khan AM, Kumar KA, Madanat YF, Wolfe HR, Yilmaz E, Awan FT, Sweetenham J and Ramakrishnan Geethakumari P. Impact of the affordable care act and medicaid expansion among patients with HIV-associated aggressive B-cell non-hodgkin lymphomas. JCO Oncol Pract 2025; 21: 683-693.
[17] Sharon CE, Song Y, Straker RJ 3rd, Kelly N, Shannon AB, Kelz RR, Mahmoud NN, Saur NM, Miura JT and Karakousis GC. Impact of the affordable care act's medicaid expansion on presentation stage and perioperative outcomes of colorectal cancer. J Surg Oncol 2022; 126: 1471-1480.
[18] Liu Y, Colditz GA, Kozower BD, James A, Greever-Rice T, Schmaltz C and Lian M. Association of medicaid expansion under the patient protection and affordable care act with non-small cell lung cancer survival. JAMA Oncol 2020; 6: 1289-1290.
[19] Bodurtha Smith AJ, Applebaum J and Fader AN. Association of the affordable care act's medicaid expansion with 1-year survival among patients with ovarian cancer. Obstet Gynecol 2022; 139: 1123-1129.
[20] Malinowski C, Lei X, Zhao H, Giordano SH and Chavez-MacGregor M. Association of medicaid expansion with mortality disparity by race and ethnicity among patients with de novo stage IV breast cancer. JAMA Oncol 2022; 8: 863-870.
[21] Jayakrishnan TT, Bakalov V, Chahine Z, Finley G, Monga D and Wegner RE. Impact of affordable care act on the treatment and outcomes for stage-IV colorectal cancer. Cancer Treat Res Commun 2020; 24: 100204.
[22] Martinez ME, Gomez SL, Canchola AJ, Oh DL, Murphy JD, Mehtsun W, Yabroff KR and Banegas MP. Changes in cancer mortality by race and ethnicity following the implementation of the affordable care act in California. Front Oncol 2022; 12: 916167.
[23] Centers for Disease C and Prevention (2024, November 20, 2024). "About NHIS. National Health Interview Survey". Retrieved Aug. 6, 2025, from https://www.cdc.gov/nchs/nhis/about/index.html.
[24] Statistics CNCfH (2022, May 11, 2022). "NCHS Data linkage: 2019 Public-Use Linked Mortality Files". Retrieved Sept. 16, 2025, from https://www.cdc.gov/nchs/data-linkage/mortality-public.htm.
[25] Lee H, Singh GK, Jemal A and Islami F. Living alone and cancer mortality by race/ethnicity and socioeconomic status among US working-age adults. Cancer 2024; 130: 86-95.
[26] Keralis JM, Zhang C, Cox CS and Mirel LB. A comparison of the mortality experience of U.S. adults estimated with the 2006-2018 national health interview survey linked mortality files and the annual U.S. life tables. Natl Health Stat Report 2023; 1-29.

[27] Cui Y and Yan Y. Association of all cause and cause-specific mortality with hearing loss among US adults: a secondary analysis study. Int J Public Health 2022; 67: 1604785.
[28] Lochner K, Hummer RA, Bartee S, Wheatcroft G and Cox C. The public-use National Health Interview Survey linked mortality files: methods of reidentification risk avoidance and comparative analysis. Am J Epidemiol 2008; 168: 336-344.
[29] Hewitt M, Breen N and Devesa S. Cancer prevalence and survivorship issues: analyses of the 1992 National Health Interview Survey. J Natl Cancer Inst 1999; 91: 1480-1486.
[30] Lee C, Kushi LH, Reed ME, Eldridge EH, Lee JK, Zhang J and Spiegelman D. Impact of the affordable care act on colorectal cancer incidence and mortality. Am J Prev Med 2022; 62: 387-394.
[31] Nurimba M, Sheth M, Swanson M and Chambers T. The impact of race and the affordable care act on thyroid carcinoma outcomes: a national cancer database study. Laryngoscope 2024; 134: 4421-4430.
[32] Chhatre S, Malkowicz SB, Gallo JJ and Jayadevappa R. Racial disparity in outcomes among prostate cancer patients in the post-affordable care act period. Urol Pract 2023; 10: 123-129.
[33] Niroomand E, Kumar SR, Goldberg D and Kumar S. Impact of medicaid expansion on incidence and mortality from gastric and esophageal cancer. Dig Dis Sci 2023; 68: 1178-1186.
[34] Nogueira LM, Boffa DJ, Jemal A, Han X and Yabroff KR. Medicaid expansion under the affordable care act and early mortality following lung cancer surgery. JAMA Netw Open 2024; 7: e2351529.
[35] Primm KM, Zhao H, Adjei NN, Sun CC, Haas A, Meyer LA and Chang S. Effect of Medicaid expansion on cancer treatment and survival among Medicaid beneficiaries and the uninsured. Cancer Med 2024; 13: e7461.
[36] Barnes JM, Johnson KJ, Osazuwa-Peters N, Yabroff KR and Chino F. Changes in cancer mortality after Medicaid expansion and the role of stage at diagnosis. J Natl Cancer Inst 2023; 115: 962-970.
[37] Lin M, O'Guinn M, Zipprer E, Hsieh JC, Dardon AT, Raman S, Foglia CM and Chao SY. Impact of Medicaid expansion on the diagnosis, treatment, and outcomes of stage II and III rectal cancer patients. J Am Coll Surg 2022; 234: 54-63.
[38] Parina R, Emamaullee J, Ahmed S, Kaur N, Genyk Y and Raashid Sheikh M. Impact of Medicaid expansion on surgical care and outcomes for hepatobiliary malignancies. Am Surg 2024; 90: 829-839.
[39] evaluation HOotasfpa. "Prior HHS Poverty Guidelines and Federal Register References". Retrieved Sept. 15, 2025, from https://aspe.hhs.gov/topics/poverty-economic-mobility/poverty-guidelines/prior-hhs-poverty-guidelines-federal-register-references.
[40] Chaiyachati KH, Hubbard RA, Yeager A, Mugo B, Shea JA, Rosin R and Grande D. Rideshare-based medical transportation for medicaid patients and primary care show rates: a difference-in-difference analysis of a pilot program. J Gen Intern Med 2018; 33: 863-868.
[41] Dimick JB and Ryan AM. Methods for evaluating changes in health care policy: the difference-in-differences approach. JAMA 2014; 312: 2401-2402.
[42] Knol MJ, Pestman WR and Grobbee DE. The (mis)use of overlap of confidence intervals to assess effect modification. Eur J Epidemiol 2011; 26: 253-254.
[43] Altman DG and Bland JM. How to obtain the *P* value from a confidence interval. BMJ 2011; 343: d2304.
[44] Bland JM and Altman DG. Statistics notes. The odds ratio. BMJ 2000; 320: 1468.
[45] Garfield R and Damico A (2017). "The coverage gap: uninsured poor adults in states that do not expand Medicaid". Peterson KFF-Health System Tracker. Retrieved Oct. 2, 2025, from http://resource.nlm.nih.gov/101717244.
[46] Lyon SM, Douglas IS and Cooke CR. Medicaid expansion under the Affordable Care Act. Implications for insurance-related disparities in pulmonary, critical care, and sleep. Ann Am Thorac Soc 2014; 11: 661-667.
[47] Murillo A, Romatoski KS, Chung SH, Davis ES, Sawhney VS, Kenzik K, Ng SC, Tseng JF and Sachs TE. Adjusting for population differences in the national cancer database to better represent united states cancer cases: a reference tool for researchers. Ann Surg Oncol 2025; 32: 4604-4615.
[48] Palis BE, Janczewski LM, Browner AE, Cotler J, Nogueira L, Richardson LC, Benard V, Wilson RJ, Walker N, McCabe RM, Boffa DJ and Nelson H. The national cancer database conforms to the standardized framework for registry and data quality. Ann Surg Oncol 2024; 31: 5546-5559.
[49] Jairam V and Park HS. Strengths and limitations of large databases in lung cancer radiation oncology research. Transl Lung Cancer Res 2019; 8 Suppl 2: S172-S183.
[50] Barnes JM, Johnson KJ, Adjei Boakye E, Sethi RKV, Varvares MA and Osazuwa-Peters N. Impact of the Patient Protection and Affordable

Care Act on cost-related medication underuse in nonelderly adult cancer survivors. Cancer 2020; 126: 2892-2899.
[51] Pruitt SL, Zhu H, Heitjan DF, Rahimi A, Maddineni B, Tavakkoli A, Halm EA, Gerber DE, Xiong D and Murphy CC. Survival of women diagnosed with breast cancer and who have survived a previous cancer. Breast Cancer Res Treat 2021; 187: 853-865.
[52] Pruitt SL, Gerber DE, Zhu H, Heitjan DF, Maddineni B, Xiong D, Singal AG, Tavakkoli A, Halm EA and Murphy CC. Survival of patients newly diagnosed with colorectal cancer and with a history of previous cancer. Cancer Med 2021; 10: 4752-4767.
[53] Mayo E, Llanos AA, Yi X, Duan SZ and Zhang L. Prognostic value of tumour deposit and perineural invasion status in colorectal cancer patients: a SEER-based population study. Histopathology 2016; 69: 230-238.
[54] Siegel RL, Miller KD, Fuchs HE and Jemal A. Cancer statistics, 2025. CA Cancer J Clin 2025; 75: 5-27.
[55] Ganggayah MD, Taib NA, Har YC, Lio P and Dhillon SK. Predicting factors for survival of breast cancer patients using machine learning techniques. BMC Med Inform Decis Mak 2019; 19: 48.
[56] Molina JR, Yang P, Cassivi SD, Schild SE and Adjei AA. Non-small cell lung cancer: epidemiology, risk factors, treatment, and survivorship. Mayo Clin Proc 2008; 83: 584-594.
[57] Sjolander A and Dickman PW. Why test for proportional hazards-or any other model assumptions? Am J Epidemiol 2024; 193: 926-927.
[58] Kuitunen I, Ponkilainen VT, Uimonen MM, Eskelinen A and Reito A. Testing the proportional hazards assumption in cox regression and dealing with possible non-proportionality in total joint arthroplasty research: methodological perspectives and review. BMC Musculoskelet Disord 2021; 22: 489.
[59] Grambsch PM and Therneau TM. Proportional hazards tests and diagnostics based on weighted residuals. Biometrika 1994; 81: 515-526.

Supplementary Table 1. Responses to the CANEV question in the survey by cohort year

Responses	2000	2005	2010	2015
Unweighted				
Yes, n (%)	2,333 (8.59)	2,428 (7.73)	2,151 (6.64)	3,289 (9.77)
No, n (%)	24,804 (91.34)	28,969 (92.18)	30,195 (93.27)	30,350 (90.13)
Refused, n (%)	10 (0.04)	13 (0.04)	12 (0.04)	18 (0.05)
Don't know, n (%)	10 (0.04)	18 (0.06)	16 (0.05)	15 (0.04)
Weighted				
Yes, n (%)	6,533,841 (7.07)	7,922,662 (8.15)	9,225,585 (9.50)	10,412,971 (10.00)
No, n (%)	85,812,966 (92.84)	89,213,414 (91.75)	87,795,508 (90.43)	93,580,638 (89.88)
Refused, n (%)	37,680 (0.04)	42,981 (0.04)	33,108 (0.03)	82,119 (0.08)
Don't know, n (%)	48,636 (0.05)	52,438 (0.05)	33,815 (0.03)	46,067 (0.04)

Supplementary Table 2. Comparison of weighted all-cause mortality between cohorts

	2000	*P* value	2005	2010	*P* value	2015	*P* value
Cancer patients							
Alive	2,648,791	<0.001	3,328,246	4,135,411	<0.001	3,743,351	<0.001
%	93.50%		93.70%	93.20%		93.40%	
Dead	185,317		223,398	301,072		266,037	
%	6.50%		6.29%	6.79%		6.64%	
Non-cancer participants							
Alive	66,602,755	<0.001	67,901,285	70,026,194	<0.001	72,204,906	0.155
%	98.60%		98.60%	98.50%		98.60%	
Dead	956,933		997,812	1,083,357		1,059,579	
%	1.40%		1.45%	1.52%		1.45%	

P values were calculated using Chi-square test compared with the 2005 cohort.

Supplementary Table 3. Baseline characteristics of study participants (percentage by column)

	2000			2005			2010			2015		
	Cancer		*P*	Cancer		*P*	Cancer		*P*	Cancer		*P*
	No	Yes		No	Yes		No	Yes		No	Yes	
Age (y)			<0.001			<0.001			<0.001			<0.001
18-34	27,425,115	404,361		27,263,697	445,852		27,235,694	423,338		27,520,141	314,092	
%	38.50%	13.70%		36.80%	11.70%		37.70%	9.50%		36.90%	7.80%	
35-44	18,929,954	601,419		17,890,563	632,862		15,368,701	601,449		15,728,194	545,324	
%	26.60%	20.40%		24.10%	16.70%		21.30%	13.40%		21.10%	13.50%	
45-54	15,055,073	906,427		16,643,980	1,098,469		16,057,358	1,291,237		15,809,408	1,019,813	
%	21.10%	30.70%		22.40%	28.90%		22.20%	28.80%		21.20%	25.20%	
55-64	9,866,940	1,037,119		12,366,651	1,623,555		13,597,640	2,159,884		15,621,110	2,172,534	
%	13.80%	35.20%		16.70%	42.70%		18.80%	48.30%		20.90%	53.60%	
Sex			<0.001			<0.001			<0.001			<0.001
Male	33,185,619	944,912		34,892,727	1,246,298		34,471,124	1,571,056		35,585,999	1,485,743	
%	46.60%	32.00%		47.00%	32.80%		47.70%	35.10%		47.70%	36.70%	
Female	38,091,463	2,004,414		39,272,164	2,554,440		37,788,269	2,904,852		39,092,854	2,566,020	
%	53.40%	68.00%		53.00%	67.20%		52.30%	64.90%		52.30%	63.30%	
Race			<0.001			<0.001			<0.001			<0.001
White	56,513,126	2,659,206		60,125,796	3,456,861		56,879,735	3,940,670		57,837,181	3,550,990	
%	82.50%	91.90%		82.20%	91.80%		80.10%	89.80%		79.20%	89.20%	
Black	9,168,134	170,532		9,722,645	233,981		10,141,980	359,052		10,268,301	328,236	
%	13.40%	5.89%		13.30%	6.20%		14.30%	8.18%		14.10%	8.24%	
AI/AN	515,588	26,626		537,321	15,192		616,826	42,910		724,807	28,966	
%	0.753%	0.92%		0.007	0.004		0.869%	0.978%		0.992%	0.727%	
Asian	2,305,242	37,031		2,733,369	60,367		3,328,648	46,405		4,227,267	73,936	
%	3.37%	1.28%		3.70%	1.69%		4.69%	1.06%		5.79%	1.86%	
Ethnicity			<0.001			<0.001			<0.001			<0.001
Non Hispanic	64,045,187	2,853,105		65,076,640	3,627,370		62,495,352	4,217,481		63,318,600	3,776,559	
%	89.90%	96.70%		87.70%	95.40%		86.50%	94.20%		84.80%	93.20%	
Hispanic	7,231,895	96,221		9,088,251	173,368		9,764,041	258,427		11,360,253	275,204	
%	10.10%	3.26%		12.30%	4.60%		13.50%	5.77%		15.20%	6.79%	
Citizenship			<0.001			<0.001			<0.001			<0.001
US Citizen	5,293,861	43,044		6,050,932	85,079		6,328,007	84,948		6,696,221	95,559	
%	7.44%	1.46%		8.20%	2.20%		8.77%	1.90%		8.98%	2.36%	
Non-US Citizen	65,817,334	2,906,282		67,891,196	3,713,784		65,852,314	4,389,581		67,864,227	3,956,204	
%	92.60%	98.50%		91.80%	97.80%		91.20%	98.10%		91.00%	97.60%	
Smoking Status			<0.001			<0.001			<0.001			<0.001
NS	38,568,553	1,212,621		42,542,559	1,663,705		42,734,427	2,062,790		47,845,023	2,088,961	

%	54.60%	41.30%		57.90%	44.10%		59.50%	46.90%		64.30%	51.80%	
FS	13,181,740	821,594		13,200,262	1,118,207		12,831,453	1,262,432		13,217,591	1,161,592	
%	18.70%	28.00%		18.00%	29.60%		17.90%	28.70%		17.80%	28.80%	
CS	18,894,409	903,225		17,761,009	991,953		16,307,115	1,073,890		13,370,179	780,633	
%	26.7%	30.7%		24.2%	26.3%		22.7%	24.4%		18.0%	19.4%	
Region of residence			0.24			0.68			0.42			0.07
Northeast	13,566,601	515,270		12,960,869	682,098		12,119,928	752,713		12,638,875	554,036	
%	19.00%	17.50%		17.50%	17.90%		16.80%	16.80%		16.90%	13.70%	
Midwest	18,296,912	706,735		18,822,602	948,063		17,329,190	1,128,849		17,642,439	992,899	
%	25.70%	24.00%		25.40%	24.90%		24.00%	25.20%		23.60%	24.50%	
South	25,652,120	1,152,937		27,250,315	1,344,418		26,319,573	1,675,161		27,645,278	1,645,817	
%	36.00%	39.10%		36.70%	35.40%		36.40%	37.40%		37.00%	40.60%	
West	13,761,449	574,384		15,131,105	826,159		16,490,702	919,185		16,752,261	859,011	
%	19.30%	19.50%		20.40%	21.70%		22.80%	20.50%		22.40%	21.20%	
Education Status			0.29			0.08			0.06			0.57
Below College	40,103,855	1,716,781		43,609,414	2,358,114		45,352,476	2,935,598		49,743,019	2,744,368	
%	56.70%	58.60%		59.30%	62.40%		63.00%	65.80%		66.90%	67.90%	
College and above	30,589,419	1,215,164		29,880,130	1,423,404		26,684,191	1,528,686		24,666,817	1,300,076	
%	43.30%	41.40%		40.70%	37.60%		37.00%	34.20%		33.10%	32.10%	
Income			0.19			0.93			0.72			<0.001
≥IT	38,203,772	1,396,712		39,721,029	1,821,811		40,946,720	2,270,720		40,520,372	1,853,485	
%	83.80%	81.60%		85.40%	85.50%		85.50%	86.00%		80.90%	87.10%	
<IT	7,385,918	315,202		6,798,882	308,321		6,967,568	370,258		9,585,857	273,847	
%	16.20%	18.40%		14.60%	14.50%		14.50%	14.00%		19.10%	12.90%	
Insurance Status			<0.001			<0.001			<0.001			<0.001
Noninsured	13,304,171	350,336		14,019,132	464,536		15,531,850	489,490		9,350,548	210,055	
%	18.80%	11.90%		19.00%	12.20%		21.60%	11.00%		12.60%	5.20%	
Insured	57,599,421	2,598,990		59,847,065	3,327,877		56,483,563	3,979,755		64,919,608	3,830,980	
%	81.20%	88.10%		81.00%	87.80%		78.40%	89.00%		87.40%	94.80%	
Vital Status (4-year FU)			<0.001			<0.001			<0.001			<0.001
Alive	66,602,755	2,648,791		67,901,285	3,328,246		70,026,194	4,135,411		72,204,906	3,743,351	
%	98.60%	93.50%		98.60%	93.70%		98.50%	93.20%		98.60%	93.40%	
Dead	956,933	185,317		997,812	223,398		1,083,357	301,072		1,059,579	266,037	
%	1.40%	6.50%		1.45%	6.29%		1.52%	6.79%		1.45%	6.64%	
Total												
	71,277,082	2,949,326		74,164,891	3,800,738		72,259,393	4,475,908		74,678,853	4,051,763	
	96.03%	3.97%		95.13%	4.87%		94.17%	5.83%		94.85%	5.15%	

Notes: AIAN, American Indian/Alaska Native; PIT, poverty income threshold; NS, never smoker; FS, former smoker; CS, current smoker; FU, follow-up.