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Stage at diagnosis and cancer-specific survival for stomach, lung, colorectal, and bladder cancers among Armenians in California

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ABSTRACT

Objective: To observe stage at diagnosis and cancer-specific survival for common cancers among Armenians in California.

Methods: We used the Armenian Surname List and birthplace information in the California Cancer Registry to identify Armenians with stomach, lung, colorectal, and bladder cancers diagnosed during 1988–2019. We used multivariable logistic regression models to calculate odds of late-stage diagnoses among Armenian and non-Armenian, non-Hispanic White patients and examine the association of sociodemographic factors with late-stage diagnoses among the Armenian patient population. We used Cox proportional hazards models to calculate cancer-specific survival among Armenian patients compared to non-Armenian, non-Hispanic White patients.

Results: Of the 639,224 cancer diagnoses identified, 6642 were among Armenian patients. Armenian individuals were more likely to be diagnosed with late-stage colorectal (OR = 1.12, 95 % CI = 1.03–1.22), lung (OR = 1.26, 95 % CI = 1.12–1.42), and stomach (OR = 1.43, 95 % CI = 1.17–1.74) cancers. Among Armenian patients, low nSES and public insurance were associated with late-stage diagnoses. Armenian individuals had better survival than non-Armenian, non-Hispanic White individuals for stomach (HR = 0.85, 95 % CI = 0.76–0.94), lung (HR = 0.86, 95 % CI = 0.82–0.91), colorectal (HR = 0.82, 95 % CI = 0.77–0.88), and bladder (HR = 0.87, 95 % CI = 0.76–0.99) cancers.

Conclusion: While Armenian patients were at greater risk of late-stage diagnoses of colorectal, lung, and stomach cancers, they had better survival compared to non-Armenian, non-Hispanic White patients. Further research is needed to understand factors impacting survival in Armenian individuals, including genetic, behavioral, and social factors. Our findings of lower nSES and public health insurance associated with late-stage diagnoses suggest a need for increased access to care and cancer screening among the Armenian population in California.

1. Introduction

Cancer continues to be a leading cause of death in California, with nearly 60,000 deaths per year (CDC, 2022). While previous population-based research studies in California have observed differences in cancer stage at diagnosis and survival among individuals in the non-Hispanic Black, Hispanic, Asian/Pacific Islander, and American Indian categories compared to those in the non-Hispanic White category, cancer survival has not been studied among many growing race/ethnic subcategories, including the Armenian population (Ellis et al., 2018a; Keegan et al., 2010; Maguire et al., 2021; Klapheke et al., 2019). California has the largest Armenian population in the United States (US) (Fittante, 2017). Out of the 259,430 Armenian individuals in California as estimated by the American Community Survey, (60.7 %) are foreign-born and 75.6 % reside in Los Angeles County (Fittante, 2017; United States Census Bureau, n.d.; Movsisyan et al., 2023). Due to a lack of a direct and consistent identification method, the Armenian population in the US has historically been included in the 'White' or 'Some Other Race' race/ethnicity categories in population-based research studies despite this population having unique genetic, behavioral, environmental, and social factors that may impact stage at diagnosis and survival (Rostomian et al., 2020; Yepiskoposyan et al., 2016). The historical

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grouping of Armenian individuals within a broad non-Hispanic White category has likely masked cancer stage at diagnosis and survival patterns among the Armenian population (Movsisyan et al., 2023).

In Armenia, lung, colorectal, stomach, and bladder cancers are among the five most commonly diagnosed cancers (World Health Organization, 2022). Additionally, our prior work using the Armenian Surname List (ASL), birthplace, and surname data from the California Cancer Registry (CCR) showed significantly higher incidence of several cancers including stomach, lung, colorectal, and bladder cancers among Armenian patients compared to non-Armenian, non-Hispanic White patients in California (Movsisyan Vernon et al., 2024). However, no studies, to our knowledge, have assessed late-stage cancer diagnoses and survival specifically among Armenian patients compared to non-Armenian, non-Hispanic White patients in California. Risk of late-stage diagnoses and cancer survival may differ, as cancer mortality rates are notably higher in Armenia (10.1 per 100,000) than in non-Hispanic White individuals in California (2.1 per 100,000), and mortality rates in Armenia have been increasing in recent years (American Cancer Society, 2023; Bedirian et al., 2022; Maguire et al., 2022). Differences in survival may relate to stage at diagnosis, as nearly half (49.6 %) of all cancers in Armenia, including stomach (69.4 %), lung (82.8 %), and colorectal (65.6 %) cancers, are diagnosed at late-stage (Bedirian et al., 2022; World Health Organization, 2020; Bardakhchyan et al., 2020). Further, previous studies have shown lower cancer survival in Armenia compared to high-income countries, including the United States (Bardakhchyan et al., 2020).

Understanding differences in stage at diagnosis and survival is needed to identify and address disparities in cancer outcomes among the growing Armenian population in California. As such, we compared odds of late-stage diagnosis for stomach, lung, colorectal, and bladder cancers between Armenian and non-Armenian, non-Hispanic White patients, examined characteristics associated with late-stage diagnoses specifically within the Armenian patient population, and compared cancer-specific survival between Armenian and non-Armenian, non-Hispanic White patients (Movsisyan et al., 2023).

2. Methods

2.1. Data sources

The California Cancer Registry (CCR), a statewide population-based cancer surveillance system composed of three National Cancer Institute Surveillance, Epidemiology, and End Results (SEER) registries, has collected cancer diagnoses in California since 1988 (CCR, 2025). The CCR is one of the largest cancer registries in the world and is Gold Certified by the North American Association of Central Cancer Registries (NAACCR) (CCR, 2025). Information available in the CCR includes patient demographics, tumor characteristics, including site and histology, and stage at diagnosis. The CCR also obtains vital status and cause of death information through routine linkages with state and national databases, providing follow-up information for vital status for all cancers except non-melanoma skin cancers.

2.2. Study population

To identify Armenian patients with cancer diagnoses, we used Match*Pro probabilistic linkage software to link the ASL and surnames from the CCR with birthplace in Armenia that were not in the ASL with the CCR for years of diagnosis 1988 through 2019 (December 2021 incidence file extract) (Movsisyan et al., 2023; Movsisyan Vernon et al., 2024). We extracted Armenian patients from the non-Hispanic White and other race/ethnicity categories to create a separate, mutually exclusive Armenian group. We selected data from the CCR on Armenian and non-Armenian, non-Hispanic White patients diagnosed with first-primary, malignant stomach, lung, colorectal, and bladder cancers. These four cancers were specifically selected for the present study, as they were among the top ten most common cancers we previously identified among Armenian patients in California, incidence patterns for these cancers were notably higher among Armenian patients compared to non-Armenian, non-Hispanic White patients, and these cancers are also common in Armenia (World Health Organization, 2022; Movsisyan Vernon et al., 2024). We compared Armenians to the non-Armenian, non-Hispanic White group because 97.2 % of patients we identified as Armenian were previously identified as non-Hispanic White in the CCR, likely masking true cancer incidence among the Armenian population in California. We excluded autopsy and death certificate diagnoses and records with missing survival time ($n = 13{,}112$). We also excluded unknown/other sex categories ($n = 72$). Tumor sites were selected based on International Classification of Diseases for Oncology, 3rd edition/World Health Organization (ICD-O-3/WHO) 2008 site codes and are shown in Supplemental Table 1 (SEER, 2024a).

2.3. Sociodemographic and clinical variables

We used SEER Summary Stage to define stage at diagnosis (localized, regional, distant, and unknown), with late-stage defined as regional or distant (SEER, 2024b). Health insurance types were organized into five categories: 1) not insured; 2) private included private insurance not otherwise specified (NOS), fee for service, managed care health maintenance organization (HMO), or preferred provider organization (PPO), Medicare with supplement, NOS, Medicare with private supplement, and TRICARE; 3) public included Medicaid, Medicaid administered through managed care plan, Medicare without supplement, Medicare, NOS, Medicare administered through a managed care plan, and Medicare with Medicaid eligibility; 4) other public included Military, Veterans Affairs, Indian/Public Health Service, and county funded, NOS; and 5) unknown, as done previously (Ellis et al., 2018b). For logistic regression analyses, we combined unknown with not insured, and public with other public due to small numbers. Neighborhood socioeconomic status (nSES) was categorized into lowest, middle, and highest groups based on a composite variable. For cases diagnosed 1988–2005, values are the tertile of an index of socioeconomic status based on principal components analysis of block group level variables from the decennial census (Yost et al., 2001). For cases diagnosed 2006–2019, values are the tertile of an index of socioeconomic status with missing values imputed based on principal components analysis of block group level variables from the American Community Survey (Yang et al., 2014). We considered sex (male, female), marital status (married/in partnership, previously married, single/never married, and unknown), nativity (US-born, foreign-born, and unknown), and number of comorbidities (none, one or two, three or more, and unknown) (Morris et al., 2021; Morris et al., 2022). Given a high percentage of missing tobacco use data available in the CCR, we provided descriptive observations of known cigarette use at time of diagnosis among Armenian and non-Armenian, non-Hispanic White patients diagnosed during 2014–2019.

2.4. Analyses

Demographic and cancer characteristics were presented for the Armenian and non-Armenian, non-Hispanic White population. To examine odds of late-stage diagnoses among Armenian patients compared to non-Armenian, non-Hispanic White patients, we used multivariable logistic regression models adjusted for year of diagnosis, age at diagnosis, sex, nSES, insurance type, marital status, comorbidity, and reporting regional cancer registry. We excluded patients with unknown stage at diagnosis ($n = 50{,}333$). Results are presented as adjusted odds ratios and 95 % confidence intervals (CI).

We also used multivariable logistic regression models to assess sociodemographic factors associated with late-stage diagnoses specifically among Armenian patients. Given the general Medicare eligibility age of 65 years (HHS.gov, n.d.), we examined the relationship between insurance type and late-stage diagnoses within separate age groups of

<65 and 65+ years old.

We used the reverse Kaplan-Meier method to calculate median follow-up time (Sathish and Wu, 2019). We used multivariable Cox proportional hazards regression models to compare stomach, lung, colorectal, and bladder cancer survival among Armenian and non-Armenian, non-Hispanic White patients, adjusting for year of diagnosis, reporting regional registry, marital status, age, tumor site and histology, nSES, sex, insurance type, first course of treatment, comorbidity, and stage at diagnosis, as done previously (Klapheke et al., 2019). Results are presented as adjusted hazard ratios (HRs) and associated 95 % CIs. Survival time was calculated using date of cancer diagnosis and date of last contact (follow-up) or death. Patients who died of other or unknown causes, or patients who were alive at the study cut-off date of December 31, 2019, were censored at that time. For each model, we assessed the proportional hazards assumption by visually inspecting survival curves (log(−log) of the survival probability) by log (survival months of active follow-up) (Kuitunen et al., 2021). Variables that violated the proportional hazards assumption were stratified in the final model. After observing a significant interaction between race/ethnicity and stage at diagnosis for lung cancer ($p = 0.017$), we assessed survival by each level of cancer stage.

In addition, to estimate patients lost to follow-up (LTFU), we calculated the time interval in years between last follow-up date and study cut-off date among those who were alive. Alive patients with last follow-up date more than two years prior to the study cut-off date were defined as LTFU. Sensitivity analyses assuming all patients LTFU and only foreign-born patients who were LTFU died at the date of last contact were conducted to determine the impact on survival differences between Armenian and non-Armenian, non-Hispanic White patients. All analyses were conducted using SAS version 9.4 software (SAS Institute Inc., Cary, NC, USA).

3. Results

From 1988 to 2019, 6642 Armenian cancer patients met inclusion criteria (Table 1). Higher proportions of Armenian individuals resided in the lowest nSES neighborhoods (31.1 %), were married (64.3 %), had public insurance (56.0 %), and were foreign-born (57.9 %) compared to non-Armenian, non-Hispanic White individuals (23.6 %, 53.8 %, 24.7 %, and 5.8 %, respectively). Analyses of known cigarette use during 2014–2019 (68.9 % of Armenian patients and 66.8 % of non-Armenian, non-Hispanic White patients) showed that 29.1 % of Armenian patients (83.0 % male) compared to 22.4 % of non-Armenian, non-Hispanic White cancer patients (56.2 % male) were current cigarette users at time of diagnosis (Supplemental Table 2).

We observed somewhat higher proportions of late-stage diagnoses for stomach (69.5 % vs. 66.1 %), lung (79.8 % vs. 73.4 %), and colorectal (60.7 % vs. 57.9 %) cancers among Armenian patients compared to non-Armenian, non-Hispanic White patients (Supplemental Fig. 1). We observed significantly higher odds of late-stage colorectal (OR = 1.12, 95 % CI = 1.03–1.22), lung (OR = 1.26, 95 % CI = 1.12–1.42), and stomach (OR = 1.43, 95 % CI = 1.17–1.74) cancers among Armenian patients compared to non-Armenian, non-Hispanic White patients (Fig. 1).

In multivariable models by cancer type among Armenian patients, lowest (OR = 1.73, 95 % CI = 1.03–2.92) and middle (OR = 1.79, 95 % CI = 1.10–2.90) nSES status was associated with late-stage stomach cancer (Table 2). Male sex (OR = 1.70, 95 % CI = 1.28–2.25) and public health insurance (OR = 1.57, 95 % CI = 1.18–2.09) was associated with late-stage lung cancer. For colorectal cancer, public health insurance among patients younger than 65 years (OR = 1.54, 95 % CI = 1.12–2.13) was associated with late-stage disease. Armenian patients residing in the lowest nSES (OR = 1.99, 95 % CI = 1.22–3.26) were significantly more likely to be diagnosed with late-stage bladder cancer compared to Armenians in high nSES. Additionally, compared to Armenian patients with private insurance, Armenian patients with public health insurance

Table 1
Characteristics of Armenian and non-Armenian, non-Hispanic White patients diagnosed with stomach, lung, colorectal, and bladder cancer in California, 1988–2019.

	Armenian (N = 6,642)		NANHW (N = 632,582)	
Characteristic	n	(%)	n	(%)
Year of diagnosis				
1988–1998	1,406	21.2	248,476	39.3
1999–2009	2,355	35.5	218,788	34.6
2010–2019	2,881	43.4	165,318	26.1
Sex				
Male	4,145	62.4	347,410	54.9
Female	2,497	37.6	285,172	45.1
Age at diagnosis (years)				
0–29	25	0.4	1662	0.3
30–49	455	6.9	35,527	5.6
50–69	2,873	43.3	259,232	41.0
70+	3,289	49.5	336,161	53.1
Cancer type				
Stomach	774	11.7	31,428	5.0
Lung	2,348	35.4	304,962	48.2
Colorectal	2,750	41.4	234,080	37.0
Bladder	770	11.6	62,112	9.8
Neighborhood socioeconomic status				
Lowest	2,065	31.1	149,149	23.6
Middle	2,756	41.5	243,785	38.5
Highest	1,821	27.4	239,648	37.9
Marital status				
Married/in partnership	4,274	64.3	340,495	53.8
Previously married	1,473	22.2	198,639	31.4
Single, never married	688	10.4	75,058	11.9
Unknown	207	3.1	18,390	2.9
Insurance type				
Not insured	102	1.5	5969	0.9
Private	1,890	28.5	299,732	47.4
Public	3,660	55.1	135,599	21.4
Other public	61	0.9	13,207	2.1
Unknown	929	14.0	178,075	28.2
Stage at diagnosis				
Localized	1,923	29.0	189,144	29.9
Regional	1,931	29.1	169,880	26.9
Distant	2,319	34.9	223,694	35.4
Unknown	469	7.1	49,864	7.9
Nativity				
US-born	635	9.6	329,852	52.1
Foreign-born	3,847	57.9	36,920	5.8
Unknown	2,160	32.5	265,810	42.0
Comorbidity				
3+	819	12.3	57,134	9.0
1–2	2,184	32.9	193,345	30.6
0	2,491	37.5	217,014	34.3
Unknown	1,148	17.3	165,089	26.1
Vital status				
Dead	4,724	71.1	522,689	82.6
Alive	1,918	28.9	109,893	17.4

NANHW: non-Armenian, non-Hispanic White.

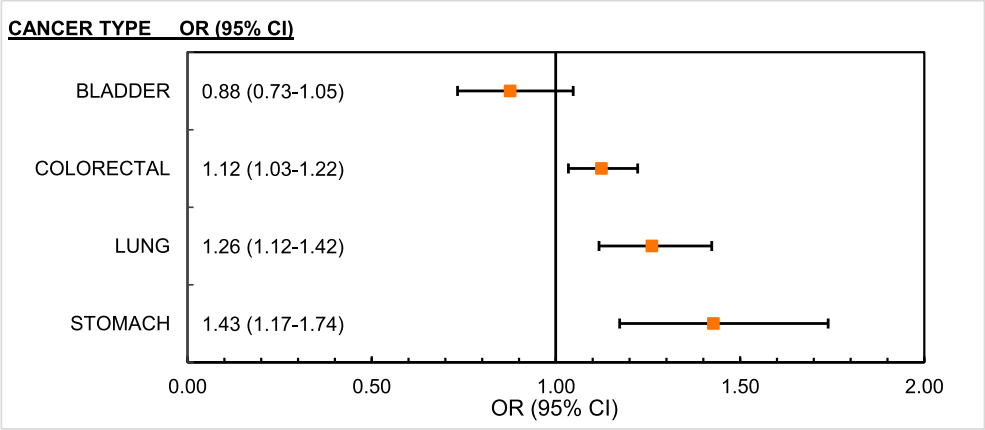

Fig. 1. Odds ratios for regional/distant stage (versus localized) cancer diagnosis among Armenian patients compared to non-Armenian, non-Hispanic White patients in California by cancer type, 1988–2019.
Multivariable logistic regression models were adjusted for age, year of diagnosis, sex, marital status, insurance type, comorbidity, reporting regional cancer registry, and socioeconomic status. OR: Odds Ratio, CI: 95 % Confidence interval. Reference group: non-Armenian, non-Hispanic White.

(OR = 1.99, 95 % CI = 1.22–3.26) were significantly more likely to be diagnosed with late-stage bladder cancer.

The median follow-up time by cancer type was 86 months for stomach (95 % CI = 84.0–88.0), 86 months for lung (95 % CI = 85.0–87.0), 108 months for colorectal (95 % CI = 108.0–109.0), and 94 months for bladder (95 % CI 93.0–95.0) (Supplemental Table 3). We observed lower hazard of death among Armenian patients compared to non-Armenian, non-Hispanic White patients, showing a modest survival advantage among Armenian patients for stomach (HR = 0.85, 95 % CI = 0.76–0.94), lung (HR = 0.86, 95 % CI = 0.82–0.91), colorectal (HR = 0.82, 95 % CI = 0.77–0.88), and bladder (HR = 0.87, 95 % CI = 0.76–0.99) cancers (Table 3). Survival estimates of Armenian patients relative to non-Armenian, non-Hispanic White individuals by stage at diagnosis for lung cancer showed no significant differences for localized and regional stage, and better survival for distant stage (HR = 0.84, 95 % CI = 0.79–0.89).

Among 111,811 patients alive at last follow-up, $n = 1918$ Armenian and $n = 109{,}893$ non-Armenian, non-Hispanic White, 7.7 % of Armenian and 3.4 % of non-Armenian, non-Hispanic White patients were LTFU. We observed a greater percentage of LTFU among foreign-born patients among Armenian (9.0 %) and non-Armenian, non-Hispanic White (9.3 %) compared to patients with US/unknown place of birth (4.8 %, 2.8 %, respectively). In two sensitivity analyses, when we assumed that all patients LTFU died at the date of last contact or all foreign-born LTFU patients died at the date of last contact, we observed similar results to our findings in Table 3, except for bladder cancer where there was similar survival between Armenian and non-Armenian, non-Hispanic White patients (Supplemental Table 4).

4. Discussion

To our knowledge, this is the first population-based study to consider stage at diagnosis and cancer-specific survival among the Armenian compared to the non-Armenian, non-Hispanic White population in California. We observed a higher likelihood of late-stage diagnoses for colorectal, lung, and stomach cancers among Armenian patients, suggesting potential barriers to timely screening for those eligible for lung and colorectal cancer screening. After consideration of stage at diagnosis and other sociodemographic and clinical factors, we found a survival advantage among Armenian patients for all four cancers studied. Our findings highlight the need to understand factors underlying higher risk of late-stage diagnoses among Armenian individuals and the observed moderate survival advantage, including the role of genetics, behavioral and social factors, or biases in ascertainment of survival data.

The higher likelihood of late-stage diagnoses for three of the four cancers among Armenian patients compared to non-Armenian, non-Hispanic White patients may indicate barriers to reliable healthcare among the Armenian population. Lung and colorectal cancers are screen-detectable, and the disparity in late-stage diagnoses signals barriers to reliable care including routine annual examinations and timely cancer screening for screen-detectable cancers among patients eligible for screening. Educational interventions in the Armenian language in trusted community settings can increase awareness of cancer screening and other preventive measures to promote early cancer detection. Our findings identify Armenian patients at risk for late-stage cancer diagnoses that can be directed towards appropriate care. Consistent with previous studies (Keegan et al., 2019; Primm et al., 2022; Alcaraz et al., 2020), public health insurance was associated with late-stage lung and colorectal cancers among younger Armenian patients (<65 years old), suggesting reliable health insurance is needed for early cancer detection. Further, compared to Armenian patients residing in high SES neighborhoods, Armenian patients residing in the lowest SES neighborhoods were more likely to be diagnosed with late-stage stomach and bladder cancers, showing a need for additional research to understand specific barriers to cancer screening among economically disadvantaged Armenian communities in California. Previous studies have identified that socioeconomic disadvantage can be associated with late-stage diagnoses due to unreliable access to health care or lack of job security and transportation (Alcaraz et al., 2020). The higher proportion of foreign-born Armenian patients may suggest additional difficulties receiving adequate healthcare, as supported by studies showing that immigrant populations face increased barriers to access, and are less likely to use preventive health services (Dee and Gomez, 2022; Breen et al., 2010; Siddiq et al., 2022; Fang and Ragin, 2020). Future studies should investigate late-stage cancer risk factors particularly among first-generation Armenian individuals, as previous studies have shown that with increased assimilation to the US culture, cancer risk factors mirror those of US-born individuals (Ziadeh et al., 2017).

The survival advantage among Armenian patients may be related to a variety of factors, such as community and family support after cancer diagnosis, the salmon bias, genetics, or better overall health among Armenian individuals (Fittante, 2017). Previous research has highlighted the connection between ethnic identity, cultural values, and self-care of cancer survivors, and this is relevant to our study as a majority of Armenian patients (57.9 %) were foreign-born and may closely adhere to traditional Armenian cultural norms (Yeom et al., 2022). Further, better survival among Armenian patients may be related to the salmon bias where patients with cancer may have left California to return to

Table 2
Odds ratios for regional/distant stage (versus localized) cancer diagnosis among Armenian patients in California, 1988–2019.

Characteristic	Stomach OR (95 % CI)	Lung OR (95 % CI)	Colorectal OR (95 % CI)	Bladder OR (95 % CI)
Year of diagnosis				
1988–1998	1.46 (0.76–2.73)	0.66 (0.45–0.96)	1.35 (1.02–1.78)	0.70 (0.35–1.37)
1999–2009	1.34 (0.86–2.08)	0.97 (0.73–1.29)	0.94 (0.78–1.13)	0.85 (0.56–1.28)
2010–2019	1.00	1.00	1.00	1.00
Age at diagnosis				
0 to 49	1.00	1.00	1.00	1.00
50 to 69	0.57 (0.25–1.29)	0.93 (0.53–1.61)	0.78 (0.57–1.07)	0.76 (0.35–1.65)
70+	0.29 (0.13–0.66)	0.94 (0.54–1.65)	0.78 (0.56–1.08)	0.51 (0.23–1.14)
Sex				
Male	1.11 (0.73–1.68)	1.70 (1.28–2.25)	1.05 (0.88–1.25)	0.75 (0.47–1.18)
Female	1.00	1.00	1.00	1.00
Neighborhood SES				
Lowest	1.73 (1.03–2.92)	0.99 (0.71–1.39)	1.06 (0.85–1.33)	1.99 (1.22–3.26)
Middle	1.79 (1.10–2.90)	1.09 (0.80–1.49)	0.94 (0.77–1.16)	1.29 (0.81–2.06)
Highest	1.00	1.00	1.00	1.00
Insurance type				
All ages (years)				
Private	1.00	1.00	1.00	1.00
Public	1.09 (0.68–1.74)	1.57 (1.18–2.09)	1.23 (1.01–1.49)	1.59 (1.02–2.49)
Unknown	1.13 (0.52–2.48)	1.52 (0.95–2.42)	1.12 (0.81–1.55)	1.46 (0.68–3.16)
Ages < 65 (years)				
Private	1.00	1.00	1.00	1.00
Public	0.53 (0.21–1.31)	2.05 (1.22–3.44)	1.54 (1.12–2.13)	1.48 (0.71–3.10)
Unknown	1.98 (0.39–9.94)	1.65 (0.79–3.45)	1.37 (0.83–2.26)	1.17 (0.35–3.91)
Ages 65+ (years)				
Private	1.00	1.00	1.00	1.00
Public	1.38 (0.77–2.45)	1.44 (1.02–2.04)	1.04 (0.81–1.35)	1.62 (0.90–2.91)
Unknown	0.84 (0.33–2.13)	1.54 (0.84–2.83)	0.89 (0.58–1.39)	1.44 (0.50–4.19)
Marital status				
Married/in partnership	1.00	1.00	1.00	1.00
Previously married	1.23 (0.74–2.06)	1.05 (0.75–1.45)	1.03 (0.83–1.28)	0.95 (0.58–1.56)
Single, never married	0.98 (0.46–2.08)	0.82 (0.55–1.21)	0.94 (0.73–1.22)	0.81 (0.43–1.51)
Unknown	0.63 (0.22–1.78)	2.82 (0.86–9.21)	0.48 (0.30–0.79)	0.39 (0.08–1.81)
Comorbidity				
3+	0.68 (0.36–1.31)	0.72 (0.48–1.07)	0.80 (0.59–1.09)	1.51 (0.85–2.68)
1–2	0.99 (0.63–1.59)	0.79 (0.58–1.07)	0.95 (0.78–1.16)	1.31 (0.84–2.03)
0	1.00	1.00	1.00	1.00
Unknown	0.68 (0.37–1.28)	1.19 (0.78–1.82)	0.75 (0.59–0.96)	0.61 (0.36–1.04)

Multivariable logistic regression models were adjusted for variables in the table and reporting regional cancer registry. SES: Socioeconomic status.

Table 3
Cancer-specific survival of Armenian patients compared to non-Armenian, non-Hispanic White patients in California by cancer type, 1988–2019.

Cancer type	HR	95 % CI	*p*-value
Stomach	0.85	(0.76–0.94)	0.0015
Lung[b]	0.86	(0.82–0.91)	<0.0001
Localized	0.99	(0.82–1.21)	0.9678
Regional	0.98	(0.87–1.11)	0.7723
Distant	0.84	(0.79–0.89)	<0.0001
Colorectal	0.82	(0.77–0.88)	<0.0001
Bladder	0.87	(0.76–0.99)	0.0308

Multivariable Cox proportional hazards regression models were adjusted for age, year of diagnosis, sex, marital status, insurance type, comorbidity, reporting regional cancer registry, socioeconomic status, first course of treatment, histology, cancer site, and stage at diagnosis. HR: Hazard Ratio, CI: Confidence interval. [b]HR shown by stage at diagnosis for lung cancer due to observed interaction between race/ethnicity and stage at diagnosis conducted using a separate model not adjusted for stage. Reference group: non-Armenian, non-Hispanic White.

their native country in later years of life or after illness (Turra and Elo, 2008). The salmon bias has been used to explain lower mortality among foreign-born Hispanic cancer patients in California, and better survival of Middle-Eastern women (including Armenian women) with advanced stage breast cancer compared to non-Hispanic White women (Nasseri, 2009; Miller et al., 2021). The higher LTFU among Armenian compared to non-Armenian, non-Hispanic White patients raises the question of whether these patients returned to Armenia or other native countries post-diagnosis. However, the similar survival patterns observed in our sensitivity analyses suggest that LTFU does not explain the observed survival advantage among Armenian patients in our study. Our findings may also relate to the healthy immigrant effect, which has been used to explain the better health of immigrants in the US compared to US-born populations (Markides and Rote, 2019). However, additional information on the health among Armenian cancer patients would be required to confirm its role in cancer survival statistics. Further, previous epigenetic studies have examined the Hispanic Paradox in the US to understand the lower mortality observed among Hispanic patients compared to non-Hispanic White patients despite lower SES, higher percentage uninsured, higher cardio-metabolic disease, higher prevalence of obesity, and type 2 diabetes (Miller et al., 2021; Horvath et al., 2016). Among other findings, researchers found that Hispanic populations of Mexican ancestry in California have lower rates of intrinsic aging in their blood and suggest this finding has a more plausible connection to the lower overall mortality risk as opposed to the healthy immigrant effect (Horvath et al., 2016). Genetic and epigenetic studies to understand cancer survival among Armenian individuals are needed given the genetic continuity maintained among the Armenian population since the Bronze Age (Movsesian et al., 2020), and a previously discovered link between Armenian ethnicity and increased cardiovascular disease risk in California (Rostomian et al., 2020).

The four cancers selected in this study are all tobacco-related (American Cancer Society, 2020). Tobacco-use remains a major public health issue in Armenia as an estimated 52.3 % of men and 1.5 % of women are current smokers, and over half of tobacco-related annual

deaths occur among individuals younger than 70 years old (Ministry of Health Armenia et al., 2021; Berg et al., 2019). Additionally, tobacco-use is associated with lower cancer survival after diagnosis (Kvaavik et al., 2023). Given the continued public health burden of tobacco-use in Armenia, and the majority foreign-born Armenian population in California, understanding tobacco-use among Armenian communities after immigration can guide public health interventions focused on tobacco-cessation (Berg et al., 2021). While tobacco-use data among the Armenian population in California is currently unavailable, among known cigarette users at time of diagnosis, we observed a higher percentage of cigarette use among Armenian cancer patients, and a gender disparity in cigarette use. Given the higher percentage of Armenian cancer patients who smoke cigarettes, and the known negative impacts of tobacco-use on cancer treatment, educational interventions regarding the negative effects of tobacco-use on cancer survival may benefit Armenian cancer patients (Kvaavik et al., 2023). While cigarette use patterns in California appear to follow those observed in Armenia, our findings should be interpreted with caution due to the more recent availability and high proportion of missing cigarette use data in the CCR, and uncertainty as to whether these variables were missing at random between the two racial/ethnic groups and among males and females.

Our study has some limitations. While we were able to identify Armenian patients in the CCR using the ASL and supported by available birthplace information, we were not able to observe survival nor odds of late-stage diagnoses by nativity due to a high missing rate of birth country in the CCR. Additionally, patients with missing country of birth in the CCR are more likely to be US-born rather than foreign-born (Gomez and Glaser, 2005). Future research efforts to better identify birth country of patients is warranted as it would allow further understanding of generational, environmental, and cultural factors on risk of late-stage cancer and survival among the Armenian population in California. Further, while the use of the ASL allowed the study of cancer survival among Armenian patients for the first time, the ASL is subject to common limitations arising with the use of surname lists (Movsisyan et al., 2023). A common limitation is the possibility of missing Armenian patients who may have changed their last names due to marriage or other reasons. While we included maiden name and father's surname where available to minimize this limitation, it is still possible we may have missed identifying Armenian patients with non-Armenian last names and missing maiden and father's surnames, or Armenian patients with non-Armenian fathers and Armenian mothers who may have had a non-Armenian last name, maiden name, and father's surname (Movsisyan et al., 2023). We may have also missed Armenian patients if their surname was not identifiable by the ASL nor by birthplace in the CCR.

Another limitation is the possibility of missed deaths during linkage to death records, which has been shown to bias survival estimates in survival studies using population-based cancer registry data (Pinheiro et al., 2014). Death linkages rely on variables including valid social security numbers, and populations with large foreign-born patients, including Armenian individuals in the present study, may have precluded the identification of foreign-born Armenian patients who have died, and these patients would have been considered alive in this study (Pinheiro et al., 2014). Further, complete follow-up with at least five years of vital status information is one way to mitigate the effects of missing deaths, and the availability of up to 31 years of vital status follow-up information used in the present study may have helped reduce the potential survival bias related to missing deaths (Pinheiro et al., 2014). However, survival bias remains a limitation as at least five years of vital status information was not available for patients diagnosed in more recent years.

Our study is the first to consider late-stage cancer and survival among the Armenian population in California, a growing minority race/ethnicity group. Our methods highlight the value of extracting minority race/ethnicity groups from broad race/ethnicity categories to understand and address previously masked cancer disparities among specific race/ethnic minorities in California. Further research is needed to understand the observed cancer survival advantage we observed among Armenians, including genetic, behavioral and social factors, or potential biases in ascertainment of survival data. Our findings of higher risk of late-stage diagnoses for colorectal, lung, and stomach cancers suggest the need for increased access to care, cancer screening, and culturally competent prevention programs. Given the collectivist Armenian culture and a majority foreign-born demography (Fittante, 2017), public health interventions in the Armenian language (Eastern and Western dialects), including partnerships among public health professionals, clinicians, and trusted community leaders in the Armenian community, are needed for successful community outreach regarding cancer risk factors and preventive measures (Siddiq et al., 2022; Ka'opua et al., 2011).

Ethics declarations/ethics approval and consent to participate

Approval for this study protocol including all methods was received from the Committee for the Protection of Human Subjects (CPHS), the Institutional Review Board (IRB) for the State of California Health and Human Services Agency. As the nature of the study is retrospective, waiver of informed consent was received from the Committee for the Protection of Human Subjects (CPHS), the Institutional Review Board (IRB) for the State of California Health and Human Services Agency. All methods were carried out in accordance with relevant guidelines and regulations.

Availability of data and materials

The data that support the findings of this study are available from the California Department of Public Health and the California Cancer Registry. Access is granted through an application process by the management or data custodians (https://www.cdph.ca.gov/Programs/CHSI/Pages/Data-Applications.aspx) and (https://www.ccrcal.org/retrieve-data/).

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CRediT authorship contribution statement

Ani S. Movsisyan Vernon: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Laura Fejerman:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Jeffrey S. Hoch:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Theresa H. Keegan:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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of Southern California, and the Public Health Institute; and the Centers for Disease Control and Prevention's National Program of Cancer Registries, under agreement awarded to the California Department of Public Health. The ideas and opinions expressed herein are those of the author (s) and endorsement by the State of California, Department of Public Health, the National Cancer Institute, the Centers for Disease Control and Prevention, or their Contractors and Subcontractors is not intended nor should be inferred.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2024.108214.

Data availability

The data that has been used is confidential.

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