

Short-term Survival Prognosis and Multivariate Analysis of Cervical Cancer in American Women: A NHANES Cohort Study

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Abstract

Objective

To compare the 1-year all-cause and cause-specific short-term survival disparities between female patients diagnosed with cervical cancer and those with other malignant tumors.

Methods

Female participants enrolled in NHANES 1999–2018 were linked to 1-year mortality follow-up data from the National Death Index (NDI). Subjects were stratified into a cervical cancer group and another malignancy group according to cancer diagnosis. Baseline data including demographic characteristics, lifestyle behaviors and comorbid chronic diseases were collected, with multiple 1-year mortality endpoints designated as study outcomes. Weighted Kaplan-Meier survival curves combined with the Log-rank test were applied to compare intergroup survival profiles. Stepwise adjusted multivariate Cox regression models were constructed to explore mortality-related risk factors.

Results

A total of 2727 female patients with malignant neoplasms were enrolled in the final analysis, including 339 patients with cervical cancer (12.4%) and 2388 patients with other malignancies (87.6%). Weighted baseline comparisons revealed statistically significant intergroup differences with respect to age, race/ethnicity, socioeconomic status, educational attainment, smoking status and the distribution of chronic comorbidities (all $P < 0.05$). One-year follow-up analyses demonstrated that weighted mortality rates for all predefined endpoints were significantly lower in the cervical cancer group relative to the group with other malignancies (all $P < 0.05$), and the Log-rank test confirmed a statistically significant divergence in survival curves between the two cohorts ($P < 0.001$). Fully adjusted Cox regression models identified advanced age, non-Hispanic Black ethnicity, widowed marital status, active smoking, type 2 diabetes mellitus, and chronic obstructive pulmonary disease (COPD) as independent risk factors for 1-year mortality among patients with cervical cancer. Elevated household income, higher body mass index (BMI), and medical histories of angina pectoris and hyperlipidemia were found to exert protective effects against mortality, whereas no remaining variables exhibited independent prognostic predictive capacity.

Conclusions

In this nationally representative female cohort in the United States, women with cervical cancer had superior 1-year overall and cause-specific survival versus those with other malignancies. Age, race, marital status, smoking, metabolic and respiratory comorbidities independently predicted short-term mortality. Standardized cervical cancer screening, smoking cessation, integrated management of

glycolipid and cardiopulmonary chronic diseases, and stratified follow-up are warranted for high-risk individuals to reduce short-term mortality.

Introduction

Cervical cancer ranks as the fourth most commonly diagnosed malignancy among women worldwide[1]. In 2022, there were more than 662,000 newly diagnosed cases of cervical cancer globally, alongside approximately 349,000 corresponding deaths[2]. This disease alone contributed to over 11 million disability-adjusted life years (DALYs) lost worldwide in that year[3]. The disease burden predominantly affects working-age women aged 30–59 years[4, 5]. Numerous patients suffer work incapacity and premature death due to the disease, resulting in severe personal health impairment, household economic losses, and substantial societal medical burdens. Although mature population-based screening strategies for cervical cancer are available[6], and long-term survival can be improved via early intervention, patients diagnosed at advanced stages face markedly elevated short-term mortality risk. Tumor prognosis therefore remains a critical public health priority[7].

Existing research on cervical cancer prognosis has notable limitations. Most previous survival analyses focused exclusively on patients with cervical cancer. Large-sample epidemiological evidence based on a single nationally representative female cohort that directly compares short-term survival outcomes between cervical cancer and other malignancies remains scarce. Accordingly, the relative short-term prognostic performance of cervical cancer versus other female cancers cannot be objectively quantified[7]. Furthermore, prior prognostic prediction models incorporated limited confounders, mostly restricted to clinical indicators such as age and tumor pathological stage. Few models simultaneously integrated multiple real-world confounding variables, including demographic characteristics, socioeconomic status, health-related behaviors, and multisystem chronic comorbidities[8], which restricts the generalizability of research findings to the general population. Studies investigating cervical cancer prognosis among US populations have largely centered on racial disparities in survival and predictions relying on isolated clinical indicators[2]. Stratified 1-year short-term follow-up analyses distinguishing multiple mortality endpoints (all-cause, cardiovascular, and cancer-specific mortality) are lacking, hindering the development of integrated management strategies for cancers and chronic diseases[9].

Addressing these research gaps, the present population-based survival analysis was conducted using data from the US National Health and Nutrition Examination Survey (NHANES). NHANES is jointly administered by the National Center for Health Statistics (NCHS) and the Centers for Disease Control and Prevention (CDC). It employs a complex multistage stratified sampling design, yielding a sample representative of the nationwide female population in the United States[10]. The database can be accurately linked to the US National Death Index (NDI), enabling 1-year longitudinal survival follow-up using cross-sectional baseline data and complete ascertainment of diverse short-term mortality events among participants[9]. Using this high-quality population cohort, this study first compared 1-year all-cause and cause-specific short-term survival between women with cervical cancer and those with other

malignancies. Second, weighted Cox regression models with sequential adjustment for multidimensional confounders were applied to systematically identify independent risk and protective factors for 1-year mortality among women with cervical cancer[11, 12]. Findings from this study characterize short-term prognostic profiles of cervical cancer from a nationwide US population perspective, and provide locally relevant epidemiological evidence to support stratified follow-up for high-risk cervical cancer populations and coordinated comprehensive interventions targeting cervical cancer together with metabolic, respiratory, and cardiovascular chronic disorders.

Materials and Methods

2.1 Data Source and Study Population

This cross-sectional study included female participants with diagnosed cancer from the National Health and Nutrition Examination Survey (NHANES) database between 1999 and 2018. Participants with missing key covariate data and unconfirmed tumor status were excluded. Tumor status was determined according to the survey question “Have you ever been diagnosed with cancer or a malignancy?” (variable code: MCQ220), and participants who answered “Yes” were assigned to the cancer group. Tumor types were identified using three survey items: “What was the first type of diagnosed cancer?” (MCQ230a), “What was the second type of diagnosed cancer?” (MCQ230b), and “What was the third type of diagnosed cancer?” (MCQ230c). Participants reporting cervical cancer in any of the three questions were categorized into the cervical cancer group, and the remaining cancer patients were allocated to the other cancer group[13].

2.2 Covariates

Covariates incorporated in this study consisted of demographic variables, behavioral variables, and histories of chronic diseases. Demographic data covered age, race (non-Hispanic White, non-Hispanic Black, Mexican American, others), marital status (unmarried, married, cohabiting with partner, divorced, widowed or separated), educational attainment (less than high school, high school graduate, above high school), and poverty income ratio (PIR). The PIR serves as an indicator of socioeconomic status, whereby lower PIR values correspond to lower socioeconomic position[9]. Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m). Laboratory indicators included white blood cell count, hemoglobin, glycated hemoglobin, creatinine and other parameters[14]. Behavioral variables comprised smoking status (never smoker, former smoker, current smoker). With regard to medical history, chronic diseases including cardiovascular disease, hyperlipidemia, and chronic obstructive pulmonary disease were dichotomized into two categories (presence or absence)[15].

2.3 Follow-up Outcome Indicators

Follow-up outcome data were obtained from the National Death Index (NDI) database linked to NHANES. The date of baseline physical examination was defined as the initiation of follow-up, and the follow-up endpoint was set at the 12th month after baseline. All mortality events occurring within one year were

recorded[10]. Five non-mutually exclusive follow-up endpoints were defined: all-cause mortality, defined as death resulting from any cause within the 1-year follow-up period; cardiovascular mortality, referring to deaths with underlying causes attributable to various cardiovascular diseases including coronary heart disease, myocardial infarction, heart failure, stroke, atherosclerosis and other related disorders; cancer-specific mortality, representing deaths whose underlying cause was the confirmed malignant neoplasm of the participant; non-cardiovascular mortality, encompassing all deaths excluding those caused by cardiovascular diseases; non-cancer mortality, covering all deaths excluding those attributable to malignant tumors. Survival time was calculated in days using the database variable permth_int. Participants who survived through the 12-month follow-up period were treated as censored data; follow-up time was truncated at 12 months, and such participants were not recorded as mortality events.

2.4 Statistical Analysis

2.4.1 Data Extraction and Cleaning

Python programs were adopted to batch extract standardized public NHANES datasets covering 1999–2018[13], which automatically realized merging of multi-cycle data tables and unified variable matching. Data cleaning scripts were developed to batch exclude samples with missing key covariates such as tumor classification, demographic characteristics, physical examination results, chronic disease conditions and follow-up outcomes. Outliers and duplicated participant records were automatically identified and removed. Only female subjects with gynecological malignancies satisfying the inclusion and exclusion criteria were retained to export a standardized analytical dataset.

2.4.2 Statistical Software and Sampling Adjustment

All statistical analyses were performed using Python and SPSS 26.0 software. The analytical procedures strictly followed the specifications of the complex multistage stratified sampling design of NHANES. The two-year MEC sampling weight WTMEC2YR was applied to adjust selection bias introduced by sampling stratification and clustering. Two-sided tests were adopted for all analyses with the significance level set at $\alpha = 0.05$. Differences with $P < 0.05$ were regarded as statistically significant.

2.4.3 Weighted Survival Analysis

Weighted Kaplan–Meier survival curves were separately constructed using 1-year all-cause, cardiovascular, cancer-specific, non-cardiovascular and non-cancer mortality as independent follow-up endpoints. The Log-rank test was used to compare differences in survival distributions between the cervical cancer group and the other malignancy group, so as to intuitively illustrate the short-term survival trends within one year in the two cohorts[16].

2.4.4 Stratified Weighted Cox Proportional Hazards Regression

Three sequentially adjusted weighted Cox regression models were constructed to estimate hazard ratios (HRs) and corresponding 95% confidence intervals (CIs) for the associations between each variable and 1-year all-cause mortality among women with cervical cancer, and to quantify the strength of associations between relevant factors and short-term all-cause mortality. Model 1 was the crude model without adjustment for any covariates, presenting unadjusted association estimates. Model 2 primarily adjusted for fundamental demographic and socioeconomic confounders, including age, race, marital status, educational attainment, and family poverty income ratio. On the basis of covariates adjusted in Model 2, Model 3 further incorporated additional confounders including BMI, smoking status, cardiovascular diseases, type 2 diabetes mellitus, chronic obstructive pulmonary disease and other covariates. The Schoenfeld residual test was used to verify the proportional hazards assumption; an overall $P>0.05$ indicated that the model assumption was satisfied. The models output HRs and corresponding CIs. An $HR>1$ represented a risk factor for mortality, whereas an $HR<1$ indicated a protective factor[17].

Results

3.1 Baseline Demographic and Clinical Characteristics of the Study Population

A total of 2727 female participants with malignant tumors from the NHANES 1999–2018 longitudinal cohort were finally enrolled in the present study. The median age of the overall population was 66.00 (53.00, 77.00) years; among them, 1824 participants (67.00%) were non-Hispanic White, and 656 participants (24.00%) had comorbid type 2 diabetes mellitus. Participants were divided into the cervical cancer group (339 cases) and the other malignancy group (2388 cases) according to primary tumor type. Weighted comparisons of all demographic characteristics, chronic disease profiles, routine blood test and biochemical indicators between the two groups are presented in Table 1.

Weighted intergroup comparisons at baseline revealed that the median age of participants in the cervical cancer group was 47.00 (36.00, 58.00) years, which was significantly lower than 68.00 (56.00, 79.00) years in the other malignancy group, with a statistically significant intergroup difference ($P<0.001$). No significant difference in racial distribution was observed between the two groups ($P=0.470$). Statistically significant disparities in the proportions of participants with hypertension, coronary heart disease, congestive heart failure, chronic kidney disease, smoking and alcohol consumption were detected between groups ($P<0.05$), whereas the prevalence of stroke and chronic obstructive pulmonary disease did not differ significantly ($P>0.05$). With respect to laboratory parameters, intergroup differences in white blood cell count, hemoglobin, platelet count, glycated hemoglobin, aspartate aminotransferase, creatinine, high-density lipoprotein cholesterol and estimated glomerular filtration rate reached statistical significance ($P<0.05$). No remarkable intergroup differences were found for alanine aminotransferase, triglycerides, total cholesterol and low-density lipoprotein cholesterol, and the between-group difference in BMI was marginally significant ($P=0.056$).

Table 1. Baseline characteristics by cancer group in NHANES 1999-2018

Characteristic	Overall (n = 2727)	Other malignancies (n = 2388)	Cervical cancer (n = 339)	P value
Age, years	66.00 (53.00, 77.00)	68.00 (56.00, 79.00)	47.00 (36.00, 58.00)	<0.001
Race/ethnicity				0.470
Mexican American	256 (9.40%)	219 (9.20%)	37 (11.00%)	-
Non-Hispanic Black	346 (13.00%)	311 (13.00%)	35 (10.00%)	-
Non-Hispanic White	1824 (67.00%)	1598 (67.00%)	226 (67.00%)	-
Other Hispanic	162 (5.90%)	138 (5.80%)	24 (7.10%)	-
Other race, including multiracial	139 (5.10%)	122 (5.10%)	17 (5.00%)	-
Hypertension	1668 (61.00%)	1508 (63.00%)	160 (47.00%)	<0.001
Type 2 diabetes mellitus	656 (24.00%)	594 (25.00%)	62 (19.00%)	-
Coronary heart disease	173 (6.40%)	164 (6.90%)	9 (2.70%)	0.003
Congestive heart failure	188 (6.90%)	177 (7.50%)	11 (3.20%)	0.004
Stroke	219 (8.10%)	190 (8.00%)	29 (8.60%)	0.700
COPD	246 (9.00%)	217 (9.10%)	29 (8.60%)	0.750
CKD	788 (33.00%)	725 (36.00%)	63 (20.00%)	<0.001
Smoking status				<0.001
Former	812 (30.00%)	736 (31.00%)	76 (22.00%)	-
Never	1459 (54.00%)	1344 (56.00%)	115 (34.00%)	-
Current	454 (17.00%)	306 (13.00%)	148 (44.00%)	-
Alcohol consumption				<0.001
Former	607 (26.00%)	537 (26.00%)	70 (23.00%)	-
Heavy	232 (9.80%)	156 (7.60%)	76 (25.00%)	-
Mild	740 (31.00%)	675 (33.00%)	65 (22.00%)	-
Moderate	337 (14.00%)	288 (14.00%)	49 (16.00%)	-
Never	450 (19.00%)	409 (20.00%)	41 (14.00%)	-
White blood cell count, 10 ⁹ /L	6.90 (5.60, 8.40)	6.80 (5.60, 8.30)	7.70 (6.30, 9.20)	<0.001

Characteristic	Overall (n = 2727)	Other malignancies (n = 2388)	Cervical cancer (n = 339)	P value
Hemoglobin, g/dL	13.50 (12.70, 14.30)	13.50 (12.70, 14.20)	13.80 (13.00, 14.50)	<0.001
Platelet count, 10 ⁹ /L	248.00 (209.00, 295.00)	246.00 (207.00, 293.00)	263.00 (226.00, 303.00)	<0.001
Glycated hemoglobin, %	5.60 (5.30, 6.00)	5.60 (5.30, 6.00)	5.40 (5.20, 5.80)	<0.001
Alanine aminotransferase, U/L	18 (15.00, 23.00)	18 (15.00, 23.00)	19 (14.00, 25.00)	0.870
Aspartate aminotransferase, U/L	22 (19.00, 26.00)	22 (19.00, 26.00)	21 (18.00, 25.00)	<0.001
Albumin, g/L	41.0 (39.00, 43.00)	41.0 (39.00, 43.00)	41.0 (39.00, 44.00)	0.890
Creatinine, µmol/L	71 (61.00, 82.00)	71 (62.00, 84.00)	64 (54.00, 75.00)	<0.001
Triglycerides, mmol/L	1.45 (1.01, 2.11)	1.45 (1.02, 2.09)	1.39 (0.96, 2.22)	0.520
Total cholesterol, mmol/L	5.17 (4.47, 5.95)	5.20 (4.53, 5.96)	5.07 (4.37, 5.87)	0.080
Low-density lipoprotein cholesterol, mmol/L	2.95 (2.38, 3.59)	2.95 (2.35, 3.60)	2.92 (2.40, 3.41)	0.500
High-density lipoprotein cholesterol, mmol/L	1.45 (1.19, 1.76)	1.47 (1.19, 1.78)	1.34 (1.11, 1.66)	<0.001
Estimated glomerular filtration rate, mL/min/1.73 m ²	81 (63.00, 97.00)	78 (61.00, 93.00)	98 (82.00, 110.00)	<0.001
Body mass index, kg/m ²	28 (24.00, 33.00)	28 (24.00, 33.00)	29 (24.00, 34.00)	0.056

Note: Data are presented as median (interquartile range) or n (%). P values were obtained using survey-weighted tests. P values for categorical variables are shown on the corresponding group row. A dash indicates that the P value was not reported in the source table.

Abbreviations: NHANES, National Health and Nutrition Examination Survey; eGFR, estimated glomerular filtration rate.

3.2 Weighted 1-Year Mortality and Kaplan–Meier Survival Analysis

After 1-year NDI-linked survival follow-up and adjustment for sampling weights, the incidences of all-cause, cardiovascular, cancer-specific, non-cardiovascular and non-cancer mortality in the cervical

cancer group were all lower than those in the other malignancy group: all-cause mortality (12.0% vs. 30.0%, $P<0.001$), cardiovascular mortality (2.7% vs. 5.9%, $P=0.015$), cancer-specific mortality (3.5% vs. 8.8%, $P<0.001$), non-cardiovascular mortality (9.7% vs. 24.0%, $P<0.001$), and non-cancer mortality (8.8% vs. 21.0%, $P<0.001$).

Weighted Kaplan–Meier survival curves were separately generated taking the five categories of 1-year mortality events as independent endpoints, and the Log-rank test was applied to compare survival distributions between the two groups. Log-rank test results demonstrated statistically significant intergroup differences in survival curves for all five endpoints (all $P<0.001$). Within the 1-year follow-up period, the cumulative survival rate of patients with cervical cancer remained higher than that of patients with other malignancies, and the survival comparison curves are illustrated in Figure 1.

3.3 Stratified Weighted Cox Proportional Hazards Regression Analysis

In the fully adjusted Cox regression model, statistically significant independent risk factors for 1-year all-cause mortality ($HR>1$, $P<0.05$) included age, non-Hispanic Black race, widowed marital status, current smoking, history of type 2 diabetes mellitus, and history of chronic obstructive pulmonary disease. Each one-year increment in age was associated with an HR of 1.091 (95%CI: 1.080–1.103, $P<0.001$). Compared with non-Hispanic White participants, non-Hispanic Black participants exhibited an HR of 1.635 (95%CI: 1.262–2.118, $P<0.001$). Widowed participants had an HR of 1.267 (95%CI: 1.043–1.537, $P=0.017$) relative to married participants. In comparison with never smokers, current smokers had an HR of 1.843 (95%CI: 1.414–2.402, $P<0.001$). Participants with comorbid type 2 diabetes mellitus showed an HR of 1.232 (95%CI: 1.033–1.470, $P=0.020$), and those with chronic obstructive pulmonary disease had an HR of 1.598 (95%CI: 1.250–2.041, $P<0.001$).

Statistically significant independent protective predictors ($HR<1$, $P<0.05$) were poverty income ratio, body mass index (BMI), history of angina pectoris, and history of hyperlipidemia. Each one-unit increase in poverty income ratio corresponded to an HR of 0.877 (95%CI: 0.822–0.936, $P<0.001$). Each 1 kg/m² elevation in BMI was associated with an HR of 0.980 (95%CI: 0.967–0.995, $P=0.007$). Participants with prior angina pectoris had an HR of 0.633 (95%CI: 0.461–0.870, $P=0.005$), and individuals with a history of hyperlipidemia presented an HR of 0.703 (95%CI: 0.573–0.862, $P<0.001$). After full adjustment for all confounders, other racial subgroups, marital strata, educational levels, former smoking status, and covariates including coronary heart disease, myocardial infarction, cardiovascular disease, atherosclerotic cardiovascular disease, hypertension, congestive heart failure and stroke failed to display independent predictive value for 1-year all-cause mortality ($P>0.05$). The fully adjusted estimates are summarized in Table 2 and displayed graphically in Fig. 2.

Table 2. Fully adjusted Cox model for 1-year mortality in cervical cancer

Variable	HR	95% CI	P value
Age, per year	1.091	1.080-1.103	<0.001
Poverty income ratio, per unit	0.877	0.822-0.936	<0.001
Body mass index, per kg/m ²	0.980	0.967-0.995	0.007
Angina pectoris	0.633	0.461-0.870	0.005
Coronary heart disease	1.320	0.949-1.836	0.099
Myocardial infarction	0.892	0.642-1.240	0.496
Cardiovascular disease	1.373	0.782-2.411	0.270
Atherosclerotic cardiovascular disease	1.020	0.532-1.958	0.951
Hyperlipidemia	0.703	0.573-0.862	<0.001
Hypertension	0.967	0.790-1.185	0.749
Type 2 diabetes mellitus	1.232	1.033-1.470	0.020
Congestive heart failure	1.326	0.932-1.887	0.117
Stroke	1.038	0.737-1.463	0.831
Chronic obstructive pulmonary disease	1.598	1.250-2.041	<0.001
Race/ethnicity (reference: Non-Hispanic White)			
Non-Hispanic Black	1.635	1.262-2.118	<0.001
Mexican American	0.969	0.672-1.398	0.868
Other Hispanic	0.629	0.362-1.093	0.100
Other race, including multiracial	0.944	0.549-1.625	0.836
Marital status (reference: Married)			
Widowed	1.267	1.043-1.537	0.017
Never married	1.129	0.723-1.762	0.594
Divorced	1.242	0.948-1.628	0.116
Living with partner	1.413	0.714-2.798	0.321
Separated	1.268	0.689-2.333	0.445
Education (reference: High school graduate/GED)			
Grades 9-11	1.179	0.920-1.511	0.193
College graduate or above	0.897	0.671-1.198	0.460

Variable	HR	95% CI	P value
Some college or associate degree	1.020	0.819-1.270	0.859
Less than grade 9	1.011	0.755-1.356	0.939
Smoking status (reference: Never)			
Former	1.108	0.922-1.332	0.273
Current	1.843	1.414-2.402	<0.001

Note: The model was adjusted for demographic, socioeconomic, lifestyle, and chronic comorbidity covariates. For binary comorbidities, the reference category was absence. HRs for continuous variables are reported per unit increase. $P < 0.05$ indicates statistical significance.

Abbreviations: HR, hazard ratio; CI, confidence interval; GED, General Educational Development; NHANES, National Health and Nutrition Examination Survey.

Discussion

Based on 1-year short-term follow-up data from the nationally representative cohort of women with malignant tumors in NHANES 1999–2018, weighted Kaplan–Meier survival curves and Log-rank test results indicated that patients with cervical cancer exhibited significantly superior short-term survival outcomes compared with women diagnosed with other malignancies, regardless of whether all-cause, cardiovascular, cancer-specific, non-cardiovascular or non-cancer mortality was adopted as the endpoint, and intergroup survival differences for all endpoints reached statistical significance. Stratified sequentially adjusted weighted Cox regression models further quantified independent prognostic associations. After adjustment for all confounding variables encompassing demographic, socioeconomic, behavioral and multisystem chronic disease factors, advanced age, non-Hispanic Black race, widowed marital status, current smoking, type 2 diabetes mellitus, and chronic obstructive pulmonary disease (COPD) were identified as independent risk factors elevating the 1-year all-cause mortality risk among women with cervical cancer. In contrast, higher poverty income ratio, body mass index (BMI), prior history of angina pectoris and hyperlipidemia constituted independent protective factors against short-term mortality, and these associations remained robust following comprehensive confounding adjustment.

The present study demonstrated that patients with cervical cancer achieved superior 1-year survival across all five mortality endpoints relative to individuals with other malignancies, which aligns with findings from multiple population-based cohort studies utilizing cancer registry databases[18]. From the perspectives of disease etiology and screening systems, cervical cancer has well-defined high-risk pathogenic pathways alongside established population screening programmes enabling detection and curative treatment of extensive pre-malignant lesions. Conversely, most other malignancies lack widely accessible, high-sensitivity early screening tools, resulting in a larger proportion of late-stage diagnoses and substantially elevated short-term mortality risk[19]. A stratified analysis based on the SEER database

reported a 5-year survival rate of 91% for early-stage cervical cancer, whereas the rate dropped to merely 19% for patients with distant metastatic disease. By contrast, more than 70% of ovarian cancer cases are initially diagnosed at advanced stages, and their 1-year all-cause mortality markedly exceeds that of patients with concurrent cervical cancer, consistent with the 1-year short-term endpoint differences observed in this investigation[20]. At the level of age at onset, baseline data revealed a younger median age among cervical cancer patients. Younger individuals possess stronger organ reserve capacity and better tolerance to anti-tumor therapies accompanied by a lower burden of chronic comorbidities, forming a fundamental basis for improved short-term survival[21]. With regard to molecular mechanisms governing apoptosis, basic research has illustrated that the expression of apoptosis-related cleaved caspase-3 is strongly correlated with cervical cancer stage. Apoptotic signalling pathways remain controllable in early lesions, leading to low postoperative recurrence and metastasis rates after radical resection. Tumors including ovarian and pancreatic cancers exhibit greater invasive and metastatic potential, tending to progress to lethal disease within a short timeframe[22,23].

Multivariable models demonstrated that each one-year increase in age corresponded to a 9.1% rise in 1-year all-cause mortality risk among cervical cancer patients, confirming advanced age as an independent adverse prognostic marker, a conclusion widely validated across Cox regression analyses focusing on gynecological malignancies[24]. A propensity-matched cohort study enrolling locally advanced cervical cancer patients receiving radiotherapy reported an HR of 1.377 for overall mortality among patients aged ≥ 65 years after adjusting for tumor stage and treatment regimens. Elderly patients experience age-related deterioration in physiological reserve of cardiopulmonary, renal and other vital organs, accompanied by elevated incidence of myelosuppression, gastrointestinal and cardiovascular adverse events induced by chemoradiotherapy, higher treatment interruption rates and increased short-term mortality risk[25]. A large multicenter adjuvant chemotherapy-associated study of ovarian cancer similarly verified that advanced age remained an independent predictor of all-cause mortality after adjustment for performance status. Older patients often suffer from multiple concurrent chronic disorders, display poor tolerance to anti-tumor treatment, and face additive mortality risks stemming from both cancer and treatment-related complications[26]. Physiologically, aging is accompanied by impaired innate and adaptive immunity, attenuated anti-tumor cytotoxicity of NK cells and CD8⁺ T lymphocytes, hindered clearance of minimal residual lesions and elevated recurrence likelihood[27]. Meanwhile, metabolic dysregulation of glucose and lipids and disrupted circulatory homeostasis contribute to high prevalence of cardiovascular, cerebrovascular and respiratory comorbidities, imposing a dual mortality burden from both cancer and chronic diseases[28].

Compared with non-Hispanic White counterparts, non-Hispanic Black women with cervical cancer exhibited an HR of 1.635 for all-cause mortality, indicating race as an independent prognostic risk factor. Prior stratified analyses of cancer mortality covering the full NHANES 1988–2019 population noted that non-Hispanic Black individuals experience greater chronic stress and higher levels of social deprivation, alongside inferior access to chronic disease management, cancer screening and standardized treatment relative to White populations. Multiple structural social factors collectively drive elevated all-cause cancer mortality risk[29]. Existing literature suggests that Black women residing in socioeconomically

disadvantaged communities in the United States are more likely to be diagnosed at advanced tumor stages, demonstrate poor postoperative follow-up adherence and low completion rates of definitive chemoradiotherapy, with a 15% lower 5-year cancer-specific survival than demographically comparable White patients, consistent with the short-term 1-year mortality disparities observed herein[30,31]. Mechanistically, structural racial inequities lead to delayed medical consultation, insufficient insurance coverage and limited access to primary care screening resources, ultimately contributing to late diagnosis[32]. Furthermore, significant racial disparities exist in the prevalence of chronic inflammatory conditions, smoking, diabetes and other risk factors[33]. Notably, the racial disparity persisted even after adjustment for diabetes, COPD, smoking and other covariates, implying that incompletely quantified social determinants including healthcare accessibility and social support constitute key confounding factors beyond behavioral and chronic disease profiles[7].

Following comprehensive adjustment for confounders, widowed patients with cervical cancer demonstrated significantly higher all-cause mortality risk than married participants. Previous studies have established that married patients achieve superior overall and cancer-specific survival relative to widowed, divorced and single individuals. Widowed patients lack routine daily care, psychological counselling and companionship during medical visits[34], contributing to increased loss to follow-up, self-initiated treatment discontinuation and elevated all-cause mortality risk[35]. Large-scale stratified analyses of vaginal cancer utilizing SEER data similarly identified significantly higher mortality among widowed women versus married controls. The core mechanism lies in stable social support conferred by marriage, which improves treatment adherence and facilitates continuous integrated management of both malignancies and chronic illnesses[36]. In contrast, persistent negative emotions commonly observed among widowed individuals trigger excessive activation of the hypothalamic–pituitary–adrenal axis, sustained release of pro-inflammatory cytokines, suppressed anti-tumor immunity, accelerated tumor progression and heightened risk of acute cardiovascular events[37]. Stratified findings from bone tumor cohorts further corroborated that widowed patients have lower rates of early tumor detection and curative surgical resection, accompanied by substantially increased risk of adverse short-term outcomes, mirroring the patterns identified among cervical cancer patients in this study[38].

Current smoking emerged as a strong independent risk factor, consistent with domestic and international research investigating the association between tobacco exposure and prognosis of gynecological cancers[39]. Mechanistically, toxic substances in tobacco disrupt the local cervical immune microenvironment, facilitating persistent HPV infection and lesion progression[40]. Tobacco exposure additionally damages airway and vascular endothelium and induces chronic inflammation, which synergistically exacerbates the cardiopulmonary toxicity of chemoradiotherapy and markedly increases the probability of fatal acute respiratory and cardiovascular events[41]. Large-scale burden-of-disease analyses revealed dose-dependent positive correlations between smoking duration, daily tobacco consumption, COPD and mortality among women with cancer; heavy smokers experience a greater than fivefold elevation in respiratory disease-related mortality risk[42]. Cervical cancer-specific epidemiological research confirmed that smoking amplifies anti-tumor treatment toxicities and

increases peri-treatment mortality from pneumonia and heart failure[43], explaining the independent association detected in our models.

Both type 2 diabetes mellitus and COPD represented independent risk factors for short-term mortality among cervical cancer patients. Persistent hyperglycaemic microenvironments in diabetes promote tumour cell proliferation and angiogenesis, while triggering microvascular and macrovascular complications and raising susceptibility to chemotherapy-induced renal injury and infectious complications[44]. Patients with COPD possess limited pulmonary ventilatory reserve, rendering them vulnerable to severe pneumonia and respiratory failure induced by chemoradiotherapy and substantially increasing short-term fatal risk[45]. Multiple retrospective cohorts reported that women with gynecological malignancies complicated by diabetes or COPD exhibit a 20%–60% higher all-cause mortality risk compared with those without chronic comorbidities[46]. From the perspective of comorbidity interaction, smoking, diabetes and COPD frequently co-occur within the same individuals, and the cumulative burden of multiple chronic conditions further amplifies short-term mortality risk, providing an important basis for clinical high-risk stratification[47].

Higher poverty income ratio corresponded to improved short-term survival, a finding consistently replicated across population-based cancer analyses utilizing NHANES datasets[48]. Households with higher income can fully cover expenses associated with screening, surgery, chemoradiotherapy and long-term medications for chronic diseases, avoiding anti-tumor treatment interruption due to financial constraints[49]. In contrast, low-income populations often experience delayed follow-up visits stemming from inadequate insurance coverage and transportation barriers, leading to elevated mortality risk from advanced complications and tumor progression[50].

A pooled analysis integrating multi-cancer TCGA datasets indicated that higher BMI correlates with reduced short-term mortality risk among cervical cancer patients[51]. Low BMI generally reflects tumor-induced wasting and cachexia accompanied by insufficient nutritional reserve, impairing tolerance to full-course chemoradiotherapy[52]. Moderate adipose tissue maintains inflammatory homeostasis and provides energy reserves, lowering the risk of treatment-related death[53]. Meta-analyses have validated that underweight patients with malignant tumors face significantly higher all-cause mortality than overweight counterparts, although this association displays cancer-type specificity[54]; elevated BMI typically constitutes an adverse prognostic factor for hormone-driven breast cancers[55].

The present study identified prior histories of angina pectoris and hyperlipidemia as independent protective factors against short-term mortality among cervical cancer patients. This correlation does not imply biological benefits conferred by cardiovascular disease itself; instead, it arises from screening bias and confounding related to healthcare-seeking behaviours[56]. Individuals diagnosed with angina pectoris or hyperlipidemia require regular long-term cardiology follow-up, during which gynecological examinations and cervical screening are routinely performed, facilitating earlier cervical cancer detection, lower tumor burden and higher curative resection rates[57]. Similar observations have been documented in international cohorts studying cardio-oncology comorbidities: patients receiving long-

term lipid-lowering and anti-ischemic medication follow-up tend to present with earlier-stage tumors. This protective effect was markedly attenuated after adjustment for cancer stage, confirming that screening bias rather than cardiovascular disease directly reduces mortality risk[58]. Patients with hyperlipidemia frequently receive standardized long-term statin therapy; statins exert potential anti-proliferative and anti-inflammatory effects on tumor cells that may modestly improve prognosis[59]. Nevertheless, the survival benefit associated with medication is smaller than disparities driven by earlier diagnosis achieved through regular physical examinations and cannot fully account for the significant protective HR observed in regression models, indicating that routine health screening constitutes the predominant underlying mechanism[59].

Collectively, combining the survival disparities from Kaplan–Meier analyses and stratified multivariable Cox regression outputs, cervical cancer demonstrates preventable and manageable disease characteristics. Sustained promotion of standardized cervical screening can reduce the proportion of late-stage cervical cancer at source and narrow the short-term survival gap relative to other malignancies. For high-risk cervical cancer patients characterized by advanced age, non-Hispanic Black race, widowed status, active smoking, and coexisting diabetes or COPD, clinical services should establish multidisciplinary collaborative follow-up frameworks enabling simultaneous management of both tumors and chronic comorbidities alongside enhanced psychological and social support interventions. Nutritional support and financial medical assistance should be delivered to low-income and low-BMI patients to alleviate the burden of short-term mortality. Additionally, drawing on the survival benefits observed among patients with chronic cardiovascular disease receiving routine physical examinations, gynecological tumor screening could be integrated into standard cardiovascular check-up programmes for adults to increase early diagnosis rates and optimize overall short-term survival outcomes.

Limitations

This study was based on retrospective cross-sectional NHANES data linked to NDI follow-up records, which only allows the assessment of variable associations rather than causal inference. The database lacks key clinical information including FIGO tumor stage and detailed regimens of radiotherapy, chemotherapy and surgical procedures, so residual confounding cannot be fully eliminated. All data regarding health behaviors and chronic disease history relied on self-reporting by participants, which may introduce recall bias. In addition, follow-up was restricted to a 1-year short-term endpoint, prohibiting the evaluation of medium- and long-term survival disparities. The study population mainly consisted of multiethnic community-dwelling women in the United States; accordingly, generalizing these findings to Chinese populations is limited by geographical discrepancies and differences in cervical cancer screening systems. Future single-center or multicenter prospective gynecological cancer cohorts incorporating complete pathological and treatment data are warranted to further validate the prognostic risk and protective factors identified in the present study, and stratified trials may be implemented to verify the efficacy of targeted interventions.

Declarations

Ethics approval and consent to participate

The NHANES protocols were approved by the National Center for Health Statistics (NCHS) Research Ethics Review Board (now the NCHS Ethics Review Board; Protocol Nos. 98-12, 2005-06, 2011-17, and 2018-01), and written informed consent was obtained from all participants. The present study was a secondary analysis of publicly available, de-identified NHANES data and linked mortality files; therefore, no additional institutional ethics approval was required. All methods were performed in accordance with relevant guidelines and regulations and the Declaration of Helsinki and its later amendments.

Consent for publication

Not applicable.

Availability of data and materials

The datasets analysed during the current study are publicly available from the National Health and Nutrition Examination Survey (NHANES) and the NCHS public-use linked mortality files.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

All authors contributed to the conception and design of the study, analysis and interpretation of the data, and drafting or critical revision of the manuscript. All authors read and approved the final manuscript.

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Figures

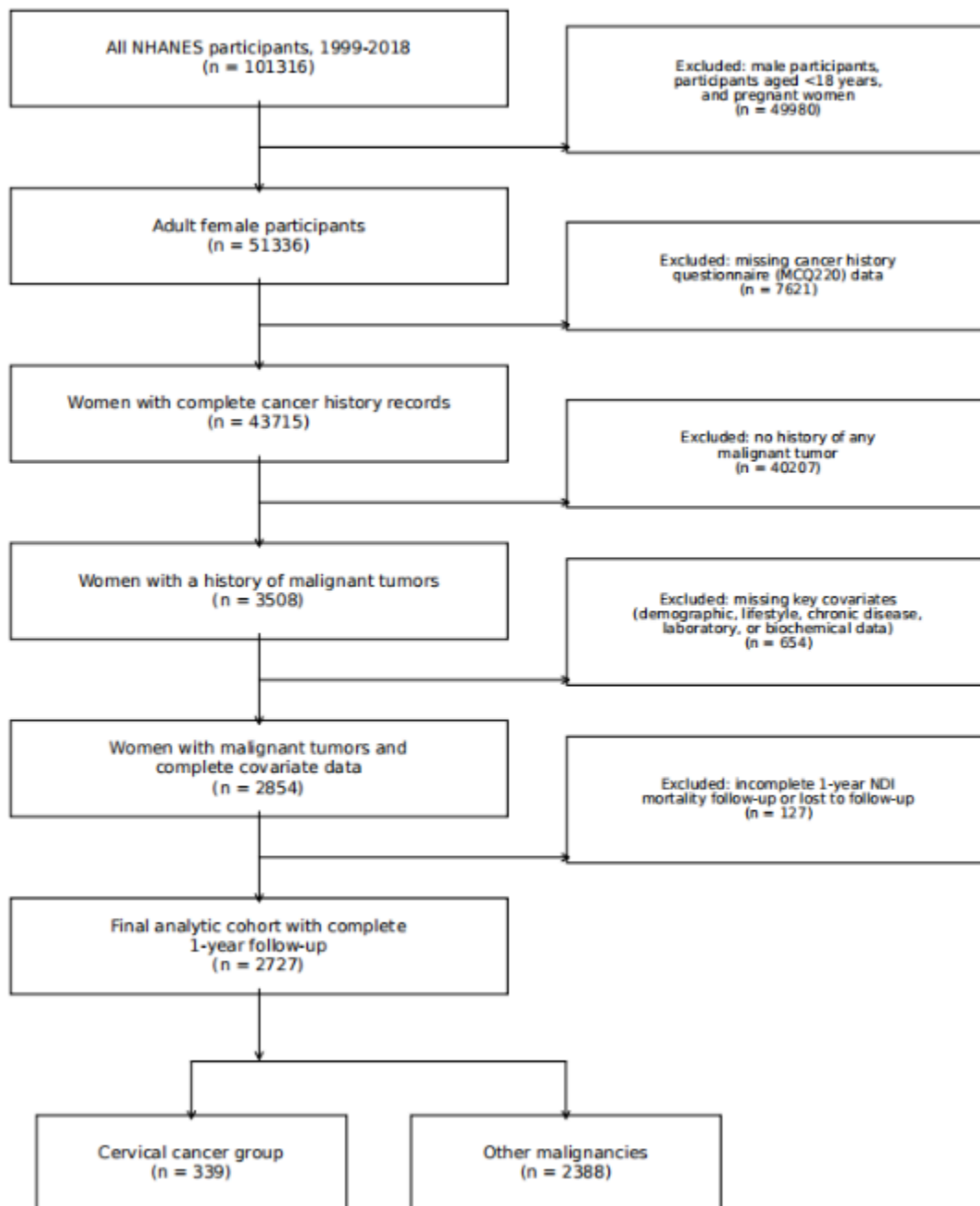


Figure 1

Participant selection flow diagram

Flow diagram showing participant selection from NHANES 1999-2018 and allocation to the cervical cancer and other malignancy groups. NHANES, National Health and Nutrition Examination Survey; NDI, National Death Index.

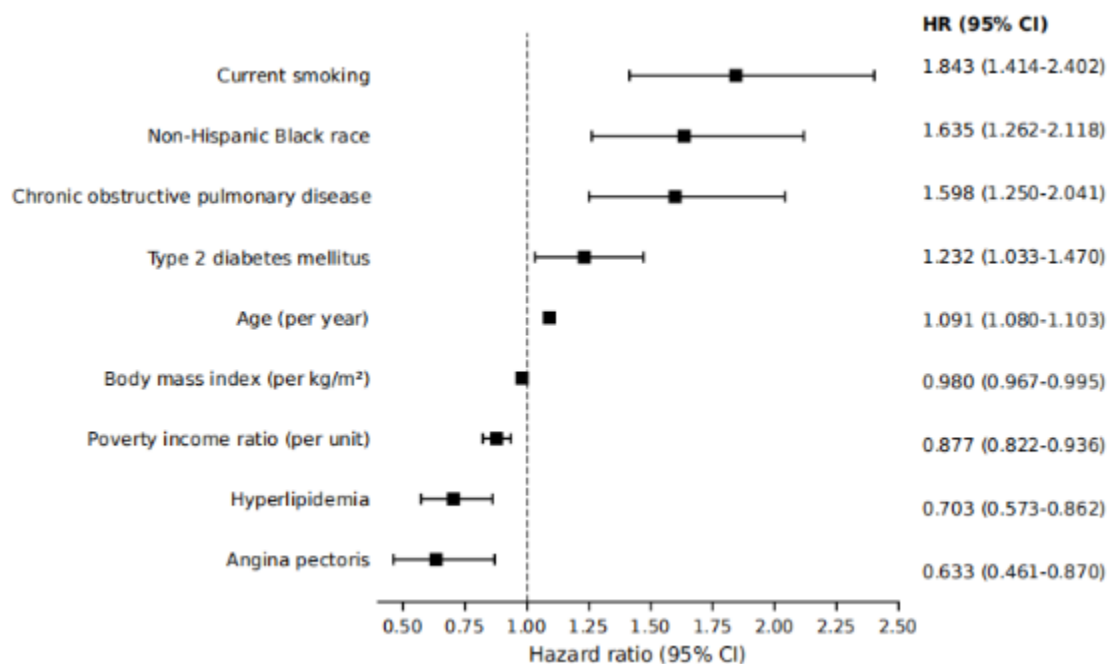


Figure 2

Independent predictors of 1-year all-cause mortality

Forest plot of statistically significant predictors in the fully adjusted weighted Cox model among women with cervical cancer. Squares indicate hazard ratios and horizontal lines indicate 95% confidence intervals. CI, confidence interval; HR, hazard ratio.