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Contribution of insurance status to the association between marital status and cancer-specific survival: a mediation analysis

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ABSTRACT

Objectives To evaluate the extent to which marriage influences cancer-specific survival (CSS) by influencing the insurance status among patients with common solid cancers and the feasibility of reducing the survival gap caused by marriage by increasing private insurance coverage for unmarried patients.

Setting A retrospective cohort study with patients retrieved from the Surveillance, Epidemiology and End Results programme.

Participants Patients with nine common solid cancers diagnosed between 2007 and 2016 were included. Patients were excluded if their marital status, insurance status, socioeconomical status, stage or cause of death was unavailable, if survival time was less than 1 month, or if they were younger than 18 years at the time of diagnosis.

Primary and secondary outcome measures The primary outcome was CSS, which was compared between married and unmarried individuals. Mediation analyses were conducted to determine the contribution of insurance status to the association between marriage and CSS.

Results Married patients had better CSS than those unmarried (time ratio 1.778; 95% CI 1.758 to 1.797). Private health insurance was a key factor mediating the association between marital status and CSS (proportion mediated (PM), 17%; 95% CI 17% to 17.1%). The PM ranges from 10.7% in prostate cancer to 20% in kidney cancer. The contribution of private insurance to the association between marital status and CSS was greater among women than among men (PM 18.5% vs 16.7%). The mediating effect of private insurance was the greatest for the comparison between married and separated individuals (PM 25.6%; 95% CI 25.3% to 25.8%) and smallest for the comparison between married and widowed individuals (PM 11.0%; 95% CI 10.9% to 11.1%).

Conclusions 17% of the marital disparities in CSS are mediated by private insurance coverage. Increasing private insurance coverage for unmarried patients may reduce the survival gap related to marital status and sex. However, it is unclear whether better publicly funded insurance would have the same effect.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Using the population-based Surveillance, Epidemiology and End Results (SEER) database, this study includes a large enough sample size.
⇒ Mediation analysis was used to quantitively determine the contribution of insurance status to the association between marital status and cancer-specific survival.
⇒ The SEER database did not provide patient-level income and education data; therefore, our study used county-level data for these variables.
⇒ Changes in marital status and insurance status after diagnosis of cancers were not recorded in the registry data.
⇒ Granular information related to marriage, such as childbearing history, marriage quality, length of marriage, spouse's age and income, was not available in the SEER database and not included as covariates.

INTRODUCTION

Cancer is the second-leading cause of death and attributed to one in four deaths.[1] The burden of cancer mortality is shared unequally in the population. Previous studies have indicated that unmarried patients with cancer (including those who have never married, are separated, divorced or widowed) are more likely to die from their cancer than married patients.[2–7] The unmarried population accounts for 50% of American people and this percentage is still rising.[8] In recent decades, the US marriage rate has declined from a rate of 9.8 marriages per 1000 people in 1990 to a rate of 6.1 per 1000 people in 2019, which was an historic low.[9 10] A similar decrease in marriage rate has also been witnessed in many other developed countries and rapidly developing low-income and middle-income countries.[11–13] Given the high proportion of the unmarried population and worse cancer-specific survival (CSS) rates of unmarried patients with cancer, the pathway

through which marital status is associated with CSS should be studied, as it may inform strategies to improve CSS for unmarried patients with cancer.

Numerous studies have been published on the association between marital status and the outcome of cancer, focusing on biological and clinical mechanisms, such as the disease grade, stage at diagnosis and treatment.[2 7 14–19] However, the impact of health insurance resources as a contributing factor for marriage-associated survival disparities is less well studied. It has been reported that married individuals generally have better access to private health insurance than unmarried individuals.[20–22] Moreover, uninsured or Medicaid-insured patients with cancer have poorer CSS than patients with private health insurance.[23–26] Therefore, we investigated whether, and to what extent, marital status influences CSS by its influence on health insurance status, which is a modifiable factor.

Mediation analysis is a statistical method to quantitatively determine the importance of causal pathways by which an exposure variable influences an outcome variable.[27] To our knowledge, this is the first study to conduct a mediation analysis to further investigate whether health insurance status mediates the association of marital status with CSS, and to quantify its mediating effects on nine common solid cancers using the Surveillance, Epidemiology and End Results (SEER) database. The mediating effect of insurance status for the association of marriage with CCS was also assessed in subgroups, stratified by sex and marital status.

METHODS

Study cohort

This retrospective, population-based cohort study was conducted between 1 January 2007 and 31 December 2016, using data from the SEER Programme registries, including Atlanta, GA; Connecticut; Detroit, MI; Hawaii; Iowa; New Mexico; San Francisco-Oakland, CA; Seattle-Puget Sound, WA; Utah; Los Angeles, CA; San Jose-Monterey, CA; rural Georgia; the Alaska Native Tumour Registry; greater Georgia; Kentucky; Louisiana; and New Jersey.[28] Patients diagnosed from 2007 to 2016 with one of nine common solid cancers (breast, lung, prostate, colorectal, bladder, kidney, endometrial, pancreatic cancers and melanoma)[1] were included in the study. Patients whose information about marital status (n=263 147), insurance status (n=42 599), socioeconomical status (n=93), stage (n=54 306) or cause of death (n=6437) were unavailable, whose survival time was less than 1 month (n=73 344), or who were younger than 18 years at diagnosis (n=2445) were excluded. A total of 1 695 515 patients were included in our final analytical cohort (online supplemental figure 1).

Study variables

In this study, the patients' demographic characteristics included age, race, sex, insurance status, residence, poverty level and educational level. Data on the marital status and insurance status of patients at the time of diagnosis were obtained from the SEER database.[29] Participants were divided into married and unmarried (including single, separated, divorced, widowed and never married) according to their marital status. Insurance status was recorded as privately insured, uninsured and Medicaid insured in the SEER database. Residence was categorised as metropolitan and non-metropolitan. Race was categorised as white, black and other (American Indian/Alaska Native, Asian/Pacific Islander). Data of poverty level (percentage living at less than 200% of the federal poverty level) and educational level (percentage with less than a high school education) were retrieved from linked county-level data.[30] CSS was defined as the length of time between diagnosis and death caused by the primary cancer through December 31, 2016.

Statistical analysis

R V.3.6.3 software was used to conduct all statistical analyses in this study. For all analyses, the p values were two sided and the threshold of 0.05 was used to determine statistical significance. Kruskal-Wallis rank-sum tests were used to assess differences in the distribution of continuous variables according to marital status, and Pearson's χ^2 tests were used for categorical variables. Differences in survival were assessed via two-sided Kaplan-Meier log-rank tests. Mediation analysis was conducted to quantify the role of insurance status (intermediate factor) in the association between marital status (exposure variable) and CSS (outcome variable). The approach to conducting these mediation analyses was based on the product method approach proposed by Valeri and VanderWeele,[31] using the R package 'regmedint.'[32] This approach includes two regressions. First, using parametric multivariate accelerated failure time (AFT) regression models with a Weibull distribution,[33] we regressed the outcome T on exposure A, mediator M and covariate C:

$$log(T) = \theta_0 + \theta_1 a + \theta_2 m + \theta_3 am + \theta_4' c + \nu\varepsilon \quad (1)$$

where ε is a random variable following an extreme value distribution, ν is a scale parameter and T follows a Weibull distribution.[34] The validation of appropriateness of Weibull distribution is displayed in online supplemental figure 2A–I. In AFT models, the relative risk of a specific group compared with the reference group is estimated using time ratio (TR). TR is defined as the ratio of the expected remaining life of the specific group to the expected remaining life of the reference group. A TR greater than 1 corresponds to longer survival of the specific group.[34]

We then used multivariable logistic regression models to regress the mediator on the exposure variable and covariates:

$$log(T) = \theta_0 + \theta_1 a + \theta_2 m + \theta_3 am + \theta_4' c + \nu\varepsilon \quad (2)$$

Next, we calculated the natural direct effect (NDE) (equation 3), natural indirect effect (NIE) (equation 4) and total effect (TE) (equation 5) of marital status on

CSS. The NIE reflects the effect mediated through insurance status. The proportion mediated (PM) (equation 6), which represents the magnitude of the effect mediated through insurance status, was further calculated. The criteria to evaluate whether insurance status is a 'key mediator' includes significant mediation effect and a PM>10%. The interaction between gender and the mediating effect of private insurance was assessed in subgroup analysis.

$$NDE = \frac{E\left[T_{aM_{a^*}}\right]}{E\left[T_{a^*M_{a^*}}\right]} = \frac{exp(\theta_1 a)\{1+exp(\theta_2+\theta_3 a+\beta_0+\beta_1 a^*+\beta_2 c)\}}{exp(\theta_1 a^*)\{1+exp(\theta_2+\theta_3 a^*+\beta_0+\beta_1 a^*+\beta_2 c)\}} \quad (3)$$

$$NIE = \frac{E\left[T_{aM_a}\right]}{E\left[T_{aM_{a^*}}\right]} = \frac{\{1+exp(\beta_0+\beta_1 a^*+\beta_2 c)\}\{1+exp(\theta_2+\theta_3 a+\beta_0+\beta_1 a+\beta_2 c)\}}{\{1+exp(\beta_0+\beta_1 a+\beta_2 c)\}\{1+exp(\theta_2+\theta_3 a+\beta_0+\beta_1 a^*+\beta_2 c)\}} \quad (4)$$

$$TE = NDE \times NIE \quad (5)$$

$$PM = \frac{NDE \times (NIE-1)}{NDE \times NIE-1} \quad (6)$$

Given the uncertain duration of Medicaid coverage, patients with Medicaid coverage and those who were uninsured were combined into one group in our principal analysis. To further explore the contribution of Medicaid and private insurance to the positive association between marriage and CSS separately, uninsured patients were compared with Medicaid-insured patients and patients with private insurance separately in the sensitivity analysis.

Patient and public involvement

Neither the patients nor the public were involved in the design, conduct, reporting or dissemination plans of our research.

RESULTS

Patient demographic and clinical characteristics

A total of 1 695 515 patients older than 18 years with a diagnosis of one of nine common cancers from 2007 to 2016 were included in the study. Patients' demographic and clinical characteristics are provided in table 1, and additional information for each cancer is further provided in online supplemental table 1. The following demographic factors were associated with being unmarried for patients with each cancer: older age, black race, female, non-private health insurance, living above 200% of the federal poverty level, having a high school educational level and living in a metropolitan area (all, p<0.001). Among included patients, 1 042 748 (61.5%) were married and 652 767 (38.5%) were unmarried. The proportion of married patients was the highest among

Table 1 Patients' demographic characteristics according to marital status

	Married	Unmarried	
Characteristics	**1 042 748 (61.5)**	**652 767 (38.5)**	**P value**
Age at diagnosis*	63.03 (11.74)	64.97 (13.64)	<0.001
Race†			<0.001
White	863 050 (82.8)	499 319 (76.5)	
Black	85 940 (8.2)	110 581 (16.9)	
Other‡	86 405 (8.3)	39 294 (6.0)	
Unknown	7353 (0.7)	3573 (0.5)	
Sex†			<0.001
Female	471 604 (45.2)	409 378 (62.7)	
Male	571 144 (54.8)	243 389 (37.3)	
Insurance†			<0.001
Privately insured	960 618 (92.1)	514 111 (78.8)	
Uninsured/medicaid	82 130 (7.9)	138 656 (21.3)	
Medicaid insured	64 887 (6.2)	115 947 (17.8)	
Uninsured	17 243 (1.7)	22 709 (3.5)	
Poverty*	32.11 (9.55)	33.05 (9.49)	<0.001
Education*	14.76 (6.22)	15.15 (6.11)	<0.001
Residence†			<0.001
Metropolitan	916 747 (87.9)	579 991 (88.9)	
Non-metropolitan	125 130 (12.0)	72 209 (11.1)	
Unknown	871 (0.1)	567 (0.1)	

*Mean (SD).
†N (%).
‡Includes American Indian, Alaska Native and Asian/Pacific Islander.

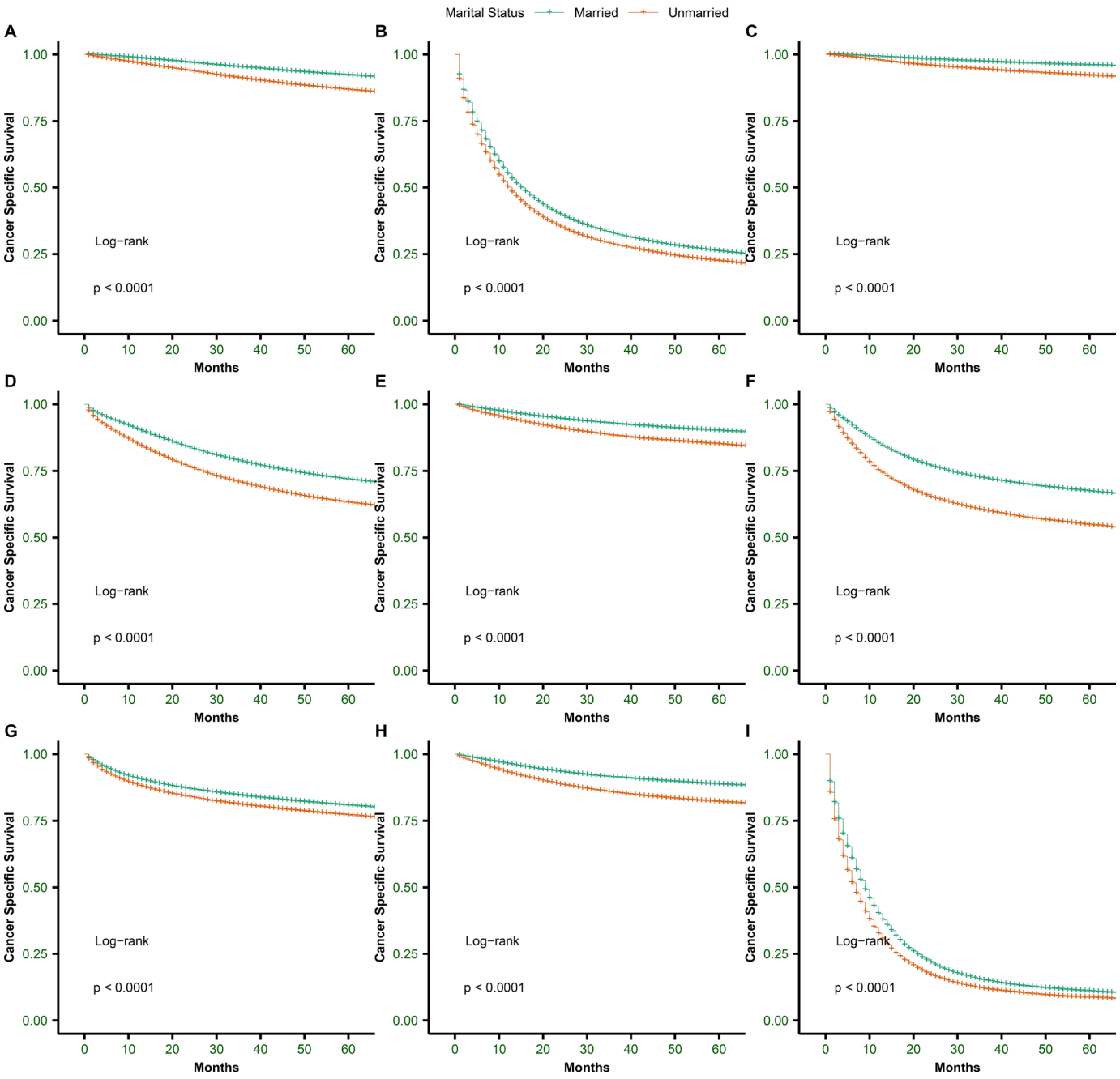

Figure 1 Survival curves of cancer-specific survival at the following sites: (A) breast, (B) lung, (C) prostate, (D) colorectum, (E) melanoma, (F) bladder, (G) kidney, (H) endometrium and (I) pancreas by marital status.

patients with prostate cancer (74.77%) and lowest in those with colorectal cancer (30.31%). In summary data, the coverage rate of private health insurance was 92.1% for married patients while only 78.8% for those unmarried. This discrepancy was largest in patients with kidney cancer (91.0% vs 74.8%) and smallest in those with prostate cancer (95.3% vs 85.2%).

Impact of marital status on CSS

For each cancer analysed, married patients had better 5-year CSS than those unmarried (all, p<0.001; figure 1). After adjustment of patients' demographic characteristics, the AFT model demonstrated that married patients were more likely than unmarried patients to have better survival (TR 1.78; 95% CI 1.76 to 1.80; figure 2A). The TR ranged from 1.21 (95% CI 1.18 to 1.24) in pancreatic cancer to 1.80 (95% CI 1.74 to 1.86) in prostate cancer (all, p<0.001; figure 2A). Married female patients had better survival rates than married male patients for all cancers except bladder cancer (all, p<0.001; online supplemental figure 3A–G). Nevertheless, figure 2C showed that men (TR 2.04; 95% CI 2.00 to 2.07) gained greater improvement in CSS associated with marriage than women (TR 1.51; 95% CI 1.49 to 1.53) across all seven cancer sites. In addition, we stratified the unmarried cohort according to

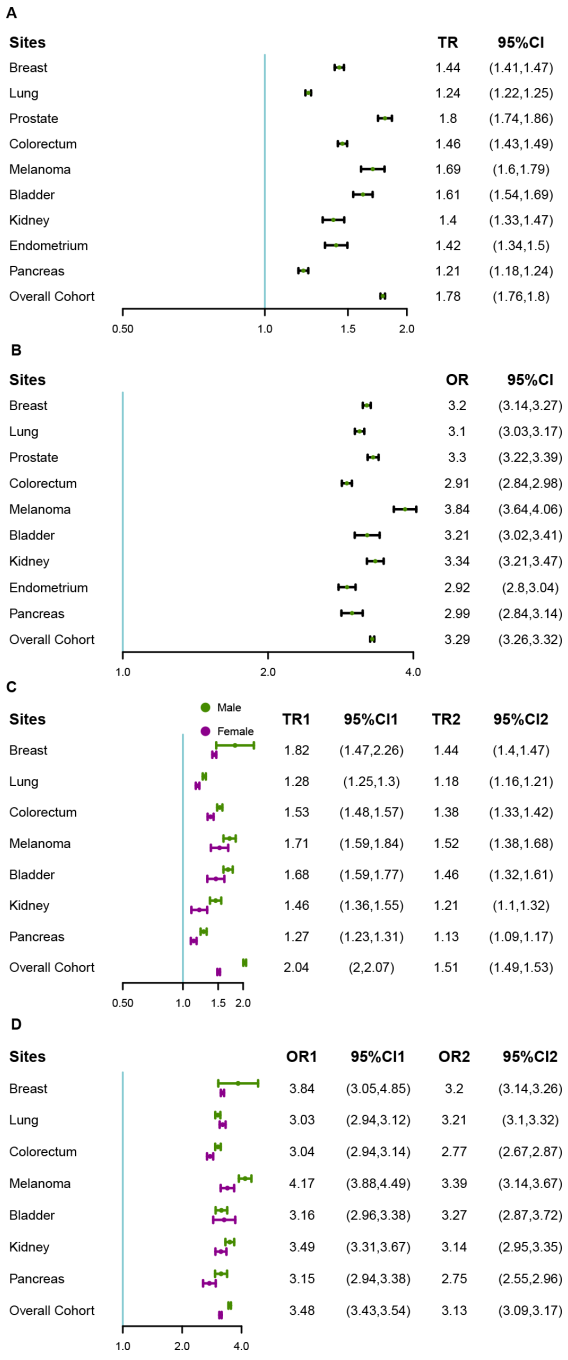

Figure 2 Forest plots depicting the association of marital status with cancer-specific survival and private insurance coverage. (A) Time ratios (TRs) and 95% CIs for cancer-specific survival for married patients as compared with unmarried patients for each of the nine cancer sites and the entire cohort. (B) ORs and 95% CIs for private insurance coverage for married patients as compared with unmarried patients for each of the nine cancer sites and the entire cohort. (C) TRS and 95% CIs for cancer-specific survival for married patients as compared with unmarried patients for seven cancers by sex. (D) ORs and 95% CIs for private insurance coverage for married patients as compared with unmarried patients for seven cancers by sex. TRs were adjusted for patients' demographics (age, race, sex, insurance status, residence, poverty level and educational level). ORs were adjusted for patients' demographics except insurance status.

its components (widowed, separated, divorced and never married) and explored the impact of marital status on CSS for all subgroups. Compared with married patients, all subgroups of unmarried patients had worse survival and were at a higher risk of cancer mortality with similar TRs (online supplemental figure 4 and table 2).

Associations between marital status and mediators

Multivariate logistic models showed that being married was associated with having private health insurance (OR, 3.29; 95% CI 3.26 to 3.32), which remained significant when each cancer was evaluated separately. The OR ranged from 2.91 (95% CI 2.84 to 2.98) in colorectal cancer to 3.84 (95% CI 3.64 to 4.06) in melanoma (all, p<0.001; figure 2B). Sex disparities in the association between marriage and private insurance coverage are shown in figure 2D. Generally, the association between marriage and private insurance coverage was significantly greater among men (OR 3.48; 95% CI 3.43 to 3.54) than among women (OR 3.13; 95% CI 3.09 to 3.17). When the seven cancers were analysed separately, the gender differences in the association between marriage and private insurance coverage were only significant among patients with colorectal cancer and melanoma. Online supplemental table 2 displays the association between marriage and private insurance coverage for specific subgroups of unmarried population. Notably, in all analysed cancers except prostate cancer, the association between marriage and private insurance coverage was the greatest for the separated group among the four subgroups.

Mediation analyses of indirect and direct effects of marriage on CSS

Mediation analysis was applied to quantify the NDE, NIE, TE and PM of marriage on CSS and results were reported in online supplemental table 3. Figure 3 displays the PM for each cancer. Private insurance coverage was a key mediator in the association between marriage and CSS in all analysed cancers. The contribution of private health insurance for the positive association between marriage and CSS was most substantial in kidney cancer (PM 20.0%; 95% CI 19.6% to 20.5%) and least substantial in prostate cancer (PM 10.7%; 95% CI 10.6% to 10.9%). In a summary of analysed cancers, the sex-based subgroup analyses showed that private health insurance made a greater contribution to the association between marriage and CSS for women (PM 18.5%; 95% CI 18.4 %to 18.6%) than for men (PM 16.7%; 95% CI 16.6% to 16.8%), with colorectal cancer being the only exception (figure 3B and online supplemental table 4). The marital status-based subgroup analyses demonstrated that for the summary of analysed cancers, the mediating effect of private health insurance was largest for the survival gap between the married and the separated (PM 25.6%; 95% CI 25.3% to 25.8%) and smallest for that between the married and the widowed (PM 11.0%; 95% CI 10.9% to 11.1%). However, for bladder and pancreatic cancers, the mediating effect was largest for the survival gap between the married and

Table 2 Associations between cancer-specific survival and marriage for specific subgroups of the unmarried population

Population	Brest TR* (95% CI)	Brest P value	Lung TR* (95% CI)	Lung P value	Prostate TR* (95% CI)	Prostate P value	Colorectum TR* (95% CI)	Colorectum P value	Melanoma TR* (95% CI)	Melanoma P value	Bladder TR* (95% CI)	Bladder P value	Kidney TR* (95% CI)	Kidney P value	Uterus TR* (95% CI)	Uterus P value	Pancreas TR* (95% CI)	Pancreas P value	Summary TR* (95% CI)	Summary P value
Married	Reference	/	Reference	/	Reference	/	Reference	/	Reference	/	Reference	/	Reference	/	Reference	/	Reference	/	Reference	/
Widowed	1.51 (1.47 to 1.56)	<0.001	1.21 (1.19 to 1.24)	<0.001	1.55 (1.47 to 1.64)	<0.001	1.35 (1.31 to 1.40)	<0.001	1.71 (1.56 to 1.89)	<0.001	1.41 (1.32 to 1.51)	<0.001	1.31 (1.20 to 1.43)	<0.001	1.34 (1.24 to 1.45)	<0.001	1.20 (1.15 to 1.24)	<0.001	1.66 (1.63 to 1.69)	<0.001
Separated	1.27 (1.17 to 1.39)	<0.001	1.20 (1.13 to 1.27)	<0.001	1.95 (1.71 to 2.22)	<0.001	1.25 (1.14 to 1.38)	<0.001	1.74 (1.31 to 2.31)	<0.001	1.69 (1.35 to 2.11)	<0.001	1.36 (1.09 to 1.69)	<0.001	1.34 (1.06 to 1.69)	<0.001	1.22 (1.09 to 1.35)	<0.001	1.77 (1.69 to 1.86)	<0.001
Divorced	1.19 (1.15 to 1.23)	<0.001	1.18 (1.16 to 1.21)	<0.001	1.73 (1.64 to 1.82)	<0.001	1.37 (1.32 to 1.42)	<0.001	1.59 (1.45 to 1.75)	<0.001	1.63 (1.51 to 1.76)	<0.001	1.37 (1.26 to 1.48)	<0.001	1.268 (1.17 to 1.38)	<0.001	1.17 (1.13 to 1.22)	<0.001	1.77 (1.74 to 1.80)	<0.001
Never Married	1.40 (1.36 to 1.44)	<0.001	1.24 (1.22 to 1.27)	<0.001	1.88 (1.80 to 1.97)	<0.001	1.50 (1.45 to 1.54)	<0.001	1.62 (1.51 to 1.75)	<0.001	1.70 (1.58 to 1.82)	<0.001	1.37 (1.28 to 1.48)	<0.001	1.47 (1.37 to 1.58)	<0.001	1.21 (1.16 to 1.25)	<0.001	1.69 (1.66 to 1.71)	<0.001

*TR, adjusted for age, race, sex, residence, poverty level and educational level.
TR, time ratio.

the never married. Moreover, for prostate cancer, private insurance was not a key mediator for the poor CSS associated with being divorced, separated and widowed. For bladder cancer and melanoma, private insurance was not a key mediator for the association between marriage and CSS in the widowed population (figure 3C and online supplemental table 5).

Sensitivity analyses

In the sensitivity analysis, the impact of marital status on CSS in the comparison between Medicaid-insured patients and uninsured patients was similar to the impact of marital status on CSS in the comparison between privately insured patients and uninsured patients (online supplemental figure 5A). In contrast, the protective association between private insurance and CSS was not observed between being Medicaid-insured and CSS. Notably, among patients with melanoma, being Medicaid-insured was even associated with significantly poorer prognosis (online supplemental figure 5B). Furthermore, being married was positively associated with private insurance coverage and negatively associated with Medicaid coverage (online supplemental figure 5C). With regard to PM according to insurance status, the PM of Medicaid coverage was smaller than that of private insurance, with the exception of patients with melanoma (online supplemental figure 5D).

DISCUSSION

It is well known that marriage has a protective association with cancer outcomes.[2–7] Using SEER data set, this study analysed the association of marital status with CSS among patients diagnosed with one of nine common cancers and, to our knowledge, is the first study to quantify the mediating effect of private health insurance for marriage-associated survival benefits. The marriage-associated survival benefit and the mediation effect of private insurance were further examined among subgroups stratified by sex and marital status. Our results suggest that to narrow the CSS gap induced by marriage and sex, it is important to promote private insurance coverage for the unmarried population, especially females and those who are separated.

Our study found that married patients have both higher private insurance coverage and better CSS than those unmarried across cancer sites, which is consistent with previous studies.[2–7 21 22] Using mediation analysis, we found that 10%–20% of the CSS advantage for married over unmarried could be explained by private insurance coverage. Gomez *et al* conducted stepwise regressions to explore the role of private insurance in marriage-associated all-cause mortality in patients with cancer.[7] After adjustment of insurance status, the HRs did not change significantly. Based on this result, Gomez *et al* made a relatively subjective inference that private insurance did not substantively explain the marriage-associated survival benefit. Compared with Gomez *et al*'s

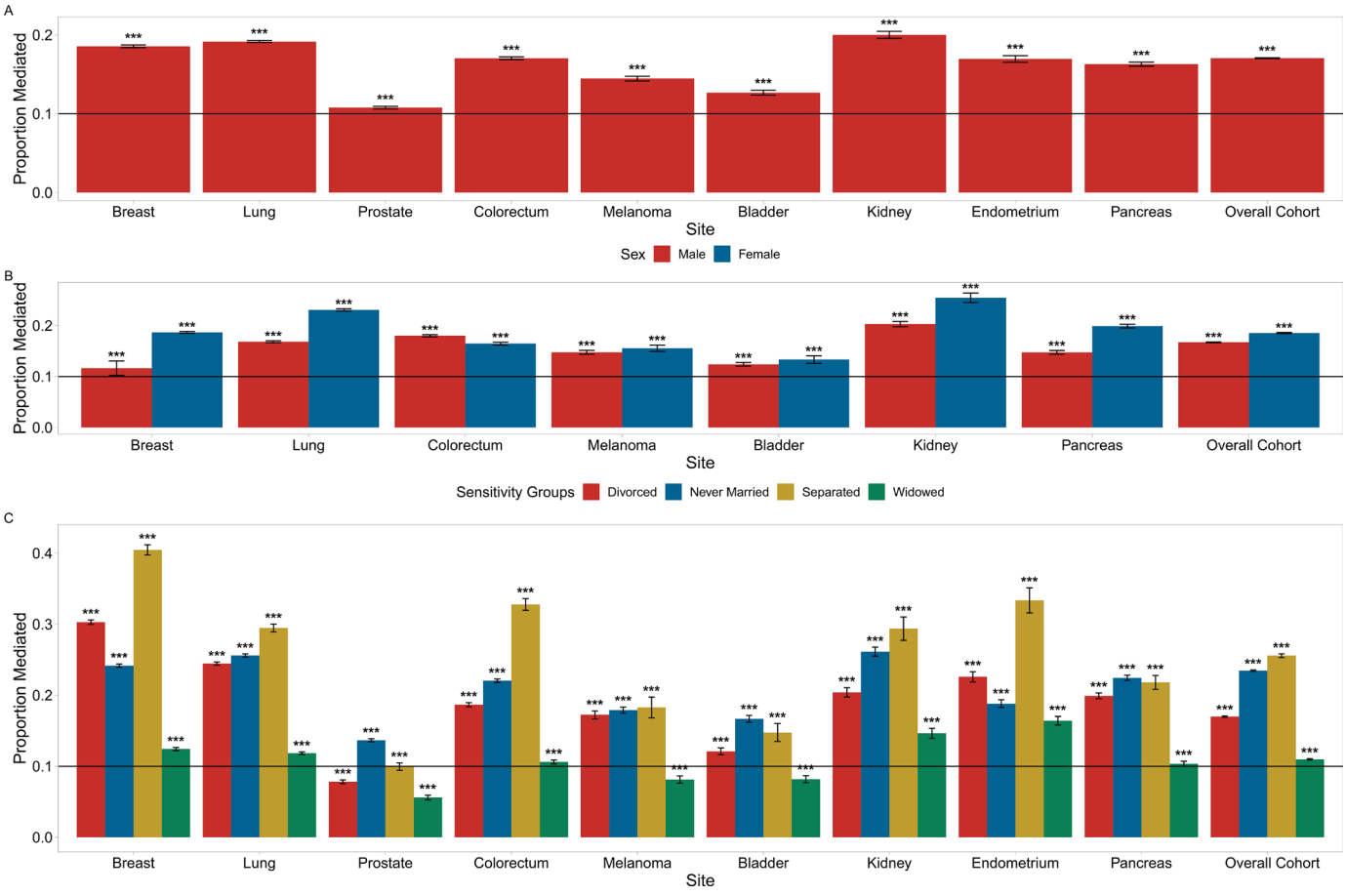

Figure 3 Mediation analyses of direct and indirect effects of marital status on cancer-specific survival mediated by private insurance. (A) Proportion-mediated measures for nine common cancers. (B) Proportion-mediated measures for seven cancers by sex. (C) Proportion-mediated measures for nine common cancers in subgroups of unmarried patients. ***p<0.001.

inference, our results are based on statistical methods that quantitively estimate the mediating effect size of private insurance. In contrast to the results of the previous study, our results suggest that private insurance is a modifiable mediator and that increasing private insurance coverage for unmarried patients could reduce the persistent CSS disparities associated with marital status.

Our results also found that males gained more pronounced marriage-associated survival benefits than females, which supports previous research.[4 7 35–37] Nevertheless, the mediation analysis demonstrated that marriage-associated survival benefits have a stronger link to private insurance among females than among males. The higher PM of private insurance in female patients supports the previous conclusion that men and women benefit differently from marriage,[38–40] with women benefiting more financially and men benefiting more socially.[38 41] For example, females are more likely to lose insurance coverage in the event of marital disruption.[42] This is expected because of patterns of spousal coverage prior to the disruption. The Agency for Healthcare Research and Quality states that employees who enrol for insurance and provide spousal coverage tend to be males. This implies that men are more likely to retain coverage in the event of disruption, which was also confirmed in research by Peters *et al*.[43] The organisation unmarried equality advocates that employer-based health insurance coverage should be maintained when marital status changes.[44] We also believe that this solution could attenuate the CSS gap induced by marital status and gender.

In the sensitivity analysis, the protective association between private insurance and CSS was not observed between having Medicaid and CSS. Notably, among patients with melanoma, having Medicaid was even associated with significantly poorer prognosis. A possible explanation for this phenomenon might be that the socioeconomic status of patients with Medicaid coverage is generally lower owing to the eligibility criteria of Medicaid coverage in the USA. Moreover, the results also indicated that Medicaid insurance was not adequate for resolving the unmet medical needs of those eligible for it. In addition, according to our results, the PM of Medicaid coverage was smaller than the PM of private insurance, with the exception of patients with melanoma. Thus, the results of our study do not provide enough evidence to prove that increase in Medicaid coverage could also improve unmarried patients' CSS and, thus, reduce the CSS gap related to marital status. However, caution should be exercised while interpreting these results, given the fact that the coverage provided by Medicaid

insurance in the USA is currently inadequate. However, it remains to be elucidated whether Medicaid insurance with expanded coverage and higher quality can help to reduce the CSS gap related to marital status.

LIMITATIONS

This study has some limitations associated with our data source, SEER registries. First, the SEER database did not provide patient-level income and education data, therefore, our study used county-level data for these variables. This strategy is reasonable to some extent, given the reduced access to medical care and lower quality of provided care in areas of lower socioeconomic status. However, it should be noted that county-level data does not represent individual socioeconomic status accurately, and variations in socioeconomic variables among different patients within the same county were not considered in this study. Thus, caution should be exercised when extrapolating the differences observed at the county-level differences in this study to individual-level differences, as this might cause an ecological bias. Second, changes in marital status and insurance status since diagnosis were not recorded in the registry data. It is possible that uninsured patients with cancer enrolled for Medicaid shortly after their diagnosis. Since the duration of Medicaid coverage was uncertain, patients with Medicaid coverage and those who were uninsured were combined into one group in our principal analysis. This might have led to underestimation of the contribution of private insurance to the association between marital status and CSS. Third, granular information related to marriage, such as childbearing history, marriage quality, length of marriage, spouse's age and income, was not available in the SEER database. Hence, our study could not include them as covariates, and the potential impact of these variables on the contribution of insurance status could not be explored in our study. Fourth, patients in the SEER database were all from the USA, so the findings of our study may be limited to the USA. Further, health insurance systems must be considered when extrapolating our conclusion to other countries. For example, in countries where insurance status is not employer-based, the contribution of insurance status to the benefit conferred by marriage might be less important, especially for females. In addition, for countries where the coverage of public health insurance provided by the government is more extensive and less dependent on marital status, such as the UK and China, the CSS disparities related to marital status are also less likely to be mediated by insurance status.

CONCLUSIONS

Unmarried patients with one of nine common cancers had worse CSS compared with married patients. Private health insurance distributes unevenly, and unmarried patients were disproportionately uninsured. Using mediation analysis, this study indicates that private insurance is a key mediator for the association between marriage and CSS. In addition, marriage was found to have a greater protective effect for CSS in men, while the mediating effects of private insurance for the association between marital status and CSS was greater for women. These study results indicate that increasing private insurance coverage for unmarried patients may be a useful solution to improve unmarried patients' CSS and thus reduce the CSS gap related to marital status and sex. However, it remains to be elucidated whether better publicly funded insurance programmes would have the same effect in terms of reducing the CSS gap related to marital status.

Contributors LL was the guarantor of this study. LL designed the study and directed its implementation, including quality assurance and control. Author C-FW, W-HZ, JK, WC, J-WC and S-FQ conducted the literature review and drafted the manuscript. QL performed data analysis. K-BY, Y-ZZ and Z-HC performed data analysis and drafted the manuscript. YS and JM helped revise the manuscript.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants but the data used in this study were obtained from the SEER database, which is anonymised and publicly available. Thus, there was no need to seek institutional ethics committee's approval and consent from the participants for this study.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement The data supporting the findings of this study are publicly available in the Surveillance Epidemiology and End Results (SEER) database at http://seer.cancer.gov/. Data directly related to the results of this study are available from the corresponding authors on reasonable request. The code for data cleaning and analysis is available from the corresponding authors on reasonable request.

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