Original Article

Survival Among Patients With Glioma in the US Military Health System: A Comparison With Patients in the Surveillance, Epidemiology, and End Results Program

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BACKGROUND: Glioma is the most common malignant brain cancer. Accessibility to health care is an important factor affecting cancer outcomes in the US general population. The US Military Health System (MHS) provides universal health care to its beneficiaries. It is unknown whether this universal health care has translated into improved survival outcomes among MHS beneficiaries with glioma. This study compared the overall survival of patients with glioma in the MHS with the overall survival of patients with glioma in the general population. **METHODS:** The MHS cases were identified from the Department of Defense's Automated Central Tumor Registry (ACTUR). Glioma cases from the general population were identified from the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) program. SEER cases were matched 2:1 to ACTUR cases by age, sex, race, histology, and diagnosis year. All cases had histologically confirmed glioma diagnosed between January 1, 1987, and December 31, 2013. A Kaplan-Meier analysis was conducted to compare survival between the ACTUR and SEER cases. Multivariable Cox proportional hazards models were used to estimate hazard ratios (HRs) and 95% confidence intervals (CIs). **RESULTS:** The study included 2231 glioma cases from ACTUR and 4462 cases from SEER. ACTUR cases exhibited significantly better overall survival than SEER cases (HR, 0.74; 95% CI, 0.67-0.83). The survival advantage of the ACTUR patients was observed in most subgroups stratified by age, sex, race, diagnosis year, and histology. For glioblastoma, the survival advantage was observed in both the pre- and post-temozolomide periods. **CONCLUSIONS:** Universal MHS health care may have translated into improved survival outcomes in glioma. Future studies are warranted to identify factors contributing to the improved survival. ***Cancer* 2020;126:3053-3060**. © *2020 American Cancer Society*.

KEYWORDS: glioma, Military Health System, survival, universal health care.

INTRODUCTION

Gliomas are the most common type of malignant brain cancer in the United States, constituting approximately 81% of primary malignant brain tumors.[1] Gliomas comprise a broad group of brain tumors of glial origin. Glioblastoma is the most common primary brain cancer in adults and has a poor prognosis with a median survival time of only 14 months.[1]

In the US general population, access to health care, as reflected by health insurance, has an impact on survival among patients with cancer.[2-5] A lack of or limited access to health care can affect the utilization of health care services, receipt of treatments, and quality of care delivered, and this can lead to reduced survival, as shown in the US general population.[2,6-9] In studies of brain cancer, studies have shown that patients without health insurance or with Medicaid have shorter survival than patients with other insurance coverage.[10-12]

Although the mortality from malignant brain tumors is not a major component of cancer mortality in the US general population, brain cancer ranks as the third most common cause of cancer death in the US active-duty military, following colon cancer and leukemia.[13] The Military Health System (MHS) provides universal health care to 9.5 million beneficiaries, including active-duty service members, National Guard and Reserve members, retirees, and their family members.[14] The beneficiaries receive medical care free of charge or with minimal out-of-pocket cost.[14] However,

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it is unknown whether this universal health care access has translated into improved outcomes among patients with glioma in the MHS. In this study, we compared the overall survival of glioma cases in the MHS with the overall survival of glioma cases in the general population. In addition, the standard of care changed for glioblastoma in 2005 when radiation therapy plus temozolomide chemotherapy replaced radiation therapy alone.[15] The change has been correlated with improved survival in the general population and other populations with glioblastoma.[16-18] For this reason, we also compared the overall survival of patients with glioblastoma between the MHS and the general population for the time period before 2005 as well as 2005 and after.

MATERIALS AND METHODS

Data Sources

The data source for MHS beneficiaries was the Automated Central Tumor Registry (ACTUR) of the Department of Defense (DOD), and the data for the general population were from the Surveillance, Epidemiology, and End Results (SEER) program of the National Cancer Institute. ACTUR records and tracks patients with cancer who are diagnosed and/or receive cancer treatment at military treatment facilities. ACTUR complies with the uniform data standards set by the North American Association of Central Cancer Registries.[19] Data are collected on demographics, tumor characteristics, cancer treatment, follow-up, vital status, and other variables. The use of de-identified ACTUR data was approved by the institutional review board of the Walter Reed National Military Medical Center.

The SEER program is a US cancer registry program that collects population-based data from the areas covered by the SEER cancer registries. In this study, we used data from the SEER-18 registries (Atlanta, Connecticut, Detroit, Hawaii, Iowa, New Mexico, San Francisco–Oakland, Seattle–Puget Sound, Utah, Los Angeles, San Jose–Monterey, Rural Georgia, the Alaska Native, Greater California, Greater Georgia, Kentucky, Louisiana, and New Jersey), which represent 28% of the US general population.[20] Data are collected on demographics, tumor characteristics, first cancer treatment, follow-up, vital status, and other variables. The SEER data are de-identified for public use.

Study Populations

Adult cases (18 years old or older) diagnosed with histologically confirmed primary glioma between January 1, 1987, and December 31, 2013, were identified from the ACTUR and SEER databases. *Glioma* was defined with the cancer site codes (C71.0-C71.9) and morphology codes (9440, 9441, 9442, 9381, 9401, 9421, 9400, 9410, 9411, 9420, 9424, 9382, 9450, 9451, 9460, 9391, 9392, 9393, 9380, 9423, and 9430) of the *International Classification of Diseases for Oncology, Third Edition* (*ICD-O-3*).[21] Cases with the diagnosis from a death certificate only or autopsy were excluded. Cases with multiple primary tumors were excluded to minimize effects of other cancers on the study outcomes. To reduce potential confounding effects of demographic variables and histology on survival, the ACTUR and SEER patients were matched on age (within 5 years), sex (male or female), race (white, black, Asian/Pacific Islander, or other), histology (glioblastoma, nonglioblastoma astrocytoma, oligodendroglia tumor, ependymoma, or other gliomas),[22,23] and diagnosis year (1987-1989, 1990-1994, 1995-1999, 2000-2004, 2005-2009, or 2010-2013) with a matching ratio of 1:2. Cases with missing values for matching variables were excluded.

Study Variables

Variables extracted from both ACTUR and SEER included demographics, cancer diagnosis, tumor features, surgery, follow-up, and vital status. Because brain tumors do not typically spread outside the brain, there are no standard staging systems for adult brain tumors.[24] According to tumor clinical features and behaviors, brain tumors were graded as well differentiated (grade 1), moderately differentiated (grade 2), poorly differentiated (grade 3), or undifferentiated (grade 4) with the *ICD-O-3* standard.[25] Histology was categorized as glioblastoma, nonglioblastoma astrocytoma, oligodendroglia tumor, ependymoma, or other gliomas.[22] Tumor location was defined as follows: supratentorial (*ICD-O-3* 71.0-71.4), infratentorial (*ICD-O-3* C71.6 or 71.7), or other (*ICD-O-3* 71.5, 71.8, or 71.9) if the site was unspecified or had overlapping regions.[26] Site-specific surgery codes were used to define surgery types and were then grouped into the categories of "cancer-directed surgery received," "no cancer-directed surgery," and "unknown or missing" according to SEER guidelines.[27] Receipt of radiation therapy was categorized as "yes," "no," or "unknown or missing." All-cause mortality was used as the study outcome because data on cause of death were not complete in ACTUR.

Statistical Analysis

Using the chi-square test, we first compared the distributions of demographic and tumor characteristics among ACTUR and SEER patients. Kaplan-Meier curves with

a log-rank test were used to compare overall survival between ACTUR and SEER cases. A multivariable Cox proportional hazards model for matched data was then used to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for overall survival among ACTUR cases in comparison with SEER cases. We checked the proportional hazards assumption by plotting the log-log survival curves.[28] The follow-up time was calculated from diagnosis to death during a 5-year period. If death was not observed during the period, the follow-up time was censored at the end of the fifth year. Patients who were not dead through the end of the study without a full 5-year follow-up time were censored on the study ending date (ie, December 31, 2013). To control for potential confounding from nonmatching variables, multivariable Cox regression models were used to adjust for tumor grade (grade 1, grade 2, grade 3, grade 4, or unknown), tumor location (supratentorial, infratentorial, or other), ethnicity (Hispanic, non-Hispanic, or unknown), cancer-directed surgery (yes, no, or unknown), and age as a continuous variable. The analysis was further stratified by age, sex, race, diagnosis year, tumor histology, surgery, or radiation. Considering potential *P* value inflation due to the testing of multiple hypotheses in this analysis, we implemented the false discovery rate correction for multiple comparisons and reported false discovery rate–corrected *P* values.[29]

Finally, multivariable Cox regression models were used to compare the survival of ACTUR cases and SEER cases with glioblastoma in the temozolomide era (ie, 2005-2013) and the pretemozolomide era (1987-2003). Data from the year 2004 were not used in this analysis because 2004 was a transition year between the 2 eras.[18]

All statistical analyses were conducted with SAS software (version 9.4.0; SAS Institute, Inc). All reported *P* values were 2-sided with a significance level of $P < .05$.

RESULTS

A total of 2231 cases were identified from ACTUR, and 4462 cases were identified from SEER. The demographic and tumor characteristics of the cases are shown in Table 1. The ACTUR and SEER cases had the same distributions of the matching variables (age group, sex, race, year of diagnosis, and histology group). ACTUR cases were more likely to have well-differentiated tumors (5.92% vs 3.45%) and poorly differentiated tumors (8.56% vs 7.31%) than the SEER cases but were less likely to have moderately differentiated tumors (10.31% vs 11.27%; $P < .001$; Table 1). ACTUR cases had a higher percentage of supratentorial tumors (74.59% vs 70.89%) and lower percentages of infratentorial tumors (6.54% vs 7.53%) and tumors of other locations (18.87% vs 21.58%; $P = .006$). With respect to surgical treatment, the ACTUR cases were less likely than the SEER cases to receive cancer-directed surgery (72.84% vs 77.21%) but were more likely to have missing information on surgery (3.72% vs 0.96%; $P < .001$).

TABLE 1. Characteristics of Glioma Cases Diagnosed Between 1987 and 2013 From the ACTUR and SEER Registries

	ACTUR (n = 2231)		SEER (n = 4462)		
Characteristic	No.	%	No.	%	*P*
Age group					1.00
18-39 y	940	42.13	1880	42.13	
40-54 y	492	22.05	984	22.05	
55-64 y	424	19.00	848	19.00	
≥65 y	375	16.81	750	16.81	
Sex					1.00
Male	1554	69.65	3108	69.65	
Female	677	30.35	1354	30.35	
Race					1.00
White	2025	90.77	4050	90.77	
Black	140	6.28	280	6.28	
Asian or Pacific Islander	54	2.42	108	2.42	
Other	12	0.54	24	0.54	
Year of diagnosis					1.00
1987-1989	240	10.76	480	10.76	
1990-1994	530	23.76	1060	23.76	
1995-1999	402	18.02	804	18.02	
2000-2004	378	16.94	756	16.94	
2005-2009	377	16.90	754	16.90	
2010-2013	304	13.63	608	13.63	
Histology group					1.00
Glioblastoma	965	43.25	1930	43.25	
Nonglioblastoma astrocytomas	782	35.05	1564	35.05	
Oligodendroglial tumors	317	14.21	634	14.21	
Ependymoma	47	2.11	94	2.11	
Other gliomas	120	5.38	240	5.38	
Tumor grade					<.001
Well differentiated, grade1	132	5.92	154	3.45	
Moderately differentiated, grade 2	230	10.31	503	11.27	
Poorly differentiated, grade 3	191	8.56	326	7.31	
Undifferentiated, grade 4	779	34.92	1564	35.05	
Unknown	899	40.30	1915	42.92	
Tumor location					.006
Supratentorial	1664	74.59	3163	70.89	
Infratentorial	146	6.54	336	7.53	
Other locations	421	18.87	963	21.58	
Cancer-directed surgery					<.001
No	523	23.44	974	21.83	
Yes	1625	72.84	3445	77.21	
Unknown or missing	83	3.72	43	0.96	
Radiation					<.001
No	659	29.54	1336	29.94	
Yes	1464	65.62	3012	67.50	
Unknown or missing	108	4.84	114	2.55	

Abbreviations: ACTUR, Automated Central Tumor Registry; SEER, Surveillance, Epidemiology, and End Results.

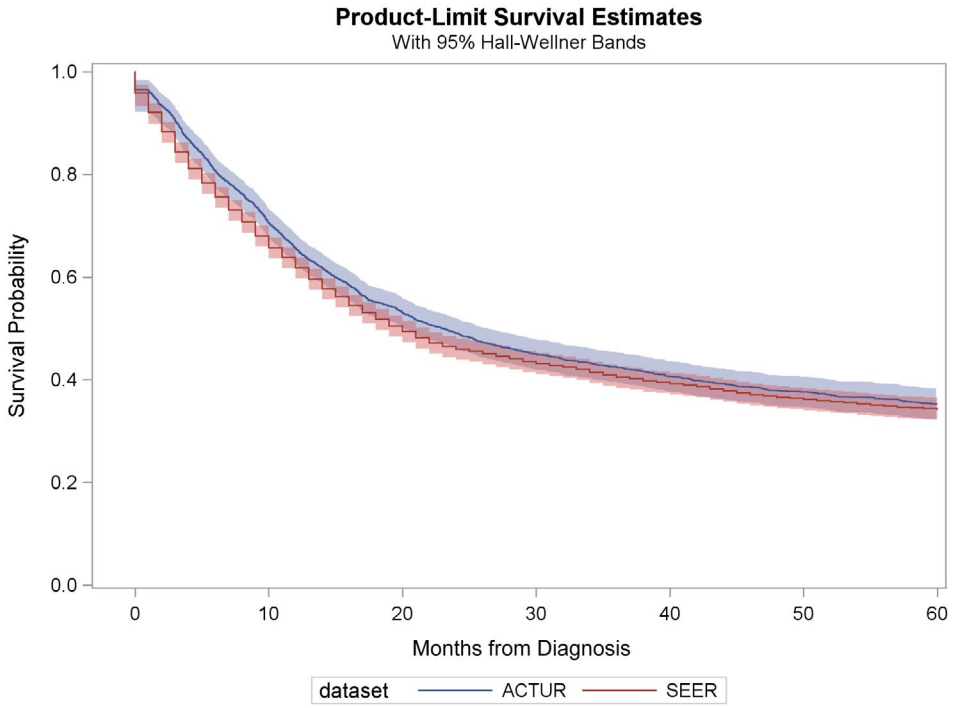

FIGURE 1. Kaplan-Meier survival curves for ACTUR and SEER patients with glioma diagnosed between 1987 and 2013. ACTUR indicates Automated Central Tumor Registry; SEER, Surveillance, Epidemiology, and End Results.

The median survival times were 20 months (95% CI, 19-21 months) and 23 months (95% CI, 21-25 months) for the SEER and ACTUR patients, respectively. The Kaplan-Meier survival curves showed slightly better overall survival for ACTUR than SEER, but the difference was not statistically significant (log-rank $P = .08$; Fig. 1). In multivariable Cox regression models, ACTUR cases exhibited significantly better overall survival than SEER cases (HR, 0.74; 95% CI, 0.67-0.83; Table 2). When the model was stratified by demographics, diagnosis year group, and histology (Table 2), a significant survival advantage for the ACTUR cases was present among subgroups of cases aged 18 to 39 (HR, 0.77; 95% CI, 0.63-0.95), 40 to 54 (HR, 0.69; 95% CI, 0.56-0.85), and 55 to 69 years (HR, 0.73; 95% CI, 0.60-0.88); men (HR, 0.73; 95% CI, 0.64-0.83) and women (HR, 0.75; 95% CI, 0.62-0.91); whites (HR, 0.82; 95% CI, 0.75-0.90) and blacks (HR, 0.49; 95% CI, 0.33-0.73); and those diagnosed during 1990-1994 (HR, 0.63; 95% CI, 0.44-0.91), 2000-2004 (HR, 0.71; 95% CI, 0.58-0.87), and 2005-2009 (HR, 0.63; 95% CI, 0.50-0.80). When cases were stratified by the age of 65 years as the cutoff point (the Medicare-eligible age), the HRs for those 65 years old or older and those younger than 65 years were 0.83 (95% CI, 0.66-1.04) and 0.71 (95% CI, 0.63-0.80), respectively (data not shown). In an analysis stratified by tumor histology, survival was significantly better for patients with glioblastomas (HR, 0.77; 95% CI, 0.67-0.89) and nonglioblastoma astrocytomas (HR, 0.69; 95% CI, 0.56-0.85). Significantly better survival for ACTUR cases than SEER cases was observed, regardless of surgery receipt, with HRs of 0.75 (95% CI, 0.66-0.86) and 0.57 (95% CI, 0.39-0.83) for patients with and without surgery, respectively. When cases were stratified by radiation, better survival was observed only among patients who did not receive radiation (HR, 0.74; 95% CI, 0.65-0.85).

Table 3 shows comparisons of patients with glioblastoma for the pretemozolomide and temozolomide eras. Better survival was observed for ACTUR glioblastoma cases than SEER cases during both periods (HR for 1987-2003 [the pretemozolomide era], 0.79; 95% CI, 0.64-0.96; HR for 2005-2013 [the temozolomide era], 0.82; 95% CI, 0.66-1.01), although the HR for the temozolomide era was only borderline significant (Table 3).

DISCUSSION

In this study, we found that glioma cases in the MHS had better overall survival than those in the general population. Our results suggest that MHS's universal health care may improve glioma survival outcomes.

TABLE 2. Overall and Stratified HRs of All-Cause Mortality Comparing ACTUR With SEER Among Glioma Cases Diagnosed Between 1987 and 2013

Variable	No.		Adjusted HR (95% CI)[a]	P[b]
	All Cases	Deaths		
Overall				
SEER	4462	2775	1.00 (reference)	
ACTUR	2231	1365	0.74 (0.67-0.83)	<.001
By age groups				
18-39 y				
SEER	1880	649	1.00 (reference)	
ACTUR	940	299	0.77 (0.63-0.95)	.022
40-54 y				
SEER	984	671	1.00 (reference)	
ACTUR	492	338	0.69 (0.56-0.85)	.001
55-69 y				
SEER	1116	993	1.00 (reference)	
ACTUR	558	499	0.73 (0.60-0.88)	.002
≥70 y				
SEER	482	462	1.00 (reference)	
ACTUR	241	229	0.80 (0.60-1.05)	.168
By sex				
Male				
SEER	3108	1953	1.00 (reference)	
ACTUR	1554	956	0.73 (0.64-0.83)	<.001
Female				
SEER	1354	822	1.00 (reference)	
ACTUR	677	409	0.75 (0.62-0.91)	.007
By race				
White				
SEER	4050	2515	1.00 (reference)	
ACTUR	2025	1245	0.82 (0.75-0.90)	<.001
Black				
SEER	280	175	1.00 (reference)	
ACTUR	140	78	0.49 (0.33-0.73)	.001
Asian or Pacific Islander				
SEER	108	75	1.00 (reference)	
ACTUR	54	36	0.51 (0.22-1.16)	.168
By year of diagnosis				
1987-1989				
SEER	480	324	1.00 (reference)	
ACTUR	240	150	0.60 (0.30-1.19)	.195
1990-1994				
SEER	1060	719	1.00 (reference)	
ACTUR	530	361	0.63 (0.44-0.91)	.022
1995-1999				
SEER	804	525	1.00 (reference)	
ACTUR	402	270	0.93 (0.75-1.17)	.655
2000-2004				
SEER	756	504	1.00 (reference)	
ACTUR	378	230	0.71 (0.58-0.87)	.003
2005-2009				
SEER	754	457	1.00 (reference)	
ACTUR	377	207	0.63 (0.50-0.80)	<.001
2010-2013				
SEER	608	246	1.00 (reference)	
ACTUR	304	147	0.85 (0.63-1.15)	.361
By histology				
Glioblastoma				
SEER	1930	1734	1.00 (reference)	
ACTUR	965	888	0.77 (0.67-0.89)	.001
Nonglioblastoma astrocytomas				
SEER	1564	758	1.00 (reference)	
ACTUR	782	344	0.69 (0.56-0.85)	.001
Oligodendroglial tumors				
SEER	634	166	1.00 (reference)	
ACTUR	317	72	0.79 (0.53-1.18)	.320
Ependymoma				
SEER	94	19	1.00 (reference)	
ACTUR	47	11	0.95 (0.19-4.76)	.951
Other gliomas				
SEER	240	98	1.00 (reference)	
ACTUR	120	50	1.04 (0.60-1.79)	.929
By surgery				
Yes				
SEER	3445	2006	1.00 (reference)	
ACTUR	1625	921	0.75 (0.66-0.86)	<.001
No				
SEER	974	736	1.00 (reference)	
ACTUR	523	377	0.57 (0.39-0.83)	.007
Unknown				
SEER	43	33	1.00 (reference)	
ACTUR	83	67	1.31 (0.39-4.42)	.712
By radiation				
Yes				
SEER	3012	2081	1.00 (reference)	
ACTUR	1464	980	0.92 (0.65-1.30)	.712
No				
SEER	1336	617	1.00 (reference)	
ACTUR	659	311	0.74 (0.65-0.85)	<.001
Unknown				
SEER	114	77	1.00 (reference)	
ACTUR	108	74	0.73 (0.48-1.11)	.195

Abbreviations: ACTUR, Automated Central Tumor Registry; CI, confidence interval; HR, hazard ratio; SEER, Surveillance, Epidemiology, and End Results.
[a]All HRs were estimated from a multivariable Cox proportional hazards model for matched data. In the overall analysis, HRs were further adjusted for age (as a continuous variable), Hispanic origin, tumor grade, tumor location, surgery, and radiation. In the stratified analysis, all variables adjusted in the overall analysis were adjusted except for the stratified variable itself.
[b]All P values were corrected for multiple comparisons.

TABLE 3. HRs of All-Cause Mortality Comparing ACTUR With SEER Among Glioblastoma Cases Stratified by Diagnosis Year Period

Variable	No.		Adjusted HR (95% CI)[a]	P
	All Cases	Deaths		
Years 1987-2003				
SEER	1227	1172	1.00 (reference)	
ACTUR	617	588	0.79 (0.64-0.96)	.019
Years 2005-2013				
SEER	634	497	1.00 (reference)	
ACTUR	317	273	0.82 (0.66-1.01)	.065

Abbreviations: ACTUR, Automated Central Tumor Registry; CI, confidence interval; HR, hazard ratio; SEER, Surveillance, Epidemiology, and End Results.
[a]Adjusted for age (as a continuous variable), sex, race, Hispanic origin, year of diagnosis, tumor grade, tumor location, surgery, and radiation.

We previously reported better overall survival for patients with non–small cell lung cancer in the MHS than those in the SEER population.[30] In a study of invasive breast cancer, Ru et al[31] found that MHS beneficiaries treated at a US military medical center had higher breast cancer–specific survival than SEER patients. The

improved survival of MHS beneficiaries with different cancers may support the benefit of universal health care for patients with cancer. In this study of glioma, we observed a nearly 25% reduced all-cause mortality rate for the MHS cases compared with the SEER cases. This adds additional evidence suggesting that the improved survival may not be cancer site specific.

In the MHS, beneficiaries receive medical care free of charge or with minimal out-of-pocket cost, and thus financial barriers to care are minimized. Studies of the US general population regarding the influence of health care access (or health insurance status) on the survival of patients with cancer have found that patients without health insurance or those with Medicaid have worse survival than patients with insurance, especially those with private insurance.[2-4,8,32,33] Among studies of brain cancer, a SEER-based study of 13,665 adult patients with glioblastoma reported that uninsured patients and patients with Medicaid had significantly worse glioblastoma-specific survival than patients with other insurance plans.[10] A recent study based on the National Cancer Database reported better overall survival for patients with private insurance and other insurance than uninsured patients with glioblastoma.[11]

To the best of our knowledge, our study is the first study comparing the survival of patients with glioma in the MHS and the US general population. As one of the largest health care providers in the United States, the MHS provides health care for 9.5 million beneficiaries.[14] Regarding cancer care, the recent report of TRICARE (DOD's health insurance program) to congress showed better utilization of screening services for several cancers among beneficiaries in comparison with national benchmarks.[14] Early detection of low-grade glioma is essential for improving survival because low-grade glioma progresses rapidly into non–de novo high-grade glioma and death.[34]

In a stratified analysis, the better survival for the MHS cases was observed in a majority of subgroups by demographics and tumor histology. In particular, better survival was significant for patients with glioblastoma and nonglioblastoma astrocytoma, the 2 most common types of glioma. The improved survival for patients with glioblastoma, an aggressive tumor with a poor prognosis, suggests that the survival advantage of the MHS cases was still evident for aggressive tumors. The better survival was not observed in other histological types, likely because of either small numbers or low death rates for these rare types of glioma. In an analysis stratified by race, although the CIs of HRs overlapped, it is noteworthy that the lowest reduced mortality was observed for blacks (ie, a nearly 50% reduction in morality). This suggests that blacks, who have less access to care than whites in the general population,[35,36] may benefit more than whites from the universal health care provided by the MHS. It is also noteworthy that in the analysis stratified by surgery, the survival advantage of ACTUR over SEER was present, regardless of whether patients received surgery or not. This suggests that the receipt of surgery might not modify the survival differences between the 2 populations. It is unknown why the survival advantage did not show among those who received radiation therapy. However, the role of radiation treatment in the survival difference should be better evaluated in the context of treatment combinations and modalities. The lack of association in this stratum may also be related to confounding factors that are not included in the study.

The mechanisms for the improved survival in the MHS may be related to multiple factors along the continuum of cancer care. In studies of the general population, the worse survival of uninsured patients and Medicaid patients with glioma was correlated with a lower likelihood of receiving the recommended treatment modality,[10-12,37-39] higher odds of delayed treatment,[38] and a lack of primary care physicians.[12] To our knowledge, there have been no studies of glioma that compare treatment receipt, health care delivery, quality of care, or other factors between the MHS and the general population. Further research on differences in these factors between the 2 populations is warranted to reveal possible mechanisms. As noted previously, the better survival of ACTUR over SEER was observed among cases with surgery and those without surgery, and the better survival was present after adjustments for surgery in the models; this indicates that surgery alone may not play an appreciable role in the survival difference observed. However, given the complexity of treatment modalities for gliomas, a heterogonous group of diseases, the potential role of treatment adherence in the survival difference cannot be fully evaluated without an in-depth analysis of specific surgery types and other therapies.

We observed a similar survival advantage of ACTUR cases over SEER cases among patients with glioblastoma during the temozolomide era and the pretemozolomide period. The similar results suggest that the differences in overall survival between the 2 populations remained despite the change in standard care from radiation therapy alone to radiation therapy plus temozolomide.

Our study has the strength of having large numbers of cases of glioma, a relatively rare cancer, from the DOD

and SEER cancer registries. We also applied a matching procedure in the study design to rigorously control for confounding effects of prognostic factors on survival. However, because of the limitation of cancer registry data, confounding effects from other factors not available in the cancer registry data cannot be excluded. In addition, because all-cause mortality rather than cancer-specific death was used as the outcome, the potential effects from causes other than glioma on the survival difference cannot be excluded. Finally, there is a concern about potential overlap between cases from the MHS and SEER. However, if there is overlap, the overlap would only dilute the survival difference between the 2 populations, and the true HRs would be lower than those observed in this study. Thus, our current estimates of HRs are rather conservative.

In conclusion, we found better survival for patients with glioma in the MHS versus the US general population. Universal care in the MHS may have translated into improved survival outcomes for patients with glioma. Future studies are warranted to identify health care and delivery factors that may contribute to the improved survival outcomes in the MHS.

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CONFLICT OF INTEREST DISCLOSURES

The authors made no disclosures.

AUTHOR CONTRIBUTIONS

Jie Lin: Conception and design, methodology and investigation, data analysis and interpretation, study supervision, and writing and review. **Julie A. Bytnar:** Data analysis and interpretation and writing and review. **Brett J. Theeler:** Data analysis and interpretation and writing and review. **Katherine A. McGlynn:** Data analysis and interpretation and writing and review. **Craig D. Shriver:** Conception and design, data analysis and interpretation, study supervision, and writing and review. **Kangmin Zhu:** Conception and design, methodology and investigation, data analysis and interpretation, study supervision, and writing and review.

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