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Inequalities in Meningioma Survival: Results from the National Cancer Database

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Abstract

Background: Meningiomas are the second most common primary tumor of the central nervous system, with an incidence of approximately 30,000 new cases per year. However, there is a paucity of literature examining how healthcare, demographic, and socioeconomic factors impact patient survival outcomes.

Methods: We conducted a retrospective study of patients from the National Cancer Database (NCDB) diagnosed with meningioma between 2004 and 2012. Univariate and multivariate analysis was performed to investigate the impact of patient, tumor, and treatment factors on overall survival: age, comorbidities, tumor behavior and size, and treatment strategy.

Results: Diagnosis and treatment at an academic/research program, private insurance, female sex, Hispanic ethnicity, Asian race, higher median household income, and high school diploma conferred a survival advantage on both univariate and multivariate analyses of the 162,222 patients in the NCDB. Black race was associated with decreased survival on multivariate analysis.

Conclusions: Disparities in survival outcomes in patients with meningiomas exist across multiple healthcare, demographic, and socioeconomic factors. Additional research is needed to elucidate the genetic and environmental factors driving these inequalities.

Keywords: Meningioma; Survival; Prognosis; Demographic; Socioeconomic

Introduction

Meningiomas account for 37% of all primary central nervous system (CNS) tumors, with an incidence of approximately 30,000 new cases per year [1]. There is a paucity of literature examining how demographic and socioeconomic factors impact survival outcomes of meningioma patients. There have been several reports of outcome differences depending on the type, geographical location, and housing area (urban, rural, or metropolitan) of the treatment facility for other cancer types and cancer in general [2-5]. McCarthy et al. [6] reported that patients with benign meningiomas seen at community hospitals versus academic hospitals had higher survival [6]. Additionally, McKee et al. reported that patients with Medicare and Medicaid had a higher mortality than those with private insurance [7]. No other literature to the authors' knowledge has previously examined these health care factors with regard to survival outcomes.

Previous studies have examined the effects of non-modifiable demographic patient factors such as sex, ethnicity, and race on meningioma survival. Notably, many of these studies only address specific subsets of the meningioma patient population, e.g., patients with only spinal [8] or only intracranial [7,9,10] meningiomas. There is little consensus among studies as to whether or not meningioma survival is affected by ethnicity and/or race, although McCarthy et al. [6], and others have reported that female sex is associated with increased survival [8-13].

Furthermore, the literature is extremely sparse in terms of reports on the effects of modifiable socioeconomic patient factors such as income and education. Previous work has shown that low socioeconomic status and lack of a college degree are associated with poor patient follow-up after meningioma resection [14]. Other studies have shown that a variety of disparities exist for patients of low socioeconomic status when being treated for brain tumors but did not specifically address meningiomas [15].

McCarthy et al. [6], previously reported that age, tumor size, and treatment strategy were all predictors of meningioma patient survival [6]. In another study specific to intracranial meningiomas, McKee et al., found that a higher CDCC score and advanced age, among other factors, were associated with poorer survival [7]. Sun et al. reported that more higher-grade tumors are associated with increased mortality [16].

Given the lack of literature addressing the subject, the present study aimed to determine the effects of facility type, facility location, facility housing area, insurance status, ethnicity, race, sex, income, and education on meningioma patient survival. A retrospective study was conducted on 162,222 meningioma patients diagnosed between 2004 and 2012 using data available in the National Cancer Database (NCDB).

Methods

Data source

Data was obtained from the National Cancer Database (NCDB) for patients with meningiomas (2004-2012). The NCDB was established in 1989 and includes data from more than 1,500 commission-accredited cancer programs, which in aggregate manage approximately 70% of newly-diagnosed cancer cases in the United States [17]. Patient demographics, characteristics of the facility, cancer characteristics, patient treatment parameters and outcomes are all reported in the NCDB. The International Classification of Diseases for Oncology definitions for topography (primary site) and morphology (histology) are used by the NCDB for cancer identification purposes. The authors note that the NCDB is a joint project of the Commission on Cancer of the American College of Surgeons and the American Cancer Society. The NCDB and the hospitals reporting data to the NCDB are the source of the data used in the paper, but they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions drawn in this study. This study was determined to be exempt by the Institutional Review Board of our institution.

Study population

The NCDB was queried for location codes corresponding to meningiomas (C72.4) as well as histology codes corresponding to meningiomas (9530). Behavior codes benign (0), borderline malignant (1), and malignant (3) were included.

Variables analyzed

Patient variables investigated were facility type, facility region, facility housing area, insurance status, sex, ethnicity, race, income, and education. Facility type was classified as follows: community cancer program (100-500 newly-diagnosed cancer cases per year), comprehensive community cancer program (>500 cases per year), academic cancer program (>500 cases per year and at least four postgraduate medical education programs), or integrated network cancer program (owns, operates, leases, or is part of a joint venture with multiple facilities providing integrated cancer care and offers comprehensive services). Each treating facility was classified by its geographic location in accordance with US Census Bureau Regions: northeast, south, midwest, or west [18]. Housing areas of the treatment facility were defined based on the size of the county in which it resided: metropolitan (>250,000 residents), urban (2,500-250,000 residents), or rural (<2,500 residents). Insurance status was classified into none, Medicare, Medicaid, other government insurance, other, or unknown. Ethnicity was reported as Hispanic, non-Hispanic, or other/unknown. Race was reported as white, black, Asian, or other/unknown. Income was determined according to the median household income in the zip code in which each patient reported residence. Finally, education level was determined from the 2012 American Community Survey based on the percentage of adults in the patient's zip code who did not have a high school diploma [19]. Findings were considered statistically-significant if $p<0.05$. For hazard ratios (HR), 95% confidence intervals (CI) are reported.

Statistical analysis

Overall survival was the primary outcome of interest. Univariate analysis was performed using Kaplan-Meier survival curves and hazard ratios. Multivariate analysis was performed with the Cox proportional hazards model. The multivariate model included all of the above demographic variables described above, in addition to the following: age (as continuous variable), total Charlson-Deyo comorbidity classification (CDCC; 0, 1, 2, 3 or more), behavior code (benign, borderline malignant, or malignant), tumor size (both as continuous and ordinal, viz. microscopic, <1 cm, 1-2, 2-3, 3-4, 4-5, 5-6, or >6), and treatment strategy (no treatment, surgery, radiation, surgery with adjuvant radiation, surgery with neoadjuvant radiation, surgery with neoadjuvant and adjuvant radiation. Statistical analyses were performed with Microsoft Open R version 3.3.2 (Microsoft Corp., Redmond, WA). Correction for multiple comparisons in the multivariate model was done using the Bonferroni correction.

Results

A total of 162,222 patients (64.9 ± 15.7 years old) met inclusion criteria. A complete breakdown of the population demographics is available in **Table 1.**

Table 1 National Cancer Database (NCDB) population characteristics for meningioma patients.

Category	Variable	Number (%)
Facility Type	Community Cancer Program	10,635 (6.6)
	Comprehensive Community Care Program	60,299 (37.2)

	Integrated Network Care Program	20,127 (12.4)
	Academic/Research Program	61,165 (37.7)
Facility Geography	Northeast	32,015 (19.7)
	South	48,060 (29.6)
	Midwest	46,713 (28.8)
	West	25,438 (15.7)
Facility Housing Area	Metro	13,5234 (83.4)
	Urban	19,546 (12.0)
	Rural	2,494 (1.5)
Insurance	Private	60,796 (37.5)
	None	6,103 (3.8)
	Medicaid	9,410 (5.8)
	Medicare	80,866 (49.8)
	Other Government	1,719 (1.1)
	Unknown	3,328 (2.1)
Sex	Female	120,477 (74.3)
	Male	41,745 (25.7)
Ethnicity	Non-Hispanic	143,329 (88.4)
	Hispanic	9,714 (6.0)
	Unknown	9,179 (5.7)
Race	White	132,725 (81.8)
	Black	20,028 (12.3)
	Other/Unknown	4,486 (2.8)
	Asian	4,983 (3.1)
Median Household Income (within zip code)	<$38,000	27,752 (17.1)
	$38,000-$47,999	36,718 (22.6)
	$48.000-$62,999	43,555 (26.8)
	>$63,000	52,609 (32.4)
Percentage with High School Diploma (within zip code)	>21%	27,761 (17.1)
	13-20.9%	41,058 (25.3)
	7-12.9%	51,591 (31.8)
	<7%	40,298 (24.8)
Tumor Behaviour	Benign	158,954 (98.0)
	Borderline Malignant	867 (0.5)
	Malignant	2,401 (1.5)
Tumor Size	Microscopic Focus	58 (0.0)
	<1 cm	14,837 (9.1)
	1-2 cm	44,691 (27.5)
	2-3 cm	29,560 (18.2)

	3-4 cm	17,799 (11.0)
	4-5 cm	11,271 (6.9)
	5-6 cm	6,922 (4.3)
	>6 cm	7,767 (4.8)
Location	Brain	116,481 (71.8)
	Spine	5,554 (3.4)
	Unspecified	34,589 (24.3)
Charlson-Deyo Comorbidity Classification	0	118,848 (73.3)
	1	28,446 (17.5)
	2	9,798 (6.0)
	3+	5,130 (3.2)

Healthcare factors

Patients diagnosed and managed at academic/research programs had a statistically significant increased risk of death in univariate analysis as compared to patients treated at community cancer programs (HR 1.91, CI [1.84-1.99], p<0.001), comprehensive community care programs (HR 1.57, CI [1.54-1.61], p<0.001), and integrated network care programs (HR 1.34, CI [1.30-1.39], p<0.001).

Survival differences were found with respect to facility geography. Compared to patients managed at facilities in the northeast, patients managed in the south had a decreased hazard of death (HR 0.95, CI [0.93-0.98], p<0.001). Patients managed in the Midwest (HR 1.00, CI [0.98-1.03], p=0.8) or west (HR 0.97, CI [0.94-1.00], p=0.1) had no difference in hazard of death compared to those from facilities in the northeast.

Interestingly, no such differences existed in terms of housing area of the facility. Patients managed at facilities in urban housing areas (HR 0.98, CI [0.95-1.00], p=0.3) and rural housing areas (HR 1.08, CI [1.00-1.16], p=0.06) had no statistically-significant difference in hazard of death compared to patients treated at facilities in metropolitan housing areas.

Patients with no insurance (HR 1.38, CI [1.28-1.49], p<0.001), Medicaid (HR 1.81, CI [1.72-1.92], p<0.001), Medicare (HR 4.46, CI [4.33-4.58], p<0.001), other government insurance (HR 1.90, CI [1.69-2.13], p<0.001), and unknown insurance status (HR 2.19, CI [2.03-2.36], p<0.001) all had an increased hazard of death compared to patients with private insurance.

Kaplan-Meier curves (**Figure 1**) and hazard ratio plots (**Table 2**) are shown for meningioma patients managed at each facility type, geography, housing area, and insurance status.

Table 2 Univariate analysis.

Category	Variable	Hazard Ratio	95% Confidence Interval	p-value
Facility Type	Academic/Research Program	Reference		
	Community Cancer Program	1.91	1.84-1.99	<0.001
	Comprehensive Community Care Program	1.57	1.54-1.61	<0.001
	Integrated Network Care Program	1.34	1.30-1.39	<0.001
Facility Geography	Northeast	Reference		
	South	0.98	0.95-0.98	<0.001
	Midwest	1	0.98-1.03	0.8
	West	0.97	0.94-1.00	0.1
Housing Area	Metro	Reference		
	Urban	0.98	0.95-1.01	0.3
	Rural	1.08	1.00-1.16	0.06
Insurance Status	Private	Reference		
	None	1.38	1.28-1.49	<0.001

	Medicaid	1.81	1.72-1.92	<0.001
	Medicare	4.46	4.33-4.58	<0.001
	Government	1.9	1.69-2.13	<0.001
	Unknown	2.19	2.03-2.36	<0.001
Sex	Female	Reference		
	Male	1.41	1.39-1.45	<0.001
Ethnicity	Non-Hispanic	Reference		
	Hispanic	0.66	0.63-.069	<0.001
	Unknown	0.97	0.93-1.01	0.092
Race	White	Reference		
	Black	0.97	0.94-1.00	0.068
	Other/Unknown	0.58	0.54-0.63	<0.001
	Asian	0.72	0.67-0.77	<0.001
Income	<$38,000	Reference		
	$38,000-$47,999	0.95	0.92-0.98	<0.001
	$48.000-$62,999	0.88	0.86-0.91	<0.001
	$63,000+	0.79	0.77-0.82	<0.001
Education	>21%	Reference		
	13-20.9%	1.02	0.99-1.05	<0.001
	7-12.9%	0.97	0.95-1.00	0.08
	<7%	0.86	0.84-0.89	<0.001

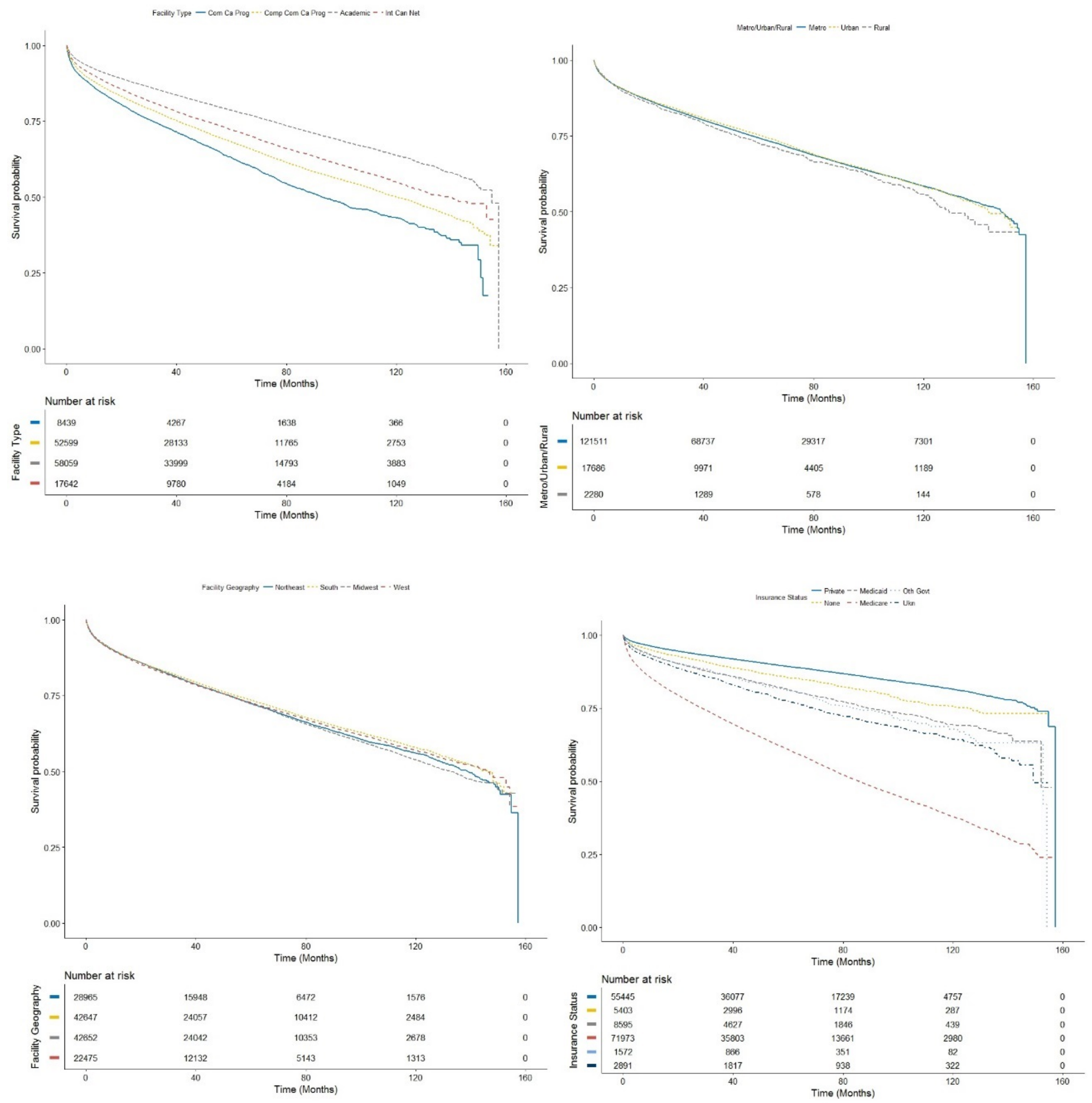

Figure 1 (A) Kaplan Meier survival curves across facility type, (B) Facility geography, (C) Housing area, (D) insurance status.

Demographic factors

Males had an increased hazard of death (HR 1.41, CI [1.39-1.45], p<0.001) compared to females. Patient ethnicity was also associated with survival differences. Compared to non-Hispanic patients, Hispanic patients had a decreased hazard of death (HR 0.66, CI [0.63-0.69], p<0.001).

Similarly, Asian patients (HR 0.72, CI [0.67-0.77], p<0.001) and patients of “other/unknown” race (HR 0.58, CI [0.54-0.63], p<0.001) had a decreased hazard of death compared to white patients. Black patients (HR 0.97; CI [0.94-1.00]; p=0.068), in contrast, had no statistically significant difference in hazard of death compared to white patients on univariate analysis (**Figure 2; Table 2**).

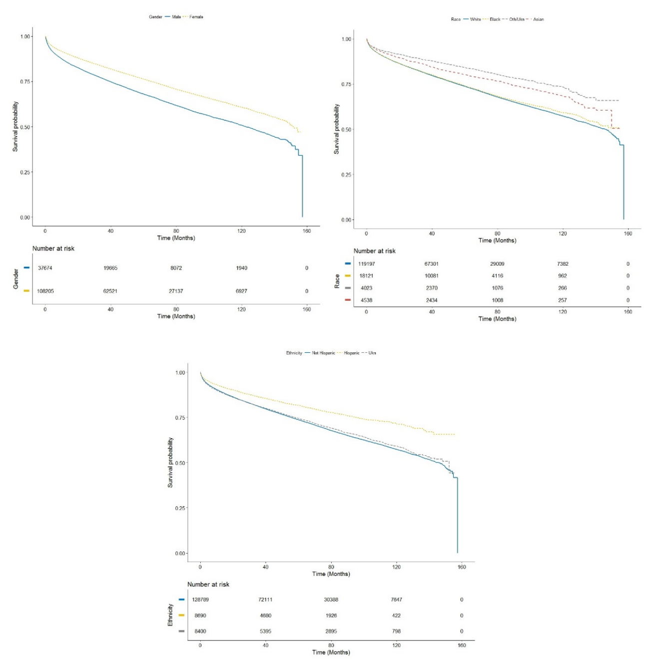

Figure 2 (A) Kaplan Meier survival curves across gender, (B) Race (C) Ethnicity.

Socioeconomic factors

Patients living in a zip code with a median household income of $38,000 to $47,999 (HR 0.95, CI [0.92-0.98], p<0.001), $48,000 to $62,999 (HR 0.88, CI [0.86-0.91], p<0.001), and above $63,000 (HR 0.79. CI [0.77-0.82], p<0.001) had a decreased hazard of death compared to patients living in a zip code with a median income of less than $38,000.

Education differences based on zip code led to analogous differences in survival. Compared to patients coming from a zip code where greater than 21% of the population did not have a high school diploma, patients from a zip code where less than 7% of the population did not have a high school diploma had a decreased hazard of death (HR 0.86, CI [0.84-0.89], p<0.001). Patients from a zip code where 13% to 20.9% (HR 1.02, CI [0.99-1.05], p=0.2), and patients from a zip code in which 7% to 12.9% (HR 0.97, CI [0.95-1.00]. p=0.08) did not have a high school diploma had no statistically-significant difference in hazard of death compared to those from a zip code in which 21% of the population did not have a high school diploma (**Figure 3; Table 2**).

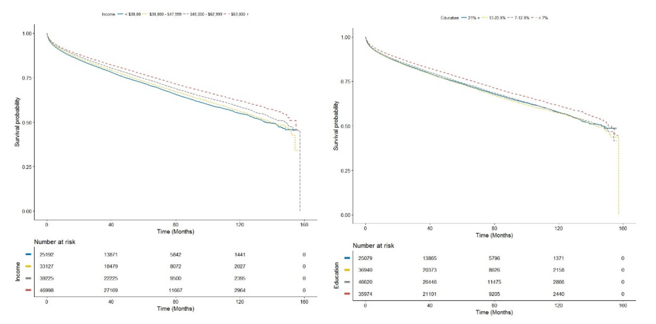

Figure 3 (A) Kaplan Meier survival curves across income, (B) Education.

Multivariate analysis

Multivariate analysis demonstrated findings concordant to the univariate analysis: there was a statistically-significant survival advantage for female patients, patients managed at academic medical centers or in facilities in the south, patients with private insurance, Hispanic patients, patients with race designated as Asian or "Other/unknown", patients residing in areas with higher median household income or a higher percentage of high school graduates (**Table 3**). After correcting for multiple comparisons, however, facility location was no longer significant, i.e., patients managed in facilities in the south did not have a survival advantage. As expected, age, co-morbidities, tumor behavior, and treatment parameters were significant predictors of survival after correction for multiple comparisons. We did not find tumor size to be a predictor of survival.

Table 3 Multivariate analysis. *p<0.05** Significant after correction for multiple comparisons.

Category	Variable	Hazard Ratio	95% Confidence Interval	p-value
Facility Type	**Academic/Research Program**		**Reference**	
	Community Cancer Program	1.12	1.08-1.17	$<10^{-7**}$
	Comprehensive Community Care Program	1.12	1.10-1.15	$<10^{-15**}$
	Integrated Network Care Program	1.09	1.05-1.13	<10-6
Facility Geography	**Northeast**		**Reference**	
	South	0.97	0.94-1.00	0.049^{*}
	Midwest	0.98	0.96-1.01	0.3
	West	1.02	0.99-1.06	0.2
Housing Area	**Metro**		**Reference**	

	Urban	1.02	0.99-1.06	0.2
	Rural	1.03	0.95-1.11	0.5
Insurance Status	**Private**	**Reference**		
	None	1.39	1.28-1.51	$<10^{-15**}$
	Medicaid	1.75	1.65-1.86	$<10^{-15**}$
	Medicare	1.3	1.25-1.34	$<10^{-15**}$
	Government	1.3	1.15-1.46	$<10^{-4**}$
	Unknown	1.2	1.10-1.30	$<10^{-4**}$
Sex	**Female**	**Reference**		
	Male	1.43	1.40-1.47	$<10^{-15**}$
Ethnicity	**Non-Hispanic**	**Reference**		
	Hispanic	0.8	0.75-0.84	$<10^{-15**}$
	Unknown	1.04	1.00-1.09	0.05
Race	**White**	**Reference**		
	Black	1.1	1.07-1.14	$<10^{-8**}$
	Other/Unknown	0.78	0.72-0.85	$<10^{-8**}$
	Asian	0.83	0.77-0.90	$<10^{-6**}$
Income	**<$38,000**	**Reference**		
	$38,000-$47,999	0.94	0.91-0.97	$<10^{-3**}$
	$48.000-$62,999	0.91	0.88-0.94	$<10^{-6**}$
	$63,000+	0.89	0.85-0.93	$<10^{-7**}$
Education	**>21%**	**Reference**		
	13-20.9%	1.01	0.98-1.04	0.6
	7-12.9%	0.97	0.93-1.00	0.08
	<7%	0.88	0.84-0.92	$<10^{-8**}$
Behavior	**Benign**	**Reference**		
	Borderline Malignant	1.11	0.97-1.28	0.11
	Malignant	2.38	2.22-2.54	$<10^{-15**}$
Tumor Size	Continuous	1	1.00-1.00	0.43
Age	Continuous	1.08	1.08-1.08	$<10^{-15**}$
Treatment	**Surgery**	**Reference**		
	Surgery with adjuvant radiation	1.31	1.20-1.42	$<10^{-9**}$
	Radiation	1.39	1.33-1.46	$<10^{-15**}$
	None	1.81	1.76-1.87	$<10^{-15**}$
	Other	1.97	1.82-2.12	$<10^{-15**}$
	Surgery with neoadjuvant and adjuvant radiation	8.58	1.21-60.95	0.03^{*}
	Surgery with neoadjuvant radiation	1.65	1.06-2.55	0.03^{*}
CDCC	**0**	**Reference**		
	1	1.38	1.34-1.41	$<10^{-15**}$

	2	1.66	1.60-1.71	<10^{-15**}
	3+	2.12	2.03-2.22	<10^{-15**}

Interestingly, although black race was not a significant predictor of survival on univariate analysis, it was significant in the multivariate model after correction for multiple comparisons (HR 1.10, CI [1.07-1.14] vs. white).

Discussion

This is a retrospective study on the impact of demographic factors on survival in patients with meningiomas based on 162,222 patients diagnosed between 2004 and 2012 using data available in the NCDB. Patients diagnosed and managed at academic/research programs, patients with private insurance, Hispanic patients, female patients, patients of Asian or "other/unknown" race, patients from zip codes with higher median household income, and patients from zip codes with a greater proportion of residents with a high school diploma had a decreased hazard of death on univariate and multivariate analysis. There was no difference in survival in terms of the housing area of the treatment facility. Although on univariate analysis patients managed at a facility in the south had a survival advantage, this factor was not significant in the multivariate model. Finally, black patients had an increased hazard of death relative to white patients only in the multivariate model. Although demographic factors have been reported to affect a variety of outcomes for patients afflicted by cancer, minimal literature exists detailing the effects of these factors on survival in meningioma patients.

Healthcare factors

McCarthy et al. [6], found a survival advantage for patients with meningiomas treated at academic medical centers in a cohort of approximately 9,000 patients from the NCDB (diagnosed 1985-1988 or 1990-1992) [1-6]. The present study corroborates this finding in larger cohort of patients by identifying a survival advantage for those managed at academic/research programs.

Insurance status has been associated with differences in patient outcomes. In an analysis of 14,239 patients with intracranial meningiomas, McKee et al. reported that Medicare and Medicaid insurance were associated with higher 30-day readmissions and mortality. We report similar findings, with decreased survival in patients with federal insurance compared to those with private insurance [7].

No literature to the authors' knowledge previously examined facility geography or housing area with regard to survival outcomes in meningioma patients. Of note, treatment at a facility in the south was a significant prognosticator of survival on univariate but not multivariate analysis, which suggests that the socioeconomic and behavioral disparities across geographic regions contributed to the univariate findings.

Demographic factors

Female patients were found to have a decreased hazard of death compared to male patients. McCarthy et al. [6], also reported an increased survival in female meningioma patients [6]. In another analysis of 12,284 patients in the Surveillance, Epidemiology, and End Results (SEER) database, Cahill et al. reported a decreased hazard of death for female patients compared to male patients with nonmalignant intracranial meningiomas [8-10]. However, there have also been conflicting reports in the literature regarding sex. Although limited to spinal meningiomas, Ambekar et al. [8], found that female patients had increased odds of an adverse event (defined as in-hospital death or discharge to a facility other than home) following surgery compared to male patients in an analysis of 13,792 patients [8].

There are a number of potential reasons for the survival differences across sex. McCarthy et al. [6], found sex was no longer a predictor of survival when treatment strategy and hospital type were included in their multivariate model [6]. Conversely, Cahill et al. also reported that male sex remained a predictor of poorer survival in their multivariate model. Interestingly, male patients were more likely than female patients to undergo surgical resection, although their multivariate model did include treatment strategy [10-15]. These findings suggest that even when different treatment strategies and/or tumor characteristics across males and females with meningiomas are controlled for, there are survival differences across sex. Our results support this finding.

Another possible explanation for the survival advantage of females is physiologic or genetic differences between male and female patients. It is well documented, and the present study supports, that there is an increased incidence of meningiomas in female compared to male patients. In a review of the literature, Sun et al. propose that increased estrogen and progesterone levels drive this difference [16]. Interestingly, although the incidence of meningiomas is higher in females, males tend to have more aggressive tumors, which could potentially be explained by the research of Juratli et al. [16,20]. In a genetic analysis of high-grade meningiomas, Juratli et al. found that inactivation of the dystrophin gene on the X-chromosome was present in 17 of 53 high-grade meningomas [20]. It is possible that this mutation or other mutations on the X-chromosome account for the aggressive nature, and therefore increased mortality, of meningiomas in males.

When investigating the effect of ethnicity on meningioma patient survival, the present study found that Hispanic patients had a decreased hazard of death compared to non-Hispanic patients. This conflicts with the findings Feun et al., in which there was no survival difference according to patient ethnicity in a population of 108 meningioma patients treated between

1977 and 1990 [9]. Notably, the present study had a significantly larger patient population.

Other studies have reported on more favorable outcomes in Hispanic patients with other types of primary CNS tumors. In an analysis of 33,204 glioblastoma (GBM) patients from 1995 to 2004, Farah et al. reported an increased survival rates of GBM patients in the first two years after diagnosis compared to non-Hispanic patients [11]. Similar findings of a survival advantage experienced by Hispanic patients has led to the term the Hispanic paradox, whereby Hispanic patients experience better health outcomes despite lower socioeconomic status [9,11,21]. Indeed, we found that Hispanic ethnicity remained a predictor of survival in the multivariate model. A number of different hypotheses have been put forth to explain this phenomenon, which occurs in a variety of different diseases. In a meta-analysis of available literature Ruiz et al. examined a variety of potential explanations for the Hispanic paradox. They suggest that the paradox is driven by a variety of factors, including Hispanic patients often having better preexisting health and differences in genetic, behavioral, social, and psychological factors between Hispanic patients and non-Hispanic patients. A few specific explanations, though none have been proven to be entirely true, are that only the healthiest Hispanic patients immigrate to the United States and that many Hispanic patients return to their home countries prior to their deaths (and are therefore not included in some mortality data) [22].

The present study found that patients of Asian or "other/unknown" race had a decreased hazard of death compared to white patients. Cahill et al. did not find this specific difference in survival, however the size of the cohort from the SEER database was only about a tenth of that in the present study and was limited to non-malignant intracranial meningiomas.

We also found that black patients had an increased hazard of death, but only in the multivariate model. As proposed by Lo et al., this may be because there is large variability in survival within the Black population with respect to difference in survival across racial groups [23]. McCarthy et al. [6], also found a decreased probability of survival for black patients compared to white patients [6]. Cahill et al., in contrast, found that although black patients were less likely to have their meningiomas resected compared to white patients there was no difference in survival [10], pointing to the need for further research. Potential reasons for ethnic/racial inequities in survival may be underlying genetic differences, or other healthcare or socioeconomic disparities that were not adequately controlled for in multivariate analysis [24].

Socioeconomic factors

We found that patients living in a zip code with a higher median household income, or a larger percentage of residents with high school diplomas have a decreased hazard of death. Although it has been widely reported that patients with a lower socioeconomic status have worse health outcomes, the literature pertaining to meningiomas is extremely limited. In a single-center study of 281 meningioma patients, Nayeri et al. found that factors associated with low socioeconomic status, including Medicaid coverage and no college degree, were predictors of poor patient follow-up after meningioma resection [14]. Curry and Barker reported lower long-term survival in economically disadvantaged patients for brain tumors in general [15].

Limitations

Limitations of this study are inherent to a retrospective analysis. Furthermore, as data in the NCDB is compiled from a number of institutions, its accuracy is limited by be inconstancies in data collection and recording across participating institutions. Additionally, income and education level were determined based on the population of the patient's zip code, which may not necessarily correspond to the individual patient's characteristics.

Conclusions

Treatment at an academic/research program, private insurance, female sex, Hispanic ethnicity, Asian race, higher income bracket, and a high school diploma were all associated with a decreased hazard of death in meningioma patients. Additional research is needed to confirm these findings, and to elucidate potential genetic and environmental drivers of these inequalities so that optimal outcomes can be obtained in all patients.

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