Health disparities and impact on outcomes in children with primary central nervous system solid tumors

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OBJECTIVE Health disparities in access to care, early detection, and survival exist among adult patients with cancer. However, there have been few reports assessing how health disparities impact pediatric patients with malignancies. The objective in this study was to examine the impact of racial/ethnic and social factors on disease presentation and outcome for children with primary CNS solid tumors.

METHODS The authors examined all children (age ≤ 18 years) in whom CNS solid tumors were diagnosed and who were enrolled in the Texas Cancer Registry between 1995 and 2009 ($n = 2421$). Geocoded information was used to calculate the driving distance between a patient's home and the nearest pediatric cancer treatment center. Socioeconomic status (SES) was determined using the Agency for Healthcare Research and Quality formula and 2007–2011 US Census block group data. Logistic regression was used to determine factors associated with advanced-stage disease. Survival probability and hazard ratios were calculated using life table methods and Cox regression.

RESULTS Children with advanced-stage CNS solid tumors were more likely to be < 1 year old, Hispanic, and in the lowest SES quartile (all $p < 0.05$). The adjusted odds ratios of presenting with advanced-stage disease were higher in children < 1 year old compared with children > 10 years old (OR 1.71, 95% CI 1.06–2.75), and in Hispanic patients compared with non-Hispanic white patients (OR 1.56, 95% CI 1.19–2.04). Distance to treatment and SES did not impact disease stage at presentation in the adjusted analysis. Furthermore, 1- and 5-year survival probability were worst in children 1–10 years old, Hispanic patients, non-Hispanic black patients, and those in the lowest SES quartile ($p < 0.05$). In the adjusted survival model, only advanced disease and malignant behavior were predictive of mortality.

CONCLUSIONS Racial/ethnic disparities are associated with advanced-stage disease presentation for children with CNS solid tumors. Disease stage at presentation and tumor behavior are the most important predictors of survival.

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KEY WORDS pediatric CNS tumors; race; ethnicity; socioeconomic status; survival; oncology

BRAIN tumors are the second most common malignancy of childhood and have the highest mortality rate of all childhood cancers (<https://nccd.cdc.gov/uscs/>).²⁸ Disparities in treatment and survival between white and nonwhite patients with cancer are well known in the adult population. Among adult patients with CNS

solid tumors, Hispanic and black patients have higher mortality rates, even when controlling for surgical management.⁸ Furthermore, insurance status is also related to survival among adult patients with primary brain tumors.⁸ However, less is known about disparities among the pediatric population with CNS solid tumors.² Several studies,

ABBREVIATIONS CDC = Centers for Disease Control and Prevention; DSHS = Department of State Health Services; HR = hazard ratio; ICD-O-3 = *International Classification of Diseases for Oncology, 3rd Edition*; NPCR = National Program of Cancer Registries; OS = overall survival; SEER = Surveillance, Epidemiology and End Results Program; SES = socioeconomic status; TCR = Texas Cancer Registry.

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primarily in children with leukemia and lymphoma, have established that race, socioeconomic status (SES), and access to care can affect outcomes for childhood malignancies.^{3,9,30}

Survival of children after diagnosis of CNS solid tumors is highly dependent on age at diagnosis, the histological subtype, the location of the tumor within the brain, and the treatment regimen.² There have been few studies evaluating racial differences in outcomes of pediatric patients with CNS solid tumors. Population-based studies have demonstrated significant differences in distribution of histological subtypes among races.¹ However, there are conflicting reports about the impact of race on survival for primary malignant CNS solid tumors in children and adolescents.^{1,27}

The objective of our study was to identify health disparities in disease stage at presentation and survival within a large cohort of children with CNS solid tumors whose records were obtained from the Texas Cancer Registry (TCR).

Methods

We conducted a retrospective study assessing 2421 pediatric patients ≤ 18 years old with primary CNS solid tumors who presented between January 1, 1995, and December 31, 2009. The study was approved by the institutional review board of the University of Texas MD Anderson Cancer Center and the Texas Department of State Health Services (DSHS). Patient data were obtained from the TCR database (<http://www.dshs.state.tx.us/tcr/>), a state-wide population-based registry that is gold-certified by the North American Association of Central Cancer Registries (<http://naaccr.org/certification/certificationlevels.aspx>). The TCR is part of the Centers for Disease Control and Prevention (CDC) National Program of Cancer Registries (NPCR), with standardized data collection and quality control protocols. To meet these standards, the TCR has quality control for both internal and external processes to insure the reliability, completeness, consistency, and comparability of TCR data. Data were abstracted on patient demographic data, primary tumor site, stage of disease at diagnosis, first course of treatment, tumor morphology, cause of death, and survival—from medical and laboratory records by trained tumor registrars. Tumor site and histological features were coded according to the WHO criteria in the *International Classification of Diseases for Oncology, 3rd Edition* (ICD-O-3).¹⁰ Primary CNS solid tumors were defined by morphology codes 9350 through 9530 (Appendix Table 1).

The TCR data set included patient demographic data (date of birth, sex, race/ethnicity, and home address); date of diagnosis; Surveillance, Epidemiology and End Results Program (SEER)-defined category of stage; date of last follow-up and status; and date of death. Patients were categorized into 3 age groups to reflect infants (< 1 year old), prepubescent children (1–10 years old), and postpubescent adolescents (> 10 years old). Patients were also categorized into 4 race/ethnicity groups (non-Hispanic white, non-Hispanic black, Hispanic, and other). The year of diagnosis was divided into 2 groups: 1995–2002 and

2003–2009, to account for changes in treatment over time. Using SEER-defined categories for disease stage, patients were categorized as having local disease if the tumor was confined to one hemisphere in one part of the brain (infra-/supratentorial), the meninges, or invading/encroaching on the ventricular system. Regional disease was defined by SEER as tumors that crossed the midline or tentorium, invaded bone, major blood vessels, cranial nerves, or spinal cord. Distant disease was defined as the presence of circulating cells in the CSF, extension to the nasal cavity, nasopharynx, posterior pharynx, or outside the CNS. Patients who had either regional disease or distant metastases were categorized as having advanced disease. Patients with *in situ* disease were excluded from analysis.

Pediatric cancer treatment centers were identified by 2 methods. First, all hospitals in Texas and bordering states (Arkansas, New Mexico, Louisiana, and Oklahoma) that are members of the Children's Oncology Group (COG, <http://www.childrensoncologygroup.org/index.php/locations/>) were included. Next, the Texas Hospital Inpatient Discharge Public Use Data File (<https://dshs.texas.gov/thcic/hospitals/Inpatientpdf.shtm>) was queried to identify any hospital with > 100 discharges of children with a primary cancer diagnosis in 2009. We then mapped and geocoded the location of each treatment center to a street road network available in ArcGIS version 10.0 (Esri). The driving distance between a patient's home address and the nearest pediatric cancer treatment center was calculated and categorized into 0–25 miles, 26–50 miles, and > 50 miles. These distances were chosen to reflect short (≤ 25 miles), intermediate (26–50 miles), and long (> 50 miles) travel distances. We selected > 50 miles as our long-distance benchmark on the basis of previous work among adult patients with cancer.^{19,22,25}

We applied 2007–2011 US Census block group data from the American Community Survey to the following SES index formula, which was developed and validated by the Agency for Healthcare Research and Quality, to calculate the neighborhood SES index score:⁵

$$\text{SES Index Score} = 50 + (-0.07 * \text{crowded}) + (0.08 * \text{prop100}) + (-0.10 * \text{pct_poverty}) + (0.11 * \text{hhinc100}) + (0.10 * \text{high_educ}) + (-0.11 * \text{low_educ}) + (-0.08 * \text{pct_unemp}).$$

The index components consisted of the following: percentage of households containing ≥ 1 person per room (crowded); the median home value standardized to range from 0% to 100% (prop100); the percentage of persons below the federally defined poverty level (pct_poverty); the median household income standardized to 0–100 (hhinc100); the percentage of persons age ≥ 25 years with at least 4 years of college (high_educ); the percentage of persons age ≥ 25 years with less than a 12th grade education (low_educ); and the percentage of persons age ≥ 16 years in the labor force who are unemployed and actively seeking work (pct_unemp). The data of the components are available at the block group level from the US Census Bureau American Community Survey. We incorporated each patient's geocoded residential address and the 2010 US census data to calculate a neighborhood SES index

score, and assigned each patient an SES quartile based on the SES index distribution of the study population. These quartiles are as follows: first quartile, < 25%; second quartile, 25%–50%; third quartile, 51%–75%; and fourth quartile, > 75%.

Overall survival (OS) was calculated from the date of diagnosis to the date of death from any cause. Patients who were alive at the last follow-up were censored at the last follow-up date. Survival curves were plotted using the Kaplan-Meier method and compared by the log-rank test. One-year and 5-year survival probabilities were estimated using the life table method. Univariate and multivariate logistic regression models were conducted to determine any association between advanced disease—defined as regional or distant metastases—and independent variables including sex, age, race/ethnicity, year of diagnosis, travel distance, SES quartile, and tumor behavior (benign or malignant) at the time of diagnosis. Significant variables in the models were presented with hazard ratio (HR), associated 95% CIs, and p values. Multivariate Cox regression analysis was carried out to identify significant predictors of OS. Covariates included in the model were sex, age, race/ethnicity, year of diagnosis, disease stage, travel distance, and SES quartile. Results were reported as HRs with 95% CIs. All analyses were performed with SAS version 9.3 (SAS Institute). Statistical comparisons were 2-sided and were considered significant at $p < 0.05$.

Results

In total, there were 2421 pediatric patients in whom CNS solid tumors were diagnosed between 1995 and 2009 and who were registered in the TCR. The median age was 7 years (range 0–18 years). Patient demographic data are shown in Table 1. The majority of patients (83%) presented with local disease, 11% with regional metastasis, and 6% with distant metastasis. The median driving distance from a patient's home to the nearest pediatric cancer treatment center was 19.1 miles (range < 0.2 to 253.2 miles). The majority of patients lived ≤ 25 miles from a pediatric cancer treatment center (60%). However, 24% lived > 50 miles from the nearest pediatric cancer treatment center, and the majority of these counties are classified as either noncore (not part of “core-based” metro- or micropolitan areas) or micropolitan (10,000–49,999 persons) according to the US Census. Malignant tumors were diagnosed in 61% of patients. The most frequently diagnosed ICD-O-3 codes for the morphological type of tumor are listed in Table 2. A complete list of diagnoses and ICD-O-3 codes is in Appendix Table 1.

The socioeconomic characteristics of the study population are presented in Table 3. The median neighborhood SES index score was 51 (range 31–78). Variability for each component of the SES index is further explored in Table 3. The median poverty level rate was 13% (range 0%–93%), and the unemployment rate was 7% (range 0%–45%).

Results of the univariate and multivariate analyses that evaluated the impact of the covariates on the odds of presenting with advanced-stage disease are shown in Table 4. In the multivariate model, patients < 1 year old were

TABLE 1. Demographic data of pediatric patients with primary CNS solid tumors

Characteristic	No. of Patients (%) [*]
Sex	
Male	1319 (54)
Female	1102 (46)
Age group	
<1 yr	114 (5)
1–10 yrs	1536 (63)
>10 yrs	771 (32)
Race/ethnicity	
Non-Hispanic white	1201 (50)
Hispanic	848 (35)
Non-Hispanic black	270 (11)
Other	102 (4)
Yr of diagnosis	
1995–2002	1042 (43)
2003–2009	1379 (57)
Stage of disease	
Local	2015 (83)
Regional	257 (11)
Distant	149 (6)
Travel distance	
0–25 miles	1445 (60)
26–50 miles	403 (17)
>50 miles	573 (24)

^{*} The percentages may not add up to 100% due to rounding.

more likely to have advanced-stage disease compared with those > 10 years (OR 1.71, 95% CI 1.06–2.75). Hispanic patients were > 50% more likely to have advanced-stage disease than non-Hispanic white patients (OR 1.56, 95% CI 1.19–2.04). Patients with CNS tumors diagnosed between 2003 and 2009 were less likely to have advanced-stage disease compared with those diagnosed between

TABLE 2. The ICD-O-3 coding for the most frequent histological type of tumor

ICD-O-3	Diagnosis	Frequency	%
9421	Pilocytic astrocytoma	641	26
9380	Glioma, malignant	504	21
9470	Medulloblastoma NOS	305	13
9400 & 9401	Astrocytoma NOS & anaplastic astrocytoma	239	10
9391 & 9392	Ependymoma NOS & anaplastic ependymoma	207	9
9473	Primitive neuroectodermal tumor	105	4
9440	Glioblastoma NOS	104	4
	Other	316	13

NOS = not otherwise specified.

TABLE 3. Socioeconomic characteristics of the study population at the block group level

Characteristic	Mean (SD)	Median	Min	Max
SES score	51.0 (7.2)	51	31	78
Percent of housing units in crowded living quarters	5.5 (7.4)	3	0	60
Ranking based on median house value; 0%–100%	52.6 (28.2)	54	0	100
Percent living below poverty level	17.0 (15.4)	13	0	93
Ranking based on median household income; 0%–100%	53.7 (28.9)	56	0	100
Percent w/ low education level; no high school graduation	21.1 (17.7)	16	0	86
Percent w/ high education level; college graduation	24.6 (20.2)	19	0	93
Percent unemployed	7.5 (6.2)	7	0	45

Max = maximum; min = minimum.

1995 and 2002 (OR 0.77, 95% CI 0.62–0.95). Driving distance to the nearest pediatric cancer treatment center and SES quartile had no significant impact on the stage of disease at presentation.

The Kaplan-Meier survival curves stratified by race/ethnicity and SES quartile are presented in Figs. 1 and 2, respectively. Hispanic and non-Hispanic black patients had worse OS compared with non-Hispanic white patients (HR 1.51, 95% CI 1.29–1.78, and HR 1.51, 95% CI 1.19–1.90, respectively). Furthermore, patients in the first and second SES quartiles had worse OS compared with patients in the fourth SES quartile (HR 1.39, 95% CI 1.13–1.70, and HR 1.28, 95% CI 1.02–1.59, respectively) (Table 5). Race/ethnicity was tightly associated with neighborhood SES (Fig. 3, $p < 0.001$). Specifically, 50% of Hispanic and 33% of non-Hispanic black patients were in the first SES quartile, whereas only 11% of non-Hispanic white patients were in the first quartile.

In the multivariate Cox regression model, malignant behavior had the most significant impact on survival, whereas race and SES were no longer significant (Table 5; HR 4.64, 95% CI 3.72–5.74). However, all nonwhite populations were more likely to receive a diagnosis of malignant tumors than non-Hispanic white patients (Fig. 4, $p < 0.001$). A subset analysis for patients with malignant tumors only showed that non-Hispanic black patients had significantly worse OS than non-Hispanic white patients (HR 1.30, 95% CI 1.01–1.68). Regional and distant disease also significantly decreased survival when compared with local disease (HR 1.32, 95% CI 1.07–1.64, and HR 1.78, 95% CI 1.40–2.27).

Driving distance to the nearest pediatric cancer treatment center had no impact on OS (Fig. 5 and Table 5).

Discussion

Neighborhood socioeconomic and racial/ethnic disparities are important factors in disease stage at presentation and survival in children with CNS solid tumors.

TABLE 4. Unadjusted and adjusted odds for presenting with advanced-stage disease*

Variable	Univariate Analysis		Multivariate Analysis	
	OR	95% CI	OR	95% CI
Sex				
Male	0.91	0.73–1.12	0.90	0.72–1.12
Female	Reference†		Reference†	
Age				
<1 yr	2.03	1.27–3.24	1.71	1.06–2.75
1–10 yrs	1.25	0.98–1.58	1.12	0.87–1.43
>10 yrs	Reference†		Reference†	
Race/ethnicity				
Non-Hispanic white	Reference†		Reference†	
Hispanic	1.78	1.41–2.24	1.56	1.19–2.04
Non-Hispanic black	1.23	0.86–1.77	1.11	0.76–1.63
Other	0.84	0.45–1.57	0.86	0.46–1.63
Yr of diagnosis				
1995–2002	Reference†		Reference†	
2003–2009	0.79	0.64–0.98	0.77	0.62–0.95
Travel distance				
0–25 miles	Reference†		Reference†	
26–50 miles	1.01	0.75–1.35	1.15	0.85–1.56
>50 miles	0.86	0.66–1.12	0.91	0.69–1.21
SES quartile				
<25%	1.58	1.18–2.12	1.19	0.85–1.67
25%–50%	1.18	0.85–1.63	1.03	0.73–1.46
51%–75%	1.03	0.75–1.41	0.98	0.71–1.36
>75%	Reference†		Reference†	
Behavior of lesion				
Benign	Reference†		Reference†	
Malignant	2.11	1.66–2.68	1.99	1.55–2.54

* Advanced disease is defined as either regional or distant disease. Boldface type indicates statistical significance.

† Reference group used in logistic regression models.

Our results support other studies that have evaluated the impact of health disparities on survival in children with cancer. Studies in children with leukemia and lymphoma have indicated that race, SES, and access to care can affect outcomes.^{3,9,15,23,30} In a review article written by Bhatia,² black children with acute myeloid leukemia had a 42% excess mortality and Hispanic children had a 33% excess mortality in comparison with their non-Hispanic white counterparts. This difference in mortality is multifactorial and includes a combination of biological factors, SES, and sociocultural factors. In contrast, minimal work has been performed to understand the impact of health disparities on pediatric primary CNS malignancies. This study is the first of its kind to examine the impact of race/ethnicity,

FIG. 1. Graph showing OS curve by race/ethnicity. NH = non-Hispanic.

FIG. 2. Graph showing OS curve by SES quartile.

SES, and driving distance to the cancer treatment center on disease presentation and OS for children with CNS malignancies.

Race/Ethnicity

The impact of race/ethnicity on disease presentation and overall survivability has not been studied extensively in pediatric CNS tumors. In a study based on SEER data from 1973 to 1996, OS was similar for Hispanic, black, and Asian patients in whom malignant CNS tumors had been diagnosed, compared with white patients.¹ However, more recent SEER data from 1992 to 2000 and 2001 to 2007 demonstrated a significant difference in 5-year survival for black pediatric patients with astrocytoma and high-grade glioma compared with white patients.¹⁸

The results of the current study demonstrated that Hispanic patients were more likely to present with advanced-stage disease, and Hispanic and non-Hispanic black patients had decreased OS in comparison with white patients. Previous studies have demonstrated increased prevalence of high-risk disease and decreased OS among black children with neuroblastoma.¹⁴ Malignant tumor behavior is the most important factor for OS, and Hispanic and non-Hispanic black patients were more likely to present with malignant disease compared with non-Hispanic white patients. Moreover, among individuals with malignant tumors, non-Hispanic black patients had worse survival than non-Hispanic white patients.

There may be biological differences between malignant tumors among black and white children. Molecular studies in other tumors such as neuroblastoma have suggested that racial differences in outcomes may potentially be explained by genetic variability in response to drug effectiveness and toxicity, tumor aggression, and resistant or residual disease that relapses or progresses.^{6,14,16,21} Less is known about the molecular genetics of pediatric CNS tumors. Recent advances in understanding the molecular subgroups of medulloblastoma have identified 4 subgroups with variable clinical behavior and outcomes among different age groups.^{12,31} Further understanding of the genetic landscape of CNS tumors among different ra-

cial/ethnic groups may help explain in part differences in incidence of high-risk disease, advanced-stage disease at presentation, and OS.¹¹

Race/ethnicity disparities are multifactorial and may be influenced by social effects. Mukherjee et al.²⁴ evaluated factors that influenced access to high-volume centers for neuro-oncological care in the US, and found that Hispanic children were 32% less likely than their white counterparts to be admitted into high-volume hospitals. It has been shown that high-volume hospitals have improved surgical outcomes with fewer complications, indirectly impacting OS.²⁴ Furthermore, studies using the SEER database have demonstrated that Hispanic and non-Hispanic black children had lower 5-year survival rates compared with non-Hispanic white children for many cancer types, including CNS solid tumors.^{13,20} However, single-institution studies have failed to demonstrate a racial disparity in survival from pediatric cancer.²⁷ Single-center studies may suffer more from greater selection bias than population-based studies, especially for those institutions that provide protocol-driven care with no direct charge to patients. These findings suggest that socioeconomic factors may play a significant role in observed differences in survival.²⁷

Socioeconomic Status

Access to quality health care, timely diagnosis, and ability to maintain compliance with recommended treatment regimens are closely associated with SES, ethnicity, and survival.²⁹ Population studies among adult patients with CNS tumors have demonstrated socioeconomic disparities in surgical management, access to high-volume centers, and increased in-hospital mortality after resection.^{4,8,17,32} Less is known about SES disparities in access to care among pediatric patients with CNS tumors. A study from the US between 1988 and 2005 revealed that Hispanic patients and those with a lower SES had less access to high-volume neuro-oncological care compared with non-Hispanic white patients and those with a higher SES.²⁴ However, survival outcomes were not evaluated. An earlier study from Wales between 1971 and 1990

FIG. 3. Bar graph showing the distribution of SES quartiles within each racial/ethnic group. There were significant differences in SES by race. $\chi^2 = 509$, $p < 0.0001$.

found that SES did not affect survival in pediatric patients with CNS solid tumors.³³

Our results demonstrated that children in the first SES quartile were more likely to present with advanced-stage disease. However, when controlling for race and other sociodemographic characteristics, SES was no longer associated with advanced-stage disease, whereas race/ethnicity remained predictive of presentation with advanced-stage disease. Furthermore, patients in the first and second SES quartiles had decreased OS compared with patients in the fourth SES quartile. However, when controlling for other factors, SES was no longer a significant predictor of survival. In our study, race/ethnicity was closely associated with SES. More than half of the Hispanic and non-Hispanic black children were within the first and second SES quartiles, compared with only 32% of non-Hispanic white children. Because race/ethnicity and SES are multifaceted and so closely intertwined, it is difficult to determine in our study whether potential genetic variability or SES disparities among different racial/ethnic groups contribute more to presentation of advanced disease and the decrease in OS.

Travel Distance for Treatment

We found no relationship between driving distance to the nearest pediatric cancer treatment center and stage of disease presentation or OS. Our study is the first to evaluate travel distance to a pediatric cancer center on survival outcomes of pediatric patients with CNS solid tumors. The SEER data have demonstrated that pediatric patients with neuroblastoma living in nonmetropolitan counties have a higher mortality rate than those living in metropolitan counties.¹⁵ In our study, the majority of patients lived ≤ 25 miles from a pediatric cancer treatment center, whereas $< 25\%$ of patients lived > 50 miles from the nearest center. The limited number of patients living far from a pediatric

cancer center may have hindered our ability to detect a difference. Furthermore, it is important to note that in our study travel distance was defined as the nearest potential treatment facility and not the actual distance traveled to the facility used by the patient. The goal was to evaluate the impact of access to care on disease presentation and overall survivability. This approach is based on the underlying assumption that access improves with geographic proximity.²⁵ Future studies are needed to evaluate the impact of the distance actually traveled by patients (i.e., realized access) on outcome measures such as stage of presentation, adherence to and completion of therapy, follow-up surveillance, and OS.

Year of Diagnosis

In this series, individuals in whom a CNS tumor was diagnosed between 2003 and 2009 were more likely to present with localized disease than individuals whose tumor was diagnosed between 1995 and 2002. This finding remained significant after controlling for other sociodemographic variables and tumor behavior. This finding may reflect increased access to care and earlier diagnosis. There may also have been changes in the distribution and incidence of tumor histological types during these periods.^{7,26} However, year of diagnosis was not associated with OS.

Limitations and Strengths

The data for the study were obtained from the TCR database. The current study has several strengths. The TCR has high-quality data that are closely monitored for accuracy in each patient. Although the TCR has a large Hispanic population, this is the fastest-growing population in the US, and our results are generalizable to the US population. The large Hispanic population in this database is also useful in elucidating racial/ethnic disparities in outcomes of pediatric patients with CNS solid tumors.

TABLE 5. Cox regression to determine independent predictors for OS*

Variable	Univariate Analysis			Multivariate Analysis		
	HR	CI	p Value	HR	CI	p Value
Sex						
Male	1.03	0.89–1.19	0.7072	0.93	0.80–1.08	0.3206
Female	Reference†			Reference†		
Age						
<1 yr	1.67	1.22–2.30	0.0016	1.21	0.87–1.69	0.2602
1–10 yrs	1.23	1.05–1.44	0.0123	1.09	0.92–1.29	0.9722
>10 yrs	Reference†			Reference†		
Race/ethnicity						
Non-Hispanic white	Reference†			Reference†		
Hispanic	1.51	1.29–1.78	<0.0001	1.14	0.95–1.37	0.1658
Non-Hispanic black	1.51	1.19–1.90	0.0006	1.26	0.99–1.61	0.0613
Other	1.09	0.73–1.65	0.6669	0.93	0.61–1.44	0.7538
Yr of diagnosis						
1995–2002	Reference†			Reference†		
2003–2009	0.90	0.77–1.04	0.1577	0.87	0.75–1.02	0.0782
Behavior of lesion						
Benign	Reference†			Reference†		
Malignant	5.08	4.10–6.29	<0.0001	4.64	3.72–5.74	<0.0001
Stage of disease						
Local	Reference†			Reference†		
Regional	1.58	1.28–1.96	<0.0001	1.32	1.07–1.64	0.0109
Distant	2.40	1.89–3.05	<0.0001	1.78	1.40–2.27	<0.0001
Travel distance						
0–25 miles	Reference†			Reference†		
26–50 miles	0.89	0.72–1.10	0.2744	0.97	0.78–1.20	0.7769
>50 miles	0.87	0.73–1.05	0.1401	0.91	0.76–1.11	0.3504
SES quartile						
<25%	1.39	1.13–1.70	0.0019	1.13	0.90–1.43	0.3056
25%–50%	1.28	1.02–1.59	0.0311	1.17	0.93–1.48	0.1824
51%–75%	0.99	0.78–1.22	0.8407	0.97	0.77–1.22	0.7919
>75%	Reference†			Reference†		

* Boldface type indicates statistical significance.

† Reference group used in multivariate Cox regression models.

The study has several limitations, including those inherent in all retrospective investigations. We chose to define advanced disease as regional or metastatic disease. Prior to 2010, the SEER definition of regional CNS tumors included tumors that crossed the midline. This definition may inadvertently label patients with localized midline tumors that involve both the right and left hemisphere as having regional disease. Furthermore, the TCR did not begin recording insurance status until 2007. Due to the small number of patients whose insurance status was available, we were not able to evaluate the influence of insurance status on outcomes. Insurance status is closely associated with a number of factors, including race/ethnicity and SES, and may be a potentially important variable on disease stage at presentation and OS. In this study, we wanted to evaluate the patient's access to care and distance to the nearest pediatric treatment center rather than the actual distance

FIG. 4. Bar graph showing the distribution of race/ethnicity among pediatric patients with CNS solid tumors. There were significant differences in tumor behavior by race. $\chi^2 = 43$, $p < 0.0001$.

FIG. 5. Graph showing OS curve by driving distance to the nearest pediatric cancer treatment center.

traveled to the treatment center used by the patient. Also, we were unable to account for patients who moved closer to treatment facilities postdiagnosis. Furthermore, we were not able to include hospital-specific factors, such as high- or low-volume center, that may have impacted OS.²⁴

Conclusions

Racial/ethnic disparities are associated with advanced-stage disease presentation for children with CNS solid tumors. Furthermore, disease stage at presentation and tumor behavior are the most important predictors of survival. The underlying causes for these disparities are multifactorial and complex. Future studies are needed to elucidate the specific causes of these disparities to develop interventions to improve outcomes among pediatric patients with CNS solid tumors.

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Author Contributions

Conception and design: Austin, Hamilton, Elting, Sandberg. Acquisition of data: Austin, Zebda, Nguyen, Eberth, Chang, Elting, Sandberg. Analysis and interpretation of data: all authors. Drafting the article: Austin, Zebda, Chang. Critically revising the article: Austin, Hamilton, Nguyen, Eberth, Elting, Sandberg. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Austin. Statistical analysis: Nguyen, Chang. Administrative/technical/material support: Chang. Study supervision: Sandberg.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

Appendix Table 1. <http://thejns.org/doi/suppl/10.3171/2016.5.PEDS15704>.

Previous Presentations

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