Neighborhood Socioeconomic Deprivation and Mortality in Children with Central Nervous System Tumors

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ABSTRACT

Background: Although there is evidence of socioeconomic disparities in survival of children diagnosed with central nervous system (CNS) tumors, the impact of neighborhood socioeconomic deprivation on the survival of these malignancies has not been adequately studied. We investigated the association between area deprivation index (ADI), a measure of neighborhood socioeconomic disadvantage, and pediatric CNS tumor survival.

Methods: Demographic and clinical characteristics, geocoded addresses at diagnosis, and vital status of pediatric CNS tumor cases (n = 5,477) for the period 1995 to 2017 were obtained from the Texas Cancer Registry. ADI scores were computed for census tracts in Texas using the U.S. Census Bureau 2010 geography. Tracts were classified into quartiles as least, third-most, second-most, and most disadvantaged. Children were mapped to quartiles based on residency at diagnosis. The adjusted hazard ratio (HR) and 95% confidence interval (CI) were calculated.

Results: The results showed a significantly increased HR for death among children in the most (HR, 1.29; 95% CI, 1.09–1.51), second-most (HR, 1.18; 95% CI, 1.01–1.38), and third-most disadvantaged census tracts (HR, 1.18; 95% CI, 1.02–1.37) compared with children in the least disadvantaged tracts.

Conclusions: Children living in the most disadvantaged neighborhoods experienced a significantly higher risk of mortality, indicating the important role of socioeconomic disparities in the survival of pediatric CNS tumors.

Impact: The demographic and socioeconomic disparities identified by this study should be considered when planning treatment strategies for these susceptible groups and thus, lead to a better outcome in socioeconomically disadvantaged children diagnosed with CNS tumors.

Introduction

Primary central nervous system (CNS) tumors are the second most common type of cancer in children and represent the leading cause of cancer-related mortality in this population (1). Brain tumors account for about 85% of all primary CNS tumors and are heterogeneous in histopathology, molecular features, and prognosis (1). The survival rate of pediatric CNS tumors varies greatly; the lowest 10-year survival rate was estimated at 45.6% pertinent to brain stem tumors, whereas the highest 10-year survival rate (97.8%) was attributable to tumors of the cranial nerves (1). Despite the improvement in the prognosis of brain tumors achieved by incorporating advanced surgical technologies and knowledge in molecular classification (2), the factors associated with differential survival are still unclear. An important set of factors and a persistent public health concern are inequalities by sociodemographic characteristics in access to general health care, neurosurgical, and neuro-oncological (3–5).

Although there is evidence of individual-level demographic and socioeconomic disparities in survival of pediatric CNS tumors, the impacts of area-based measures of socioeconomic status (SES) have been understudied (6, 7). There is increasing evidence to indicate where individuals live influences health outcomes. One important measure of neighborhood-level SES is the area deprivation index (ADI) that captures factors, including poverty, housing, employment, and education (8). Given the important effect of residential neighborhood on individuals' health, through its impacts on health care access and adherence to therapy, which is independent from individual-level measures, it is important to evaluate the influence of neighborhood socioeconomic disadvantage on pediatric CNS tumor survival (8, 9).

Previous studies have demonstrated the impact of neighborhood socioeconomic deprivation on survival among children with acute leukemia (10–12); however, little knowledge is available on the association between neighborhood socioeconomic deprivation and pediatric CNS tumor survival (5, 13). Therefore, we aimed to examine the influence of neighborhood socioeconomic deprivation, using ADI, on the survival of pediatric CNS tumors and to investigate whether demographic characteristics such as sex, race/ethnicity, and metropolitan residency could potentially modify the identified associations.

Materials and Methods

Study design and setting

Individuals up to 20 years old who resided and were diagnosed with a primary malignant CNS tumor in Texas during the period between January 1, 1995 and December 31, 2017 were included in the study. Information on birth year, sex, race/ethnicity, tumor morphology and

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behavior, vital status, geocoded home address at diagnosis, and metropolitan residency was obtained from the Texas Cancer Registry (TCR). Cases of primary malignant CNS tumors were defined as those with behavior code 3 and a group III code according to the International Classification of Childhood Cancer, third edition (ICCC-3; ref. 14), which is based on the International Classification of Diseases for Oncology, third edition (ICD-O-3; ref. 15). We identified cases with the most common histological subtypes of brain tumors based on ICCC-3, group III (ICD-O-3 morphology codes provided) as follows: ependymoma, IIIa (9383, 9391–9394); astrocytoma, IIIb (9380, 9384, 9400–9411, 9420, 9421–9424, 9440–9442); and medulloblastoma, IIIc (9470–9472, 9474, 9480).

The following variables were included in the analysis as potential confounders: sex (male vs. female); birth year (continuous variable); race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, other); residency (metropolitan vs. non-metropolitan).

The study was approved by the Institutional Review Boards at Baylor College of Medicine and the Texas Department of State Health Services.

Computation of ADI

The ADI, which represents neighborhood-level disadvantage, was calculated at the census tract level. To compute ADI, Singh (8) used factor analysis to identify 17 indicators drawn from four major categories of the U.S. census, including poverty (median family income, income disparity, families below poverty level, population below 150% poverty threshold, single parent households with dependents <18, households without a motor vehicle, households without a telephone, occupied housing units without complete plumbing), housing (owner occupied housing units, households with >1 person per room, median monthly mortgage, median gross rent, median home value), employment (employed person 16+ in white collar occupation, civilian labor force unemployed; aged 16+), and education (population 25+ with <9yr education, population 25+ with at least a high school education; ref. 8). We retrieved the same 17 indicators from the U.S. Census Bureau 2007–2011 American Community Survey (ACS). The ACS is a nationwide survey that collects and produces information on social, economic, housing, and demographic characteristics about the U.S. population every year (16). ACS data are summarized at the census tract level. We followed Singh's formula for computing the ADI (17). Briefly, each indicator was weighted using Singh's computed factor score coefficient. Afterwards all 17 indicators were summed to produce an ADI score for each census tract in Texas ($n = 5{,}265$). We used the 2010 census tract geography as the unit of analysis for the ADI. Census tracts were grouped into quartiles based on the observed distribution of scores in Texas as follows: Least disadvantaged (lowest ADI scores), third-most disadvantaged, second-most disadvantaged, and most disadvantaged (highest ADI scores). Geocoded addresses provided by the TCR were then mapped to census tracts, and each child was assigned an ADI quartile, based on their address at the time of their diagnosis. The 3-digit codes for Texas county (001–507) issued by Federal Information Processing Standards were used to define census tracts as metropolitan or non-metropolitan (18–20). Children with missing addresses, or addresses outside Texas, were excluded ($n = 9$). All geographic information system analyses were performed in ArcGIS Pro 2.2 (Esri).

Statistical analysis

We used χ^2 tests to assess the differences in distributions of categorical demographic variables and ADI quartiles. Cox regression was used to assess the impact of ADI on survival of all pediatric CNS tumors combined and the most common histological subtypes individually. The results of Cox regression models were then adjusted for sex, race/ethnicity, diagnosis year, age at diagnosis, and metropolitan residency. We defined the survival time as the date of diagnosis to the date of death or the end of the study follow-up, December 31, 2017. Kaplan–Meier plots were used to illustrate the overall survival in patients in relation to ADI quartiles. The association between ADI and survival for all pediatric CNS tumors were further investigated using stratified analyses by sex, race/ethnicity, and metropolitan residency.

The analyses were conducted using Stata statistical software version 16 (StataMP).

Results

Summary statistics

In total, we identified 5,477 cases with pediatric primary malignant CNS tumors. The distribution of the most common histological subtypes was as follows: 3,327 astrocytomas, 668 medulloblastomas, and 448 ependymomas. The distributions of demographic characteristics, including sex, race/ethnicity, diagnosis year, age at diagnosis, and metropolitan residency according to neighborhood socioeconomic disadvantage are summarized in **Table 1**. Notably, there were significant differences for all demographic characteristics, other than sex and diagnosis age.

Figure 1 illustrates the distribution of ADI scores in Texas and selected metropolitan areas. Median (± interquartile range) ADI score in the least, third-most, second-most, and the most disadvantaged quartile was 77.5 (21.4), 98.8 (6.2), 109.2 (3.9), and 117.1 (4.5), respectively.

Survival for all pediatric CNS tumors

The crude Cox regression analysis investigating the association between ADI and survival of all pediatric CNS tumors showed a significantly increased hazard ratio (HR) for death among children in the most disadvantaged census tracts [HR, 1.49; 95% confidence interval (CI), 1.29–1.73)], second-most disadvantaged census tracts (HR, 1.29; 95% CI, 1.12–1.50) and third-most disadvantaged census tracts (HR, 1.25; 95% CI, 1.08–1.44) compared with children in the least disadvantaged tracts ($P_{\text{Trend}} < 0.001$; **Table 2**).

The observed associations remained statistically significant after adjustment for covariates (**Table 2**), although the effect estimates of the adjusted results were attenuated [(HR, 1.29; 95% CI, 1.09–1.51; HR, 1.18; 95% CI, 1.01–1.38), and (HR, 1.18; 95% CI, 1.02–1.37)] for the most, second most, and third most disadvantaged census tracts, respectively ($P_{\text{Trend}} = 0.019$).

Survival for the most common CNS histological subtypes

Histology-specific analyses revealed that in the crude model (**Table 2**), children diagnosed with astrocytoma, living in the most and second-most disadvantaged census tracts had a significantly higher risk of death (HR, 1.50; 95% CI, 1.24–1.83 and HR, 1.29; 95% CI, 1.06–1.57, respectively) compared with children diagnosed with astrocytoma, living in the least disadvantaged tracts. A nonsignificant increased point estimate was observed for children with astrocytoma in the third-most disadvantaged census tracts (HR, 1.13; 95% CI, 0.93–1.37; $P_{\text{Trend}} < 0.001$). As **Table 2** illustrates, these findings did not remain statistically significant after adjustment for covariates.

As **Table 2** shows, in the crude model, among children diagnosed with medulloblastoma, those living in the most (HR, 1.58; 95% CI, 1.09–2.27), second-most (HR, 1.11; 95% CI, 0.75–1.64), and third-

Table 1. Demographic characteristics of children with CNS tumors according to quartile of ADI.

Demographic characteristics	Quartile 1 (least disadvantaged)	Quartile 2 (third-most disadvantaged)	Quartile 3 (second-most disadvantaged)	Quartile 4 (most disadvantaged)	*P*
Number of cases, *n* (%)	1,471 (26.9)	1,440 (26.3)	1,284 (23.4)	1,282 (23.4)	
Sex, *n* (%)					0.156
Male	783 (26.9)	784 (27.0)	693 (23.9)	646 (22.2)	
Female	688 (26.8)	656 (25.5)	591 (23.0)	636 (24.7)	
Missing	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Race/Ethnicity, *n* (%)					<0.001
Non-Hispanic White	997 (38.7)	788 (30.6)	535 (20.8)	258 (10.0)	
Non-Hispanic Black	96 (16.4)	153 (26.2)	172 (29.5)	163 (27.9)	
Hispanic	263 (12.5)	450 (21.3)	550 (26.0)	849 (40.2)	
Other	108 (57.8)	44 (23.5)	23 (12.3)	12 (6.4)	
Missing	7 (43.8)	5 (31.3)	4 (25.0)	0 (0.0)	
Metropolitan Area, *n* (%)					<0.001
Yes	1,457 (30.2)	1,351 (28.0)	1,008 (20.9)	1,013 (21.0)	
No	14 (2.2)	89 (13.7)	276 (42.6)	269 (41.5)	
Missing	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Diagnosis year, *n* (%)[a]					<0.001
1995–1999	202 (21.2)	249 (26.2)	253 (26.6)	248 (26.1)	
2000–2009	634 (26.6)	613 (25.7)	561 (23.5)	578 (24.2)	
2010–2017	635 (29.7)	578 (27.0)	470 (22.0)	456 (21.3)	
Missing	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Diagnosis age, *n* (%)					0.140
0–4	474 (26.0)	512 (28.1)	436 (23.9)	400 (22.0)	
5–9	408 (26.5)	401 (26.0)	355 (23.0)	377 (24.5)	
10–14	328 (29.4)	274 (24.6)	265 (23.8)	247 (22.2)	
15–19	261 (26.1)	253 (25.3)	228 (22.8)	258 (25.8)	
Missing	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	

[a]Children who were diagnosed with a primary malignant CNS tumor in Texas during the period between January 1, 1995 and December 31, 2017 were included in the study.

most (HR, 1.74; 95% CI, 1.19–2.53) disadvantaged census tracts showed an elevated risk of death compared with children living in the least disadvantaged tracts; however, the findings were not significant for those living in the second-most disadvantaged tracts ($P_{Trend} = 0.006$). The identified point estimates were slightly more pronounced in the adjusted model compared with the crude model; (HR, 1.67; 95% CI, 1.09–2.56; HR, 1.13; 95% CI, 0.75–1.70), and (HR, 1.75; 95% CI, 1.19–2.56) for the most, second most, and third most disadvantaged census tracts, respectively ($P_{Trend} = 0.007$; **Table 2**).

None of the crude and adjusted models revealed significant associations between neighborhood socioeconomic disadvantage and survival of children diagnosed with ependymoma (**Table 2**).

Stratified analyses

We investigated the association between ADI and survival of all pediatric CNS tumors stratified by sex, race/ethnicity, and metropolitan residency. As **Table 3** summarizes, the results revealed significantly increased HRs for death among males in the most and second-most disadvantaged tracts (HR, 1.46; 95% CI, 1.17–1.82 and HR, 1.28; 95% CI, 1.04–1.58, respectively), whereas no statistically significant association was observed among females. In addition, among non-Hispanic Black children, those who live in the most disadvantaged tract showed a significant high risk of death (HR, 2.11; 95% CI, 1.32–3.37), whereas no statistically significant association was observed among non-Hispanic White children. For Hispanic children, a non-significant trend toward elevated HRs with increasing disadvantage in the census tracts was detected. Stratified analysis by metropolitan residency showed significant associations between neighborhood socioeconomic disadvantage and survival of all pediatric CNS tumors among children living in metropolitan areas [(HR 1.28, 95% CI, 1.09–1.52 and HR, 1.19; 95% CI, 1.03–1.39) for the most and third most disadvantaged census tracts, respectively], whereas the findings were nonsignificant among children living in non-metropolitan areas.

Kaplan–Meier estimates

As **Fig. 2** illustrates, among all pediatric CNS tumor cases, children in the least disadvantaged tract had distinct superior survival compared with children in any other ADI quartile, whereas children in the most disadvantaged tract experienced the worse survival ($P < 0.001$). This was also true among astrocytoma ($P < 0.001$) and medulloblastoma cases ($P = 0.005$), although the results were less pronounced. Among ependymoma cases, children in the most disadvantaged tract had worse survival compared with others, but the results were not statistically significant ($P = 0.188$).

Discussion

This study provides evidence that neighborhood socioeconomic disadvantage is associated with adverse survival outcomes among children diagnosed with primary CNS tumors. We identified a significant increasing trend in the hazard for mortality with elevating socioeconomic disadvantage in Texas census tracts. Similar associations were observed among children diagnosed with astrocytoma and medulloblastoma subtypes. In stratified analyses, the association between ADI and CNS tumor survival was modified by sex, such that elevated disadvantage was more strongly associated with increasing

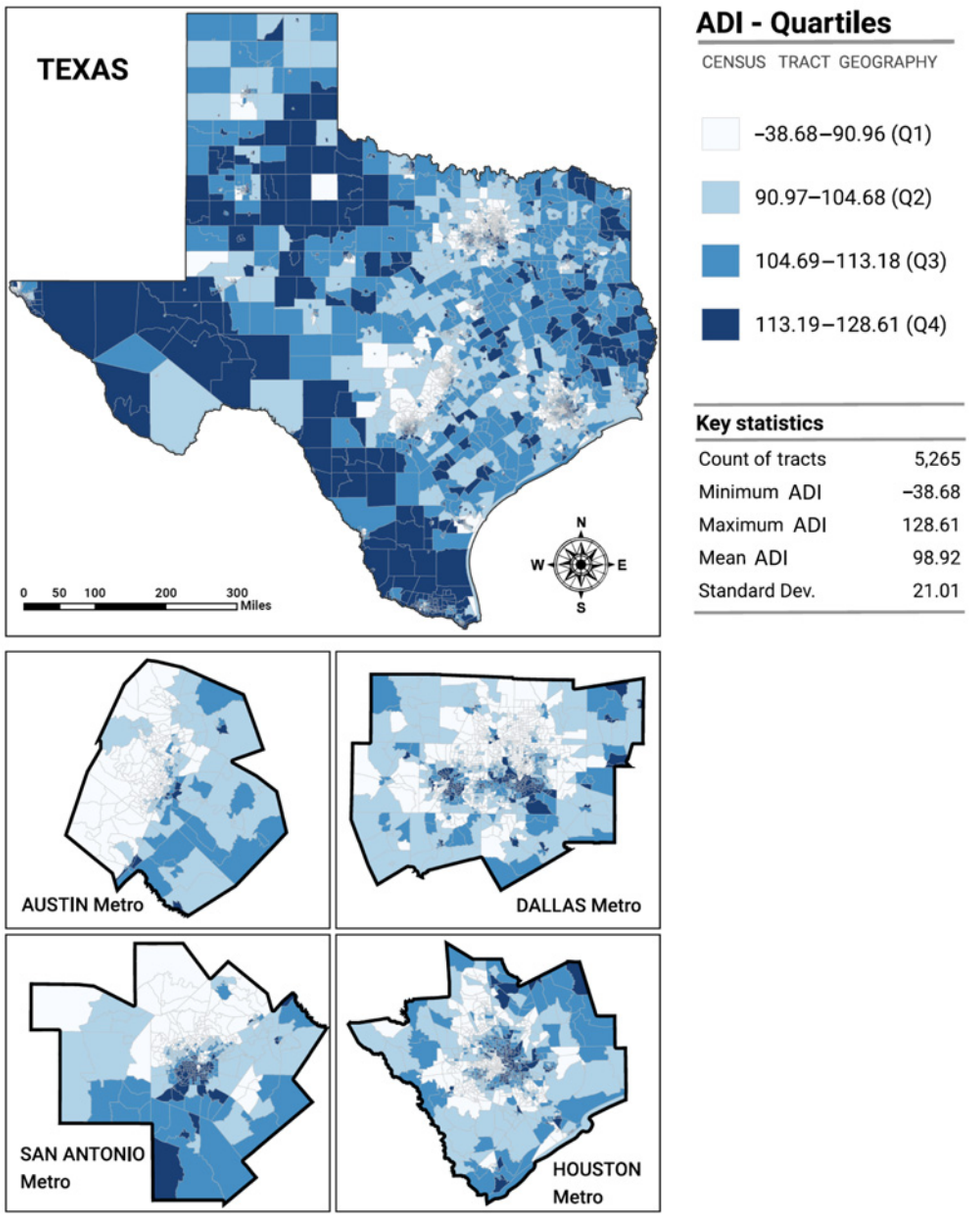

Figure 1.

Distribution of area deprivation index (ADI) scores in Texas and selected metropolitan areas. ADI score was calculated for each census tract ($N = 5,265$) according to the 2010 census geography and data from the 2007–2011 American Community Survey, using the formula of Singh (8). Tracts were grouped into quartiles based on the observed distribution of scores, ranging from least disadvantaged (Q1; white) to most disadvantaged (Q4; dark blue).

mortality in males than females. Similar associations were detected for children living in metropolitan areas compared with those living in non-metropolitan areas and non-Hispanic Blacks compared with non-Hispanic Whites. These findings emphasize the important role of demographic and socioeconomic disparities in the survival of pediatric CNS tumors.

The impact of neighborhood socioeconomic deprivation on survival of some adult (21, 22) as well as pediatric (10–12) cancer types have been previously assessed; however, knowledge on the association between neighborhood socioeconomic disadvantage and survival of children diagnosed with CNS tumors is limited (5). There is evidence that the mechanisms underlying the association between neighborhood socioeconomic deprivation and pediatric cancer survival are multifactorial (23). It has been shown that neighborhood disadvantage is associated with various biological markers pertinent to pediatric cancer survival, including alteration in maternal DNA methylation (24) and shorter maternal telomere length (25). In addition, factors, including access to first-line diagnostics, treatment centers, neurosurgical and neuro-oncological services, and supportive care, may vary by area SES and thus influence pediatric cancer

Table 2. Unadjusted and adjusted associations between ADI and survival of pediatric CNS tumor cases.

All nervous system tumors	Cases	(%)	HR[a] (95% CI)	*P*	HR[b] (95% CI)	*P*
ADI Quartile						
Least disadvantaged	1,471	(26.9)	Reference		Reference	
Third-most disadvantaged	1,440	(26.3)	1.25 (1.08–1.44)	0.003	1.18 (1.02–1.37)	0.024
Second-most disadvantaged	1,284	(23.4)	1.29 (1.12–1.50)	0.001	1.18 (1.01–1.38)	0.038
Most disadvantaged	1,282	(23.4)	1.49 (1.29–1.73)	<0.001	1.29 (1.09–1.51)	0.002
Missing	0	(0.0)				
Race/ethnicity						
Non-Hispanic White	2,578	(47.1)	Reference		Reference	
Non-Hispanic Black	584	(10.7)	1.56 (1.33–1.83)	<0.001	1.49 (1.27–1.76)	<0.001
Hispanic	2112	(38.6)	1.43 (1.28–1.59)	<0.001	1.33 (1.18–1.50)	<0.001
Other	187	(3.4)	1.29 (0.98–1.72)	0.071	1.37 (1.03–1.82)	0.031
Missing	16	(0.3)				
Metropolitan area						
Yes	4829	(88.2)	Reference		Reference	
No	648	(11.8)	0.99 (0.85–1.15)	0.867	0.97 (0.82–1.14)	0.706
Missing	0	(0.0)				
Astrocytoma						
ADI Quartile						
Least disadvantaged	944	(28.4)	Reference		Reference	
Third-most disadvantaged	940	(28.3)	1.13 (0.93–1.37)	0.204	1.07 (0.88–1.30)	0.480
Second-most disadvantaged	759	(22.8)	1.29 (1.06–1.57)	0.010	1.17 (0.95–1.45)	0.134
Most disadvantaged	684	(20.6)	1.50 (1.24–1.83)	<0.001	1.24 (1.00–1.55)	0.050
Missing	0	(0.0)				
Race/ethnicity						
Non-Hispanic White	1,649	(49.6)	Reference		Reference	
Non-Hispanic Black	377	(11.3)	1.63 (1.32–2.01)	<0.001	1.56 (1.26–1.94)	<0.001
Hispanic	1,178	(35.4)	1.53 (1.32–1.78)	<0.001	1.49 (1.26–1.76)	<0.001
Other	116	(3.5)	1.47 (1.02–2.12)	0.037	1.55 (1.08–2.24)	0.018
Missing	7	(0.2)				
Metropolitan area						
Yes	2,982	(89.6)	Reference		Reference	
No	345	(10.4)	0.91 (0.72–1.14)	0.400	0.86 (0.67–1.09)	0.203
Missing	0	(0.0)				
Ependymoma						
ADI Quartile						
Least disadvantaged	102	(22.8)	Reference		Reference	
Third-most disadvantaged	120	(26.8)	1.29 (0.78–2.12)	0.322	1.02 (0.61–1.71)	0.925
Second-most disadvantaged	109	(24.3)	0.91 (0.53–1.56)	0.726	0.71 (0.41–1.25)	0.233
Most disadvantaged	117	(26.1)	1.46 (0.89–2.37)	0.131	1.01 (0.59–1.73)	0.974
Missing	0	(0.0)				
Race/ethnicity						
Non-Hispanic White	184	(41.1)	Reference		Reference	
Non-Hispanic Black	41	(9.2)	1.76 (1.01–3.06)	0.047	1.82 (1.02–3.23)	0.042
Hispanic	214	(47.8)	1.35 (0.93–1.96)	0.114	1.39 (0.93–2.07)	0.113
Other	8	(1.8)	0.49 (0.07–3.59)	0.486	0.52 (0.07–3.83)	0.518
Missing	1	(0.2)				
Metropolitan area						
Yes	388	(86.6)	Reference		Reference	
No	60	(13.4)	1.65 (1.06–2.56)	0.027	1.66 (1.06–2.62)	0.028
Missing	0	(0.0)				
Medulloblastoma						
ADI Quartile						
Least disadvantaged	175	(26.2)	Reference		Reference	
Third-most disadvantaged	148	(22.2)	1.74 (1.19–2.53)	0.004	1.75 (1.19–2.56)	0.004
Second-most disadvantaged	167	(25.0)	1.11 (0.75–1.64)	0.613	1.13 (0.75–1.70)	0.555
Most disadvantaged	178	(26.7)	1.58 (1.09–2.27)	0.014	1.67 (1.09–2.56)	0.018
Missing	0	(0.0)				
Race/ethnicity						
Non-Hispanic White	279	(41.8)	Reference		Reference	
Non-Hispanic Black	61	(9.1)	0.94 (0.59–1.49)	0.786	0.85 (0.52–1.38)	0.507
Hispanic	297	(44.5)	1.12 (0.85–1.47)	0.421	0.97 (0.71–1.32)	0.828
Other	29	(4.3)	0.99 (0.50–1.97)	0.990	1.13 (0.56–2.25)	0.736
Missing	2	(0.3)				

(Continued on the following page)

Table 2. Unadjusted and adjusted associations between ADI and survival of pediatric CNS tumor cases. (Cont'd)

All nervous system tumors	Cases	(%)	HR[a] (95% CI)	*P*	HR[b] (95% CI)	*P*
Metropolitan area						
Yes	584	(87.4)	Reference		Reference	
No	84	(12.6)	0.87 (0.59–1.29)	0.488	0.79 (0.53–1.22)	0.296
Missing	0	(0.0)				

Abbreviations: ADI, area deprivation index; CI, confidence interval.
[a]Hazard ratios were not adjusted for any variable.
[b]Hazard ratio adjusted for all variables in the model in addition to sex, diagnosis year (continuous), and age at diagnosis (continuous).

survival (3, 4, 23). Other basic living factors such as instability in housing and food access also play important roles in the observed associations as issues in access to basic needs will consequently influence resolving other needs, including access to health care services. The possible implementations of these findings in planning treatment strategies for the susceptible groups include encouraging them to participate in clinical trials, equally distributing them in treatment centers, and providing them more intensive supportive care. Overall, although screening of the social determinants of health is important in achieving a better outcome, it is often not part of the clinical care and therefore it should be taken into consideration. In addition, it is beneficial to potentially provide the susceptible groups links to community resources to cover their needs beyond what can be addressed in the clinical setting.

Previous assessments have shown an association between parental SES and pediatric CNS tumor survival (5–7). As reviewed by Mogensen and colleagues (6), there is evidence of an association between lower parental SES and higher mortality among pediatric CNS tumor cases. Furthermore, Fineberg and colleagues (5), by using county-level socioeconomic information based on census data, obtained from SEER data that cover approximately 28% of the U.S. population, identified that living in areas with high poverty was associated with poorer survival in children diagnosed with CNS tumors. Thus, our findings on area SES are in line with previous reports on individual-level as well as area SES.

In addition, there is evidence of sex and racial/ethnic disparities in survival of pediatric CNS tumors (5, 26, 27). Survival is worse among males and non-Hispanic Blacks compared with females and non-Hispanic Whites, diagnosed with pediatric CNS tumors (5, 26). In this study, we observed that increasing neighborhood socioeconomic deprivation was associated with worse survival among males but not females. Also, living in the most disadvantaged tract was associated with significantly poorer survival among non-Hispanic Blacks but not non-Hispanic Whites. The mechanisms underlying these observed associations are unclear. However, hormonally mediated epigenetic alterations in response to exposure to neighborhood disadvantage (28), genetic variability, and sociocultural differences among racial groups could explain these observations (3, 4).

The significant strengths of our study are that it is population-based assessing one of the most racially, ethnically, and geographically diverse states in the U.S. Using population-based registry data for case identification and obtaining information about vital status, residency at diagnosis, and demographic characteristics limit selection and recall bias. In addition, to our knowledge, this is the only available study to date, investigating the association between neighborhood socioeconomic disadvantage and the survival of pediatric CNS tumors by using ADI, a comprehensive index, based on census tract that is a small and homogenous unit.

Given these strengths, our study also has some limitations. Although the study was performed on the basis of one of the largest

Table 3. Adjusted associations between ADI and survival of all pediatric CNS tumor cases stratified by sex, race/ethnicity, and metropolitan residency.

ADI Quartile	Cases	HR (95% CI)	*P*	Cases	HR (95% CI)	*P*
		Male[a]			**Female[a]**	
Least disadvantaged	783 (26.9)	Reference	688 (26.8)		Reference	
Third-most disadvantaged	784 (27.0)	1.21 (0.99–1.48)	0.068	656 (25.5)	1.15 (0.93–1.42)	0.200
Second-most disadvantaged	693 (23.9)	1.28 (1.04–1.58)	0.023	591(23.0)	1.07 (0.85–1.35)	0.544
Most disadvantaged	646 (22.2)	1.46 (1.17–1.82)	0.001	636 (24.7)	1.12 (0.89–1.42)	0.336
		Non-Hispanic White[b]			**Non-Hispanic Black[b]**	
Least disadvantaged	997 (38.7)	Reference		96 (16.4)	Reference	
Third-most disadvantaged	788 (30.6)	1.19 (0.98–1.45)	0.071	153 (26.2)	1.38 (0.85–2.26)	0.193
Second-most disadvantaged	535 (20.8)	1.21 (0.96–1.52)	0.109	172 (29.5)	1.33 (0.82–2.17)	0.250
Most disadvantaged	258 (10.0)	1.15 (0.86–1.55)	0.347	163 (27.9)	2.11 (1.32–3.37)	0.002
		Metropolitan area[c]			**Non-metropolitan area[c]**	
Least disadvantaged	1,457 (30.2)	Reference		14 (2.2)	Reference	
Third-most disadvantaged	1,351 (28.0)	1.19 (1.03–1.39)	0.017	89 (13.7)	1.02 (0.29–3.44)	0.981
Second-most disadvantaged	1,008 (20.9)	1.16 (0.98–1.36)	0.079	276 (42.6)	1.40 (0.44–4.46)	0.565
Most disadvantaged	1,013 (21.0)	1.28 (1.09–1.52)	0.003	269 (41.5)	1.43 (0.45–4.53)	0.546

Abbreviation: ADI, area deprivation index.
[a]Adjusted for race/ethnicity, metropolitan residency, diagnosis year (continuous), and age at diagnosis (continuous).
[b]Adjusted for sex, metropolitan residency, diagnosis year (continuous), and age at diagnosis (continuous).
[c]Adjusted for sex, race/ethnicity, diagnosis year (continuous), and age at diagnosis (continuous).

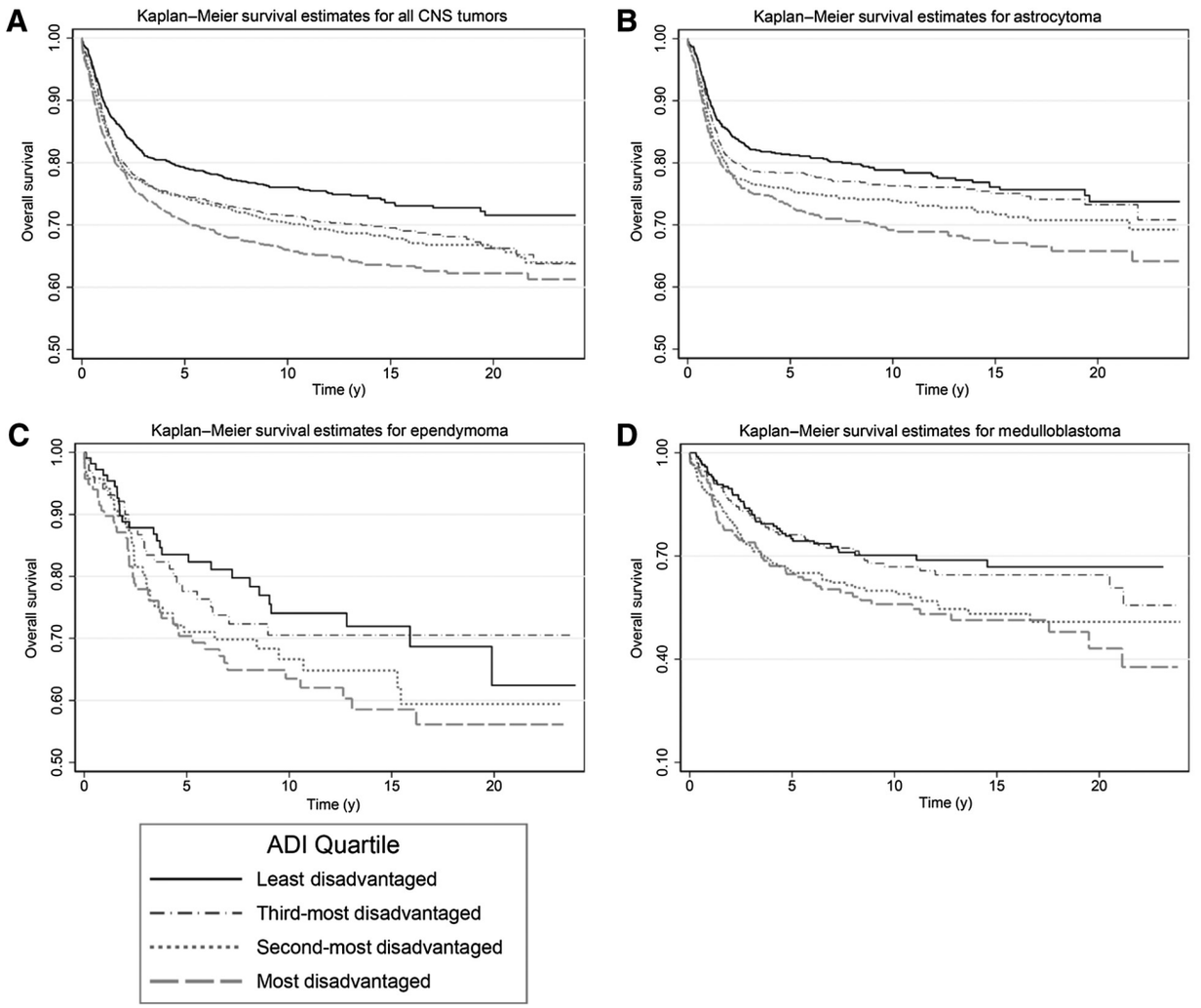

Figure 2.

Kaplan–Meier estimates for overall survival (OS) in cases with pediatric central nervous system tumors according to area deprivation index (ADI; $n = 5{,}477$). OS based on Kaplan–Meier estimates for (**A**) all CNS tumor cases and ADI Quartile ($P < 0.001$); **B,** Astrocytoma cases and ADI Quartile ($P < 0.001$); **C,** Ependymoma cases and ADI Quartile ($P = 0.188$); **D,** Medulloblastoma cases and ADI Quartile ($P = 0.005$).

existing series of pediatric CNS tumors, the sample size was not large enough to investigate the association between neighborhood socioeconomic disadvantage and rare histological subtypes. In addition, the cancer registry did not have information on parental education, and income as well as insurance status of children. Texas contains 5 out of 10 U.S. counties with the largest numbers of uninsured children (Harris, Dallas, Tarrant, Hidalgo, and Bexar counties; ref. 29). However, we were not able to investigate the effects of these potential confounders on our analyses. Furthermore, information on the molecular characterization of the histological subtypes of brain tumors was not available in the cancer registry; thus, our ability to investigate the mechanisms underlying these findings is limited.

In conclusion, this large registry-based study provides evidence that neighborhood socioeconomic disadvantage is associated with pediatric CNS tumor survival. We found that children living in the most disadvantaged neighborhoods experienced a significantly higher risk of mortality compared with those in the least disadvantaged tracts; and the survival was worse among males. The demographic and socioeconomic disparities identified by this study should be considered when planning treatment strategies for these susceptible groups and thus, lead to a better outcome in socioeconomically disadvantaged children diagnosed with CNS tumors.

Authors' Disclosures

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Authors' Contributions

M. Adel Fahmideh: Formal analysis, investigation, visualization, writing–original draft. **J.M. Schraw:** Formal analysis, writing–review and editing. **M. Chintagumpala:** Investigation, writing–review and editing. **P.J. Lupo:** Conceptualization, resources, writing–review and editing. **A.O. Oluyomi:** Conceptualization, formal analysis, methodology, writing–review and editing. **M.E. Scheurer:** Conceptualization, resources, supervision, methodology, writing–review and editing.

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