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Population-based impact of rurality and neighborhood-level socioeconomic disadvantage on pediatric cancer mortality in Washington State

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Abstract

Background: Childhood cancer mortality differs by socioeconomic factors, but the impact of residential location, including rurality and neighborhood-level socioeconomic disadvantage, is not well-characterized.

Methods: This retrospective cohort study linked Washington State cancer registry data (1992-2013) to state birth (1974-2013) and death records (1992-2013) to identify residents <20 years diagnosed with cancer (n=4,306). Census-based rural-urban commuting area codes and Area Deprivation Index (ADI) defined rural residence and neighborhood socioeconomic disadvantage at time of cancer diagnosis, respectively. Neighborhoods in the highest state ADI quintile were classified as the most disadvantaged. Kaplan-Meier estimates and Cox hazards models, adjusted for key characteristics, were used to compare mortality by rural and ADI classification.

Results: Five-year overall survival for children from non-rural low ADI neighborhoods (referent) was 80.9±0.8%, versus 66.4±2.9% from non-rural high ADI neighborhoods, 69.4±3.8% from rural low ADI neighborhoods, and 66.9±3.8% from rural high ADI neighborhoods ($p<0.01$ for each comparison versus referent). Compared with the referent group, children from comparator neighborhoods had a greater mortality risk: rural low ADI (hazard ratio [HR] 1.50, 95% confidence interval [CI] 1.12–2.02), rural high ADI (HR 1.53, 95% CI 1.16–2.01), and non-rural high ADI (HR 1.64, 95% CI 1.32–2.04). Associations of ADI and rurality with mortality varied in sub-analyses by cancer type.

Conclusions: Children with cancer living in rural and/or socioeconomically disadvantaged neighborhoods at diagnosis experienced greater mortality relative to those without either factor.

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Impact: Future investigation is needed to examine how rurality and poverty potentially impact healthcare utilization and health-related outcomes in pediatric oncology.

Keywords

Pediatric cancers; rural populations; social deprivation; cancer disparities; survival analysis; survivorship research

INTRODUCTION

Despite advances in care that have resulted in an approximate 85% 5-year survival, cancer remains the leading non-injury cause of childhood and adolescent mortality in the United States (1,2). Disparities in cancer-related outcomes persist (3), and mortality differences related to race and ethnicity (4–6), health insurance coverage (7,8), and poverty/socioeconomic status (5,9–13) are well-established. Geographic factors such as travel time to treatment center and rural/urban status have been studied to a lesser extent, but emerging evidence provides rationale for concern. Rural or geographically remote residence at cancer diagnosis is associated with unique challenges during treatment, lower school attendance, and increased caregiver stress (14,15).

Limited investigation of pediatric cancer survival related to geographic factors has yielded mixed results to date, for both children with hematologic and solid organ malignancies (16–21). A national U.S. study using cancer registry data from the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) Program found no difference in childhood cancer survival based on county-level rural-urban continuum code designation with adjustment for county level median income and other factors (22). However, county-level measurement does not account for the considerable geographic variation present in many U.S. counties, and may potentially mask differences through misclassification (23,24). For this reason, more precise geographic designations, when available, are favored over county-level measures, particularly when comparing individuals based on rurality (25).

We used population-based databases from Washington State (WA) to evaluate whether rural residence—in combination with socioeconomic factors—impacts pediatric cancer mortality. Given the heterogeneity of disease and treatment characteristics by cancer type, we also examined whether any associations between these factors and mortality differed by cancer type.

MATERIALS AND METHODS

Database linkage and study population

This retrospective cohort study utilized a database linkage between WA cancer registries (1992-2013) and state birth (1974-2013) and death (1992-2013) records as part of an existing study to identify individuals born in WA who were diagnosed with cancer at <20 years of age from 1992-2013 (26). We obtained cancer data from two population-based cancer registries in WA that together capture all cases of pediatric cancer in the state: (1) the SEER program-funded Cancer Surveillance System (CSS) and (2) the Washington State Cancer Registry (WSCR), funded by the Centers for Disease Control and

Prevention's National Program of Central Cancer Registries. Both cancer registries provided diagnosis date, International Classification of Childhood Cancer (ICCC) third edition cancer type, International Classification of Diseases for Oncology (ICD-O) code, demographic information at diagnosis (age, sex, race, ethnicity), basic initial treatment information (chemotherapy, radiation, and/or surgery), and census block group-level residence at diagnosis. Sex assigned at birth was identified from birth certificate records.

Diagnoses representing non-malignant disease—typically non-malignant central nervous system (CNS) tumors, non-melanomatous skin cancers, or cervical carcinoma in situ—were excluded from analysis (n=641). Cases missing data for race and ethnicity (n=57) or census designation (n=15), and those living in locations missing key indicators for calculation of area-level predictor variables (n=39), were also excluded, 111 (2.5%) total cases. We determined vital status via CSS/WSCR's quarterly follow up and the state death registry, the latter of which maintains agreements with the National Center for Health Statistics and the WA Department of Health to identify deaths to residents occurring out of state. We evaluated all-cause mortality, as 94% of deaths listed cancer as the cause of death.

This study was approved by the Institutional Review Boards of the Fred Hutchinson Cancer Center and the WA Department of Health. The requirement for written informed consent was not required for this study.

Predictor definitions

Census tracts are relatively permanent statistical subdivisions of a county that each contain approximately 4,000 residents (1,500 housing units) and are designed to be relatively homogeneous with regard to demographic characteristics and living conditions (27). Census block groups are more refined geographic subdivisions of census tracts, containing approximately 1,500 people each and closely resembling neighborhoods (27). All study cases were geocoded to 2010 U.S. Census block groups.

Rurality—Using 2010 Census Rural-Urban Commuting Area (RUCA) codes corresponding to census tract at diagnosis, residences were classified as rural (primary RUCA code 4-10) or non-rural (primary RUCA code 1-3), consistent with recommendations (25,28).

Neighborhood socioeconomic status—Area deprivation index (ADI) is a composite measure consisting of 17 items concerning income, employment, education, and housing, developed from U.S. Census data and the American Community Survey to proxy neighborhood-level socioeconomic disadvantage (29). ADI has been used to assess the impact of neighborhood socioeconomic disadvantage on healthcare access and outcomes, including pediatric cancer (11,12). Scores by census block group are reported as national percentiles, with 1 indicating the lowest level of socioeconomic disadvantage and 100 corresponding to the greatest socioeconomic disadvantage. State-level norms have been established, including for WA. *A priori*, we categorized all WA census block groups as either having high ADI or low ADI, using a cutoff of the highest WA quintile to define high ADI neighborhoods. The 80th percentile ADI cutoff that we used for WA corresponded to approximately the 66th percentile of social deprivation on the national scale.

Statistical analysis

We estimated 5- and 15-year overall survival (OS) by rural residence and ADI classification with Kaplan-Meier survival analysis. Differences in OS were compared between neighborhood groups using pairwise log rank tests. We then used Cox proportional hazard models to estimate mortality hazard ratios (HR) with 95% confidence intervals (CI) according to rural and ADI status as our main predictors of interest. Cox models were adjusted for race and ethnicity, sex assigned at birth, age at diagnosis (categorically: <1, 1-4.9, 5-9.9, 10-14.9 and ≥15 years), birth year (ordinally: by decade), and ICCC category. Multivariate models notably did not include insurance information, due to incomplete data in the cancer registry (n=2629 missing). Receipt of chemotherapy, surgery, and/or radiation was not included in multivariate models, as these were likely mediators, rather than confounders, of the exposures and outcomes of interest. We did, however, perform descriptive statistics to compare rates of these treatments by neighborhood classification. Proportionality assumptions for each model were verified by plotting and testing Schoenfeld residuals (30). To address potential challenges to proportionality assumptions, we performed stratified Cox regression for some variables, allowing for separate baseline hazards by age at diagnosis, birth year, and ICCC. To test for effect modification between rurality and ADI classification, we also included an interaction term between rural status and high ADI. Because this term was significant, we performed Kaplan-Meier estimates and Cox proportional hazards models with rurality and ADI status categorized into four mutually exclusive groupings: non-rural with low ADI (referent), non-rural with high ADI, rural with low ADI, and rural with high ADI. Results with cell sizes <5 were nctressed in all tables.

We performed two sensitivity analyses to examine the robustness of our main Cox regression models and ADI definitions. First, we created an identical hazards model to the main analysis, but instead defined high ADI using the highest WA quartile rather than the highest quintile. This cutoff corresponded to the 44th percentile on the national scale. We tested a statistical interaction term between rural residence and high ADI, followed by analysis by neighborhood grouping. Next, we tested an interaction term between rural residence and linear national ADI percentile, rather than a binary variable, in an otherwise identical multivariate model.

We also performed separate Cox regression sub-analyses by cancer type: acute lymphoblastic and myeloid leukemias (ALL, AML), lymphoma, CNS malignancies, and other solid tumors (neuroblastoma, renal tumors, hepatoblastoma, bone tumors, soft tissue sarcomas, and malignant germ cell tumors). Categories were determined using ICCC group types and ICD-O-3 morphology codes. Specifically, acute lymphoblastic leukemia (ALL) was defined using the ICCC classification of leukemia, in addition to one of the following ICD-O-3 codes: 9811/3-9818/3 or 9835/3-9837/3. Acute myeloid leukemia (AML) was defined by having the ICCC leukemia classification plus one of the following ICD-O-3 codes: 9840/3, 9860/3, 9861/3, 9865/3-9874/3, 9876/3-9912/3, or 9930/3. Multivariate HRs of these hazards models adjusted for the same variables as the main model, except rural residence and high ADI were adjusted for individually, as opposed to a multi-level combined variable, because there was no significant statistical interaction between these predictors in

cancer type-specific sub-analyses. All analyses were conducted with R 4.1.3 (R Foundation, Vienna, Austria) and utilized the 'survival' package (31).

Data availability

The data generated in this study are not publicly available to protect patient privacy and confidentiality, and are available only with separate approval from the WA Institutional Review Board.

RESULTS

Demographics

The study sample included 4,306 cases after exclusions (51.7% male; 77.7% non-Hispanic White), with 20% of the study population residing in a neighborhood classified as high ADI and 13% residing in a rural neighborhood at the time of diagnosis (Table 1). Proportions of cases identified as having Hispanic ethnicity were greater in rural and/or high ADI neighborhoods compared with the total cohort. Distribution of sex and diagnosis type did not seem to differ in rural and/or high ADI cases. Cancer survivors were followed up for a median of 5.0 years (inter-quartile range 1.0-11.5). Over the study period, 18.9% of the cohort died, with 94% of deaths reported as cancer-related.

Association of neighborhood categories with mortality

Estimated 5-year OS for the referent group (children from non-rural neighborhoods with low ADI) was 80.9% (Figure 1). For children from neighborhoods that were non-rural with high ADI, rural with low ADI, and rural with high ADI, 5-year OS was 66.4%, 69.4%, and 66.9%, respectively. Estimated 15-year OS in the referent group was 75.8%. For comparison neighborhoods, 15-year OS was 57.0%, 66.9%, and 56.2%. Compared with the referent category, OS was significantly lower for all comparison groups by pairwise log rank testing at 15 years (Figure 1). Survival did not differ significantly between the three comparison categories themselves. OS at 5 years differed similarly via log rank testing.

In adjusted Cox proportional hazards models, residence in neighborhoods categorized as non-rural with high ADI, rural with low ADI, or rural with high ADI was associated with greater mortality relative to living in a non-rural neighborhood with low ADI, with HRs of 1.64 (95% CI 1.32–2.04), 1.50 (95% CI 1.12–2.02), and 1.53 (95% CI 1.16–2.01), respectively (Table 2). In adjusted analyses, Hispanic ethnicity was also associated with increased mortality compared with those identifying as non-Hispanic White.

Effect modification between rurality and ADI

In our proportional hazards model, the interaction term between rural status and high ADI was significant ($p=0.03$), suggestive of effect modification. Therefore, we also plotted Kaplan-Meier survival curves stratified by rurality and ADI status (Figure 2). Amongst children from non-rural neighborhoods, we found a survival difference based on ADI classification (log rank test, $p<0.001$). However, for children from rural neighborhoods, ADI did not have an appreciable survival effect (log rank test, $p=0.58$). Similarly, rural status had a strong effect on survival among children from low ADI neighborhoods (log

rank test, p<0.001), but not among children from high ADI neighborhoods (log rank test, p=0.60). We observed similar results in our stratified Cox proportional hazards models. In the non-rural subset of children, the adjusted mortality Cox HR for high ADI versus low ADI was 1.76 (95% CI 1.43–2.17, p<0.0001). In the rural subset, no association with ADI was identified (HR 1.07, 95% CI 0.72–1.58, p=0.75). Similarly, when stratified by ADI category, the association between rurality and survival varied. Rural residence was associated with mortality in the low ADI subset (HR 1.56, 95% CI 1.17–2.07, p=0.002), but not in the high ADI subset (HR 0.94, 95% CI 0.68–1.29, p=0.68). There was no statistical interaction identified between rurality and ADI category in cancer type-specific sub-analyses (Table 3); therefore, we did not calculate HRs for neighborhood groupings outside of the main analysis.

Disease-specific sub-analyses

When individual associations of rural residence and high ADI for different cancer types were examined (Table 3), rural status (HR 1.82, 95% CI 1.01–3.27), but not high ADI (HR 1.16, 95% CI 0.69–1.97) was associated with greater mortality among children with ALL. For children with solid tumors, high ADI was associated with mortality (HR 1.62, 95% CI 1.16–2.26), but not rural status (HR 1.06, 95% CI 0.72–1.56). Similar results were observed among children with CNS tumors, for whom high ADI (HR 1.47, 95% CI 1.01–2.13) but not rural status (HR 1.08, 95% CI 0.70–1.68) was associated with mortality. No associations for ADI or rurality were detected in children with AML or lymphoma, the two smallest cancer type categories.

Sensitivity analyses

The Cox hazards model with ADI corresponding to the highest WA quartile, rather than quintile, was similar to the main analysis. The interaction between rural status and ADI remained significant (p=0.036). HRs by neighborhood grouping were also similar. Residence in neighborhoods categorized as non-rural with high ADI, rural with low ADI, or rural with high ADI was associated with HRs of 1.75 (95% CI 1.41–2.08), 1.49 (95% CI 1.06–2.07), and 1.60 (95% CI 1.23–2.07), respectively. In our sensitivity analysis using national ADI percentile, the statistical interaction between rural status and ADI in the multivariate model also remained significant (p=0.005).

DISCUSSION

In this population-based study of more than 4,000 children with cancer in WA, we observed mortality differences associated with rural residence and neighborhood-level socioeconomic disadvantage defined by geocoded address information. Compared with children living in non-rural neighborhoods with lower socioeconomic disadvantage at diagnosis and after adjusting for important patient- and disease-related factors, children in neighborhoods with rurality and/or high poverty experienced greater mortality. Socioeconomic status also modified the effect of rurality on mortality. Rural residence was associated with greater mortality amongst children living in neighborhoods with low socioeconomic disadvantage, but not for children in neighborhoods with greater socioeconomic disadvantage. We also observed variability in the relative impact of rurality and neighborhood poverty by cancer

type. Most notably, among children with ALL, rural residence was associated with mortality, whereas among children with CNS and solid tumors, neighborhood socioeconomic status had a stronger association.

Our finding of an association between mortality and rural residence in children with cancer in WA is novel. Although associations between rurality and cancer mortality have been demonstrated in adults (32–34), our findings contrast with prior pediatric studies in the U.S., which were conducted with SEER national cancer registry data over similar time periods to our study and did not detect an association between county-level rurality and mortality (22,35). However, county-level designations of rurality are subject to greater misclassification compared with the more granular census block group and tract-level definitions we used (23–25). Another potential explanation for this discrepancy is that WA cancer cases may differ from other U.S. regions with respect to sociodemographic factors, geography, distribution of cancer centers, and/or legislative policy. In the 2020 Census, WA's rural distribution (16.0%) is similar to the U.S. aggregate (19.3%), ranking 35th of 50 states (36). WA's rates of poverty (18.2%) and health insurance coverage (93.6%) in children <18 years rank similarly (19th and 25th, respectively) (36). Conversely, WA has comparatively greater educational attainment (31.1% of adults >25 years with a bachelor's degree or higher, ranked 11th) (36). However, given prior work associating geographic distance or rurality with cancer survival outcomes in specific populations (18,20), these findings may be applicable to other states, and possibly much of the U.S.

The demonstrated association of neighborhood-level poverty with mortality corroborates previously published survival disparities in multiple pediatric cancer types (8–12). This association may be reflective of the impact of household socioeconomic status on survival, although effects of the neighborhood environment itself—such as food deserts, healthcare resources, or community support—likely exert additional influence beyond individual household financial resources. However, our study design cannot evaluate the impact of household poverty itself. Additionally, historical race-based discriminatory policies, such as redlining, have been known to shape neighborhood socioeconomic factors that are associated with poorer pediatric health outcomes (37). While not the main focus of this study, survival disparities related to race and ethnicity were also identified in our multivariate analysis, consistent with existing literature (4–6). The impact of systemic racism on pediatric cancer mortality deserves continued attention.

The mechanisms by which rural/non-rural survival differences may occur are not fully understood. Travel time to cancer care could inherently contribute to poorer outcomes. Geographically distant families, in the U.S. and elsewhere, are known to spend significant time and resources on travel, which may increase stress and difficulty with treatment adherence (14,38). The stronger associations with rurality observed amongst patients with ALL—for which treatment is largely outpatient, is longer in duration, and involves frequent travel—may support this, as other authors have also hypothesized (18). Barriers to accessing emergency care are also documented, and patients in communities with fewer pediatric healthcare resources could be at greater risk for complications such as severe infection (15), or therapy-related comorbidities that may contribute to later mortality differences. It is also possible that children in rural locations have less access to diagnostic resources,

leading to delayed diagnosis and more advanced disease at presentation, as observed in adults (39). However, pediatric research to date has not necessarily supported this (21). Finally, rural-dwelling patients may experience greater difficulty accessing clinical trials or specialized treatment for relapsed or refractory cancer, access to which may mediate important survival disparities in some marginalized populations (40).

In adults with cancer, whereas clear disparities exist for rural patients, receiving treatment at an academic cancer center versus a community clinic is associated with improved survival and mitigates much of this risk (41). Such results are likely confounded by socioeconomic status or other factors, as rural adults traveling to central locations may be more affluent or have different functional status compared with those receiving local care. Given the centralized nature of pediatric cancer care (42), it is also likely that proportionately fewer rural children receive cancer treatment at non-tertiary centers compared with adults. However, our study did not explicitly confirm this, as the cancer registry data did not precisely define patients' treating institutions. Further investigation will help elucidate mechanisms by which geographic survival disparities may develop.

Mechanisms underlying the observed effect modification between ADI and rurality are also unclear. Our observation of ADI-related survival disparities being greater in non-rural versus rural areas could indicate non-rural locations to be more sensitive to neighborhood poverty, whether due to the built environment, systemic discrimination or racism, public policy, or other factors. Conversely, survival disparities related to rurality—apparent in low ADI neighborhoods only—may suggest that rurality impacts certain protective factors more commonly present in wealthier versus less-resourced areas. Finally, rural residence, itself associated with higher ADI (43), may be associated with other unmeasured socioeconomic disadvantage incompletely accounted for by ADI in our analyses. Ultimately, understanding these mechanisms will be critical to tailor interventions and policymaking to address these factors independently.

Interventions to address potential gaps are lacking in pediatrics, but initiatives to address other disparities may provide insight. For rural adults, telehealth and other strategies to decentralize specialty oncology care have been successful (44–46). In pediatric oncology, a program providing remote hospice support to rural populations was feasible (47). Similarly, increased participation from community centers for supportive care and oncologic emergencies could ameliorate difficulties that geographically remote families report during treatment (15). Rigorous financial support for housing and transportation is another promising strategy, the feasibility and effectiveness of which are currently being studied in pediatric populations with low household income (48). If effective, similar approaches could be considered for families traveling long distances for care.

This study has several limitations. First, socioeconomic status was measured at the census block group level but not at the household level, potentially understating the effect of household socioeconomic factors. Nevertheless, census block group data represent a more focused measurement of area-level socioeconomic status than used in many prior studies, reducing misclassification of neighborhood deprivation. While our analysis adjusted for several important patient and disease factors—including treatment era, proxied by age at

diagnosis and birth year—the extent of missing insurance data precluded its inclusion as a covariate. The relatively small samples sizes of some disease types should also prompt caution in the interpretation of our sub-analyses. In addition, our study time period consists largely of years preceding the Affordable Care Act, which may have benefitted health care access disproportionately for patients identified as rural and/or impoverished (49,50), potentially limiting generalizability to the current era. Finally, measurements of census tract/block group data were also taken at a single point in time and may introduce misclassification. However, RUCA classifications in WA appear to be relatively stable over the study period (25).

In summary, we observed novel pediatric cancer survival disparities associated with rural residence in combination with the well-known impact of neighborhood socioeconomic disadvantage over a 20-year period in Washington State. We also observed effect modification between rurality and neighborhood socioeconomic disadvantage with regard to mortality. Future investigation is necessary to confirm these results in other U.S. populations, and to examine how rurality and socioeconomic factors impact other health-related outcomes such as hospital utilization, treatment complications/morbidity, health-related quality of life, financial toxicity, and clinical trial enrollment. Additional analyses incorporating geographic distance to care as a possible mechanism underlying these disparities are also warranted. Such strategies may elucidate mechanisms and mediators of survival disparities. Investigation into the variability of effects by cancer type is also merited. Ultimately, interventions to address these disparities will be necessary.

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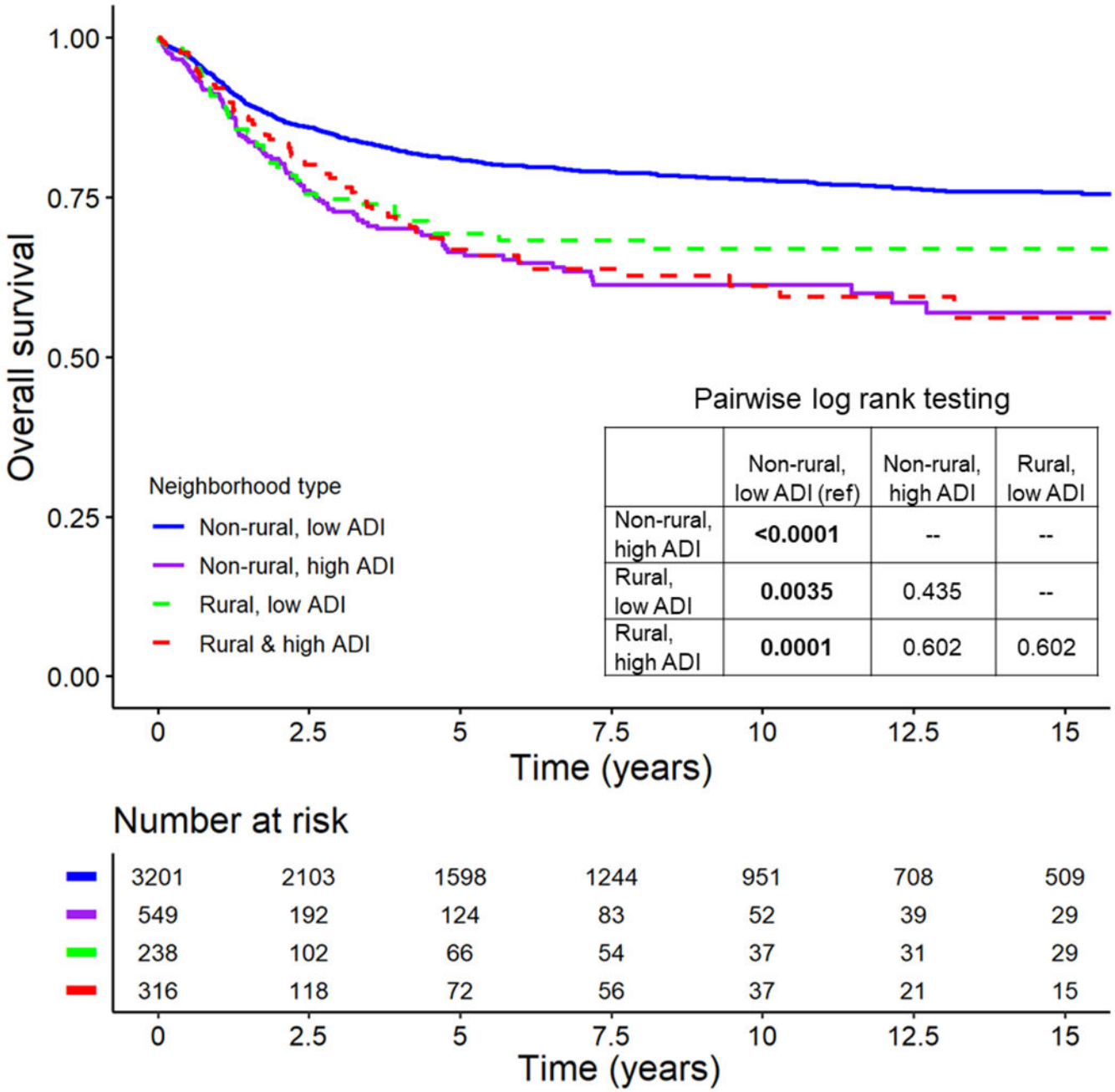

FIGURE 1.

Kaplan-Meier survival estimates for all Washington State children diagnosed with cancer, 1993-2013, according to neighborhood characteristics. 5-year overall survival (OS) for children living in non-rural low area deprivation index (ADI) neighborhoods was 80.9% ± 0.8%, versus 66.4% ± 2.9% for non-rural with high ADI, 69.4% ± 3.8% for rural with low ADI, and 66.9% ± 3.8% for rural with high ADI. Estimated 15-year OS in the referent group was 75.8% ± 1.0%, compared with 57.0% ± 3.8% for non-rural with high ADI, 66.9% ± 4.1% for rural with low ADI, and 56.2% ± 5.3% for rural with high ADI. Pairwise log rank testing represents OS differences at 15 years.

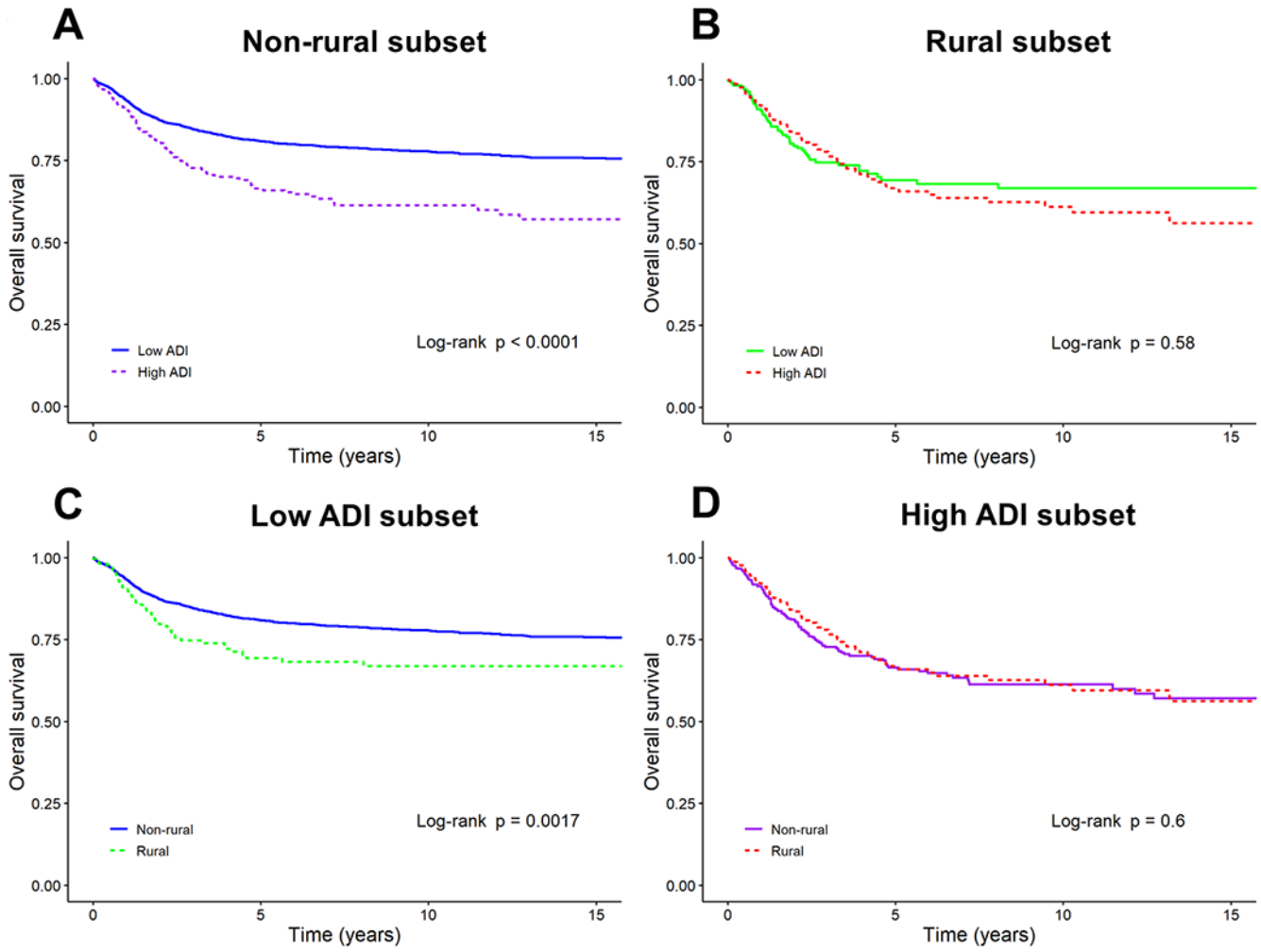

FIGURE 2.

Kaplan-Meier survival estimates for Washington State children diagnosed with cancer, 1992-2013, stratified by rural classification (A, non-rural patients; B, rural patients) and neighborhood area deprivation index (ADI) status (C, low ADI; D, high ADI).

Table 1:

Characteristics of children < 20 years old with cancer in Washington State, diagnosed 1992-2013

Characteristic	Total cohort n = 4,306		Children in rural neighborhoods n = 554		Children in neighborhoods with high socioeconomic disadvantage[b] n = 865	
	N	%	N	%	N	%
Sex						
Female	2,078	48.3	284	51.3	419	48.4
Male	2,228	51.7	270	48.7	446	51.6
Race & ethnicity						
Alaska Native or Native American	98	2.3	>5		>5	
Asian	200	4.6	<5		>5	
Black (non-Hispanic)	168	3.9	>5		>5	
Hispanic	457	10.6	124	22.4	213	24.6
Pacific Islander or other race	36	0.9	<5		<5	
White (non-Hispanic)	3,347	77.7	396	71.5	552	63.8
Age at diagnosis (years)						
0-0.99	382	8.9	47	8.5	78	9.0
1-4.99	1,231	28.6	162	29.2	305	35.3
5-9.99	745	17.3	89	16.1	135	15.6
10-14.99	744	17.3	97	17.5	137	15.8
15+	1,204	28.0	159	28.7	210	24.3
Cancer type						
Central nervous system	986	22.9	116	20.9	177	20.5
Acute lymphoblastic leukemia	854	19.8	120	21.7	193	22.3
Acute myeloid and other leukemia	287	6.7	28	5.1	59	6.8
Lymphoma	583	13.5	71	12.8	111	12.8
Solid tumor	1,216	28.2	160	28.9	261	30.2
Other malignancy[c]	380	8.8	59	10.6	64	7.4
Treatment era						
1993-1999	1,358	31.5	199	35.9	288	33.3
2000-2013	2,948	68.5	355	64.1	577	66.7
Received chemotherapy[d]						
Yes	2,508	69.0	274	71.9	417	75.0
No	1,128	31.0	107	28.1	139	25.0
Received radiation[d]						
Yes	1,132	26.6	147	26.8	211	24.6
No	3,123	73.4	401	73.2	648	75.4

Characteristic	Total cohort n = 4,306		Children in rural neighborhoods n = 554		Children in neighborhoods with high socioeconomic disadvantage[b] n = 865	
	N	%	N	%	N	%
Received surgery[d]						
Yes	2138	49.6%	278	50.2%	432	50.0%
No or not applicable	1994	46.3%	255	46.0%	411	47.5%
Unknown	174	4.0%	21	3.7%	22	2.5%
Vital status						
Alive	3,492	81.1	437	78.9	686	79.3
Deceased	814	18.9	117	21.1	179	20.7

[a] Some percentages may not add up to 100% due incomplete rounding. The rural and high ADI categories are not mutually exclusive and there is overlap (n=316).

[b] Defined by area deprivation index belonging to the highest Washington State quintile.

[c] Includes International Classification of Childhood Cancer (third edition) groups XI and XII.

[d] Refers to treatment during initial therapy only.

TABLE 2:

Multivariate hazard ratios (HR) and 95% confidence intervals (CI) for mortality among children with cancer by neighborhood classification.

Neighborhood classification[a]	No. of events/ Person-years at risk	Rate per 1,000 person-years	Adjusted HR (95% CI)[b]	*p*
Non-rural, low ADI	583 / 22,302	26.1	1.00 (ref)	
Non-rural, high ADI	114 / 1,839	62.0	**1.64 (1.32–2.04)**	**<0.001**
Rural, low ADI	52 / 1,120	46.4	**1.50 (1.12–2.02)**	**0.007**
Rural, high ADI	65 / 1,140	57.0	**1.53 (1.16–2.01)**	**0.002**
Sex				
Female	362 / 12,703	28.5	1.00 (ref)	
Male	452 / 13,698	33.0	1.07 (0.93–1.24)	0.35
Race and ethnicity				
Non-Hispanic White	610 / 21,590	28.3	1.00 (ref)	
Hispanic	90 / 1,692	53.2	**1.35 (1.07–1.72)**	**0.012**
Non-Hispanic Black	33 / 1,087	30.4	0.88 (0.61–1.27)	0.49
Non-Hispanic Other[c]	81 / 2,033	39.8	**1.34 (1.05–1.70)**	**0.018**

[a]High area deprivation index (ADI) neighborhoods are defined as having an ADI value in the highest Washington State quintile, corresponding to greater neighborhood socioeconomic disadvantage.

[b]Analyses were adjusted for all variables shown, plus age at diagnosis, birth year, and cancer diagnosis type.

[c]"Other" race combines individuals identified as non-Hispanic Asian, Alaska Native, American Indian, Pacific Islander, and other identification not listed above in another race and ethnicity category.

TABLE 3.

Multivariate hazard ratios (HR) and 95% confidence intervals (CI) for mortality by individual neighborhood variables, stratified by cancer diagnosis type.[a]

Cancer type	Person-years at risk/No. of events	Rate per 1,000 person-years	Adjusted HR (95% CI) Rural residence	*p*	Adjusted HR (95% CI) High ADI	*p*
ALL (n=854)	109 / 5,524	19.7	**1.82 (1.01–3.27)**	**0.045**	1.16 (0.69–1.97)	0.57
AML (n=189)	78 / 802	97.3	1.22 (0.52–2.81)	0.64	1.56 (0.84–2.87)	0.16
Lymphoma (n=583)	52 / 3,970	13.1	1.15 (0.42–3.17)	0.77	1.32 (0.58–3.04)	0.51
Solid tumors (n=1215)	264 / 7,338	36.0	1.06 (0.72–1.56)	0.76	**1.62 (1.16–2.26)**	**0.004**
CNS tumors (n=896)	246 / 5,270	46.7	1.08 (0.70–1.68)	0.73	**1.47 (1.01–2.13)**	**0.044**

[a]Adjusted HRs are compared with children from non-rural neighborhoods without socioeconomic disadvantage (low area deprivation index) as a reference group. Analyses are adjusted for sex, race and ethnicity, age at diagnosis, birth year, and cancer diagnosis type.