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Historical redlining and survival among children, adolescents, and young adults with cancer diagnosed between 2007-2019 in Seattle/Tacoma

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Abstract

Historical redlining and survival among children, adolescents, and young adults with cancer diagnosed between 2007-2019 in Seattle/Tacoma

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Introduction: Historic redlining has been associated with inferior survival in adult-onset cancers, however whether there is an association in pediatric, adolescent, and young-adult-onset cancers is unknown. **Methods**: Cancer cases among individuals living in Seattle and Tacoma between 2007-2019 were identified via Cancer Surveillance System. Case redlining status was determined using Home Owner Loans Corporation (HOLC) data overlayed with 2000 and 2010 census tracts. Kaplan-Meier methods and multivariable Cox proportional hazards models were used to determine 5 and 15-year overall survival and hazard ratio (HR) of death between redlined exposed and unexposed cases. A series of Cox regression models were tested including an unadjusted model, and adjusted models for patient and tumor-characteristics alone, patient and tumor-characteristics with area-level poverty, and patient and tumor-characteristics with area-

level poverty and individual insurance status. Finally, a model accounting for interaction between redlining and poverty was included to test for effect modification. **Results:** Unadjusted overall survival at 5 years was lower (86.0%; 95% CI: 84.0, 87.7) in individuals with cancer exposed to redlining than unexposed individuals (90.5%; 95% CI: 88.9, 91.8). The unadjusted hazard of death for redlined-exposed individuals with cancer was higher than redlined-unexposed (HR: 1.53, 95% CI: 1.25, 1.86). In the fully adjusted model, the hazard of death between individuals exposed to redlining was substantially attenuated (1.17, 95% CI: 0.95, 1.43). There was insufficient evidence of effect modification from area-level poverty in the relationship between redlining and death (p= 0.61). **Conclusion**: In this retrospective population-based study of children, adolescents and young adults with cancer, residence at the time of diagnosis in an area previously redlined in the 1930s was associated with an increased hazard of death compared to those who were not living in a previously redlined area. Notably, this relationship was attenuated after adjusting for patient and tumor factors, area-level poverty and insurance, suggesting that contemporary socioeconomic status may mitigate the harmful effects of historical redlining.

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INTRODUCTION

Despite monumental advances in survival for children, adolescents, and young adults (CAYAs) with cancer, CAYAs with cancer who identify with marginalized racial and ethnic groups continue to experience worse survival than their non-Hispanic White peers.[1] Given the rapidly diversifying population of children in the United States, addressing racial and/or ethnic disparities is essential for the next frontier in improvement of overall survival for CAYAs with cancer. Racial and ethnic disparities persist even after accounting for biological characteristics and socioeconomic status, suggesting that biology and proximal social determinants of health alone are not sufficient to explain said disparities.[2, 3]

Recently an abundance of literature has developed outlining how systemic racism negatively impacts the health and wellbeing of marginalized communities.[4-7] Systemic racism refers to the discrimination of individuals and groups based on race or ethnicity that arises from systems and structures within society and institutions.[4] For example, discrimination may occur within political, economic, health care, education, and/or criminal justice systems, and these systems work together to install and maintain structures that disfavor and disempower historically marginalized and minoritized peoples.[6] Although systemic racism is a complex entity, several measures of systemic racism have been implemented in clinical and public health research. Many sources of systemic racism are geographically based and born from policy; these include measures of racial segregation, area-level disadvantage, and historic redlining.[8-11] These measures are critical because an individual's race/ethnicity alone is a poor proxy for exposure to racism.[12]

Historic redlining is a systemically racist policy that was enacted over 90 years ago by the Home Owners' Loan Corporation (HOLC), a U.S. government sponsored organization. HOLC created maps of U.S. cities which labeled areas in descending order "A" through "D", corresponding to "Best," "Still Desirable," "Declining," and "Hazardous", respectively, based solely on racial/ethnic composition. The purpose of these maps was to signal areas worthy of investment to banks and mortgage loaners, which favored White neighborhoods and disfavored marginalized racial and ethnic groups. Redlining resulted in nation-wide disinvestment of non-White neighborhoods and perpetuated racial segregation over the course of decades, leading to long-standing inequitable distribution of resources and poverty throughout the nation.[13]

In addition to adverse socioeconomic consequences, serious health issues have been documented for those living in redlined areas. Populations living in redlined areas experience higher rates of pre-term birth, COVID-19 infection, asthma, obesity, adult cancer mortality, shorter life expectancy and poorer self-reported mental and physical health.[14-20] Plausible mechanisms for these relationships include limited access to health care, lower education and/or literacy, exposure to chronic stress and environmental hazards.[19, 21-24]

Historic redlining has been associated with increased adult-onset cancers mortality.[18, 19] For example, individuals with breast cancer living in a redlined census tract in Atlanta, GA, have a 1.6 times greater mortality than patients living in non-redlined tracts.[18] One possible mechanism specifically pertaining to higher cancer mortality rates is poorer access to care at cancer presentation, as redlining exposure also is associated with advanced stage colon, breast, cervical, and lung cancer.[17] The negative racism mechanisms that drive racial/ethnic disparities in adults with cancer may apply to CAYAs with cancer. In fact, individuals living in areas that

have been redlined are less likely to be insured and/or have access to health care, and more likely to be impoverished,[25] both of which are associated with adverse survival in childhood cancer.[26]

This purpose of this population-based study is to assess whether historic redlining as a form of systemic racism is associated with inferior survival for CAYAs with cancer. Specifically, we tested the hypothesis that CAYAs exposed to historic redlining experience inferior survival compared with those who have not been exposed will be tested using population-based cancer data covering residents of Seattle and Tacoma, WA between 2007-2019. We also tested for potential effect modification of area-level poverty on the relationship between historical redlining and survival.

METHODS

Study subjects

Study subjects include all CAYAs (defined in this study as <40 years-old at diagnosis) residing in HOLC-graded areas of Seattle or Tacoma diagnosed with cancer between 2007-2019. The CAYA case data were obtained from the Cancer Surveillance System (CSS), a population-based cancer registry funded by the NCI Surveillance, Epidemiology, and End Results (SEER) Program. Cases were restricted to 2007-2019 due to covariable restrictions (insurance data were available for 2007 and later only), and did not include 2020 onward to avoid the COVID-19 pandemic as a potential complicating factor compromising reliable cancer surviellance data. All malignant cancer types were included; tumors that were classified as benign, low/uncertain concern for malignancy or in-situ, were excluded. Only first, primary tumors were considered in this analysis. This research was approved by the University of Washington Institutional Review Board as not human subject research. All data were deidentified prior to analysis.

Measures

Cancer case characteristics.

Case characteristics were obtained through CSS as defined by the North American Association of Central Cancer Registries (NAACCR) data dictionary[27]. Tumor-level characteristics included cancer site, histology and stage at diagnosis. Individual-level characteristics included age at diagnosis, sex, race, and Hispanic ethnicity. For the analysis, race and ethnicity were combined and individuals who reported Hispanic ethnicity and any race were categorized as Hispanic. Individuals who reported more than one race and non-Hispanic were categorized as the least-represented race by Seattle population estimates[28] using whole-bridging

deterministic assignment[29]. Cancer type that best represented CAYA were assigned using the 2020 AYA Site Recode revision within relatively broad categories for descriptive purposes[30]; there were too few of any particular cancer type to permit type-specific analyses. Insurance status was unknown for 325 (11%) cases, and categories included in the analysis included no insurance, public insurance, private insurance, and unknown. Cancer stage categories included localized, regional, distant sites involved, and unknown, where leukemia qualifies as distant sites involved by definition.

Redlining exposure (by HOLC maps).

The primary exposure for is area-level historic redlining, based on the 1930's HOLC redlining maps (**Supplemental Figure 1**).[31] These publicly available redlining maps have been overlayed with 2000 and 2010 census tracts, such that a single census tract's composition of redlined areas can be determined. Each census tract was assigned a continuous HOLC score using previously published methods.[32] The score is the sum of each HOLC graded area (where "A" corresponds to 1, "B" corresponds to 2, "C" corresponds to 3, and "D" corresponds to 4), weighted by the geographic proportion of the tract occupied. For example, a census tract that is 100% HOLC grade "A" would receive a HOLC score of 1, and a tract that is 100% grade "D" would receive a score of 4. A tract that is 25% "C" and 75% "D" would be given a score of 3.75 ((0.25*3) + (0.75*4)). Following published recommendations, tracts with <5% HOLC grade assigned were omitted.[20] We utilized a binary HOLC variable that divided scores by median HOLC score into "exposed to redlining" (i.e., above the median HOLC score) and "unexposed to redlining" or (i.e., below the median HOLC score). Analyses of HOLC score quartiles were explored (results available in **Supplementary Figure 2**).

Area-level characteristics.

Area-level poverty was obtained from the 2000 U.S. Census for cases prior to 2010, and 2017 American Community Survey 5-Year estimates for cases following 2009. Census-tract level poverty was defined as >20% households in the census tract were living below the federal poverty level)[33].

Outcomes

The CSS routinely follows all cases for vital status through passive methods including annual electronic linkages with the Washington State death certificate database and the US National Death Index. Cause of death is determined based on ICD codes from the death certificate linkages. The primary endpoint of this study was overall survival. Overall survival is reported at several time periods including 5 and 15 years. For cases who died during follow-up, survival was calculated as the number of months between the date of diagnosis and date of death. For cases that were not known to have died during follow-up, survival was calculated as the number of months between date of diagnosis and the earlier of June 1st, 2022 or date last known to be alive. Overall survival was considered rather than cancer-specific survival, as death secondary to another cause other than cancer was relatively infrequent in this young cohort (n=44 or 12% of deaths).

Analysis

Exploratory analyses included descriptive summary statistics (i.e., measures of central tendency and frequency) and distribution of case characteristics (age, sex, race/ethnicity of cases, and cancer type and stage) and area-level characteristics (poverty and median income). Kaplan-

Meier (K-M) methods were used to calculate overall 5- and 15-year survival stratified by redlining exposure. Log rank tests were performed to test the null hypothesis of no survival differences between redlined exposed and unexposed groups. The proportional hazard assumption for redlining exposed and unexposed groups was confirmed visually by K-M curves. Notably, this assumption was violated in the HOLC variable where scores were designated quartiles. Specifically, quartiles 3 and 4 (the second HOLC quartile with the second highest and highest HOLC scores i.e., most redlined quartiles) overlapped (**Supplemental Figure 2**). Therefore, HOLC quartiles were not used for further analytic purposes.

A Cox proportional hazards regression model was fit to estimate hazard ratios (and corresponding 95% confidence intervals) for redlined exposed versus unexposed populations. The multivariable regression model considered confounders in a stepwise fashion such that Model 1 was unadjusted; Model 2 adjusted for age at diagnosis (continuous), sex, race/ethnicity (American Indian/Alaska Native, Asian, Black, Hispanic, Native Hawaiian/Pacific Islander, White) and cancer stage (localized, regional, distant sites involved, unknown); Model 3 additionally adjusted for area-level poverty (low poverty and high poverty), and Model 4 additionally adjusted for individual-level insurance status (no insurance, public insurance, private insurance, unknown).

Finally, effect modification by area-level poverty was assessed by a likelihood ratio (LR) test of the nested multivariate model without an interaction between poverty and redlining and expanded model that included the interaction term. Specifically, the LR test is for the null hypothesis that the fit of the model was not improved by inclusion of the interaction term. HRs and associated 95% CI were obtained using linear combinations of parameter estimates.

RESULTS

Individual-, residential- and tumor-level baseline characteristics are available in **Table 1**. Overall, 2,987 persons <40 years of age were diagnosed with a first primary malignancy between 2007-2019 and lived in census tracts with ≥5% redlining data in either Seattle (n=2242) or Tacoma (n=745) at diagnosis. Of the 17,960 cases in Seattle and Tacoma, 3,265 (18%) lived in HOLC graded areas. Of the cases living in HOLC graded areas, 278 were excluded (8%) for the cut-off for proportion of the tract graded (<5%). The mean age was 30 years (with a range 1-39). Overall, 278 (9%) of cases were pediatric cases (<18 years of age). Compared to non-redlined cases, redlined cases were more frequently Black (n=167, 11% vs. n=63, 4%), publicly insured (n=373, 25% vs. n=191,13%), and live in census tracts characterized by poverty (n= 393 26% vs n=114 8%). Univariable analyses of incorporating all cases versus restricting to only those that were not missing insurance did not meaningfully alter associations between redlining and survival, which supported incorporation of individuals with missing insurance data in the analysis.

A total of 298 census tracts (144 tracts from 2000 and 154 tracts from 2010) were included in the analysis. About half (n=151, 51%) of census tracts were comprised of a single HOLC Grade (A, B, C, or D), while 19% (n=58) tracts were comprised of two HOLC grades, and 23% (n=68) were comprised of three HOLC grades, and 8% (n=25) of tracts comprised all four HOLC grades. The average census tract proportion with HOLC grading was 71.7% (standard deviation 0.29) and the majority of tracts (74%) were composed of 3 HOLC graded areas.

In an unadjusted analysis, the cases exposed to redlining had poorer survival compared to cases not exposed to redlining (**Figure 1**). This difference in survival between redlined exposed and unexposed groups is most pronounced about 2 years from diagnosis and beyond. Overall survival at 5 years was lower (86.0%; 95% CI: 84.0, 87.7) in individuals exposed to redlining than unexposed individuals (90.5%; 95% CI: 88.9, 91.8) (**Supplemental Table 1**). Survival at 15 years was lower (79.3%; 95%CI: 75.8, 82.3) in redlined exposed individuals than unexposed individuals (85.7%; 95%CI: 82.9, 88.1).

The hazard ratio of death comparing cases exposed to redlining versus unexposed to redlining was 1.53 (95% CI: 1.25, 1.86 in the unadjusted Model 1) (**Table 3**). After adjusting for age, sex, year of diagnosis, cancer stage, race/ethnicity (Model 2), the HR estimate was reduced compared to Model 1 (HR: 1.30, 95% CI:1.06, 1.59). Additionally adjusting for area-level poverty (Model 3) further reduced the effect size (HR: 1.25, 95% CI: 1.02, 1.53), and additionally adjusting for individual level insurance reduced the effect size even further (HR:1.17, 95% CI: 0.95, 1.43). Estimates from the fully adjusted Model 4 are available in **Supplemental Table 2**. Interaction between neighborhood poverty status and redlining exposure was tested and did not demonstrate statistical significance (p= 0.61) (**Table 3**).

DISCUSSION

In this retrospective population-based study of children, adolescents, and young adults diagnosed with cancer in Seattle and Tacoma between 2007-2019, residence at the time of diagnosis in an area previously redlined in the 1930s was associated with a 53% increase in hazard of death. That association was attenuated substantially when contemporary characteristics (area-level poverty and individual insurance type) were considered.

While these findings are the first to report that a measure of systemic racism may be a risk-factor for inferior survival for CAYAs with cancer, this work has important limitations. First, this study features a geographically restricted cohort with a relatively homogenous racial/ethnic demographic composition and therefore may be limited in its generalizability. Second, the sample size of this study was relatively small due to 1) population parameters of the study (i.e., restricted to Seattle and Tacoma), 2) the rarity of cancer in CAYAs and 3) missing covariate data. Broadly, the limited sample size prevented us from making inferences regarding subgroups such as specific racial or ethnic populations and/or a strictly pediatric population. Third, there is no generally accepted consensus on how to link HOLC map data to modern census tracts. We utilized previously published methods[20] to convert HOLC grades into a continuous score, which both allowed us to include tracts that were not 100% HOLC graded and risks misclassification. To meet the assumptions of the PH model, we had to dichotomize the HOLC score. Thus, we could not assess whether our data showed evidence of poorer outcomes with increasingly worse HOLC score. Finally, this study deliberately did not account for competing risks such as death from other cause because only a small minority of individuals died from a cause other than cancer.

To the extent that these findings are valid, they appear to support two conclusions. First, that historical racist actions nearly a century ago are associated with inferior survival among younger patients with cancer. Second, the impact of historic redlining may be mediated, in whole or part, by contemporary socioeconomic status.

To better understand the role of previously established multi-level characteristics that influence survival for individuals with cancer, several models were fit with additive covariates in a stepwise fashion. The magnitude of the effect of redlining on survival from unadjusted Model 1 dampened substantially with the addition of individual medical factors (Model 2), area-level socioeconomic factors (Model 3), and individual socioeconomic factors (Model 4). Notably, individual-level insurance status grossly appears to be more impactful for survival than area-level poverty. These findings may be explained by collinearity between redlining and area-level poverty. Previous research regarding the impact of insurance and area-level poverty in CAYAs have not been harmonious across cancer types. Previous research in young cancer patient cohorts demonstrate independent adverse associations with survival for 1) insurance poverty *without* area-level poverty associations,[34, 35] 2) area-level poverty independently[36], and 3) insurance and area-level poverty as an additive effect, but not with area-level poverty alone.[35] Further investigations to better characterize the undoubtedly complex interplay between multilevel redlining, poverty exposures, and survival are needed.

In addition to a multivariable, stepwise analysis of multi-level confounders, the impact of area-level poverty on the relationship between redlining and survival was formally tested. Area-level poverty does not modify the relationship between redlining and survival in this cohort, contrary to our hypothesis. Although not statistically significant, the effect size of the redlining hazard ratio is greater in individuals in high poverty areas than those in low poverty areas.

Importantly, the lack of significance may in part be due to the significant overlap between areas that were historically redlined and currently impoverished, which limited discordant populations and therefore power in detection of effect modification. Although not formally addressed in this study, contemporary poverty may mediate the relationship between redlining and survival by way of continued unfair housing policies[15]. Further formal mediation studies are needed to test specific hypotheses about this conceptual model.

The negative impact of redlining on mortality and late-stage at diagnosis have been previously described in adults with breast, colon, lung, and cervical cancer[17, 18, 37]. To our knowledge, this is the first study of younger individuals with cancer that identifies redlining as a social determinant of survival. These findings highlight the importance of contextualizing contemporary health care disparities in CAYAs with cancer, and emphasize the potential lasting impact of discriminatory sociopolitical actions in the distant past. Previous conceptual frameworks to describe mechanisms of systemic racism such as access to care, patient/health care system interactions, and toxic stress have been postulated.[38, 39] This study provides evidence that redlining/unfair housing policies should be incorporated into these frameworks. Importantly, current poverty exposures appear to explain the impact of historical redlining. If confirmed in future studies, such a finding would support individual level interventions such as patient navigation focused on access to insurance,[40] or policy level interventions such as state-level expansion of Medicaid.[41] Poverty interventions such as those that target unmet basic needs and financial education[42] may also benefit CAYAs with cancer living in formally redlined areas.

Historic redlining is associated with inferior survival and mortality in this study of CAYA with cancer diagnosed in among Seattle and Tacoma residents between 2007-2019. Redlining and other objectively racist policies may be useful surrogate measures of exposure to

systemic racism in CAYAs with cancer, and therefore deployed in future risk-stratification to address health inequities. Modern socioeconomic factors downstream of systemic racism such as insurance remain strongly associated with survival and mortality in CAYAs with cancer. Further studies are needed to assess the relationship of redlining and other measures of systemic racism in CAYAs with cancer.

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TABLES AND FIGURES

Table 1. Characteristics of childhood, adolescent and young adult cancer cases among Seattle and Tacoma Residents, 2007-2019, Overall and by Redlined status

	Total N=2987	Not redlined N=1489	Redlined N=1498
	n (%)	n (%)	n (%)
Age at diagnosis, years			
0-18	294 (10%)	154 (10%)	140 (9%)
19-29	723 (24%)	334 (22%)	389 (26%)
29-39	1970 (66%)	1001 (67%)	969 (65%)
Sex			
Male	1254 (42%)	627 (42%)	627 (42%)
Female	1732 (58%)	861 (58%)	871 (58%)
Race			
American Indian/Alaska Native	44 (1%)	13 (1%)	31 (2%)
Asian	321 (11%)	148 (10%)	173 (12%)
Black	230 (8%)	63 (4%)	167 (11%)
Native Hawaiian/Pacific Islander	46 (2%)	15 (1%)	31 (2%)
White	2290 (77%)	1224 (82%)	1066 (71%)
Unknown	56 (2%)	26 (2%)	30 (2%)
Ethnicity			
Non-Hispanic	2759 (92%)	1407 (94%)	1352 (90%)
Hispanic	228 (8%)	82 (6%)	146 (10%)
Insurance			
No insurance	637 (21%)	326 (22%)	311 (21%)
Public Insurance	564 (19%)	191 (13%)	373 (25%)
Private Insurance	1461 (49%)	790 (53%)	671 (45%)
Unknown	325 (11%)	182 (12%)	143 (10%)
Area-Level Poverty			
Low Poverty	2480 (83.0%)	1375 (92.3%)	1105 (73.8%)
High Poverty	507 (17.0%)	114 (7.7%)	393 (26.2%)
Year of Diagnosis			
2007-2011	1105 (37%)	584 (39%)	521 (35%)
2012-2015	887 (30%)	429 (29%)	458 (31%)
2016-2019	995 (33%)	476 (32%)	519 (35%)
Stage			
Localized	1598 (53%)	835 (56%)	763 (51%)
Regional	719 (24%)	348 (23%)	371 (25%)
Distant sites involved	606 (20%)	277 (19%)	329 (22%)
Unknown	64 (2%)	29 (2%)	35 (2%)
Cancer Type			
Melanoma	437 (15%)	252 (17%)	185 (12%)
Breast	372 (12%)	195 (13%)	177 (12%)
Thyroid	388 (13%)	195 (13%)	193 (13%)
Germ cell/trophoblastic	258 (9%)	138 (9%)	120 (8%)
Gastrointestinal	255 (9%)	116 (8%)	139 (9%)
Leukemia	209 (7%)	103 (7%)	106 (7%)
Non-Hodgkin Lymphoma	196 (7%)	85 (6%)	111 (7%)

CNS/intraspinal neoplasms	192 (6%)	98 (7%)	94 (6%)
Hodgkin Lymphoma	174 (6%)	79 (5%)	95 (6%)
Gonads and genitals	163 (5%)	74 (5%)	89 (6%)
Sarcomas	81 (3%)	43 (3%)	38 (3%)
Urinary tract	63 (2%)	25 (2%)	38 (3%)
Head and neck	52 (2%)	22 (1%)	30 (2%)
Bone and soft tissue	30 (1%)	12 (1%)	18 (1%)
Other carcinomas	69 (2%)	23 (2%)	46 (3%)
Other tumors	42 (1%)	25 (2%)	17 (1%)
Unspecified neoplasms	6 (0%)	4 (0%)	2 (0%)

*= based on census tract of the subject at diagnosis, low poverty: <20% of population are below federal poverty level, ≥20% of population are below the federal poverty level.

Figure 1. Overall Survival by redlined status in CAYA cancer patients diagnosed among Seattle and Tacoma Residents, 2007-2019. Total N = 2962, # of events = 406.

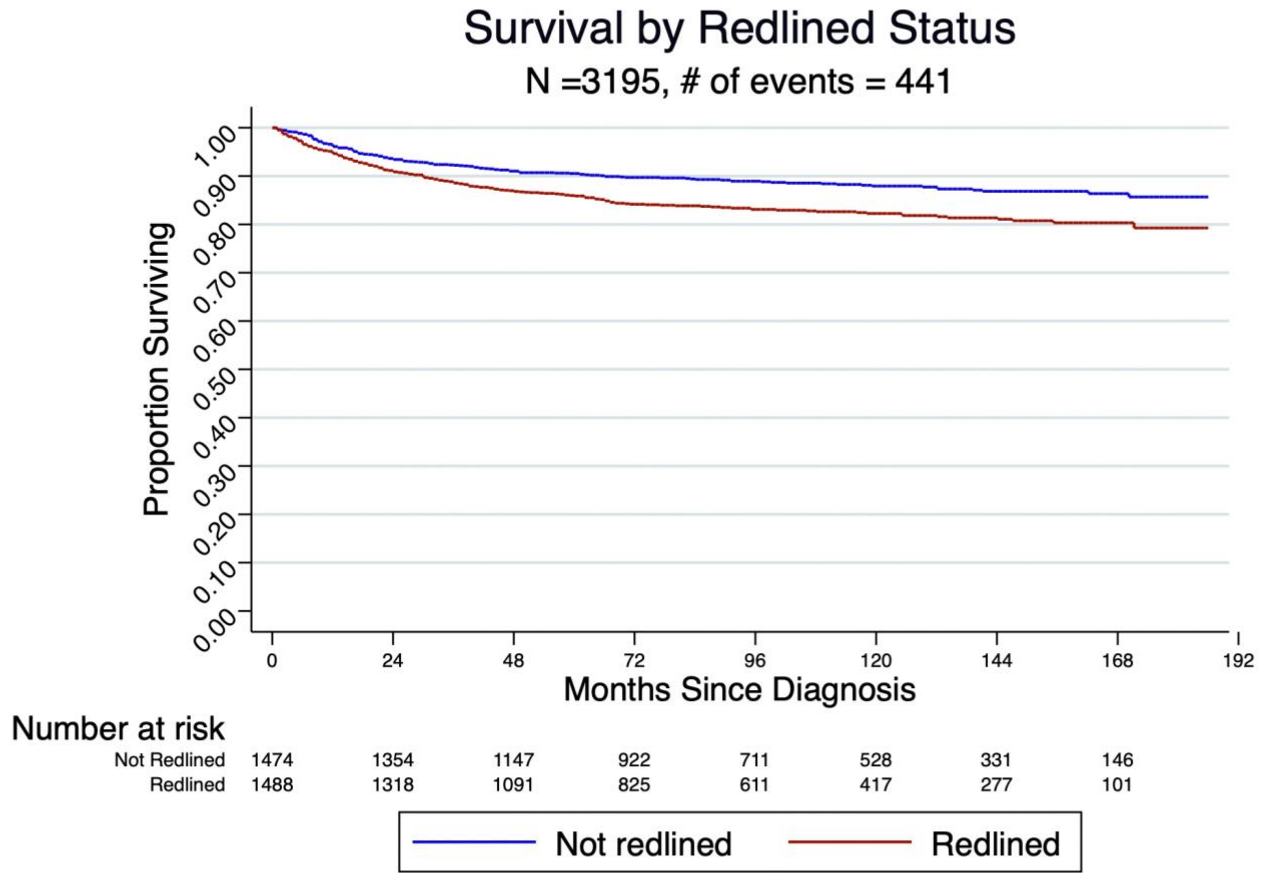
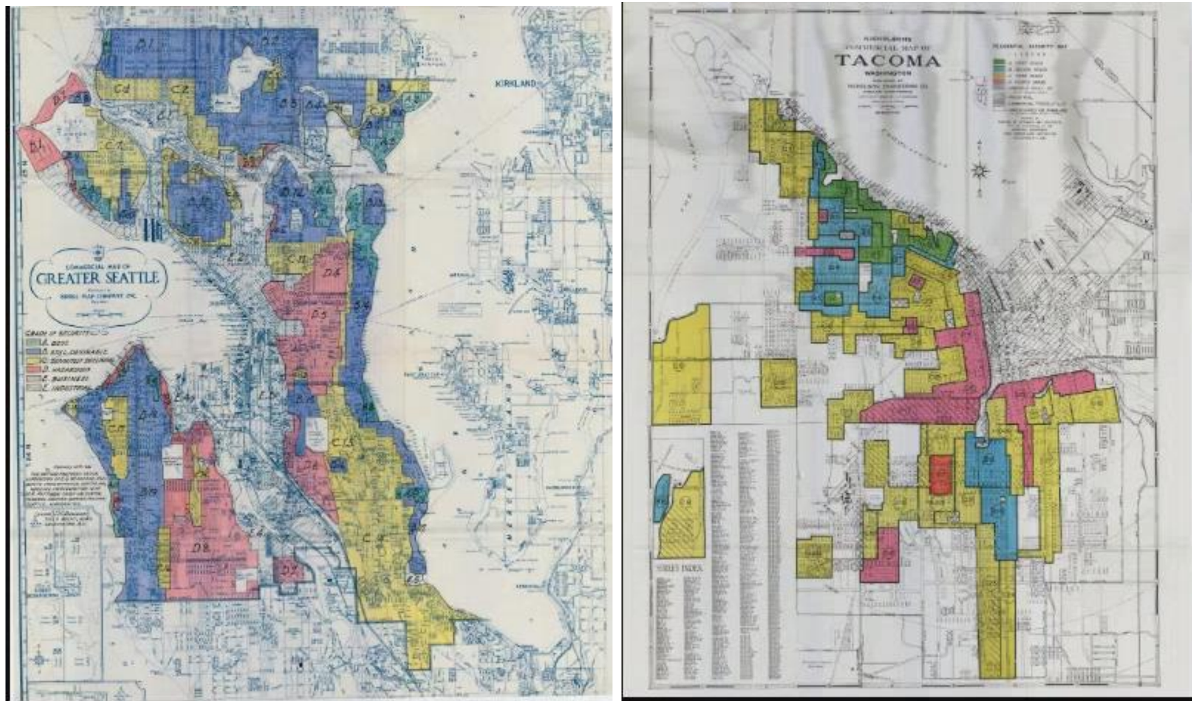


Table 2. Hazard of death in redlined exposed versus unexposed cancer cases diagnosed among Seattle and Tacoma Residents, 2007-2019.

Cox PH models	Hazard Ratio	95% CI
Model 1	1.53	(1.25, 1.86)
Model 2	1.30	(1.06, 1.59)
Model 3	1.25	(1.02, 1.53)
Model 4	1.17	(0.95, 1.43)
Area-level poverty		
Low poverty	1.14	(0.91, 1.43)
High poverty	1.32	(0.78, 2.24)

Footnote: Model 1: unadjusted; Model 2: adjusted for age, sex, race/ethnicity, year of cancer diagnosis, cancer stage; Model 3: additionally adjusted for area-level poverty; Model 4: additionally adjusted for insurance status; Area-level poverty: Low poverty refers to <20% (high poverty >20%) of population in census tract reports income below the poverty level.

Supplemental Figure 1. Home Owners Loan Corporation Maps of Seattle (1936) and Tacoma (1929).[31]



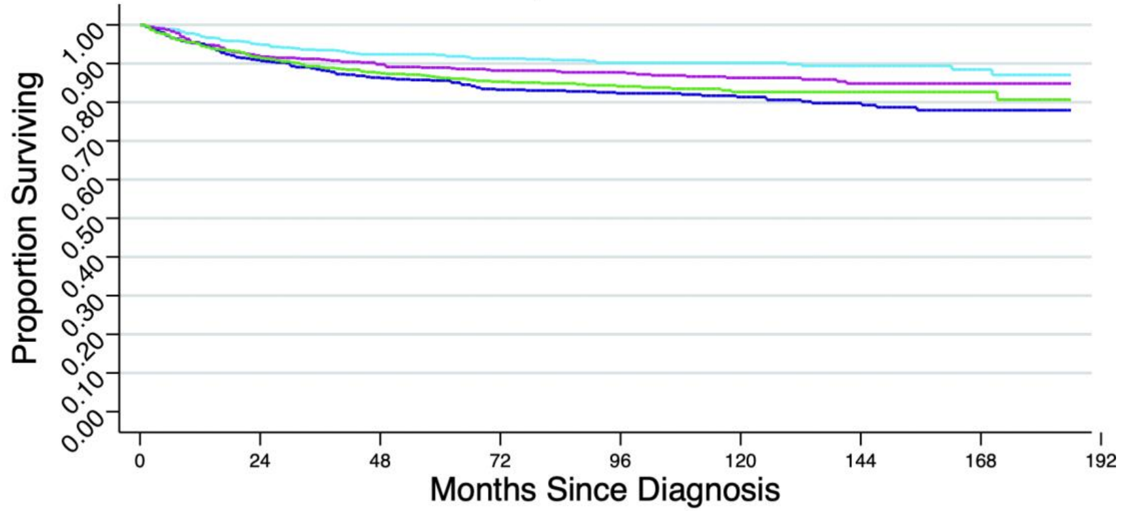
Supplemental Table 1. Kaplan-Meier overall survival probability in CAYA cancer patients diagnosed among Seattle and Tacoma Residents, 2007-2019, Overall and by Redlined Status

	Overall		Not Redlined		Redlined	
Months	Survival	95% CI	Survival	95% CI	Survival	95% CI
12	95.9	(95.1, 96.5)	96.6	(95.6, 97.4)	95.1	(93.9, 96.1)
24	92.4	(91.4, 93.3)	93.6	(92.3, 94.8)	91.1	(89.6, 92.5)
60	88.2	(87.0, 89.4)	90.5	(88.9, 91.9)	86.0	(84.1, 87.7)
120	85.1	(83.6, 86.5)	87.9	(86.0, 89.6)	82.3	(80.0, 84.3)
180	82.5	(80.4, 84.45	85.7	(82.9, 88.1)	79.3	(75.8, 82.3)

Supplemental Figure 2. Overall Survival by HOLC Quartile in CAYA cancer patients in Seattle and Tacoma, 2007-2019. Total N = 2962, # of events = 406. Q1: lowest HOLC score (i.e., least redlined), Q4: highest HOLC score (i.e., most redlined).

Survival by HOLC Score

N = 2962, # of events = 406



Number at risk

	0	24	48	72	96	120	144	168
Q1	726	681	578	467	359	270	175	74
Q2	713	640	544	436	340	252	151	70
Q3	770	683	571	425	320	234	156	49
Q4	753	668	545	419	303	189	126	54

Supplemental Table 2. Adjusted hazard ratios for mortality by redlining status by redlined status in CAYA cancer patients diagnosed among Seattle and Tacoma Residents, 2007-2019.

	Hazard Ratio	95% CI
Not redlined (ref)	1.0 (ref)	-
Redlined	1.17	(0.95, 1.43)
Age at Diagnosis	1.02	(1.01, 1.03)
Sex		
Male	1.0 (ref)	-
Female	0.84	(0.69, 1.03)
Race/ethnicity		
Non-Hispanic White	1.0 (ref)	-
American Indian/Alaska Native	1.38	(0.70, 2.72)
Asian	1.44	(1.07, 1.93)
Black	1.32	(0.97, 1.80)
Hispanic	1.00	(0.70, 1.42)
Native Hawaiian/Pacific Islander	2.56	(1.52, 4.29)
Unknown	0.28	(0.04, 1.97)
Year of Diagnosis	0.81	(0.1, 0.92)
Cancer Stage		
Localized	1.0 (ref)	-
Regional	2.82	(2.11, 3.76)
Distant sites involved	7.22	(5.53, 9.43)
Unknown	3.97	(1.89, 8.33)
Area-Level Poverty		
Low	1.0 (ref)	-
High	1.20	(0.94, 1.53)
Insurance		
Uninsured	1.0 (ref)	-
Public Insurance	1.78	(1.34, 2.35)
Private Insurance	0.78	(0.59, 1.01)
Unknown	0.36	(0.18, 0.71)