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Evi A. Farazi

Shinobu Watanabe-Galloway

L. Westman

B. Rettig

P. Hunt

See next page for additional authors

Authors

Evi A. Farazi, Shinobu Watanabe-Galloway, L. Westman, B. Rettig, P. Hunt, R. Cammack, John W. Sparks, and Don W. Coulter

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Temporal and geospatial trends of pediatric cancer incidence in Nebraska over a 24-year period

P.A. Farazi[a,*], S. Watanabe-Galloway[a], L. Westman[a], B. Rettig[b], P. Hunt[c], R. Cammack[c], J.W. Sparks[d], D.W. Coulter[d]

[a] College of Public Health, University of Nebraska Medical Center, Omaha, NE, United States
[b] Department of Health and Human Services, Lincoln, NE, United States
[c] Department of Geography and Geology, University of Nebraska-Omaha, Omaha, NE, United States
[d] Department of Pediatrics, University of Nebraska Medical Center, Omaha, NE, United States

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ABSTRACT

Background: Data from the Surveillance, Epidemiology, and End Results (SEER) revealed that the incidence of pediatric cancer in Nebraska exceeded the national average during 2009–2013. Further investigation could help understand these patterns.

Methods: This retrospective cohort study investigated pediatric cancer (0–19 years old) age adjusted incidence rates (AAR) in Nebraska using the Nebraska Cancer Registry. SEER AARs were also calculated as a proxy for pediatric cancer incidence in the United States (1990–2013) and compared to the Nebraska data. Geographic Information System (GIS) mapping was also used to display the spatial distribution of cancer in Nebraska at the county level. Finally, location–allocation analysis (LAA) was performed to identify a site for the placement of a medical center to best accommodate rural pediatric cancer cases.

Results: The AAR of pediatric cancers was 173.3 per 1,000,000 in Nebraska compared to 167.1 per 1,000,000 in SEER. The AAR for lymphoma was significantly higher in Nebraska (28.1 vs. 24.6 per 1,000,000; $p = 0.009$). For the 15–19 age group, the AAR for the 3 most common pediatric cancers were higher in Nebraska ($p < 0.05$). Twenty-three counties located > 2 h driving distance to care facilities showed at least a 10% higher incidence than the overall state AAR. GIS mapping identified a second potential treatment site that would alleviate this geographic burden.

Conclusions: Regional differences within Nebraska present a challenge for rural populations. Novel use of GIS mapping to highlight regional differences and identify solutions for access to care issues could be used by similar states.

1. Introduction

Cancer is the leading cause of death from disease among children in the United States [1]. In 2017, it is expected that there will be 10,270 new cases of pediatric tumors in children 0–14 years old [1]. Pediatric cancer represents a spectrum of diseases. A report of pediatric cancer incidence from 62 countries revealed an AAR of 140.6 per million person-years in children 0–14 years old (2001–2010). Leukemia was the most common cancer, followed by CNS tumors and lymphomas [2]. A study in the United States showed that acute lymphoblastic leukemia (ALL) increased during 2001–2008 and was most prevalent in Hispanic populations and Western regions of the US [3]. Furthermore, disparities in pediatric cancer mortality have been suggested in a Tennessee study, which showed that African American children tended to reside in proximity to death clusters in rural areas [4].

The etiologies of pediatric cancers are poorly understood; genetic and environmental factors play key roles [5]. Pediatric cancer patient care remains an imposing challenge to patients and their families since treatment often requires multiple therapeutic techniques (e.g., surgery, chemotherapy, radiation therapy, stem cell transplantation [6]) administered by a team of specialists located in an urban area [7,8]. Consequently, a major public health issue arises for states with a large rural population living a great distance from urban specialized children's cancer care centers [8,9]. The problem is further magnified by the fact that three-quarters of pediatric cancer survivors will require long-term subspecialty management [10]. Therefore, from the time of

* Corresponding author at: Department of Epidemiology, College of Public Health, University of Nebraska Medical Center, 984395 Nebraska Medical Center | Omaha, NE 68198-4395, United States.
E-mail address: evi.farazi@unmc.edu (P.A. Farazi).

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diagnosis to the survivorship and surveillance phase, patients and their families will make multiple trips to medical professionals. Previous research has shown that rural patients experience greater disruptions in school, work and other obligations than their urban counterparts for cancer care [9,11–17].

One of the rural states facing these issues in pediatric cancer care is Nebraska, which is the 15th largest state covering 77,355 square miles [18,19]. Data from the National Cancer Institute 's SEER Program and the National Program of Cancer Registries reveal that the average incidence of pediatric cancer in Nebraska exceeds the national average for 2009 to 2013 (19.3 versus 17.4 per 100,000) [20–22]. Over one third of Nebraska residents live in a rural area, but pediatric cancer care for the entire population is provided only in the urban area of Omaha in the eastern part of the state. Consequently, many patients and their families need to travel a long distance to seek care. Furthermore, concerns about the potential effects of environmental factors (e.g., pesticide, agricultural run-offs) on pediatric cancer rates have been debated [23]. Nebraska is one of the leading agriculture states, ranking 4th in total agriculture receipts [24]. In 2016, 48,400 farms were in operation in Nebraska with over 45,000,000 acres utilized by operating farms [24].

Considering the challenges in pediatric cancer care due to the rural nature of the state, and recent data from SEER indicating an increased incidence of pediatric cancer in Nebraska in recent reporting periods, we sought to evaluate the incidence of pediatric cancer in Nebraska by comparing the state registry data to a nationally representative sample from the Surveillance, Epidemiology, and End Results (SEER). We hypothesized that pediatric cancer incidence within the State may vary by location given the existence of some urban areas amidst the large distinctive rural areas of the State. Given that pediatric cancer is a rare event, we evaluated 24 years of registry data to ensure the validity of our statistics. Geographic Information System (GIS) mapping was employed to display the spatial distribution of children with cancer in the state. Finally, we used our data to develop a strategy to improve the access to care for rural populations in Nebraska and identified a potential secondary site for a pediatric cancer care center.

2. Methods

2.1. Study design and data sources

This was a retrospective cohort study using the Nebraska Cancer Registry (NCR) and SEER 9 Registries as data sources. The NCR received gold certification from the North American Cancer Registry for 95% case ascertainment, ensuring the reliability of the analysis results [25]. SEER 9 registries research data (2015 November submission [20]) cover areas including San Francisco, Connecticut, Detroit, Hawaii, Iowa, New Mexico, Seattle, Utah, and Atlanta [26].

2.2. Case definition

Cases were restricted to children and adolescent patients (0–19 years) diagnosed with a primary malignant neoplasm between year 1990 and 2013. Diagnoses were grouped into 12 main groups by histology and primary site according to SEER Site/Histology Recode based on the International Classification of Childhood Cancer Third Edition (ICCC-3) and the International Classification of Diseases for Oncology, Third Edition (ICD-O-3) [27]. We included in situ and malignant cases for urinary bladder cancer (ICD-O-67.9) to be consistent with other SEER reports [28]. To analyze the brain and CNS cancers, we also evaluated benign and uncertain cases for 2004- 2013.

2.3. Measures and data analysis

The following variables were examined in the analyses: age group, gender, and race/ethnicity. Due to the small size of certain races/ethnicities, race/ethnicity was re-coded as non-Hispanic white, non-Hispanic black, and other. Age was grouped into four categories: 0–4, 5–9, 10–14, and 15–19 years. Fisher exact test was used for comparing proportions between groups (NE versus SEER). All incidence rates (IRs) were calculated per million people and age-adjusted to the 2000 US standard population. IRs were displayed with 95% confidence intervals (CI) and compared with relative risk (RR) between Nebraska (primary group) and SEER (comparison group). All Nebraska IRs were calculated with SAS 9.4 [29] by using bridge-race population estimates prepared by the U.S. census Bureau and the National Center for Health Statistics [30]. SEER IRs were calculated with SEER*Stat, version, 8.3.2[31]. Due to restriction of race and ethnicity in SEER 9, age-adjusted IRs (AARs) by race and ethnicity groups were retrieved by using SEER 13 [26], which restricted the year of interest to 1992–2013. For the trend analysis, annual percentage change (APC) was calculated by fitting a regression line to data where the dependent variable was the natural logarithm of the data and calendar year was the independent variable. SEER*Stat was used to generate APCs and corresponding CIs for Nebraska data and SEER data. Trends of Nebraska pediatric cancer incidence were shown against national pediatric cancer incidence trends represented by SEER.

Location–Allocation analysis (LAA) of ArcGIS version 10.5 [32] was employed to determine a secondary site that would decrease the burden of travel from rural communities. To obtain possible facility locations, we started with existing pediatric cancer centers and added potential new facility locations based on existing adult cancer centers in the study area. With network/impedance, facility locations, and demands (locations of existing or potential cancer patients), the LAA can select the best candidate location to reduce travel time for patients and their family in the study area. Such selection was based on the calculations of LAA using alternative demands: first with the pediatric cancer patient's addresses and second with the existing child population at county centroids. This study was approved by the University of Nebraska Medical Center Institutional Review Board (543-15 EP).

3. Results

3.1. Demographics and tumor patterns of pediatric cancer patients

Of the 2094 pediatric cancer patients identified in Nebraska during 1990–2013, similar to the pattern in the US (SEER data), more pediatric cancers were observed in the youngest (0–4 years) and oldest (15–19 years) age groups (Table 1). A higher proportion of leukemias were observed at the oldest age (15–19) group in Nebraska (21%) compared to the US (15.4%) ($p = 0.001$). This age trend was also true for all pediatric cancers, lymphoma and CNS tumors. The race distribution of pediatric cancers was different between Nebraska and US SEER, underlining a predominance of non-Hispanic white patients in Nebraska.

3.2. Incidence rates of pediatric cancers in Nebraska versus US SEER

In general, the incidence of all and individual pediatric cancers was slightly higher in Nebraska compared to the US SEER population, however, the relative risk was within the 95% confidence intervals (Table 2). AAR of all pediatric cancers was 173.3 per million in Nebraska compared to 167.1 per million in the US SEER population. The AAR for lymphoma was significantly higher in Nebraska (28.1 per million vs. 24.6 per million; $p = 0.009$). Interestingly, for the oldest (15–19) age group, the age-specific rates for all and three most common pediatric cancers were higher in Nebraska compared to US SEER (Table 2). The IR for leukemias in 15–19 year-old patients was 33.7 per million in Nebraska compared to 25.9 per million in US SEER (RR = 1.3, 95% CI = 1.1–1.6). Similarly, the IRs for lymphomas and CNS tumors were higher in Nebraska compared to US SEER (RR = 1.2, 95% CI = 1.0–1.4 for lymphoma and RR = 1.3, 95% CI = 1.0–1.6).

The AARs of overall pediatric cancers differed by sex, with males showing higher incidence than females in both populations (Table 2).

Table 1
Demographic characteristics of pediatric cancer patients in Nebraska and SEER database (1990–2013).

Nebraska	All Pediatric Cancers (N = 2094)		Leukemia (n = 496)		Lymphoma (n = 339)		CNS (n = 401)	
Age	No.	%	No.	%	No.	%	No.	%
0–4	645	30.8	226	45.5	32	9.4	126	31.4
5–9	362	17.3	99	20.0	52	15.3	108	26.9
10–14	371	17.7	67	13.5	71	20.9	84	21.0
15–19	716	34.2	104	21.0*	184	54.4	83	20.7
Gender								
Male	1155	55.2	273	55.0	215	63.4	230	57.4
Female	939	44.8	223	45.0	124	36.6	171	42.6
Race								
NH-White	1569	81.5	344	77.3	275	87.9	316	84.0
OTHER	296	15.4	97	21.8	34	10.9	49	13.0
Unknown	60	3.1	4	0.9	4	1.2	11	3.0

SEER	All Pediatric Cancers (N = 30136)		Leukemia (n = 7459)		Lymphoma (n = 4373)		CNS (n = 5447)	
Age	No.	%	No.	%	No.	%	No.	%
0–4	9655	32.1	3438	46.1	342	7.8	1816	33.3
5–9	5107	16.9	1663	22.3	629	14.4	1474	27.1
10–14	5816	19.3	1208	16.2	1139	26.1	1235	22.7
15–19	9558	31.7	1150	15.4*	2263	51.7	922	16.9
Gender								
Male	16182	53.7	4160	55.8	2576	58.9	3006	55.2
Female	13954	46.3	3299	44.2	1797	41.1	2441	44.8
Race								
NH-White	21484	52.5	5059	45.9	3200	55.5	4014	57.1
OTHER	18944	46.3	5860	53.2	2499	43.3	2917	41.5
Unknown	528	1.2	93	0.9	71	1.2	93	1.4

* P = 0.001 Nebraska vs US SEER Leukema for 15–19 year olds.

Males in Nebraska showed overall a higher incidence of pediatric cancer compared to US SEER data. This sex difference was more pronounced in lymphoma and CNS tumors ($p < 0.05$). The AAR for lymphomas in males was 34.7 per million in Nebraska compared to 28.2 per million in US SEER (RR = 1.3, 95% CI = 1.1–1.4). The same trend was shown for CNS tumors with AARs of 37.4 per million in Nebraska compared to 32.5 per million in US SEER (RR = 1.2, 95% CI = 1.0–1.3, $p < 0.05$). The AARs of all and individual pediatric cancers were very similar between females in Nebraska and US SEER. The AARs of all pediatric cancers, leukemia, lymphoma and CNS were not statistically different between non-Hispanic whites (NHW) in Nebraska and US SEER.

We next investigated the trends of these pediatric cancers over time in both Nebraska and US SEER (Fig. 1). While the AAR trends were similar between Nebraska and US SEER between years 1990 and 2007, differences were observed during 2008–2013 when the AARs for lymphomas, and CNS tumors were higher in Nebraska compared to US SEER. The most consistent difference over time for years 2008–2013 was observed for CNS tumors. The APCs for all pediatric cancers, as well as leukemias, lymphomas, and CNS were higher for Nebraska compared to US SEER (2008–2013). This difference was particularly pronounced for lymphomas (APC were 1.9% for Nebraska and 0.5% for SEER) and CNS tumors (APCs were 1.7% for Nebraska and 0.2% for SEER).

For CNS tumors, both US SEER and Nebraska started accurately reporting on benign cases after 2004. Therefore, we investigated the incidence of CNS tumors for two periods (1990–2003 and 2004–2013) (Table 3). During 1990–2003, only malignant cases were required to be recorded, and therefore the SEER database may have an under-representation of the benign cases that were not reported. For this reason, our analyses did not address benign and uncertain cases for this period. Interestingly, the AARs of malignant CNS tumors were the same in Nebraska and US SEER over this period. During 2004–2013, however, a higher incidence was observed for both malignant and benign brain tumors in Nebraska compared to US SEER (Nebraska AAR: 38.1/1,000,000 vs SEER AAR: 30.5/1,000,000 and Nebraska AAR: 22.7/1,000,000 vs SEER AAR: 17.2/1,000,000). This was consistent with the higher APC observed for the entire period.

3.3. Geographic distribution of pediatric cancers in Nebraska

We mapped the incidence of pediatric cancers in Nebraska at the county level to determine if there are clusters of higher pediatric cancer incidence. The distribution of all pediatric cancers and brain cancer is shown in Fig. 2. Delineating the distribution of pediatric cancer cases across the state is important in addressing access to care issues. Nebraska is a rural state with Children's Hospital and Medical Center and Nebraska Medicine being the two main pediatric care centers located in urban Omaha. Geographic distribution of the incidence rates of all pediatric cancers varies across Nebraska, with 26 counties showing at least 10% higher incidence compared to the overall state incidence rate and 24 of these counties located in rural areas at a large distance (more than 1-h driving distance) from urban health care centers.

4. Discussion and conclusions

These data represent the longest evaluation of the cumulative incidence of pediatric cancer within a state. In accordance with data from SEER, our study revealed higher APCs for pediatric cancers in Nebraska compared to US SEER for the last five years of our evaluation period (2008–2013). However, the incidence of pediatric cancer in Nebraska is similar to that reported in the US SEER database over 1990–2013. This finding warrants further investigation to determine the causes for the increased incidence of pediatric cancer in Nebraska in the most recent years. Furthermore, IR calculations at a finer geospatial resolution within the state reveals interesting intrastate regional differences in pediatric cancer incidence. Most of the areas with higher incidence are rural areas at a greater distance from the specialized cancer treatment centers in urban Omaha, raising access to care issues for these patients. Finally, age-specific IR analyses reveal higher incidence of pediatric cancers in adolescents in Nebraska compared to US SEER, which needs to be investigated further both at the etiological and psychosocial level.

Our geospatial analyses suggest regional differences in pediatric cancer incidence. Specifically, an area stretching from Holt and Knox counties in the north through Red Willow, Furnas, Harlon, and Franklin counties in the south exhibits a higher IR than the rest of the state. These counties are an average of 227 miles from the treatment centers in the urban area of Omaha, with 4–7 h of travel time for these patients to obtain care. Given the rural nature of these counties and the effect of access to care for patients in these locations, this increased incidence can have a profound impact. Previous research investigating the geographic burden of care in pediatric cancer reveals that a two-hour or greater driving distance from the treatment center can have financial and social impacts for patients and their families [9]. Rural patients have greater out-of-pocket travel expenses, report significantly greater financial burden, miss more school days, and are at an increased risk of having to repeat a grade [9],11–17,33–35]. A closer examination of the patients and families living in these rural locations in Nebraska to evaluate differences in survival, quality of life, and overall cost of care would provide more definitive information on how pediatric cancer care delivery in Nebraska could be improved.

Another interesting observation is that the APC over the entire period evaluated is higher for Nebraska than US SEER; especially for

Table 2
Incidence rates of all and the three most common pediatric cancers in Nebraska and US/SEER (1990–2013) (rates per 1,000,000).

	All Pediatric Cancers			Leukemia			Lymphoma			CNS		
	NE IR (95% CI)	SEER IR (95% CI)	RR RR (95% CI)	NE IR (95% CI)	SEER IR (95% CI)	RR RR (95% CI)	NE IR (95% CI)	SEER IR (95% CI)	RR RR (95% CI)	NE IR (95% CI)	SEER IR (95% CI)	RR RR (95% CI)
All	173.3[a] (165.8–180.0)	167.1[a] (165.2–169.0)	1.0 (0.9–1.1)	41.1[a] (37.5–44.7)	41.0[a] (40.1–42.0)	1.0 (0.9–1.1)	28.1[a] (25.3–31.0)	24.6[a] (23.9–25.3)	1.1 (1.0–1.2)*	33.3[a] (30.0–36.6)	30.2[a] (29.4–31.0)	1.1 (1.0–1.2)
Age												
0–4	220.0 (203.0–236.9)	214.0 (209.7–218.3)	1.0 (0.9–1.1)	77.1 (67.0–87.1)	76.2 (73.7–78.8)	1.0 (0.9–1.1)	10.9 (7.1–14.7)	7.6 (6.8–8.4)	1.4 (1.0–2.1)*	43.0 (35.5–50.5)	40.2 (38.4–42.1)	1.1 (0.9–1.3)
5–9	121.6 (109.1–134.1)	113.8 (110.7–116.9)	1.1 (1.0–1.2)	33.3 (26.7–39.8)	37.0 (35.3–38.9)	0.9 (0.7–1.1)	17.5 (12.7–22.2)	14.0 (12.9–15.1)	1.3 (0.9–1.7)	36.3 (29.4–43.1)	32.8 (31.2–34.6)	1.1 (0.9–1.3)
10–14	122.2 (109.8–134.6)	128.3 (125.1–131.7)	1.0 (0.9–1.1)	22.1 (16.8–27.4)	26.7 (25.2–28.2)	0.8 (0.6–1.1)	23.4 (17.9–28.8)	25.1 (23.7–26.6)	0.9 (0.7–1.2)	27.7 (21.7–33.6)	27.3 (25.8 28.8)	1.0 (0.8–1.2)
15–19	232.3 (215.3–249.3)	215.1 (210.8–219.4)	1.1 (1.0–1.2)*	33.7 (27.6–40.9)	25.9 (24.4–27.4)	1.3 (1.1–1.6)*	59.7 (51.4–69.0)	50.9 (48.8–53.1)	1.2 (1.0–1.4)*	26.9 (21.5–33.4)	20.7 (19.4–22.1)	1.3 (1.0–1.6)*
Gender												
Male	186.8[a] (176.0–197.6)	175.2[a] (172.5–177.9)	1.1 (1.0–1.1)*	44.2[a] (38.9–49.5)	44.7[a] (43.4–46.1)	1.0 (0.9–1.1)	34.7[a] (30.0–39.4)	28.2[a] (27.2–29.4)	1.3 (1.1–1.4)*	37.4[a] (32.6–42.2)	32.5[a] (31.4–33.7)	1.2 (1.0–1.3)*
Female	159.2[a] (149.0–169.4)	158.6[a] (156.0–161.2)	1.0 (0.9–1.1)	37.8[a] (32.8–42.8)	37.2[a] (35.9–38.4)	1.0 (0.9–1.2)	21.0[a] (17.3–24.7)	20.7[a] (19.8–21.7)	1.0 (0.8–1.2)	29.1[a] (24.7–33.5)	27.7[a] (26.6–28.8)	1.1 (0.9–1.2)
Race												
NH-White	174.5[a] (165.9–183.2)	182.3[a] (179.9–184.8)	1.0 (0.9–1.0)	38.9[a] (34.8–42.9)	43.0[a] (41.9–44.2)	0.9 (0.8–1.0)	29.9[a] (26.3–33.6)	27.1[a] (26.2–28.1)	1.1 (1.0–1.3)	35.5[a] (31.6–39.4)	34.2[a] (33.1–35.3)	1.0 (0.9–1.1)
Other	139.3[a] (123.4–155.3)	148.2[a] (146.1–150.3)	0.9 (0.8–1.1)	44.4[a] (35.3–53.5)	45.2[a] (44.1–46.4)	1.0 (0.8–1.2)	17.2[a] (11.8–22.6)	20.1[a] (19.3–20.9)	0.9 (0.6–1.1)	22.6[a] (16.2–29.1)	22.7[a] (21.9–23.5)	1.0 (0.8–1.3)

IR = Incidence Rate, CI = Confidence Interval, RR = Relative Risk.
[a] Age-adjusted incidence rates.
* Significant: $p < .05$.

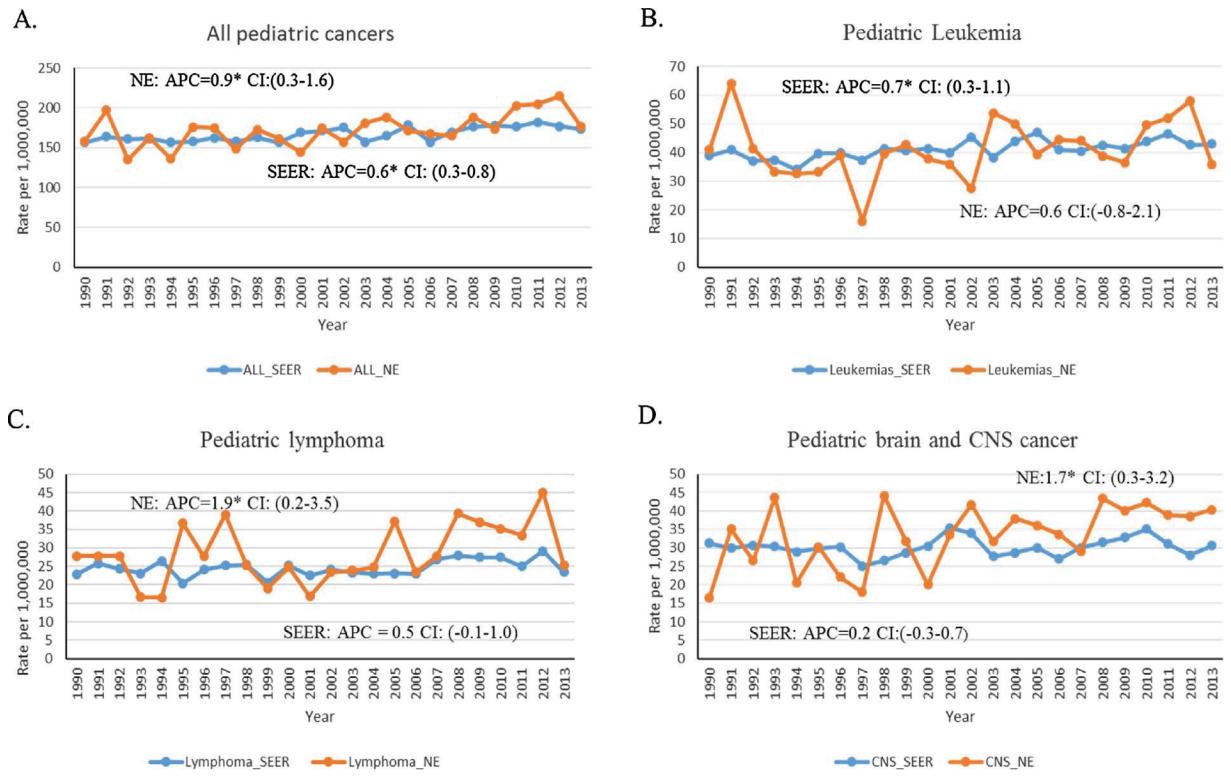


Fig. 1. Age-adjusted incidence rates of all pediatric cancers, leukemia, lymphoma, and brain and CNS tumors in Nebraska and SEER: 1990–2013. APC = Annual percentage change.

Table 3
Incidence rates of CNS tumors in Nebraska and US/SEER: 1990–2003 and 2004–2013 (per 1,000,000).

	1990–2003		2004–2013			
	Malignant		Malignant		Benign and Uncertain	
	NE	SEER	NE	SEER	NE	SEER
All	29.8[a]	29.9[a]	38.1[a]	30.5[a]	22.7[a]	17.2[a]
Age						
0–4	37.2	39	50.3	41.9	16.2	9.7
5–9	29.0	32.1	46.4	33.8	24.0	10.4
10–14	29.0	28.4	25.7	25.8	24.9	16.3
15–19	24.2	20.6	30.6	20.9	25.2	32.0

[a] Age-adjusted incidence rates.

lymphoma and CNS. The incidence rates for these cancers are higher in Nebraska compared to US SEER for the latest years within that period. It is interesting that for CNS tumors, both malignant and benign IRs are higher in Nebraska and US SEER during 2004–2013. This may reflect an increase in the etiologic factors for these tumor types, which include radiation exposures. Interestingly, a nuclear plant is located in Nemaha county which had the highest IRs of CNS tumors along with two other surrounding counties (Pawnee and Richardson). Of note, Nebraska is also a state with high levels of radon. There is a statewide program for testing for the levels of radon in homes [36]. Notably, of the 24 counties with higher levels of CNS tumors (labeled red on the map), 18 report more than 50% of the homes having radon levels above 4.0 pCi/L [36]. Beyond these observations we cannot make any connections between radiation exposures and increased incidence of CNS tumors in these counties.

We also identified a statistically significant increased RR in all cancer types for patients aged 15–19. The NCI defines the adolescent and young adult age group as beginning at 15 years of age. Previous research shows that cancers of these patients are biologically and clinically different from those of their younger counterparts [37,38]. Furthermore, this age group presents a unique set of issues, including fertility preservation, education, career development, employment, independence and decreased representation on clinical trials [38,39]. All these issues are potentially magnified in a rural area and should be considered when developing an appropriate treatment plan. Consequently, these patients are increasingly vulnerable to the impacts of access to care. Future studies can address issues regarding quality of life and access to care related with education and future college attendance for this age group in rural areas.

Finally, the spatial analyses based on LAA in GIS environment enabled us to address access to care issues concerning travel time. LAA identified Kearney as the secondary location most suitable to minimize the total travel time for Nebraska's pediatric cancer patients. Using Kearney and the two existing pediatric cancer locations in Omaha, we estimated that over 90% of the pediatric cancer population is within 2 h of these facilities (Fig. 3). This would improve financial burden to rural families, which was reported to be higher in a study addressing the burden of pediatric cancer in patients and their families [32]. The pediatric cancer center in Kearney would cover patients from 20 of the 26 counties with higher pediatric cancer incidence compared to the state average. Omaha would only serve 6 of those high incidence counties: Burt, Dodge, and Butler (1–2 h driving distance), Platte (2–3 h driving distance), and Knox and Antelope (3–4 h driving distance). This information could guide hospital systems and state legislators in the development of future care teams for pediatric cancer patients. Furthermore, this strategy can be utilized by other states to evaluate their own populations and health care systems.

In summary, the incidence of pediatric cancer in Nebraska is similar to the incidence in the United States over a 24-year period; however, regional differences within Nebraska present a challenge for the health management of rural populations. We believe that these challenges are not unique to Nebraska, and other rural states may have similar issues. Our investigations provide the framework for future studies, including attempts to understand the interplay between environmental and genetic factors as potential explanations for the regional differences

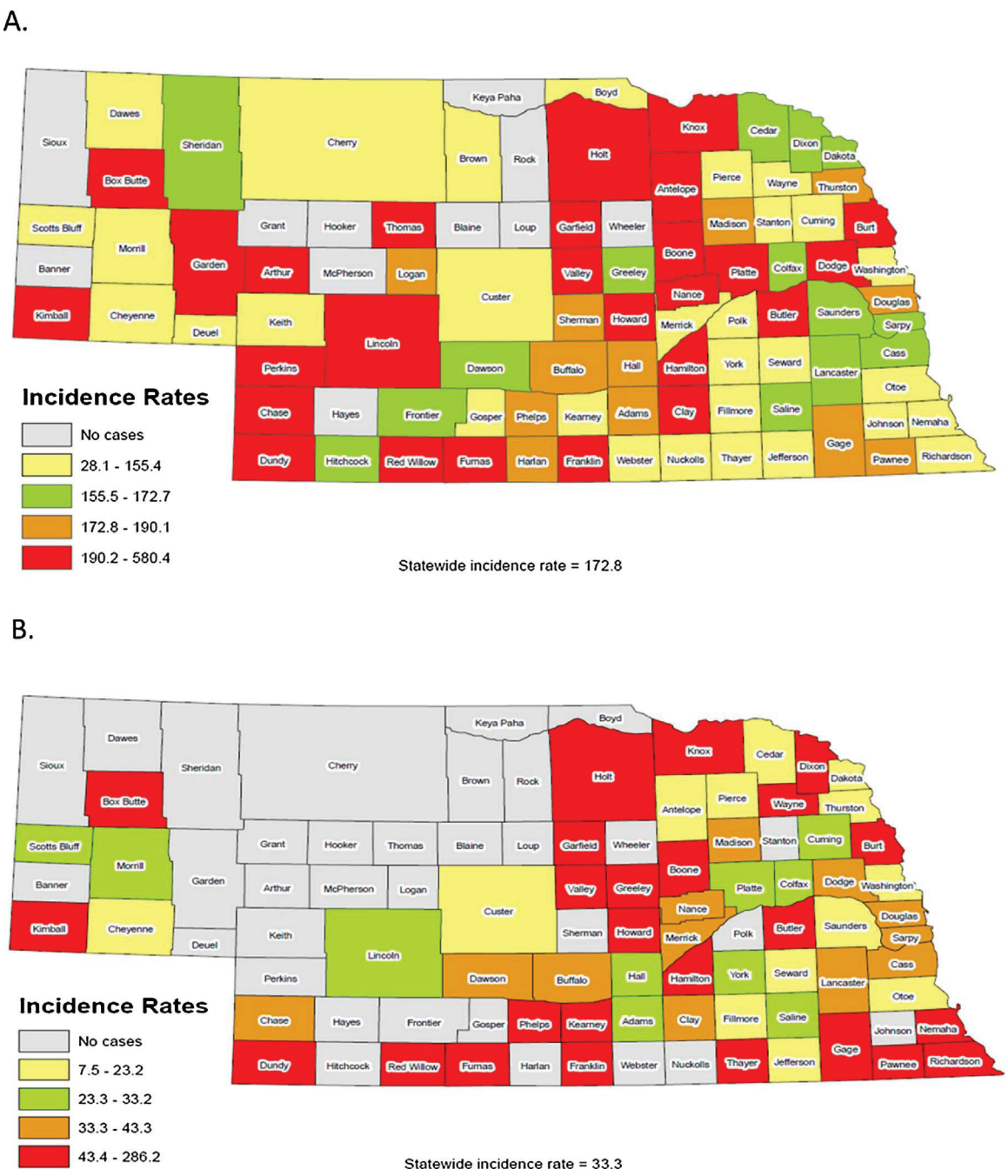


Fig. 2. A. Pediatric Cancer Diagnoses in Nebraska, 1990–2013 (Incidence Rates* by County of Residence). B. Pediatric Brain Cancer Diagnoses in Nebraska, 1990–2013 (Incidence Rates* by County of Residence) *Average annual number of new invasive cases per 1 million population < 20 years of age, age-adjusted to the 2000 US population.

identified in Nebraska. In addition, survival studies comparing cancer survival in urban vs rural populations is warranted.

Authors contribution

Drs. Farazi,Watanabe-Galloway, Coulter, and Sparks conceptualized and designed the study, drafted the initial manuscript, and approved the final manuscript as submitted.

Ms. Westman carried out statistical analyses and drafted methods section, reviewed and revised the manuscript, and approved the final manuscript as submitted.

Mr. Rettig provided statewide incidence rate maps, reviewed and revised the manuscript, and approved the final manuscript as submitted.

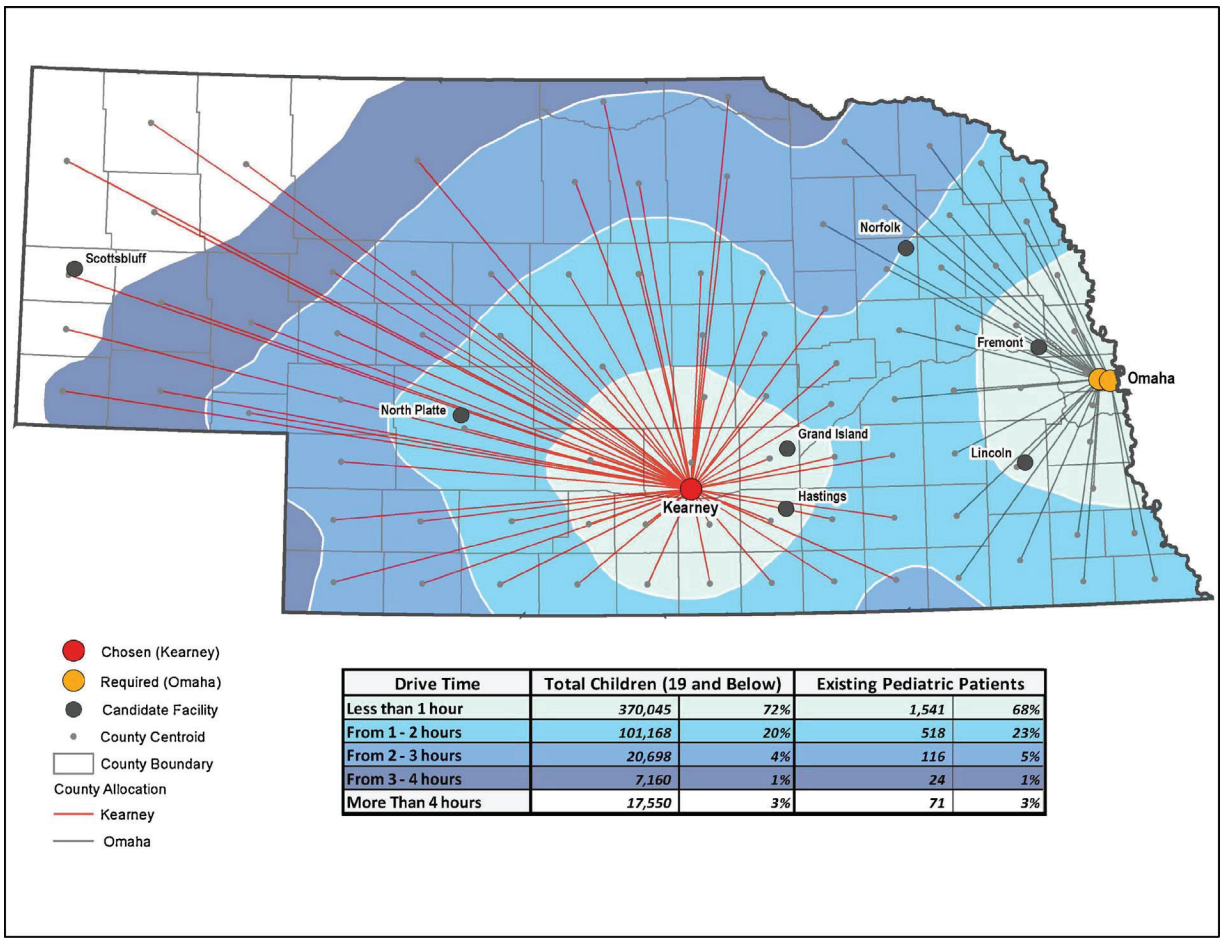
Dr. Cammack and Mr. Hunt conducted GIS analyses, reviewed and revised the manuscript, and approved the final manuscript as submitted.

Conflict of interest

None.

Roles

All authors participated in writing the manuscript and approved the final version. Li Westman curated data, Dr. Coulter administered the project.



Drive Time	Total Children (19 and Below)		Existing Pediatric Patients	
Less than 1 hour	370,045	72%	1,541	68%
From 1 - 2 hours	101,168	20%	518	23%
From 2 - 3 hours	20,698	4%	116	5%
From 3 - 4 hours	7,160	1%	24	1%
More Than 4 hours	17,550	3%	71	3%

Fig. 3. Optimal Pediatric Cancer Treatment Facility Expansion Location (Minimum Impedance Analysis Method).

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