The Effects of Hydraulic Fracturing on Childhood Cancer

by

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Abstract

Background/Objective: Cancer is the leading cause of death by disease among children, yet little is known about its risk factors. Exposure to hydraulic fracturing has been implicated in many health conditions, including childhood cancer. However, little is known about the relationship between hydraulic fracturing and childhood cancer in states with significant hydraulic fracturing activity. The objective of this study is to determine whether rates of childhood cancer are elevated in counties with hydraulic fracturing activity in Texas.

Methods: Childhood cancer case data for individuals ages 0-19 diagnosed with CNS tumors, acute myeloid leukemia, acute lymphocytic leukemia, Ewing's tumors, Hodgkin's Lymphoma, or non-Hodgkin's Lymphoma between 2010-2018 were obtained from the Texas Cancer Registry. County-level hydraulic fracturing data for 2010 were obtained from the Texas Railroad Commission. Average age-specific cancer rates were calculated for each of the cancer types of interest by five-year age group for 2010-2018. Standardized Incidence Ratios and 95% confidence intervals were calculated for each of these cancer types from 2014 to 2018 in relation to 2010 hydraulic fracturing activity.

Results: Average age-specific cancer rates according to hydraulic fracturing exposure varied by cancer type. Cases of CNS tumors, Ewing's tumors, leukemias, and lymphomas were higher than expected in counties without drilling activity (SIR=1.12, 95% CI: 0.99-1.26; SIR=1.31, 95% CI: 0.77-2.11; SIR=1.14, 95% CI: 1.00-1.30; SIR=1.07, 95% CI: 0.90-1.27; respectively).

Cases of CNS tumors were higher than expected in counties with horizontal drilling activity (SIR=1.02, 95% CI: 0.95-1.09). In counties with other drilling activity, cases of leukemias and lymphomas were slightly but not statistically significantly elevated (SIR=1.01, 95% CI: 0.96-1.06; SIR=1.00, 95% CI: 0.94-1.07; respectively).

Conclusion: This study did not find evidence of a relationship between elevated childhood cancer rates and hydraulic fracturing activity. Future research using individual-level data is needed to evaluate risk factors for childhood cancer. By gaining an understanding of the role that hydraulic fracturing exposure plays in childhood cancer development, evidence will be gathered that can inform future evaluations about the risks of childhood cancer, the leading cause of death by disease in children.

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1.0 Introduction

1.1 Hydraulic Fracturing Overview

Hydraulic fracturing is an oil and gas drilling technique that allows for increased production of oil and gas. This technique involves injecting high pressure fluids underground to create fractures in deep oil and gas formations, allowing oil and gas to flow into the well and up to the surface.[1] Hydraulic fracturing allows for deeper drilling and increased access to oil and gas formations that were previously inaccessible, leading to increased profitability and a decreased dependence on imported fossil fuels.[2]

Hydraulic fracturing has been used in conventional, vertical wells since the late 1940s. "Conventional" resources refer to those that can economically be extracted using long-established technologies. In contrast, "unconventional" resources are those that can only be extracted through the recent advances of hydraulic fracturing. Modern hydraulic fracturing, also known as high-volume hydraulic fracturing, uses long horizontal wells and higher volumes of fluids as compared to previous fracturing practices.[1]

The first horizontal wells were drilled in the mid-1980s in the Austin Chalk oil-bearing formation in Texas. However, technological advances in the early 2000s made hydraulic fracturing economical enough to become a standard technique in the oil and gas industry. Since this time, hydraulic fracturing operations have increased significantly, both in the United States and across the world. As of 2010, almost 2.5 million fracturing treatments have been performed globally.[1] Today, it is estimated that almost 10 million people in the United States live within a mile of a hydraulically fractured well.[3]

Texas is the leading oil and gas production state in the U.S., with 54,958 hydraulically fractured wells documented as of 2016.[4] Texas is home to some of the biggest shale plays in the U.S., including the Permian, Eagle Ford, Barnett, Haynesville, and Granite Wash plays. Other states that contain major shale plays include Arkansas, Colorado, Louisiana, Nebraska, North Dakota, Ohio, Oklahoma, Pennsylvania, South Dakota, West Virginia, and Wyoming.[1]

1.2 Hydraulic Fracturing Process

Hydraulic fracturing works by injecting high pressure fluids underground to create fractures in a reservoir rock, allowing hydrocarbons to flow through the fractures to the well, and then from the well up to the surface. This process has made it possible to extract oil and gas from unconventional geologic formations, including shales, tight formations, and coalbeds. While hydraulic fracturing itself is a short process that lasts around 2-10 days, the activities that lead up to and follow hydraulic fracturing can take much longer, lasting from years to decades. The timeframe of these activities depends on factors such as rate of depletion of the oil or gas, cost of production, and the price of oil and gas.[1]

While hydraulic fracturing allows for deeper drilling and increased profitability, the process also releases a variety of toxic chemicals.[2] Hydraulic fracturing can emit chemicals including benzene, polycyclic aromatic hydrocarbons, diesel exhaust, and other hydrocarbons into air and water.[3] Additionally, when a hydraulic fracturing well is completed, between 10% and 90% of the fluid used is returned to the surface. This fluid contains toxic gases, liquids, and solid materials that are naturally present in underground oil and gas formations.[2]

1.3 Health Risks of Hydraulic Fracturing

The health risks associated with the chemicals released during the hydraulic fracturing process are well-documented. Chemicals of primary concern include benzene, toluene, ethylbenzene, and xylene. These chemicals are carcinogenic, and can also damage the immune, respiratory, and nervous systems.[5] Benzene is a carcinogen of particular concern, as it has been established as a cause of acute myeloid leukemia in adults.[6]

A study conducted by Colborn et al. found that more than 75% of the chemicals used throughout the hydraulic fracturing process can affect the skin, eyes, sensory organs, respiratory system, gastrointestinal system, and the liver. Authors also found that over 25% of chemicals used throughout the hydraulic fracturing process were carcinogenic.[2] A similar study by Elliott et al. investigated the carcinogenicity of water and air pollutants related to unconventional oil and gas drilling. Of the 111 water chemicals and 29 air chemicals evaluated, 49 water and 20 air pollutants were known, possible, or probable human carcinogens. Additionally, 17 water and 11 air pollutants showed evidence of increased risk for leukemia or lymphoma.[7]

The water that returns to the surface at the end of the hydraulic fracturing process, also known as "flowback" water, has been found to contain radioactive materials. Because shale and sandstone formations often contain radioactive materials, radioactivity has been detected in the water produced by these formations. This water contains radioactive materials including uranium, radium, and other radionuclides.[1] Exposure to uranium and radium is linked to an increased risk of bone and lung cancer, hematopoietic and lymphatic tissue tumors, lymphoma, and leukemia.[3] Exposure to high levels of radiation can harm a fetus throughout various stages of pregnancy. High doses of radiation can cause damages to cellular structure and DNA, which may lead to the development of cancer, particularly childhood cancer, as young people are more vulnerable to radiation exposure.[8]

Exposure to hydraulic fracturing chemicals primarily occurs through contaminated water or air. Factors such as faulty or deteriorating well infrastructure, equipment failure, spills of fracturing fluids or wastewater, migration of chemicals from fractures to shallow aquifers, leakage from wastewater pits, or unauthorized discharge and release of inadequately treated wastewater into the environment can all lead to water contamination. Similarly, air can be polluted by operation of diesel-powered equipment, use of vehicles to transport materials and waste to and from the fracking site, addition of sand to the fracturing fluid mixture, volatilization of compounds from wastewater, and processing and distribution of oil and gas.[7] Individuals are then exposed by breathing polluted air or drinking, bathing, or cooking with contaminated water.[5]

1.4 Cancer and Hydraulic Fracturing

Given that several chemicals involved in the hydraulic fracturing process are known to cause cancer, researchers have begun to investigate the association between hydraulic fracturing and the development of cancer. While research on this topic is limited, some studies suggest a potential association between hydraulic fracturing and cancer development.[3,6] McKenzie et al. conducted a case-control study among 0-24-year-olds diagnosed with cancer in rural Colorado between 2001-2013 (N=743) to determine whether risk for childhood hematologic cancers was associated with residential proximity to oil and gas development. Inverse distance weighted (IDW) oil and gas counts within a 16.1-kilometer radius of residence at diagnosis were calculated for each participant for each year in a 10-year latency period. Overall, individuals with acute lymphocytic leukemia (ALL) aged 0-24 were more than 2 times as likely to live in the highest IDW well count tertiles compared to controls, however the difference was not statistically significant (p=0.22). Participants aged 5-24 were 4.3 times as likely to live in the highest IDW well count tertile compared to controls (95% CI: 1.1 to 16, p = 0.035). However, no statistically significant association was found between oil and gas proximity and ALL among children ages 0-46.[6]

Another study by Dr. Madelon Finkel from Weill Cornell Medical College used an ecologic design to evaluate the extent to which unconventional gas development leads to increased cancer incidence in heavily drilled areas of Southwest Pennsylvania. Standardized incidence ratios by county, diagnosis, and sex were calculated, as well as the percent difference between observed cases from 2000-2004 and 2008-2012. The analysis revealed that the observed number of urinary bladder cases was higher than expected in counties with shale activity. However, due to the nature of the ecologic study design, other potential risk factors including occupational exposures, smoking, alcohol, diet, and genetic history were unable to be evaluated, and might have confounded the observed results in this study.[3]

Fryzek et al. aimed to determine whether childhood cancer incidence was associated with residing in counties with hydraulic fracturing sites. Using standardized incidence ratios (SIRs) and 95% confidence intervals measurements, the total number of childhood cancers observed was close to expected both before and after drilling began for counties with natural gas wells, suggesting that living near hydraulic fracturing operations did not increase risk of childhood cancer.[9] However, a major criticism of this study is that it did not account for the lag period between exposure to a carcinogen and the development of cancer, which is important to consider when drawing conclusions about cancer development.[10]

1.5 Childhood Cancer

While childhood cancer is rare, it is the leading cause of death by disease and the second leading cause of mortality in children.[11] The incidence of childhood cancer has steadily increased in the past few decades, from 15 children per 100,000 in 1980 to over 21 children per 100,000 in 2017.[12] The American Cancer Society estimates that approximately 10,470 children will be diagnosed with cancer in 2022.[11] Common childhood cancers include leukemia, brain and spinal cord tumors, neuroblastoma, Wilms tumors, lymphoma (Hodgkin and non-Hodgkin), rhabdomyosarcoma, retinoblastoma, and bone cancers including osteosarcoma and Ewing's sarcoma.[13]

Due to advances in treatment, the 5-year survival rate for children after cancer diagnosis has increased from 10% to over 85% in the past 40 years.[11] However, the 5-year survival rate is much lower for rarer cancers. For example, Ewing's tumors have a survival rate of 62%.[14] Additionally, nearly 60% of childhood cancer survivors will experience severe or life-threatening complications as an adult.[12]

1.6 Gaps in Knowledge

The causes of childhood cancer are not well-understood. In adults, cancer risk is often influenced by lifestyle-related factors, which take many years or even decades to impact cancer development. In children, however, these lifestyle factors may play less of a role in cancer development. Childhood cancer is primarily influenced by genetic changes, but most childhood cancers are not caused by inherited mutations. In fact, only 6-8% of all cancer cases in children are caused by an inherited genetic mutation. Thus, childhood cancers are often the result of changes to DNA due to environmental exposures that occur early in the child's life, potentially even before birth.[15]

Since 2018, concerns have been raised regarding childhood cancer in Pennsylvania counties with high hydraulic fracturing activity. Concerns have also been raised regarding an increased prevalence of Ewing's tumors, a rare childhood cancer, in the Southwestern area of Pennsylvania. An ongoing case-control study led by Dr. Evelyn Talbott at the University of Pittsburgh School of Public Health is currently investigating whether those diagnosed with childhood cancers in Pennsylvania, including Ewing's tumors, are more likely to be exposed to hydraulic fracturing.[16,17] However, to further the knowledge base on this hypothesis, the relationship between hydraulic fracturing and childhood cancer must be evaluated in other populations with similar exposures. While Texas is the national leader in shale oil production, the relationship between hydraulic fracturing and childhood cancer in Texas is not well-understood. Thus, the aim of this study is to determine whether rates of childhood cancer are elevated in counties with hydraulic fracturing activity in the state of Texas.

1.7 Overall Public Health Significance

As the leading cause of death by disease among children, childhood cancer is a public health problem. Given that childhood cancer rates have steadily risen in recent decades, it is critical that the risk factors for childhood cancer are investigated in a timely manner.[11] Despite the impact that cancer has on children, risk factors of childhood cancer are not well understood. By gaining an understanding of the role that hydraulic fracturing exposure plays in childhood cancer development, baseline evidence will be gathered that can inform future evaluations about the risks of cancer development in children.

2.0 Objectives

The objectives of this essay were to 1) calculate average age-specific rates of childhood cancers at the county level among individuals ages 0-19 in Texas from 2010-2018; 2) calculate Standardized Incidence Ratios of childhood cancers among individuals ages 0-19 in Texas from 2014-2018; and 3) assess these rates in relation to county-level hydraulic fracturing activity using drilling permit data from the Texas Railroad Commission. These objectives will help provide additional data for the potential role of hydraulic fracturing exposure in the risk of childhood cancer development.

3.0 Methods

3.1 Data Sources

An IRB exemption for this study was submitted to the University of Pittsburgh Human Research Protection Office and was deemed as Not Human Subjects Research on February 14 2022 (STUDY22020022). Cancers selected for inclusion in this ecologic study include the following: Central Nervous System tumors, Ewing's family of tumors, acute myeloid leukemia, acute lymphocytic leukemia, Hodgkin's lymphoma, and non-Hodgkin's lymphoma.

Individual, de-identified cancer case data were obtained from the Texas Cancer Registry (TCR).[18] Cancer cases were classified according to the International Classification of Childhood Cancer Recode Third Edition ICD-O-03/WHO 2008. TCR data include cases aged 0-19 that were diagnosed with cancer from 2010-2018 in the state of Texas. Annual county-level population estimates from 2010-2018 were downloaded from the U.S. Census Bureau.[19]

Quantifying hydraulic fracturing exposure poses a challenge as there is no complete database or registry of hydraulically fractured wells in the U.S. Thus, this study utilized drilling permit data from the Texas Railroad Commission (TRC) to characterize a county's drilling activity. These TRC data provide the location, permit approval date, and wellbore profile of each well.[20] While these data do not state whether a well has been hydraulically fractured, the wellbore profile can serve as an indicator of hydraulic fracturing, as the majority of horizontal wells are hydraulically fractured.[21] This study utilized permits issued in 2010 to serve as the exposure period. County-level data on covariates including race, sex, poverty, and education level for 2010 were obtained from the U.S. Census Bureau.[22] Covariate race definitions for U.S. Census data differed slightly from those of TCR data due to differences in race data availability.

3.2 Variables

To calculate average age-specific incidence rates, cancer cases were separated by cancer type and were grouped into four categories: CNS tumors, Ewing's family of tumors, leukemias (including acute myeloid leukemia and acute lymphocytic leukemia), and lymphomas (including Hodgkin's and non-Hodgkin's lymphomas). For each cancer grouping, cases were then separated into five-year age groups according to their age at diagnosis.

Drilling permit data was utilized to categorize the type of drilling activity that occurred in each county. Categorization of drilling activity was based on permits issued in 2010 to allow for a prospective analysis of cancer cases following exposure to drilling activity. Directional and vertical drilling activity were combined to form the category of "other" drilling activity. Each county was then classified as having one or more of the following types of drilling activity: Horizontal Drilling, Other Drilling, or No Drilling.

3.3 Statistical Analyses

Data from the Texas Cancer Registry, U.S. Census Bureau, and Texas Railroad Commission were used to calculate average age-specific cancer incidence rates according to drilling exposure. The total population at risk for each drilling exposure group was calculated by averaging the total annual population estimates of the counties with horizontal, other, or no drilling activity, respectively. Age-specific cancer case counts for 2010-2014 and 2015-2018 were then divided by the population at risk for each time period to calculate an average, age-specific cancer rate for each of the four cancer types by five-year age groups (0-4, 5-9, 10-14, 15-19). Additionally, average population covariate data were calculated for each of the drilling activity categories. These data included the following variables: race, Hispanic origin, sex, percent poverty, and educational attainment.

In addition, standardized incidence ratios (SIR) and 95% confidence intervals for CNS tumors, Ewing's tumors, leukemias, and lymphomas were calculated by drilling category for 2014-2018 to determine if the number of cases was higher than expected after exposure to hydraulic fracturing, accounting for a lag period. These SIRs were calculated by dividing the number of observed cases in each drilling category by the number of expected cases. Expected cases were calculated by multiplying the age-specific statewide cancer rate by the total population of each respective age group. A SIR greater than 1.0 indicates that there is a greater number of cases observed than would be expected in a given area, and a 95% confidence interval that does not contain 1.0 indicates that the number of cases observed in the study population is significantly different from that of the comparison population.

4.0 Results

Table 1 represents the demographic information for the childhood cancer cases. A total of 8,914 cases for the period 2010-2018 were included in this study. The case distribution reflected a slightly higher ratio of males (53.32%) to females and other sex (46.67%). The race distribution for the majority of cases were white (85.25%), followed by black (9.60%) and other race (4.33%). Of the four cancer categories, CNS tumors and leukemias had the highest case counts (40.04% and 35.88%, respectively), followed by lymphomas (21.89%) and Ewing's tumors (2.20%).

Table 2 represents county-level population covariate data aggregated by drilling category. Overall, distribution of covariates remained consistent across the three drilling types. Across all three groups, approximately 70% of the population was white, followed by 12% black and between 8-11% other race. Around 32% of the overall population was Hispanic or Latino, and 67% of the population was not Hispanic or Latino. 51% of the population was male, and 48% of the population was female. Between 16-18% of the population was in poverty, and about 82% was not in poverty. For counties with horizontal or other drilling, 81% of the population aged 18 and over obtained a high school diploma, and 84% of the population in the counties with no drilling obtained a high school diploma.

Figure 1 displays a map of the drilling categorizations for each county in Texas. A total of 115 counties had horizontal drilling, and 113 of these counties had other drilling activity as well. 99 counties only had other drilling activity, and a total of 212 counties had other drilling activity overall. 40 counties had no drilling activity.

Overall, average age-specific cancer rates varied for CNS tumors, Ewing's family of tumors, leukemias, and lymphomas. Table 3 displays the average age-specific cancer rates by 5-

year age groups for horizontal drilling counties. Across all age groups, rates of CNS tumors and lymphomas decreased from 2010-2014 to 2015-2018, while changes in rates of Ewing's tumors and leukemias varied by age group. Table 4 displays the average age-specific cancer rates by 5-year age groups for other drilling counties. Rates of CNS tumors, leukemias, and lymphomas decreased from 2010-2014 to 2015-2018 for all age groups, while changes in rates of Ewing's tumors varied by age group. Table 5 displays the average age-specific cancer rates by 5-year age groups for counties with no drilling. For all age groups, rates of leukemias decreased from 2010-2014 to 2015-2018, while changes in rates of CNS tumors, Ewing's tumors, and lymphomas varied by age group.

Figure 2 shows the average age-specific rate of CNS tumors for all ages in the study population. When examining CNS tumor rates among the three drilling categories, all counties showed a decrease in cancer rates from 2010-2018. However, this decrease was larger in counties with horizontal or other drilling activity.

Figure 3 shows the average age-specific rate of Ewing's tumors for all ages in the study population. Rates of Ewing's tumors decreased from 2010-2018 in counties with no drilling and other drilling. However, rates of Ewing's tumors increased steadily from 2010-2018 in counties with horizontal drilling.

Figure 4 shows the average age-specific rate of leukemia for all ages in the study population. All counties showed a decrease in leukemia rates from 2010-2018. However, this decrease was greater in counties with no drilling activity.

Figure 5 shows the average age-specific rate of lymphoma for all ages in the study population. Lymphoma cases in horizontal and other drilling counties showed a prominent decrease from 2010-2018, while counties without drilling only showed a slight decrease in lymphoma rates.

Table 6 displays the standardized incidence ratios and 95% confidence intervals of CNS Tumors, Ewing's Tumors, Lymphomas, and Leukemias based on drilling category. In counties with horizontal drilling, a SIR of 1.02 (95% CI: 0.05-1.09) was observed for CNS Tumors, 0.99 (95% CI: 0.71-1.33) for Ewing's Tumors, 0.94 (95% CI: 0.87-1.01) for Leukemia, and 0.98 (95% CI: 0.88-1.07) for Lymphoma. In counties with no drilling, an SIR of 1.12 (95% CI: 0.99-1.26) was observed for CNS Tumors, 1.31 (95% CI: 0.77-2.11) for Ewing's Tumors, 1.14 (95% CI: 1.00-1.30) for Leukemia, and 1.07 (95% CI: 0.90-1.27) for Lymphoma. In counties with other drilling, an SIR of 0.98 (95% CI: 0.93-1.02) was observed for CNS Tumors, 0.96 (95% CI: 0.78-1.18) for Ewing's Tumors, 1.01 (95% CI: 0.96-1.06) for Leukemia, and 1.00 (95% CI: 0.94-1.07) for Lymphoma.

Table 1. Demographic Characteristics for Texas Cancer Registry Data, 2010-2018

	Frequency	**Percentage (%)**
Age		
0-4	2804	31.46
5-9	2092	23.47
10-14	1640	18.40
15-19	2378	26.68
Sex		
Male	4753	53.32
Female	4155	46.61
Other	6	0.06
Race		
White	7599	85.25
Black	856	9.60
American Indian	49	0.55
Other	386	4.33
Unknown	24	0.27
Cancer Type		
CNS Tumors	3569	40.04
Ewing's Tumors	196	2.20
Leukemia	3198	35.88
Lymphoma	1951	21.89

Table 2. County-Level Covariate Data Aggregated by Drilling Category, Texas, 2010

	Horizontal Drilling	Other (Vertical or Directional) Drilling	No Drilling
Race			
White	71.0%	69.6%	73.0%
Black or African American	12.5%	12.2%	10.5%
American Indian and Alaska Native	0.7%	0.7%	0.7%
Asian	2.6%	3.6%	4.7%
Native Hawaiian and Other Pacific Islander	0.1%	0.1%	0.1%
Other Race	10.8%	11.1%	8.2%
Two or More Races	2.4%	2.7%	2.8%
Hispanic Origin			
Hispanic or Latino	33.0%	32.1%	32.0%
Not Hispanic or Latino	67.0%	67.9%	68.0%
Sex			
Male	51.5%	51.5%	51.8%
Female	48.5%	48.5%	48.2%
Poverty			
In Poverty	18.4%	17.7%	16.0%
Not in Poverty	81.6%	82.3%	84.0%
Educational Attainment			
High School Diploma or Higher	81.2%	81.0%	84.8%
Lower than a High School Diploma	18.8%	19.0%	15.2%

Table 3. Average Age-Specific Cancer Rates per 100,000 Population in Counties with Horizontal Drilling, 2010-2018 (N=254)

	2010-2014				2015-2018			
	0-4 years	**5-9 years**	**10-14 years**	**15-19 years**	**0-4 years**	**5-9 years**	**10-14 years**	**15-19 years**
CNS Tumors	28.9	24.8	18.8	31.9	21.3	21.7	15.9	20.6
Ewing's Tumors	0.5	0.9	0.7	2.1	0.3	0.6	1.5	2.2
Leukemia	37.7	14.4	9.7	14.2	30.0	16.2	11.5	11.0
Lymphoma	9.6	11.2	10.2	22.2	8.4	7.7	8.4	16.3

Table 4. Average Age-Specific Cancer Rates per 100,000 Population in Counties with Other Drilling, 2010-2018 (N=254)

	2010-2014				2015-2018			
	0-4 years	**5-9 years**	**10-14 years**	**15-19 years**	**0-4 years**	**5-9 years**	**10-14 years**	**15-19 years**
CNS Tumors	27.7	25.1	18.9	29.8	21.5	19.6	14.7	22.2
Ewing's Tumors	0.5	1.4	1.1	2.2	0.2	0.8	1.4	1.8
Leukemia	38.0	19.5	13.0	14.3	32.3	17.4	12.3	11.2
Lymphoma	10.4	11.2	11.7	23.7	7.9	8.3	8.9	17.4

Table 5. Average Age-Specific Cancer Rates per 100,000 Population in Counties with No Drilling, 2010-2018 (N=254)

	2010-2014				2015-2018			
	0-4 years	5-9 years	10-14 years	15-19 years	0-4 years	5-9 years	10-14 years	15-19 years
CNS Tumors	34.1	22.8	20.7	25.5	25.0	23.2	15.2	26.2
Ewing's Tumors	1.4	0.4	1.7	4.0	0.9	1.3	2.1	2.1
Leukemia	48.6	25.5	15.1	15.8	42.7	21.9	9.9	12.9
Lymphoma	12.1	9.2	10.3	19.8	8.6	8.6	11.1	16.6

Table 6. Standardized Incidence Ratios of CNS Tumors, Ewing's Tumors, Leukemia, and Lymphoma by Drilling Type, 2014-2018

Drilling Type	Cancer Type	Observed Cases	Expected Cases	SIR	95% CI Lower	95% CI Upper
Horizontal	CNS Tumors	783.00	770.30	1.02	0.95	1.09
	Ewing's Tumors	42.00	42.55	0.99	0.71	1.33
	Leukemia	645.00	687.97	0.94	0.87	1.01
	Lymphoma	410.00	420.44	0.98	0.88	1.07
None	CNS Tumors	262.00	234.05	1.12	0.99	1.26
	Ewing's Tumors	17.00	12.93	1.31	0.77	2.11
	Leukemia	239.00	209.04	1.14	1.00	1.30
	Lymphoma	137.00	127.69	1.07	0.90	1.27
Other	CNS Tumors	1743.00	1783.66	0.98	0.93	1.02
	Ewing's Tumors	95.00	98.52	0.96	0.78	1.18
	Leukemia	1606.00	1593.01	1.01	0.96	1.06
	Lymhoma	974.00	973.08	1.00	0.94	1.07

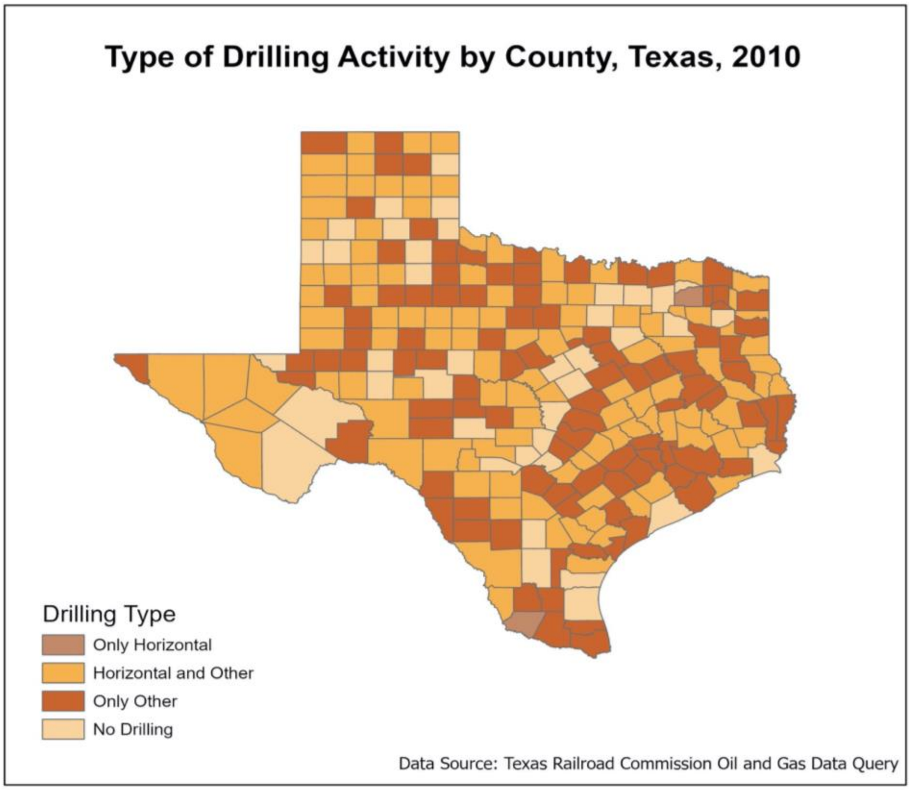

Figure 1. Map of Drilling Type by County, Texas, 2010

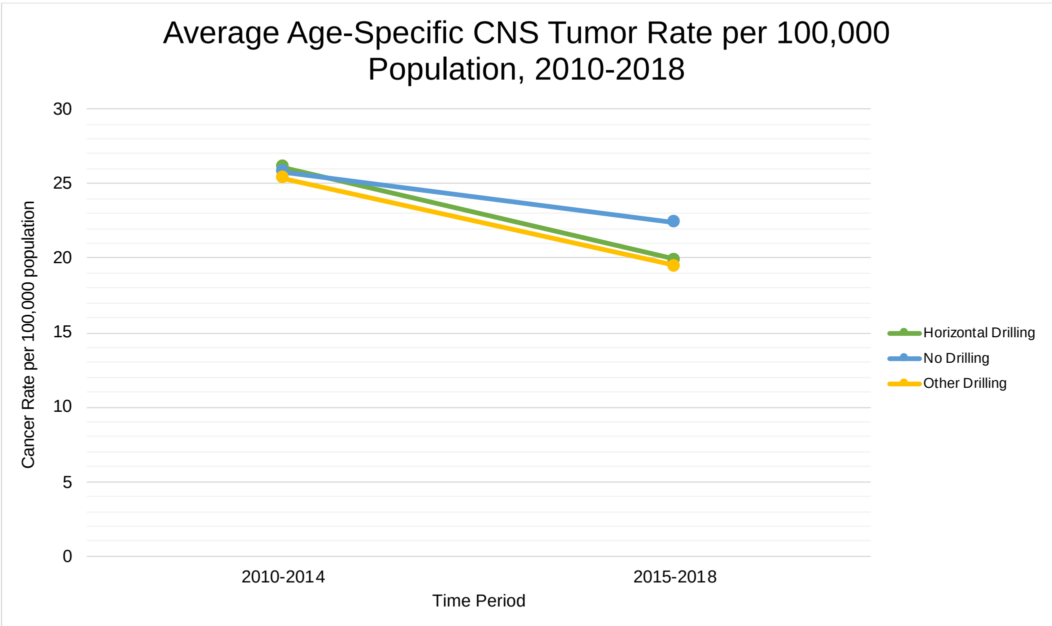

Figure 2. Graph of Average Age-Specific CNS Tumor Rate per 100,000 Population, All Age Groups, 2010-2018

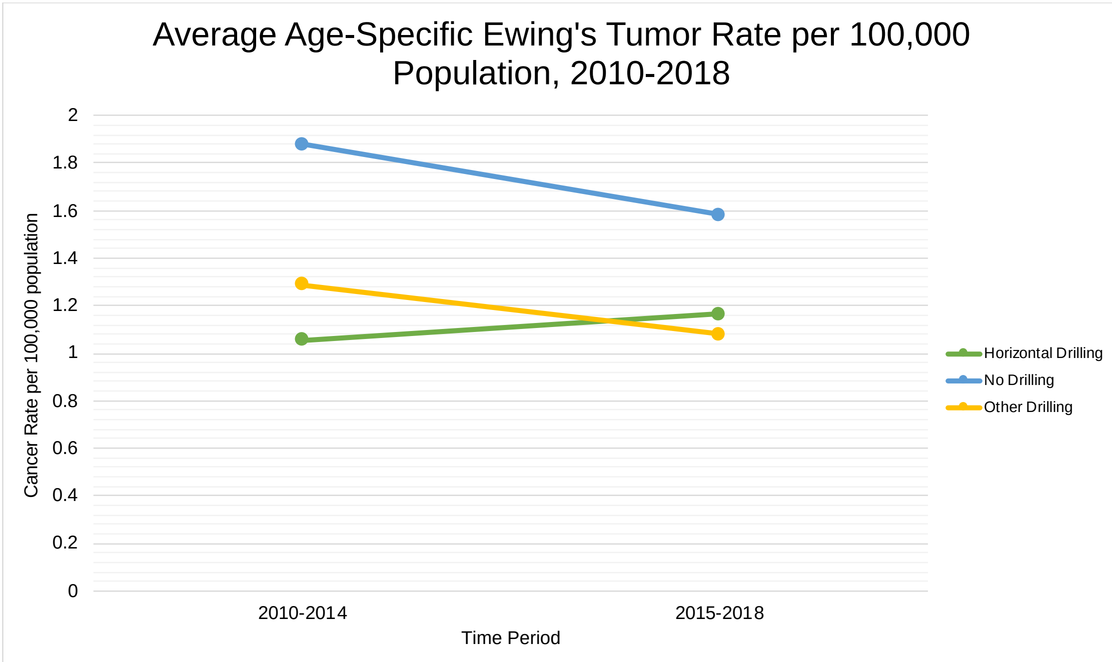

Figure 3. Graph of Average Age-Specific Ewing's Tumor Rate per 100,000 Population, All Age Groups, 2010-2018

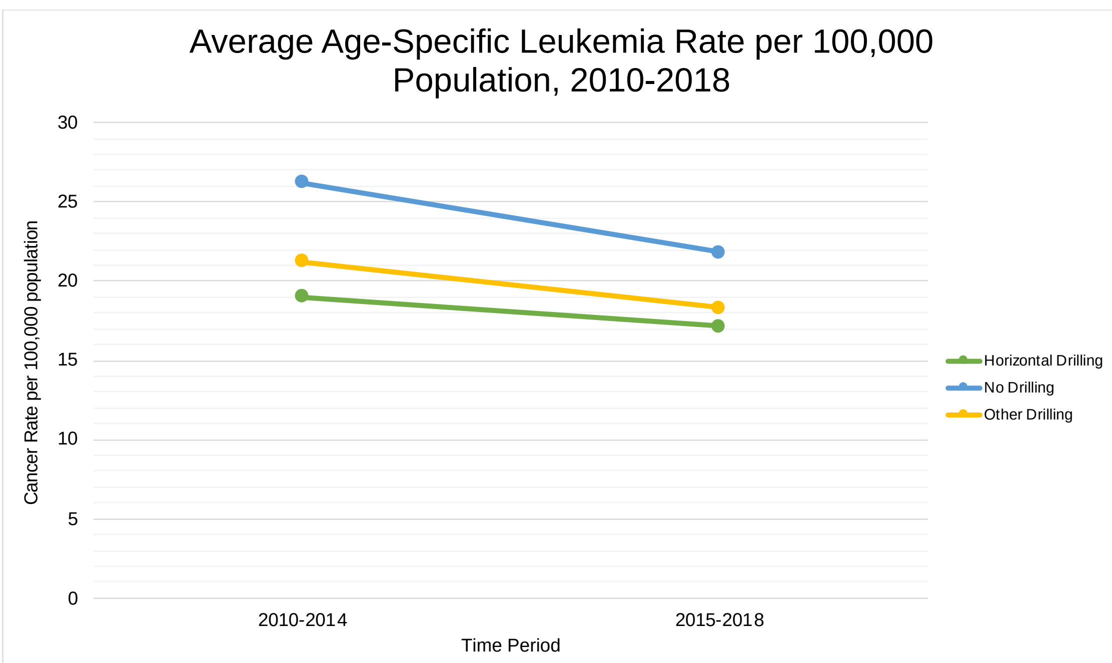

Figure 4. Graph of Average Age-Specific Leukemia Rate per 100,000 Population, All Age Groups, 2010-2018

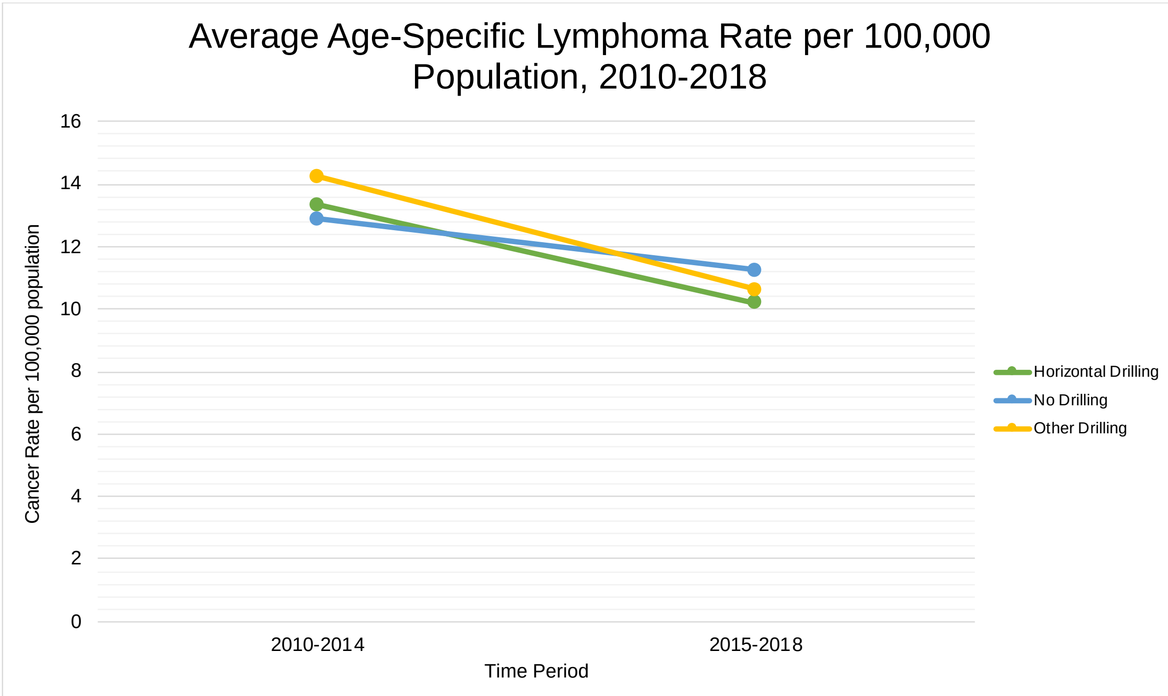

Figure 5. Graph of Average Age-Specific Lymphoma Rate per 100,000 Population, All Age Groups, 2010-2018

5.0 Discussion

The goal of this study was to determine whether rates of childhood cancer were elevated in counties with hydraulic fracturing activity in Texas. This study did not find evidence of a relationship between elevated childhood cancer rates and hydraulic fracturing activity. SIRs varied by drilling category and cancer type, and a SIR greater than 1.0 was observed for CNS tumors in horizontal drilling counties (SIR=1.02) and leukemias and lymphomas in other drilling counties (SIR=1.01 and 1.00, respectively). Additionally, all four cancer types saw SIRs greater than 1.0 for counties with no drilling. However, the 95% confidence intervals for SIRs of all cancers and drilling types contain 1.0, indicating that it cannot be concluded with sufficient confidence that the observed number of cases is not the result of chance and reflects a real cancer increase or decrease. Further, average age-specific cancer rates showed an inconsistent relationship between drilling activity and childhood cancer rates over time. Thus, we cannot conclude whether there is a clear relationship between childhood cancer and hydraulic fracturing activity.

The causes of childhood cancer are not well-understood, and the limited research on this topic has not yet reached a consensus on whether unconventional gas development is a risk factor for childhood cancer.[17] Nevertheless, the findings of this study add to the growing knowledge base on the risk factors for childhood cancer. This ecologic study assessed childhood cancer rates and hydraulic fracturing activity at the county level for the state of Texas, the leading producer of oil and gas in the U.S.[4] However, county-level aggregations do not offer the same level of detail as data for more granular geographic areas, such as zip code or census tract. Given that every well differs in size, location, and proximity to residences, county-level rates may have hindered this study's ability to detect potential effects of hydraulic fracturing on childhood cancer. This limitation may be of heightened importance for rare cancers such as Ewing's tumors. Additionally, this analysis did not account for drilling that occurred after 2010. Future research on this topic should evaluate childhood cancer rates and hydraulic fracturing activity over longer periods of time using data with increased granularity as opposed to aggregated rates in order to fully ascertain this relationship.

A major limitation of quantifying hydraulic fracturing activity is the lack of a complete database or registry of hydraulically fractured wells in the U.S. A strength of this study was the use of Texas drilling permit data, which provided information on the wellbore profile of each well, to classify drilling status. While the majority of horizontally drilled wells are hydraulically fractured, these drilling permit data did not explicitly state whether a well was hydraulically fractured.[21] Additionally, the majority of horizontal drilling counties also had other drilling activity, which made it difficult to differentiate the effects of one type of drilling. Thus, wellbore profile alone may not indicate whether hydraulic fracturing plays a role in childhood cancer risk. A complete database of hydraulically fractured wells would help to address this limitation in future research. FracFocus, a national hydraulic fracturing chemical disclosure registry, provides information to the general public about chemicals used in hydraulic fracturing. As of 2017, 27 U.S. states either require or allow companies to disclose chemical data to FracFocus. Future legislation requiring all states to report to FracFocus would allow for increased knowledge on the chemicals used during the hydraulic fracturing process and their effects on human health.[23]

Despite the limitations discussed, this study had several strengths. The large population of Texas allowed for a sufficient sample size of childhood cancer cases (N=8,914). Cancer case coding from the TCR database was consistent with ICCC/ICD-O-3 WHO 2008 coding guidelines, allowing for clear definition of cancer cases. Additionally, analyzing age-specific cancer trends over time in addition to Standardized Incidence Ratios allowed for a broader understanding of the data.

This study did not allow us to draw a conclusion on whether exposure to hydraulic fracturing activity increases risk of childhood cancer. However, the health effects of hydraulic fracturing are still of concern to public health. Chemicals released throughout the hydraulic fracturing process are known to pose risks to human health, and several are carcinogenic. For example, benzene is a known cause of acute myeloid leukemia in adults, and radioactive materials such as uranium and radium are known to increase risk of bone and lung cancer, lymphoma, and leukemia. Prenatal exposure to these chemicals can also harm a developing fetus.[1,3,6] Given the potential that these chemicals have to harm human health, future research must continue to investigate the health effects of hydraulic fracturing.

The risk factors of childhood cancer are still not well-understood. Despite recent advances in treatment and survival rates, the incidence of childhood cancer is on the rise, and nearly 60% of survivors experience severe or life-threatening complications as adults.[12,17] Thus, it is crucial that future research continues to investigate causes of childhood cancer to make the world a safer and healthier place for future children.

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