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INCLUSIVITY IN PEOPLE, METHODS, AND OUTCOMES

RESEARCH ARTICLE

Using Geospatial Analysis to Identify Priority Communities for Cervical Cancer Prevention in Texas



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Introduction: Despite being almost entirely preventable, cervical cancer is the fourth most frequently diagnosed cancer among women worldwide. Cervical cancer incidence suggests missed opportunities for prevention. Geospatial analysis could strategically guide public health interventions. This study aimed to identify geographic clusters of cervical cancer incidence in Texas, a state with higher than national rates of cervical cancer incidence and mortality.

Methods: In this population-based cross-sectional study, the authors analyzed incident cervical cancer data among Texas women aged 30–64 years, from 2014 to 2018. The authors conducted a purely spatial Poisson-based analysis function in SaTScan to examine geographic clusters of higher-than-expected proportions of cervical cancer incidence (i.e., hot spots) and adjusted for age.

Results: A total of 5,060 women aged 30–64 years with incident cervical cancer diagnosis (mean age: 45.7 years, SD=9.6), including 1,840 (36.4%) Hispanic, 591 (11.7%) non-Hispanic Black, 2,397 (47.4%) non-Hispanic White, and 232 (4.6%) other races, were analyzed. Spatial scan analysis detected 7 significant hot spots of cervical cancer incidence. Hot spots were identified in the South Texas Plains (near Mexico border), Gulf Coast (Houston), Prairies and Lakes (North Texas), Panhandle Plains (Northwest Texas), and Piney Woods (Southeast Texas) regions of Texas. Hot spots, compared with the rest of Texas, had higher proportions of Hispanic population and individuals with socioeconomic disadvantages.

Conclusions: This study found spatial variation in cervical cancer incidence in Texas. The hot spot areas can benefit from targeted, novel, scalable, and cost-effective interventions to increase human papillomavirus vaccination and screening and early detection and treatment of precancerous cervical lesions.

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INTRODUCTION

Texas is one of the geographically largest and demographically heterogeneous states in the U.S. and had one of the highest cervical cancer (CC) incidence rates nationally (9.2 cases per 100,000 vs the U.S. rate of 7.6 cases per 100,000 women) from 2012 to 2016.¹ In addition, Texas had lower than the national rates of CC screening (up-to-date Papanicolaou [Pap]/HPV test, women 25–65 years) (82% in Texas vs 87% U.S.) in 2020² and up-to-date human papillomavirus (HPV)

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vaccination among eligible females (54.8% in Texas vs 63.8% U.S.) in 2021.³ CC is almost entirely preventable⁴ through vaccination against HPV and screening, early detection, and treatment of precancerous lesions.^{5,6} The 2020 updated American Cancer Society guidelines for CC prevention recommends a primary HPV test for women ages 25 to 65 years every 5 years as the preferred method of CC screening, an HPV/Pap co-test every 5 years, or a Pap test alone every 3 years, if primary HPV screening is not available.⁷

Additionally, the Centers for Disease Control and Prevention (CDC) recommends HPV vaccination of children starting at 9 years and routinely at 11 or 12 years.⁸ The CDC's Advisory Committee on Immunization Practices also recommends HPV catch-up vaccination for older individuals through age 26 if they are not adequately vaccinated.⁸ However, studies have shown that the uptake of these effective preventive measures remains suboptimal across the U.S.⁹ Texas has lower rates of CC screening² and up-to-date HPV vaccination than the national average rates.¹⁰ Some studies have suggested that disparities in CC have geographic and racial–ethnic variation,^{11,12} but specific information on geographic clustering of the disease incidence in Texas is scarce.¹³

There is a need to target interventions for precision public health geographically.¹⁴ Previous studies globally have demonstrated the effectiveness of spatial scan statistics in detecting hot spots of diseases such as cancers, drug poisoning, and infectious diseases (e.g., COVID-19).^{13,15–17} Spatial cluster analysis could identify areas with higher-than-expected CC incidence to inform interventions to address the issue. Given the disproportionately high CC incidence in Texas and suboptimal uptake of HPV vaccination and CC screening, this study aimed to examine spatial clusters of CC incidence in Texas among women aged 30–64 years.

METHODS

Study Population

The Texas Cancer Registry (TCR) served as the source for the CC cases diagnosed in Texas from 2014 to 2018. The TCR is a population-based cancer registry that collects data on all cancers diagnosed in the state of Texas. The TCR¹⁸ is a part of the U.S. National Cancer Institute Surveillance, Epidemiology and End Results and has a case-completion rate above 95%. TCR data meet high-quality standards set by the CDC and the North American Association of Central Cancer Registries. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines.¹⁹

The incident CC cases analyzed in the current study comprised women aged 30–64 years with primary CC

from January 1, 2014, to December 31, 2018 (n=5,124). Primary CC was ascertained based on the following International Classification of Diseases for Oncology, 3rd Edition codes: C530, C531, C538, and C539. Cases retrieved from death certificates (n=40) or autopsy (n=0), with missing or nonvalid geographic identification (n=22), and duplicate (n=2) were excluded; the final set of analyses was performed with 5,060 cases of incident CC. The study was restricted to a subgroup of CC screening-eligible women (30–64 years) for multiple reasons:

1. There have been major medical advancements in CC prevention in recent years, including the introduction of HPV vaccination, HPV-based screening for high-risk HPV subtypes (recognized carcinogens)²⁰ and precancerous lesions, and treatments.
2. Some women older than 65 years may not have had the opportunity to utilize some of these interventions for prevention compared with younger women.
3. Investigating CC diagnosis among screening-eligible women may highlight missed opportunities and the need for a more aggressive approach to CC prevention in this population.

Measures

The outcome of interest was primary CC incidence, and the exposure was census tract of residence at diagnosis. For the geospatial analysis, the authors created 3 input files.²¹

1. Case file – The authors summed the counts of all CC cases among women aged 30–64 years from 2014 to 2018 in each census tract by geocoding the TCR-provided patient's address longitude (X) and latitude (Y) at the time of diagnosis.
2. Population file – At-risk population data (women aged 30–64 years) were retrieved from the 2014–2018 American Community Survey (ACS) 5-year estimates and matched to CC cases in the 5,265 census tracts in Texas.
3. Coordinate file – The census tract location identification numbers, longitude (X), and latitude (Y) for CC cases and at-risk population were specified in this file. All individual-level variables were accessed from the 2014–2018 TCR data, and population-level variables were retrieved from the U.S. Census Bureau's 2014–2018 ACS 5-year estimates.²²

This study was reviewed and approved by the IRBs of Baylor College of Medicine and Texas Department of State Health Services.

Statistical Analysis

First, descriptive analyses of incident CC cases were conducted. Based on the Surveillance, Epidemiology, and

End Results summary stage at diagnosis, the authors categorized cases into early-stage, late-stage, and unstaged CC. Early-stage CC was defined as in situ or localized; late-stage CC comprised CC with regional or distant spread; and unstaged CC included those with missing or unknown stage. The cases were also described in terms of age at diagnosis, race and ethnicity, payer at diagnosis, and year of diagnosis.

Second, the authors performed a purely spatial cluster analysis of all primary incident CC cases reported to TCR from 2014 to 2018 using the Poisson-based model in SaTScan software version 10.1.²¹ The Poisson-based spatial analytic model uses a systematically moving spatial circular window to identify statistically significant clusters of higher-than-expected proportions of cases (hot spots).²¹ The model is based on the null hypothesis that cases are independent of each other and that disease risk is the same inside and outside the spatial scanning window. The alternative hypothesis is that the disease risk within the scanning window is different from that outside the window. The model uses indirect standardization to calculate the expected number of cases in each geographic location under the null hypothesis. The SaTScan's default is to set the maximum clusters to cover half of the population at risk (50%), but because the study's area of coverage is large (the state of Texas), using a 50% maximum cluster setting can cover a large area and lead to huge clusters. Thus, the maximum cluster size was set at 25% of the at-risk population (recommended for large areas)²¹ and the authors conducted a sensitivity analysis using the maximum cluster setting of 50% of the at-risk population. The results for both settings were similar, that is, the authors observed equal clusters at the same locations. The spatial analysis was conducted at the census tract level and used the log-likelihood ratio test to examine the alternate hypothesis that there were greater or lower proportions of cases in the detected clusters compared with nonclusters. The authors used 999 Monte Carlo replications to ensure the stability of the estimates and report the RRs of clusters based on a 2-sided $p < 0.05$. An initial unadjusted analysis followed by a model that adjusted for age at diagnosis was conducted. The authors defined significant clusters as those very unlikely to occur due to chance ($\alpha = 0.05$).

Third, to assess demographic differences between the hot spot and non-hot spot census tracts in the state, the Wilcoxon rank-sum test was used. The test compares medians of selected features between nonparametric independent groups. Neighborhood-level variables from the 2014 to 2018 ACS 5-year estimates used in the hot versus non-hot spots comparison included median age, race and ethnicity, nativity, English language proficiency, educational attainment, employment status, median household income, and health insurance coverage.

RESULTS

The descriptive analysis results are shown in [Table 1](#). Data from 5,060 women aged 30–64 years with primary CC incidence in Texas within the study period of 2014–2018 was included. The mean age was 45.7 years ($SD = 9.6$), and median age was 45 years ($IQR = 38–54$); 1,840 (36.4%) were Hispanic, 591 (11.7%) non-Hispanic Black, 2,397 (47.4%) non-Hispanic White, and 232 (4.6%) identified as other races. Of the 5,060 women, 2,208 (43.6%) were diagnosed with early-stage CC (mean age was 43.6 years [$SD = 9.3$], and the median age was 42 years [$IQR = 36–51$]), 2,241 (44.3%) had late-stage CC (mean age was 47.8 years [$SD = 9.3$], and the median age was 48 years [$IQR = 40–55$]), and 611 (12.1%) were unstaged CC (mean age was 45.6 years, [$SD = 9.9$] and median age was 45 years [$IQR = 37–54$]). Early-stage CC and late-stage CC differed by age, race and ethnicity, and payer at diagnosis. The late-stage group had significantly ($p < 0.05$) higher proportions of older, racially minoritized, and uninsured women than the early-stage group ([Table 1](#)).

The spatial analysis detected 7 significant hot spots of CC incidence, comprising 1,755 (33.3%) of Texas's 5,265 census tracts ([Table 2](#) and [Figure 1](#)). Hot spots were in the following Texas regions: South Texas Plains (near Mexico border), Gulf Coast (Houston), Prairies and Lakes (North Texas), Panhandle Plains (Northwest Texas), Piney Woods (Southeast Texas). Additional cluster information is provided in [Appendix Table 1](#) and [Appendix Figures 1–7](#). [Table 3](#) shows the comparison of hot spot and non-hot spot demographics, suggesting statistically significant differences by age, race and ethnicity, English language proficiency, educational attainment, employment status, median household income, and health insurance coverage, but not by nativity. Specifically, a significantly higher proportion of the Hispanic population, individuals with low English proficiency, unemployed individuals, and uninsured individuals were in hot spots compared with the rest of Texas. Hot spots had lower median household income and lower proportions of non-Hispanic Black, non-Hispanic White, and individuals with some college educational attainment.

DISCUSSION

Results from this study affirm geographic information systems (GIS) as an effective tool for precision public health surveillance. The data exhibited spatial variation in primary CC incidence among women aged 30–64 years in Texas. Specifically, the study found 7 hot spots of CC incidence, with significantly higher-than-

Table 1. Characteristics of Women Aged 30–64 Years With Cervical Cancer in Texas, 2014–2018^a by Stage of Diagnosis^b

Characteristics	All CC (n=5,060; 100%) patients, No. (%)	Early-stage CC (n=2,208; 43.6%) patients, No. (%)	Late-stage CC (n=2,241; 44.3%) patient, No. (%)	Unstaged CC (n=611; 12.1%) patient, No. (%)	p-value ^c
Age, mean (SD)	45.7 (9.6)	43.6 (9.3)	47.8 (9.3)	45.6 (9.9)	<0.001
Age, median (IQR)	45 (38–54)	42 (36–51)	48 (40–55)	45 (37–54)	<0.001
Age, years					<0.001
30–44	2,482 (41.1)	1,303 (52.6)	881 (31.7)	298 (37.9)	
45–54	1,443 (23.9)	537 (21.7)	740 (26.6)	166 (21.1)	
55–64	1,135 (18.8)	368 (14.9)	620 (22.3)	147 (18.7)	
Race/ethnicity					<0.001
Hispanic	1,840 (36.4)	788 (35.7)	851 (38.0)	201 (32.9)	
NHB	591 (11.7)	204 (9.2)	315 (14.1)	72 (11.8)	
NHW	2,397 (47.4)	1,099 (49.8)	999 (44.6)	299 (48.9)	
Other ^d	232 (4.6)	117 (5.3)	76 (3.4)	39 (6.4)	
Payer at diagnosis ^e					<0.001
Private	2,128 (42.1)	1,176 (53.3)	762 (34.0)	190 (31.1)	
Public	1,198 (23.7)	417 (18.9)	650 (29.0)	131 (21.4)	
Uninsured	1,080 (21.3)	354 (16.0)	598 (26.7)	128 (21.0)	
Unknown	654 (12.9)	261 (11.8)	231 (10.3)	162 (26.5)	
Diagnosis year					0.303
2014	1,031 (20.4)	491 (22.2)	442 (19.7)	98 (16.0)	
2015	976 (19.3)	394 (17.8)	428 (19.1)	154 (25.2)	
2016	1,027 (20.3)	431 (19.5)	458 (20.4)	138 (22.6)	
2017	980 (19.4)	434 (19.7)	449 (20.0)	97 (15.9)	
2018	1,046 (20.7)	458 (20.7)	464 (20.7)	124 (20.3)	

Note: Boldface indicates statistical significance ($p < 0.05$).

^aData retrieved from incident cervical cancer data provided by Texas Cancer Registry, 2014–2018.

^bCervical cancer staging definition: Early-stage (SEER summary stage 0 [in situ, intraepithelial, noninvasive] and 1 [localized]); late-stage (SEER summary stage 2–4 [regional spread] and 7 [distant spread]); unstaged (SEER summary stage 9 [missing or unknown stage]) cervical cancer at diagnosis.

^cp-value derived from chi-square tests comparing characteristics of ECC and LCC groups for categorical variables and t-test of difference in means for the continuous variable.

^dPatients of non-White and non-Black races were recoded into the Other category.

^ePayer at diagnosis: private, types of private insurance; public/government, includes Medicare, Medicaid, TRICARE, military, Veterans Affairs, Indian/Public Health Service; uninsured, includes not insured, self-pay; unknown, insurance not otherwise specified, insurance status unknown.

CC, incident cervical cancer; ECC, Early-stage cervical cancer; LCC, Late-stage cervical cancer; NHB, non-Hispanic Black; NHW, non-Hispanic White; SEER, Surveillance, Epidemiology, and End Results.

expected proportions of CC cases. The largest hot spots were in the South Texas Plains (near the Mexico border) and the Texas Panhandle Plains (Northwest Texas). Other hot spots were in the Gulf Coast (Houston), Piney Woods (Southeast Texas), and Prairies and Lakes (North Texas). In alignment with other studies highlighting geographic disparities in CC in Texas,^{13,23} this investigation substantiates these trends at the census tract level. Compared to the 2 previous studies that investigated late-stage CC clusters in Texas,^{13,23} the present study examined spatial clusters of all CC diagnoses regardless of stage among a subgroup of screening-eligible women (30–64) who ideally should have had at least 1 CC screening encounter and possible exposures to HPV vaccination, or the newer and more sensitive early detection screening strategies, that is, HPV-based screening (HPV test or HPV/Pap cotest), unlike older women who may

have been exposed to cytology-based screening (Pap test) only. This heightened spatial resolution allows for a more nuanced understanding of CC disparities, providing a foundation for targeted interventions at localized levels.

Moreover, some of the regions identified as hotspots in this study have also been identified in other studies as regions with poor HPV vaccination, cancer screening behaviors, and late-stage CC diagnosis.^{13,24,25} This alignment underscores a concerning correlation established in the broader context of cancer prevention, where populations with suboptimal uptake of preventive measures tend to experience poorer cancer outcomes.^{26,27} Thus, this study contributes to the growing body of evidence emphasizing the geographic dimension of CC and sheds light on the interconnectedness of prevention behaviors and health outcomes.

Table 2. Age-adjusted Purely Spatial Scan Statistics Output Showing Hot Spots of Cervical Cancer Incidence in Texas, 2014–2018^a

Cluster ^b	Coordinate/radius	Observed cases	Expected cases	RR	LLR	p-value
1	26.515432 N, 97.579083 W / 339.23 km	766	566.1	1.42	36.27	<0.001
2	29.765751 N, 95.328238 W / 22.44 km	538	402.2	1.38	22.71	<0.001
3	32.646998 N, 96.700372 W / 14.33 km	132	145.2	1.81	19.06	<0.001
4	29.664167 N, 95.565104 W / 1.98 km	22	5.9	3.73	12.83	0.017
5	32.841051 N, 100.070721 W / 215.33 km	299	222.4	1.37	12.50	0.022
6	32.733049 N, 97.281788 W / 6.27 km	55	26.2	2.11	12.06	0.028
7	31.157482 N, 94.713113 W / 112.04 km	164	110.0	1.51	11.79	0.036
8	32.758616 N, 96.966177 W / 10.86 km	118	74.3	1.60	11.09	0.058
9	29.550648 N, 98.420767 W / 0 km	6	0.6	9.60	8.19	0.576
10	32.938731 N, 96.795192 W / 0 km	5	0.4	11.78	7.75	0.728
11	32.769046 N, 97.386474 W / 0 km	6	0.8	7.59	6.95	0.918
12	32.655616 N, 97.340516 W / 0 km	5	0.6	8.34	6.20	0.988
13	32.324804 N, 96.011901 W / 47.00 km	52	31.3	1.67	5.74	0.998
14	31.542402 N, 97.162452 W / 1.32 km	8	1.8	4.43	5.71	0.999

Note: Boldface indicates statistical significance ($p < 0.05$).

^aPoisson-based purely spatial scan statistic was used to identify areas with significantly higher than expected proportion (hot spots) of primary cervical cancer incidence in Texas. Maximum spatial cluster size was set at 25% of the population at risk, using circular scan window and Replication 999.

^bAdditional cluster information: Cluster 1 – South Texas Plains/South Texas; Cluster 2 – Gulf Coast/Upper Gulf Coast; Cluster 3 – Prairies and Lakes/North Texas; Cluster 4 – Gulf Coast/Upper Gulf Coast; Cluster 5 – Panhandle Plains/West Texas; Cluster 6 – Prairies and Lakes/North Texas; Cluster 7 – Piney Woods/East Texas; Cluster 8 – Prairies and Lakes/North Texas; Cluster 9 – South Texas Plains/South Texas; Cluster 10 – Prairies and Lakes/North Texas; Cluster 11 – Prairies and Lakes/North Texas; Cluster 12 – Prairies and Lakes/North Texas; Cluster 13 – Prairies and Lakes/North Texas; and Cluster 14 – Prairies and Lakes/North Texas; LLR, log likelihood ratio.

The regions identified as having elevated CC incidence in this study consist of disproportionately racially minoritized populations, notably Hispanic individuals. This observation highlights the pivotal role of understanding and addressing cancer health disparities within racially minoritized communities. Furthermore, the study found hot spots of CC incidence in both urban and rural Texas. Perhaps most striking are the similarities in hot spots identified in urban and rural areas of Texas, including higher than national and state poverty levels and racially minoritized populations.²⁸ This finding contrasts with previous studies that have suggested that rural populations have disproportionately higher cancer incidence than their urban counterparts.²⁹ Compared with urban hot spots, possible explanations for rural hot spots include availability issues, greater travel distances to preventive services, lack of insurance, and lower health literacy in rural communities.³⁰ The availability of preventive services does not guarantee equitable access. Urban hot spots suggest that socioeconomically deprived and racially minoritized communities may have poorer access to CC prevention compared to affluent neighborhoods in urban areas. Barriers to CC prevention among urban women include costs, lack of childcare, appointment scheduling issues, and lack of insurance.³¹

The findings of this study underscore suboptimal CC intervention uptake in both urban and rural Texas.³² In 2021, Texas ranked 48th nationally in HPV vaccination rate,³³ which may be further worsened by accentuated vaccine hesitancy during the COVID-19 pandemic. Moreover, CC screening rates in the hot spots fall below the CDC's Healthy People 2030 target of 84.3%.³⁴ Long-time barriers to HPV vaccine uptake in Texas include parental lack of awareness, beliefs about the need for vaccination, safety concerns, and perceived low susceptibility.³⁵ Furthermore, Texas has a higher proportion of uninsured individuals compared to the U.S. rate due to the lack of Medicaid expansion. Past studies have reported the lack of health insurance, cost, and low health literacy as hindrances to guideline-concordant CC screening in Texas.^{36,37} The findings indicate that hot spots tended to have higher rates of individuals without health insurance, college education, and low income, further supporting the previously reported barriers.

Cervical cancer is preventable. Hot spots of CC incidence suggest missed opportunities for prevention, including HPV vaccination and screening, and early detection and treatment of precancerous lesions in the cervix. In addition, this study underscores the documented utility of GIS in pinpointing areas requiring intervention and facilitating the development of targeted strategies. The spatial insights provided by GIS emerge

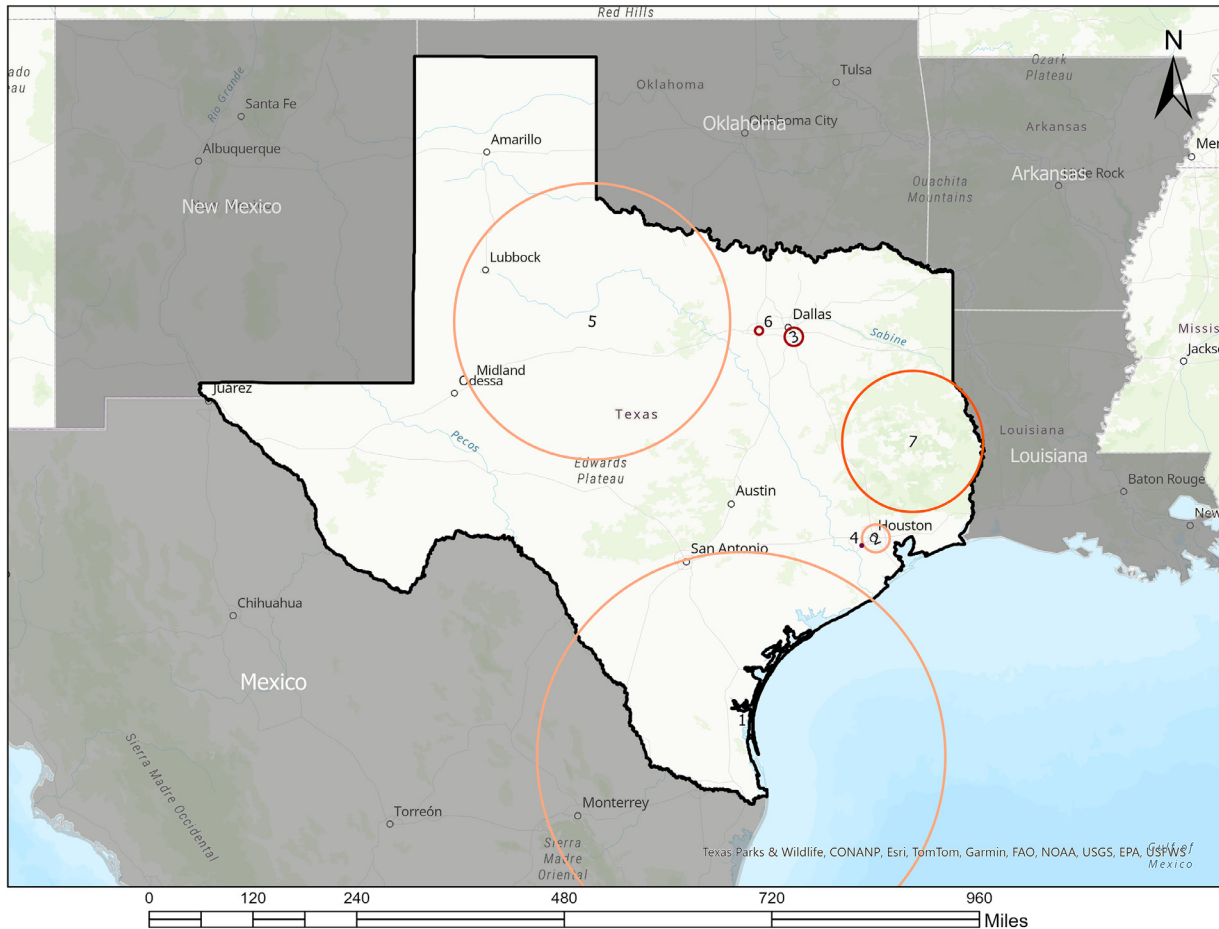


Figure 1. Hot spots of cervical cancer incidence among women aged 30–64 years in Texas, 2014–2018.

Geospatial map showing clusters of cervical cancer incidence in Texas from 2014 to 2018.

Red or orange circles represent clusters with higher-than-expected proportions of cervical cancer incidence (hot spots, $RR > 1.00$).

Greyed area did not contribute data to the cluster.

Clusters were determined using the age-adjusted Poisson-based model of the SaTScan spatial analysis. Maximum spatial cluster size was set at 25% of population at risk using circular scan window. Statistical significance was set at 0.05 and Monte Carlo replication at 999.

as a valuable resource for precision public health planning to address and alleviate CC health disparities effectively. There is a need to develop and scale up innovative, targeted, and effective interventions to expand equitable access to CC primary prevention in rural and urban communities. The results of this study could strategically guide CC prevention to reduce the disease health disparities in affected communities.

Limitations

This study has some limitations. First, TCR does not collect data on previous cancer screenings. Thus, the authors could not assess CC screening utilization, which is critical in CC prevention. However, it is well recognized that most CCs in the U.S. occurs among underscreened women. This spatial analysis could not be conducted at a more granular area level than the

census tract level because CC is relatively rare. These results may not be attributable to individuals within hot spots due to the possibility of ecological fallacy. Lastly, the current spatial analysis focused on all CC among women aged 30–64 years. This restriction may exclude potential CC clusters among women outside of this age range who were excluded from this study.

CONCLUSIONS

In this population-based study, 7 geographic clusters with higher-than-expected CC incidence in Texas from 2014 to 2018 were identified. These hot spots consisted of rural and urban census tracts. Compared with the rest of Texas, they had significantly greater proportions of Hispanic, uninsured, low-income individuals with lower rates of college education. These areas can benefit from

Table 3. Comparing Census Tract-Level Characteristics by Cluster Classification (Texas Census Tract N=5,265)

Census tract characteristics ^a	Incident cervical cancer census tracts		
	Hot spots (n=1,755; 33.3%) median (IQR)	Rest of Texas (n=3,510; 66.7%) median (IQR)	p-value ^b
Demographics			
Median age, female	35.0 (30.9–40.6)	36.9 (32.5–42.2)	<0.001
% Hispanic	52.0 (23.9–83.8)	25.1 (14.2–45.6)	<0.001
% Non-Hispanic Black	3.5 (0.5–13.3)	7.0 (2.3–15.6)	<0.001
% Non-Hispanic White	21.1 (5.8–58.6)	50.8 (27.4–70.1)	<0.001
% Foreign born	14.0 (6.0–26.0)	12.7 (7.0–22.1)	0.053
% Household with limited English proficiency, Spanish	6.8 (1.9–17.2)	2.5 (0.6–7.11)	<0.001
Socioeconomic status			
% Some college education, female ≥25 years	45.6 (33.2–58.7)	62.2 (48.6–76.1)	<0.001
% Unemployed ≥16 years	5.7 (3.5–8.5)	4.7 (3.1–6.7)	<0.001
Median household income (\$)	43,610 (33,208–57,230)	60,539 (45,368–81,321)	<0.001
Healthcare access			
% Uninsured, female ≥18 years	23.2 (14.6–33.3)	15.4 (9.0–23.5)	<0.001

Note: Boldface indicates statistical significance ($p < 0.05$).

Statistical significance ($p < 0.05$, 2-sided) determined using Wilcoxon rank-sum test comparing medians of nonparametric independent groups.

^aCensus tract-level data retrieved from the American Community Survey 5-year estimate 2014–2018 data.

^bp-value comparing hot spots versus rest of Texas.

novel, scalable, cost-effective, community-engaging interventions to ramp up HPV vaccination and screening, early detection, and treatment of precancerous lesions, particularly for affected communities.

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Declaration of interest: none.

DATA AVAILABILITY STATEMENT

The data that support the findings of our study are available from the corresponding author upon reasonable request and with permission of the Texas Department of State Health Services.

CREDIT AUTHOR STATEMENT

Itunu O. Sokale: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Visualization, Validation. Aaron P. Thrift: Funding acquisition, Investigation, Writing – review & editing. Jane R. Montealegre: Writing – review & editing. Onyema G. Chido-Amajuoyi: Writing – review & editing. Victor T. Adekanmbi: Writing – review & editing. Abiodun O. Oluyomi: Methodology, Software, Investigation, Visualization, Writing – review & editing, Supervision.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at [doi:10.1016/j.focus.2024.100247](https://doi.org/10.1016/j.focus.2024.100247).

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