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Correlation Between Air Quality and Lung Cancer Incidence: A County by County Analysis

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Abstract

Background—Poor air quality has previously been associated with lung cancer development, but the risks associated with regional differences in air quality are poorly understood. We investigated the association of air quality indices with development of lung cancer in all Texas counties.

Methods—Lung cancer incidence, air quality indicators (particulate matter less than 2.5 micrometers [$PM_{2.5}$], radon levels, oil well density) and known risk factors were obtained using data from the Texas Commission on Environmental Quality and the Texas Cancer Registry. Linear regression models were constructed to correlate air quality indicators with lung cancer incidence and advanced stage at diagnosis (stage III or IV), while controlling for other patient characteristics.

Results—Lung cancer incidence ranged from 27.6 to 103.4 cases per 100,000 people. $PM_{2.5}$ was associated with increased lung cancer incidence ($\beta = 4.38$, $p < 0.0001$), but not radon levels ($\beta = -2.70$, $p=0.41$). Air quality indicators were not significantly associated with an advanced cancer diagnosis.

Conclusion—There are wide differences in the incidence of lung cancer across Texas. These differences appear to be related to air quality. Identifying high-risk areas may help to guide strategies such as implementation of targeted lung cancer screening programs.

Keywords

Lung cancer incidence; Air quality; Epidemiology

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Introduction

Lung cancer is the most lethal cancer worldwide, accounting for more than 150,000 deaths annually. [1] Nearly 7% of the population will be diagnosed with lung cancer at some point in their life.[2] While smoking is the most significant risk factor for lung cancer, other important causes such as radon, asbestos and some inhaled chemicals are also important causes of lung cancer.

Though there is literature supporting the association of air pollution with lung cancer, the majority of studies have focused on each individual's exposure using surveys, questionnaires, and ambient monitors in metropolitan areas.[3–5] As such, our understanding of air pollution effects have been primarily derived from urban environments. [6–9] Prior data have also revealed higher exposure levels of particulate matter 2.5 microns ($PM_{2.5}$), a commonly used measure of air pollution, in the southeastern region of the United States[10].

In a state with relatively heterogeneous environment exposures, a population-based investigation of air quality differences could allow for a better understanding of the environmental factors which are associated with lung cancer and more efficient implementation of population-based screening or treatment programs. There are few available studies which have performed population-based risk assessments using a county by county analysis.[7, 10, 11] Our goal was to perform an analysis of the correlation between air quality indices and lung cancer development in all Texas counties.

Methods

Demographic data

Institutional review board approval was obtained from the University of Texas Medical Branch Review Committee. For each county in Texas (n = 254), the most recent United States Census Bureau data and the 2018 County Health Rankings database were used to collect sociodemographic data including county population, mean age, smoking rate, ethnicity percentages and rural status. According to the Census Bureau, a county with under 50,000 people was considered to be rural.

Environmental data

The Railroad Commission of Texas, Environmental Protection Agency (EPA), Texas Commission on Environmental Quality and the Texas Radon Program were used to collect the following environmental quality indicators: $PM_{2.5}$ level, number of oil wells per person in each county and radon levels. $PM_{2.5}$ levels were taken as an average level in each county from January 1, 1998 when levels were first recorded to December 31st, 2017. To designate radon exposure, the EPA categorized each county into zone 1 (> 4.0 pCi/L), zone 2 (2.0—4.0 pCi/L) or zone 3(< 2.0 pCi/L). No county in Texas was designated as zone 1.

Cancer data

For each county, the Texas Cancer Registry (TCR) was used to collect the lung cancer incidence per 100,000 people and the stage at diagnosis. Stage at diagnosis was categorized as early (Stage I and II) and advanced (Stage III and IV).

Statistical Analysis

We analyzed the relative risk of both the incidence and stage at diagnosis for lung cancer in each county using linear regression models. As our focus was on air quality indices, linear regression models were constructed to determine the association of air quality indicators with lung cancer incidence and stage at diagnosis while controlling for county-level sociodemographic characteristics and smoking rates. All statistical analyses were performed using SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA).

Results

Demographics

All counties in Texas (n=254) were analyzed (Table 1). The mean smoking rate in Texas was 14%. Sixty-eight percent (172/254) of counties were rural.

Air quality

Table 2 shows air quality data for each county. Eighty-five percent of counties had radon levels in zone 3 (215/254). There was significant variation in the $PM_{2.5}$ levels in each county, ranging from 5.8 to 12.0 micrograms/meter^3 ($\mu g/m^3$).

Lung Cancer Data

Lung cancer incidence varied widely across counties, ranging from 27.6 to 103.4 cases per 100,000 people (Figure 1). Many of the counties with the highest rates of lung cancer appeared to cluster in east Texas. Overall, 79.2% of all lung cancer cases were diagnosed at an advanced stage (Figure 2).

Univariate analysis

Across all counties, the incidence of lung cancer was directly associated with the county smoking rate ($p < 0.01$), county minority percentage ($p < 0.01$) and county $PM_{2.5}$ level ($p < 0.01$). Rural counties tended to have an increased rate of advanced stage at diagnosis ($p = 0.04$). County radon levels were not associated with lung cancer incidence ($p = 0.40$) or stage at diagnosis ($p = 0.20$).

We further analyzed the association of $PM_{2.5}$ levels with lung cancer incidence by dividing all Texas counties into two halves based on lung cancer incidence. Each group had 127 counties. The average $PM_{2.5}$ level in the group with the higher lung cancer rate was significantly different than the group with the lower lung cancer incidence rate (8.67 vs. 7.74, $p < 0.01$) and is shown in Figure 3.

We also analyzed the smoking rate in east Texas (Figure 4) compared to the rest of the state. The rate of smoking in east Texas was significantly higher than the rest of the state (16.9% vs. 13.7%, $p < 0.01$).

Logistic regression of air quality indices

When using linear regression analysis to control for the smoking rate and minority percentage, the county $PM_{2.5}$ level remained as a statistically significant factor associated with the incidence of lung cancer ($p < 0.01$). No other variables were significantly associated with either lung cancer incidence or stage at diagnosis.

Discussion

Lung cancer remains a public health concern nationwide, and the majority of patients who are eligible for screening computed tomography scans do not receive them.[12] Previous efforts to reduce lung cancer incidence have used plans targeting high-risk individuals, such as smoking cessation counseling and lung screening programs.[13] But there have not been widespread attempts to identify and target high-risk areas. Given the relative lack of success in getting eligible patients screened, it may be appropriate to focus efforts to decrease lung cancer mortality to individuals in these high-risk areas first.

We felt that this analysis in a state like Texas would be useful because this state is very heterogenous in many aspects. Many of the 254 counties in Texas have different ethnic, socioeconomic and air quality compositions. We expected to find different rates of lung cancer development among the counties, but we did not expect that some counties would have an almost 4-fold higher rate than other counties. And we certainly did not expect there to be such a strong cluster of counties in east Texas. We feel that this finding is important, because we can now conduct a more detailed analysis to find what factors other than air quality are associated with lung cancer incidence. It appears that the level of air pollution, as represented by $PM_{2.5}$, does correlate considerably with lung cancer incidence. But there are likely other factors which we did not measure which contribute to the high rate in east Texas. And given that the smoking rate is higher in this part of the state, it appears that both smoking and worse air quality contribute to a higher incidence of lung cancer. Our future studies will look at other environmental exposures, such as the number and distribution of factories, and more detailed demographic data to see what other factors correlate with lung cancer incidence in a population analysis.

Previous literature has demonstrated small particulate matter to be a human health hazard. The International Agency for Research on Cancer (IARC) categorized outdoor pollutants as class I carcinogens.[14] More specifically, increased exposure to high $PM_{2.5}$ levels has been associated with an increased rate of morbidity and mortality from several cardiovascular diseases. [15] And reductions in $PM_{2.5}$ levels have been reported to result in a significant longer life expectancy.[7] In 2012 the EPA enacted rigorous National Ambient Air Quality Standards for $PM_{2.5}$ by reducing the standard level from 15 $\mu g/m^3$ to12 $\mu g/m^3$ in communities.[16, 17] Our results coincide with the previous literature showing $PM_{2.5}$ levels to be associated with worse overall health. Improving air quality in areas with worse pollution should result in a decrease in the incidence of several disease processes, including lung cancer. Some of these efforts to improve air quality may be aided by examining the factors in low air-quality areas which may negatively impact air quality. A truly comprehensive approach to reducing lung cancer incidence should focus on both improving air quality and reducing smoking rates.

While we chose to focus on the relationship of air quality to lung cancer development, it is clear that many other factors contribute to the wide differences in lung cancer incidence in different parts of the state. Previous literature has shown that people in rural areas tend to have a higher rate of lung cancer when compared to their urban counterparts.[18] A complete analysis would need to investigate other disparities in rural areas, such as income level, amount of smoking exposure, access to health care and smoking cessation counseling, medically uninsured rate and many other factors. [19–22] But we feel that our study is important in that it shows that there are geographic high-risk regions for lung cancer development. Using this information to determine how to allocate funds for public health initiatives will help to make those initiatives more effective. Additionally, a lack of public policy in rural communities focused on tobacco control have led several authors to conclude that individuals residing in rural areas should be considered a vulnerable population.[23–25]

Our study can serve as a model for other centers to use to identify high-risk areas for lung cancer development in their states. While our study shows a correlation between air quality and lung cancer incidence, there are limitations. We used county-level data but would have preferred to analyze lung cancer incidence in different zip codes. We did not have this zip code data available on a state-wide level, however. Secondly, we analyzed the available air quality indices which we had but would have favored more granular data. The radon levels, for instance, were reported in only 3 very broad categories. The reporting of more fine-tuned radon levels would be useful and should be considered in the future by government agencies. Despite these limitations, we do feel that our analysis will be helpful in determining how to target high-risk areas with increased rates of lung cancer development.

Conclusion

Air quality is associated with lung cancer development. Specifically, elevated $PM_{2.5}$ levels are associated with an increased incidence of lung cancer. This information may help to target high-risk areas with surveillance and treatment strategies to lessen the morbidity and mortality from lung cancer. Future studies should investigate other factors which may lead to such wide differences in lung cancer development in different areas. And efforts should be undertaken to improve air quality, which will likely reduce the incidence and morbidity from several disease processes including lung cancer.

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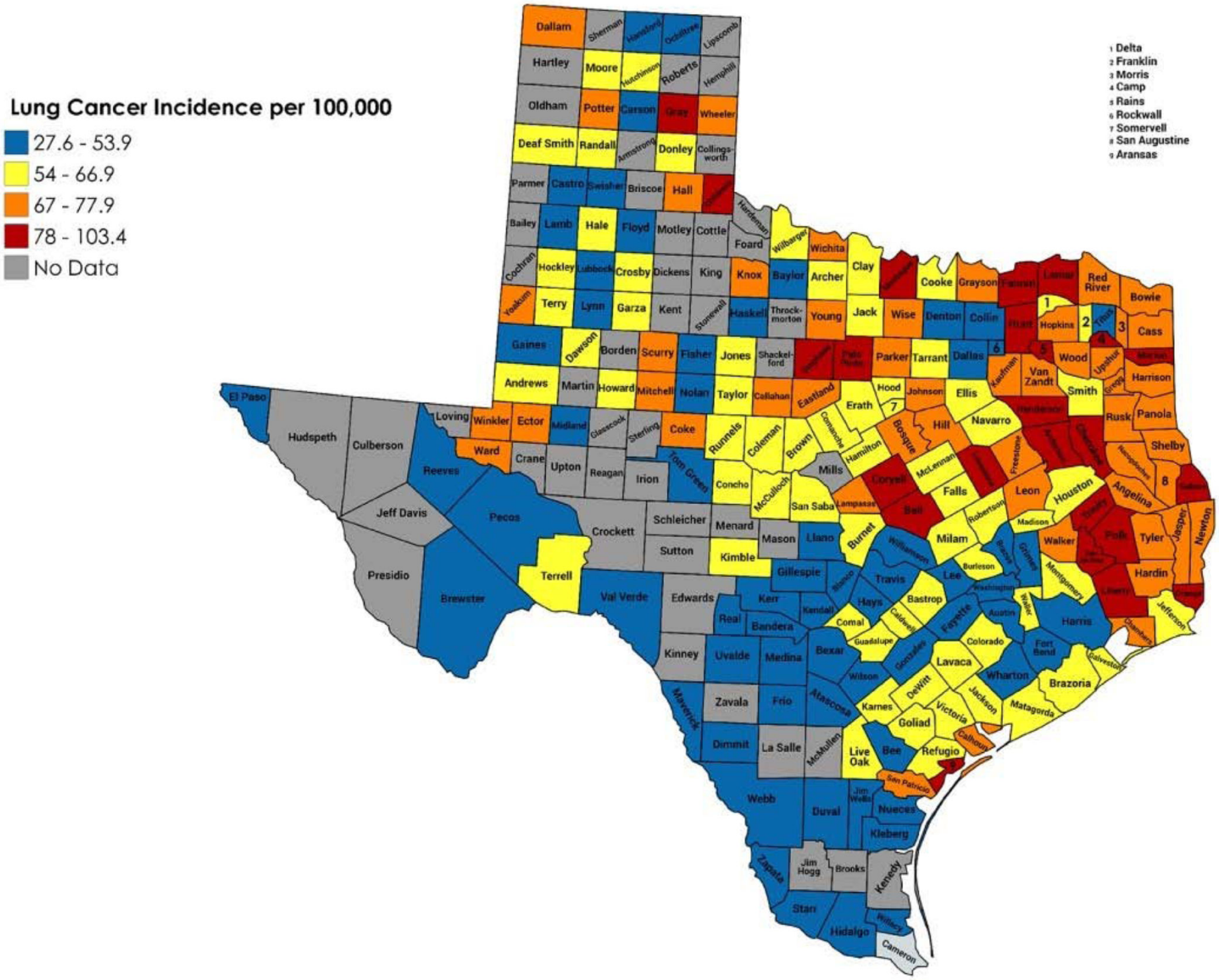

Figure 1—.
Incidence of lung cancer in Texas counties

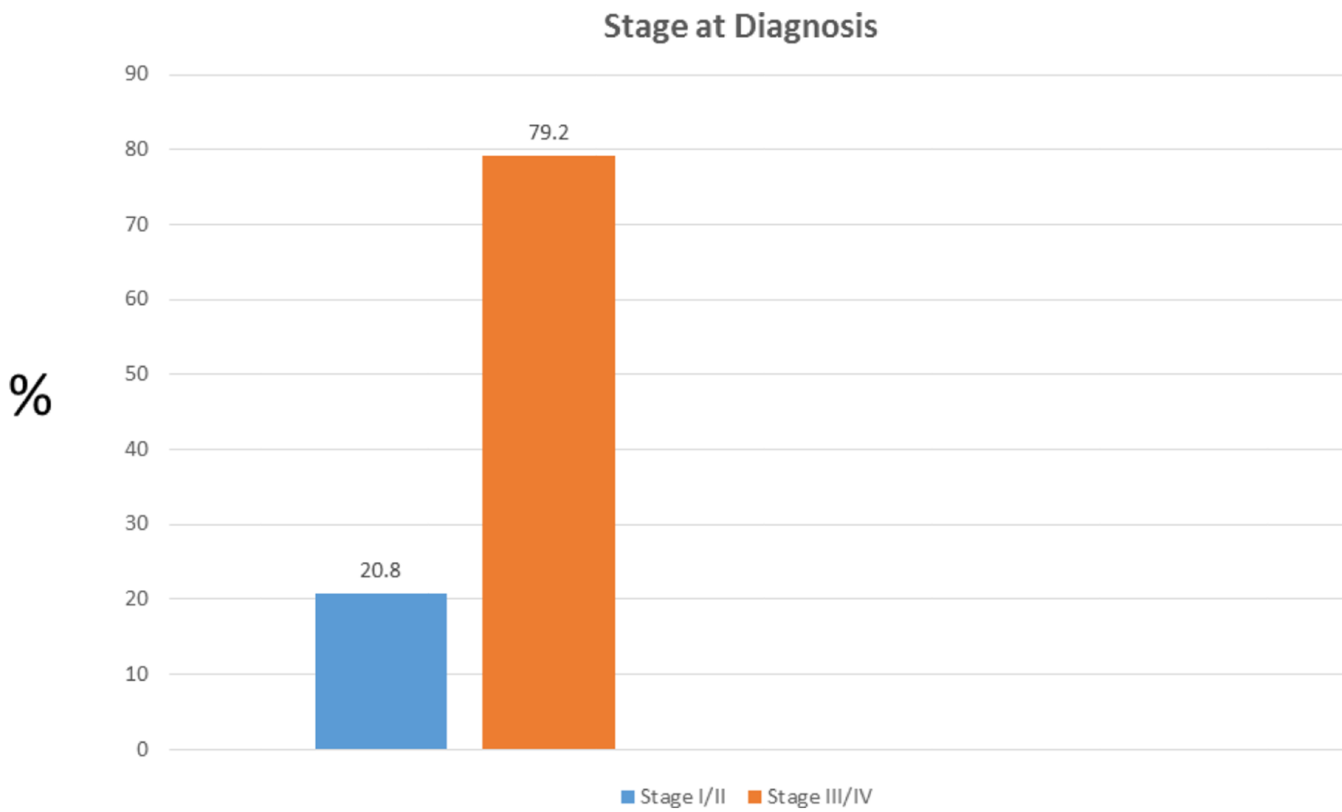

Figure 2—.
Stage at diagnosis of lung cancer in Texas

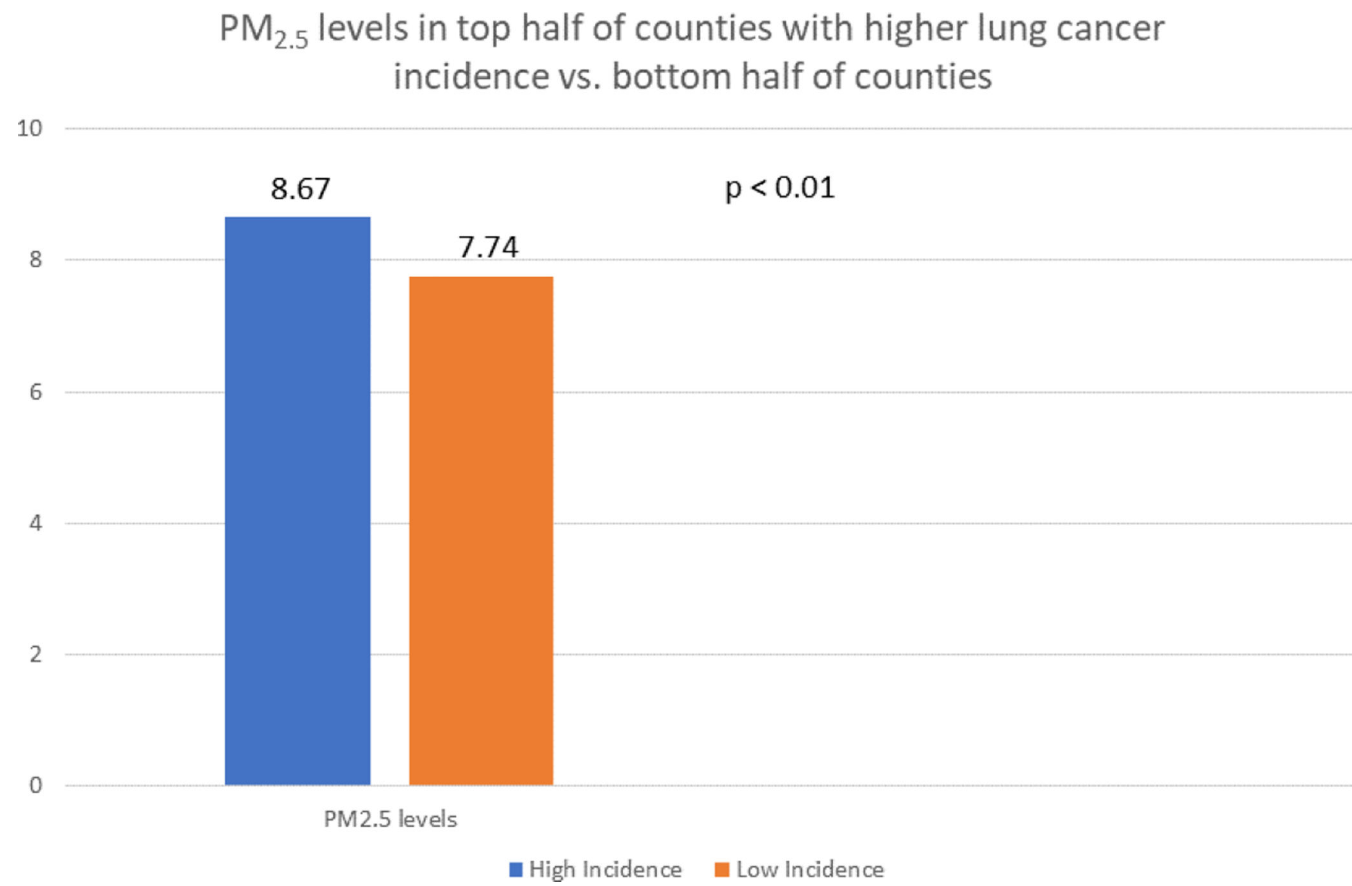

Figure 3—.

Average $PM_{2.5}$ levels in the 127 counties with higher lung cancer incidence compared to the 127 counties with lower lung cancer incidence

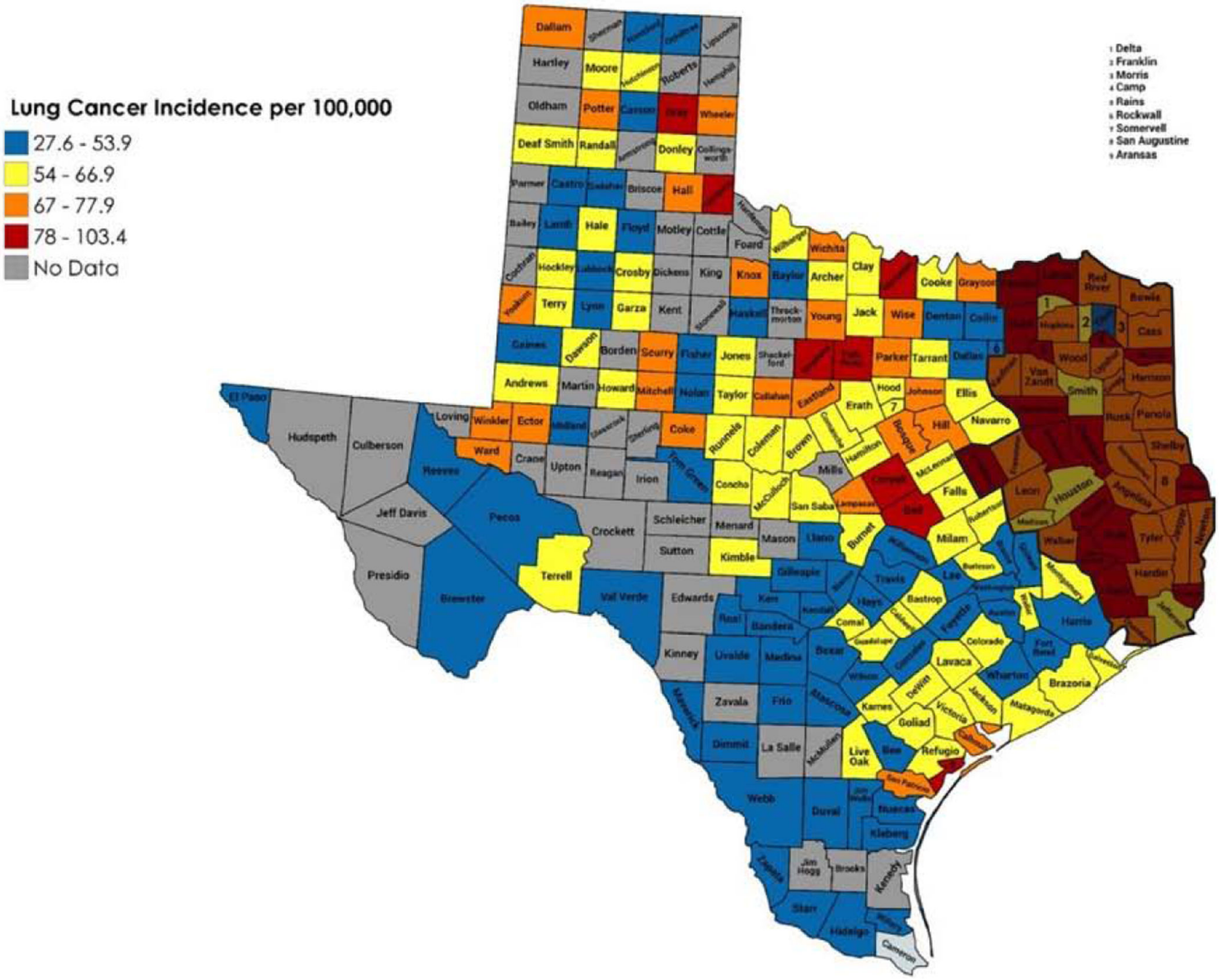

Figure 4—.
High incidence of lung cancer in East Texas

Table 1—

State and county demographics

N	254
Population (total)	29,366,479
Ethnicity	
Caucasian	42.6%
Hispanic	39.1%
African American	11.8%
Asian	4.8%
Other	1.7%
County smoking rate (mean)	14% (11—20)
Rural county status	68% (172/254)

Table 2—

Air quality indices

N	**254**
Radon	
Zone 1	0
Zone 2	15% (39/254)
Zone 3	85% (215/254)
$PM_{2.5}$ (mean)	8.21 micrograms/meter^3 (5.8—12.0)
Oil wells per county (mean)	1,168 (0—16,917)