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Patterns and Differences in Lung Cancer Treatment — United States, 2015–2020

Christine M. Kava, PhD^{1,2}, David A. Siegel, MD², Jin Qin, ScD², Susan A. Sabatino, MD², Reda Wilson, MPH², Manxia Wu, MD²

¹Epidemic Intelligence Service, Centers for Disease Control and Prevention, Atlanta, GA

²Division of Cancer Prevention and Control, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, GA

Abstract

Background: Treatment for lung cancer can improve prognosis, but 5-year survival remains low at 26%. An examination of treatment using data with higher population coverage, and among a broader number of treatment modalities and individual characteristics, would provide greater insight into differences in lung cancer treatment.

Research Question: Among adults diagnosed with lung cancer, how does reported receipt of lung cancer treatment differ by sociodemographic characteristics?

Study Design and Methods: We used 2015–2020 National Program of Cancer Registry data covering 89% of the US population to describe first-course treatment among persons ages ≥20 years diagnosed with lung and bronchus cancer. We performed multivariable logistic regression to examine associations between sociodemographic characteristics and treatment received.

Results: Among 1,068,155 people diagnosed with lung cancer, 22% received surgery, 41% received chemotherapy, 40% received radiation, 13% received immunotherapy, and 75% received at least one of the four treatments. People who were ages ≥45 years (odds ratio [OR] range=0.08–0.67); American Indian or Alaska Native (OR=0.82; 95% CI: 0.77–0.87), Black (OR=0.82; 95% CI: 0.81–0.84), or Hispanic (OR=0.80; 95% CI: 0.78–0.82); resided in a non-metropolitan county (OR=0.98; 0.96–0.99); resided in the bottom 25% (OR=0.80; 95% CI: 0.78–0.81) and middle 50% (OR=0.87; 95% CI: 0.86–0.88) of counties by economic status (considers unemployment rate, per capita market income, and poverty rate); and in the West US census region (OR=0.95; 95% CI: 0.94–0.97) had significantly lower odds of receiving at least one of the four treatments.

Interpretation: Chemotherapy and radiation were the most common types of first-course treatment reported. Receipt of at least one of the four treatments examined was lower among several groups, including certain racial and ethnic groups and those residing in counties with

Corresponding author: Christine M. Kava, PhD, MA, Division of Cancer Prevention and Control, Centers for Disease Control and Prevention, 4770 Buford Hwy NE, Atlanta, GA 30341. tqz1@cdc.gov.

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lower economic status. Future studies might further identify and intervene upon factors underlying differences.

Keywords

disparities; drug therapy; lung cancer; National Program of Cancer Registries; therapeutics

Between 2014–2020, lung cancer had a five-year relative survival of 28%.^{1,2} Standard treatments for lung cancer include surgery, chemotherapy, radiation, and immunotherapy. Treatment varies according to several factors, including histology (e.g., non-small cell vs. small cell lung cancer) and stage.^{3,4} Treatment can improve lung cancer survival and reduce mortality,^{5–7} especially when diagnosed at earlier stages of disease.⁸

Previous studies have reported differences in lung cancer treatment by sociodemographic characteristics and have primarily focused on surgery, chemotherapy, and radiation. Studies using Surveillance, Epidemiology, and End Results (SEER) cancer registry data,⁹ which covered approximately 35% of the US population in 2018,¹⁰ have found lower treatment rates among people who are male, Black or African American, who have lower levels of socioeconomic status, and in rural vs. urban counties.^{11–14} An examination of data with higher population coverage, and among a broader number of treatment modalities and sociodemographic characteristics, would provide additional insight into differences in lung cancer treatment.

This study describes first-course lung cancer treatment patterns between 2015–2020 by sociodemographic characteristics. Our study used data available on lung cancer treatment from the Centers for Disease Control and Prevention's (CDC's) National Program of Cancer Registries (NPCR).¹⁵ This study examined receipt of surgery, chemotherapy, and radiation, as reported by cancer registries. We also examined reported receipt of immunotherapeutic (biologic response modifiers) agents, defined as biological or chemical agents that modify the immune system or body's response to tumor cells to fight cancer.¹⁶ Immunotherapy is a relatively new and promising approach to treating lung cancer.^{17,18} To date, there is limited information on the prevalence of this treatment among persons with lung cancer.

Study Design and Methods

Data and Sample

Our population-based study used data from NPCR,¹⁹ a national surveillance system that captures information on newly diagnosed cancer cases in the United States. NPCR collects cancer registry data in 46 states, District of Columbia, and three US territories.¹⁵ Institutional Review Board approval was exempted under the Common Rule (45 CFR §46) because we used de-identified data.

Cancer is diagnosed in multiple settings, including hospitals and cancer treatment centers.²⁰ Information about the cancer diagnosis, including first-course treatment, is recorded in the patient's medical chart.²⁰ A local cancer registrar identifies the cancer case through different notification systems, reviews the patient's medical chart, and records information into a local registry database.²⁰ Local registry data are reported to central cancer registries, where

the data are reviewed, consolidated, and sent to CDC annually.²⁰ The North American Association of Central Cancer Registries²¹ provides standards on how to collect and code cancer registry data.

Our dataset included adults diagnosed with lung and bronchus [lung] cancer between 2015–2020. We defined lung cancer using a predefined SEER site recode variable based on *International Classification of Diseases for Oncology, Third Edition* (ICD-O-3) site codes C340–C349.^{22,23} We restricted our analysis to 41 states and District of Columbia, which cover 89% of the US population (Figure 1).

Data from five central cancer registries were excluded: two registries (Indiana and Nevada) did not meet data quality standards for all years between 2015–2020; two registries (Kansas and Minnesota) did not have available county-level data needed to calculate county economic status; and one registry (Virginia) had a coding issue affecting the quality of data for county economic status. We further restricted our analysis to adults ages ≥ 20 years at diagnosis. We included malignant cases only and excluded cases identified by death certificate or autopsy only. We also excluded data reported from non-hospital settings due to low level of completeness.

Measures

Our primary outcomes were first-course treatment, defined as the first cancer-directed treatment(s) administered to the person.²⁴ First-course treatment ends when the treatment plan is completed; in the event of disease progression, recurrence, or treatment failure; or after one year of the date of diagnosis if there is no documented treatment plan.²⁵ We examined whether individuals were reported to have received surgery, chemotherapy, radiation, immunotherapy, and at least one of the four treatments (1=yes vs. 0=no) as the first course of treatment. Immunotherapy was defined as immunotherapeutic (biologic response modifiers) agents, including targeted therapies that evoke an immune response.¹⁶ People whose treatment was coded as “unknown” in the database were recoded to missing for our analysis. For each treatment, among people reported as not receiving treatment, we examined the reason recorded for this decision.

We included information on the following characteristics: age at diagnosis (20–44, 45–54, 55–64, 65–74, 75–84, and ≥ 85 years), sex (female and male), reported race and ethnicity (non-Hispanic [NH] American Indian and Alaska Native [AI/AN], NH Asian and Pacific Islander [Asian/PI], NH Black [Black], NH White [White], and Hispanic), county classification (metropolitan and non-metropolitan), county economic status (bottom 25%, middle 50%, and top 25%), and US Census region (Northeast, Midwest, South, and West). County economic status was defined for 2018 by the Appalachian Regional Commission²⁶ and considers three-year average unemployment rate, per capita market income, and poverty rate. We defined county classification based on the 2013 National Center for Health Statistics Urban-Rural Classification Scheme for Counties.²⁷

We also included information on cancer histology, summary stage at diagnosis (localized, regional, and distant), and year of diagnosis (2015–2020). Similar to previous papers,²⁸ histology groups were defined using ICD-O-3 codes. Non-small cell carcinomas included

adenocarcinoma (8140–8239; 8250–8384; 8440–8490; 8550–8551; 8570–8574; 8576), squamous cell carcinoma (8050–8084), and other histology (8000–8040; 8046–8049; 8085–8139; 8240–8249; 8385–8439; 8491–8549; 8552–8569; 8575; 8577–9992). Small-cell carcinoma was defined by codes 8041–8045.

Between 2015–2020, NPCR collected information on cigarette smoking [smoking] status (currently smoked, formerly smoked, and never smoked) in 10 states.^{29,30} We examined smoking status in eight states meeting NCPDR data quality standards: Alaska, California, Colorado, Florida, Idaho, Louisiana, New Hampshire, and Texas.

Data Analysis

Analyses were conducted in R Studio 4.1.0.³² We produced descriptive statistics for all variables and conducted bivariate analyses to examine each treatment received (surgery, chemotherapy, radiation, immunotherapy, at least one of the four treatments) by sociodemographic and cancer characteristics. We ran five separate logistic regression models—one for each treatment outcome—to predict odds of receipt of treatment. We imputed missing data ($m = 20$ imputations, where m = the number of complete datasets in which missing values were generated for) using the `aregImpute` function from the `Hmisc` package³³ in R. We included all candidate predictors and the four individual treatment outcomes in the multiple imputation process.

Each regression model included age at diagnosis, sex, race and ethnicity, county classification, county economic status, US census region, histology, stage at diagnosis, and year of diagnosis. From the regression models, we estimated adjusted average predicted probabilities of receiving treatment. We conducted subgroup analyses—with smoking status included as a covariate—in the eight states listed above. As a sensitivity analysis, we also restricted our analysis to people diagnosed with first primary tumors only.

Results

Our analytic sample comprised 1,068,155 individual diagnoses. The percentage of people that were reported to have received surgery, chemotherapy, radiation, or immunotherapy was 22%, 41%, 40%, and 13%, respectively (Table 1). Three-fourths of people (75%) were reported to have received at least one of the four treatments. Conversely, treatment was not reported for 25% of people. Not being planned as part of first-course treatment was the primary reason (range: 84–98%) for reported non-receipt recorded for each treatment (e-Table 1).

The largest proportions of people were 65–74 years old at diagnosis (36%), male (51%), and White (81%). Eighty-seven percent of people were diagnosed with non-small cell carcinoma and 13% were diagnosed with small cell carcinoma. Of the eight states where smoking status was collected, 80% ($n=240,848$) of people had available data on this measure. Of these people, 51% formerly smoked, 33% currently smoked, and 16% had never smoked.

The largest differences in reported receipt of treatment were observed by age at diagnosis, histology, and stage at diagnosis (Table 2). The largest variations in receipt of treatment

were generally observed for surgery. For example, 26% of people residing in the top 25% of counties by economic status were reported to have received surgery, compared to 17% residing in a county in the bottom 25%.

People ages ≥ 45 years (vs. ages 20–44) had generally lower odds of reported treatment (Table 3). Females vs. males had higher odds of surgery and lower odds of chemotherapy, radiation, and immunotherapy. People reported as AI/AN vs. White had lower odds of surgery, chemotherapy, and immunotherapy; there was not a statistically significant difference for radiation. People reported as Asian/PI vs. White had higher odds of surgery and chemotherapy and lower odds of radiation and immunotherapy. People reported as Black vs. White had lower odds of surgery, chemotherapy, and immunotherapy; no statistically significant difference was observed for radiation. People reported as Hispanic vs. White had higher odds of surgery and lower odds of radiation and immunotherapy; there was not a statistically significant difference for chemotherapy.

People residing in non-metropolitan vs. metropolitan counties had lower odds of surgery and higher odds of chemotherapy, radiation, and immunotherapy. People in the Northeast and Midwest vs. South had higher odds of reported receipt of all four treatments. People in the West vs. South had higher odds of surgery and lower odds of chemotherapy, radiation, and immunotherapy. People residing in counties in the bottom 25% and middle 50% vs. top 25% by economic status had lower odds of surgery, chemotherapy, and immunotherapy, and higher odds of radiation.

People with small cell carcinoma and squamous cell carcinoma vs. adenocarcinoma had lower odds of surgery and immunotherapy, and higher odds of chemotherapy and radiation. People with other histology types had lower odds of reported receipt of all four treatments. People diagnosed at the localized and regional vs. distant stage had higher odds of surgery and lower odds of immunotherapy. People diagnosed at the localized stage had lower odds of chemotherapy and radiation, while people diagnosed at the regional stage had higher odds of reported receipt of these treatments. By year of diagnosis, people diagnosed in 2016 or later vs. 2015 had lower odds of surgery and generally higher odds of radiation and immunotherapy. Odds of chemotherapy were lower for years 2017 and later; there was no statistically significant difference in receipt of chemotherapy between 2016 vs. 2015.

When modeling odds of reported receipt of at least one of the four treatments, people who were older; reported as being AI/AN, Black, or Hispanic; resided in non-metropolitan counties; resided in the bottom 25% and middle 50% of counties by economic status; resided in the West US census region; diagnosed with small cell carcinoma, squamous cell carcinoma, or other histology; and diagnosed in 2017 and 2020 had lower odds of treatment. In contrast, people who were female; Asian/PI; resided in the Northeast and Midwest US census regions; and diagnosed at the localized and regional stages had higher odds of treatment. There were no statistically significant differences in receipt of treatment between 2016, 2018, and 2019 vs. 2015.

The largest differences in the mean predicted probability of receiving at least one of the four treatments were observed by age at diagnosis (0.90 for 20–44 years vs. 0.48 for ≥ 85 years),

histology (0.81 for adenocarcinoma vs. 0.62 for other histology), and stage at diagnosis (0.84 for localized vs. 0.64 for distant) (e-Table 2).

In our analysis among the eight states that included smoking status as a covariate (Table 4), people who currently and formerly smoked vs. never smoked had lower odds of surgery and higher odds of radiation and immunotherapy. People who currently vs. never smoked had lower odds of chemotherapy and at least one of the four treatments. People who formerly smoked had higher odds of receiving at least one of the four treatments; we did not find a statistically significant difference for receipt of chemotherapy between people who formerly vs. never smoked. Our findings for treatment between models with and without smoking status included were generally similar. Our findings were also generally comparable when restricting our main analyses to people with first primary tumors only (n=791,665) (e-Table 3).

Discussion

We used 2015–2020 NPCR data to describe patterns in first-course treatment for lung cancer and examine differences in treatment. Reported receipt of at least one treatment was lower among several groups, including males; people reported as AI/AN, Black, or Hispanic; and people residing in counties designated as non-metropolitan and with lower economic status. Our findings align with previous studies that have found similar differences in lung cancer treatment by sex, race and ethnicity, socioeconomic status, and rural vs. urban status.¹¹⁻¹⁴

As noted earlier, lower treatment proportions have been observed among people who are male, Black or African American, who have lower levels of socioeconomic status, and who live in rural vs. urban counties.¹¹⁻¹⁴ Possible reasons that these differences exist include inequitable receipt of guideline-concordant treatment due to unequal healthcare access,^{34,35} presence of co-morbidities,³⁶ and individual preferences for treatment.³⁷ For example, Harrison et al.³⁴ highlight lower rates of curative-intent surgery for early-stage lung cancer and lower receipt of guideline-concordant treatment among Black vs. White individuals. The authors describe multiple factors, including unequal healthcare access as noted above, and mistrust of the healthcare system among Black individuals due to historical mistreatment and discrimination,^{38,39} that could explain these differences.³⁴

Interventions that identify and address underlying causes leading to a lower percentage of people treated for lung cancer among specific populations may improve differences in treatment. For example, the Accountability for Cancer Care through Undoing Racism and Equity (ACCURE) study tested an intervention to improve cancer treatment quality and completion among people with early-stage lung cancer and breast cancer.⁴⁰ The intervention included a real-time registry system that triggered warnings for missed appointments and treatment delays, feedback to clinical care teams on cancer treatment completion by race, and nurse navigation.⁴⁰ The authors found a significant reduction in Black-White differences in treatment completion in the intervention vs. control group.⁴⁰ Continued efforts like ACCURE to improve treatment differences may reduce the burden of lung cancer among groups most impacted by this disease.

The most common treatments in our study were chemotherapy (41%), radiation (40%), and surgery (22%). Ahmed et al.¹¹ found comparable treatment rates for surgery (22%) and radiation (43%), while Williams et al.¹² found that 16% and 25% of SEER and Veterans Administration patients did not receive any treatment, respectively. Reported receipt of chemotherapy was lower in our study compared to prior reports,⁴¹ though differences in dataset composition (e.g., age, stage at diagnosis, histology, year of diagnosis and treatment, treatments examined) across studies makes it harder to compare findings.

Immunotherapy was the least reported treatment (13%). In a scoping review of target and immunotherapies for lung cancer, the reported incidence of use of immunotherapy as a second-line treatment for non-small cell lung cancer ranged from 10% to 50%.⁴² The authors highlight differences in study period as one reason for the large variation in use.⁴² Data reporting for cancer treatment also has limitations; for example, oral therapies are less likely to be captured in cancer registry data.⁴³ Given this, use of immunotherapy is likely to be higher than what is reported here.

We also observed a large increase in odds of immunotherapy from 2015 to 2020, which is consistent with advancements in treatment over time. The first immunotherapy treatment for lung cancer (nivolumab) was approved by the Federal Drug Administration in 2015,⁴⁴ and several treatments have been approved since. Future studies that examine the prevalence of immunotherapy treatment among people with lung cancer could provide further insight into its use. Stratifying receipt of treatment by characteristics like sex, histology, and year of diagnosis combined could additionally inform our understanding of treatment patterns.

In our subgroup analysis, people with a history of smoking had lower odds of surgery. A 2018 survey among thoracic surgeons revealed that 40% required individuals to quit smoking before lung resection⁴⁵; this finding could explain why we found lower rates of surgery among people who currently smoked. Current National Comprehensive Cancer Network guidelines for treating non-small cell lung cancer recommend that people who actively smoke receive counseling and cessation support, and that people should not be denied surgery solely on the basis of smoking status.³ Further, postoperative mortality and major morbidity after lung resection has been found similar between people who currently vs. formerly smoke.⁴⁶

Limitations

Our analysis including smoking status was conducted among a subset of cases in eight states and may lack representation from all groups; the results from this subgroup analysis should be interpreted with caution. The COVID-19 pandemic led to disruptions in multiple health services, including lung cancer treatment.^{47,48} Odds of receiving treatment for lung cancer in 2020 may not be as comparable to other years. We examined the odds of each reported treatment separately, limiting our ability to understand how correlations between treatment types may have impacted their receipt.

The NPCR captures information on first-course treatment only, so we were unable to estimate the percentage of people who reportedly received any treatment during their illness. Relatedly, we were not able to compare or distinguish between different types of

immunotherapeutic agents received. Combined with issues of under-reporting of treatment modalities, the true prevalence of treatment may be higher than what we found in our study. NPCR does not collect data on contextual factors that might influence receipt of treatment, including individual-level (vs. county-level) socioeconomic status, health insurance coverage, comorbidities, and perceived barriers to treatment. Data were also unavailable for date of treatment, limiting our ability to understand how the time from diagnosis to initiation of treatment may have impacted receipt of treatment.

It is possible that race and ethnicity were misclassified for some individuals due to lack of self-report data on these characteristics in medical records. To overcome this limitation, NPCR uses identification algorithms to increase reporting accuracy for Asian/PI and Hispanic persons, as well as several methods to improve estimates among AI/AN populations.⁴⁹ Cases with unknown stage at diagnosis were coded as missing and excluded from our analysis. While we coded unknown in this manner to obtain consistency across our measures and estimates, it is possible that their exclusion could have impacted our findings for receipt of treatment.

Lastly, analyses using big datasets like NPCR may find small effects that are statistically significant⁵⁰ but not necessarily clinically relevant. To address this limitation, we estimated adjusted average predicted probabilities to aid in the interpretation and understanding of our results. Future research seeking to reduce disparities could help to further quantify meaningful differences in treatment outcomes.

Interpretation

This study used NPCR data covering 89% of the population to understand differences in receipt of lung cancer treatment. Reported receipt of at least one treatment was lower among certain racial and ethnic groups and those residing in counties with lower economic status. Our study provides support for the use of cancer registry data to track patterns in lung cancer treatment and has implications for intervention efforts to reduce differences. Based on our findings, interventions might focus on identifying and addressing underlying causes (e.g., unequal healthcare access) that lead to a lower percentage of people being treated for lung cancer among specific populations.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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The first author (Christine M. Kava [CMK]) takes responsibility for all content of the manuscript, including data and analysis. All authors made substantial contributions to study conception and design. CMK led data analysis, interpretation, and manuscript writing. All authors critically reviewed the manuscript for important intellectual content and approved the final version for publication. All authors agree to be accountable for all aspects of the

work, including ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Abbreviations

ACCURE	Accountability for Cancer Care through Undoing Racism and Equity
AI/AN	American Indian and Alaska Native
Asian/PI	Asian and Pacific Islander
CDC	Centers for Disease Control and Prevention
ICD-O-3	International Classification of Diseases for Oncology, Third Edition
NH	Non-Hispanic
NPCR	National Program of Cancer Registries
SEER	Surveillance, Epidemiology, and End Results Program

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Take-Home Points

Study Question:

Among adults diagnosed with lung cancer, how does reported receipt of lung cancer treatment differ by sociodemographic characteristics?

Results:

Reported receipt of at least one of four treatments (surgery, chemotherapy, radiation, and immunotherapy) was lower among several groups, including males; people reported as American Indian or Alaska Native, Black, and Hispanic; and people residing in counties designated as non-metropolitan and lower economic status.

Interpretation:

Our study provides support for the use of cancer registry data to track patterns in lung cancer treatment and has implications for intervention efforts to reduce differences in reported receipt of lung cancer treatment.

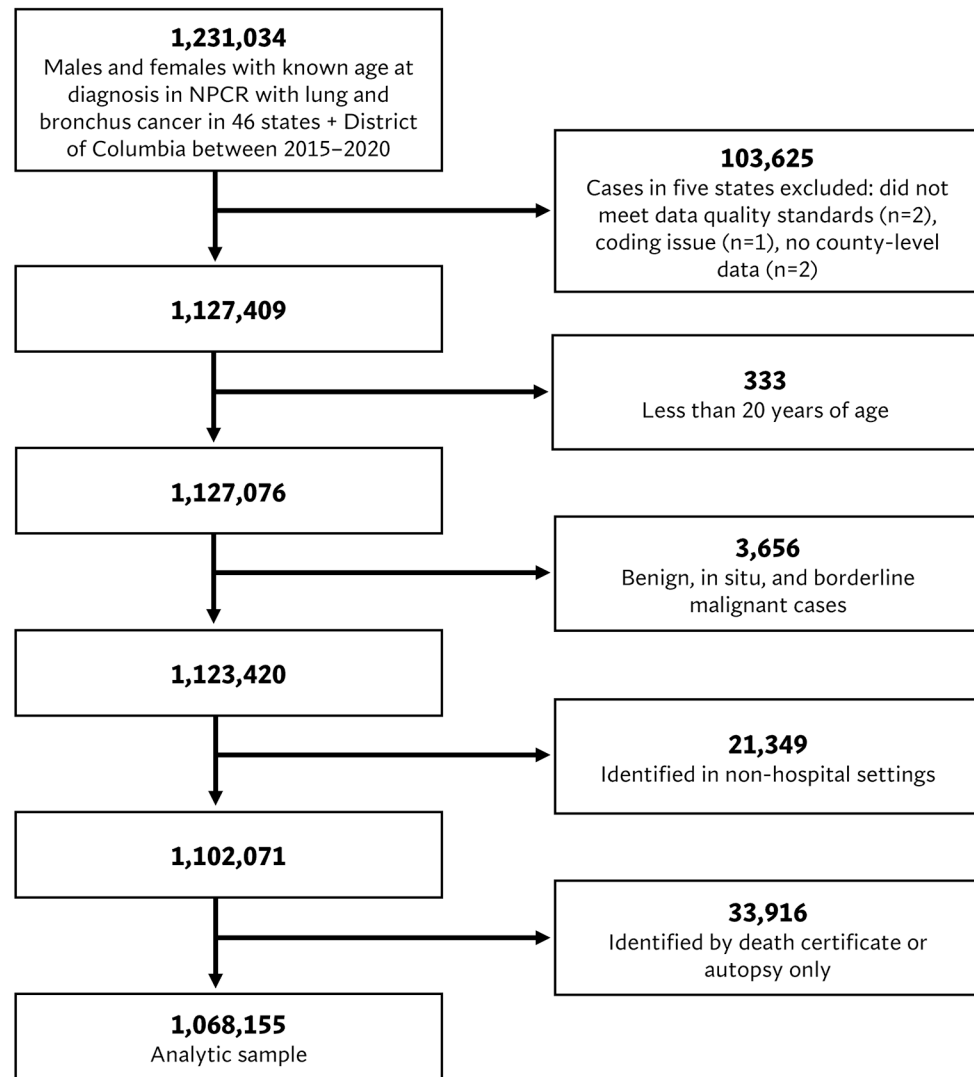


Figure 1.
Study Inclusion Flow Chart, National Program of Cancer Registries

Table 1.

Characteristics of Lung Cancer Cases, National Program of Cancer Registries, 41 states and District of Columbia, United States, 2015–2020, n=1,068,155

Variable	No.	%
First-course treatment (% received) ^a		
Surgery	233,490	22.11
Chemotherapy	423,864	40.94
Radiation	414,188	39.51
Immunotherapy	138,210	13.10
At least one of the four treatments	768,735	75.15
None of the four treatments	254,169	24.85
Age at diagnosis (years)		
20–44	11,714	1.10
45–54	63,374	5.93
55–64	249,970	23.40
65–74	384,082	35.96
75–84	278,334	26.06
≥85	80,681	7.55
Sex		
Female	521,835	48.85
Male	546,320	51.15
Race and ethnicity		
NH American Indian or Alaska Native	6,593	0.62
NH Asian or Pacific Islander	30,474	2.86
NH Black	117,029	10.99
NH White	858,427	80.62
Hispanic, all races	52,301	4.91
County classification ^b		
Metropolitan	869,323	81.41
Non-metropolitan	198,462	18.59
County economic status ^c		
Bottom 25%	125,949	11.80
Middle 50%	648,603	60.74
Top 25%	293,206	27.46
US Census region		
Northeast	221,188	20.71
Midwest	213,595	20.00
South	456,376	42.73
West	176,996	16.57
Smoking status ^d		
Currently smoked	80,203	33.30

Variable	No.	%
Formerly smoked	122,275	50.77
Never smoked	38,370	15.93
Histology ^e		
Adenocarcinoma	484,470	45.36
Small cell carcinoma	135,073	12.65
Squamous cell carcinoma	237,963	22.28
Other	210,649	19.72
Stage		
Localized	284,496	27.62
Regional	245,859	23.87
Distant	499,515	48.50
Year of diagnosis		
2015	187,767	17.58
2016	188,098	17.61
2017	190,645	17.85
2018	189,073	17.70
2019	187,308	17.54
2020	125,264	11.73

Abbreviations: NH, non-Hispanic.

^aThe number and percentage missing data for surgery was 12,226 (1.14%); 32,799 (3.07%) for chemotherapy; 19,738 (1.85%) for radiation, and 13,519 (1.27%) for immunotherapy.

^bDefined based on the 2013 National Center for Health Statistics Urban-Rural Classification Scheme for Counties.

^cDefined for 2018 by the Appalachian Regional Commission and considers three-year average unemployment rate, per capita market income, and poverty rate.

^dReported for a subset of cases in eight states (n=240,848): Alaska, California, Colorado, Florida, Idaho, Louisiana, New Hampshire, and Texas.

^eHistology groups were defined using *International Classification of Diseases for Oncology, Third Edition* site codes: adenocarcinoma (8140–8239; 8250–8384; 8440–8490; 8550–8551; 8570–8574; 8576), small cell carcinoma (8041–8045), squamous cell carcinoma (8050–8084), and other histology (8000–8040; 8046–8049; 8085–8139; 8240–8249; 8385–8439; 8491–8549; 8552–8569; 8575; 8577–9992).

Number and Percentage of People Diagnosed with Lung Cancer Reported to have Received Treatment, National Program of Cancer Registries, 41 states and District of Columbia, 2015–2020, n=1,068,155

Table 2.

Variable	Surgery		Chemotherapy		Radiation		Immunotherapy		At least one of the four treatments	
	No.	%	No.	%	No.	%	No.	%	No.	%
Age at diagnosis (years)										
20–44	3,855	33.32	6,608	58.26	4,439	38.61	2,118	18.34	10,034	88.66
45–54	15,236	24.30	36,903	60.05	28,842	46.29	11,337	18.10	52,429	85.60
55–64	60,199	24.33	126,097	52.02	106,403	43.34	40,140	16.25	197,576	82.02
65–74	97,645	25.71	161,026	43.26	149,439	39.62	50,156	13.22	291,855	79.10
75–84	52,157	18.97	83,107	30.82	100,972	36.99	29,295	10.67	183,195	69.24
≥85	4,398	5.53	10,123	12.94	24,093	30.51	5,164	6.50	33,646	44.33
Sex										
Female	126,942	24.59	200,740	39.60	197,167	38.45	64,094	12.43	380,881	76.08
Male	106,548	19.75	223,124	42.22	217,021	40.52	74,116	13.75	387,854	74.26
Race and ethnicity										
NH American Indian or Alaska Native	1,155	17.69	2,663	41.60	2,697	41.68	814	12.51	4,592	72.42
NH Asian or Pacific Islander	8,037	26.55	13,640	46.12	9,338	31.05	3,815	12.64	22,481	77.06
NH Black	20,710	17.90	47,902	42.38	47,001	40.92	15,617	13.51	81,871	73.29
NH White	190,997	22.50	338,476	40.60	338,386	40.14	111,632	13.17	623,060	75.67
Hispanic, all races	11,780	22.95	20,052	40.44	15,747	30.98	5,910	11.49	34,501	70.12
County classification ^a										
Metropolitan	196,368	22.82	342,058	40.54	331,924	38.84	112,145	13.05	627,469	75.29
Non-metropolitan	37,035	18.99	81,702	42.71	82,141	42.44	25,993	13.32	141,012	74.55
County economic status ^b										
Bottom 25%	21,325	17.23	50,708	41.83	50,760	41.31	15,395	12.42	86,512	72.06
Middle 50%	137,558	21.45	257,888	41.04	252,587	39.67	82,950	12.95	463,851	74.69
Top 25%	74,517	25.65	115,160	40.35	110,702	38.37	39,794	13.73	218,100	77.50
US Census region										
Northeast	60,599	27.48	87,841	40.46	85,209	38.87	30,064	13.70	168,350	78.64

Variable	Surgery		Chemotherapy		Radiation		Immunotherapy		At least one of the four treatments	
	No.	%	No.	%	No.	%	No.	%	No.	%
Midwest	44,821	21.20	90,690	43.38	94,691	44.98	30,849	14.61	162,769	78.84
South	89,165	19.91	180,719	41.44	172,318	38.86	56,782	12.67	315,720	73.07
West	38,905	22.09	64,614	37.33	61,970	35.36	20,515	11.66	121,896	71.58
Histology ^c										
Adenocarcinoma	143,610	29.87	188,389	40.01	177,259	37.13	77,470	16.16	374,771	80.87
Small cell carcinoma	4,816	3.59	93,867	71.10	58,985	44.35	15,822	11.82	101,747	77.14
Squamous cell carcinoma	54,252	23.03	93,650	40.62	111,638	47.76	29,574	12.58	180,755	79.42
Other	30,812	14.99	47,958	23.74	66,306	32.46	15,344	7.44	111,462	55.73
Stage										
Localized	135,670	48.15	29,065	10.44	101,854	36.35	4,969	1.76	239,506	85.94
Regional	80,295	32.87	141,277	59.22	116,871	48.26	26,779	11.00	199,872	83.71
Distant	15,448	3.11	246,933	50.88	189,989	38.58	105,085	21.26	318,743	67.33
Year of diagnosis										
2015	40,418	21.80	78,909	43.59	72,134	39.18	6,761	3.63	135,171	74.30
2016	41,509	22.33	77,207	42.42	73,520	39.78	10,015	5.37	136,550	75.13
2017	41,861	22.20	73,213	39.67	74,246	39.54	19,019	10.10	136,152	74.90
2018	41,875	22.39	74,109	40.22	74,748	40.17	32,671	17.52	136,860	75.86
2019	41,692	22.50	72,930	39.98	73,064	39.76	41,499	22.50	135,991	76.13
2020	26,135	21.11	47,496	39.21	46,476	38.11	28,245	23.00	88,011	74.33
Smoking status ^d										
Currently smoked	13,208	16.80	31,132	41.15	28,579	36.81	9,096	11.59	51,628	68.55
Formerly smoked	27,227	22.62	45,937	39.35	43,102	36.18	15,169	12.64	84,959	73.58
Never smoked	9,868	26.20	13,718	37.56	9,519	25.50	3,924	10.40	25,111	69.33

Abbreviations: NH, non-Hispanic.

^aDefined based on the 2013 National Center for Health Statistics Urban-Rural Classification Scheme for Counties.

^bDefined by the Appalachian Regional Commission and considers three-year average unemployment rate, per capita market income, and poverty rate.

^cHistology groups were defined using *International Classification of Diseases for Oncology, Third Edition* site codes: adenocarcinoma (8140–8239; 8250–8384; 8440–8490; 8550–8551; 8570–8574; 8576), small cell carcinoma (8041–8045), squamous cell carcinoma (8050–8084), and other histology (8000–8040; 8046–8049; 8085–8139; 8240–8249; 8385–8439; 8491–8549; 8552–8569; 8575; 8577–9992).

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^dReported for a subset of cases in eight states (n=240,848): Alaska, California, Colorado, Florida, Idaho, Louisiana, New Hampshire, and Texas.

Table 3.

Odds of Reported Receipt of Lung Cancer Treatment, National Program of Cancer Registries, 41 states and District of Columbia, 2015–2020, n=1,068,155^a

Variable	Model 1: Surgery	Model 2: Chemotherapy	Model 3: Radiation	Model 4: Immunotherapy	Model 5: At least one of the four treatments
	OR (95 CI%)	OR (95 CI%)	OR (95 CI%)	OR (95 CI%)	OR (95 CI%)
Age at diagnosis (years) (ref: 20–44)					
45–54	0.52 (0.49–0.55)	0.84 (0.80–0.88)	1.23 (1.18–1.28)	0.97 (0.92–1.03)	0.67 (0.62–0.71)
55–64	0.42 (0.40–0.44)	0.61 (0.59–0.64)	1.04 (1.00–1.09)	0.84 (0.80–0.89)	0.47 (0.44–0.50)
65–74	0.37 (0.35–0.39)	0.45 (0.43–0.47)	0.89 (0.86–0.92)	0.72 (0.68–0.76)	0.36 (0.34–0.38)
75–84	0.20 (0.19–0.22)	0.26 (0.25–0.27)	0.81 (0.78–0.84)	0.54 (0.52–0.57)	0.20 (0.19–0.22)
≥85	0.05 (0.05–0.05)	0.08 (0.08–0.09)	0.65 (0.63–0.68)	0.29 (0.28–0.31)	0.08 (0.07–0.08)
Sex (ref: Male)					
Female	1.16 (1.15–1.17)	0.96 (0.95–0.97)	0.95 (0.94–0.96)	0.95 (0.93–0.96)	1.04 (1.03–1.05)
Race and ethnicity (ref: NH White)					
NH American Indian or Alaska Native	0.76 (0.71–0.82)	0.89 (0.84–0.94)	1.01 (0.96–1.06)	0.90 (0.83–0.98)	0.82 (0.77–0.87)
NH Asian or Pacific Islander	1.31 (1.26–1.35)	1.32 (1.29–1.36)	0.75 (0.73–0.77)	0.69 (0.66–0.72)	1.09 (1.06–1.13)
NH Black	0.70 (0.69–0.71)	0.93 (0.92–0.95)	1.01 (1.00–1.02)	0.86 (0.84–0.88)	0.82 (0.81–0.84)
Hispanic, all races	1.13 (1.10–1.16)	0.98 (0.96–1.00)	0.72 (0.70–0.73)	0.72 (0.70–0.75)	0.80 (0.78–0.82)
County classification ^b (ref: Metropolitan)					
Non-metropolitan	0.89 (0.87–0.90)	1.02 (1.00–1.03)	1.06 (1.05–1.07)	1.02 (1.00–1.04)	0.98 (0.96–0.99)
County economic status ^c (ref: Top 25%)					
Bottom 25%	0.75 (0.74–0.77)	0.87 (0.86–0.89)	1.04 (1.03–1.06)	0.81 (0.79–0.83)	0.80 (0.78–0.81)
Middle 50%	0.86 (0.85–0.87)	0.93 (0.92–0.94)	1.02 (1.01–1.03)	0.89 (0.88–0.90)	0.87 (0.86–0.88)
US Census region (ref: South)					
Northeast	1.41 (1.39–1.43)	1.06 (1.04–1.07)	1.07 (1.05–1.08)	1.14 (1.12–1.16)	1.33 (1.32–1.35)
Midwest	1.02 (1.01–1.04)	1.10 (1.09–1.12)	1.28 (1.27–1.30)	1.21 (1.19–1.23)	1.35 (1.33–1.37)
West	1.07 (1.06–1.09)	0.90 (0.88–0.91)	0.96 (0.94–0.97)	0.93 (0.92–0.95)	0.95 (0.94–0.97)
Histology ^d (ref: Adenocarcinoma)					
Small cell carcinoma	0.11 (0.11–0.11)	2.66 (2.63–2.70)	1.27 (1.26–1.29)	0.43 (0.42–0.43)	0.94 (0.93–0.95)
Squamous cell carcinoma	0.50 (0.49–0.50)	1.05 (1.04–1.07)	1.48 (1.46–1.50)	0.88 (0.87–0.90)	0.84 (0.82–0.85)

Variable	Model 1: Surgery	Model 2: Chemotherapy	Model 3: Radiation	Model 4: Immunotherapy	Model 5: At least one of the four treatments
	OR (95 CI%)	OR (95 CI%)	OR (95 CI%)	OR (95 CI%)	OR (95 CI%)
Other	0.36 (0.36–0.37)	0.46 (0.45–0.46)	0.84 (0.83–0.85)	0.40 (0.39–0.40)	0.31 (0.31–0.31)
Stage at diagnosis (ref: Distant)					
Localized	33.22 (32.60–33.84)	0.13 (0.12–0.13)	0.95 (0.94–0.96)	0.05 (0.05–0.05)	3.53 (3.49–3.58)
Regional	18.01 (17.67–18.35)	1.42 (1.41–1.44)	1.40 (1.39–1.42)	0.38 (0.38–0.39)	2.42 (2.39–2.45)
Year of diagnosis (ref: 2015)					
2016	0.90 (0.88–0.91)	1.01 (1.00–1.03)	1.03 (1.02–1.04)	1.64 (1.59–1.69)	1.01 (0.99–1.02)
2017	0.84 (0.82–0.85)	0.90 (0.89–0.92)	1.02 (1.01–1.04)	3.47 (3.37–3.57)	0.97 (0.95–0.98)
2018	0.82 (0.80–0.83)	0.95 (0.93–0.96)	1.05 (1.04–1.07)	7.14 (6.95–7.34)	0.99 (0.98–1.01)
2019	0.82 (0.80–0.84)	0.93 (0.92–0.95)	1.04 (1.02–1.05)	10.27 (9.99–10.55)	1.01 (1.00–1.03)
2020	0.75 (0.73–0.76)	0.86 (0.85–0.88)	0.96 (0.95–0.98)	10.30 (10.01–10.60)	0.89 (0.88–0.91)

Abbreviations: CI, confidence interval; NH, non-Hispanic; OR, odds ratio.

Boldface indicates statistical significance (p<0.05).

^aTotal sample size; people missing data on the outcome of interest in each model were excluded from analyses.

^bDefined based on the 2013 National Center for Health Statistics Urban-Rural Classification Scheme for Counties.

^cDefined by the Appalachian Regional Commission and considers three-year average unemployment rate, per capita market income, and poverty rate.

^dHistology groups were defined using *International Classification of Diseases for Oncology, Third Edition* site codes: adenocarcinoma (8140–8239; 8250–8384; 8440–8490; 8550–8551; 8570–8574; 8576), small cell carcinoma (8041–8045), squamous cell carcinoma (8050–8084), and other histology (8000–8040; 8046–8049; 8085–8139; 8240–8249; 8385–8439; 8491–8549; 8552–8569; 8575; 8577–9992).

Odds of Reported Receipt of Lung Cancer Treatment with Smoking Status, National Program of Cancer Registries, 8 States, 2015–2020, n=240,848^a

Table 4.

Variable	Model 1: Surgery	Model 2: Chemotherapy	Model 3: Radiation	Model 4: Immunotherapy	Model 5: At least one of the four treatments
	OR (95 CI%)	OR (95 CI%)	OR (95 CI%)	OR (95 CI%)	OR (95 CI%)
Age at diagnosis (years) (ref: 20–44)					
45–54	0.64 (0.58–0.71)	0.87 (0.80–0.94)	1.06 (0.98–1.15)	0.92 (0.83–1.03)	0.68 (0.61–0.75)
55–64	0.52 (0.48–0.57)	0.65 (0.60–0.70)	0.91 (0.84–0.98)	0.80 (0.72–0.89)	0.49 (0.44–0.54)
65–74	0.46 (0.42–0.50)	0.49 (0.45–0.53)	0.78 (0.72–0.84)	0.70 (0.63–0.77)	0.39 (0.36–0.43)
75–84	0.25 (0.23–0.27)	0.28 (0.26–0.30)	0.72 (0.67–0.78)	0.53 (0.48–0.59)	0.23 (0.20–0.25)
≥85	0.06 (0.05–0.06)	0.09 (0.08–0.10)	0.63 (0.58–0.68)	0.33 (0.29–0.37)	0.09 (0.08–0.10)
Sex (ref: Male)					
Female	1.15 (1.13–1.18)	0.97 (0.95–0.99)	0.97 (0.95–0.98)	0.97 (0.94–0.99)	1.05 (1.03–1.07)
Race and ethnicity (ref: NH White)					
NH American Indian or Alaska Native	0.80 (0.69–0.94)	0.81 (0.72–0.91)	1.15 (1.04–1.28)	0.85 (0.71–1.02)	0.87 (0.78–0.98)
NH Asian or Pacific Islander	1.03 (0.98–1.08)	1.20 (1.16–1.25)	0.94 (0.91–0.97)	0.77 (0.73–0.82)	1.09 (1.05–1.13)
NH Black	0.63 (0.60–0.65)	0.91 (0.89–0.94)	1.02 (0.99–1.05)	0.81 (0.77–0.84)	0.80 (0.78–0.82)
Hispanic, all races	1.07 (1.04–1.11)	0.94 (0.91–0.96)	0.78 (0.76–0.80)	0.75 (0.72–0.79)	0.83 (0.81–0.85)
County classification ^b (ref: Metropolitan)					
Non-metropolitan	0.89 (0.86–0.93)	0.95 (0.92–0.98)	1.07 (1.04–1.10)	0.96 (0.92–1.00)	0.96 (0.93–0.99)
County economic status ^c (ref: Top 25%)					
Bottom 25%	0.77 (0.73–0.80)	0.94 (0.91–0.97)	1.01 (0.98–1.04)	0.86 (0.81–0.90)	0.80 (0.78–0.83)
Middle 50%	0.92 (0.90–0.95)	0.98 (0.96–1.00)	0.95 (0.93–0.97)	0.91 (0.88–0.93)	0.88 (0.86–0.90)
Histology ^d (ref: Adenocarcinoma)					
Small cell carcinoma	0.12 (0.11–0.13)	2.29 (2.23–2.36)	1.15 (1.12–1.18)	0.44 (0.42–0.46)	0.93 (0.90–0.96)
Squamous cell carcinoma	0.52 (0.50–0.53)	1.06 (1.03–1.08)	1.35 (1.33–1.38)	0.87 (0.84–0.89)	0.81 (0.79–0.83)
Other	0.40 (0.38–0.41)	0.45 (0.44–0.47)	0.73 (0.71–0.74)	0.37 (0.35–0.38)	0.32 (0.32–0.33)
Stage at diagnosis (ref: Distant)					
Localized	32.58 (31.46–33.74)	0.14 (0.13–0.14)	0.98 (0.96–1.00)	0.06 (0.06–0.07)	3.01 (2.94–3.08)
Regional	18.32 (17.68–18.99)	1.29 (1.26–1.32)	1.34 (1.32–1.37)	0.40 (0.39–0.41)	2.29 (2.23–2.34)
Year of diagnosis (ref: 2015)					

Variable	Model 1: Surgery	Model 2: Chemotherapy	Model 3: Radiation	Model 4: Immunotherapy	Model 5: At least one of the four treatments
	OR (95 CI%)	OR (95 CI%)	OR (95 CI%)	OR (95 CI%)	OR (95 CI%)
2016	0.91 (0.88–0.95)	1.05 (1.02–1.08)	1.02 (1.00–1.05)	1.60 (1.50–1.70)	1.01 (0.98–1.04)
2017	0.85 (0.82–0.88)	0.90 (0.88–0.93)	1.00 (0.98–1.03)	3.00 (2.84–3.18)	0.93 (0.90–0.96)
2018	0.83 (0.80–0.86)	0.96 (0.93–0.98)	1.01 (0.98–1.03)	5.85 (5.54–6.17)	0.96 (0.93–0.99)
2019	0.87 (0.84–0.90)	0.95 (0.93–0.98)	0.99 (0.97–1.02)	8.10 (7.69–8.54)	0.98 (0.95–1.01)
2020	0.79 (0.75–0.82)	0.86 (0.83–0.89)	0.89 (0.86–0.91)	7.91 (7.48–8.36)	0.82 (0.79–0.85)
Smoking status (ref: Never smoked)					
Currently smoked	0.51 (0.49–0.53)	0.73 (0.71–0.75)	1.41 (1.37–1.45)	1.10 (1.05–1.15)	0.75 (0.73–0.78)
Formerly smoked	0.77 (0.74–0.79)	1.00 (0.97–1.03)	1.45 (1.41–1.48)	1.37 (1.31–1.42)	1.13 (1.10–1.16)

Abbreviations: CI, confidence interval; NH, non-Hispanic; OR, odds ratio.

Boldface indicates statistical significance (p<0.05).

^aTotal sample size of people with smoking status available in eight states; people missing data on the outcome of interest in each model were excluded from analyses. US census region excluded as a covariate in the models due to collinearity given the limited number of states included.

^bDefined based on the 2013 National Center for Health Statistics Urban-Rural Classification Scheme for Counties.

^cDefined by the Appalachian Regional Commission and considers three-year average unemployment rate, per capita market income, and poverty rate.

^dHistology groups were defined using *International Classification of Diseases for Oncology, Third Edition* site codes: adenocarcinoma (8140–8239; 8250–8384; 8440–8490; 8550–8551; 8570–8574; 8576), small cell carcinoma (8041–8045), squamous cell carcinoma (8050–8084), and other histology (8000–8040; 8046–8049; 8085–8139; 8240–8249; 8385–8439; 8491–8549; 8552–8569; 8575; 8577–9992).