County-Level Variations in Receipt of Surgery for Early-Stage Non-small Cell Lung Cancer in the United States

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BACKGROUND: Although counties are the smallest geographic level for comprehensive health-care delivery analysis, little is known about county-level variations in receipt of curative-intent surgery for early-stage non-small cell lung cancer (NSCLC) and factors contributing to such variations in the United States.

METHODS: A total of 179,189 patients aged ≥ 35 years who were diagnosed with stage I to II NSCLC between 2007 and 2014 in 2,263 counties were identified from 39 states, the District of Columbia, and Detroit population-based cancer registries; the data were compiled by the North American Association of Central Cancer Registries. The percentage of patients who underwent surgery was calculated for each county with ≥ 20 cases. Adjusted risk ratios were generated by using generalized estimating equation models with modified Poisson regression.

RESULTS: Receipt of surgery for early-stage NSCLC during 2007 to 2014 according to county ranged from 12.8% to 48.6% in the lowest decile of counties, to 74.3% to 91.7% in the highest decile of counties. There were pockets of low surgery receipt rate counties within each state. For example, there was a 25% absolute difference between the lowest and highest surgery receipt rate counties in Massachusetts. Counties in the lowest quartile for receipt of surgery were those with a high proportion of non-Hispanic black subjects, high poverty and uninsured rates, low surgeon-to-population ratio, and nonmetropolitan status.

CONCLUSIONS: Receipt of curative-intent surgery for early-stage NSCLC varied substantially across counties in the United States, with pockets of low receipt counties in each state. Low surgery receipt counties were characterized by unfavorable area-level socioeconomic and health-care delivery factors.

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ABBREVIATIONS: NAACCR = North American Association of Central Cancer Registries; NSCLC = non-small cell lung cancer

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Lung cancer is the leading cause of cancer-related death in the United States, with non-small cell lung cancer (NSCLC) accounting for about 85% of the incident cases.^{1,2} There is a substantial geographic variation in lung cancer incidence and mortality rates in the United States, with the highest rates clustered in Southern and Midwestern counties.³ Although curative-intent surgery is the standard treatment for early-stage (I or II) disease,⁴ variations in receipt of curative-intent surgery according to race,⁵ facility type,⁶ and geography⁷ have been shown.

We reported substantial state-level variations in receipt of curative-intent surgery in the United States.⁷ However, state-level analyses may mask local-level

(eg, county-level) variations within states and across contiguous states, obscuring the extent of the care delivery problem and blunting recognition of the need for more targeted interventions, regardless of state boundaries. Also, due to data availability, counties are the smallest primary geographic level for comprehensive health-care delivery analysis, and they are commonly used as the basic unit for interventions and as the default starting point for measuring access to health care in the United States.⁸ For these reasons, we extended our previous state-level analysis of variation in receipt of surgical treatment for patients with early-stage NSCLC to the county level. We also examined associations between area-level factors and county-level variation in receipt of curative-intent surgery.

Patients and Methods

Data Source and Patient Cohorts

This study used the National Association of American Central Cancer Registries (NAACCR) Cancer in North American analytic data file, with data from 39 states, the District of Columbia, and Detroit registries that consented to share their data and fulfilled NAACCR's criteria for high quality of incidence data⁹; these data represent about 80% of the US population. Eligible patients were those aged ≥ 35 years, not diagnosed by autopsy or death certificate, and who were diagnosed from 2007 to 2014 with a first primary derived American Joint Committee on Cancer (6th edition) stage I or II NSCLC, categorized according to the *International Classification of Diseases for Oncology (Third Edition)* topography and morphology codes.¹⁰ We excluded patients with missing/unknown data on race/ethnicity, census tract-level poverty status, tumor size, and surgical treatment, and who had Veteran Affairs or public health services insurance (Fig 1). There were 179,189 patients from 2,263 of the 3,142 US counties or county equivalents (72% of US counties) in the final cohort, after excluding 9,031 patients. The study received exempt status from the Institutional Review Board of NAACCR.

Outcome of Interest

Patients were categorized based on receipt of definitive curative-intent surgery, defined as NAACCR surgery codes 20 to 80 (e-Table 1).¹¹ Others were categorized as not having received surgery. We then calculated county-level percentage of patients who received surgery, which was used as a continuous or categorical outcome variable in the analyses. Of the 2,263 counties, however, percentage was suppressed for 979 counties with a total case count < 20 each; the goal was to minimize potential identification of patients and outlier effect when calculating the percentage, mean, and quartiles of county-level receipt of curative-intent surgery. Quartiles of county-level receipt of surgery were determined by using county as the unit of observation.

Independent Variables

Our main independent variables of interest were county of residence at diagnosis and area-level variables. Area-level variables included: socioeconomic and health-care delivery characteristics (census-tract level poverty [$< 5.0\%$, 5.0% - 9.99% , 10.0% - 19.99% , and $> 20.0\%$ below the federal poverty line], urban/rural [rural, urban, and metro; categorized by using population size and proximity to metropolitan area according to the 2013 Rural/Urban Continuum codes¹¹],

uninsured rate [county-level percentage of the population aged 18-64 years without insurance in 2013], and hospital bed-to-population ratio and surgeon-to-population ratio). We calculated the county-level hospital bed-to-population ratio per 100,000 by dividing total number of hospital beds in 2010 by the 2010 US Census total county population aged ≥ 35 years. The surgeon-to-population ratio per 100,000 was derived by dividing the total number of surgeons in 2010 (general surgeons and thoracic surgeons) for each county by the 2010 US Census total county population aged ≥ 35 years) using data from the 2016 to 2017 Area Health Resources Files data release.¹² Other patient-level variables included: demographic characteristics (age at diagnosis [35-49, 50-59, 60-69, 70-79, and ≥ 80 years], race/ethnicity [non-Hispanic white, non-Hispanic black, Hispanic, and non-Hispanic "other"], sex [male, female]), insurance-

Figure 1 – Flowchart of cohort inclusion/exclusion criteria for patients with early-stage non-small cell lung cancer in the NAACCR. NAACCR = North American Association of Central Cancer Registries; VA = Veterans Affairs.

primary payer at diagnosis (uninsured, Medicaid, younger Medicare [patients aged 18-64 years], older Medicare [patients aged $\geq$ 65 years], private insurance [unspecified]), diagnosis year, registry, tumor characteristics (tumor stage [IA, IB, IIA, or IIB] and tumor size [$\leq$ 2 cm, > 2-5 cm, and > 5 cm]).

Statistical Analysis

A descriptive analysis was performed to examine the distributions of patient demographic, geographic, socioeconomic, health-care delivery, and tumor characteristics according to receipt of surgical resection. Statistical significance for categorized variables was tested by using χ^2 or the Fisher exact tests. For descriptive purposes only, the percent receipt of curative-intent surgery was calculated for each county. Counties were grouped into quartiles based on the county-level percent receipt of surgery to determine socioeconomic and health-care delivery characteristics of counties across the quartiles. We also calculated deciles for county-level percent receipt of surgery to display level of variation more clearly.

To adjust for the demographic characteristics and other factors that might account for the variations seen in the descriptive analyses, we

modeled the probability of receiving surgery at the individual level and calculated adjusted risk ratios by using a modified Poisson regression model because there were convergence issues with the log-binomial model.¹³ Here, we excluded patients diagnosed in counties with < 20 total cases and accounted for within-county clustering by using generalized estimating equations. To adjust for individual-level covariates, they were included in the model with each area-level factor to determine the association of each area-level factor with receipt of surgery after accounting for individual-level covariates (model = each area-level factor + all potential individual-level demographic + tumor characteristic factors). We also conducted three separate sensitivity analyses after excluding patients aged > 80 years to assess the association of older age and county-level percent receipt of surgery, after including patients diagnosed from counties with < 20 cases in the multivariable analysis, and also after using the thoracic surgeon-to-population ratio as an independent variable in the multivariable analysis.

Analyses were conducted by using SEER*Stat version 8.1.5 (National Cancer Institute) and SAS version 9.4 (SAS Institute, Inc.). The two-sided statistical significance level was set at 0.05.

Results

Table 1 presents the descriptive characteristics for 179,189 patients diagnosed with early-stage NSCLC according to receipt of surgery. Non-Hispanic white patients had a higher rate of surgery (64.8%) than non-Hispanic black patients (58.8%), but patients categorized as non-Hispanic “other,” who were predominantly Asian-American subjects, had the highest rate (72.5%). Patients with higher stage and larger tumors had lower receipt of surgery than their counterparts with lower stage and small tumors. Receipt of surgery was most frequent (68.5%) among patients diagnosed in counties with the lowest uninsured rate in the age group 18 to 64 years. Patients in the lowest quartile county-level surgeon-to-population ratio had the lowest percent receipt of curative-intent surgery (62.6% vs > 65% for other quartiles of surgeon-to-population ratio).

Figure 2 illustrates the quartiles of the percentage of early-stage NSCLC patients in receipt of curative-intent surgery according to state and county in the United States. Receipt of curative-intent surgery for early-stage NSCLC varied considerably across counties in the United States, ranging from 12.8% to 48.6% in the lowest decile of counties, to 74.3% to 91.7% in the highest decile of counties (about a 26% difference between the 10th and 90th percentiles; median, 62.5%; interquartile range, 55.6%-69.1%). Such variation was evident within each state, including in those states with the highest surgery receipt rate (Fig 3). For example, in Massachusetts, which was among the states with the highest receipt rate, surgery varied from 56.7% to 81.8% (about a 25% absolute difference). Overall, approximately 25% of

counties had a surgery rate < 55.6% (Fig 2, Table 2). In descriptive analyses according to quartiles of county-level percent receipt of surgery, counties in the lowest quartile were those with a high non-Hispanic black population (30% vs 17%), high poverty census tracts (38.5% vs 19%), a high uninsured rate (37% vs 18%), and a low surgeon-to-population ratio (28% vs 24%) compared with counties in the highest quartile (Fig 4). The county-level variations did not significantly change after excluding patients aged > 80 years in whom receipt of surgery is low because of comorbidities (data not shown).¹⁴

Table 3 displays adjusted risk ratios for receipt of surgical resection. Compared with metropolitan residents, urban patients had a 4% lower likelihood of receiving surgery after accounting for individual-level covariates. Patients who resided in the lowest quartile of county-level surgeon-to-population ratio had a 4% lower likelihood of receiving curative-intent surgery compared with those patients who resided in the highest quartile. There was a 6% lower likelihood of receiving surgery among patients who resided in the highest quartile of county-level uninsured rate compared with those in the lowest quartile. Including patients diagnosed in counties with < 20 cases or using a thoracic surgeon-to-population ratio as an independent variable did not change the results (e-Tables 2 and 3).

Discussion

This large contemporary national population-based study documented a greater than twofold difference

TABLE 1] Descriptive Characteristics of Patients Diagnosed With Early-Stage Non-small Cell Lung Cancer in the United States, 2007 to 2014, According to Receipt of Curative-Intent Surgery

Characteristic	Total (N = 179,189)	No Definitive Surgery (n = 63,651)	Definitive Surgery (n = 115,538)	P Value
Age group, y				
35-49	5,612 (3.1)	854 (15.2)	4,758 (84.8)	< .0001
50-59	24,983 (13.9)	5,223 (20.9)	19,760 (79.1)	
60-69	55,617 (31.0)	15,153 (27.2)	40,464 (72.8)	
70-79	62,287 (34.8)	22,891 (36.8)	39,396 (63.2)	
≥ 80	30,690 (17.1)	19,530 (63.6)	11,160 (36.4)	
Race/ethnicity				
NH white	150,062 (83.7)	52,882 (35.2)	97,180 (64.8)	< .0001
NH black	16,614 (9.3)	6,843 (41.2)	9,771 (58.8)	
Hispanic	6,425 (3.6)	2,254 (35.1)	4,171 (64.9)	
NH other	6,088 (3.4)	1,672 (27.5)	4,416 (72.5)	
Sex				
Female	91,819 (51.2)	32,052 (34.9)	59,767 (65.1)	< .0001
Male	87,370 (48.8)	31,599 (36.2)	55,771 (63.8)	
Year of diagnosis				
2007	22,028 (12.3)	6,815 (30.9)	15,213 (69.1)	< .0001
2008	22,523 (12.6)	7,188 (31.9)	15,335 (68.1)	
2009	21,902 (12.2)	7,303 (33.3)	14,599 (66.7)	
2010	22,096 (12.3)	7,734 (35.0)	14,362 (65.0)	
2011	22,030 (12.3)	7,948 (36.1)	14,082 (63.9)	
2012	22,095 (12.3)	8,379 (37.9)	13,716 (62.1)	
2013	22,726 (12.7)	8,830 (38.9)	13,896 (61.1)	
2014	23,789 (13.3)	9,454 (39.7)	14,335 (60.3)	
Insurance				
Private	28,817 (16.1)	6,158 (21.4)	22,659 (78.6)	< .0001
Medicare for 18- to 64-year-olds	9,143 (5.1)	3,021 (33.0)	6,122 (67.0)	
Medicare for those aged ≥ 65 y	84,089 (46.9)	36,024 (42.8)	48,065 (57.2)	
Medicaid	6,587 (3.7)	2,364 (35.9)	4,223 (64.1)	
Uninsured	3,030 (1.7)	1,040 (34.3)	1,990 (65.7)	
Insurance, NOS	7,055 (3.9)	1,776 (25.2)	5,279 (74.8)	
Unknown	40,468 (22.6)	13,268 (32.8)	27,200 (67.2)	
Stage				
IA	81,988 (45.8)	27,347 (33.4)	54,641 (66.6)	< .0001
IB	64,269 (35.9)	23,723 (36.9)	40,546 (63.1)	
IIA	7,409 (4.1)	2,378 (32.1)	5,031 (67.9)	
IIB	25,523 (14.2)	10,203 (40.0)	15,320 (60.0)	
Tumor size, cm				
≤ 2	61,151 (34.1)	16,696 (27.3)	44,455 (72.7)	< .0001
> 2-5	91,263 (50.9)	34,155 (37.4)	57,108 (62.6)	
> 5	26,775 (14.9)	12,800 (47.8)	13,975 (52.2)	
Percent below poverty level				
≥ 20.0	30,554 (17.1)	11,997 (39.3)	18,557 (60.7)	< .0001
10.0-19.99	123,527 (68.9)	44,264 (35.8)	79,263 (64.2)	
5.0-9.99	24,337 (13.6)	7,169 (29.5)	17,168 (70.5)	
< 5.0	771 (0.4)	221 (28.7)	550 (71.3)	

(Continued)

TABLE 1] (Continued)

Characteristic	Total (N = 179,189)	No Definitive Surgery (n = 63,651)	Definitive Surgery (n = 115,538)	P Value
Urban/rural				
Rural	3,310 (1.8)	1,213 (36.6)	2,097 (63.4)	< .0001
Urban	29,424 (16.4)	11,591 (39.4)	17,833 (60.6)	
Metro	146,455 (81.7)	50,847 (34.7)	95,608 (65.3)	
Surgeon-to-population ratio ^a				
< 13.03 per 100,000	42,757 (23.9)	15,994 (37.4)	26,763 (62.6)	< .0001
13.03 to < 22.27 per 100,000	42,633 (23.8)	14,839 (34.8)	27,794 (65.2)	
22.27 to < 33.25 per 100,000	42,064 (23.5)	14,693 (34.9)	27,371 (65.1)	
≥ 33.25 per 100,000	43,547 (24.3)	14,939 (34.3)	28,608 (65.7)	
Unknown	8,188 (4.6)	3,186 (38.9)	5,002 (61.1)	
Hospital bed-to-population ratio ^b				
< 363.5 per 100,000	42,260 (23.6)	15,071 (35.7)	27,189 (64.3)	< .0001
363.5 to < 530.5 per 100,000	42,956 (24.0)	14,304 (33.3)	28,652 (66.7)	
530.5 to < 783.4 per 100,000	42,965 (24.0)	15,050 (35.0)	27,915 (65.0)	
≥ 783.4 per 100,000	42,820 (23.9)	16,040 (37.5)	26,780 (62.5)	
Unknown	8,188 (4.6)	3,186 (38.9)	5,002 (61.1)	
Percent people without insurance, quartile ^c				
< 14.9	41,586 (23.2)	13,081 (31.5)	28,505 (68.5)	< .0001
14.9 to < 19.9	43,576 (24.3)	14,838 (34.1)	28,738 (65.9)	
19.9 to < 23.6	42,560 (23.8)	16,073 (37.8)	26,487 (62.2)	
≥ 23.6	43,279 (24.2)	16,473 (38.1)	26,806 (61.9)	
Unknown	8,188 (4.6)	3,186 (38.9)	5002 (61.1)	

Data are presented as No. (%). NH = non-Hispanic; NOS = not otherwise specified.

^aCalculated by dividing total surgeons (general surgeons and thoracic surgeons) by the total population aged ≥ 35 years during the 2010 US Census.

^bCalculated by dividing the total hospital beds in the county in 2010 by the total population aged ≥ 35 years in the county during the 2010 US Census.

^cPercentage of people without insurance among the population aged 18 to 64 years in 2013.

between the lowest and highest counties in percentage of patients with early-stage NSCLC who received surgical resection in the United States. We also found pockets of low-receipt counties within each state, even in those states with the highest overall proportions of curative-intent resection. Potentially modifiable area-level socioeconomic and health-care delivery factors such as uninsured rate, poverty level, and surgeon-to-population ratio may have partially contributed to these variations.

Major unexplained geographic variations in receipt of surgical treatment have been documented over the last several decades,¹⁵ with variations according to race, facility type, and region or state.⁵⁻⁷ For example, Bach et al⁵ found racial (64% in black subjects vs 76.7% in white subjects) and geographic (range, 55.7%-74.6%) variations in rate of curative-intent surgery for lung cancer. We previously reported substantial state-level variation in curative-intent surgery rates, but state-level analyses can mask larger differences across smaller geographic units.⁷ The county-level variation in the

current study was substantially greater than the state-level variation we previously reported, emphasizing that higher level geographic analysis can underestimate local-level variations in health-care utilization patterns, potentially adversely affecting corrective policy decisions. We found no previous studies for comparison that examined county-level variation in curative-intent surgery for patients diagnosed with early-stage NSCLC. Counties in the United States are the most commonly used geopolitical/administrative boundaries, and the documentation of surgical treatment variations at the county level in each state contributes invaluable evidence to stimulate corrective policy changes by state and local authorities, as well as corrective measures outside state boundaries.

Area-level socioeconomic factors such as percentage of people without health insurance, rural/urban status, and percentage of people below the federal poverty line were significantly associated with the county-level variation. Marked area-level heterogeneity in these socioeconomic

Figure 2 – Quartiles of percentage in receipt of curative-intent surgery for patients with early-stage non-small cell lung cancer grouped according to state and county in the United States, 2007 to 2014. Darker red indicates higher receipt of surgery. Only the top and bottom quartiles of receipt of surgery are presented for the counties. Black dots represent the lowest receipt of surgery, and white dots represent counties with the highest receipt of surgery. Counties in other quartiles are represented as polygons with no dots. The state of Michigan rate represents only the Detroit cancer registry. NA = not applicable.

Figure 3 – Quartiles of within-state percent difference in county-level percent receipt of curative-intent surgery for patients with early-stage non-small cell lung cancer in the United States, 2007 to 2014. Darker red indicates greater variation within the state. The state of Michigan rate represents only the Detroit cancer registry. Percent difference was calculated by subtracting the lowest county-level percent receipt of surgery from the highest county-level percent receipt of surgery within the state. See [Figure 2](#) legend for expansion of abbreviation.

TABLE 2] Descriptive Characteristics of US Counties According to Quartile of County Level Percent Receipt of Surgery for Patients Diagnosed With Early-Stage Non-small Cell Lung Cancer

Characteristic	Total (N = 1,284)	County-Level Percent Receipt of Surgery Quartile				P Value
		< 55.6 (n = 317)	55.6 to < 62.5 (n = 314)	62.5 to < 69.1 (n = 332)	≥ 69.1 (n = 321)	
Percent NH black subjects, quartile						
< 1.1	315 (24.5)	86 (27.1)	71 (22.6)	76 (22.9)	82 (25.5)	< .007
1.1 to < 3.7	321 (25.0)	60 (18.9)	79 (25.2)	90 (27.1)	92 (28.7)	
3.7 to < 13.0	325 (25.3)	77 (24.3)	76 (24.2)	80 (24.1)	92 (28.7)	
≥ 13.0	323 (25.2)	94 (29.7)	88 (28.0)	86 (25.9)	55 (17.1)	
Surgeon-to-population ratio, quartile^a						
< 6.8	324 (25.2)	89 (28.1)	82 (26.1)	77 (23.2)	76 (23.7)	< .26
6.8 to < 13.1	321 (25.0)	81 (25.6)	82 (26.1)	82 (24.7)	76 (23.7)	
13.1 to < 20.9	320 (24.9)	83 (26.2)	64 (20.4)	82 (24.7)	91 (28.3)	
≥ 20.9	319 (24.8)	64 (20.2)	86 (27.4)	91 (27.4)	78 (24.3)	
Hospital bed-to-population ratio, quartile^b						
< 230.7	321 (25.0)	73 (23.0)	75 (23.9)	85 (25.6)	88 (27.4)	< .09
230.7 to < 420.4	321 (25.0)	78 (24.6)	65 (20.7)	90 (27.1)	88 (27.4)	
420.4 to < 701.8	321 (25.0)	70 (22.1)	90 (28.7)	82 (24.7)	79 (24.6)	
≥ 701.8	321 (25.0)	96 (30.3)	84 (26.8)	75 (22.6)	66 (20.6)	
Percent people without insurance, quartile^c						
< 17.1	317 (24.7)	49 (15.5)	64 (20.4)	95 (28.6)	109 (34.0)	< .0001
17.1 to < 21.4	320 (24.9)	66 (20.8)	90 (28.7)	80 (24.1)	84 (26.2)	
21.4 to < 24.8	316 (24.6)	84 (26.5)	89 (28.3)	72 (21.7)	71 (22.1)	
≥ 24.8	331 (25.8)	118 (37.2)	71 (22.6)	85 (25.6)	57 (17.8)	
Percent below poverty level						
< 5.0	6 (0.5)	0 (0)	2 (0.6)	1 (0.3)	3 (0.9)	< .0001 ^d
5.0-9.99	108 (8.4)	12 (3.8)	21 (6.7)	28 (8.4)	47 (14.6)	
10.0-19.99	809 (63.0)	183 (57.7)	201 (64.0)	215 (64.8)	210 (65.4)	
≥ 20.0	361 (28.1)	122 (38.5)	90 (28.7)	88 (26.5)	61 (19.0)	
Urban/rural status						
Rural	46 (3.6)	9 (2.8)	11 (3.5)	13 (3.9)	13 (4.1)	< .008
Urban	534 (41.8)	163 (51.4)	129 (41.1)	122 (36.7)	123 (38.3)	
Metro	701 (54.6)	145 (45.7)	174 (55.4)	197 (59.3)	185 (57.6)	

Data are presented as No. (%). See Table 1 legend for expansion of abbreviation.

^aCalculated by dividing the total number of surgeons (general surgeons and thoracic surgeons) by the total population aged ≥ 35 years in the county during the 2010 US Census.

^bCalculated by dividing the total number of hospital beds in the county in 2010 by the total population aged ≥ 35 years in the county during the 2010 US Census.

^cPercentage of people without insurance among the population aged 18 to 64 years in 2013.

^dFisher exact test.

variables has been reported across counties within specific US states^{16,17} and contributes to county-level variations in health service utilization, including the likelihood of receiving surgical treatment.¹⁸⁻²³ We describe the specific association of these variables with

the use of surgery for NSCLC. County-level uninsured rate is known to have strong association with demographic and area-level socioeconomic factors,^{17,24} and corrective measures mitigating adverse consequences of area-level socioeconomic factors can

Figure 4 – Quartiles of percentage in county-level receipt of curative-intent surgery for patients with early-stage non-small cell lung cancer according to quartiles of county-level surgeon-to-population ratio in the United States, 2007 to 2014. Dark blue represents the lowest quartiles for both variables, and dark red represents the top quartile for both. Counties with < 20 patients are suppressed and shown as dots. The state of Michigan rate represents only the Detroit cancer registry. States with no data are gray with no county boundaries. See [Figure 2](#) legend for expansion of abbreviation.

improve access to health services and outcomes.^{22,25} For example, federal, state, and county policy initiatives such as Medicaid eligibility expansions, health-care safety nets, and public health programs targeting rural communities may enhance financial well-being, insurance coverage, and access to health care at the county level.^{17,26-30}

Although the national recommended surgeon-to-population ratio by various authorities such as the Graduate Medical Education National Advisory Committee is approximately nine surgeons per 100,000 population,^{31,32} surgeon-to-population ratios vary substantially across counties in the United States.^{18,33} By one report, about 25% of the US population lives in a county without a general surgeon.³⁴ The variation in surgeon-to-population ratio could be due to clustering of surgeons in metropolitan and academic environments, leading to shortages of surgeons in some counties, creating “surgical deserts” (ie, counties without surgeons).^{18,33,35,36} Counties without surgeons have low surgical volume for inpatient surgical treatments.^{18,37} Our finding of an association between surgeon-to-population ratio and receipt of NSCLC surgery identifies

a potential modifiable area-level health-care delivery factor worthy of policy makers’ attention. In addition to changes in workforce development and incentives for surgeons to work in underserved communities, dissemination of innovative community-based surgical practice models that improve access to surgical services may reduce county-level variations in receipt of curative-intent surgery.^{38,39} A major potential benefit of county-level analyses such as the current one is that they can stimulate initiatives that target improving referral or care coordination between adjacent counties (irrespective of state boundaries).^{40,41}

Although our study examined the association between potentially modifiable area-level socioeconomic and health-care delivery factors and county-level receipt of surgery, there may be contributory factors not considered in this analysis that vary across counties. One such factor in county-level variation is prevalence of comorbid conditions,^{42,43} which may have affected receipt of surgery across counties. Although previous studies reported county-level variations in prevalence of comorbid conditions, other studies showed that most patients with lung cancer and with comorbid conditions

TABLE 3] Adjusted Risk Ratios With 95% CIs for Receipt of Surgery Among Patients Diagnosed With Early-Stage Non-small Cell Lung Cancer in the United States, 2007 to 2014

Characteristic	Risk Ratios (95% CI)	
	Crude	Adjusted ^a
Percent below poverty level		
< 5.0	1.00	1.00
5.0-9.99	0.97 (0.87-1.08)	1.01 (0.94-1.08)
10.0-19.99	0.90 (0.82-1.00)	0.98 (0.92-1.05)
≥ 20.0	0.86 (0.77-0.95)	0.94 (0.88-1.01)
Urban/rural		
Metro	1.00	1.00
Rural	1.00 (0.95-1.05)	0.98 (0.93-1.03)
Urban	0.96 (0.94-0.97)	0.96 (0.95-0.97)
Surgeon-to-population ratio ^b	1.00	1.00
22.27 to < 33.25 per 100,000	0.99 (0.96-1.02)	0.98 (0.95-1.01)
13.03 to < 22.27 per 100,000	0.99 (0.96-1.02)	0.98 (0.95-1.00)
< 13.03 per 100,000	0.97 (0.94-0.99)	0.96 (0.94-0.98)
Percent people without insurance, quartile ^c		
< 14.9	1.00	1.00
14.9 to < 19.9	0.98 (0.95-1.00)	0.98 (0.96-1.01)
19.9 to < 23.6	0.94 (0.92-0.97)	0.96 (0.93-0.99)
≥ 23.6	0.91 (0.88-0.93)	0.94 (0.90-0.97)

^aAdjusted for race/ethnicity, diagnosis age, sex, year of diagnosis, registry, insurance, stage, and tumor size.

^bCalculated by dividing the total number of surgeons (general surgeons and thoracic surgeons) by the total population aged > 35 years during the 2010 US Census 2010.

^cCounty level percentage of people without insurance among the population aged 18 to 64 years in 2013.

receive surgery, and accounting for differences in state-level COPD prevalence did not change state-level variations in receipt of surgery for patients with early-stage lung cancer.^{7,44}

The current study is limited because of the absence of information on the decision-making process in our analytic database, such as patient-physician communication, referral patterns, surgeon practice preferences, and patient perceptions and preferences.⁴⁵⁻⁴⁸ Other patient-, provider-, institutional-, and community-level factors can influence the treatment decision-making process.⁴⁹⁻⁵¹ Furthermore, technical factors such as differences in ascertainment of treatment information by registry and seeking care outside smaller counties could cause county-level variations. We have not accounted for use of curative-intent nonsurgical options such as radiation therapy, including stereotactic body radiation, radiofrequency, and other ablation techniques, although we note that resection remains the primary recommendation for stage I and II NSCLC. Although there is an overall downward trend in the use of surgical resection, this trend will not account for the

wide county-level variation. We have no county-level information on performance status or comorbidity status to account for their effect on variation in receipt of surgery for early-stage NSCLC across counties, although it is unlikely that the proportion of patients with medically unresectable NSCLC will fully explain the wide amplitude of variation across counties. In some states, uninsured patients newly diagnosed with cancer gain eligibility for Medicaid coverage only following their cancer diagnosis, and they may be more similar to uninsured patients in terms of their interactions with health care than those with continuous Medicaid coverage.^{52,53}

We were also unable to account for differences in between-county travel to access surgical care, especially for patients who live in rural counties. The NAACCR data cannot be used to identify patients who gain insurance coverage only following their cancer diagnosis, and associations between Medicaid coverage and receipt of surgery may be overstated. Nevertheless, our study has several strengths. First, we used large contemporary national population-based data with

county-level information supplemented with provider characteristic variables. Second, the NAACCR implements stringent data quality and ascertainment criteria. Third, we used generalized estimating equation models to estimate the effects of area-level and individual-level factors on receipt of surgery controlling for county-level clustering.

Conclusions

Receipt of curative-intent surgery for early-stage NSCLC varied substantially across counties in the United States, with pockets of low-receipt counties,

even within states with high surgical resection rates. Area-level socioeconomic and health-care delivery factors partially contributed to these variations, suggesting that concerted policy interventions targeting low-access and high-poverty counties may reduce variations in receipt of curative-intent surgery. Further studies are needed to identify and address gaps in access to surgical treatment of early-stage NSCLC, such as more direct evaluation of patient-, provider-, institution-, and community-level factors influencing access to and choice for or against curative-intent treatment modalities.

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