Temporal Changes in Treatment Patterns for Rural and Urban Patients With Early-Stage Non-Small Cell Lung Cancer

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BACKGROUND Our objectives were to evaluate geographic access to lung cancer treatment modalities in North Carolina and to characterize how practice patterns are changing over time. We hypothesized that rural patients would be less likely to undergo treatment compared to urban patients, with widening disparities over time.

METHODS We identified patients with Stage I non-small cell lung cancer (NSCLC) from 2006 to 2015 using the North Carolina Central Cancer Registry linked with Medicaid, Medicare, and private insurance claims. The primary outcome was first-course treatment: surgery, radiation, or no treatment. Calendar years were split into earlier (2006–2010) and later (2011–2015) periods. We estimated the adjusted odds ratio (OR) of rural/urban status and time period with 1) surgery and 2) any treatment (surgery or radiation) using multivariable logistic regression.

RESULTS Among 5504 patients, 3206 (58%) underwent surgery as initial therapy, 1309 (24%) received radiation as initial therapy, and 989 (18%) had no therapy. There were no rural-urban disparities in treatment patterns. For rural and urban patients, the odds of surgery decreased over time and the odds of radiation increased. We also found that only 48% of those receiving no treatment ever reached a surgeon or radiation oncologist.

LIMITATIONS This was an insured, single-state population. Treatment preferences are unknown.

CONCLUSIONS Among all treated patients, whether urban or rural, there was increasing use of radiation and decreasing use of surgery over time. Many patients without treatment never had a consultation with a surgeon/radiation oncologist, and this is an actionable target for improving treatment access for early-stage NSCLC.

In the United States, individuals living in rural areas have worse cancer-related outcomes, including lower rates of screening [1], later stage of diagnosis [2], less guideline-concordant therapy [3, 4], and higher mortality when compared to urban patients [5]. Rural patients with lung cancer are no exception, as rural patients with non-small cell lung cancer (NSCLC) have higher mortality than urban patients with early-stage NSCLC [3, 6, 7]. Factors such as higher smoking rates and higher rates of other chronic life-limiting health conditions may play a role in increased mortality but these factors do not explain all differences [7–9]. Decreased access to surgical care for early-stage NSCLC may also contribute, but the data are mixed [3, 6, 7, 10–13]. Differences in surgical access are important to understand as surgical resection is the standard of care for patients who are medically operable [14].

Multiple area-level and individual factors may contribute to differences in surgical care among rural and urban patients, and the mixed findings among prior studies may be due to the methodologic challenges of accounting for these factors [15]. Rural areas have fewer thoracic surgeons and are increasingly geographically isolated from surgical cancer care, leading to decreasing prevalence of surgery in general for rural patients [16, 17].

In addition, rural patients are more likely to be poor surgical candidates due to higher rates of chronic lung disease [18, 19]. Thus, access to radiation therapy for rural patients as an alternative to surgical resection is important but may also be limited for rural areas due to fewer radiotherapy facilities [20]. On the other hand, research suggests radiation is also increasingly used in patients with NSCLC who are operative candidates [21].

The primary objective of this study is to characterize rural-urban differences in treatment patterns over time for early-stage NSCLC using a multipayer database in North Carolina. We hypothesized that rural patients would have lower rates of both surgery and radiation compared to urban patients and that this disparity is growing over time. The secondary objective is to evaluate the patient- and area-level factors associated with differences in treatment among rural patients. Rural areas are not homogenous, and we explored differences in rural areas with high treatment prevalence compared to those with low treatment prevalence, hypothesizing that the primary difference among these areas would

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be proximity of health resources, including providers and cancer treatment facilities.

Methods

Data Source

We used the University of North Carolina Lineberger Comprehensive Cancer Center's Cancer Information and Population Health Resource (CIPHR), a unique database consisting of North Carolina Central Cancer Registry cases matched with administrative claims data from Medicare, Medicaid, and private insurance plans [22]. This database includes insurance claims for 85% of the cancer population of North Carolina. Additional county-level data for North Carolina was obtained from the 2019 Area Health Resource File (AHRF) [23].

Study Population

We identified adults diagnosed with Stage I NSCLC, based on American Joint Committee on Cancer 7th edition staging criteria, from 2006 to 2015. Medicare and private insurance claims were available up to 2015 at the time of the study, and Medicaid claims were available through 2012. We included patients who were continuously enrolled from 6 months prior to diagnosis to 6 months after diagnosis; this time window was used to optimize capture of comorbidity and initial treatment information. Additional cohort selection criteria are available in Supplemental Figure 1.

SUPPLEMENTAL FIGURE 1
Cohort Derivation for Study Sample

This appendix is available in its entirety in the online edition of the NCMJ.

Study Variables

The primary exposure was rural/urban status. This was defined at the county level using the 2013 Rural-Urban Continuum Codes (RUCCs). Each county is assigned a code from 1 to 9. These codes distinguish metropolitan counties (codes 1–3) based on population size, and nonmetropolitan counties (codes 4–9) by their level of urbanization and adjacency to a metropolitan area [24]. Due to small sample sizes in isolated rural counties (codes 8 and 9), we dichotomized county rurality with nonmetropolitan areas (codes 4–9) designated rural, and metropolitan areas (codes 1–3) designated urban.

The primary outcome of interest was first-course curative intent treatment: surgery, radiation, or no treatment. For a secondary outcome analysis, we also examined any first-course locoregional treatment (surgery or radiation) versus no treatment. Treatment variables were defined using ICD-9, ICD-10, and CPT codes identified in the claims files. Surgery included patients who had wedge resections, segmentectomy, lobectomy, or pneumonectomy. To optimize sensitivity for capturing treatment, radiation treatment with stereotactic body radiation therapy (SBRT), as well as other methods, was included. If no treatment was delivered in the first 6 months, subsequent treatment was considered treatment for recurrent or advancing disease rather than first course of therapy. Thus, the no-treatment group included 125 patients (8%) who received treatment between 6–12 months. These patients were not dropped from the analysis. Patients who received both surgery and radiation were classified according to the first treatment received.

Additional covariates included age at diagnosis (18–64, 65–69, 70–74, 75–79, and 80 years or older), year of diagnosis, race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, and other), insurance (any Medicaid, any private, and Medicare only), and comorbidities—measured by the weighted Elixhauser comorbidity index within 6 months prior to cancer diagnosis [25]. Proximity to care was examined for each patient by calculating road network travel distance from location of residence to nearest hospital performing at least 10 lung resections over the study period using ArcGIS (Environmental Systems Research Institute, Redlands, CA). Area-level covariates captured from the AHRF included surgeon density, radiation oncologist density, presence of Commission on Cancer (CoC) accredited hospital in the county, high poverty (> 20% of population below the federal poverty level in the 2008–2012 American Community Survey [26]), and low education (> 20% of adult population with no high school education).

Statistical Analysis

Baseline descriptive statistics were computed for the study population and stratified by treatment received as well as by time period, dichotomized into early (2006–2010) and late (2011–2015) years. Unadjusted comparisons were made for baseline characteristics using Chi-squared tests for categorical variables, and T-tests or ANOVA for continuous variables.

For the primary analysis, to characterize rural-urban differences in treatment patterns over time, multivariable mixed logistic regression modeling was performed. Models also included random intercepts at county level to account for correlated data for people living in the same counties. Three models were performed for each treatment outcome: surgery versus no surgery, radiation versus no radiation, and any treatment versus no treatment. Each model included rural-urban, time period, and the interaction between the two as the primary study variables and adjustment for Elixhauser comorbidity index, age, sex, race (collapsed into non-Hispanic White and others), insurance, poverty, and education. An interaction of rural/urban and race was tested but was not significant, so results stratified by race were not reported. As Medicaid claims were only available through 2012, we also performed a sensitivity analysis excluding patients with Medicaid insurance.

To understand factors related to differences in treatment patterns among rural patients, in a secondary analysis the proportion of patients undergoing surgical resection by county was grouped into 3 tertiles: low-, middle-, and high-prevalence of surgical resection at the rural county level. Descriptive statistics were computed for the study population stratified by tertile of residence. Categorical variables were compared with Chi-squared testing and continuous variables were compared with ANOVA testing. Next, county-level characteristics (surgeon density, radiation-oncologist density, presence of a CoC hospital, high poverty) were compared among low, middle, and high resection tertiles in a similar manner. To avoid variance instability due to small sample size, the analyses for county-level attributes were weighted by the square root of the population and the significance level was computed using Somer's D test [27]. This county-level stratified analysis was repeated for the any treatment versus no treatment outcome.

P-values were considered significant at $P < .05$. The mixed model confidence intervals were adjusted for multiple comparisons using Bonferroni adjustment. All analyses were performed using SAS (9.4, Cary, North Carolina). The University of North Carolina Institutional Review Board approved the study.

Results

Baseline Characteristics

We identified 5504 patients with Stage I NSCLC who met inclusion criteria. Among these, 3206 (58%) underwent surgery as first-course treatment, 1309 (24%) underwent radiation as first-course treatment, and 989 (18%) underwent no up-front locoregional therapy. There was significant variation in treatment patterns across the state. The county-level prevalence of surgery ranged from 26% to 100%. For any treatment, the range was 50% to 100%. Patients undergoing no therapy were older, were more likely to be non-Hispanic Black, had higher Elixhauser scores, and had higher frequencies of Medicaid insurance compared to those undergoing either surgery or radiation. Patients undergoing surgery were younger, more likely to be non-Hispanic White, had lower Elixhauser scores, and were more likely to have private insurance compared to patients undergoing radiation or no treatment (Table 1). Comparing across time periods, patients diagnosed from 2011 to 2015 were older, had higher Elixhauser scores, and were more likely to be female compared to patients diagnosed from 2006 to 2010 (Table 2).

Primary Objective: Rural-Urban Treatment Patterns Over Time

Figure 1 provides an overview of unadjusted time trends in treatment patterns for early-stage NSCLC across the state of North Carolina. In the mixed regression model, there were no significant differences in the adjusted odds of surgery, radiation, or any treatment between rural and urban patients in either time period (Table 3). There was also no significant change in adjusted odds of any treatment versus no treatment over time for rural patients (2011–2015 versus 2006–

TABLE 1.
Baseline Characteristics by Treatment Modality for Patients With Stage I NSCLC in North Carolina, 2006–2015

Characteristic	Total (N = 5504)	Surgery (n = 3206)	Radiation (n = 1309)	No Treatment (n = 989)	*P*-Value
Age					
18–64	961	672 (70)	158 (16)	131 (14)	< .001
65–69	1136	767 (68)	198 (17)	171 (15)	
70–74	1294	826 (64)	288 (22)	180 (14)	
75–79	1075	591 (55)	289 (27)	195 (18)	
80+	1038	350 (34)	376 (36)	312 (30)	
Sex					
Male	2675	1549 (58)	614 (23)	512 (19)	0.061
Female	2829	1657 (59)	695 (25)	477 (17)	
Race					
NH-White	4721	2791 (59)	1127 (24)	803 (17)	< .001
NH-Black	681	353 (52)	165 (24)	163 (24)	
Hispanic	37	23 (62)	< 15	< 15	
Other	65	39 (60)	< 15	15 (23)	
Insurance					
Privately insured	420	341 (81)	36 (9)	43 (10)	< .001
Any Medicaid	922	408 (44)	200 (22)	314 (34)	
Medicare only	4162	2457 (59)	1073 (26)	632 (15)	
Elixhauser Comorbidity Index					
Mean Weighted Score (SD)	5.0 (6.4)	3.9 (5.6)	6.5 (6.9)	6.7 (7.5)	< .0001
History of Chronic Lung Disease					
No	2575	1713 (67)	412 (16)	450 (17)	< .001
Yes	2929	1493 (51)	897 (31)	539 (18)	
Rural/Urban					
Urban	3932	2313 (59)	917 (23)	702 (18)	0.105
Suburban	1394	792 (57)	357 (26)	245 (18)	
Isolated Rural	178	101 (57)	35 (20)	42 (24)	

TABLE 2.
Baseline Characteristics by Study Period for Patients With Stage I NSCLC in North Carolina, 2006–2015

Characteristic	Total (N = 5504)	2006–2010 (n = 2800)	2011–2015 (n = 2704)	*P*-Value
Age				
18–64	961 (17)	528 (19)	433 (16)	.017
65–69	1136 (21)	562 (20)	574 (21)	
70–74	1294 (24)	642 (23)	652 (24)	
75–79	1075 (20)	566 (20)	509 (19)	
80+	1038 (19)	502 (18)	536 (20)	
Sex				
Male	2675 (49)	1403 (50)	1272 (47)	.023
Female	2829 (51)	1397 (50)	1432 (53)	
Race				
NH-White	4721 (86)	2421 (86)	2300 (85)	0.231
NH-Black	681 (12)	334 (12)	347 (13)	
Hispanic	37 (1)	19 (1)	18 (1)	
Other	65 (1)	26 (1)	39 (1)	
Insurance				
Privately Insured	420 (8)	212 (8)	208 (8)	< .001
Any Medicaid	922 (17)	684 (24)	238 (9)	
Medicare only	4162 (76)	1904 (68)	2258 (84)	
Elixhauser Comorbidity Index				
Weighted Mean Score (SD)	5.0 (6.4)	4.6 (5.9)	5.5 (7.0)	< .0001
Chronic Lung Disease				
Yes	2929 (53)	1457 (52)	1472 (54)	.074
No	2575 (47)	1343 (48)	1232 (46)	
Rural/Urban				
Urban	3932 (71)	2000 (71)	1932 (71)	.192
Suburban	1394 (25)	698 (25)	696 (26)	
Isolated Rural	178 (3)	102 (4)	76 (3)	

2010, OR, 0.96; 95% CI, 0.68, 1.36). However, for patients from rural areas, adjusted odds of surgery over time were lower (2011–2015 versus 2006–2010, OR, 0.65; 95% CI, 0.49, 0.86), and adjusted odds of radiation over time were significantly higher (2011–2015 versus 2006–2010, OR, 1.61; 95% CI, 1.18, 2.19). Urban patients followed a similar pattern with similar adjusted odds of undergoing any treatment versus no treatment over time (2011–2015 versus 2006–2010, OR, 1.01; 95% CI, 0.81, 1.27) (Table 3). For patients from urban areas, adjusted odds of surgery over time were significantly lower (2011–2015 versus 2006–2010, OR, 0.72; 95% CI, 0.60, 0.87), and adjusted odds of undergoing radiation over time were significantly higher (2011–2015 versus 2006–2010, OR, 1.50; 95% CI, 1.23, 1.84). The sensitivity analysis, removing patients with Medicaid, did not change the results.

Secondary Objective: Within Rural Analysis

Patients with lung cancer from rural counties with low, middle, and high surgery prevalence did not differ with respect to age, race, sex, or comorbidity distributions. Patients from the highest-tertile counties had shorter mean travel distances to the nearest surgeon compared to the lower tertiles (20.5 miles versus 30.3 miles, respectively; $P < .001$) (Table 4). Counties in the highest tertile for surgery had lower radiation oncologist density, but had similar surgeon density, CoC-certified hospitals, education, and poverty levels as the middle- and low-surgery tertiles.

Patients from rural counties with low, middle, and high rates of any treatment (radiation or surgery) were similar with respect to age, stage, and comorbidities (Table 5). Mean travel distance was significantly lower in the highest-treatment counties versus the lowest (20.0 miles versus 33.3 miles, respectively; $P < .001$). Counties in the highest-treatment tertile had a higher frequency of having a CoC hospital, but otherwise did not differ among provider density or socioeconomic measures.

Post-Hoc Analyses

To further elucidate reasons for the treatment pattern changes over time, 2 post-hoc analyses were performed. In the first, we tested the hypothesis that declining rates of surgery overall would be due to decreases in sublobar resections rather than in lobectomies, suggesting patients who previously would have received sublobar resections were instead now undergoing radiation. We evaluated the overall unadjusted proportion of patients undergoing radiation and surgery over time, but stratified the surgical patients into those undergoing lobectomies and those undergoing sublobar resections. Due to the way the data are coded, we could not differentiate segmental resection versus wedge resection, so these were both categorized together as sublobar resections. The percentage of patients undergoing sublobar resections ranged from 10% to 15% during the study period (Supplemental Figure 2) with no significant trend over time

FIGURE 1.
Treatment Patterns Over Time for Early-Stage Non-Small Cell Lung Cancer in North Carolina by Rural and Urban County, 2006–2015

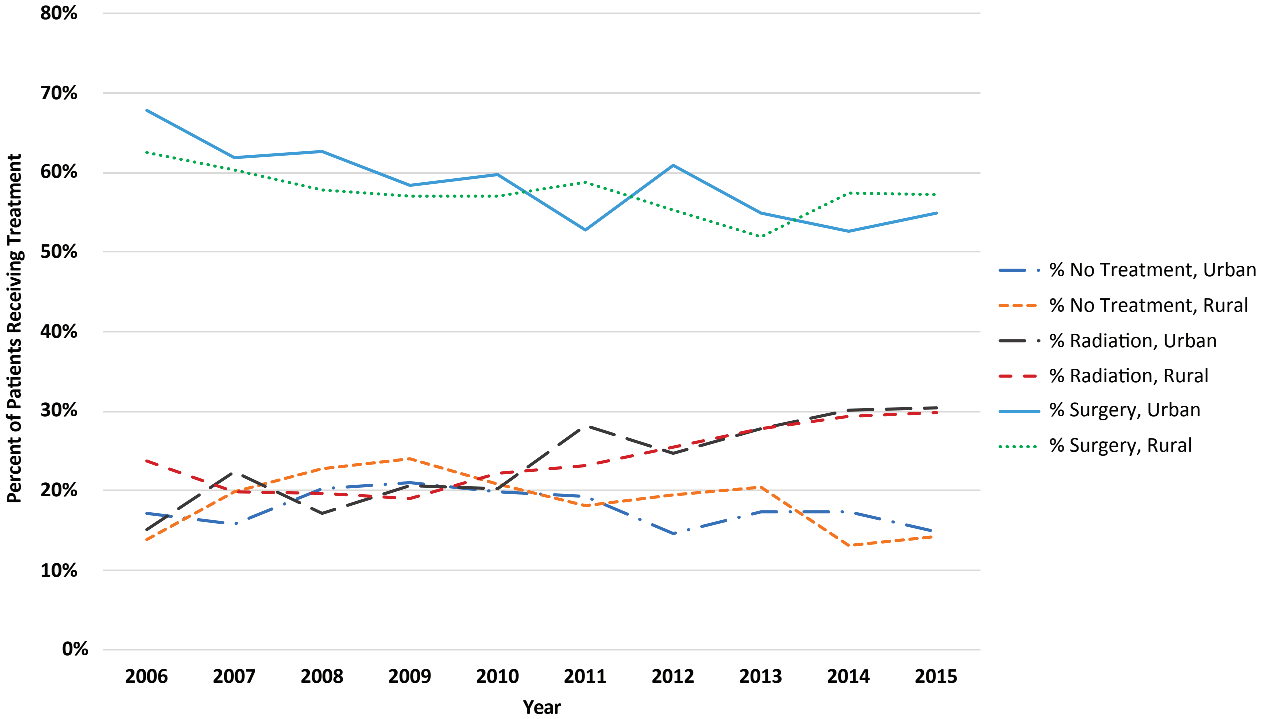

TABLE 3.
Adjusted Odds of Treatment by Rural-Urban Location and Study Period, 2006–2015

Outcome	Comparison	Adjusted OR (95% CI)*
Surgery	Rural vs Urban, 2006–2010	0.98 (0.68,1.41)
	Rural vs Urban, 2011–2015	0.88 (0.61,1.27)
	Rural, 2011-2015 vs 2006-2010	**0.65 (0.49,0.86)**
	Urban, 2011-2015 vs 2006-2010	**0.72 (0.60,0.87)**
Radiation	Rural vs Urban, 2006–2010	0.97 (0.66,1.44)
	Rural vs Urban, 2011–2015	1.04 (0.71,1.52)
	Rural, 2011–2015 vs 2006–2010	**1.61 (1.18,2.19)**
	Urban, 2011–2015 vs 2006–2010	**1.50 (1.23,1.84)**
Any Treatment	Rural vs Urban, 2006–2010	0.93 (0.64,1.35)
	Rural vs Urban, 2011–2015	0.88 (0.60,1.30)
	Rural, 2011–2015 vs 2006–2010	0.96 (0.68,1.36)
	Urban, 2011–2015 vs 2006–2010	1.01 (0.81,1.27)

Abbreviations: OR: odds ratio; CI: confidence interval
*Models adjusted for age, sex, race, comorbidities, area-level poverty, education, surgeon density, radiation oncologist density, and presence of a cancer hospital within the county. Random intercepts allowed at county level. Confidence intervals/significance adjusted for multiple comparisons within each model.

(*P*-value = .77 for Pearson correlation coefficient between proportion of sublobar and year).

In the second post-hoc analysis, we examined the outpatient visits to a radiation-oncologist or a surgeon over time to understand whether these mirrored changes in treatment patterns and whether there may be referral bias driving the observed changes. We examined the proportion of all patients in the cohort who were evaluated by a surgeon or radiation oncologist, or both over time. We also evaluated consultations by treatment received (Supplemental Table 1). Surgical consultations decreased from 83% in 2006 to 71% in 2015 (Trend $P < .01$) and increased from 34% to 56% for radiation oncology (Trend $P < .01$). Proportion of patients who had pretreatment consultations with both types of providers increased from 28% to 35%, but this was not statistically significant. Similarly, proportion of patients who had consultation with at least 1 of the 2 types of providers

SUPPLEMENTAL FIGURE 2
Unadjusted Trends in Treatment Modality for Stage I and II NSCLC, 2006–2015. P-value Denotes Significance Testing for Trend

This appendix is available in its entirety in the online edition of the NCMJ.

SUPPLEMENTAL TABLE 1
Diagnosis and Procedure Codes Used to Define Treatment Variables

This appendix is available in its entirety in the online edition of the NCMJ.

TABLE 4.
Comparison of Patient and Area Level Variables in Rural Areas of Low, Medium, and High Surgery Rates

Level of Measurement	Characteristic	County Tertile for Surgery Total (N = 1572)	1 (n = 492)	2 (n = 636)	3 (n = 444)	*P*-Value
Patient Level						
N = 1572 Rural Patients	**Age Group**					
	18–64	263 (17)	90 (18)	102 (16)	71 (16)	.886
	65–69	325 (21)	99 (20)	139 (22)	87 (20)	
	70–74	381 (24)	119 (24)	153 (24)	109 (25)	
	75–79	327 (21)	105 (21)	132 (21)	90 (20)	
	80+	276 (18)	79 (16)	110 (17)	87 (20)	
	Gender					
	Male	805 (51)	260 (53)	310 (49)	235 (53)	.272
	Female	767 (49)	232 (47)	326 (51)	209 (47)	
	Race					
	White	1329 (85)	423 (86)	525 (83)	381 (86)	.196
	Non-White	243 (15)	69 (14)	111 (17)	63 (14)	
	Elixhauser Comorbidity, Mean (SD)	5.12 (6.41)	5.39 (6.66)	5.01 (6.34)	5.0 (6.22)	0.535
	Travel Distance, Mean (SD)	24.88 (16.83)	30.32 (20.06)	23.77 (12.03)	20.46 (14.92)	< .0001
Area Level						
N = 54 Rural Counties	**Surgeon density**					
	Low	24 (44)	7 (39)	10 (56)	7 (39)	.29
	High	30 (56)	11 (61)	8 (44)	11 (61)	
	Rad-Onc Density					
	Low	39 (72)	12 (67)	13 (72)	14 (78)	.004
	High	15 (28)	6 (33)	5 (28)	4 (22)	
	COC Hospital					
	None	43 (80)	15 (83)	14 (78)	14 (78)	.61
	At least 1	11 (20)	3 (17)	4 (22)	4 (22)	
	High Poverty					
	< 20%	21 (39)	7 (39)	7 (39)	7 (39)	.54
	> 20%	33 (61)	11 (61)	11 (61)	11 (61)	
	Low Education					
	< 20%	29 (54)	10 (56)	9 (50)	10 (56)	.47
	> 20%	25 (46)	8 (44)	9 (50)	8 (44)	

increased from 88% to 93%, but this was not statistically significant. Among patients who did not receive treatment, only 48% had a consultation with either a radiation oncologist or a surgeon, compared to 99% who were treated. Only 11% of patients who did not receive treatment saw both types of providers. Results were similar when stratified by patient rurality. Logistic regression models were performed for the primary outcomes of pretreatment consultation with a surgeon, radiation oncologist, at least 1 provider (i.e., saw a surgeon or radiation oncologist), and both (i.e., saw a surgeon and radiation oncologist), with study year as the primary variable (analyzed as a continuous variable) with adjustment for age, race, sex, insurance, and weighted Elixhauser comorbidity index. Separate models were performed for each outcome. After adjustment, increasing study year was associated with increased adjusted odds of radiation oncologist evaluation (per year OR, 1.07; 95% CI, 1.05, 1.09) and decreased adjusted odds of surgeon evaluation (per year OR, 0.90; 95% CI, 0.88-0.92). There was no association of study year with odds of being seen by at least 1 clinical specialty, nor being seen by both clinical specialties (Supplemental Table 2).

SUPPLEMENTAL TABLE 2
Post-Hoc Analysis Evaluating Proportion of Patients with Stage I NSCLC in North Carolina Receiving Surgical Consultation, 2006–2015

This appendix is available in its entirety in the online edition of the NCMJ.

Discussion

In this study of insured patients with early-stage NSCLC in North Carolina, both rural and urban patients were less likely to undergo surgical therapy over time and more likely to undergo radiation, but there were no demonstrated disparities in treatment between rural and urban patients. Among rural areas, counties with high prevalence of treatment had better geographic access compared to counties with low prevalence of treatment. Finally, nearly 1 in 5 patients underwent no therapy over the study period, and only half of these patients even received consultation with a surgeon or radiation oncologist.

The results of prior studies that examined rural-urban dif-

TABLE 5.
Comparison of Patient and Area Level Variables in Rural Areas of Low, Medium, and High Treatment (Surgery or Radiation) Rates

Level of Measurement	Characteristic		County Tertile for Surgery			
		Total (N = 1572)	1 (n = 393)	2 (n = 595)	3 (n = 584)	*P*-Value
Person Level						
N = 1572 Rural Patients	**Age Group**					
	18–64	263 (17)	68 (17)	106 (18)	89 (15)	.610
	65–69	325 (21)	87 (22)	128 (22)	110 (19)	
	70–74	381 (24)	85 (22)	142 (24)	154 (26)	
	75–79	327 (21)	81 (21)	116 (19)	130 (22)	
	80+	276 (18)	72 (18)	103 (17)	101 (17)	
	Gender					
	Male	805 (51)	214 (54)	302 (51)	289 (49)	.302
	Female	767 (49)	179 (46)	293 (49)	295 (51)	
	Race					
	White	1329 (85)	349 (89)	475 (80)	505 (86)	< .001
	Non-White	243 (15)	44 (11)	120 (20)	79 (14)	
	Elixhauser Comorbidity (mean, st dev.)	5.12 (6.41)	5.51 (6.92)	5.22 (6.25)	4.77 (6.19)	.1831
	Travel Distance (mean, st dev.)	24.88 (16.83)	33.32 (22.57)	24.09 (13.69)	20.01 (12.56)	< .0001
Area-Level						
N = 54 counties	**Surgeon Density**					
	Low	24 (44)	8 (44)	9 (50)	7 (39)	.24
	High	30 (56)	10 (56)	9 (50)	11 (61)	
	Radon Density					
	Low	39 (72)	14 (78)	11 (61)	14 (78)	.56
	High	15 (28)	4 (22)	7 (39)	4 (22)	
	COC Hospital					
	0	43 (80)	17 (94)	13 (72)	13 (72)	< .001
	At Least 1	11 (20)	1 (6)	5 (28)	5 (28)	
	High Poverty					
	< 20%	21 (39)	9 (50)	5 (28)	7 (39)	.44
	> 20%	33 (61)	9 (50)	13 (72)	11 (61)	
	Low Education					
	< 20%	29 (54)	12 (67)	8 (44)	9 (50)	.06
	> 20%	25 (46)	6 (33)	10 (56)	9 (50)	

ferences in the likelihood of surgical treatment for lung cancer are mixed. Most have shown lower likelihood of surgical care for early-stage lung cancer among patients from rural areas [3, 6, 7, 12]. Others have shown this is mediated by worse socioeconomic deprivation in rural areas [28]. In contrast, recent data by Sineshaw and colleagues demonstrated that county-level receipt of surgery was not significantly different among rural and urban areas after adjustment for other factors [13]. Our findings are consistent with this study, but may differ from the majority of the previous literature because we limited to an insured population in order to capture claims-based information. This suggests that after adjustment for insurance and other personal and contextual factors, rural and urban early-stage NSCLC patients in North Carolina have equivalent likelihood of receiving treatment. However, rural patients in North Carolina are more likely to be uninsured than urban patients [29]. Thus, this study may underestimate the rural-urban differences in treatment, as the uninsured could be less likely than insured patients to receive treatment.

Radiation is typically reserved for patients with poor pulmonary function and/or functional status who cannot tolerate lung resections [14]. In this study, increased utilization of radiation over time was independent of age and comorbidities for both rural and urban patients. Due to lack of pulmonary function data and other factors, we cannot determine whether these patients had other contraindications to surgery; however, we would expect that weighted comorbidity score and age would correlate with surgical candidacy. Other recent studies among patients with early-stage NSCLC demonstrate similar findings [21, 30].

In a select subset of patients who cannot tolerate lobectomy but may be candidates for more limited resection, the American Society for Radiation Oncology recommends that SBRT be considered as an alternative [31]. As radiation use increased while rates of surgical resection decreased over time in this study cohort, we considered whether this could have represented transition from sublobar resections to SBRT for patients who are not candidates for lobectomy. However, the proportion of patients undergoing sublobar resection was constant over time despite increasing use of radiation, suggesting this was not the case. Claims data provide only a limited view of this question, however, and it is difficult to infer what a patient today would have done earlier in the study period, particularly when both radiation and surgical techniques have improved over this time frame (e.g., improvements in SBRT and minimally invasive surgery). Another possibility is that SBRT allows access to radiation treatment for patients who would have otherwise undergone no treatment, as has been noted previously [32]. SBRT is accomplished in a shorter time period (3–5 treatments over 1–2 weeks) than traditional external beam radiotherapy (30–35 treatments over 6–7 weeks), with similar survival and improved local control, so it may be preferred for some patients over invasive surgery [33–36]. However, in this study, the proportion of patients receiving no treatment did not change over time, arguing against this as the etiology of the increasing use of SBRT.

Declining rates of surgery for early-stage NSCLC in North Carolina may be due to a lack of surgical consultation. This finding was consistent with data from other tumor types that show disparities in surgical evaluation by age, race, and comorbidities [37]. Evaluation by a specialist cancer provider, ideally a multidisciplinary team, increases the likelihood of undergoing treatment [37, 38]. Ultimately, a surgeon experienced in lung cancer care is the only one who can determine whether a patient is a candidate for surgical resection, thus surgical evaluation is an important component of multidisciplinary care [14]. On the other hand, although radiation oncology consultations increased, they were still less common than surgeon evaluation. Further research is needed to understand the drivers behind these trends, but we hypothesize that changing referral patterns from community providers, fragmented care, and/or a shift in patient preferences over time to radiation versus surgery may all contribute [34]. Additionally, multidisciplinary tumor boards are critical to multidisciplinary care, and a patient's individual case may still be evaluated by a surgeon or radiation oncologist as part of this. Thus, even though surgical referrals were declining, it is possible surgeons were still consulted through tumor boards or other informal conversations.

Maybe the most important finding from this study is that nearly 1 in 5 insured patients do not undergo treatment at all for potentially curable lung cancer, and this remained unchanged over time. Those with Medicaid insurance and those who were underrepresented persons of color were less likely to undergo treatment, consistent with prior studies [10, 39–41]. While many studies consider access to surgical care or radiation separately in early-stage NSCLC, relatively few studies have focused on access to any treatment at all [12, 13, 40]. In North Carolina, the proportion of patients undergoing no treatment is slightly higher than reported in earlier studies using the National Cancer Institute SEER registry, which does not include the North Carolina State Cancer Registry [7, 42]. In contrast, an analysis by Nicoli and colleagues noted a significantly higher proportion (50.7%) of patients undergoing no treatment for Stage I NSCLC using the National Cancer Database, but their definition was narrower and only included guideline-concordant management with lobectomy or SBRT [3]. Our study adds to this literature by including an all-payer claims data source, which may be more accurate for identifying treatments, specifically radiotherapy for lung cancer [43]. Additionally, this study demonstrated that roughly half of patients who do not receive therapy never even had a consultation with a surgeon or a radiation oncologist. Thus, there is a process and/or referral gap that should be further studied to improve rates of treatment for early-stage NSCLC.

Finally, rural areas with a high prevalence of care compared to those with lower prevalence had overall better measures of geographic access, such as shorter travel distance to surgeon and presence of a CoC hospital in the county. Travel distance is a known barrier to many aspects of cancer care for rural patients, but there are limited data on travel distance as a barrier to receipt of surgical care specifically for the US health care system [44, 45]. These findings in our rural-only analysis are important because they indicate that geographic access may explain variations in care *between* rural areas, suggesting some rural areas will be more sensitive to interventions to improve geographic access to care than others. That portion of the analysis was exploratory, however, and should be considered hypothesis generating. Further work in our group aims to understand how travel distance impacts access to surgical treatment in rural patients with early-stage NSCLC.

This study has several additional important limitations. First, these data are from a single state, which may limit generalizability to the broader US population. However, North Carolina is a diverse state with a large rural population and has a comparable but slightly higher lung cancer incidence compared to the broader United States (67.7 compared to 58.3 cases per 100,000, respectively) [46–48]. There were also limitations in sample size, especially at the county level and among non-White patients. Similarly, the model results were adjusted for multiple comparisons using the Bonferroni adjustment, which adjusts for Type I error but can increase the likelihood of Type II error [49]. Inherent to all large database analyses, we cannot know the patient and provider interaction that led to the ultimate treatment decision.

Conclusion

In an insured population with early-stage NSCLC in North Carolina, there were no differences between rural and urban patients with regard to treatment patterns for early-stage lung cancer. Over time, both rural and urban patients have become less likely to undergo surgery but more likely to undergo radiation, which may be due in part to changes in referral patterns and improvements in radiation technology. The proportion of patients who receive no therapy has not changed over time, and improved rates of specialist consultation is a potentially actionable target for improving access to treatment for early-stage NSCLC in North Carolina. NCMJ

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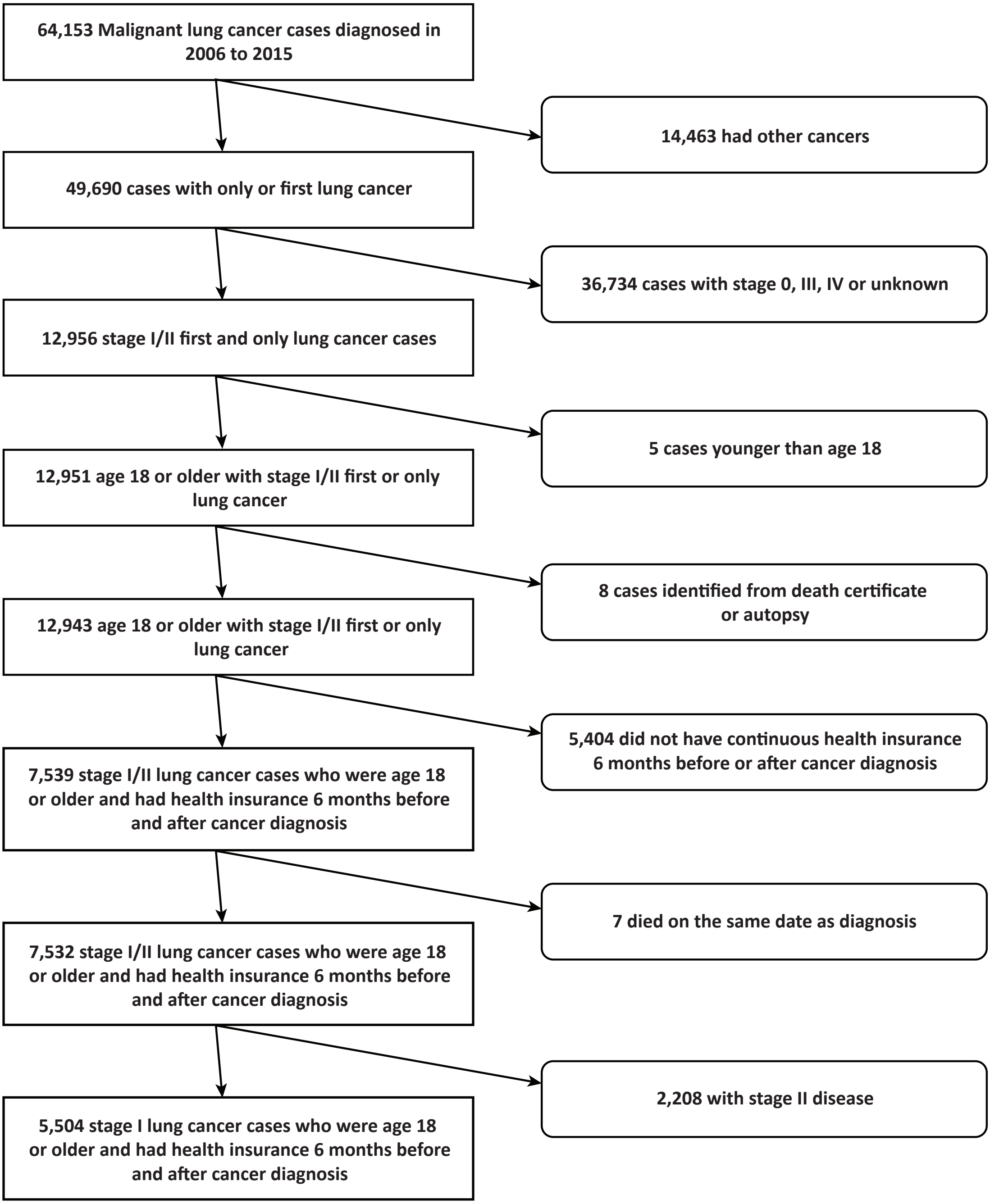
SUPPLEMENTAL FIGURE 1.
Cohort Derivation for Study Sample



SUPPLEMENTAL FIGURE 2.
Unadjusted Trends in Treatment Modality for Stage I and II NSCLC, 2006–2015. *P*-value Denotes Significance Testing for Trend