Pathologic upstaging and survival outcomes for patients undergoing segmentectomy versus lobectomy in clinical stage T1cN0M0 non–small cell lung cancer

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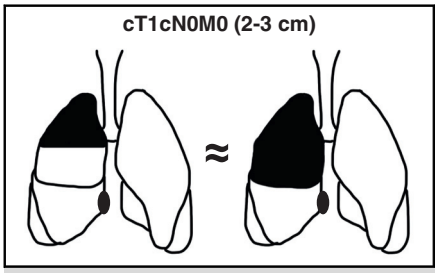
ABSTRACT

Objectives: To assess the impact of the extent of surgical resection on overall survival in patients with clinical T1cN0M0 (cT1cN0M0) non–small cell lung cancer (NSCLC), with and without pathologic nodal upstaging (pN1+).

Methods: The National Cancer Database (NCDB) was queried to identify patients with cT1cN0M0 NSCLC who underwent lobectomy or segmentectomy without receiving neoadjuvant therapy between 2010 and 2021. Bivariate analyses were performed to compare demographic and clinical characteristics across surgical groups. Propensity score matching was used to compare outcomes of segmentectomy versus lobectomy. Cox proportional hazard models and Kaplan-Meier survival estimates were used to assess the association of overall survival on the interaction between extent of resection and pathologic nodal upstaging.

Results: A total of 22,945 patients were analyzed, including 21,875 (95.3%) who underwent lobectomy and 1070 (4.7%) who underwent segmentectomy. Pathologic nodal upstaging to pN1+ occurred in 14.5% of lobectomy cases and in 6.6% of segmentectomy cases. Propensity score–matched analysis revealed that patients undergoing segmentectomy had comparable overall survival to those undergoing lobectomy (hazard ratio [HR], 1.00; 95% confidence interval [CI], 0.86-1.16), and those undergoing segmentectomy with pN1+ had comparable overall survival to those undergoing lobectomy with pN1+ (HR, 1.04; 95% CI, 0.65-1.66).

Conclusions: In patients with cT1cN0M0 NSCLC, overall survival outcomes are similar between segmentectomy recipients and lobectomy recipients, including those incidentally found to have pN1+, suggesting a potential role of lobe-preserving approaches. Additionally, completion lobectomy may not offer a survival benefit in cT1cN0M0 patients incidentally discovered to have pathologic N1 nodes. (JTCVS Open 2025;24:394-408)



clinical T1cN0M0.

CENTRAL MESSAGE

Among patients with clinical T1cN0M0 non–small cell lung cancer with pathologic N1 involvement, survival outcomes are similar in those undergoing lobectomy and those undergoing segmentectomy.

PERSPECTIVE

Patients with clinical T1cN0M0 non–small cell lung cancer experience similar overall survival following segmentectomy and following lobectomy. Additionally, for those with unexpected pathologic nodal upstaging, overall survival is comparable in segmentectomy recipients and lobectomy recipients.

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Abbreviations and Acronyms

AJCC	= American Joint Committee on Cancer
CoC	= Commission on Cancer
CT	= computed tomography
cT1cN0M0	= clinical T1cN0M0
HR	= hazard ratio
ICD-O-3	= International Classification of Disease for Oncology, 3rd Edition
IQR	= interquartile range
NCDB	= National Cancer Database
NSCLC	= non–small cell lung cancer
PUF	= Participant User File

Lung cancer is the third most common cancer and the leading cause of cancer-related mortality in the United States.[1] With the use of low-dose chest tomography (CT) screening associated with reduced mortality from lung cancer,[2,3] the incidence of early-stage lung cancer is increasing.[4] Management of early-stage lung cancer is centered around surgical resection with mediastinal lymph node sampling, with an expected rise in the annual number of surgical resections done for lung cancer.[5]

For patients diagnosed with clinical T1N0M0 (cT1N0M0) non–small cell lung cancer (NSCLC), lobectomy had been the standard of care[6] until 2 multicenter randomized controlled trials demonstrated that sublobar resection is noninferior to lobar resection in patients diagnosed with NSCLC with tumor size $\leq$2 cm.[7,8] Although these trials included only well-selected patients with minimal medical comorbidities and peripherally located disease, the role for sublobar resection in patients with tumor size >2 cm is a question of interest, especially for patients with compromised pulmonary function, in whom maximal preservation of lung parenchyma is desired.[9,10]

Additionally, the question of whether locoregional recurrence can be mitigated through a greater parenchymal resection following a segmentectomy that reveals pathologic nodal upstaging is unknown. Completion lobectomy is a potential option proposed for managing patients with occult micrometastatic nodal disease found intraoperatively in patients with cT1N0M0 who may have sufficient pulmonary function,[11,12] given a concern for locoregional recurrence. However, whether locoregional recurrence or pathologic nodal upstaging plays a greater role in overall survival prognostication is unclear. Therefore, the objectives of this study were to (1) compare pathologic staging for patients with cT1cN0M0 NSCLC undergoing lobectomy versus those undergoing segmentectomy and (2) compare overall survival outcomes for patients with cT1cN0M0 NSCLC undergoing lobectomy versus those undergoing segmentectomy with and without pathologic nodal upstaging (pN1+). We hypothesized that rates of pathologic nodal upstaging outcomes may be lower in segmentectomy recipients compared to lobectomy recipients.[13] Additionally, we hypothesized that overall survival may be better in patients undergoing lobectomy compared to those undergoing segmentectomy regardless of the presence of pathologic nodal upstaging.[14]

METHODS

Study Design/Data Source

This study is a retrospective observational cohort analysis of patients diagnosed with cT1cN0M0 NSCLC from the National Cancer Database (NCDB) NSCLC Participant User File (PUF) for 2010 to 2021. A joint project of the American Cancer Society and the Commission on Cancer (CoC) of the American College of Surgeons, the NCDB is a nationwide facility-based, comprehensive clinical surveillance resource oncology data set that currently captures 72% of all newly diagnosed malignancies in the United States annually.[15,16] The American College of Surgeons has executed a Business Associate Agreement that includes a data use agreement with each of its CoC-accredited hospitals. The data used in this study were derived from a deidentified NCDB file. The American College of Surgeons and the CoC have not verified and are not responsible for the analytic or statistical methodology used, or for the conclusions drawn from these data by the investigators.

Patients were categorized into those who underwent wedge resection, segmentectomy, or lobectomy, based on site-specific surgery codes in the NCDB NSCLC PUF (see Appendix E1 for codes). The Northwestern University Institutional Review Board deemed this study exempt from review, as all data used were deidentified.

Participants

Inclusion criteria were a confirmed histologic diagnosis of NSCLC, treatment received at a reporting facility, presence of only a single primary malignancy, cT1cN0M0 disease, surgical resection with an operative extent of segmentectomy or lobectomy, and the surgical procedure as the definitive operation. Clinical staging criteria were based on American Joint Committee on Cancer (AJCC) 8th edition standards. From 2018 to 2021, clinical T1c was included, and for patients diagnosed between 2010 and 2017 when AJCC 7th edition standards were used, clinical T1b criteria were used, defined as tumor size of 2 to 3 cm, which matches the AJCC 8th edition definition of clinical T1c disease.[17] Patients were excluded who had a neuroendocrine or carcinoid histology or unknown/missing histology; whose operative resection was wedge resection, extended lobectomy, bilobectomy, or pneumonectomy; had missing data on operative extent; had missing data on number of lymph nodes resected; underwent neoadjuvant systemic therapy, radiation therapy, or had an unknown sequence of systemic/radiation therapy and surgical treatment strategies; or had missing survival data (Figure 1). The rationale for excluding patients undergoing wedge resection from an analysis of sublobar versus lobar resection is related to intractable selection biases present in this retrospective data set.

Patient Demographic and Clinical Characteristics

Independent demographic variables included patient age (categorical), sex, race/ethnicity (categorical: non-Hispanic White, non-Hispanic Black, Hispanic, Asian/American Indian/Pacific Islander/Native American, and unknown), Charlson-Deyo Comorbidity Index (categorical: 0, 1, 2-3), insurance status (categorical: uninsured, private, Medicaid, Medicare, other government), education quartile (categorical: predefined in the NCDB), income quartile (categorical: predefined in the NCDB), treatment area (categorical: metropolitan, urban, rural), facility type (categorical: academic,

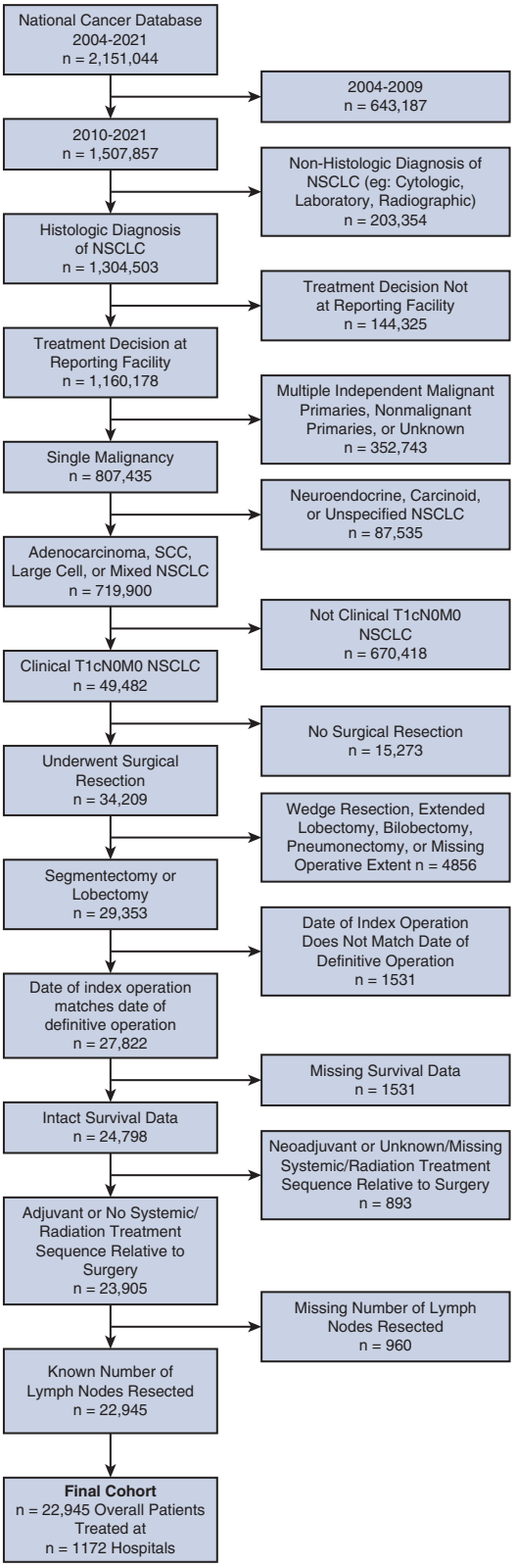

FIGURE 1. Flow diagram with inclusion and exclusion criteria. *NSCLC*, Non–small cell lung cancer; *SCC*, squamous cell carcinoma.

community, comprehensive community, integrated, predefined in the NCDB), and facility location (categorical: predefined census tract regions in the NCDB). Independent clinical variables included laterality (binary), histology (categorical: by International Classification of Disease for Oncology, 3rd edition [ICD-O-3] codes; see Appendix E1 for codes), lymphovascular invasion (binary), hospital-level annual surgical volume (categorical: derived from number of pulmonary resections performed at a hospital over the duration of the study period [2010-2021] divided by 12, which was further categorized by quartile), operative approach (categorical: predefined in the NCDB, documented cases requiring conversion to open categorized by initial intended approach), adjuvant chemotherapy (binary: defined by either treatment sequence of systemic therapy after surgery with days after diagnosis of chemotherapy initiation being greater than days after diagnosis of definitive surgical resection or treatment sequence of systemic therapy before and after surgery), adjuvant radiation therapy (binary: defined by either treatment sequence of radiation therapy after surgery with days after diagnosis of radiation therapy initiation being greater than days after diagnosis of definitive surgical resection or treatment sequence of radiation therapy before and after surgery).

Outcomes

The primary outcome measure was survival, as defined by a time-to-event variable using "Last Vital Status" as the binary outcome variable and "Last Contact, Months from Diagnosis" as the time variable. Secondary outcome measures included margin status (binary variable, with microscopic or macroscopic residual tumor as the outcome measure), pathologic T stage relative to pathologic T1c (categorical), pathologic N stage (categorical and binary), pathologic M stage (binary), quartiles of number of lymph nodes resected (categorical), and number of lymph nodes positive for malignancy using number cutoffs by Fukui and colleagues[18] (categorical). For pathologic T stage relative to pathologic T1c, patients were categorized as being downstaged, accurately staged, or upstaged. Patients were defined as downstaged if they had pT1b or less disease, accurately staged if they had pT1c disease, and upstaged if they had pT2 or greater disease. For the binary pathologic N stage relative to pathologic N0 variable, patients were categorized as accurately staged if they had pN0 disease and upstaged if they had pN1 or greater disease. The binary pathologic N stage variable was used as an interaction term to compare patients with and those without pathologic nodal upstaging, and the categorical pathologic N stage variable was used as a covariate in adjusted analyses. In the categorical pathologic N stage variable, pathologic N2 and pathologic N3 stage were combined into one code because of the small number of observations for pathologic N3 disease. All pathologic staging criteria were based on AJCC 8th edition standards. If a patient was diagnosed in 2010 to 2017, when AJCC 7th edition standards were used to define their clinical or pathologic stage, their respective T and N stages were matched to meet AJCC 8th edition criteria.[17]

Statistical Analysis

Patient demographic characteristics, clinical characteristics, and unadjusted outcome measures were described with summary statistics and compared across segmentectomy and lobectomy cohorts with the bivariate *t* test for continuous parametric variables, Wilcoxon rank-sum test for continuous nonparametric variables, and bivariate χ^2 test for categorical variables. Unadjusted and multivariable Poisson regression models with robust variance and clustering by a deidentified facility key were estimated to evaluate the association between pathologic upstaging and margin status outcome measures and operative extent cohorts (segmentectomy and lobectomy), reported as relative risk.[19] Covariates used in the multivariable Poisson regression models with robust variance and clustering by a deidentified facility key included age (continuous), sex (binary), race

(categorical), Charlson-Deyo score (categorical), insurance status (categorical), education quartile (categorical), income quartile (categorical), treatment area (categorical), annual hospital-level surgical volume quartile (categorical), facility type (categorical), facility location (categorical), laterality (binary), histology (categorical), and operative approach (categorical).

Propensity score matching was used to create cohorts comparing patients undergoing segmentectomy and those undergoing lobectomy. In the segmentectomy-lobectomy matched cohort, 1:1 nearest-neighbor matching without replacement using a caliper width of 0.2 times the logit standard deviation (0.011) was used.[20,21] Absolute mean standardized differences and bivariate analyses between unmatched and matched cohorts were used to assess covariate balance. Then Cox proportional hazard models with clustering by a deidentified facility key were estimated to evaluate the association of survival with the interaction of operative extent and pathologic N upstaging (binary) for the matched segmentectomy-lobectomy cohort. Covariates used in the propensity score–matched model included age (categorical), sex (binary), race (categorical), Charlson-Deyo score (categorical), insurance status (categorical), education quartile (categorical), income quartile (categorical), treatment area (categorical), annual hospital-level surgical volume quartile (categorical), facility type (categorical), facility location (categorical), laterality (binary), histology (categorical), operative approach (categorical), pathologic tumor stage (categorical), pathologic nodal stage (categorical), quartiles of number of lymph nodes resected (categorical), number of positive malignant lymph nodes (categorical), and receipt of adjuvant chemotherapy (binary).

Kaplan-Meier curves were estimated for the propensity score–matched cohorts to evaluate the association of overall survival on operative extent, as well as the association of overall survival on the interaction of pathologic N upstaging (binary) and operative extent (segmentectomy vs lobectomy), with comparison of survival outcomes by operative extent with a log-rank test comparing segmentectomy versus lobectomy as well as segmentectomy versus lobectomy with and without pathologic nodal upstaging. Log-rank test comparisons comparing segmentectomy versus lobectomy with and without pathologic nodal upstaging included lobectomy with pN0 versus lobectomy with pN1+, segmentectomy with pN0 versus segmentectomy with pN1+, lobectomy with pN0 versus segmentectomy with pN0, and lobectomy with pN1+ versus segmentectomy with pN1+.

Missing data were handled using a missing indicator approach.[22,23] All analyses were performed using Stata version 18.5 (StataCorp).

RESULTS

Patient Demographic and Clinical Characteristics

A total of 22,945 patients were included for analysis after accounting for inclusion and exclusion criteria (Figure 1). The cohort comprised 21,875 patients (95.3%) who underwent lobectomy and 1070 (4.7%) who underwent segmentectomy. Patients who underwent segmentectomy were older compared to those who underwent lobectomy (mean, 69.9 ± 8.7 years vs 67.6 ± 9.1 years; $P < .001$). Higher proportions of patients who underwent lobectomy had a Charlson-Deyo comorbidity score of 0 (52.8% vs 46.4%; $P < .001$) and had private insurance (28.2% vs 22.9%; $P < .001$). Patients in the segmentectomy group were more often treated at an academic facility (42.7% vs 35.1%; $P < .001$) and more often treated at a hospital in the highest quartile of annual surgical volume (27.5% vs 24.5%; $P < .001$). The rate of receipt of adjuvant chemotherapy was lower in the segmentectomy group (9.6% vs 16.7%; $P < .001$) (Table 1).

Unadjusted Outcomes by Operative Extent

The incidences of 30-day readmission and 90-day mortality were similar in the lobectomy and segmentectomy groups. The rate of 30-day mortality was slightly lower in the segmentectomy group (1.1% vs 1.7%; $P = .038$). Regarding oncologic outcomes, patients undergoing segmentectomy had a similar rates of microscopic or macroscopic margin involvement were similar in the segmentectomy and lobectomy groups (2.5% vs 2.2%; $P = .108$). The incidence of pathologic T stage of T1b or less was significantly higher in the segmentectomy group (23.6% vs 14.0%; $P < .001$). Patients undergoing lobectomy had higher rates of pathologic N1 and N2/N3 upstaging compared to those undergoing segmentectomy (8.9% and 5.5%, respectively vs 3.9% and 2.7%, respectively; $P < .001$). Patients undergoing segmentectomy more often had fewer than 5 lymph nodes resected (38.0% vs 15.1%; $P < .001$). Patients undergoing lobectomy had a greater number of cases with at least 1 lymph node positive for malignancy resected (14.5% vs 6.6%; $P < .001$). Additionally, the proportion of lymph nodes not sampled was higher in the segmentectomy group (8.1% vs 1.3%; $P < .001$), as indicated by the missingness of number of positive lymph nodes. There was no difference in the rate of distant metastatic disease between the segmentectomy and lobectomy groups (0.5% vs 0.4%; $P = .650$) (Table 2).

Pathologic Upstaging Outcomes

In multivariable Poisson regression model estimates with robust variance, after adjusting for covariates, the segmentectomy group had a 55% lower relative risk of pathologic nodal upstaging (adjusted relative risk, 0.45; 95% confidence interval, 0.33-0.61). After adjusting for covariates, compared to patients undergoing lobectomy, patients undergoing segmentectomy did not have a significantly different relative risk of pathologic T upstaging, systemic metastatic disease, or a positive margin (Table 3).

Survival Outcomes

Figure 2 demonstrated survival outcomes for patients in propensity score-matched cohorts of patients undergoing segmentectomy versus lobectomy. A total of 2120 patients were included in the segmentectomy-lobectomy 1:1-matched cohort. The cohort was well matched on age, sex, race, Charlson-Deyo comorbidity score, insurance, education, income, treatment area, facility type, facility location, laterality, histology, annual hospital-level surgical volume, operative approach, number of lymph nodes

TABLE 1. Demographic and clinical characteristics of patients undergoing pulmonary resection for clinical T1cN0M0 NSCLC, by treatment type

Characteristic	Overall	Segmentectomy	Lobectomy	*P* value
Number of patients (%)	22,945 (100.0)	1070 (4.7)	21,875 (95.3)	
Age, y, mean (SD)	67.7 (9.1)	69.9 (8.7)	67.6 (9.1)	<.001*
Age quartile				
<62 y	5580 (24.3)	174 (16.3)	5406 (24.7)	<.001†
62-69 y	6014 (26.2)	269 (25.1)	5745 (26.3)	
69-<75 y	5781 (25.2)	290 (27.1)	5491 (25.1)	
≥75 y	5570 (24.3)	337 (31.5)	5233 (23.9)	
Sex				
Male	10,027 (43.7)	473 (44.2)	9554 (43.7)	.733†
Female	12,918 (56.3)	597 (55.8)	12,321 (56.3)	
Race				
Non-Hispanic White	18,549 (80.8)	888 (83.0)	17,661 (80.7)	.329†
Non-Hispanic Black	1965 (8.6)	76 (7.1)	1889 (8.6)	
Hispanic	840 (3.7)	40 (3.7)	800 (3.7)	
Asian	890 (3.9)	35 (3.3)	855 (3.9)	
Other	701 (3.1)	31 (2.9)	670 (3.1)	
Charlson-Deyo comorbidity score				
0	12,044 (52.5)	497 (46.4)	11,547 (52.8)	<.001†
1	6816 (29.7)	342 (32.0)	6474 (29.6)	
2-3	4085 (17.8)	231 (21.6)	3854 (17.6)	
Insurance status				
Uninsured	330 (1.4)	7 (0.7)	323 (1.5)	<.001†
Private	6422 (28.0)	245 (22.9)	6177 (28.2)	
Medicaid	1287 (5.6)	56 (5.2)	1231 (5.6)	
Medicare	14,349 (62.5)	746 (69.7)	13,603 (62.2)	
Other government	359 (1.6)	8 (0.7)	351 (1.6)	
Missing	198 (0.9)	8 (0.7)	190 (0.9)	
Education quartile, n (%)				
15.3%+, no high school degree	3912 (17.0)	146 (13.6)	3766 (17.2)	<.001†
9.1-15.2%, no high school degree	5963 (26.0)	245 (22.9)	5718 (26.1)	
5.0-9.0%, no high school degree	5678 (24.7)	252 (23.6)	5426 (24.8)	
<5.0%, no high school degree	4122 (18.0)	229 (21.4)	3893 (17.8)	
Missing	3270 (14.3)	198 (18.5)	3072 (14.0)	
Income quartile, n (%)				
<$46,277	3390 (14.8)	114 (10.7)	3276 (15.0)	<.001†
$46,277-$57,856	4602 (20.1)	183 (17.1)	4419 (20.2)	
$57,857-$74,062	4809 (21.0)	206 (19.3)	4603 (21.0)	
$74,063+	6811 (29.7)	365 (34.1)	6446 (29.5)	
Missing	3333 (14.5)	202 (18.9)	3131 (14.3)	
Treatment area, n (%)				
Metro	18,599 (81.1)	887 (82.9)	17,712 (81.0)	.002†
Urban	3266 (14.2)	121 (11.3)	3145 (14.4)	
Rural	389 (1.7)	15 (1.4)	374 (1.7)	
Missing	691 (3.0)	47 (4.4)	644 (2.9)	
Facility type, n (%)				
Academic	8125 (35.4)	457 (42.7)	7668 (35.1)	<.001†
Community	962 (4.2)	64 (6.0)	898 (4.1)	
Comprehensive community	8840 (38.5)	328 (30.7)	8512 (38.9)	
Integrated	4943 (21.5)	220 (20.6)	4723 (21.6)	
Missing	75 (0.3)	1 (0.1)	74 (0.3)	

(Continued)

TABLE 1. Continued

Characteristic	Overall	Segmentectomy	Lobectomy	*P* value
Facility location, n (%)				
Northeast	4771 (20.8)	355 (33.2)	4416 (20.2)	<.001†
Midwest	5977 (26.0)	212 (19.8)	5765 (26.4)	
West	2987 (13.0)	178 (16.6)	2809 (12.8)	
South	9135 (39.8)	324 (30.3)	8811 (40.3)	
Missing	75 (0.3)	1 (0.1)	74 (0.3)	
Laterality, n (%)				
Right	13,591 (59.2)	483 (45.1)	13,108 (59.9)	<.001†
Left	9315 (40.6)	585 (54.7)	8730 (39.9)	
Missing	39 (0.2)	2 (0.2)	37 (0.2)	
Histology, n (%)				
Adenocarcinoma	14,791 (64.5)	657 (61.4)	14,134 (64.6)	.025†
Squamous cell carcinoma	4800 (20.9)	223 (20.8)	4577 (20.9)	
Large cell	159 (0.7)	10 (0.9)	149 (0.7)	
Mixed	3195 (13.9)	180 (16.8)	3015 (13.8)	
Lymphovascular invasion, n (%)				
No	17,771 (77.5)	853 (79.7)	16,918 (77.3)	.178†
Yes	3876 (16.9)	165 (15.4)	3711 (17.0)	
Missing	1298 (5.7)	52 (4.9)	1246 (5.7)	
Hospital-level annual surgical volume, n (%)				
Lowest-volume quartile (<5.3)	5531 (24.1)	279 (26.1)	5252 (24.0)	.006†
2nd quartile (5.3-<10.3)	5972 (26.0)	268 (25.0)	5704 (26.1)	
3rd quartile (10.3-<17.2)	5796 (25.3)	229 (21.4)	5567 (25.4)	
Highest-volume quartile (≥17.2)	5646 (24.6)	294 (27.5)	5352 (24.5)	
Operative approach, n (%)				
Robotic	5087 (22.2)	241 (22.5)	4846 (22.2)	<.001†
VATS	7316 (31.9)	446 (41.7)	6870 (31.4)	
Open	9687 (42.2)	352 (32.9)	9335 (42.7)	
Missing	855 (3.7)	31 (2.9)	824 (3.8)	
Adjuvant chemotherapy, n (%)				
No	19,199 (83.7)	967 (90.4)	18,232 (83.3)	<.001†
Yes	3746 (16.3)	103 (9.6)	3643 (16.7)	
Adjuvant radiation therapy, n (%)				
No	21,994 (95.9)	1035 (96.7)	20,959 (95.8)	.142†
Yes	951 (4.1)	35 (3.3)	916 (4.2)	

NSCLC, Non–small cell lung cancer; *SD*, standard deviation; *VATS*, video-assisted thoracoscopic surgery. **P* value calculated by the *t* test. †*P* value calculated by the χ^2 test.

resected, number of positive lymph nodes, pathologic T stage, pathologic N stage, and adjuvant chemotherapy (Tables E1 and E2). The median follow-up was 44.7 months. The 5-year overall survival for patients undergoing lobectomy was 68.4% for the lobectomy group and 67.0% for the segmentectomy group. There was no significant difference in mortality risk between the 2 groups (hazard ratio [HR], 1.00; 95% CI, 0.86-1.16; log-rank $P = .999$) (Tables 4 and 5).

In the segmentectomy-lobectomy propensity score–matched cohort, pathologic nodal upstaging was modeled as an interaction term with operative extent. The cohort included 900 patients undergoing lobectomy with no pathologic nodal upstaging (pN0), 905 patients undergoing segmentectomy with pN0, 81 patients undergoing lobectomy with pathologic nodal upstaging (pN1+), and 69 patients undergoing segmentectomy with pN1+. The 5-year overall survival was 71.2% for patients undergoing lobectomy with pN0, 69.2% for those undergoing segmentectomy with pN0, 46.2% for those undergoing lobectomy with pN1+, and 55.2% for those undergoing segmentectomy with pN1+ (Figure 3). Compared to patients undergoing lobectomy with pN0, patients undergoing lobectomy with pN1 had a 92% higher risk of death (HR, 1.92; 95% CI, 1.31-2.80; log-rank $P < .001$). Patients undergoing lobectomy with pN0 and patients undergoing segmentectomy with pN0 had no significant difference in risk of death (HR, 0.98; 95% CI, 0.82-1.16; log-rank $P = .784$). Compared to

TABLE 2. Unadjusted outcomes of patients undergoing pulmonary resection for clinical T1cN0M0 NSCLC, by treatment type

Outcome	Overall	Segmentectomy	Lobectomy	*P* value
Number of patients (%)	22,945 (100.0)	1070 (4.7)	21,875 (95.3)	
Length of stay, d, median (IQR)	5 (3-7)	4 (2-6)	5 (3-7)	<.001*
30-d readmission, n (%)				
No readmission	21,640 (94.3)	1006 (94.0)	20,634 (94.3)	.413†
30-d readmission	1196 (5.2)	56 (5.2)	1140 (5.2)	
Missing	109 (0.5)	8 (0.7)	101 (0.5)	
30-d mortality, n (%)				
Alive	22,432 (97.8)	1047 (97.9)	21,385 (97.8)	.038†
Dead	385 (1.7)	12 (1.1)	373 (1.7)	
Missing	128 (0.6)	11 (1.0)	117 (0.5)	
90-d mortality, n (%)				
Alive	22,095 (96.3)	1033 (96.5)	21,062 (96.3)	.098†
Dead	654 (2.9)	23 (2.1)	631 (2.9)	
Missing	196 (0.9)	14 (1.3)	182 (0.8)	
Margin status, n (%)				
R0	22,369 (97.5)	1036 (96.8)	21,333 (97.5)	.108†
R1, R2, or margin involved	502 (2.2)	27 (2.5)	475 (2.2)	
Missing	74 (0.3)	7 (0.7)	67 (0.3)	
Relative pathologic T stage, n (%)				
Downstaged (pT1b or less)	3306 (14.4)	253 (23.6)	3053 (14.0)	<.001†
Accurately staged (pT1c)	10,716 (46.7)	442 (41.3)	10,274 (47.0)	
Upstaged (pT2 or greater)	8668 (37.8)	360 (33.6)	8308 (38.0)	
Missing	255 (1.1)	15 (1.4)	240 (1.1)	
Pathologic N stage, n (%)				
pN0	19,354 (84.3)	933 (87.2)	18,421 (84.2)	<.001†
pN1	1995 (8.7)	42 (3.9)	1953 (8.9)	
pN2/pN3	1241 (5.4)	29 (2.7)	1212 (5.5)	
Missing	355 (1.5)	66 (6.2)	289 (1.3)	
Pathologic M stage, n (%)				
pM0	22,857 (99.6)	1065 (99.5)	21,792 (99.6)	.650†
pM1	88 (0.4)	5 (0.5)	83 (0.4)	
Number of lymph nodes resected, median (IQR)	10 (6-15)	6 (3-11)	10 (6-15)	<.001*
Number of lymph nodes resected, quartile, n (%)				
0-<5	3700 (16.1)	407 (38.0)	3293 (15.1)	<.001†
5-<9	5828 (25.4)	271 (25.3)	5557 (25.4)	
9-<14	6233 (27.2)	211 (19.7)	6022 (27.5)	
14-90	7184 (31.3)	181 (16.9)	7003 (32.0)	
Number of positive lymph nodes, n (%)				
0	19,317 (84.2)	913 (85.3)	18,404 (84.1)	<.001†
1-3	2599 (11.3)	62 (5.8)	2537 (11.6)	
4-6	453 (2.0)	5 (0.5)	448 (2.0)	
7+	200 (0.9)	3 (0.3)	197 (0.9)	
Missing	376 (1.6)	87 (8.1)	289 (1.3)	
Time from diagnosis to definitive surgical treatment, d, median (IQR)	36 (16-57)	34 (0-60)	36 (17-57)	.013*

R0 indicates no evidence of microscopic or macroscopic disease on margin of pathology specimen; R1, evidence of microscopic disease on margin of pathology specimen; R2, evidence of macroscopic disease on margin of pathology specimen; *NSCLC*, Non–small cell lung cancer; *IQR*, interquartile range; *T*, tumor; *pT1b*, pathologic T1b stage; *pT1c*, pathologic T1c stage; *pT2*, pathologic T2 stage; *N*, node; *pN0*, pathologic N0 stage; *pN1*, pathologic N1 stage; *pN2*, pathologic N2 stage; *pN3*, pathologic N3 stage; *M*, metastasis; *pM0*, pathologic M0 stage; *pM1*, pathologic M1 stage. **P* values calculated by the Wilcoxon rank-sum test. †*P* values calculated by the χ^2 test.

TABLE 3. Modified multivariable Poisson regression model estimates evaluating the association of staging outcomes and extent of resection for patients with clinical T1cN0M0 undergoing pulmonary resection

Operation	Margin status	Pathologic T upstaging	Pathologic N upstaging	Pathologic M upstaging
Adjusted relative risk (95% CI)				
Lobectomy	Reference	Reference	Reference	Reference
Segmentectomy	1.39 (0.97-2.01)	1.00 (0.91-1.09)	0.45 (0.33-0.61)	1.30 (0.53-3.20)
Unadjusted relative risk (95% CI)				
Lobectomy	Reference	Reference	Reference	Reference
Segmentectomy	1.38 (0.97-1.95)	1.00 (0.92-1.10)	0.45 (0.33-0.62)	1.23 (0.50-3.03)

Covariates adjusted for in models: age (categorical), sex (female as reference), race (white as reference), Charlson-Deyo score (0 as reference), insurance (Medicare as reference), education (lowest quartile as reference), income (lowest quartile as reference), treatment area (metropolitan as reference), annual hospital volume (lowest quartile as reference), facility (academic center as reference), facility location (South as reference), laterality (right side as reference), histology (adenocarcinoma as reference), operative approach (open as reference). T upstaging: defined as a patient having pathologic T2 or greater disease based on the 8th edition of the American Joint Cancer Commission (AJCC) staging system. N upstaging: defined as a patient having pathologic N1 or greater disease. M upstaging: defined as a patient having pathologic M1 disease. *CI*, Confidence interval.

patients undergoing segmentectomy with pN0, patients undergoing segmentectomy with pN1+ had a 105% higher risk of death (HR, 2.05; 95% CI, 1.45-2.90; log-rank $P < .001$). Patients undergoing lobectomy with pN1+ and those undergoing segmentectomy with pN1+ had no significant difference in risk of death (HR, 1.04; 95% CI, 0.65-1.66; log-rank $P = .887$).

DISCUSSION

In this retrospective cohort analysis using NCDB data, patients with cT1cN0M0 NSCLC undergoing segmentectomy had a lower rate and lower relative risk of pathologic nodal upstaging compared to those undergoing lobectomy. Propensity score–matched Cox proportional hazards modeling and Kaplan-Meier estimates indicated similar survival outcomes for patients undergoing segmentectomy and those undergoing lobectomy. When assessing the association of overall survival and the interaction of operative extent and pathologic nodal upstaging, segmentectomy was associated with similar survival outcomes as lobectomy irrespective of pathologic nodal upstaging. These findings support segmentectomy as a possible surgical option for selected patients with cT1cN0M0 NSCLC. Additionally, in patients undergoing segmentectomy found to have occult micrometastatic nodal disease, there might not be a need to consider completion lobectomy and to instead consider adjuvant systemic therapy for control of micrometastatic disease. This concept warrants further prospective investigation, however.

The lower incidence and relative risk of pathologic nodal upstaging in patients undergoing segmentectomy could be due to less rigorous lymphadenectomy, as indicated by a greater degree of missing data on lymph node counts in patients undergoing segmentectomy. Adequate mediastinal lymphadenectomy, defined as resection of at least 10 mediastinal lymph nodes from at least 3 mediastinal stations, had been recommended as criteria for adequate mediastinal lymph node sampling associated with improved survival.[24-26] The NCDB does not specify the exact stations from which lymph nodes are resected, and recent standards from the American College of Surgeons CoC have shifted away from using the number of lymph nodes as a sole metric for adequacy. The limited lymph node dissection in sublobar resections aligns with the literature indicating suboptimal nodal staging in these procedures.[27]

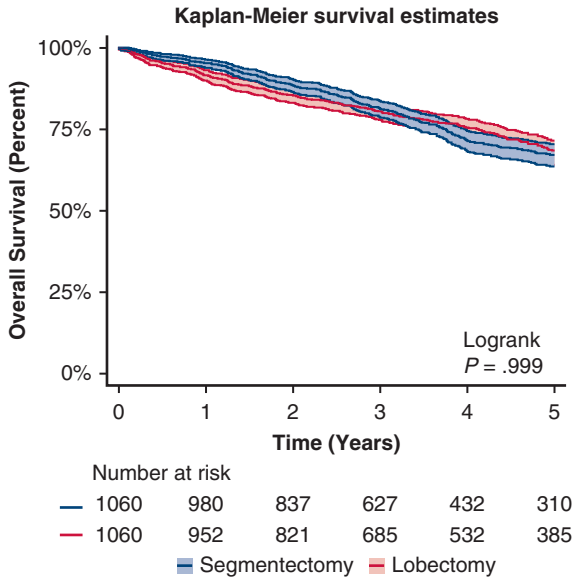

FIGURE 2. Kaplan-Meier survival estimates, propensity score–matched segmentectomy group versus lobectomy group, with 95% confidence interval.

TABLE 4. Propensity score–matched Cox regression and Kaplan-Meier 5-year overall survival estimates, association of survival with operative extent for patients with clinical T1cN0M0 undergoing pulmonary resection

Operative extent	HR (95% CI)	5-y OS, % (95% CI)
Lobectomy	Reference	68.4 (65.1-71.5)
Segmentectomy	1.00 (0.86-1.16)	67.0 (63.5-70.3)

Log-rank, lobectomy versus segmentectomy: $P = .999$. *HR*, Hazard ratio; *OS*, overall survival; *CI*, confidence interval.

TABLE 5. Propensity score–matched Cox regression and Kaplan-Meier 5-year overall survival estimates, association of survival with interaction of operative extent and pathologic N upstaging for patients with clinical T1cN0M0 undergoing pulmonary resection

Pathologic N stage interaction term	Operative extent	HR (95% CI)	HR (95% CI)	5-y OS, % (95% CI)
pN0	Lobectomy	Reference	0.52 (0.36-0.76)	71.2 (67.7-74.5)
	Segmentectomy	0.98 (0.82-1.16)	0.54 (0.25-1.18)	69.2 (65.5-72.7)
pN1+	Lobectomy	1.92 (1.31-2.80)	Reference	46.2 (33.7-57.7)
	Segmentectomy	1.87 (1.19-2.93)	1.04 (0.65-1.66)	55.2 (39.2-68.5)

Log-rank, lobectomy pN0 versus lobectomy pN1+: $P < .001$. Log-rank, lobectomy pN0 versus segmentectomy pN0: $P = .784$. Log-rank, segmentectomy pN0 versus segmentectomy pN1+: $P = .001$. Log-rank, lobectomy pN1+ versus segmentectomy pN1+: $P = .887$. Covariates used in the propensity score–matched segmentectomy versus lobectomy model: age (categorical), sex (female as reference), race (white as reference), Charlson-Deyo score (0 as reference), insurance (Medicare as reference), education (lowest quartile as reference), income (lowest quartile as reference), treatment area (metropolitan as reference), annual hospital volume (lowest quartile as reference), facility (academic center as reference), facility location (South as reference), laterality (right side as reference), histology (adenocarcinoma as reference), operative approach (open as reference), number of lymph nodes resected (lowest quartile as reference), number of positive lymph nodes (0 as reference), pathologic T stage (pT1c as reference), pathologic nodal stage (pN0 as reference), and adjuvant chemotherapy. *HR*, Hazard ratio; *CI*, confidence interval; *OS*, overall survival; *pN0*, pathologic N0; *pN1+*, pathologic N1 or greater.

Our findings also show a lower incidence of pathologic upstaging of T stage in the segmentectomy group compared to the lobectomy group. This finding may reflect overestimation of clinical T stage owing to preoperative selection based on radiographic features, such as ground-glass opacities, which may overestimate tumor size on pathologic evaluation. Conversely, patients undergoing lobectomy may have had tumors with more aggressive characteristics, such as a central location or a larger solid component, not captured by the NCDB, contributing to a selection bias supporting a greater likelihood of higher pathologic T stage in patients undergoing lobectomy, which may bias the lobectomy cohort to having lower overall survival.[28] Comparable rates of systemic metastatic disease and positive surgical margins between segmentectomy and lobectomy suggest that segmentectomy may be performed by high-volume surgeons skilled in the technique, a factor not captured by the NCDB.[29]

Overall, in propensity score–matched analysis, patients undergoing segmentectomy had similar survival outcomes as those undergoing lobectomy. This suggests that for certain patients with cT1cN0M0 NSCLC, the risk of locoregional recurrence may be similar with segmentectomy and lobectomy. These findings need to be considered in light of several nuances, however. First, although there were no observed differences in margin status between patients undergoing segmentectomy and those undergoing lobectomy, achieving such similar survival outcomes depends on

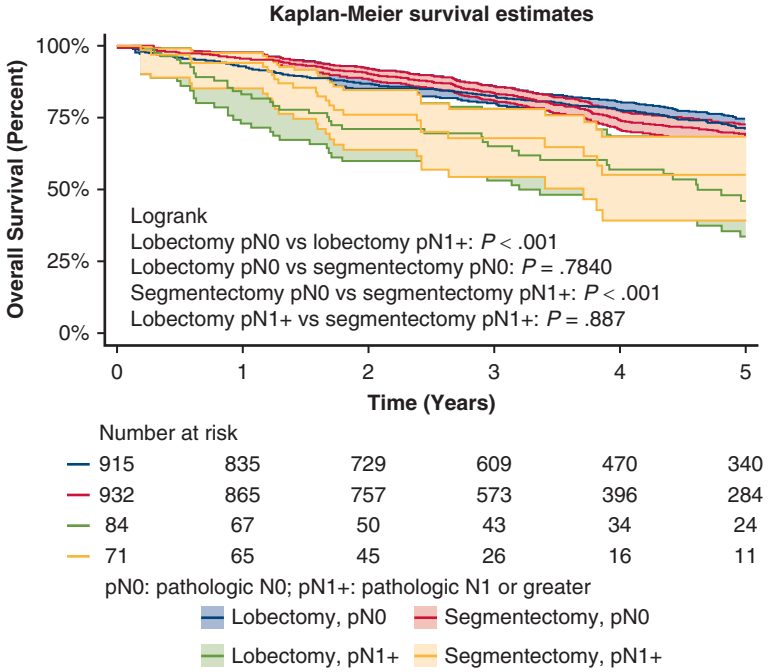

FIGURE 3. Kaplan-Meier survival estimates, propensity score–matched segmentectomy versus lobectomy with and without pathologic nodal upstaging, with 95% confidence interval.

achieving a margin-negative resection with adequate margin width,[30] which may be difficult based on the anatomic location of the tumor and certain proposed segmentectomy plans. Second, selection biases favoring segmentectomy may exist despite propensity score matching, as patients undergoing lobectomy are more likely to have centrally located tumors or tumors with a larger solid component, as evidenced by higher rates of pathologic tumor upstaging. Third, lymphadenectomy in the segmentectomy cohort might have been inadequate, which could result in missed micrometastatic nodal disease, increasing the risk of systemic metastasis. Fourth, the quality of segmentectomy could not be fully assessed through the NCDB, as margin widths were not reported despite their known association with improved survival.[30]

The lack of significant survival differences between segmentectomy and lobectomy patients with pathologic nodal upstaging suggests that nodal status may play a greater impact in long-term survival in these patients regardless of locoregional recurrence risk. This aligns with findings from smaller retrospective studies on clinical T1N0M0 NSCLC.[11,12,31-33] It is essential to consider that patients undergoing sublobar resection often have lower cardiopulmonary reserve and may face higher morbidity if reoperation for locoregional control is required.[9,10,34] Therefore, in patients for whom segmentectomy is planned, assuming that surgical margins are negative, a completion lobectomy might not be necessary if occult micrometastatic nodal disease is found, and instead, adjuvant systemic therapy may be considered as an alternative to mitigate the risk of locoregional and distant recurrence. This would be especially applicable in clinical scenarios in which intraoperative frozen nodal sections of N1 and N2 nodes in patients undergoing sublobar resection are analyzed to determine whether further resection is needed. Our analysis suggests that even if occult micrometastatic nodal disease is encountered, completion lobectomy might not be necessary; however, this concept requires further validation using prospectively collected data.

This study has some limitations. The NCDB does not capture critical prognostic factors, such as consolidation-to-tumor ratio[35] and tumor location.[36] Quality of mediastinal nodal staging is not fully assessed, as detailed station-level data beyond pathologic N1, N2, and N3 are not available.[25,26] The Charlson-Deyo Comorbidity Index used here might not fully represent the burden of comorbidities, particularly those affecting pulmonary function. Furthermore, such outcomes as disease-free survival and quality of life measures could not be analyzed. Finally, while the NCDB covers approximately 70% of US lung cancer cases, these findings might not be generalizable to the entire population.[37]

CONCLUSIONS

This study demonstrates that pathologic nodal upstaging is observed more frequently following lobectomy compared to segmentectomy in patients with cT1cN0M0 NSCLC. Nonetheless, overall survival is similar in patients undergoing segmentectomy and those undergoing lobectomy. Notably, in patients with pathologic nodal upstaging, survival outcomes were similar in segmentectomy and lobectomy recipients in matched cohorts. Therefore, segmentectomy may be an acceptable surgical approach for selected patients with cT1cN0M0 NSCLC. Additionally, in the subset of patients for whom segmentectomy is considered, pathologic nodal upstaging may have a more significant impact on prognosis than the risk of locoregional recurrence, suggesting that in certain cases in the setting of occult micrometastatic nodal disease, lung parenchymal-sparing approaches and the use of adjuvant systemic therapy could be considered instead of completion lobectomy. Prospective studies with detailed clinical data are essential to further identify specific patient subgroups in which segmentectomy may be appropriate, as well as to validate the ability to forgo intraoperative completion lobectomy if occult micrometastatic nodal disease is encountered intraoperatively.

Audio

Audio Recording: You can listen to the audio recording of the presentation and discussion associated with this paper: https://doi.org/10.1016/j.xjon.2025.01.014.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: lung cancer, lobectomy, segmentectomy, nodal staging, survival

APPENDIX E1. DEFINITIONS OF VARIABLES

Histology

International Classification of Disease for Oncology, Third Edition (ICD-O-3) terms

Histology	ICD-O-3 code
Adenocarcinoma	8140, 8141, 8143, 8144, 8146, 8147, 8200, 8201, 8210, 8211, 8230, 8250, 8251, 8252, 8253, 8254, 8255, 8260, 8262, 8263, 8280, 8290, 8310, 8313, 8320, 8323, 8333, 8340, 8341, 8350, 8380, 8382, 8400, 8401, 8410, 8440, 8441, 8453, 8460, 8470, 8471, 8480, 8481, 8490, 8500, 8510, 8520, 8525, 8530, 8550, 8551, 8570, 8571, 8572, 8573, 8575, 8576
Squamous cell carcinoma	8050, 8051, 8052, 8070, 8071, 8072, 8073, 8074, 8075, 8076, 8078, 8080, 8082, 8083, 8084
Large cell	8012, 8013, 8014, 8015, 8030, 8031, 8032, 8033, 8034, 8035
Mixed	8013, 8033, 8072, 8073, 8074, 8253, 8254, 8255, 8560, 8562, 8574

Extent of resection

Surgical Procedure of Primary Site (from National Cancer Database Participant User File Site-Specific Surgery Codes)

Extent of resection	Site-specific surgery code number
Segmentectomy	22
Lobectomy	30, 33

TABLE E1. Absolute standardized mean differences in propensity score–unmatched and –matched segmentectomy group versus lobectomy cohort

Variable	Unmatched	Matched	*P* value, *t* test
Age			
62-<69 y	2.6	1.5	.725
69-<75 y	2.6	2.4	.589
≥75	17.0	2.5	.576
Sex			
Male sex	1.1	4.2	.337
Race			
Black	5.7	4.6	.289
Hispanic	0.4	0.5	.910
Asian	3.4	4.1	.295
Other	1.0	0.6	.897
Charlson-Deyo comorbidity score			
1	5.1	0.2	.963
2-3	10.0	3.3	.454
Insurance status			
Uninsured	−8.0	1.8	.563
Private	12.3	6.7	.102
Medicaid	1.7	5.4	.227
Other government	8.0	0.0	1.000
Missing	1.4	10.5	.048
Education			
15.3%+ no high school diploma	9.9	8.4	.034
9.1-15.2% no high school diploma	7.5	0.9	.836
5.0-9.0% no high school diploma	2.9	2.0	.647
<5.0% no high school diploma	12.1	3.8	.408
Income			
$46,277-$57,856	8.0	1.0	.817
$57,857-$74,062	4.5	3.8	.373
$74,063+	10.0	3.7	.412
Missing	12.3	3.8	.411
Treatment area			
Urban	9.2	0.8	.837
Rural	2.5	0.8	.857
Missing	7.7	1.0	.831
Facility type			
Community	8.6	0.9	.855
Comprehensive community	17.4	2.6	.544
Integrated	2.5	4.2	.326
Missing	5.3	0.0	1.000
Facility location			
Northeast	29.7	0.6	.890
Midwest	15.6	5.8	.167
West	21.0	3.0	.476
Missing	5.3	0.0	1.000
Laterality			
Left	29.9	0.4	.931
Unknown	0.4	0.0	1.000
Histology			
Squamous cell carcinoma	0.2	4.4	.317
Mixed	2.8	0.0	1.000
Missing	8.4	2.6	.567
Annual hospital-level surgical volume			
2nd quartile (5.3-<10.3)	2.4	1.5	.727
3rd quartile (10.3-<17.2)	9.6	0.0	1.000
Highest-volume quartile (≥17.2)	6.9	4.7	.279
Operative approach			
Robotic	0.9	3.8	.371
VATS	21.5	0.8	.860
Missing	4.8	2.1	.617
Number of lymph nodes resected			
5-<9	0.2	6.1	.156
9-<15	35.7	0.9	.705
15-90	20.7	4.0	.818
Number of positive lymph nodes			
1-3	20.7	4.0	.288
4-6	14.2	0.8	.763
≥7	8.1	1.2	.655
Missing	32.5	1.4	.805
Relative pathologic T stage			
Downstaged (pT1b or less)	25.0	3.4	.469
Upstaged (pT2 or greater)	9.0	1.8	.680
Missing	2.7	2.5	.599
Pathologic N stage			
pN1	20.5	3.1	.394
pN2/pN3	14.3	2.4	.523
Missing	25.7	2.0	.705
Adjuvant chemotherapy			
Yes	20.9	3.6	.354

VATS, Video-assisted thoracoscopic surgery; *T*, tumor; *pT1b*, pathologic T1b stage; *pT2*, pathologic T2 stage; *pN1*, pathologic N1 stage; *pN2*, pathologic N2 stage; *pN3*, pathologic N3 stage.

TABLE E2. Demographic and clinical covariates following propensity score matching for patients undergoing segmentectomy versus lobectomy for clinical T1cN0M0 NSCLC

Variable	Overall	Segmentectomy	Lobectomy	*P* value
Number of patients (%)	2120 (100.0)	1060 (50.0)	1060 (50.0)	
Age quartile, n (%)				
<62 y	354 (16.7)	174 (16.4)	180 (17.0)	.891*
62-<69 y	529 (25.0)	268 (25.3)	261 (24.6)	
69-<75 y	563 (26.6)	287 (27.1)	276 (26.0)	
≥75 y	674 (31.8)	331 (31.2)	343 (32.4)	
Sex, n (%)				
Male	962 (45.4)	470 (44.3)	492 (46.4)	.337*
Female	1158 (54.6)	590 (55.7)	568 (53.6)	
Race, n (%)				
Non-Hispanic White	1755 (82.8)	880 (83.0)	875 (82.5)	.709*
Non-Hispanic Black	163 (7.7)	75 (7.1)	88 (8.3)	
Hispanic	81 (3.8)	40 (3.8)	41 (3.9)	
Asian	60 (2.8)	34 (3.2)	26 (2.5)	
Other	61 (2.9)	31 (2.9)	30 (2.8)	
Charlson-Deyo comorbidity score, n (%)				
0	1003 (47.3)	495 (46.7)	508 (47.9)	.735*
1	677 (31.9)	338 (31.9)	339 (32.0)	
2-3	440 (20.8)	227 (21.4)	213 (20.1)	
Insurance status, n (%)				
Uninsured	12 (0.6)	7 (0.7)	5 (0.5)	.172*
Private	457 (21.6)	244 (23.0)	213 (20.1)	
Medicaid	123 (5.8)	55 (5.2)	68 (6.4)	
Medicare	1486 (70.1)	738 (69.6)	748 (70.6)	
Other government	16 (0.8)	8 (0.8)	8 (0.8)	
Missing	26 (1.2)	8 (0.8)	18 (1.7)	
Education quartile, n (%)				
15.3%+ no high school degree	260 (12.3)	146 (13.8)	114 (10.8)	.288*
9.1-15.2% no high school degree	480 (22.6)	242 (22.8)	238 (22.5)	
5.0-9.0% no high school degree	509 (24.0)	250 (23.6)	259 (24.4)	
<5.0% no high school degree	466 (22.0)	227 (21.4)	239 (22.5)	
Missing	405 (19.1)	195 (18.4)	210 (19.8)	
Income quartile, n (%)				
<$46,277	215 (10.1)	114 (10.8)	101 (9.5)	.652*
$46,277-$57,856	358 (16.9)	181 (17.1)	177 (16.7)	
$57,857-$74,062	396 (18.7)	206 (19.4)	190 (17.9)	
$74,063+	738 (34.8)	360 (34.0)	378 (35.7)	
Missing	413 (19.5)	199 (18.8)	214 (20.2)	
Treatment area, n (%)				
Metro	1758 (82.9)	877 (82.7)	881 (83.1)	.989*
Urban	239 (11.3)	121 (11.4)	118 (11.1)	
Rural	31 (1.5)	15 (1.4)	16 (1.5)	
Missing	92 (4.3)	47 (4.4)	45 (4.2)	
Facility type, n (%)				
Academic	903 (42.6)	450 (42.5)	453 (42.7)	.899*
Community	128 (6.0)	63 (5.9)	65 (6.1)	
Comprehensive community	669 (31.6)	328 (30.9)	341 (32.2)	
Integrated	418 (19.7)	218 (20.6)	200 (18.9)	
Missing	2 (0.1)	1 (0.1)	1 (0.1)	

(Continued)

TABLE E2. Continued

Variable	Overall	Segmentectomy	Lobectomy	*P* value
Facility location, n (%)				
Northeast	699 (33.0)	351 (33.1)	348 (32.8)	.725*
Midwest	450 (21.2)	212 (20.0)	238 (22.5)	
West	338 (15.9)	173 (16.3)	165 (15.6)	
South	631 (29.8)	323 (30.5)	308 (29.1)	
Missing	2 (0.1)	1 (0.1)	1 (0.1)	
Laterality, n (%)				
Right	958 (45.2)	480 (45.3)	478 (45.1)	.996*
Left	1158 (54.6)	578 (54.5)	580 (54.7)	
Missing	4 (0.2)	2 (0.2)	2 (0.2)	
Histology, n (%)				
Adenocarcinoma	1273 (60.0)	651 (61.4)	622 (58.7)	.633*
Squamous cell carcinoma	459 (21.7)	220 (20.8)	239 (22.5)	
Large cell	20 (0.9)	10 (0.9)	10 (0.9)	
Mixed	368 (17.4)	179 (16.9)	189 (17.8)	
Hospital-level annual surgical volume, n (%)				
Lowest-volume quartile (<5.3)	567 (26.7)	276 (26.0)	291 (27.5)	.717*
2nd quartile (5.3-<10.3)	537 (25.3)	265 (25.0)	272 (25.7)	
3rd quartile (10.3-<17.2)	454 (21.4)	227 (21.4)	227 (21.4)	
Highest-volume quartile (≥17.2)	562 (26.5)	292 (27.5)	270 (25.5)	
Operative approach, n (%)				
Robotic	461 (21.7)	239 (22.5)	222 (20.9)	.801*
VATS	884 (41.7)	440 (41.5)	444 (41.9)	
Open	709 (33.4)	350 (33.0)	359 (33.9)	
Missing	66 (3.1)	31 (2.9)	35 (3.3)	
Number of lymph nodes resected, quartile, n (%)				
0-<5	811 (38.3)	397 (37.5)	414 (39.1)	.564*
5-<9	514 (24.2)	271 (25.6)	243 (22.9)	
9-<14	429 (20.2)	211 (19.9)	218 (20.6)	
14-90	366 (17.3)	181 (17.1)	185 (17.5)	
Number of positive lymph nodes, n (%)				
0	1809 (85.3)	912 (86.0)	897 (84.6)	.821*
1-3	136 (6.4)	62 (5.8)	74 (7.0)	
4-6	11 (0.5)	5 (0.5)	6 (0.6)	
7+	5 (0.2)	3 (0.3)	2 (0.2)	
Missing	159 (7.5)	78 (7.4)	81 (7.6)	
Relative pathologic T stage, n (%)				
Downstaged (pT1b or less)	484 (22.8)	249 (23.5)	235 (22.2)	.851*
Accurately staged (pT1c)	882 (41.6)	440 (41.5)	442 (41.7)	
Upstaged (pT2 or greater)	721 (34.0)	356 (33.6)	365 (34.4)	
Missing	33 (1.6)	15 (1.4)	18 (1.7)	
Pathologic N stage, n (%)				
pN0	1847 (87.1)	932 (87.9)	915 (86.3)	.709*
pN1	92 (4.3)	42 (4.0)	50 (4.7)	
pN2/pN3	63 (3.0)	29 (2.7)	34 (3.2)	
Missing	118 (5.6)	57 (5.4)	61 (5.8)	
Adjuvant chemotherapy, n (%)				
No	1901 (89.7)	957 (90.3)	944 (89.1)	.354*
Yes	219 (10.3)	103 (9.7)	116 (10.9)	

NSCLC, Non–small cell lung cancer; *VATS*, video-assisted thoracoscopic surgery; *T*, tumor; *pT1b*, pathologic T1b stage; *pT1c*, pathologic T1c stage; *pT2*, pathologic T2 stage; *N*, node; *pN0*, pathologic N0 stage; *pN1*, pathologic N1 stage; *pN2*, pathologic N2 stage; *pN3*, pathologic N3 stage. **P* values calculated by the χ^2 test.