Association of dementia with clinical and financial outcomes following lobectomy for lung cancer

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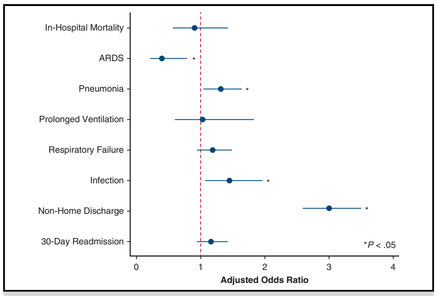
ABSTRACT

Objective: The number of adults with dementia is rising worldwide. Although dementia has been linked with inferior outcomes following various operations, this phenomenon has not been fully elucidated among patients undergoing elective lung resection. Using a national cohort, we evaluated the association of dementia with clinical and financial outcomes following lobectomy for cancer.

Methods: Adults undergoing lobectomy for lung cancer were identified within the 2010-2020 Nationwide Readmissions Database. Patients with a comorbid diagnosis of dementia were considered the Dementia cohort (others: Non-Dementia). Multivariable regressions were developed to evaluate the association between dementia and key outcomes.

Results: Of ~314,436 patients, 2863 (0.9%) comprised the Dementia cohort. Compared with Non-Dementia, the Dementia cohort was older (75 vs 68 years, $P < .001$), less commonly female (49.4 vs 53.9%, $P = .01$), and had a greater burden of comorbid conditions. After adjustment, dementia remained associated with similar odds of in-hospital mortality (adjusted odds ratio [aOR], 0.86; 95% confidence interval [CI], 0.54-1.38) but greater likelihood of pneumonia (aOR, 1.31; CI, 1.04-1.65) and infectious complications (aOR, 1.37; CI, 1.01-1.87). Further, dementia was associated with longer length of stay (β +0.96 days; CI, 0.51-1.41), but no difference in hospitalization cost (β \$1528; CI, −92 to 3148).

Conclusions: Patients with dementia faced similar odds of mortality, but greater complications and resource use following lobectomy for lung cancer. Novel interventions are needed to improve care coordination and develop standardized recovery pathways for this growing cohort. (JTCVS Open 2023;16:965-75)



Comorbid dementia is linked with similar odds of mortality, but greater complications and resource utilization following lobectomy for lung cancer.

CENTRAL MESSAGE

A growing number of patients with dementia undergo lobectomy for lung cancer treatment. Comorbid dementia is associated with equivalent odds of mortality but greater risk for certain complications.

PERSPECTIVE

Using a national cohort of patients undergoing elective lobectomy for lung cancer, we found comorbid dementia to be linked with similar odds of mortality but greater postoperative complications and resource use, compared with others. Our findings suggest lobectomy to be safe among select patients with dementia. Future work is needed to improve perioperative optimization and management.

With the steadily aging US population, senescent conditions and their sequelae are of growing significance.[1] Dementia, defined as an acquired disorder of cognitive function characterized by memory, attention, language, and motor impairments, is one such condition that has increased in prevalence, with nearly 7 million individuals in the United

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Read at the 49th Annual Meeting of the Western Thoracic Surgical Association, Coeur d'Alene, Idaho, June 21-24, 2023.

Received for publication June 19, 2023; revisions received Sept 9, 2023; accepted for publication Sept 18, 2023; available ahead of print Oct 26, 2023.

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2666-2736

https://doi.org/10.1016/j.xjon.2023.09.019

Abbreviations and Acronyms

aOR	= adjusted odds ratio
ARDS	= acute respiratory distress syndrome
CI	= confidence interval
ICD	= *International Classification of Diseases*
LOS	= length of stay
NRD	= Nationwide Readmissions Database

States currently affected.[2] This figure is expected to reach 12 million by 2040.[3] Meanwhile, lung cancer remains the leading cause of cancer-related deaths, with adults ≥65 years of age representing 50% of new cases annually.[4] Although anatomic resection remains the standard of care for select patients with lung cancer, perioperative outcomes in patients with dementia remain ill-defined.

Previous work has demonstrated the association of dementia with adverse postoperative outcomes across a myriad of procedures, ranging from orthopedic to general surgery.[5,6] In a study of patients with dementia presenting with hip fractures, Jorissen and colleagues[5] demonstrated significantly greater odds of mortality and reduced postoperative functional status, with >50% of subjects requiring postoperative long-term at-home care. Considering the changing paradigm in lung cancer treatment, a contemporary characterization of lobectomy outcomes in patients with dementia is paramount to appropriate patient selection and shared decision-making.

In the present work, we used a nationally representative database to evaluate the association between dementia and acute clinical and financial outcomes following elective lobectomy for lung cancer. We hypothesized dementia to be independently associated with increased mortality, perioperative complications, length of stay (LOS), hospitalization costs, and nonelective readmissions within 30 days of discharge.

METHODS

This was a retrospective cohort study of the 2010-2020 Nationwide Readmissions Database (NRD). As the largest all-payer readmissions database, the NRD provides accurate estimates for ~60% of all hospitalizations in the United States.[7] All elective adult (≥18 years) hospitalizations entailing pulmonary lobectomy for lung cancer were identified using relevant *International Classification of Diseases, Ninth* and *Tenth Revision* (ICD-9/10) diagnosis and procedure codes (Table E1). Those with a diagnosis of dementia were classified as the Dementia cohort (others: Non-Dementia). Records missing key data were excluded from analysis (1.4%, Figure 1).

The NRD data dictionary was used to define patient and hospital characteristics, including age, sex, income quartile, insurance coverage, and hospital teaching status.[7] The van Walraven and colleagues[8] modification of the Elixhauser Comorbidity Index was used to quantify burden of chronic conditions. Relevant comorbidities and complications were identified using ICD-9 and ICD-10 codes, as previously described.[9] Perioperative complications included acute respiratory distress syndrome, pneumonia, pneumothorax, prolonged mechanical ventilation >96 hours, and respiratory failure as well as cerebrovascular (intracranial hemorrhage, stroke, or transient ischemic attack), cardiac (cardiac arrest, ventricular fibrillation, ventricular tachycardia, tamponade and myocardial infarction), renal (acute renal failure requiring dialysis), infectious (sepsis or surgical-site infection), thrombotic (deep-vein thrombosis or pulmonary embolism), or intraoperative (accidental puncture or hemorrhage) complications, and the need for blood transfusion (Table E2).

Hospitalization costs were calculated via application of center-specific cost-to charge ratios to overall hospitalization costs and inflation-adjusted using the 2020 Personal Health Index.[10] Institutional lobectomy volume was tabulated as the total number of elective cases performed during each calendar year and treated as a continuous variable in all analyses.

The primary outcome of interest was mortality at index hospitalization. Secondary outcomes included perioperative complications, LOS, hospitalization costs, nonhome discharge, and nonelective readmission within 30 days of discharge.

Categorical variables are reported as group proportions (%) and continuous variables as means with standard deviation or medians with interquartile range. Pearson χ^2, Mann–Whitney *U*, and adjusted Wald tests were used for bivariate comparison of patient and hospital characteristics, as appropriate. Trends were assessed using Cuzick's nonparametric trend testing (nptrend).[11] For risk adjustment, entropy balancing was used to generate population weights that would produce covariate balance between groups.[12] Multivariable regressions with inclusion of entropy balancing–derived weights were subsequently developed to examine the relationship of dementia with outcomes of interest. Covariate selection was guided by elastic net regularization, a penalized least-squares methodology that minimizes collinearity and overfitting of models.[13] Logistic regression model outputs are reported as adjusted odds ratios (aORs), whereas linear regression model outputs are detailed as beta-coefficients (β), both with 95% confidence intervals (95% CIs). An α of 0.05 was set for significance.

Stata 16.1 was used for all statistical analyses (StataCorp). This study was deemed exempt from full review by the institutional review board at the University of California, Los Angeles and was written in accordance with the Strengthening the Reporting of Observational studies in Epidemiology Guidelines.

RESULTS

Of an estimated 314,436 hospitalizations meeting inclusion criteria, 2863 (0.9%) comprised the *Dementia* cohort. The proportion of patients undergoing lobectomy with a diagnosis of dementia increased from 0.3% in 2010 to 1.0% in 2020 (nptrend <.001). Although the annual lobectomy volume increased from 28,001 in 2010 to 30,671 in 2019 (nptrend <.001), there was a substantial drop in 2020, corresponding to the first year of the coronavirus pandemic in the United States (nptrend <.001; Figure 2).

Compared with Non-Dementia, the Dementia cohort was older (75 [71-79] vs 68 [62-74] years, $P < .001$), less commonly female (49.5 vs 53.9%, $P = .01$), and, on average, presented with a greater Elixhauser comorbidity index (4 [3-5] vs 3 [2-5], $P < .001$). Specifically, patients in the Dementia group had greater rates of coronary artery disease (25.3 vs 19.9%, $P < .001$), congestive heart failure (9.1 vs 4.9%, $P < .001$), peripheral vascular disease (11.6 vs 8.4%, $P < .001$), and diabetes (25.6 vs 18.9%, $P < .001$), relative to Non-Dementia. Furthermore, patients with dementia were more often classified in the lowest income quartile (29.0% vs 23.9%, $P < .001$) and insured by

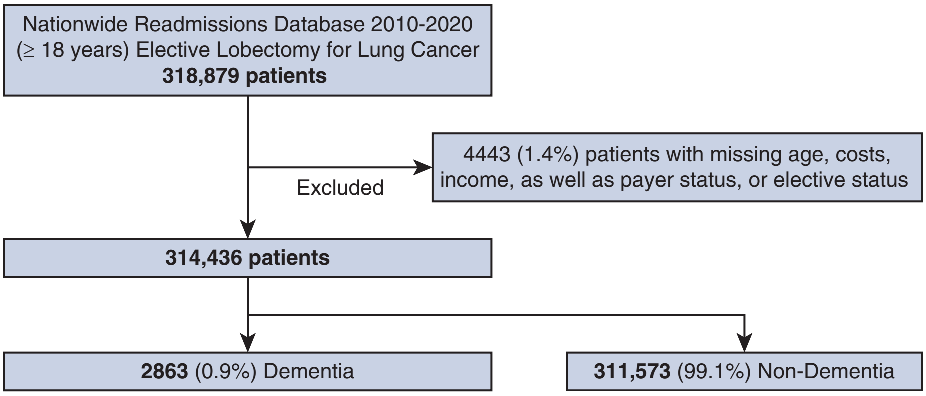

FIGURE 1. Study CONSORT diagram.

Medicare (89.7% vs 64.5%, $P < .001$). Notably, over the study period, the proportion of patients with dementia in the lowest income quartile increased from 0.05% in 2010 to 1.9% in 2020 (nptrend <.001). The Dementia and Non-Dementia cohorts similarly often underwent thoracoscopic (36.1% vs 37.6%, $P = .21$) and robotic (17.8% vs 15.9%, $P = .21$) lobectomy, as shown in Table 1.

Upon unadjusted analysis, rates of in-hospital mortality were equivalent between groups (Table 2). However, the Dementia cohort more frequently developed pneumonia (9.3 vs 5.6%, $P < .001$), respiratory failure (8.0 vs 4.9%, $P < .001$), acute renal failure (7.6 vs 4.8%, $P < .001$), and infectious complications (3.4 vs 1.6%, $P < .001$), compared with Non-Dementia. Further, patients with dementia more often required blood transfusions (9.4 vs 5.6%, $P < .001$; Table 2). Relative to others, the Dementia cohort faced increased LOS (7 [4-11] vs 5 [3-8] days, $P < .001$) and hospitalization costs ($26,300 [19,400-36,400] vs 23,200 [17,400-31,600], $P < .001$), as well as greater rates of nonhome discharge (31.6 vs 7.1%, $P < .001$) and nonelective readmission within 30 days of discharge (11.3 vs 7.9%, $P < .001$).

Following entropy balancing and risk adjustment, Dementia was associated with similar odds of in-hospital mortality (aOR, 0.86; 95% CI, 0.54-1.38). However, Dementia

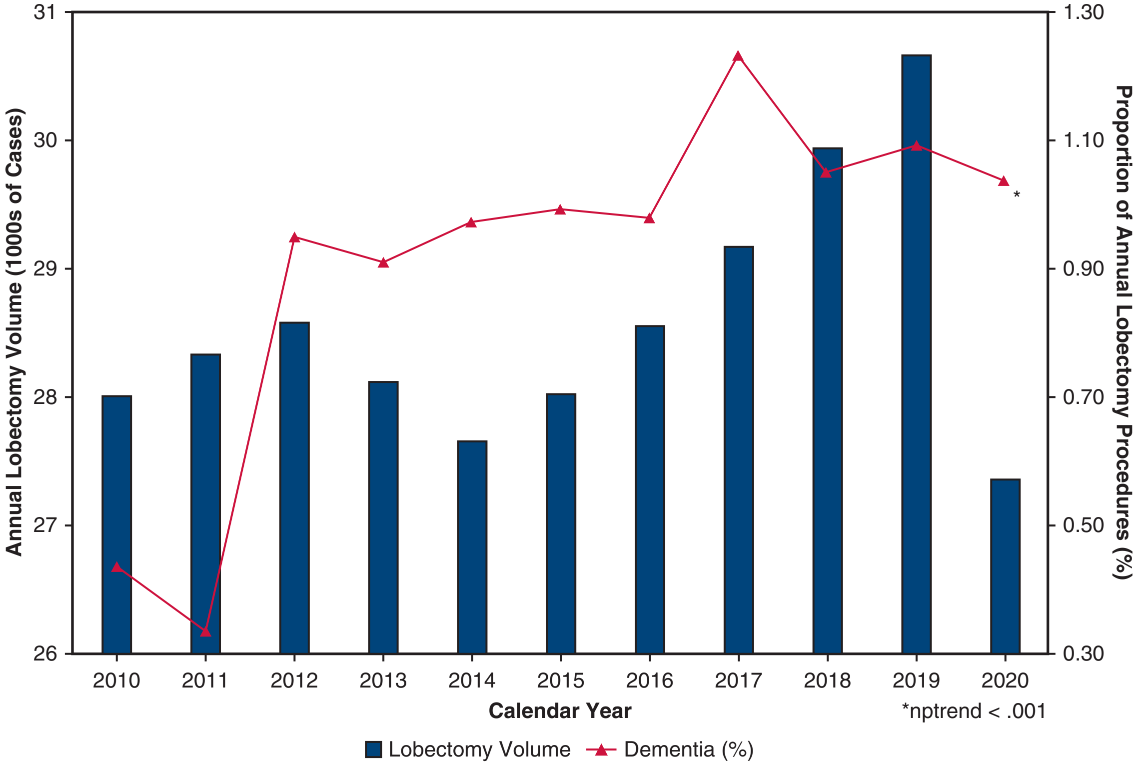

FIGURE 2. Annual trends in elective lobectomy volume and proportion of patients with concomitant dementia. *nptrend <.001.

TABLE 1. Baseline patient, clinical, and hospital characteristics of patients undergoing elective lobectomy for cancer with and without dementia

	Dementia (n = 2863)	Non-Dementia (n = 311,573)	*P* value
Age, y, median [IQR]	75 [71-79]	68 [62-74]	<.001
Female, %	49.5	53.9	.01
Elixhauser comorbidity index, median [IQR]	4 [3-5]	3 [2-5]	<.001
Operative approach, %			.21
Open	46.1	46.6	
Thoracoscopic	36.1	37.6	
Robotic	17.8	15.9	
Income quartile, %			.01
>75%	21.0	23.7	
51%-75%	25.7	25.4	
26%-50%	24.3	27.1	
0%-25%	29.0	23.9	
Insurance coverage, %			<.001
Private	6.6	27.2	
Medicare	90.0	64.5	
Medicaid	2.3	5.5	
Other payer	1.4	2.9	
Comorbidities, %			
Cardiac arrhythmias	32.7	24.2	<.001
Congestive heart failure	9.1	4.9	<.001
Coronary artery disease	25.3	19.9	<.001
Valvular disease	4.8	4.1	.17
Pulmonary circulation disorders	3.6	1.8	.01
Peripheral vascular disease	11.6	8.4	<.001
Hypertension	61.6	59.6	.16
Chronic lung disease	48.1	46.4	.30
Late-stage kidney disease	1.2	0.1	.01
Chronic liver disease	1.9	2.4	.34
Diabetes	25.6	18.9	<.001
Coagulopathy	3.1	2.3	.07
Hospital teaching status, %			.54
Nonmetropolitan	2.9	2.7	
Metropolitan nonteaching	20.8	19.5	
Metropolitan teaching	76.4	77.8	

IQR, Interquartile range.

was linked with increased odds of pneumonia (aOR, 1.31; 95% CI, 1.04 1.65) and infectious complications (aOR, 1.37; 95% CI, 1.01-1.87; Figure 3). Although Dementia was associated with longer adjusted LOS (β +0.96 days, 95% CI, 0.51-1.41), no difference was observed in hospitalization costs (β \$ 1528, 95% CI, −92 to −3148; Figure 4). In addition, Dementia demonstrated a 3-fold increase in adjusted likelihood of nonhome discharge (aOR, 3.00; 95% CI, 2.58-3.49) but did not alter the risk of nonelective rehospitalization within 30 days (aOR, 1.21; 95% CI, 0.99-1.48; Table 3).

DISCUSSION

In the present analysis, we characterized the acute clinical and financial outcomes of patients with dementia undergoing lobectomy for lung cancer between 2010 and 2020. First, we observed that the proportion of patients with dementia increased 3-fold over the study period. Comorbid dementia was linked with similar mortality but greater likelihood of respiratory and infectious complications. Finally, patients with dementia faced longer adjusted LOS and increased odds of nonhome discharge but equivalent hospitalization costs and odds of 30-day readmission. Several of these findings merit further discussion.

In our study, we noted a 0.7% increase in the prevalence of dementia among patients undergoing lobectomy for cancer. Our findings are consistent with a recent study of patients undergoing spinal fusion, which reported a 1.2% increase in comorbid dementia over a 20-year time frame.[14] A variety of factors may contribute to the increasing prevalence of dementia among patients who undergo lobectomy. First, broader awareness of mental health and cognitive

TABLE 2. Unadjusted outcomes of patients undergoing elective lobectomy for cancer with and without dementia

	Dementia (n = 2863)	Non-Dementia (n = 311,573)	*P* value
Clinical outcomes			
In-hospital mortality, %	2.3	1.4	.02
Respiratory complications, %			
ARDS	0.7	1.3	.08
Pneumonia	9.3	5.6	<.001
Pneumothorax	10.3	10.0	.77
Prolonged ventilation	1.8	1.2	.12
Respiratory failure	8.0	4.9	<.001
Additional complications, %			
Cerebrovascular complications	0.1	<0.1	.01
Cardiac complications	2.8	1.7	.01
Acute renal failure	7.6	4.8	<.001
Infectious complications	3.4	1.6	<.001
Thromboembolic complications	1.3	<0.1	.14
Intraoperative complications	2.4	2.2	.58
Blood transfusion	9.4	5.6	<.001
Resource use			
Length of stay, d, median [IQR]	7 [4-11]	5 [3-8]	<.001
Cost, $1000s, median [IQR]	26.3 [19.4-36.4]	23.2 [17.4-31.6]	<.001
Nonhome discharge, %	31.6	7.1	<.001
30-d readmission, %	11.3	7.9	<.001

ARDS, Acute respiratory distress syndrome; *IQR*, Interquartile range.

decline have yielded increased public awareness, expanded screening efforts, and improved early-stage diagnosis.[15,16] Widening adoption of thoracoscopic and robotic-assisted lung resection has also expanded the number of patients who are candidates for resection, particularly among those who are elderly and frail.[17] In addition, the Association of Anesthetists has introduced guidelines outlining perioperative care pathways for patients with dementia who undergo lobectomy, which aim to minimize postoperative cognitive changes to facilitate recovery.[18] Our findings may also be

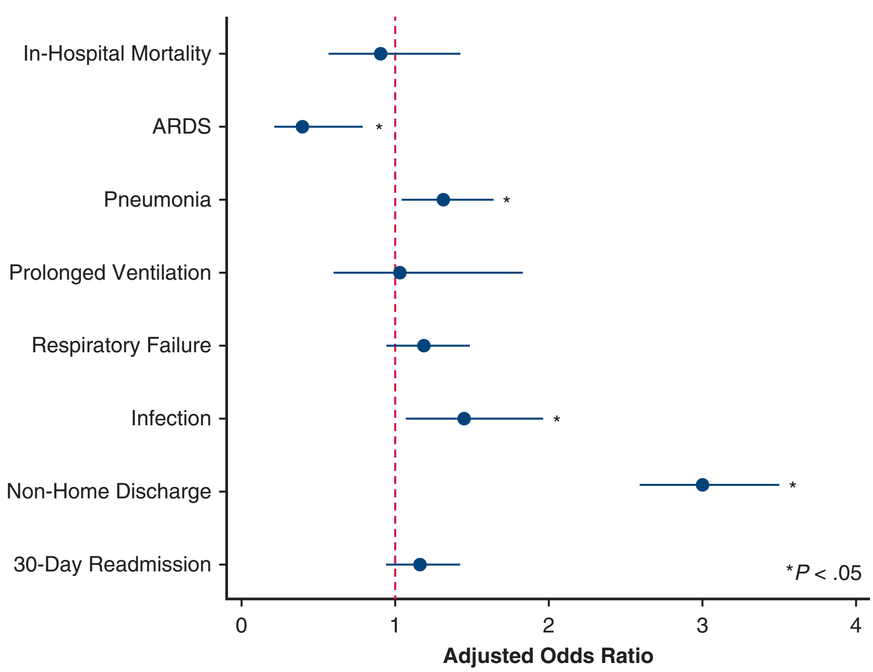

FIGURE 3. Adjusted odds of mortality, perioperative complications, and postdischarge outcomes in patients undergoing elective lobectomy for cancer with a concomitant diagnosis of dementia (ref: Non-dementia). *ARDS*, Acute respiratory distress syndrome.

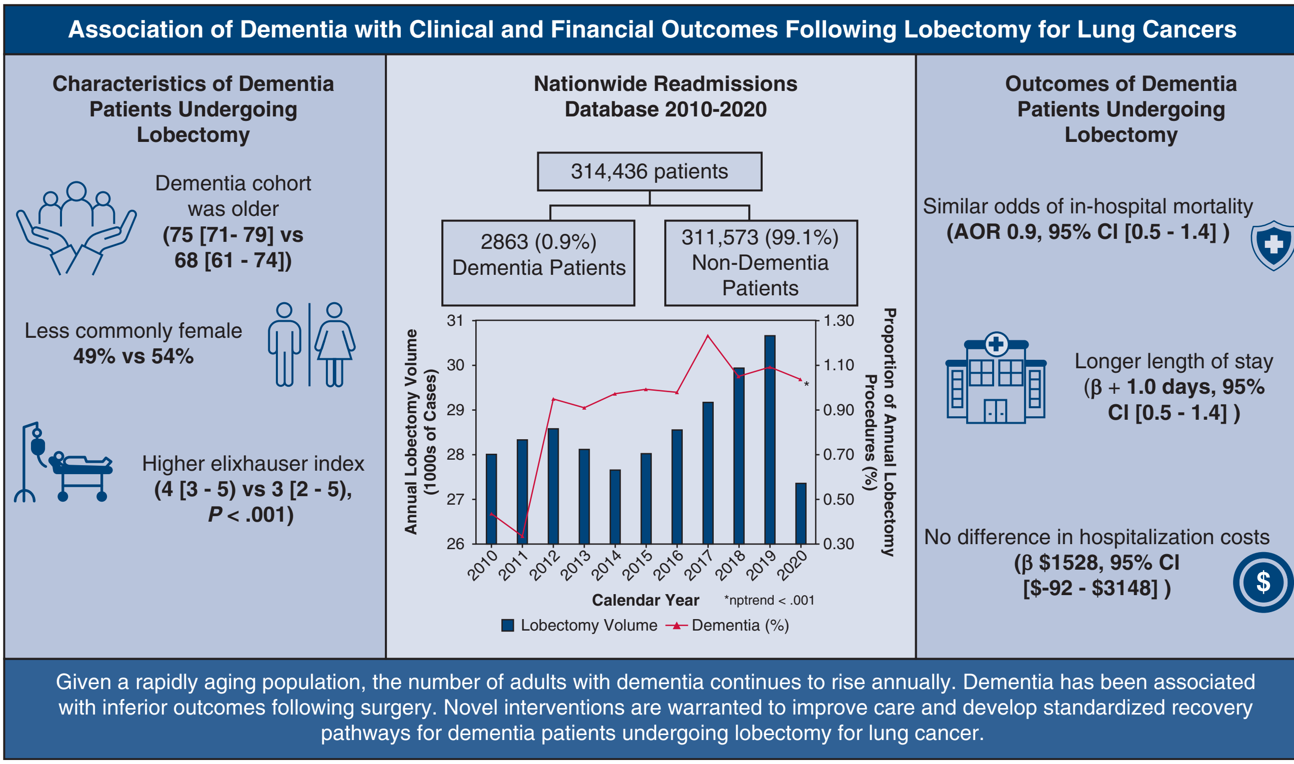

FIGURE 4. Dementia was not associated with increased odds of mortality after lobectomy for lung cancer. However, it was linked with increased odds of certain complications, length of stay (*LOS*), and nonhome discharge. There was no difference in hospitalization costs. *aOR*, Adjusted odds ratio; *CI*, confidence interval.

attributable to increasing life expectancy, the growing proportion of elderly patients with lung cancer, and increasing comfort surrounding the management of these patients with novel care pathways and minimally invasive operative techniques. Taken together, the increasing trend of surgical intervention in patients with dementia necessitates continued observation and directed improvements in perioperative optimization. Although in the present study we could not characterize patients who did not receive operative management, future work should evaluate patient, disease, and hospital factors linked with receipt of surgical versus nonoperative management among patients with lung cancer and dementia. Further, building on our study of acute outcomes, additional studies should consider the extent of resection with short- and long-term survival among this cohort. Lastly, recognizing physiologic vulnerability may further compound the impact of cognitive decline, additional work should consider how patient frailty and dementia intersect to influence outcomes.

Notably, concurrent dementia was associated with equivalent odds of in-hospital mortality following lobectomy. Previous work has yielded conflicting results regarding the association of dementia with mortality following various operations. For example, Wu and colleagues[19] demonstrated a positive correlation between dementia and mortality rates following major surgery, whereas Iorio and colleagues[20] found no such association. Several factors may underlie the conflicting results in the literature as they relate to the findings of our study. First, mortality rates following lobectomy have declined overall, attributable to significant improvements in lobectomy technique and care, widespread adoption of standardized protocols, and increasing use of minimally invasive resection.[21] Second, patients undergoing elective procedures often benefit from both risk-stratification and preoperative optimization. Receipt of preoperative therapies may also influence any independent risks associated with dementia and its related comorbid conditions.[22,23] Thus, our observations suggest that dementia is not independently linked with greater risk of mortality following lobectomy among select patients. However, careful preoperative assessment and cognitive evaluation via validated tools like the Montreal Cognitive Assessment should be performed when considering operative management, with results shaping shared decision-making regarding postoperative quality of life.[24]

In addition, we found patients with dementia to experience greater postoperative respiratory and infectious complications. Our results directly support previous work

TABLE 3. Adjusted outcomes of patients undergoing elective lobectomy for cancer with and without dementia

	aOR or β-coefficient	95% CI	*P* value
Clinical outcomes			
In-hospital mortality, aOR	0.86	0.54-1.38	.54
Respiratory complications, aOR			
ARDS	0.40	0.20-0.78	.01
Pneumonia	1.31	1.04-1.65	.02
Pneumothorax	1.00	0.83-1.23	.93
Prolonged ventilation	0.98	0.56-1.73	.95
Respiratory failure	1.18	0.94-1.48	.15
Additional complications, aOR			
Cerebrovascular complications	1.35	0.76-2.39	.31
Cardiac complications	1.11	0.75-1.64	.61
Acute renal failure	0.93	0.74-1.16	.52
Infectious complications	1.37	1.01-1.87	.05
Thromboembolic complications	1.42	0.60-3.40	.43
Intraoperative complications	0.97	0.68-1.37	.86
Blood transfusion	1.28	1.00-1.65	.05
Resource use			
Length of stay, β, d	0.96	0.51-1.41	<.001
Cost, β, \$1000s	1.53	−0.09 to 3.15	.06
Non-home discharge, aOR	3.00	2.58-3.49	<.001
30-d readmission, aOR	1.21	0.99-1.48	.10

aOR, Adjusted odds ratio; *CI*, confidence interval; *ARDS*, acute respiratory distress syndrome.

evaluating outcomes following major operations that found patients with dementia to face greater likelihood of pneumonia, urinary tract infection, and sepsis.[19] Indeed, cognitive decline and memory loss have been linked with weight loss, dysphagia, increased infection risk, and sensory abnormalities, all of which contribute to patients' vulnerability to adverse postoperative sequelae.[19,25] Further, whether due to dysphagia, anorexia, or disease, poor preoperative nutrition is linked with decreased immune response and inferior wound healing, both factors of which may have contributed to the increased likelihood of postoperative sepsis observed in our study.[26] Additional work is needed to evaluate optimal antibiotic prophylaxis, particularly given these patients may be prone to polypharmacy and develop early-identification and intervention strategies to mitigate the impact of postoperative infection.[27] These patients may also require longer duration of endotracheal intubation or may be more likely to experience postextubation dysphagia, which contribute to greater risk of postoperative hospital-acquired or aspiration pneumonia.[28] Indeed, mechanical ventilation that relies on high tidal volume ventilation has been linked with the release of inflammatory markers and greater lung injury, potential contributors to the greater likelihood of the respiratory complications these patients face.[19] Although incentive spirometers are regularly included in many postoperative pathways, patients with dementia may not be able to actively engage in their use and could experience extended postoperative atelectasis as a result.[29] Additional work is needed to evaluate optimal antibiotic prophylaxis, particularly given these patients may be prone to polypharmacy and develop early-identification and intervention strategies to mitigate the impact of postoperative infection.[27] Further, the development and implementation of specific prehabilitation programs aimed at improving nutrition and physical fitness, among other areas of preoperative optimization, could be particularly beneficial for this cohort.

Considering resource use, we found that patients with dementia demonstrated increased LOS and nonhome discharge. Dementia has been associated with pre-existing functional ability deficit, which, in combination with acute pharmacologic effects, may contribute to prolonged LOS.[30] Similarly, functional deficit may also underlie the noted increase in odds of nonhome discharge among patients with dementia.[31] Indeed, studies have shown that patients with cognitive impairment undergo a 4-fold increase in the likelihood of discharge to nonhome facilities.[32] However, the process of coordinating discharge to skilled nursing or rehabilitation facilities requires conversations with family members and extensive involvement of social workers, occupational or physical therapists, nurses, and physicians.[31] Thus, early screening and identification of patients at high risk for nonhome discharge could both accelerate the placement process as well as potentially reduce added LOS. Further, previous work evaluating outcomes after colorectal surgery and subarachnoid hemorrhage have reported increased readmission risk following nonhome discharge.[33,34] Improved predischarge care coordination, as well as postdischarge follow-up care, could potentially mitigate this risk and improve patient outcomes.[35]

Due to our use of an administrative database, the present study has several important limitations. The NRD relies on ICD codes, which may vary based on local, regional, or hospital practices. In addition, the database lacks certain granular clinical, laboratory, and radiographic information. Thus, we could not account for tumor stage, pulmonary function, or baseline patient functional status, nor could we access data regarding in-person regarding in-person clinical frailty assessments. In addition, information regarding individual physician–patient decision-making as well as patient or caretaker financial burden was unavailable for analysis. Despite these limitations, however, we applied thorough statistical methods to evaluate the impact of concurrent dementia on lobectomy outcomes.

In conclusion, we report a growing number of patients with comorbid dementia are undergoing lobectomy for lung cancer. Patients with concurrent dementia demonstrate similar in-hospital mortality but increased complications, resource use, and nonhome discharge, compared to others. Given these patients' unique comorbidity burden and perioperative risk factors, future work is needed to develop standardized preoperative optimization and postoperative recovery pathways to improve outcomes. Ultimately, our findings underscore the importance of careful risk-stratification and shared-decision making for these patients, their caregivers, and their families.

Conflict of Interest Statement

P.B. received fees from AtriCure as a surgical proctor. This article does not discuss any related products or services. All other 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: lobectomy, lung cancer, thoracic surgery, dementia, outcomes, resource utilization

TABLE E1. ***International Classification of Diseases*, *Ninth* and *Tenth Revision* (ICD-9, ICD-10) codes for studying the population**

Procedure	ICD-9 and ICD-10 codes
Lobectomy	32.4, 32.41, 32.49, 0BTC0ZZ, 0BTD0ZZ, 0BTF0ZZ, 0BTG0ZZ, 0BTH0ZZ, 0BTJ0ZZ, 0BTC4ZZ, 0BTD4ZZ, 0BTF4ZZ, 0BTG4ZZ, 0BTH4ZZ, 0BTJ4ZZ
Dementia	F01, F02, F03, G30, G31, 294.2, 294.1, 290.0, 290.8, 290.9, 290.11, 290.10, 290.13, 290.21, 331.0, 331.2, 331.6, 331.7, 331.9, 331.11, 331.19, 331.82, 331.89

TABLE E2. ***International Classification of Diseases*, *Ninth* and *Tenth Revision* (ICD-9, ICD-10) codes for medical and surgical complications**

Complications	ICD-9 and ICD-10 codes
Cerebrovascular	
Intracranial hemorrhage	431, 432.0, 432.1, 432.9, 430, I62.1, I62.0, I61.9, I62.9, I60.9
Stroke	997.01, 997.02, G97.81, G97.82, I97.811, I97.821
Transient ischemic attack	433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, 437.0, 437.1, 437.4, 437.5, 437.7, 437.9, G45.4, I63.019, I63.119, I63.139, I63.20, I63.219, I63.22, I63.239, I63.30, I63.40, I63.50, I63.59, I67.2, I67.5, I67.7, I67.81, I67.82, I67.89, I67.9
Cardiac	
Arrest	427.5, I46.2, I46.8, I46.9
Ventricular fibrillation	427.41, I49.01
Ventricular tachycardia	427.1, I47.2
Tamponade	423.3, I31.4
Myocardial infarction	410, I21
Respiratory	
ARDS	518.5, 518.82, J80, R06.03
Pneumonia	480.0, 480.1, 480.2, 480.3, 480.9, 480.9, 481, 482.0, 482.1, 482.30, 482.31, 482.32, 482.39, 482.40, 482.41, 482.42, 482.49, 482.81, 482.83, 482.84, 482.89, 482.9, 483.0, 483.1, 483.8, 485, 486, 997.31, 997.32, J12.0, J12.1, J12.2, J12.81, J12.89, J12.9, J13, J14, J15.0, J15.1, J15.20, J15.211, J15.212, J15.29, J15.3, J15.4, J15.5, J15.6, J15.7, J15.8, J15.9, J16.0, J16.8, J18.0, J18.1, J18.9, J95.851, J95.89
Pneumothorax	512.1, J95.811
Prolonged mechanical ventilation >48 h	96.72, 5A1855Z
Respiratory failure	518.51, 518.53, 518.81, 518.84, J95.821, J95.822, J96.00, J96.20, J96.90
Renal	
Acute renal failure requiring dialysis	584.5, 584.6, 584.7, 584.8, 584.9, 584, 585.4, 585.5, 585.6, N18.4, N18.5, N18.6, N17.0, N17.2, N17.8, N17.9, N17, V54.11, Z99.2
Infectious	
Sepsis	038.0, 038.1, 038.10, 038.11, 038.12, 038.19, 038.2, 038.3, 038.4, 038.40, 038.41, 038.42, 038.43, 038.44, 038.49, 038.8, 038.9, 995.91, 995.92, 998.51, 998.50, 999.3, A40.3, A40.9, A41.01, A41.02, A41.1, A41.2, A41.3, A41.4, A41.50, A41.9, K68.11, R65.20, T80.211A, T80.212A, T80.219A, T80.22XA, T80.29XA, T81.4XXA
Surgical site infection	998.31, 998.32, 998.5, T81.31XA, T81.32XA, T81.4XXA, K68.11

(Continued)

TABLE E2. Continued

Complications	ICD-9 and ICD-10 codes
Thrombotic	
Deep-vein thrombosis	451.1, 451.2, 451.81, 451.9, 453.2, 453.40, 453.41, 453.42, 453.8, 453.9, I80.10, I80.209, I80.219, I80.3, I82.429, I82.439, I82.449, I82.499, I82.4Y9, I82.890, I82.91, I82.A19, I82.B19, I82.C19
Pulmonary embolism	415.1, 415.11, 415.12, 415.19, I26.90, I26.99, T800XXA, T81718A, T8172XA, T82817A, T82818A
Intraoperative	
Accidental puncture	998.2, D78.11, D78.12, E36.11, E36.12, G97.48, G97.49, H59.219, H5.9229, H95.31, H95.32, I97.51, I97.52, J95.71, J95.72, K91.71, K91.72, L76.11, L76.12, M96.820, M96.821, N99.71, N99.72, T888XXA
Hemorrhage	998.11, D7801, D7802, D7821, D7822, E3601, E36.02, E89.810, E89.811, G97.31, G97.32, G97.51, G97.52, H59.111, H59.112, H59.113, H59.119, H59.313, H59.319, H59.321, H59.322, H59.323, H593.29, H95.21, H95.22, H95.41, H95.42, I97.410, I97.411, I97.418, I97.42, I97.610, I97.611, I97.618, I97.620, J95.61, J95.62, J95.830, J95.831, K91.61, K91.62, K91.840, K91.841, L76.01, L76.02, L76.21, L76.22, M96.810, M96.811, M96.830, M96.831, N99.61, N99.62, N99.820, N99.821
Blood transfusion	990, 30233H0, 30233N0, 30243H0, 30243N0, 30253H0, 30253N0, 30263H0, 30263N0, 30233H1, 30243H1, 30253H1, 30263H1, 30233H0, 30233N0, 30233W0, 30243H0, 30243N0, 30243W0, 30253H0, 30253N0, 30253W0, 30233H0, 30233N0, 30233W0, 30243H0, 30263H0, 30263N0, 30263W0, 30233H1, 30243H1, 30253H1, 30263H1, 30233N1, 30233P1, 30243N1, 30243P1, 30253N1, 30253P1, 30263N1, 30263P1, 30233R1, 30243R1, 30253R1, 30263R1, 30233T1, 30233V1, 30233W1, 30243T1, 30243V1, 30243W1, 30253T1, 30253V1, 30253W1, 30263T1, 30263V1, 30263W1, 30233J1, 30233K1, 30233L1, 30233M1, 30243J1, 30243K1, 30243K1, 30243M1, 30253J1, 30253K1, 30253L1, 30253M1, 30263J1, 30263K1, 30263L1, 30263M1, 30233Q1, 30243Q1, 30253Q1, 30263Q1

ARDS, Acute respiratory distress syndrome.