Is wedge a dirty word? Demographic and facility-level variables associated with high-quality wedge resection

Check for updates

Micaela L. Collins, MD, MPH,[a,b] Gregory L. Whitehorn, BS,[a,b] Shale J. Mack, BS,[a,b] Brian M. Till, MD,[a,b] Hamza Rshaidat, MD,[a,b] Tyler R. Grenda, MD, FACS,[a,b] Nathaniel R. Evans III, MD, FACS,[a,b] and Olugbenga T. Okusanya, MD, FACS[a,b]

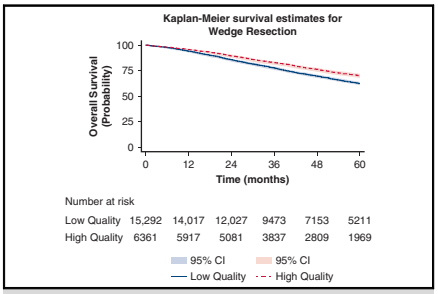
ABSTRACT

Objectives: Although sublobar resections have gained traction, wedge resections vary widely in quality. We seek to characterize the demographic and facility-level variables associated with high-quality wedge resections.

Methods: The National Cancer Database was queried from 2010 to 2018. Patients with T1/T2 N0 M0 non–small cell lung cancer 2 cm or less who underwent wedge resection without neoadjuvant therapy were included. A wedge resection with no nodes sampled or with positive margins was categorized as a low-quality wedge. A wedge resection with 4 or more nodes sampled and negative margins was categorized as a high-quality wedge. Facility-specific variables were investigated via quartile analysis based on the overall volume and proportion of high-quality wedge or low-quality wedge resections performed.

Results: A total of 21,742 patients met inclusion criteria, 6390 (29.4%) of whom received a high-quality wedge resection. Factors associated with high-quality wedge resection included treatment at an academic center (3005 [47.0%] vs low-quality wedge 6279 [40.9%]; $P < .001$). The 30- and 90-day survivals were similar, but patients who received a high-quality wedge resection had improved 5-year survival (4902 [76.7%] vs 10,548 [68.7%]; $P < .001$). Facilities in the top quartile by volume of high-quality wedge resections performed 69% (4409) of all high-quality wedge resections, and facilities in the top quartile for low-quality wedge resections performed 67.6% (10,378) of all low-quality wedge resections. A total of 113 facilities were in the top quartile by volume for both high-quality wedge and low-quality wedge resections.

Conclusions: High-quality wedge resections are associated with improved 5-year survival when compared with low-quality wedge resections. By volume, high-quality wedge and low-quality wedge resections cluster to a minority of facilities, many of which overlap. There is discordance between best practice guidelines and current practice patterns that warrants additional study. (JTCVS Open 2023;15:481-8)



Kaplan–Meier curve showing 5-year survival after HQW or LQW resection.

CENTRAL MESSAGE

HQW resections are associated with improved survival compared with LQW resections. There is discordance between best practice guidelines and current practice patterns.

PERSPECTIVE

Sublobar resection is poised to become the treatment of choice for small, peripheral NSCLC. The noninferiority of wedge resection in this context hinges on surgical quality. Currently, most wedge resections do not adhere to this standard and are of low quality, resulting in worse patient outcomes. There is discordance between best practice guidelines and current practice patterns.

Lobectomy has long been the standard recommended surgical therapy for early-stage, non–small cell lung cancer (NSCLC). This notion has been challenged in recent years as data supporting sublobar resection for small, peripheral, early-stage NSCLCs have grown. Initially, data from JCOG0802/WJOG4607 presented segmentectomy as a sound alternative to lobectomy for small peripheral tumors.[1] Several analyses subsequently demonstrated that wedge resection with adequate lymph node sampling may be comparable to segmentectomy or lobectomy with respect to overall survival.[2-4] More recently, results from the CALGB/ALLIANCE 140503 trial demonstrated no

From the [a]Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia Pa; and [b]Division of Esophageal and Thoracic Surgery, Department of Surgery, Thomas Jefferson University Hospital, Philadelphia, Pa.

Received for publication March 7, 2023; revisions received June 16, 2023; accepted for publication July 5, 2023; available ahead of print Aug 12, 2023.

Address for reprints: Olugbenga T. Okusanya, MD, FACS, Division of Esophageal and Thoracic Surgery, Department of Surgery, Thomas Jefferson University Hospital, 211 South 9th St, Suite 300, Philadelphia, PA 19107 (E-mail: okusanya@gmail.com).

2666-2736

Copyright © 2023 The Author(s). Published by Elsevier Inc. on behalf of The American Association for Thoracic Surgery. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

https://doi.org/10.1016/j.xjon.2023.07.007

Abbreviations and Acronyms

CCI = Charlson-Deyo Comorbidity Index
CoC = Commission on Cancer
HQW = high-quality wedge
LQW = low-quality wedge
NCCN = National Comprehensive Cancer Network
NCDB = National Cancer Database
NSCLC = non–small cell lung cancer

significant differences in perioperative morbidity or mortality between sublobar (wedge or segmentectomy) and lobar resections, and reported that sublobar resection was noninferior to lobectomy with respect to disease-free survival.[5-7] Most notably, the subset analysis from this trial has indicated that a high-quality wedge (HQW) is noninferior to lobectomy with respect to disease-free survival.[6]

Although a wedge resection with mediastinal lymph node sampling appears to be noninferior to segmentectomy or lobectomy for select cases, a wedge resection with a positive margin or without nodal sampling is not an oncologically sound procedure. CALGB/ALLIANCE 140503 applied strict quality metrics to their wedge resections, including nodal sampling minimums; however, data examining the relationship between the surgical quality of wedge resections currently being performed for treatment of NSCLC and patient outcomes are sparse.[5] Furthermore, the distribution of HQW resections at the facility level is unknown. As wedge resections are likely to increase in popularity for treatment of NSCLC, we set out to perform a descriptive analysis of the frequency, quality, and distribution of nonanatomic wedge resections and the relationship to patient outcomes using the National Cancer Database (NCDB).

MATERIALS AND METHODS

We performed a retrospective analysis of the NCDB 2010 to 2018. The NCDB is a joint project of the Commission on Cancer (CoC) of the American College of Surgeons and the American Cancer Society. The database captures approximately 70% of newly diagnosed cancers in the United States annually from 1500 hospitals with CoC-accredited cancer programs.[8] The American College of Surgeons and the CoC have not verified and are not responsible for the analysis or conclusions drawn from this study. This project was deemed exempt from Institutional Review Board approval at Thomas Jefferson University.

Patients aged 18 years or older with clinical T1 or T2, N0, M0 NSCLC 2 cm or smaller who received a wedge resection as definitive surgical therapy were considered for inclusion. Patients who received neoadjuvant therapy and those with carcinoid tumors were excluded from this analysis. Patient data on age, sex, race, insurance status, median income, Charlson-Deyo Comorbidity Index (CCI) score, and year of diagnosis were abstracted. Additional patient data included tumor histology, size, and location, and year of diagnosis. Facility-level variables included hospital type, rural/urban designation, and hospital geographic setting.

Patients who met inclusion criteria were stratified into 2 groups using previously validated methods,[8] based on an aggregate of resection margins and number of lymph nodes harvested. Wedge resections with negative margins and at least 4 nodes sampled were deemed to be high-quality resections, and wedge resections with positive margins or no nodes sampled were deemed to be low-quality resections. Prior research used a cutoff of more than 5 nodes sampled to designate a high-quality resection, a number extrapolated from the then current CoC guideline of assessing 10 nodes during anatomic resection, and additionally included an "average quality" group composed of individuals who underwent resection with negative margins and 0 to 5 nodes sampled.[8] The designation of 5 nodes sampled as a cutoff is somewhat arbitrary based on current CoC recommendations. In 2021, the CoC changed their standard on curative-intent pulmonary resection. Citing research validating the National Comprehensive Cancer Network (NCCN) station-based node sampling recommendations, the CoC's operative standards now include lymph node sampling from at least 3 mediastinal stations and 1 hilar station, even in nonanatomic, parenchymal-sparing resections.[9] We opted to classify our data based on 4 or more lymph nodes resected because it is closer to what is currently recommended by the NCCN and CoC, and is similar to sampling guidelines adhered to by CALGB/ALLIANCE 140503.[5,7,9,10] The NCDB does not provide information on lymph node stations. The decision to group margin positivity with nodal sampling rates was decided on for 2 reasons. First, this closely aligns with prior validated methods as referenced above. Second, our intent was to perform a broad review of the surgical quality of wedge resections writ large, and both margin positivity and nodal sampling are quality metrics that are captured by the NCDB.

Statistical Analysis

Pearson's chi-square and Student *t* tests were used to compare patient, facility, and treatment characteristics. Kaplan–Meier survival analysis with log-rank tests were used to analyze the 5-year overall survival for patients for whom long-term follow up information was available. Facility-specific variables were investigated via quartile analysis based on overall volume and proportion of HQW or low-quality wedge (LQW) resections performed. For facilities in the top quartile by volume for both HQW and LQW resections, univariable regression analysis was used to examine patient variables associated with receipt of an HQW resection. Multivariable regression analysis was then performed and included variables that were statistically significant on univariable regression or deemed to be clinically relevant by the research team. Univariable and multivariable analyses were reported with an odds ratio and a 95% confidence interval (CI). All analyses used STATA/SE 15.1 statistical software (StataCorp LLC).

RESULTS

Patient Demographics

A total of 21,742 patients met inclusion criteria over the period analyzed, 15,352 of whom received an LQW resection and 6390 of whom received an HQW resection. The overall annual number and proportion of HQW resections increased over time, from 433 (22.3% of wedge resections performed that year) in 2010 to 1051 (38.5% of wedge resections performed that year) in 2018 ($P < .001$) (Figure 1). Patients who underwent an HQW resection were more likely to be female (3887 [60.8%] vs LQW 9083 [59.2%], $P = .023$), to have a CCI score of zero (3131 [49.0%] vs 7189 [46.8%]; $P < .001$), and more likely to undergo surgery at an academic center (3005 [47.0%] vs LQW 6279 [40.9%]; $P < .001$), or in a metropolitan county (5341 [86.7%] vs 12,641 [85.6%]; $P < .001$). Although statistically significant, age at diagnosis was similar between the HQW and LQW groups (69 years, interquartile range

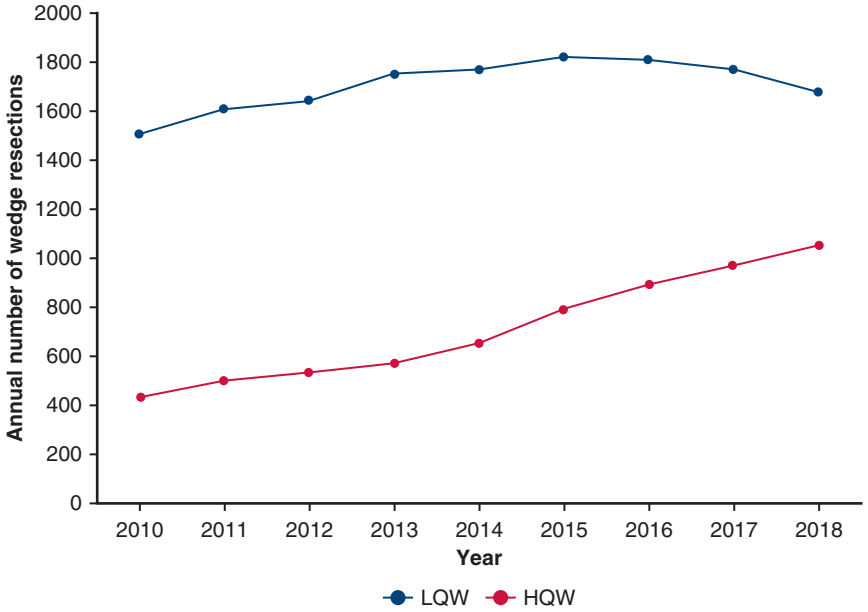


FIGURE 1. Number of HQW resections and LQW resections performed annually, 2010 to 2018. *LQW*, Low-quality wedge; *HQW*, high-quality wedge.

[IQR], 63-75 vs 70, IQR, 63-76; $P < .001$) as was tumor size (HQW: 1.4 cm [1.1-1.7 cm]; LQW: 1.3 cm [1.0-1.6 cm], $P < .001$). No significant differences were seen between groups with respect to tumor histology (Table 1).

In total, 12,875 patients had at least 1 lymph node sampled intraoperatively. A total of 6485 (42%) of all LQW resections had at least 1 lymph node sampled, and 146 (2.3%) of these patients were upstaged postoperatively. Among the HQW group, 248 (3.9%) were upstaged postoperatively, a significantly higher rate than in the LQW group ($P < .001$).

Patient Outcomes

No statistically significant differences were seen between groups with respect to 30- and 90-day survival (Table 2). Overall survival at 5 years was significantly higher in patients who had an HQW resection (4902 [76.7%] vs 10,548 [68.7%]; $P < .001$) (Figure 2).

Quartile Analysis

Over the period assessed, 1024 facilities performed at least 1 LQW resection. Of all LQW resections performed, 10,378 (67.6%) were performed at facilities in the top quartile by volume for LQW resections. With respect to HQW resections, 803 facilities over the period analyzed performed at least 1 HQW resection. 4409 (69%) of the total number of HQW resections were performed at facilities in the top quartile by facility volume for HQW resections. A total of 113 facilities were found to be in the top quartile by volume for both HQW and LQW resections. These 113 "overlap facilities" tended to be academic centers (60 [53.1%]) or in a metropolitan area (96 [85.0%]).

Univariable and Multivariable Analyses

A logistic regression analysis was undertaken to assess patient-specific variables associated with receipt of an HQW at centers in the top quartile by volume for both HQW and LQW resections (Table 3). On univariable analysis, year of diagnosis, tumor size, and diagnosis before the day of definitive surgery were all associated with receipt of an HQW resection ($P < .001$), as was female sex ($P = .003$).

On multivariable analysis, year of diagnosis, tumor size, and diagnosis before the day of definitive surgery were all associated with receipt of an HQW resection ($P < .001$), as was female sex ($P = .001$).

DISCUSSION

CALGB/ALLIANCE 140503 validates the choice to perform wedge resections for treatment of small, peripheral NSCLC if the procedure performed is of high quality, including systematic nodal sampling and confirmation of node-negative disease. Using the NCDB 2010-2018, we have shown that wedge resections are being performed for treatment of NSCLC, but not all are created equal. HQW resections were associated with higher overall survival at 5 years, but comprised a minority of resections performed over the period studied. HQW resections became more common over the period analyzed and were associated with female sex, care at an academic medical center, and lower CCI score. Rates of nodal upstaging were higher in

TABLE 1. Characteristics of patients undergoing high-quality wedge and low-quality wedge resections

Category	Total N = 21,742	LQW N = 15,352	HQW N = 6390	*P* value
Year of diagnosis (% per annum)				
2010	1939	1506 (77.7%)	433 (22.3%)	<.001
2011	2107	1607 (76.3%)	500 (23.7%)	
2012	2177	1643 (75.5%)	534 (24.5%)	
2013	2319	1751 (75.5%)	568 (24.5%)	
2014	2423	1769 (73.0%)	654 (27.0%)	
2015	2611	1820 (70.0%)	791 (30.0%)	
2016	2702	1809 (67.0%)	893 (33.0%)	
2017	2736	1770 (65.0%)	966 (35.0%)	
2018	2728	1677 (61.5%)	1051 (38.5%)	
Median age, y (IQR)	70 (63-75)	70 (63-76)	69 (63-75)	<.001
Sex (%)				
Male	8772 (40.3%)	6269 (40.8%)	2503 (39.2%)	.023
Female	12,970 (59.7%)	9083 (59.2%)	3887 (60.8%)	
Race (%)				
White	18,758 (86.3%)	13,365 (87.1%)	5393 (84.4%)	<.001
Black	1722 (7.9%)	1189 (7.7%)	533 (8.3%)	
Hispanic	526 (2.4%)	334 (2.2%)	192 (3.0%)	
API	478 (2.2%)	296 (1.9%)	182 (2.8%)	
Other	258 (1.2%)	168 (1.1%)	90 (1.4%)	
Insurance (%)				
Private	5103 (23.7%)	3528 (23.2%)	1575 (24.9%)	.026
Medicare	14,962 (69.4%)	10,623 (69.8%)	4339 (68.5%)	
None/other	1496 (6.9%)	1073 (7.0%)	423 (6.7%)	
Median income (%)				
<$38,000	2831 (14.7%)	2017 (14.7%)	814 (14.8%)	.97
$38,000-$47,999	4032 (21.0%)	2872 (20.9%)	1160 (21.1%)	
$48,000-$62,999	5010 (26.1%)	3578 (26.0%)	1432 (26.1%)	
≥$63,000	7358 (38.3%)	5269 (38.4%)	2089 (38%)	
Charlson-Deyo score (%)				
0	10,320 (47.5%)	7189 (46.8%)	3131 (49.0%)	.004
≥1	11,422 (52.5%)	8163 (53.2%)	3259 (51.0%)	
Histology (%)				
SCC	9291 (42.7%)	6547 (42.6%)	2744 (42.9%)	.83
AC	9246 (42.5%)	6530 (42.5%)	2716 (42.5%)	
LCNE	230 (1.1%)	169 (1.1%)	61 (1.0%)	
AS	417 (1.9%)	301 (2.0%)	116 (1.8%)	
Other	2558 (11.8%)	1805 (11.8%)	753 (11.8%)	
Median tumor size [cm] (IQR)	1.4 (1.0-1.6)	1.3 (1.0-1.6)	1.4 (1.1-1.7)	<.001
Lymph nodes examined, median (IQR)	1 (0-4)	0 (0-2)	7 (5-10)	<.001
Hospital type (%)				
Academic	9284 (42.7%)	6279 (40.9%)	3005 (47.0%)	<.001
Community	840 (3.9%)	648 (4.2%)	192 (3.0%)	
Comprehensive	7723 (35.5%)	5776 (37.6%)	1947 (30.5%)	
Integrated	3839 (17.7%)	2608 (17.0%)	1231 (19.3%)	
Other	56 (0.3%)	41 (0.3%)	15 (0.2%)	
Geographic setting (%)				
Metro	17,982 (85.9%)	12,641 (85.6%)	5341 (86.7%)	.014
Urban	2600 (12.4%)	1862 (12.6%)	738 (12.0%)	
Rural	345 (1.6%)	265 (1.8%)	80 (1.3%)	

LQW, Low-quality wedge; *HQW*, high-quality wedge; *IQR*, interquartile range; *API*, Asian/Pacific Islander; *SCC*, squamous cell carcinoma; *AC*, adenocarcinoma; *LCNE*, large cell neuroendocrine; *AS*, sarcomatoid carcinoma.

TABLE 2. Mortality after high-quality wedge and low-quality wedge resection

Category	Total N = 21,742	LQW N = 15,352	HQW N = 6390	*P* value
30-d mortality (%)				
Survived	21,559 (99.0%)	15,228 (99.2%)	6331 (99.1)	.40
Died	183 (0.8%)	124 (0.8%)	59 (0.9%)	
90-d mortality (%)				
Survived	21,408 (98.5%)	15,103 (98.4%)	6305 (98.7%)	.11
Died	334 (1.5%)	249 (1.6%)	85 (1.3%)	
5-y mortality (%)				
Survived	15,450 (71.1%)	10,548 (68.7%)	4902 (76.7%)	<.001
Died	6292 (28.9%)	4804 (31.3%)	1488 (23.3%)	

LQW, Low-quality wedge; *HQW*, high-quality wedge.

the HQW group than in the LQW group, similar to prior studies.[8] At the facility level, HQW and LQW clustered to a minority of institutions. Of note, 113 "overlap" facilities were in the top quartile by volume for both HQW and LQW resections. Receipt of an HQW resection at these "overlap" facilities was associated with several variables, including larger tumor size, year of diagnosis, and female sex (Figure 3).

Overall, women were more likely to receive an HQW than men. We also found that female sex was independently associated with receipt of a HQW at facilities in the top quartile by volume for both HQW and LQW. The relationship between sex and patient outcomes has been studied in other contexts. In North America, female sex has been associated with lower chance of admission to an intensive care unit and higher likelihood of death after a critical illness, although data are mixed.[11,12] Further study is necessary to explore the interaction between patient sex and surgical quality.

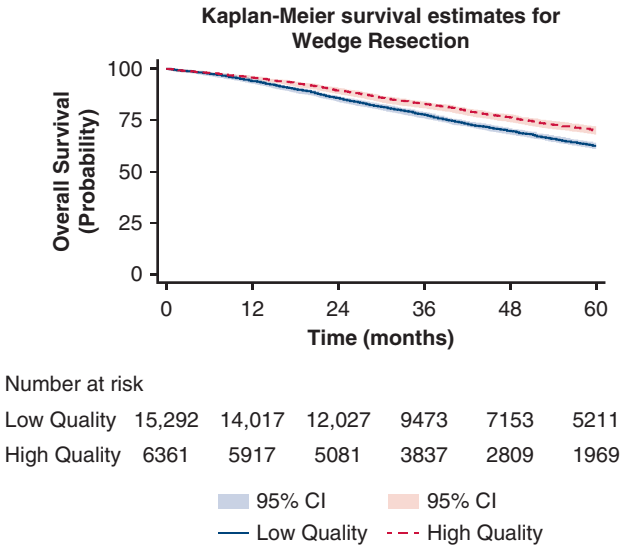


FIGURE 2. Kaplan–Meier curve demonstrating 5-year survival after HQW or LQW resection. *CI*, 95% Confidence interval.

There are many reasons that surgeons may opt to perform a wedge resection as definitive surgical therapy for NSCLC. In some patients, pulmonary function testing may disqualify patients from anatomic resection. Performing a wedge resection offers these patients at least removal of the primary cancer for optimal diagnosis and molecular data.[13] Surgeon experience may preclude segmentectomy in patients who would otherwise not tolerate a lobectomy, and wedge resection may be the best available option.[14] In these situations, however, lymph node sampling should be performed for proper staging. There may also be diagnostic uncertainty in the operating room leading to wedge being performed as the definitive operation. Additionally, not all centers may have the capacity for accurate intraoperative frozen analysis.

The CALBG/ALLIANCE 140503 trial has strict guidelines around lymph node sampling, in line with current nodal sampling guidelines set out by the NCCN and the CoC.[9,10] These guidelines do not necessarily reflect reality: Many wedge resections are performed with minimal or no nodal sampling, and even in anatomic resections, mediastinal lymph node sampling is not performed uniformly.[3,15-18] The American College of Surgeons Surgical Oncology Group Z4032 randomized control trial found that wedge resection was associated with lower lymph node harvest and lower rates of upstaging when compared with segmentectomy, a finding that has been echoed in subsequent work.[19,20] Wedge resection without nodal dissection or with suboptimal nodal sampling risks understaging and subsequent administration of stage-inappropriate care. As in our study, multiple studies have demonstrated that wedge resection with inadequate lymph node sampling is associated with increased mortality at 5 years.[18,19,21]

That wedge resections by volume clustered to a minority of facilities implies that there are facility-level characteristics not captured by the scope of the NCDB that influence surgical quality. However, that many facilities are in the top quartile by volume for both HQW and LQW resections

TABLE 3. Univariable and multivariable analyses of factors associated with high-quality wedge resection at facilities in the top quartile by surgical volume for both low- and high-quality wedge resections

	HQW			
	UVA		MVA	
Covariate	Odds ratio (95% CI)	*P* value	Odds ratio (95% CI)	*P* value
Year of diagnosis				
Continuous	1.10 (1.08-1.12)	<.001	1.10 (1.08-1.12)	<.001
Age				
Continuous	1.00 (0.99-1.00)	.056	0.99 (0.99-1.00)	.018
Sex, vs male				
Female	1.14 (1.04-1.25)	.003	1.17 (1.07-1.28)	.001
Race, vs White				
Black	1.08 (0.92-1.26)	.36	1.03 (0.88-1.21)	.715
Hispanic	1.20 (0.91-1.57)	.199	1.19 (0.90-1.58)	.212
API	1.33 (1.02-1.73)	.036	1.23 (1.00-1.73)	.047
Other	1.40 (0.99-1.97)	.056	1.31 (0.92-1.87)	.131
Insurance, vs Medicare				
Private	1.04 (0.94-1.15)	.418	1.00 (0.89-1.12)	.958
None/other	1.00 (0.84-1.20)	.974	0.89 (0.73-1.08)	.252
Charlson-Deyo Score, vs 0				
≥1	1.01 (0.93-1.10)	.853	1.03 (0.94-1.12)	.563
Time of diagnosis, vs in operating room				
Preoperative	1.25 (1.15-1.37)	<.001	1.19 (1.09-1.31)	<.001
Tumor size (cm)				
Continuous	1.41 (1.28-1.57)	<.001	1.45 (1.30-1.62)	<.001
Anatomic location, vs right upper lobe				
Left upper lobe	0.85 (0.77-0.95)	.005	0.86 (0.77-0.96)	.008
Right middle lobe	0.69 (0.55-0.87)	.002	0.70 (0.55-0.89)	.003
Right lower lobe	0.88 (0.78-1.00)	.047	0.87 (0.77-0.99)	.032
Left lower lobe	0.95 (0.83-1.08)	.425	0.93 (0.82-1.07)	.316

HQW, High-quality wedge; *UVA*, univariable analysis; *MVA*, multivariable analysis; *CI*, 95% confidence interval.

(overlap facilities) implies that there are surgeon-specific variables at play as well. For example, surgeons may not be aware of the guidelines surrounding appropriateness of wedge resections or minimum lymph node sampling suggestions for pulmonary resections with curative intent such as the "1 + 3 rule" from CoC Operative Standards 5.8.[8] They may feel convinced that a widely negative margin and complete removal of a small tumor is a sufficient operation. Although wide (10-15 mm) surgical margins have been associated with improved disease-free and overall survival after wedge resection, without nodal sampling, adequate staging cannot be performed.[2,22] Additionally, positive margins have been consistently tied to worse outcomes.[8] Application of a risk-adjusted, margin positivity rate has been suggested as a possible quality metric to identify underperforming surgeons and facilities.[23]

Study Limitations

This study has several limitations. The biggest limitations are secondary to our data source. The NCDB is a retrospective database and may introduce biases, such as selection bias. We are limited by the variables captured by the NCDB and are thus unable to comment on additional aspects that may impact the quality of wedge resection. For example, the NCDB does not capture data on width of surgical margin, surgeon volume, surgeon specialty, or lymph node stations sampled. Data are presented up until the year 2018 because that is the last year available with long-term survival data. Last, the NCDB draws data only from hospitals with CoC accreditation, thereby limiting the generalizability of findings. There is also the potential for coding errors during initial data entry into the database.

CONCLUSIONS

Wedge resections are likely to become more common as a definitive resection for NSCLC, but failure to adopt this without scrupulous adherence to guideline standards risks serious patient harm. HQW resections are significantly better than LQW resections with respect to overall survival. Wedge resections cluster to a minority of facilities, and there is intra-facility variability with respect to surgical quality that necessitates further investigation. In current

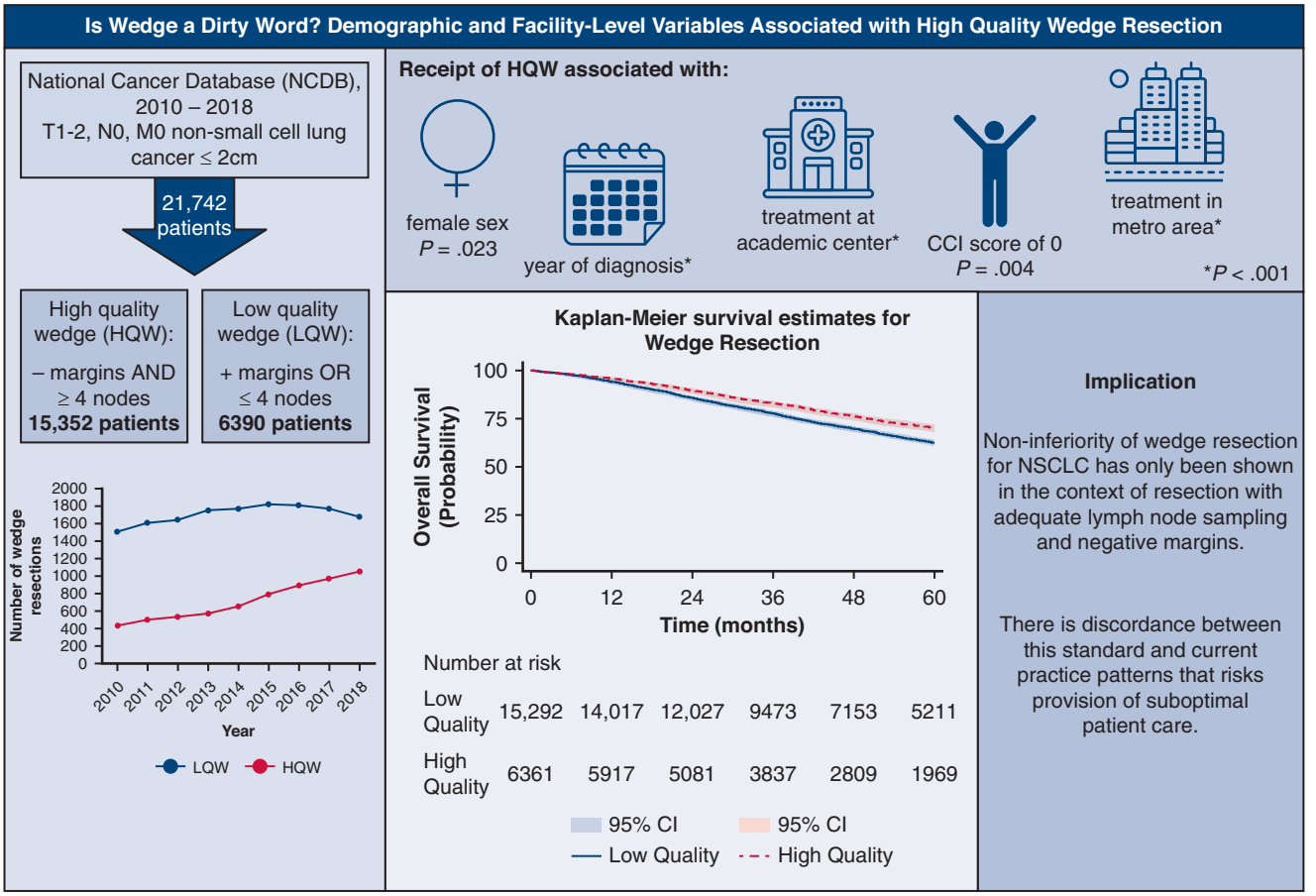


FIGURE 3. Graphical Abstract with summary and key findings of the study indicating that HQW resection is associated with improved long-term outcomes. *CCI*, Charlson-Deyo Comorbidity Index; *OR*, odds ratio; *NSCLC*, non–small cell lung cancer; *CI*, 95% confidence interval.

practice, many patients are receiving wedge resections that amount to suboptimal care.

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.

References

1. Saji H, Okada M, Tsuboi M, Nakajima R, Suzuki K, Aokage K, et al. Segmentectomy versus lobectomy in small-sized peripheral non-small-cell lung cancer (JCOG0802/WJOG4607L): a multicentre, open-label, phase 3, randomised, controlled, non-inferiority trial. *Lancet*. 2022;399:1607-17. https://doi.org/10.1016/S0140-6736(21)02333-3
2. Dolan D, Swanson SJ, Gill R, Lee DN, Mazzola E, Kucukak S, et al. Survival and recurrence following wedge resection versus lobectomy for early-stage non-small cell lung cancer. *Semin Thorac Cardiovasc Surg*. 2022;34:712-23. https://doi.org/10.1053/j.semtcvs.2021.04.056
3. Kamel MK, Lee B, Harrison SW, Port JL, Altorki NK, Stiles BM. Sublobar resection is comparable to lobectomy for screen-detected lung cancer. *J Thorac Cardiovasc Surg*. 2022;163:1907-15. https://doi.org/10.1016/j.jtcvs.2021.06.056
4. Yendamuri S, Sharma R, Demmy M, Groman A, Hennon M, Dexter E, et al. Temporal trends in outcomes following sublobar and lobar resections for small (≤2 cm) non–small cell lung cancers—a Surveillance Epidemiology End Results database analysis. *J Surg Res*. 2013;183:27-32. https://doi.org/10.1016/j.jss.2012.11.052
5. Altorki N, Wang X, Kozono D, Watt C, Landreneau R, Wigle D, et al. Lobar or sublobar resection for peripheral stage IA non–small-cell lung cancer. *N Engl J Med*. 2023;388:489-98. https://doi.org/10.1056/NEJMoa2212083
6. Altorki NK, Wang X, Damman B, Mentlick J, Landreneau R, Wigle D, et al. Lobar Versus Sublobar Resection for Peripheral Clinical T1AN0 Non-small Cell Lung Cancer (NSCLC): A Post-hoc Analysis of CALGB/ALLIANCE 140503. Presented at AATS 103rd Annual Meeting, May 8, 2023, Los Angeles, California.
7. Altorki NK, Wang X, Kozono D, Watt C, Landreneau R, Wigle D, et al. PL03.06 lobar or sub-lobar resection for peripheral clinical stage IA = 2 cm non-small cell lung cancer (NSCLC): results from an international randomized phase III trial (CALGB 140503 [Alliance]). *J Thorac Oncol*. 2022;17:S1-2. https://doi.org/10.1016/j.jtho.2022.07.012
8. Nissen AP, Vreeland TJ, Teshome M, Archer MA, Francescatti A, Katz MH, et al. American College of Surgeons Commission on Cancer standard for curative-intent pulmonary resection. *Ann Thorac Surg*. 2022;113:5-8. https://doi.org/10.1016/j.athoracsur.2021.05.051
9. Ajmani GS, Wang CH, Kim KW, Howington JA, Krantz SB. Surgical quality of wedge resection affects overall survival in patients with early stage non–small cell lung cancer. *J Thorac Cardiovasc Surg*. 2018;156:380-91.e2. https://doi.org/10.1016/j.jtcvs.2018.02.095
10. Huckaby LV, Sultan I, Trimarchi S, Leshnower B, Chen EP, Brinster DR, et al. Sex-based aortic dissection outcomes from the International Registry of Acute

Aortic Dissection. *Ann Thorac Surg*. 2022;113:498-505. https://doi.org/10.1016/j.athoracsur.2021.03.100
11. Fowler RA, Sabur N, Li P, Juurlick DN, Pinto R, Hladunewich M, et al. Sex-and age-based differences in the delivery and outcomes of critical care. *CMAJ Can Med Assoc J*. 2007;177:1513-9. https://doi.org/10.1503/cmaj.071112
12. National Comprehensive Cancer Network. NCCN Guidelines in Oncology: Non-Small Cell Lung Cancer, Version 5.2022. National Comprehensive Cancer Network. Accessed December 12, 2022. https://www.nccn.org/professionals/physician_gls/pdf/nscl_blocks.pdf
13. British Thoracic Society of Cardiothoracic Surgeons of Great Britain Ireland working party guidelines on the selection of patients with lung cancer for surgery. *Thorax*. 2001;56:89-108.
14. Weksler B. Defining the learning curve for minimally invasive segmentectomy. *J Thorac Cardiovasc Surg*. 2018;156:2004-5.
15. Osarogiagbon RU, Allen JW, Farooq A, Wu JT. Objective review of mediastinal lymph node examination in a lung cancer resection cohort. *J Thorac Oncol*. 2012;7:390-6. https://doi.org/10.1097/JTO.0b013e31823e5e2d
16. Osarogiagbon RU, Ray MA, Faris NR, Smeltzer M, Fehnal C, Houston-Harris C, et al. Prognostic value of National Comprehensive Cancer Network lung cancer resection quality criteria. *Ann Thorac Surg*. 2017;103:1557-65. https://doi.org/10.1016/j.athoracsur.2017.01.098
17. Gulack BC, Yang CFJ, Speicher PJ, Meza JM, Gu L, Wang X, et al. The impact of tumor size on the association of the extent of lymph node resection and survival in clinical stage I non-small cell lung cancer. *Lung Cancer Amst Neth*. 2015;90:554. https://doi.org/10.1016/j.lungcan.2015.10.011
18. Speicher PJ, Gu L, Gulack BC, Wang X, D'Amico TA, Hartwig MG, et al. Sublobar resection for clinical stage IA non-small cell lung cancer in the United States. *Clin Lung Cancer*. 2016;17:47-55. https://doi.org/10.1016/j.cllc.2015.07.005
19. Yendamuri S, Dhillon SS, Groman A, Dy G, Dexter E, Picone A, et al. Effect of the number of lymph nodes examined on the survival of patients with stage I non–small cell lung cancer who undergo sublobar resection. *J Thorac Cardiovasc Surg*. 2018;156:394-402. https://doi.org/10.1016/j.jtcvs.2018.03.113
20. Kent M, Landreneau R, Mandrekar S, Hillman S, Nichols F, Jones D, et al. Segmentectomy versus wedge resection for non-small cell lung cancer in high-risk operable patients. *Ann Thorac Surg*. 2013;96:1747-55. https://doi.org/10.1016/j.athoracsur.2013.05.104
21. Cao J, Xu J, He Z, Yuan P, Huang S, LV W, et al. Prognostic impact of lymphadenectomy on outcomes of sublobar resection for stage IA non–small cell lung cancer $\leq$2 cm. *J Thorac Cardiovasc Surg*. 2018;156:796-805.e4. https://doi.org/10.1016/j.jtcvs.2018.03.122
22. Mohiuddin K, Haneuse S, Sofer T, Gill R, Jaklitsch MT, Colson YL, et al. Relationship between margin distance and local recurrence among patients undergoing wedge resection for small ($\leq$2 cm) non–small cell lung cancer. *J Thorac Cardiovasc Surg*. 2014;147:1169-77. https://doi.org/10.1016/j.jtcvs.2013.11.056
23. Lin CC, Smeltzer MP, Jemal A, Osarogiagbon RU. Risk-adjusted margin positivity rate as a surgical quality metric for non-small cell lung cancer. *Ann Thorac Surg*. 2017;104:1161-70. https://doi.org/10.1016/j.athoracsur.2017.04.033

Key Words: nonanatomic resection, surgical quality, thoracic surgery, wedge resection