Comprehensive value implications of surgeon volume for lung cancer surgery: Use of an analytic framework within a regional health system

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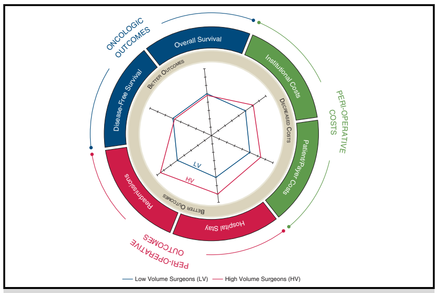
ABSTRACT

Objective: We used a framework to assess the value implications of thoracic surgeon operative volume within an 8-hospital health system.

Methods: Surgical cases for non–small cell lung cancer were assessed from March 2015 to March 2021. High-volume (HV) surgeons performed >25 pulmonary resections annually. Metrics include length of stay, infection rates, 30-day readmission, in-hospital mortality, median 30-day charges and direct costs, and 3-year recurrence-free and overall survival. Multivariate regression-based propensity scores matched patients between groups. Metrics were graphed on radar charts to conceptualize total value.

Results: All 638 lung resections were performed by 12 surgeons across 6 hospitals. Two HV surgeons performed 51% (n = 324) of operations, and 10 low-volume surgeons performed 49% (n = 314). Median follow-up was 28.8 months (14.0-42.3 months). Lobectomy was performed in 71% (n = 450) of cases. HV surgeons performed more segmentectomies (33% [n = 107] vs 3% [n = 8]; $P < .001$). Patients of HV surgeons had a lower length of stay (3 [2-4] vs 5 [3-7]; $P < .001$) and infection rates (0.6% [n = 1] vs 4% [n = 7]; $P = .03$). Low-volume and HV surgeons had similar 30-day readmission rates (14% [n = 23] vs 7% [n = 12]; $P = .12$), in-hospital mortality (0% [n = 0] vs 0.6% [n = 1]; $P = .33$), and oncologic outcomes; 3-year recurrence-free survival was 95% versus 91%; $P = .44$, and 3-year overall survival was 94% versus 90%; $P = 0$. Charges were reduced by 28%, and direct costs were reduced by 23% (both $P < .001$) in the HV cohort.

Conclusions: HV surgeons provide comprehensive value across a health system. This multidomain framework can be used to help drive oncologic care decisions within a health system. (JTCVS Open 2024;17:286-94)



Radar plots demonstrate total value contributions based on surgeon operative volume.

CENTRAL MESSAGE

High-volume thoracic surgeons offer comprehensive value in health networks; radar plots effectively visualize total value across health care systems.

PERSPECTIVE

The value implications of surgeon operative volume in centralized thoracic oncologic care are unclear. A standardized framework to analyze value remains lacking. This study shows that high-volume surgeons provide comprehensive value, as demonstrated by improved outcomes and reduced costs. Radar plots are an effective tool to visualize total value.

See Discussion on page 295.

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Abbreviations and Acronyms

HV	= high volume
LOS	= length of stay
LV	= low volume
NSCLC	= non–small cell lung cancer
VATS	= video-assisted thoracoscopic surgery

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With a recent shift in care from community-based hospitals to a more centralized model of oncologic care and physicians pursuing additional training in various subspecialties, the face of health care in the United States is evolving.[1] Concurrently, the United States is transitioning from a volume-based health care system to a more value-based system, with improvements in quality of care and costs.[2] Traditionally, value in health care has been defined as the quality of health outcomes that matter to patients relative to the costs incurred to achieve them.[3] However, the quality of health outcomes is composed of multiple components that can be evaluated from varying perspectives. Therefore, it is difficult to measure health outcome quality within a comprehensive framework. Although several frameworks have been proposed, there is no current standard by which to measure value.[3,4]

Previous work in thoracic oncology has demonstrated improved pulmonary resection outcomes, including decreased intraoperative mortality rates, decreased serious postoperative events, and increased postoperative survival rates at high-volume (HV) centers when compared with those performed at low-volume (LV) centers.[5,6] Similarly, in-hospital mortality is lower when pulmonary resections are performed by HV surgeons instead of LV surgeons.[7,8] There has been a growing body of literature examining the impact of operative volume on the value of care in thoracic surgery.[9-11] However, value is a multifaceted concept, and the comprehensive effect of HV thoracic surgeons on value is still not fully understood.

Herein, we sought to better understand the overall value implications of processes in a large health system and the applicability of a large network wide database to determine overall health care value. Through this, we used a conceptual framework and visualization tool to assess the overall value implications associated with receiving thoracic surgical care from HV surgeons compared with LV surgeons in a health network.

METHODS

The institutional review board of Allegheny Health Network approved the study protocol and publication of data. A waiver of informed consent was obtained (protocol# 2022-078-AHNMR, approved May 13, 2022).

Study Population/Database

We included patients who underwent curative surgery for non–small cell lung cancer (NSCLC) in a large health network. An institutional database was constructed by incorporating various sources and patient information into one database. Patient electronic medical records were queried for demographic information, admission dates, and discharge diagnoses. We obtained surgical information by abstracting data from operative notes. Tissue diagnosis was obtained from pathology records. Clinical outcomes and postoperative complications were obtained from the electronic medical records. Oncologic outcomes, cancer diagnosis, and management data were obtained from the institutional tumor registry. Cost metrics were obtained from our health network finance department and included 30-day direct costs and total charges. Direct costs refer to the costs directly related to patient care such as staff salaries, supplies used, and additional services on the wards, such as meals, linens etc. Total charges are the dollar amount a hospital sets for services before negotiating any discounts. For this study, charges/costs are reported as a percentage change to avoid the use of absolute values.

Based on volume standards investigated in previous studies,[7] we defined HV surgeons as those who performed more than 25 pulmonary resections (including pneumonectomy, lobectomy, segmentectomy, or wedge) annually between March 2015 and March 2021. Average yearly case volume was calculated by the sum of the surgeons' total cases and dividing by the number of years that they worked in the health system.

Radar Plot

Excel (version 2013; Microsoft) was used to create radar plots to visualize total value. Radar chart design is based on previous works.[12-15] The radar chart is a graphical method of displaying data in which quantitative variables are represented on multiple axes that originate from the same point. More favorable outcomes are plotted farther from the center on each axis; metrics for which a negative change is favorable (ie, costs, complications, length of stay [LOS]) are plotted inversely. The relative change in each metric is displayed against an index value. Increased area inside the curve represents improved overall value. Propensity-matched cohorts were used for the creation of radar plots.

Statistical Analysis

Parametric data are reported as mean ± standard deviation, and nonparametric data are reported as median and interquartile range. Kaplan–Meier curves and log-rank analysis were used to determine 3-year overall survival and recurrence-free survival. Multivariate regression-based propensity scores were used to match patients between groups. Propensity scores were assigned to each patient using a logistic regression model for predicting whether a patient would receive surgery from an HV or LV surgeon using only pretreatment variables, including patient and tumor characteristics. These variables included age, sex, race, Charleson comorbidity index, and clinical stage. A 1:1 fixed ratio of nearest-neighbor matching was used to minimize bias without sacrificing power.[16] Statistical analysis was performed with SPSS, version 28 (IBM Corp).

RESULTS

In total, 638 patients underwent lung resection for NSCLC over a 6-year period. The surgical procedures were performed by 12 surgeons across 6 different hospitals in a large health network. The mean age of the patients was 68 ± 9 years, and 54% (n = 346) of them were female. The median follow-up time was 28.8 (14-42) months. Adenocarcinoma was the most common pathologic diagnosis in all patients (n = 424, 67%), and stage I disease was the most

TABLE 1. Clinical characteristics of entire population (n = 638)

Clinical characteristics	Values	
Mean age, y	68.4 ± 8.8	
Median follow-up, mo	28.8 (14.0-42.3)	
Sex		
Male	291	45.6%
Female	347	54.4%
Race		
White	582	91.4%
Non-White	55	8.6%
CCI		
0	354	55.5%
1	181	28.4%
2	80	12.5%
3	19	3.0%
4	4	0.6%
Clinical stage		
0	2	0.4%
I	401	75.2%
II	68	12.8%
III	55	10.3%
IV	7	1.3%
Adenocarcinoma	424	66.5%
Surgery		
Lobectomy	450	70.5%
Segmentectomy	115	18.0%
Pneumonectomy	13	2.0%
Wedge	60	9.4%

CCI, Charlson Comorbidity Index.

frequent indication for surgery. Among the procedures performed, lobectomy was the most common, accounting for 71% (n = 450) of cases.

In this study, 51% (n = 324) of the procedures were performed by 2 HV surgeons, whereas the remaining 49% (n = 314) were performed by 10 LV surgeons. HV surgeons operated predominantly at a large tertiary care hospital (n = 298, 92%), whereas LV surgeons operated at predominantly community hospitals (n = 229, 73%). Both HV surgeons solely practice general thoracic surgery, whereas 60% of the LV surgeons perform both cardiac and thoracic surgery as part of their practice. Although lobectomy was the most frequently performed procedure by both groups, HV surgeons performed more segmentectomies than LV surgeons (33% [n = 107] vs 3% [n = 8]; $P < .001$). More than 50% of the surgeries in both groups were performed on patients with stage I disease. However, HV surgeons operated on a larger proportion of patients with late-stage cancer (stage III and IV) than the LV surgeons (15% vs 8%; $P = .006$). Table 1 provides the clinical characteristics of the entire cohort. When analyzing surgical approach, we found that HV surgeons performed almost exclusively robotic surgery, whereas LV surgeons performed a combination of open, video-assisted thoracoscopic surgery (VATS), and robotic approaches ($P < .001$).

Clinicodemographic differences between patients in the HV and LV groups in shown in Table 2. We used propensity scores to match 340 patients (170 HV and 170 LV) in a 1:1 ratio based on age, Charlson Comorbidity Index, race, and clinical stage (Table 3). The groups were well matched, with standardized mean differences all <0.25. The value metrics of the 2 matched surgeon cohorts were then compared. Patients of HV surgeons had a shorter median LOS (3 [2-4] vs 5 [3-7]; $P < .001$) and lower infection rates than patients of LV surgeons (0.6% [n = 1] vs 4% [n = 7]; $P = .03$). The infectious complications observed in the LV group included surgical-site infections, urinary tract infections, and 1 patient who developed pneumonia, whereas the single infectious complication in the HV group was a surgical-site infection. Patients in the LV and HV groups had similar 30-day readmission rates (14% [n = 23] vs 7% [n = 12]; $P = .12$) and in-hospital mortality (0% [n = 0] vs 0.6% [n = 1]; $P = .33$). The oncologic outcomes were also comparable, with 3-year recurrence-free survival of 95% versus 91% ($P = .44$) and 3-year overall survival of 94% versus 90% ($P = .87$) for patients in the LV and HV groups, respectively. For procedures performed by HV surgeons, charges were reduced by 28%, and direct costs were reduced by 23% (both $P < .001$). There was no difference in the type of insurance (government or commercial) between the 2 groups ($P = .491$).

Radar plots display the value metrics for propensity-matched HV and LV surgeons, including perioperative costs and oncologic outcomes (Figure 1). The larger the area inside the curve, the greater the overall value. Overall, the radar plots demonstrated that HV surgeons provided a higher value of care compared with their LV counterparts.

DISCUSSION

This study used a propensity-matched cohort of HV and LV thoracic surgeons to compare their value implications within a large health network. HV surgeons demonstrated reduced costs and improved perioperative outcomes compared with LV surgeons, whereas oncologic outcomes were similar between groups. Using a conceptual value framework, HV thoracic surgeons provide a higher value of care within a regional health network.

The radar chart is a practical visual tool to show the relationships between multiple variables, effectively communicating multivariate health care data in a single graphic.[13,14] Allen and colleagues[15] demonstrated the usefulness of a radar chart in communicating value across multiple outcome and cost metrics based on a set of new clinical care pathways for patients undergoing pancreatectomy. Other frameworks developed to measure value in oncologic care include the Net Health Benefit score proposed by the American Society of Clinical Oncology and the Evidence Blocks

TABLE 2. Unmatched cohorts, low- versus high-volume surgeons (n = 638)

Clinicodemographics	Low-volume (n = 314)	High-volume (n = 324)	Significance
Mean age, y	68.1 ± 8.6	68.6 ± 9	.541
Race			
White	292	290	.149
Non-White	22	33	
Sex			
Male	142	149	.846
Female	172	175	
Clinical stage			
0	2	0	.001
1	193	208	
2	44	24	
3	16	39	
4	4	3	
CCI			
0	162	192	.075
1	90	91	
2	51	29	
3	9	10	
4	2	2	

CCI, Charlson Comorbidity Index.

proposed by the National Comprehensive Cancer Network.[4,17] The American Society of Clinical Oncology's Net Health Benefit measures value as a numerical output derived from clinical benefit, toxicity, symptom palliation, and costs from cancer treatments.[4] However, it is unclear whether value can fully and accurately be determined via a single metric value. The National Comprehensive Cancer Network's Evidence Blocks improves upon this by measuring the efficacy, safety, quality of evidence, and costs of cancer treatments through a visual matrix.[17] Still, these metrics are derived from predominantly expert opinion rather than outcomes data. The radar chart can visually show multiple metrics of value based on available data. Providers, patients, and payers can thus use this framework to make informed decisions on the best treatment center and surgeon to provide optimized value-based care.

Our results show that patients of HV surgeons had significantly shorter LOS compared with patients of LV surgeons after undergoing lung resection. There is ample existing literature on the relationship between hospital surgical volume and LOS.[5,18,19] Our findings are also consistent with the observations of Swanson and colleagues,[9] that doubling the number of VATS performed by a surgeon was associated with a 15% reduction in LOS, and doubling a VATS surgeon's experience was associated with an 8% reduction in LOS after lung resection. Similarly, Basques and colleagues[20] showed that surgeons performing anterior cervical fusions with a volume less than the 25th percentile were associated with significantly increased patient LOS compared with their HV counterparts. Increased hospital LOS has been associated with adverse effects on patient outcomes, including increased risk of venous thromboembolism postdischarge, deconditioning, and hospital-acquired infections.[21-24] LOS is a useful metric for value-based evaluations of thoracic surgeon operative volume.

We also found that patients of HV surgeons had lower infection rates postsurgery than patients of LV surgeons. The association between overall surgical volume and infection rate is well established; greater hospital surgical volume and individual surgeon volume are associated with a decreased risk of postoperative infection.[25-29] Kajihara and colleagues[29] corroborated these findings when studying

TABLE 3. Propensity matched cohorts, low-volume versus high-volume surgeons (n = 340)

	Low-volume (n = 170)	High-volume (n = 170)	Significance	SMD
Mean age, y	68.5 ± 8.1	68.1 ± 9.1	.659	0.05
Sex				
Male	73	80	.445	0.17
Female	97	90		
Race				
White	154	153	.855	0.08
Non-White	16	17		
Clinical stage				
0-II	157	150	.200	0.02
III- IV	13	20		
CCI				
0	90	96	.133	0.14
1	46	55		
2	28	14		
3	6	5		

Values reported as mean ± standard deviation or median (interquartile range). *SMD*, Standardized mean difference; *CCI*, Charlson Comorbidity Index.

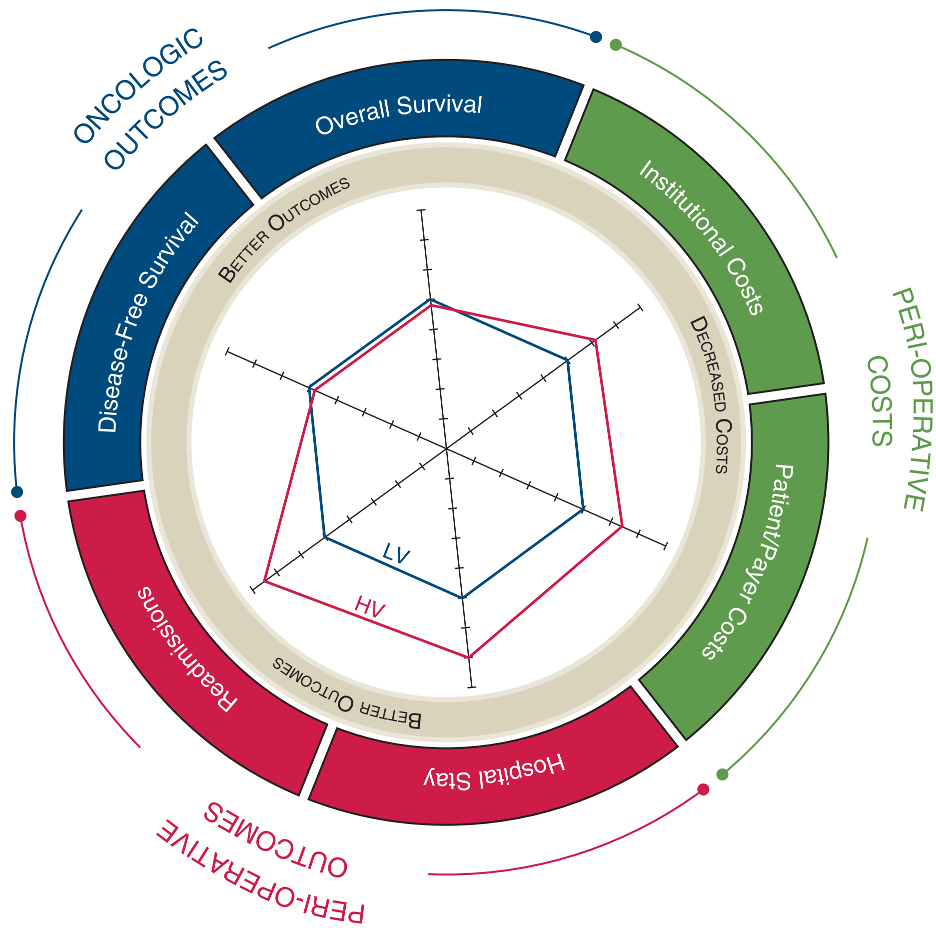

FIGURE 1. Radar plot depiction of a multidomain framework comparing high-volume (HV) and low-volume (LV) thoracic surgeons in a regional health care network. More favorable outcomes are plotted farther from the center on each axis; metrics for which a negative change is favorable (ie, costs, complications, length of stay) are plotted inversely. The relative change in each metric is displayed against an index value. Increased area inside the curve represents improved overall value.

VATS cases, and they found the incidence of surgical-site infections to be significantly decreased with increased volume of VATS. Unfortunately, there are few studies evaluating infection rates after lung resections. Our study adds to the sparse literature and helps to better clarify the association between surgeon volume and patient infection rates. Understanding this relationship could aid in decreasing the rate of postoperative infections, which is important for reducing patient morbidity as well as reducing patient costs. In addition, reducing the rate of postoperative infections leads to reduced patient LOS. In turn, this reduces revenue that hospitals lose when patient beds are occupied for longer periods of time.[30]

There are few studies evaluating the relationship between thoracic surgical volume and cost. We found that HV surgeons are associated with reduced costs and direct charges, potentially leading to improved total institution and patient costs. Our results are concordant with those of Subramanian and colleagues,[31] who demonstrated that lung resections for stage 1 NSCLC at hospitals meeting Leapfrog volume standards were more cost-effective than non-Leapfrog hospitals. Findings by Swanson colleagues[9] also showed decreased costs with HV VATS surgeons compared with LV surgeons. However, Wakeam and colleagues[10] conducted a 4-year retrospective study examining lung resection outcomes based on hospital volume; they found that costs were equivalent across all volume quartiles and patient strata. Costs are an important aspect of value for clinicians, patients, and payers. Improving costs through HV thoracic surgeons could thus be a key determinant of value based on surgical volume.

Lastly, we found that surgeon volume had no significant association with several key outcomes, including 30-day readmission rates, in-hospital mortality, and long-term survival. Previous research has indicated an inverse relationship between surgical volume and readmission rate.[7] In addition, previous literature has suggested that increased hospital surgical volume is associated with

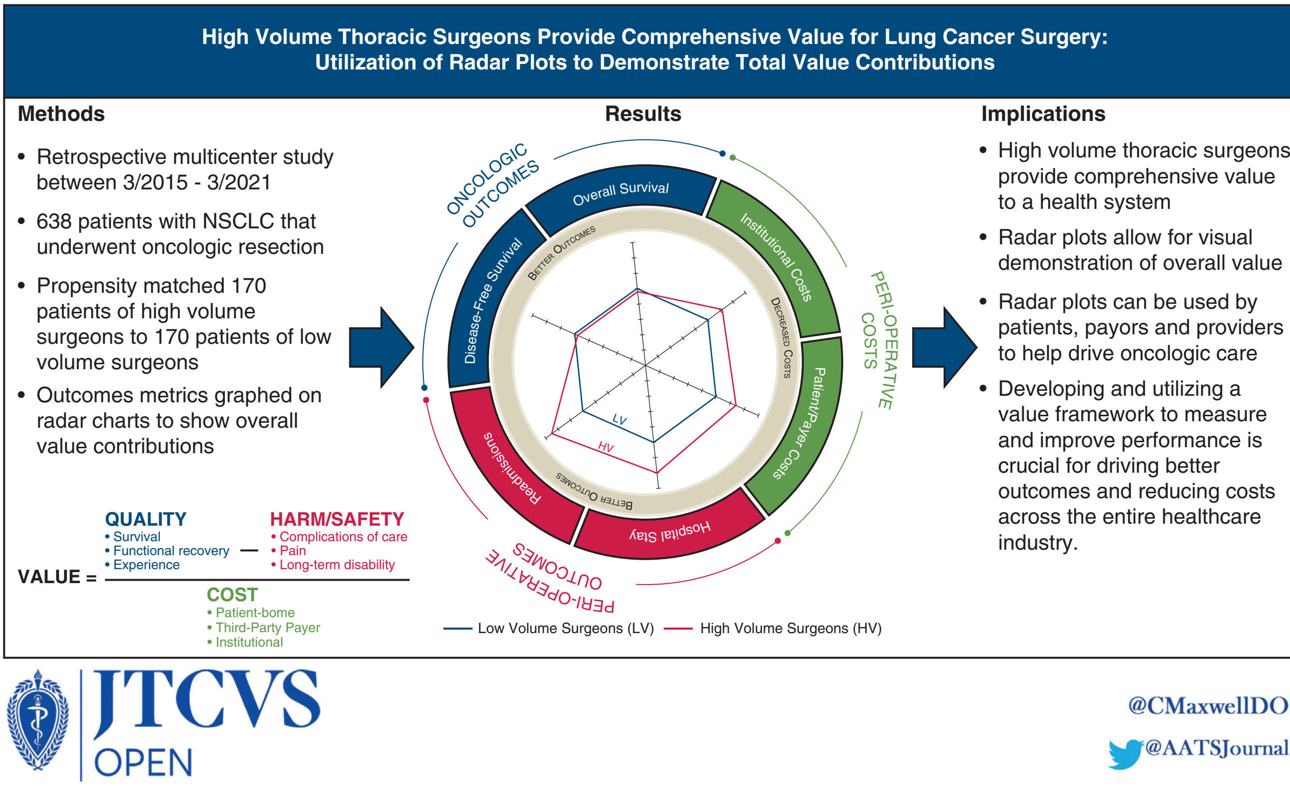

FIGURE 2. Key methods, results, and implications of the study. Radar plot depicts a multidomain framework comparing high-volume (HV) and low-volume (LV) thoracic surgeons in a regional health care network. Increased area inside the curve represents improved overall value. *NSCLC*, Non–small cell lung cancer.

increased long-term survival, and that increased hospital volume and individual surgeon volume are associated with decreased in-hospital mortality rates after lung resection.[5-8,32] However, this has not been consistently agreed upon, as some studies suggest that HV hospitals do not have an impact on 30-day mortality rate after lung resection.[33,34] Furthermore, Treasure and colleagues[35] argue that the volume of procedures performed by a thoracic surgeon is not related to in-hospital mortality. Ultimately, further work is needed to reach a consensus on the effect of an individual thoracic surgeon's volume on readmission and mortality rates in order to optimally evaluate these factors' effects on overall value.

It is important to acknowledge that the performance of individual practices and practices within larger health networks may vary significantly. Therefore, it is not advisable to use the results of a single study to predict the performance of any other group or practices across various health systems and industries. Instead, it is crucial to measure one's own data and performance to derive the best value of care delivery. This approach allows health care providers to identify their strengths and weaknesses and strive to improve their value implications by tailoring their practices to meet the unique needs of their patient population. One effective way to evaluate, critique, and communicate one's own performances is to use a value framework. In this study, we hypothesize and propose a uniform, standard, and robust framework for evaluating value implications in thoracic surgery. Using such a framework allows health care providers to drive better performance across their own practice and health system. By using a standardized value framework, health care providers can assess the performance of their own practice against industry standards and best practices. This provides a clear understanding of where improvements can be made and how value implications can be enhanced. Ultimately, the use of a value framework can lead to improved patient outcomes and satisfaction while reducing overall costs. Therefore, we highly recommend sing a value framework as an essential tool for evaluating and improving the value of care delivery in the health care industry.

There are several limitations to this exploratory study that should be considered. One inherent limitation is the retrospective nature of the study. Although a large amount of patient information was obtained efficiently through the electronic medical records and tumor registry, this method can be influenced by coding and documentation errors. In addition, the study included patients of various ages, ethnicities, comorbidities, and surgical risks. To mitigate these differences, propensity matching was used to assess differences between groups and match between patient clinicodemographics. Unfortunately, certain preoperative variables such as lung function testing and smoking status for example were unable accessed in our database and likely could have influenced the measured outcomes. Financial data are also difficult to report, and variation may exist between hospitals and patient's insurance status for example. This is especially true when analyzing data on a network wide level and is a limitation of the study.

Since a power analysis was not performed in this study, a potential type I error may occur when attempting to detect small differences in outcomes such as overall survival, recurrence-free survival, and mortalities. This is a limitation of the study and inherent limitation of evaluating a multidimensional concept such as health care value. An additional limitation exists in the methodology used to calculate surgeon volume. Not all surgeons in the study worked in our network for the entire duration of the study and their case volume was averaged over the years that they were present. Furthermore, although most cases involved lobectomies, other procedures such as pneumonectomy, segmentectomy, and wedge resection were also included. These resection types were not used to match patients in HV and LV groups, and a range of operations were compared. Although lobectomies remained the most common operation in both groups, a greater proportion of segmentectomies were performed by HV surgeons. These cases may represent differing morbidity, mortality, outcomes, and cost implications, which were not incorporated into the study. Outcomes were analyzed irrespective of case complexity, which is another limitation that should be noted. The study also did not factor in the surgical approach used in each case. For instance, surgeries could be performed using a robotic, thoracoscopic, or open approach. The type of surgical approach used could have influenced the costs and outcome measures, such as LOS, for each case. In addition, surgeon characteristics, such as subspecialty training, years of practice, or whether they perform both cardiac and thoracic surgery or thoracic surgery alone, were not considered when comparing patient outcomes. Both HV surgeons performed general thoracic surgery alone whereas LV surgeons included general thoracic surgeons as well as those that perform both cardiac and thoracic surgery as part of their practice. In addition to this, the care pathways of surgeons in our network likely vary between surgeon/institution and are unable to be accounted for in our data collection and analysis. A final aspect that may have influenced the study's results is the inherent differences between certain hospitals within our network. Outcomes may be influenced by differences in hospital case volume, staffing such as the presence of residents versus midlevel providers, or anesthesiologists versus nurse anesthetists, for example. Large tertiary centers often have access to greater resources and staffing, including services such as interventional radiology, hospitalists, and 24-hour in-house surgical staff. This potential confounder arises because HV surgeons primarily operate at these large tertiary centers, whereas some LV surgeons performed most of their operations in community hospitals. It is unclear how these factors would influence the various outcome measures.

These limitations present a potential future topic of research, especially as there is increasing divergence between the 2 specialties. Still, it is important to stress that using a value framework, such as a multidimension network wide database such as the one used in this study, is not just about analyzing our own data and performance. It is about encouraging every health care provider to develop their own framework to measure and improve their value implications. The ultimate goal is to drive better performance across the entire industry and improve patient outcomes while reducing overall costs. It is incredibly challenging to accurately measure a multidimensional metric such as value and inherent limitations still exist. This study represents an initial step toward the development of such a framework and highlights the need for further research to address the limitations and challenges of measuring value in health care.

CONCLUSIONS

In conclusion, multidimensional network wide databases and radar plots, such as the one used in this study, allow for a practical way to communicate total value across multiple domains in a health care system. In addition, this study adds to the growing body of literature supporting the value of HV surgical care, especially in the context of increasing sub-specialization in care (Figure 2). Although limitations and confounders exist, such as the influence of hospital services, the methodology proposed in this study can be used by patients, providers, and payers to make informed oncologic care decisions. Future studies should incorporate patient-reported outcomes and investigate the impact of diverging thoracic and cardiac surgery specialties on total value. Developing and using a value framework to measure and improve performance is crucial for driving better outcomes and reducing costs across the entire health care industry.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/comprehensive-value-implications-of-surgeon-volume-for-lung-cancer-surgery-utilization-of-an-analytic-framework-within-a-regional-health-system.

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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