Failure to rescue and pulmonary resection for lung cancer

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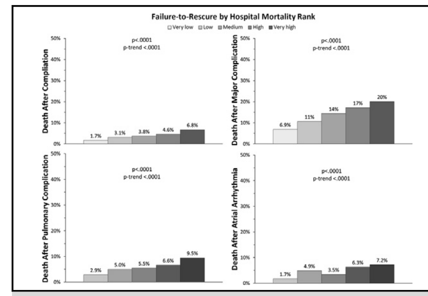
ABSTRACT

Objective: Failure to rescue is defined as death after an acute inpatient event and has been observed among hospitals that perform general, vascular, and cardiac surgery. This study aims to evaluate variation in complication and failure to rescue rates among hospitals that perform pulmonary resection for lung cancer.

Methods: By using the Society of Thoracic Surgeons General Thoracic Surgery Database, a retrospective, multicenter cohort study was performed of adult patients with lung cancer who underwent pulmonary resection. Hospitals participating in the Society of Thoracic Surgeons General Thoracic Surgery Database were ranked by their risk-adjusted, standardized mortality ratio (using random effects logistic regression) and grouped into quintiles. Complication and failure to rescue rates were evaluated across 5 groups (very low, low, medium, high, and very high mortality hospitals).

Results: Between 2009 and 2012, there were 30,000 patients cared for at 208 institutions participating in the Society of Thoracic Surgeons General Thoracic Surgery Database (median age, 68 years; 53% were women, 87% were white, 71% underwent lobectomy, 65% had stage I). Mortality rates varied over 4-fold across hospitals (3.2% vs 0.7%). Complication rates occurred more frequently at hospitals with higher mortality (42% vs 34%, $P < .001$). However, the magnitude of variation (22%) in complication rates dwarfed the 4-fold magnitude of variation in failure to rescue rates (6.8% vs 1.7%, $P < .001$) across hospitals.

Conclusions: Variation in hospital mortality seems to be more strongly related to rescuing patients from complications than to the occurrence of complications. This observation is significant because it redirects quality improvement and health policy initiatives to more closely examine and support system-level changes in care delivery that facilitate early detection and treatment of complications. (J Thorac Cardiovasc Surg 2015;149:1365-73)



Failure-to-rescue rates by risk-adjusted hospital mortality rankings for lung resection.

Central Message

Hospital mortality rankings appear to be more strongly related to rescuing patients from complications than preventing complications.

Perspective

Preventing complications is unarguably the best way to curb early deaths after pulmonary resection. However, the data show that variability in rescuing patients from complications is the dominant driver of variability in mortality. This observation suggests that system-level interventions that optimize the early detection and treatment of postoperative complications are needed to improve outcomes.

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Supplemental material is available online.

Variability in operative mortality is well documented for many operations and is an indicator of poor-quality surgical care.[1] Conventional wisdom suggests that the best way to avoid an early death is to avoid complications. For many types of major operations, complication rates do not vary across hospitals ranked by risk-adjusted mortality.[2-4] One explanation for this observation is that some systems of care fail to identify or intervene on complications early. Failure to rescue is a metric commonly used to evaluate this concept and is defined by the number of deaths among hospitalized patients experiencing an acute event, such as a postoperative complication.

Lung cancer is the second most common malignancy in the United States and the number one cause of death from cancer.[5] Billions of dollars are spent yearly to care for these patients.[6] National quality improvement initiatives attempt to mitigate the burden of this deadly and costly disease. Such efforts would likely be enhanced by a better understanding of mechanisms underlying early adverse outcomes. A first step toward achieving this goal is to better understand whether variation in operative mortality appears to be explained by complications, failure to rescue, or both.

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Abbreviations and Acronyms

ASA	= American Society of Anesthesiologists
SMR	= standardized mortality ratio
STS-GTSD	= Society of Thoracic Surgeons-General Thoracic Surgery Database

We used the Society of Thoracic Surgeons-General Thoracic Surgery Database (STS-GTSD) to describe variation in complication and failure to rescue rates across hospitals ranked and grouped by risk-adjusted operative mortality.

MATERIALS AND METHODS

A retrospective, multicenter cohort study was performed of adults with primary lung cancer who underwent pulmonary resection between January 2, 2009, and December 31, 2012. Potentially eligible study subjects included those with an International Classification of Disease, 9th Revision diagnostic code for lung cancer and a Common Procedure Terminology code for pulmonary resection as indicated on the STS data-collection form (versions 2.081-2.2) by the STS-GTSD participant. Sequential exclusion criteria included reoperations for synchronous or metachronous lung cancer (n = 891), children (n = 66), missing gender information (n = 1), emergency or "palliative" resections (n = 1474), an erroneous American Society of Anesthesiologists (ASA) classification of "VI" (n = 1), missing discharge mortality (n = 19), or in situ carcinoma or an inability to identify cancer in the pathologic specimen (n = 245). A total of 35,620 patients from 213 institutions were considered eligible for study. The University of Washington Institutional Review Board considered this work exempt from review.

Outcomes assessed in this study were complication and failure to rescue rates. A complication was defined by the occurrence of any reportable adverse outcome as defined on the STS data-collection form (versions 2.081-2.2). Major complications were based on a prior definition and include tracheostomy, reintubation, initial ventilatory support greater than 48 hours, adult respiratory distress syndrome, bronchopleural fistula, pulmonary embolus, pneumonia, bleeding requiring reoperation, or myocardial infarction.[7] Pulmonary complications were based on the occurrence of any 1 of the following events: air leak for more than 5 days, pneumonia, atelectasis requiring bronchoscopy, reintubation, other pulmonary event, adult respiratory distress syndrome, tracheostomy, initial ventilator support for more than 48 hours, bronchopleural fistula, pulmonary embolus, pneumothorax, respiratory failure, or pneumothorax requiring drainage. Because atrial arrhythmias occur commonly after pulmonary resection,[8] this event was also evaluated. Failure to rescue was primarily defined by early death among patients who experienced any complication, but was also calculated among patients with major or pulmonary complications or atrial arrhythmia. Early death is universally defined throughout this study as a patient who died during the index hospitalization or within 30 days of resection. The cause of death is not recorded by the STS-GTSD. Because causes of death not attributable to a complication (eg, inpatient suicide) are extraordinarily rare, we assumed that all deaths were a result of a complication.

Variation in complication and failure to rescue rates was assessed across hospitals ranked by their risk-adjusted standardized mortality ratio (SMR). An SMR greater than 1.0 indicates that the hospital had a higher than average operative mortality rate. The SMR was calculated for each hospital as the ratio of the hospital's risk-adjusted operative mortality rate divided by the risk-adjusted operative mortality rate of a hypothetical "average" hospital using a hierarchical (random effects) logistic regression model with nesting of patients within hospitals. Covariate selection and parameterization were based on a previously published model[7] and included both hospital-specific random effects and 23 patient-level covariates: age, gender, calendar year, body mass index, urgency, hypertension, steroid use, congestive heart failure, coronary artery disease, peripheral vascular disease, cerebrovascular disease, diabetes, renal insufficiency, smoking status, forced expiratory volume, ASA classification, Zubrod, prior thoracic surgery, preoperative chemotherapy or radiation therapy, extent and approach to resection, and pathologic stage. Because the risk-adjustment model requires complete data on all covariates, an additional 5620 patients were excluded from the study because of missing covariate data. Some of these 5620 patients account for all contributed cases at 5 centers, resulting in the exclusion of these 5 centers. A comparison of patients with and without missing covariate data is provided in Table E1. Hospitals were ranked according to SMR and then grouped into quintiles similar to a prior study.[2] These groups serve as the primary exposure variable for the analysis.

The Kruskal–Wallis test was used to test for differences in the median of continuous variables across groups. A comparison of categoric variables was initially made using a chi-square test to avoid assumptions of linearity. A test for ordinal trends is also reported. An adjusted analysis of variation in failure to rescue rates across hospital rank groups was performed using general estimating equations to account for clustering of patients within hospitals. All analyses were performed using SAS version 9.3 (SAS Institute, Inc, Cary, NC), WinBUGS version 3.2.2 (Freeware, http://www.mrc-bsu.cam.ac.uk/bugs/welcome.shtml and Imperial College of Science, Technology and Medicine at St Mary's, London, UK), and R version 2.14.1.

RESULTS

A total of 30,000 patients at 208 hospitals underwent pulmonary resection for lung cancer between 2009 and 2012. Patients were grouped according to their hospital's quintile of risk-adjusted hospital-specific mortality. Mortality rates varied by at least 4-fold between very high versus very low mortality hospitals (3.2% vs 0.7%). The 5 groups had statistically significant differences in nearly all demographic, risk factor, treatment, and stage variables. However, an overwhelming majority of absolute differences were no greater than 5% in magnitude (Table 1). The prevalence of chronic obstructive pulmonary disease varied by 8% across groups, but forced expiratory volume in 1 second and the diffusion capacity of carbon monoxide did not vary in a clinically meaningful way. Both ASA and Zubrod scores differed by more than 5% across groups, but the low mortality hospitals did not necessarily have the lowest (best) ASA and Zubrod scores. The pattern of variation in ASA and Zubrod score did not demonstrate a discernable relationship with risk-adjusted hospital performance. In terms of clinically meaningful differences (>5%), the groups appeared balanced overall in terms of the distribution of patient-level factors that influence outcomes.

Figure 1, *A* shows significant variation in the frequency of overall, major, and pulmonary complications, as well as atrial arrhythmias across hospitals. In general, but not always, complication rates were higher at hospitals with higher mortality rates. However, very high mortality

TABLE 1. Patient characteristics by hospital quintile of operative mortality

	Overall	Very low	Low	Medium	High	Very high	*P* value	*P* trend
Hospitals	208	41	42	42	42	41	—	
Patients	30,000	10,307	5226	2009	5727	6731	—	
Operative mortality	1.6%	0.7%	1.2%	1.4%	2.1%	3.2%	—	
Median age, y (25th-75th percentile)	68 (60-74)	68 (61-74)	68 (60-75)	68 (61-74)	68 (61-75)	67 (60-74)	<.001	.006
Men	47%	46%	48%	44%	47%	47%	.021	.234
Race								
White	87%	87%	84%	88%	86%	88%	<.001	.102
Black	8.4%	7.7%	8.5%	5.6%	9.7%	9.0%	<.001	<.001
Other	4.6%	4.7%	7.3%	6.5%	4.0%	2.4%	<.001	<.001
Comorbidity*								
CHF	2.9%	2.4%	2.5%	3.7%	2.6%	4.0%	<.001	<.001
CAD	22%	21%	22%	22%	23%	22%	.357	.235
HTN	61%	60%	61%	61%	62%	63%	.002	<.001
PVD	10%	9.2%	9.3%	12%	10%	12%	<.001	<.001
CVD	8.2%	8.1%	7.6%	8.2%	7.6%	9.3%	.004	.049
COPD	38%	34%	39%	42%	38%	41%	<.001	<.001
Diabetes	18%	18%	17%	20%	19%	18%	.178	.279
Dialysis	0.6%	0.5%	0.4%	0.8%	0.7%	0.7%	.215	.119
Steroids	3.6%	4.0%	2.8%	3.8%	3.7%	3.6%	.003	.268
Prior CTS	16%	16%	15%	15%	20%	14%	<.001	.462
Preoperative chemotherapy	9.3%	9.2%	8.2%	8.1%	8.6%	11%	<.001	.003
Preoperative radiation	8.0%	8.4%	7.4%	6.6%	7.2%	8.9%	<.001	.770
Median predicted FEV_1 (25th-75th percentile)	80 (66-94)	80 (66-94)	80 (66-94)	81 (66-95)	80 (66-95)	80 (66-93)	.069	.501
Median predicted DLCO (25th-75th percentile)	70 (56-86)	71 (57-85)	72 (57-88)	71 (57-87)	71 (56-87)	68 (55-83)	<.001	<.001
ASA							<.001	<.001
I	0.4%	0.4%	0.4%	0.3%	0.2%	0.5%		
II	15%	17%	15%	15%	14%	15%		
III	74%	71%	77%	75%	75%	73%		
IV	11%	11%	8.1%	9.8%	11%	12%		
V	0.02%	0.01%	0.02%	0.05%	0.03%	0.03%		
Zubrod							<.001	<.001
0	39%	38%	41%	39%	45%	32%		
1	56%	60%	54%	55%	50%	59%		
2	4.2%	2.0%	4.1%	4.8%	3.8%	7.7%		
3	0.6%	0.4%	0.8%	0.5%	0.6%	1.0%		
4	0.1%	0.1%	0.1%	0.2%	0.1%	0.04%		
5	0.04%	0.02%	0.1%	0.1%	0.02%	0.0%		
Extent of resection							<.001	.011
Wedge	16%	17%	17%	19%	15%	13%		
Segmentectomy	3.1%	3.1%	2.8%	2.7%	3.0%	3.4%		
Lobectomy	71%	68%	71%	70%	73%	73%		
Sleeve	1.5%	1.8%	1.2%	1.1%	1.1%	1.7%		
Bilobectomy	3.3%	3.6%	3.1%	2.5%	3.0%	3.5%		
Pneumonectomy	4.9%	5.5%	4.6%	4.9%	4.2%	4.9%		
NOS	0.7%	1.0%	0.8%	0.2%	0.6%	0.4%		
VATS	50%	48%	49%	54%	57%	47%	<.001	.017
Pathologic stage							.055	.048
I	65%	65%	65%	67%	65%	64%		
II	21%	21%	21%	20%	21%	22%		
IIIA	11%	11%	11%	10%	12%	12%		
IIIB	2.6%	2.5%	2.5%	2.7%	2.5%	2.6%		

CHF, Congestive heart failure; *CAD*, coronary artery disease; *HTN*, hypertension; *PVD*, peripheral vascular disease; *CVD*, cerebrovascular disease; *COPD*, chronic obstructive pulmonary disease; *CTS*, cardiothoracic surgery; *FEV1*, forced expiratory volume; *DLCO*, diffusion capacity of carbon monoxide; *ASA*, American Society of Anesthesiologists; *NOS*, not otherwise specified; *VATS*, video-assisted thoracoscopic surgery. *Columns may not add to 100% because some patients may have more than 1 comorbid condition.

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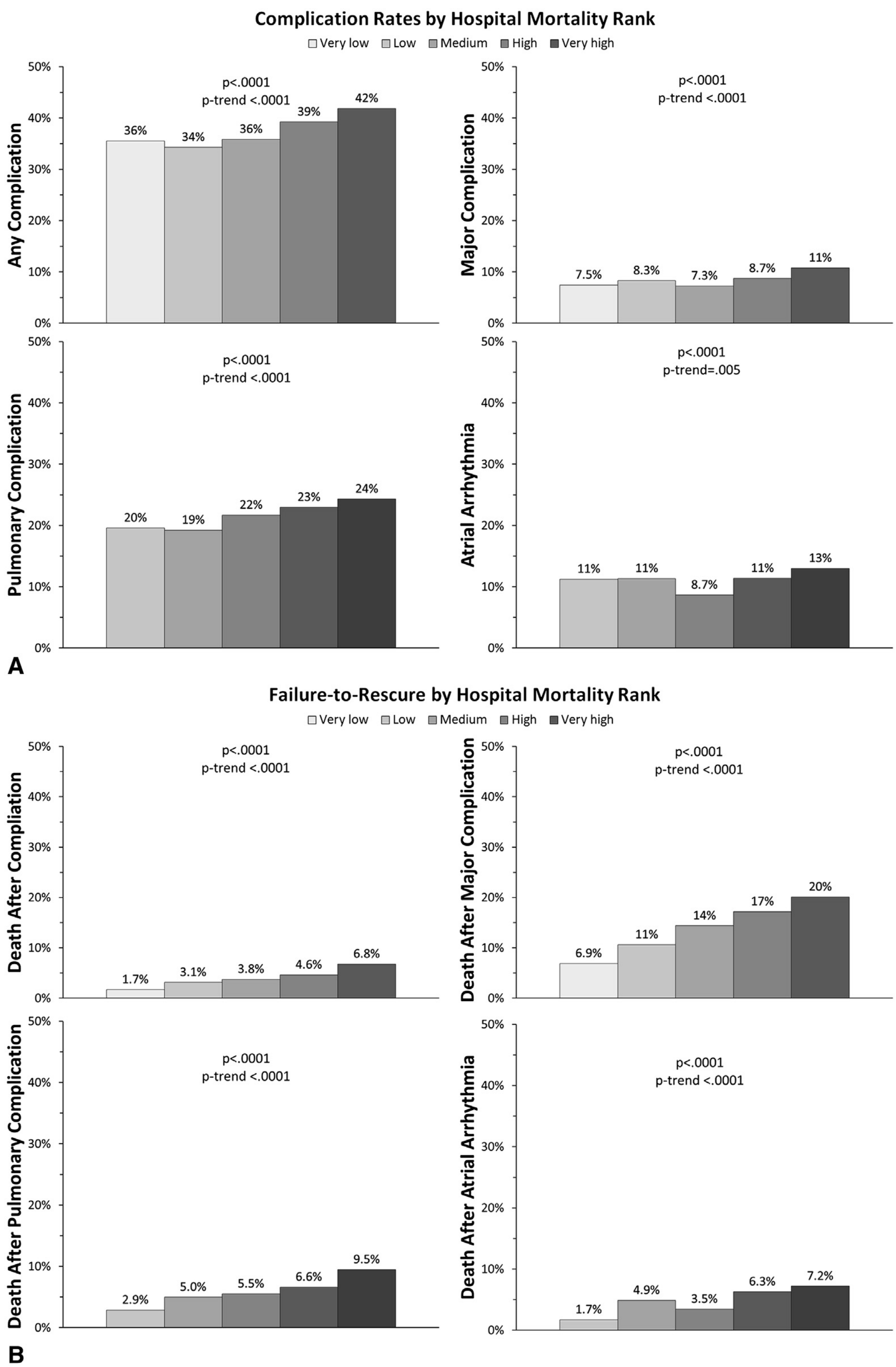

FIGURE 1. A, Complication rates by hospital quintile of mortality. B, Failure to rescue by hospital quintile of mortality. Major complication refers to the occurrence of any 1 or more of the following events: tracheostomy, reintubation, initial ventilatory support greater than 48 hours, adult respiratory distress syndrome, bronchopleural fistula, pulmonary embolus, pneumonia, bleeding requiring reoperation, or myocardial infarction. Pulmonary complication refers to the occurrence of any 1 or more of the following events: air leak for more than 5 days, pneumonia, atelectasis requiring bronchoscopy, reintubation, other pulmonary event, adult respiratory distress syndrome, tracheostomy, initial ventilator support for more than 48 hours, bronchopleural fistula, pulmonary embolus, pneumothorax, respiratory failure, and pneumothorax requiring drainage.

TABLE 2. Adjusted analysis comparing failure to rescue between very high and very low mortality hospitals

	Adjusted* OR (95% CI) for very high versus very low mortality hospitals
Failure to rescue definition	
Death after any complication	4.18 (3.28-5.32)
Death after major complication†	3.53 (2.50-4.99)
Death after pulmonary complication‡	3.48 (2.62-4.61)
Death after atrial arrhythmia	4.39 (2.85-6.76)

OR, Odds ratio; *CI*, confidence intervals. *Adjusted for age, gender, calendar year, body mass index, urgency, hypertension, steroid use, congestive heart failure, coronary artery disease, peripheral vascular disease, cerebrovascular disease, diabetes, renal insufficiency, smoking status, forced expiratory volume, ASA classification, Zubrod, prior thoracic surgery, preoperative chemotherapy or radiation therapy, extent and approach to resection, and pathologic stage. †Major complication refers to the occurrence of any 1 or more of the following events: tracheostomy, reintubation, initial ventilatory support greater than 48 hours, adult respiratory distress syndrome, bronchopleural fistula, pulmonary embolus, pneumonia, bleeding requiring reoperation, or myocardial infarction. ‡Pulmonary complication refers to the occurrence of any 1 or more of the following events: air leak more than 5 days, pneumonia, atelectasis requiring bronchoscopy, reintubation, other pulmonary event, adult respiratory distress syndrome, tracheostomy, initial ventilator support more than 48 hours, bronchopleural fistula, pulmonary embolus, pneumothorax, respiratory failure, and pneumothorax requiring drainage.

hospitals uniformly had the highest complication rates. Across all 5 hospital groups, complication rates varied by 20% (42% vs 34%, $P < .001$), major complications varied by 51% (11% vs 7.3%, $P < .001$), pulmonary complications varied by 26% (24% vs 19%, $P < .001$), and atrial arrhythmias varied by 49% (13% vs 8.7%, $P < .001$). Absolute differences in complication rates across hospital groups were generally no greater than 5%.

Figure 1, *B* shows significant variation in failure to rescue rates across hospitals. The risk of dying after a complication progressively increased across hospitals with higher mortality rates. More than 4-fold variation across hospitals was observed for failure to rescue defined as death after any complication (6.8% vs 1.7%, $P < .001$). Death after major complications varied by approximately 3-fold (20% vs 6.9%, $P < .001$), death after pulmonary complications differed by more than 3-fold (9.5% vs 2.9%, $P < .001$), and death after atrial arrhythmia varied by more than 4-fold (7.2% vs 1.7%, $P < .001$). Absolute differences in failure to rescue rates were greater than 5%. Even after adjustment for potential residual confounding by case-mix, a similar magnitude of variation in failure to rescue rates was observed across hospitals (Table 2).

DISCUSSION

National efforts to improve the quality of surgical care commonly measure risk-adjusted, hospital-level outcomes. For many procedures, variability in rescuing patients from complications (as opposed to variability in the occurrence of complications) appears to explain variability in early death. An increasing number of organizations—including the National Quality Forum and the Agency for Healthcare Research and Quality—use failure to rescue as a quality measure for hospital performance.[9,10] Failure to rescue has not been well characterized among patients with resected lung cancer. A better understanding of the determinants of early death after pulmonary resection may allow for more actionable quality improvement. By using the STS-GTSD, we demonstrated that failure to rescue rates vary with far greater magnitude than overall complication rates across hospitals ranked by risk-adjusted mortality. Although both complications and failure to rescue can lead to an untimely death, our findings suggest that failure to rescue has a dominant role in the variability observed in early deaths across hospitals performing pulmonary resection for lung cancer.

Failure to rescue has only recently been described among patients with resected lung cancer by using administrative data.[11,12] Several other investigations included patients with lung cancer in their analyses, but they did not separately report failure to rescue rates for pulmonary resection.[13-15] Although administrative datasets are commonly used to measure failure to rescue in the research and quality improvement settings,[10,16] a well-established limitation of these sources of information is that claims data do not reliably and accurately capture diagnoses, particularly postoperative complications.[17-19] Clinical registries, such as the STS-GTSD, are an alternative source of information for failure to rescue studies. The STS-GTSD is a national, voluntary clinical database maintained for quality improvement purposes. It was recently audited and found to be accurate and complete.[20] Use of the GTSD minimizes the chances of misclassifying complications and complication-derived metrics such as failure to rescue. Our study is the first to use a clinical registry to evaluate failure to rescue among patients with lung cancer.

Two mechanisms potentially underlie variability in risk-adjusted hospital performance: (1) the occurrence of a complication and (2) the failure to detect or intervene early when a complication occurs. In our study, complication rates were higher at higher mortality hospitals, and differences in complications rates were statistically significant. However, absolute differences in complication rates across hospitals were small, and the magnitude of variation in complication rates dwarfed the magnitude of variation in mortality and failure to rescue rates. This observation suggests that failure to rescue appears to be the dominant factor underlying early death. Findings from our study are similar to investigations evaluating patients undergoing general, vascular, adult cardiac, and congenital heart surgery.[2-4] For these procedures, mortality rates varied 2- to 4-fold across hospitals, complication rates varied by only 10% to 20%, and failure to rescue rates varied by up to 2-fold. The reproducibility of these observations across disparate patient populations suggests that system-level

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determinants of care—rather than patient, disease, or procedure characteristics—influence failure to rescue rates.

Whereas administrative data are limited in their ability to adjust for case-mix, they do have the advantage of allowing exploration of hospital-level determinants of failure to rescue. Limitations notwithstanding, these studies suggest that system-level factors—such as nurse education and staffing levels,[21-23] hospital teaching[11,24,25] and accreditation status,[13] payer-mix,[26] bed size and daily census,[2] and intensity of critical care services[27]—may account for variation in failure to rescue rates across hospitals. However, an optimal approach to implementing system-wide changes to hospital care remains elusive. For instance, although research supports hiring nurses with higher levels of education and minimizing patient-to-nurse ratios,[21,22,28] hospitals may be constrained by limited financial resources and a nationwide shortage of nurses.[29] Popularized rapid-response teams are intended to quickly intervene on concerns raised by frontline providers, but there is no evidence that these resource-intensive teams lead to better outcomes.[30] Participation in a regional quality improvement collaborative may be one approach for hospitals and clinicians to share information about their systematic approaches to early detection of and interventions for postoperative complications.[31] Such knowledge may lead to rapidly deployable, locally acceptable, and cost-efficient strategies for system-level change. Finally, interventions aimed at reducing variability in failure to rescue should not be misconstrued as an abandonment of interventions aimed at primary prevention of complications. Although one aim of quality improvement is to reduce variability in early deaths, another equally if not more important goal is to decrease the overall rates of early death. Primary prevention of complications is a key strategy in achieving this latter goal.

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Study Limitations

Our study has several important limitations. The STS-GTSD does not have sufficient granularity to determine the degree to which failure to rescue was the result of failure to detect or failure to treat complications early. Although both factors are likely contributory, a better understanding of the factors that account for failure to rescue may lead to more effective interventions to curb early deaths. Another limitation is the limited generalizability of the STS-GTSD to care delivery across the United States. STS-GTSD participants account for only a fraction of lung cancer resections performed in the United States and have lower operative mortality rates than nonparticipants.[32] The potential bias associated with using the STS-GTSD to study failure to rescue may be predictable. STS-GTSD participants are often considered the highest quality thoracic surgeons in the United States. If failure to rescue exists among their ranks, then it seems likely to exist among the general population of surgeons and hospitals performing lung resections. Also because of the high-quality nature of STS-GTSD participants and institutions, the magnitude of the relationship between the mere occurrence of complications and early death may be underestimated. Another important limitation of the STS-GTSD, and all other national sources of surgical data, is the absence of information on the severity of the complication at the time of presentation. Differences in the severity of a complication on presentation may account for variation in failure to rescue. Patients with severe complications on presentation may be more difficult or impossible to rescue.[33] If the severity of complications varies across centers, then systems of care may have less of an impact on mitigating failure to rescue, in which case the focus of quality improvement initiatives may have to shift back to the individual surgeon (ie, patient selection, technical skill, communication, and so on). An opportunity for future studies will be to address variability in complication and failure to rescue rates across surgeons. Another limitation of this analysis is that there is no information on the cause of death. Accordingly, a death after atrial arrhythmia is not necessarily synonymous with death because of atrial arrhythmia. Therefore, failure to rescue definitions other than death after any complication do not allow one to infer the inciting event leading to death. Although most patients experience only 1 complication after lung resection, those at higher risk of death usually experience multiple adverse outcomes.[33] Finally, the exclusion of patients with missing covariate data may have biased our findings. The most common reason for exclusion was missing pathology information. A comparison of measurable patient characteristics revealed a higher than average wedge resection rate among patients with missing covariate data. It is possible that some of these patients had presumed lung cancer but benign findings on final pathology. Because no clinically important differences in age, gender, lung function, ASA classification, Zubrod score, or approach to resection were observed across patients with and without complete covariate data, biased outcomes analyses are unlikely. A post hoc analysis using imputation did not reveal findings that differed from our primary analysis (Table E2).

CONCLUSIONS

Failure to rescue seems to be a dominant driver of variation in risk-adjusted mortality rates across hospitals that perform pulmonary resection for lung cancer. Understanding the mechanisms underlying adverse outcomes is imperative for designing system-level interventions to reduce the frequency of early and untimely death after thoracic surgery. Stakeholders in health care delivery may want to reconsider current approaches to quality improvement. For instance, the Center for Medicare and

Medicaid Services has promoted value-based purchasing as a means of rewarding hospitals for the quality of care they provide patients. Among their quality metrics are process of care metrics that aim to prevent complications, for example, infections (Surgical Care Improvement Project), which incidentally are extraordinarily rare events (0.3%) after pulmonary surgery.[8] Efforts to improve the quality of care may be bolstered by value-based initiatives that also reward hospitals for adopting systems of care that recognize and treat complications early. Supporting this assertion is the Agency for Healthcare Research and Quality's and National Quality Forum's endorsement of failure to rescue as a quality measure.[9,10] An increasing focus on failure to rescue represents an opportunity for the STS to align with other national efforts to improve patient outcomes and the delivery of optimal care.

Conflict of Interest Statement

Michael S. Mulligan reports consulting fees from Boston Scientific and Covidien. Douglas E. Wood reports consulting fees from Spiration. All other authors have nothing to disclose with regard to commercial support.

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Discussion

Dr Farjah. There are widespread efforts to improve the quality and value of thoracic surgery in the United States. Early death is a common and generally excepted quality metric assuming, of course, there is adequate adjustment for case mix. To improve quality, we have to understand the mechanisms underlying early death. Complications are, no doubt, the main cause of an untimely surgical death. If you were to imagine taking hundreds of hospitals and rank them according to risk-adjusted mortality, you might guess or hypothesize that the lowest mortality hospitals have the

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lowest complication rates and that the highest mortality hospitals would have the highest complication rates.

A group of researchers from Penn in the 1990s asked this question among a group of patients undergoing cholecystectomy or transurethral prostatectomy, and surprisingly, complication rates did not vary significantly across hospitals. Although these findings do not refute the causal role of a complication leading to a death, it does challenge the idea that the frequency of complications is driving hospital-level variability in mortality. They hypothesized if it wasn't the frequency of complications, perhaps it was the hospital's ability to rescue the patient from a complication.

To test their theory, they calculated the proportion of deaths among those who had a complication and called it failure to rescue. Sure enough, the lowest mortality hospitals had the lowest failure to rescue rates, and the highest mortality hospitals had the highest failure to rescue rates. One limitation of their work was that they used administrative data, and administrative data are notorious for misclassifying postoperative complications but also for risk adjustment. Since then, various investigators have used clinical registries and looked at different surgical populations, including general, vascular, adult cardiac, and congenital heart surgery, and Table summarizes the findings that are seen across these different populations; risk-adjusted mortality rates vary 2-to 4-fold across hospitals. Complications vary by only 10% to 20%. Failure to rescue varies 2- to 4-fold.

These analyses have not been done in patients undergoing pulmonary resection, and accordingly the objectives of our study were to evaluate variation, if any, in complication and failure to rescue rates across hospitals performing lung resection for cancer. We conducted a retrospective multicenter cohort study using STS-GTSD. Adult patients with lung cancer who underwent an operation between 2009 and 2012 were eligible for study. We used a previously published risk adjustment model developed using the STS database to calculate risk-adjusted mortality rates for hospitals, and then we ranked the hospitals by standardized mortality rates, grouped them into quintiles for simplicity of presentation, and compared the complication and failure to rescue rates across those groups. The University of Washington Institutional Review Board considered this research exempt from review because the Duke Clinical Research Institute did not disclose any patient-level data. All the data were transferred in aggregate, so there are tables and figures only. Our study included 30,000 patients who were cared for at 208 participating STS sites. The overall mortality rate for this group was 1.6%. Mortality ranged from 0.7% to 3.2% across hospitals, and the magnitude of variation was more than 4.5-fold. Complication rates varied from 34% to 42% across hospitals. It was a statistically significant difference, and the magnitude of variation was approximately 23%. Failure to rescue rates varied from 1.7% to 6.8% across hospitals. Again, a statistically significant difference was observed, as was a 4-fold magnitude variation. Failure to rescue rates varied with greater magnitude than complication rates across hospitals performing pulmonary resection for lung cancer, and our findings are in line with the findings of others who have studied other surgical populations using clinical registries.

One limitation of our study is that the STS-GTSD does not have enough granularity for us to further understand the mechanisms of early death. Specifically, failure to rescue may result from an inability to recognize a complication, and do so early, or it may be that it's an inability or deficiency in treating aggressively and quickly. It is also possible that our results were confounded by the severity of the complication on presentation. We know from clinical experience in a single institution study that the short-term risk of death is higher for those with more severe complications, so it may be the severity of the complication or failure to rescue that accounts for hospital-level variation in mortality. Unfortunately, there are no population-based databases, administrative, or clinical registries that capture the grade of the severity of a complication.

This line of investigation is important because there is a tremendous amount of effort, resources, and time being directed toward minimizing the frequency of postoperative complications. To the extent that we have level 1 evidence to support those interventions, it is hard to argue against preventing complications. That said, if we want to move the needle with respect to early deaths, we should also consider investing resources in system-level determinants that will rescue patients from a complication when they do occur. System-level factors have been associated with failure to rescue in other settings, but it is unlikely that these variables are modifiable or effective. So for instance, financial resources and a national shortage of nurses might preclude a hospital from simply hiring more nurses with higher educational levels. Rapid response teams are a popularized and increasingly implemented system-level intervention to curb inpatient deaths. A recent clustered randomized trial demonstrated that rapid response teams had no impact on inpatient deaths.

Another problem is that the system-level determinants are not necessarily specific to pulmonary surgery or even cardiothoracic surgery. An example of one is a ward tailored to thoracic or cardiothoracic surgery. Databases are unlikely to provide additional insights into failure to rescue, but quality improvement initiatives might. For example, the Michigan Quality Improvement Collaborative in cardiac surgery implemented the phase of care or mortality, which is essentially a structured, glorified, statewide morbidity and mortality conference. What they found was that potentially up to 50% of deaths after cardiac surgery may have been due to patient selection. You could easily imagine modifying this process so you are looking at patient selection, technical errors, errors in judgment, and patient disease, but also the frequency and causes of failure to rescue with an eye toward system redesign. There are emerging regional collaboratives in thoracic surgery that are partnered with national data that are currently under development, and they will be poised to fill our knowledge gaps about how to avoid untimely deaths and to improve overall care and outcomes.

Dr Cerfolio *(Birmingham, Ala)*. I don't want to just thank the Western for the chance to discuss the article, but for something more profound. I don't have words to thank everybody for all the love and support, the emails, the pat on the backs, and everything everybody gave me when my wife passed away a year and half ago or even less. Everyone knows how Lorraine and I felt about this meeting, that it's a family, and I appreciate that. I don't have words to express my thanks for that. The reason I mention it is because I heard a conversation outside about the return on investment of becoming a member of The Western

Thoracic Surgical Association. In other words, the fees, are the meetings good enough? Do the fees warrant that? Or the science? Or the children's programs? I would say that having another family is priceless, so I think the return on investment cannot even be quantified.

First, you presented that really well, so well that I'm going to be even kinder as we go on. I have 2 quick questions for you because I know time is of the essence. You have shown a beautiful surrogate for excellence, but you have shown 2 other surrogates that everyone in this room has used for 20 years. You did not tell me yours was better, and that is risk-adjusted mortality. You showed me it was 4-fold, and this new surrogate failure to rescue is 4-fold. Then we talked about hospital volume; you quickly put that slide up there. So we had 10,000 patients in the hospital that was one, and the next one closest had 6700 patients. Can you tell me if the hazard ratio was higher for your new surrogate compared with what I have been using for the last half a century?

Dr Farjah. I cannot tell you because we did not do that analysis. We looked at the adjusted odds ratio for failure to rescue comparing high with low mortality hospital. You mentioned the 4-fold variability in mortality. We did not look at volume and outcome because Kozower and colleagues have used the STS database to look at this, and they did not find a relationship, but clearly....

Dr Cerfolio. But that was a different dataset than what you have shown us.

Dr Farjah. Okay.

Dr Farjah. There is some empirical evidence of a volume–outcome relationship. You mentioned that for the risk-adjusted mortality….

Dr Cerfolio. Right.

Dr Farjah. ….of the group with lowest mortality. They had a disproportionally higher volume of patients. We did not analyze that explicitly, so I cannot tell you about a volume–outcome relationship. I think your question is getting at the following issue: Before we adopt new metrics, we should demonstrate their value.

Dr Cerfolio. Agreed.

Dr Farjah. Above and beyond old ones. Unfortunately, in quality improvement, demonstration of value is not always done. For instance, the National Quality Forum and Agency for Healthcare Research and Quality have already endorsed these metrics.

Dr Cerfolio. Agreed.

Dr Farjah. Without the evidence you're asking for.

Dr Cerfolio. To argue for you, the other hospitals were not, but then they went up in hospitals 4 and 5.

Dr Farjah. Yes.

Dr Cerfolio. My second question is, so anytime we hear a presentation, we want to say, what can we do to get better? Is it really failure to rescue because we diagnose the problem quicker? Or is it that we treat it quicker? There's a big difference because sometimes it's hard to reoperate on patients, and sometimes we diagnose things.

Dr Farjah. Yes.

Dr Cerfolio. But we do not act on them quickly enough. Can you tell me what you think? Because I know the database will not tell you that.

Dr Farjah. Agreed.

Dr Cerfolio. What do you think is more important? Is it the quickness to diagnose or the quickness and agility to treat it?

Dr Farjah. I think it's probably both. It depends on the circumstance. You mention that one might diagnose bleeding but might be reluctant to go back and operate. That's one example. Another example is one neglects someone who could be having a complication because one is not looking for problems or diagnosing them early. So I do not know which one's more dominant or if they are equal, but I suspect both contribute.

TABLE E1. Comparison of measured characteristics of patients with and without missing covariate data

	Complete covariate data n = 30,000	Missing covariate data n = 5620	*P* value
Median age, y (range)	68 (18-99)	67 (18-94)	<.001
Men	47%	47%	.444
Median predicted FEV_1 (range)	80 (10-150)	79 (10-147)	.002
Median predicted DLCO (range)	70 (10-150)	70 (10-150)	<.001
ASA			.375
I	0.4%	0.6%	
II	15%	15%	
III	74%	74%	
IV	11%	10%	
V	0.02%	0.05%	
Zubrod			.578
0	39%	39%	
1	56%	54%	
2	4.2%	4.4%	
3	0.6%	1.4%	
4	0.1%	0.6%	
5	0.04%	0.1%	
Extent of resection			<.001
Wedge	16%	33%	
Segmentectomy	3.1%	3.8%	
Lobectomy	71%	54%	
Sleeve	1.5%	1.6%	
Bilobectomy	3.3%	2.7%	
Pneumonectomy	4.9%	4.2%	
NOS	0.7%	1.1%	
VATS	50%	52%	.026

ASA, American Society of Anesthesiologists; *DLCO*, diffusing capacity of the lungs for carbon monoxide; *FEV_1*, forced expiratory volume in 1 second; *NOS*, not otherwise specified; *VATS*, video-assisted thoracoscopic surgery.

TABLE E2. Results with missing data imputation

	Overall	Very low	Low	Medium	High	Very high	*P* value	*P* trend
Hospitals	213	42	43	43	43	42	—	
Patients	35,620	12,932	5212	4214	5198	8064	—	
Operative mortality	1.7%	0.8%	1.2%	1.7%	2.4%	3.0%	—	
Median age, y (25th-75th percentile)	68 (60-74)	68 (60-74)	68 (60-75)	68 (60-74)	68 (60-75)	67 (60-74)	<.001	<.001
Men	47%	47%	45%	48%	48%	47%	.053	.204
Race								
White	86%	88%	84%	82%	88%	87%	<.001	.138
Black	8.6%	7.7%	9.9%	8.8%	7.8%	9.5%	<.001	<.001
Other	4.8%	4.2%	6.4%	9.1%	3.8%	3.2%	<.001	.012
Comorbidity								
CHF	3.0%	2.5%	3.1%	2.9%	3.4%	3.3%	<.001	<.001
CAD	21%	21%	22%	19%	23%	21%	<.001	.214
HTN	60%	60%	61%	60%	62%	60%	<.001	.002
PVD	9.6%	8.9%	9.3%	10%	11%	9.4%	<.001	.001
CVD	7.9%	7.6%	7.5%	8.1%	7.2%	8.9%	.009	.004
COPD	36%	33%	39%	38%	37%	38%	<.001	<.001
Diabetes	18%	17%	19%	18%	18%	18%	.053	.026
Dialysis	0.6%	0.5%	0.6%	0.7%	0.5%	0.7%	.319	.062
Steroids	3.6%	4.0%	2.8%	3.8%	3.7%	3.6%	.003	.466
Prior CTS	16%	16%	15%	18%	15%	15%	.003	.657
Preoperative chemotherapy	9.7%	9.7%	9.5%	9.2%	9.9%	10%	.195	.136
Preoperative radiation	8.3%	8.5%	8.3%	6.4%	8.1%	9.2%	<.001	.318
Median predicted FEV_1 (25th-75th percentile)	80 (66-94)	80 (65-94)	79 (65-93)	82 (68-95)	79 (65-94)	80 (65-94)	<.001	.659
Median predicted DLCO (25th-75th percentile)	70 (56-86)	71 (57-86)	68 (54-84)	75 (61-90)	69 (55-84)	69 (56-84)	<.001	.004
ASA							<.001	<.001
I	0.4%	0.4%	0.6%	0.2%	0.3%	0.5%		
II	15%	16%	17%	14%	9.8%	18%		
III	74%	73%	72%	78%	78%	70%		
IV	10%	11%	9.8%	8.2%	11%	11%		
V	0.03%	0.02%	0.08%	0.05%	0%	0.02%		
Zubrod							<.001	<.001
0	39%	38%	41%	46%	35%	37%		
1	56%	59%	54%	50%	56%	57%		
2	4.2%	2.8%	4.2%	2.9%	7.4%	5.2%		
3	0.8%	0.7%	0.9%	0.6%	1.4%	0.6%		
4	0.2%	0.2%	0.2%	0.1%	0.1%	0.2%		
5	0.04%	0.02%	0.02%	0.3%	0.04%	0.0%		
Extent of resection							<.001	.013
Wedge	18%	20%	17%	18%	19%	16%		
Segmentectomy	3.2%	3.3%	3.2%	2.5%	4.8%	2.3%		
Lobectomy	68%	65%	71%	70%	68%	71%		
Sleeve	1.5%	1.9%	1.2%	0.9%	1.4%	1.5%		
Bilobectomy	3.2%	3.3%	3.0%	3.4%	2.6%	3.4%		
Pneumonectomy	4.8%	5.5%	4.3%	4.0%	4.1%	5.0%		
NOS	0.8%	1.1%	0.7%	0.8%	0.4%	0.5%		
VATS	50%	48%	49%	54%	57%	47%	<.001	.110
Pathologic stage							.271	.676
I	61%	61%	62%	62%	61%	61%		
II	20%	19%	19%	19%	20%	20%		
IIIA	11%	11%	10%	11%	11%	11%		
IIIB	2.7%	2.7%	2.7%	2.9%	2.9%	2.4%		
Complications								
Any	36%	34%	37%	35%	37%	40%	<.001	<.001
Major	8.3%	7.3%	7.9%	7.6%	9.0%	9.9%	<.001	<.001
Pulmonary	21%	19%	21%	20%	23%	22%	<.001	<.001
Atrial arrhythmia	11%	11%	11%	9.9%	11%	12%	<.001	.003

(Continued)

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TABLE E2. Continued

	Overall	Very low	Low	Medium	High	Very high	*P* value	*P* trend
Death after complication								
Any	4.0%	2.2%	3.0%	4.0%	5.6%	6.7%	<.001	<.001
Major	14%	8.7%	11%	15%	19%	21%	<.001	<.001
Pulmonary	6.0%	3.5%	4.6%	5.9%	7.7%	9.8%	<.001	<.001
Atrial arrhythmia	4.7%	2.7%	3.3%	4.8%	7.4%	7.2%	<.001	<.001

ASA, American Society of Anesthesiologists; *CAD*, coronary artery disease; *CHF*, congestive heart failure; *COPD*, chronic obstructive pulmonary disease; *CTS*, cardiothoracic surgery; *CVD*, cardiovascular disease; *DLCO*, diffusing capacity of the lungs for carbon monoxide; *FEV_1*, forced expiratory volume in 1 second; *HTN*, hypertension; *NOS*, not otherwise specified; *PVD*, peripheral vascular disease; *VATS*, video-assisted thoracoscopic surgery.