Outcomes and Costs for Major Lung Resection in the United States: Which Patients Benefit Most From High-Volume Referral?

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Background. **Accountable care organizations are designed to improve value by decreasing costs and maintaining quality. Strategies to maximize value are needed for high-risk surgery. We wanted to understand whether certain patient groups were differentially associated with better outcomes at high-volume hospitals in terms of quality and cost.**

Methods. **In all, 37,746 patients underwent elective major lung resection in 1,273 hospitals in the Nationwide Inpatient Sample from 2007 to 2011. Patients were stratified by hospital volume quartile and substratified by preoperative mortality risk, age, and chronic obstructive pulmonary disease status. Mortality was evaluated using clustered multivariable hierarchical logistic regression controlling for patient comorbidity, demographics, and procedure. Adjusted cost was evaluated using generalized linear models fit to a gamma distribution.**

Results. **Patients were grouped into volume quartiles based on cases per year (less than 21, 21 to 40, 40 to 78, and more than 78). Patient characteristics and procedure mix differed across quartiles. Overall, mortality decreased across volume quartiles (lowest 1.9% versus highest 1.1%, $p < 0.0001$). Patients aged more than 80 years were associated with greater absolute and relative mortality rates than patients less than 60 years old in highest volume versus lowest volume hospitals (age more than 80 years, 4.2% versus 1.3%, $p < 0.0001$, odds ratio 3.31, 95% confidence interval: 1.89 to 5.80; age less than 60 years, 1.0% versus 0.8%, $p = 0.19$, odds ratio 1.38, 95% confidence interval: 0.74 to 2.56). Patients with high preoperative risk (more than 75th percentile) were also associated with lower absolute mortality in high-volume hospitals. Adjusted costs were not significantly different across quartiles or patient strata.**

Conclusions. **Older patients show a significantly stronger volume-outcome relationship than patients less than 60 years of age. Costs were equivalent across volume quartile and patient strata. Selective patient referral may be a strategy to improve outcomes for elderly patients undergoing lung resection.**

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Healthcare costs currently consume 18% of US gross domestic product [1], yet the United States ranks low in terms of the quality of care [2]. To address this discrepancy, the Affordable Care Act authorized the creation of accountable care organizations (ACOs), which are designed to improve quality and reduce cost through incentives for the delivery of efficient and coordinated care. Therefore, the balance between cost and outcomes is an emerging policy priority. Surgery is a major focus of these efforts, but specific strategies are needed. One such approach may be to match appropriate patients to hospitals that have the expertise, resources, and systems to effectively manage their conditions. One such large-scale effort in this domain has been the Leapfrog Group volume-based referral program [3]; the Veterans' Affairs complexity initiative to route complex surgery to hospitals with the structures and staffing to support those patients is another example [4].

Lung resection is an ideal target for these efforts because it is a common and costly procedure performed in the United States, with national costs estimated at more than 1.9 billion dollars annually [5]. Additionally, it continues to be performed at hospitals of varying size and complexity by thoracic and general surgeons alike [6, 7]. This heterogeneity may create an opportunity to determine whether different subsets of patients can be safely and efficiently treated in hospitals of varying resources, size, and expertise. Although the impact of risk-based

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Abbreviations and Acronyms

ACO = accountable care organization
CI = confidence interval
COPD = chronic obstructive pulmonary disease
HV = high volume
LV = low volume
MV = moderate volume
NIS = Nationwide Inpatient Sample
OR = odds ratio
VHV = very high volume

referral on mortality has been evaluated in other populations [8–10], specific patient criteria that should trigger referral to resource intensive, presumably high cost hospitals for surgery have not been well defined. Moreover, the impact that such strategies might have on cost is also unknown.

Hence, we sought to determine whether we could identify specific patient groups for high-volume (HV) referral. We hypothesized that patient groups who were at higher risk for lung surgery, such as those who were elderly, with chronic obstructive pulmonary disease (COPD), or with high preoperative mortality risk would be associated with improved outcomes at HV hospitals. Furthermore, we hypothesized that, although overall cost has been shown not to vary with volume, there would be differences in the cost-volume relationship after stratification by patient characteristics.

Material and Methods

Data Sources

Patient-level discharge data were obtained using the Nationwide Inpatient Sample (NIS) for years 2007 to 2011. The NIS is a stratified, survey-weighted 20% sample of all US hospitals provided by the Healthcare Cost and Utilization Project of the Agency for Healthcare Quality Research [11]. The NIS contains data on procedures, comorbid conditions, insurance status, and demographic characteristics. It also contains certain hospital characteristics (size, teaching status, ownership, rural/urban location) as well as inpatient charges and costs. This study was exempted by the Partner's Health System Institutional Review Board.

Hospital Volume

Hospital volume has been used nationally as a surrogate for quality and in regionalization efforts. In this analysis, however, we used volume as a surrogate for other hospital characteristics, such as size, teaching status, hospital complexity, and advanced technology and resources [12]. We used volume cutoffs that grouped patients equally among quartiles—namely, low volume (LV), moderate volume (MV), high volume (HV), and very high volume (VHV)—as prior researchers have done [13–16], which maximizes statistical power and yields the additional benefit of yielding policy-relevant volume cutoffs. Lastly, we include any lung resection performed at a given hospital in our volume calculations, and not only those performed for cancer, as that yields the most accurate representation of a hospital's thoracic surgical volume and experience.

Patient Study Population

Included patients underwent a major lung resection during the study period, as defined by International Classification of Diseases, 9th edition, codes for lung lobectomy, segmentectomy and pneumonectomy (Appendix 1). That resulted in an initial cohort of 43,609 patients. Patients were excluded if they had missing admission, discharge, or sex information (n = 628), were younger than 18 years old (n = 685), or underwent an emergent lung resection (n = 4,550). That left a final study cohort of 37,746 patients undergoing elective major lung resections.

Outcomes and Covariates

Our study focused on two main outcomes: inhospital mortality and inpatient costs. Inhospital mortality is defined as coded within the NIS. Inpatient costs were converted from NIS charges using the hospital-specific cost-to-charge ratios with the NIS, and adjusted for inflation to 2011 dollars using the medical component of the consumer price index [17]. Comorbidities were scored based on the Walraven comorbidity index (a weighted score of the Elixhauser comorbidity variables [18]), which has been well validated and used by others [19, 20]. Lastly, the cost analysis was adjusted for the wage index, which is a measure of the local costs of hospital labor [21] as well as hospital region to account for regional cost differences.

Stratification Variables

Three variables were chosen a priori for stratification of patients. The first was age, which was divided into four groups by decade: less than 60 years old, 60 to 70 years old, 70 to 80 years old, and more than 80 years old. Chronic obstructive pulmonary disease was defined by International Classification of Diseases, 9th edition, codes (49.1 to 49.6, 50.64) as a potentially more complex group of patients. Finally, we chose patient preoperative risk of mortality as a final stratification variable, as these patients may differentially benefit from the resources that HV hospitals provide. Expected mortality risk was calculated using logistic regression with covariates for patient characteristics (age, sex, race, insurance, income, diagnosis, comorbidities, and procedure). The predictive model demonstrated excellent discrimination (C statistic 0.83). Preoperative mortality risk was dichotomized to form two groups, high and low. High-risk patients were defined as those at more than the 75th percentile of preoperative predicted mortality, corresponding to more than 1.95% predicted mortality risk.

Statistical Analysis

We used the Rao-Scott χ^2 test to compare patient-level demographic, comorbidities, and procedural characteristics