

Volume-Outcome Relationships in Thoracic Surgery

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KEYWORDS

• Volume outcome • Thoracic surgery • Cancer resection • Lung cancer • Esophageal cancer

KEY POINTS

- Most thoracic surgery studies indicate that hospital and surgeon procedure volume are inversely associated with mortality.
- Controversy exists regarding the strength and validity of this volume-outcome association.
- Because thresholds of procedure volume are used to recommend the regionalization of care, investigation of the volume-outcome relationship is imperative.
- Careful examination of the literature demonstrates that lung and esophageal cancer resection volume is not strongly associated with mortality and should not be used as a proxy measure for quality.

INTRODUCTION

Surgeons and hospitals are under incredible pressure to improve the quality of care they deliver. However, debate exists regarding which outcomes measures should be used to reflect surgical quality.¹ Procedure volume has been studied as a predictor of surgical outcomes since Luft and colleagues² first promoted the volume-outcome relationship in 1979. Volume is an appealing predictor of surgical outcomes because it is easily measured, inexpensive, and because it makes intuitive sense. Higher-volume hospitals are more likely to have the structural and process measures in place to achieve better outcomes.¹ Most studies examining the volume-outcome relationship after lung cancer resection conclude that patients in hospitals with higher procedure volumes have significantly lower mortality risk.³⁻⁶ These studies show a decrease of 1% to 4% in 30-day mortality rates between the highest- and lowest-volume centers.

Methodologic reviews of volume-outcome studies have noted serious concerns with the statistical methods used to identify this association.^{7,8} Despite these concerns, procedure volume has been used to recommend the regionalization of surgical procedures using selected volume thresholds.⁹ The volume-outcome association is complex, and debate continues as to how it should be used by public and private organizations caring for patients.^{10,11} Furthermore, there are a range of unintended consequences that need to be considered if procedure volume is used to direct patient referrals and regionalize health care.¹⁰

EVIDENCE SUPPORTING THE VOLUME OUTCOME RELATIONSHIP IN LUNG CANCER RESECTION

The seminal article describing the relationship between increasing case volume and improved outcomes was published by Luft and colleagues² in 1979. They demonstrated that hospitals in which

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certain complicated operations were performed 200 or more times annually had case-adjusted death rates up to 41% lower than hospitals with lower volumes. Twenty years later, the interest in the volume-outcome association in lung cancer resection increased exponentially, led by publications from Birkmeyer and colleagues³ and Bach and colleagues.⁴ Bach and colleagues⁴ investigated the volume-outcome relationship using patients from the linked Surveillance, Epidemiology, and End Results Program and Medicare Databases, and who underwent surgery in a hospital that participates in the Nationwide Inpatient Sample. This article was unique in that it looked at 5-year survival rather than in-hospital or 30-day survival. The authors divided volume into five groups (quintiles) and used traditional survival modeling techniques to examine the association between hospital procedure volume and survival. The article concluded that patients who undergo resection for lung cancer at the highest-volume hospitals had an 11% increase in 5-year survival and had lower complication rates. The following year (2002), Birkmeyer and colleagues³ also published their findings on the volume-outcome relationship. Using data from Medicare claims and the Nationwide Inpatient Sample, they investigated the relationship between hospital procedure volume and 30-day mortality for 14 different procedures, including lung cancer resection. The authors also divided volume into arbitrarily defined categories and concluded that in the absence of other information about the quality of surgery at the hospitals near them, Medicare patients undergoing selected procedures can significantly reduce their risk of operative death by selecting a high-volume hospital.

Birkmeyer and colleagues¹² also demonstrated that surgeon volume is directly related to outcome. Using information from the national Medicare claims database, they examined mortality among 474,108 patients who underwent one of eight cardiovascular procedures or cancer resections. They demonstrated that surgeon volume was inversely related to operative mortality for all eight high-risk operative procedures, including lung cancer resection. The adjusted odds ratio for postoperative mortality for low-volume surgeons compared with high-volume surgeons was 1.24 for lung cancer resection. In addition, they demonstrated that much of the observed association between hospital volume and operative mortality was mediated by individual surgeon volume. The authors concluded that patients may be able to improve their chances of survival substantially, even at high-volume hospitals, by selecting surgeons who perform particular operations frequently.

METHODOLOGIC ISSUES WITH CURRENT EVIDENCE

There are serious methodologic concerns with the three landmark studies cited previously and most volume-outcome studies reported in the literature. First, most volume-outcome studies place procedure volumes into arbitrarily defined categories (tertiles, quartiles, quintiles), rather than treating volume as a continuous variable. This results in a loss of information and arbitrarily inflates the effect of volume on mortality risk when measured by odds ratios.¹³ It also makes odds ratios difficult to compare from one study to the next because studies use different volume category partitioning. The preferred method for studying the relationship between procedure volume and mortality is to represent volume as a continuous variable and assess its linear and nonlinear relationships with mortality. This can best be accomplished using restricted cubic spline regression.^{14,15} Spline regression creates a functional representation of the shape of the relationship between volume and the outcome of mortality using piecewise polynomial functions. Spline regression is the most accurate method to characterize nonlinearity present in the volume-outcome relationship, because it uses all the data points to estimate the shape of an association between an exposure (volume) and the outcome (mortality).^{11,16-18} Unfortunately, most researchers are not familiar with this technique and have not used it to determine if a true threshold value exists for the volume-outcome relationship in lung cancer resection.

A second common problem is the use of traditional multivariable logistic regression models to test the significance of the relationship between procedure volume and inpatient mortality.^{8,11} When the predictor variables include patient-level variables (age, sex, comorbidity) and hospital-level variables (procedure volume), it is essential to use multilevel modeling techniques, such as hierarchical generalized linear models. This modeling technique accounts for correlated outcomes within hospitals and adjusts for potentially overdispersed variance estimates. It is imperative that volume-outcome studies use hierarchical modeling, including hospitals as random effects in the models, to allow the relationship between volume and inpatient death to be different across hospitals.¹⁹ Urbach and Austin²⁰ compared the use of conventional statistical models with multilevel regression models in volume-outcome analyses. They determined that the modeling techniques yield substantially different results, with conventional models overestimating the

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