The effect of volume on esophageal cancer resections: What constitutes acceptable resection volumes for centers of excellence?

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Objective: Volume–outcome relationships for esophageal cancer resection have been well described with centers of excellence defined by volume. No consensus exists for what constitutes a ''high-volume'' center. We aim to determine if an objective evidence-based threshold of operative volume associated with improvement in operative outcome for esophageal resections can be defined.

Methods: Retrospective analysis was performed on patients undergoing esophageal resection for cancer in the 1998 to 2005 Nationwide Inpatient Sample. A series of multivariable analyses were performed, changing the resection volume cutoff to account for the range of annual hospital resections. The goodness of fit of each model was compared by pseudo r^2, the amount of data variance explained by each model.

Results: A total of 4080 patients underwent esophageal resection. The median annual hospital resection volume was 4 (range: 1–34). The mortality rate of ''high-volume'' centers ranged from 9.94% ($\geq$2 resection/year) to 1.56% ($\geq$30 resections/year). The best model was with an annual hospital resection volume greater than or equal to 15 (3.87% of data variance explained). The difference in goodness of fit between the best model and other models with different volume cutoffs was 0.64%, suggesting that volume explains less than 1% of variance in perioperative death.

Conclusion: Our data do not support the use of volume cutoffs for defining centers of excellence for esophageal cancer resections. Although volume has an incremental impact on mortality, volume alone is insufficient for defining centers of excellence. Volume seems to function as an imperfect surrogate for other variables, which may better define centers of excellence. Additional work is needed to identify these variables.

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Resection of the esophagus, either total or partial, is a complex surgical procedure that carries a relatively high risk of operative mortality. Because of this, a significant body of work has focused on the relationship between volume and outcome for esophageal resections. The beneficial effect of increased volume of esophagectomy on outcome has been clearly demonstrated in multiple studies.[1-4] On the basis of the results of these and similar studies, esophageal resection has been identified as a potential procedure for volume-based regionalization, and as such resection volume has been proposed as a measurement for defining centers of excellence. An example of this is the Leapfrog Group, which defined criteria for ''evidence-based hospital referral'' for esophageal resection as hospitals performing a minimum of 13 resections per year.[5]

In addition to the volume cutoff for esophageal resections set by the Leapfrog Group, various other thresholds for defining high-volume centers have been used in the literature. These annual hospital volume thresholds range from 6 to 20 esophageal resections per year.[2,6,7] However, these cutoff points have often been imprecisely or arbitrarily defined, and there are little data to support the use of specific volume cutoffs.

The aim of this study was to determine if an objective, evidence-based threshold of operative volume associated with improved hospital-level outcomes for esophageal resection for cancer could be defined. Should this threshold be identified, it could potentially be considered a candidate in the criteria for defining high-volume hospitals for esophageal resection.

MATERIALS AND METHODS

Data Source

A retrospective analysis was performed using patient data collected from the Nationwide Inpatient Sample (NIS) file between 1998 and 2003. The NIS database comprises discharge records approximating a 20% sample of hospital discharges in the United States and is maintained by the Agency for Healthcare Research and Quality as part of the Healthcare Cost and Utilization Project.[8] It approximates 7 million patient discharge records per year, originating from approximately 1000 different hospitals per year nationwide. Data available within the NIS include patient and hospital demographics, payer information, treating and concomitant diagnoses, inpatient

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Abbreviations and Acronyms
AUC = area under the curve
ICD-9 = International Classification of Diseases, Ninth Revision
NIS = Nationwide Inpatient Sample

procedures, inpatient mortality, and length of stay.[9] This study was approved by the Johns Hopkins Institutional Review Board, who exempted the need for patizent consent.

Patient Population

Initial inclusion criteria for this study were patients from the NIS database older than 17 years of age admitted with the diagnosis of esophageal cancer as identified by the International Classification of Diseases, Ninth Revision (ICD-9) diagnosis codes (150.X).[10] Inclusion criteria was further limited to patients who underwent esophageal resection as identified by ICD-9 Clinical Modification procedure codes of 42.4 and 42.40 (esophagectomy NOS), 42.41 (partial esophagectomy), 42.42 (total esophagectomy), and 43.99 (esophagogastrectomy).[2]

Statistical Analysis

Multivariable analysis was performed with in-hospital death as the outcome of record from the discharge summaries. Independent variables included annual hospital resection volume, teaching status of the hospital where the procedure was performed, the year the procedure was performed, patient age, gender, race, and comorbidities as measured by the Charlson Index. The NIS dataset defines teaching hospital status as hospitals that have any American Medical Association-approved residency program, belong to the Council of Teaching Hospitals, or have a ratio of no more than 4:1 beds to full-time equivalent interns and residents.[11]

Patient comorbidities were standardized via calculation of the Deyo modification of the Charlson Index[12,13] per the methods of Romano and colleagues.[14] A standardized calculation of patient health, the Charlson Index is determined by weighted scoring of comorbidities, including cardiac, vascular, pulmonary, neurologic, endocrine, renal, hepatic, gastrointestinal, and immune diseases, as well as any documented history of cancer.

Individual annual hospital procedure volume was determined by calculating the number of esophageal resections performed using NIS-assigned unique hospital identification numbers. The annual hospital mortality rate for esophageal resections was calculated using the NIS annual hospital resection volume for esophageal resections.

Esophageal resection volume was included as a dichotomous variable to identify the volume cutoff that best models outcome. A series of sequential multiple logistic regression models with a dependent variable of in-hospital death; a set of common independent variables including patient age, gender, race, and Charlson Index of comorbidities, procedure year, and hospital teaching status; and a sequentially changing independent variable of dichotomized annual hospital resection volume were tested. This sequentially changing variable of annual hospital resection volume was dichotomized at 2 continuously up to 34, accounting for all of the esophageal resections in the NIS database in the time period studied. The resection volumes within this range are nearly continuous.

Each volume threshold dichotomizes the data and creates 2 categories for comparison: hospitals with an annual resection volume less than that cutoff and hospitals with an annual resection volume greater than or equal to that cutoff. Each volume threshold is then taken forward in the multivariable regression analysis as the independent variable.

Statistical analysis was performed using the software package STATA 10.0 (StataCorp LP, College Station, Tex). Bivariate analysis of categoric data was performed using the chi-square test. Analysis of continuous data was performed using the Student *t* test. Multivariable analysis was performed using linear and logistic regression models. The goodness of fit, a measurement of the amount of variability in the data explained by the model, was tested for each model by calculation of McFadden's pseudo r^2 and the area under the curve (AUC). McFadden's pseudo r^2 is one such measure of goodness of fit and has been re-scaled from 0% to 100% for ease of interpretation and comparison. It represents the percent of variance in a data pattern that is explained by the set of variables in a particular model. For instance, a model explaining 7% of the variation in the data would have a pseudo r^2 of 0.07. Results are primarily reported as pseudo r^2.[15-17] AUC is also reported and improves as the value approaches 1.

RESULTS

Patient Population

Analysis of the NIS dataset identified 53,168 patients with the diagnosis of esophageal cancer, of whom 4080 (7.7%) underwent esophageal resection, as defined by the previously listed ICD-9 Clinical Modification codes. Of these patients, 79.6% were male, and the median age was 64 years. These esophagectomies were performed at 1506 hospitals. The median annual hospital resection volume was 4, with the range from 1 to 34 (interquartile range 2–9). Of the patients studied, 83.9% were white, 8.8% were black, and the remainder were of unreported race. A total of 2883 patients (70.7%) underwent resection at teaching hospitals. The median Charlson Comorbidity Index for the 4080 patients studied was 3, with an interquartile range of 2 to 8 and a range of 2 to 14 (of a possible range from 0 to 33). Between 444 and 552 patients underwent esophageal resection per year. There were 387 in-hospital deaths for this patient group, resulting in an overall in-hospital mortality rate of 9.49%. See Table 1 for demographics.

Hospital Volume–Mortality Relationship

The unadjusted annual in-hospital mortality rate was calculated for each hospital. This ranged between 0% and 100%, with a median value of 0 and a mean value of 11.5% (Figure 1).

In-Hospital Mortality

A series of multiple logistic regression models were tested with a dependent variable of in-hospital death and common independent variables, including patient age, gender, race, and Charlson Index of comorbidities, procedure year, and hospital teaching status. In each model a sequentially changing variable of annual hospital resection volume threshold was inserted, dichotomizing volume into ''less than'' versus ''greater than or equal to'' that volume threshold. The mortality of patients at ''high-volume'' and ''low-volume'' hospitals defined at each threshold level and the various representations of goodness of fit (McFadden's pseudo r^2 and AUC of that particular multiple logistic regression model) are presented in Table 2.

The values represent the average mortality rate for all hospitals with esophagectomy volumes less than the volume