ORIGINAL ARTICLE

Teaching Hospital Status and Operative Mortality in the United States

Tipping Point in the Volume-Outcome Relationship Following Colon Resections?

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Objective: To compare risk- and volume-adjusted outcomes of colon resections performed at teaching hospitals (THs) vs non-THs to assess whether benign disease may influence the volume-outcome effect.

Design: Retrospective data analysis examining colon resections determined by *International Classification of Diseases, Ninth Revision, Clinical Modification* classification performed in the United States from 2001 through 2005 using the Nationwide Inpatient Sample (NIS) and the Area Resource File (2004). Patient covariates used in adjustment included age, sex, race, Charlson Index comorbidity score, and insurance status. Hospital covariates included TH status, presence of a colorectal surgery fellowship approved by the Accreditation Council for Graduate Medical Education, geographical region, institutional volume, and urban vs rural location. County-specific surgeon characteristics used in adjustment included average age of surgeons and proportion of colorectal board-certified surgeons within each county. Environmental or county covariates included median income and percentage of county residents living below the federal poverty level.

Setting: A total of 1045 hospitals located in 38 states in the United States that were included in the NIS.

Patients: All patients older than 18 years who had colon resection and were discharged from a hospital included in the NIS.

Main Outcome Measures: Operative mortality, length of stay (LOS), and total charges.

Results: A total of 115 250 patients were identified, of whom 4371 died (3.8%). The mean LOS was 10 days. Fewer patients underwent surgical resection in THs than in non-THs (46 656 vs 68 589). Teaching hospitals were associated with increased odds of death (odds ratio, 1.14) ($P=.03$), increased LOS ($P=.003$), and a nonsignificant trend toward an increase in total charges ($P=.36$).

Conclusions: With the inclusion of benign disease, colon surgery displays a volume-outcome relationship in favor of non-THs. Inclusion of benign disease may represent a tipping point.

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TEACHING HOSPITALS (THs) are responsible for training surgical residents and fellows in the United States, which requires a considerable allocation of resources from the federal government and a large capital outlay to offset the costs of training. The involvement of trainees in operative and clinical care has raised concerns about potential contribution to negative outcomes, and studies have endeavored to address these concerns.[1,2] The most convincing arguments in favor of outcomes in THs, however, pertain to patients undergoing complex surgical procedures who benefit from the presence of board-certified specialty surgeons, multidisciplinary teams, and intensive care unit staffing. These characteristics improve outcomes and consequently attract patients to teaching institutions and high-volume medical centers. There is a growing interest in the interaction between TH status and volume and the individual and combined effects of these characteristics on outcomes.[2] Dimick et al[3] demonstrated that teaching status is not a predictor of operative mortality after adjusting for hospital volume. Studies from state and national databases have also been used to demonstrate better outcomes for complex cardiovascular and general surgical oncology procedures performed in high-volume THs.[3-6] Meguid et al[7] reported improved outcomes when lung resections were performed in THs. These outcomes predominantly pertained to comparatively complex oncological resections of the esophagus, pancreas, liver, and lung

and were performed by specialty-trained surgeons with ready accessibility to adjunctive clinical resources.

In contrast to complex procedures performed at THs, colon surgery is more commonly performed by general surgeons in non-THs and comparatively less sophisticated settings.[8] There is some evidence within the literature to support improved outcomes in teaching hospitals for patients undergoing resections for colon and rectal cancer on the basis of the volume-outcome ratio.[9-11] Few reports, however, describe the inclusion of benign colonic disease in these considerations. Less specialized procedures for benign disease make up the bulk of surgical volume and colon resections performed in non-THs and the United States as a whole.[8,12] Khuri et al,[13] in an analysis of the Veterans Affairs National Surgical Quality Improvement Program data showed that, following volume adjustment, care at non-THs was associated with lower charges and decreased length of stay (LOS) compared with THs. This may also be true for colon resections performed in non-THs. We sought to compare risk- and volume-adjusted perioperative outcomes as they relate to all colon resections except rectal and emergency resections performed at THs vs non-THs over a 5-year period in the United States, hypothesizing that there would be no significant differences in risk-adjusted in-hospital mortality, LOS, or total charges.

METHODS

DATA SOURCES

A retrospective linked analysis was performed of data from the National Inpatient Sample (NIS) and the Area Resource File (ARF). Patient data were abstracted over a 5-year period (2001-2005) from the 2006 NIS, a nationally representative database of all discharge data from 1045 hospitals located in 38 states in the United States. The NIS is maintained by the Agency for Healthcare Research and Quality as part of the Healthcare Cost and Utilization Project.[3] It is a 20% representative sample of all hospital charges in the Unites States stratified by geographic region, hospital size, urban vs rural location, and teaching vs nonteaching status. The ARF (maintained by the US Department of Health and Human Services, Health Resources and Services Administration, Bureau of Health Professions, Rockville, Maryland) is a nationwide database of health care, economic, and demographic sources including the American Medical Association, American Hospital Association, US Census Bureau, Centers for Medicare & Medicaid Services, Bureau of Labor Statistics, Veterans Administration, and the National Center for Health Statistics and includes aggregate data collected from all 3219 counties in the United States. The ARF is the largest composite health care data set, including over 6000 variables of socioeconomic, health, and demographic details including those from the last US census conducted in April 2000. The sampling error was minimized because the data from all the counties in the United States were used. The criterion for high-volume status was determined from the literature to be 115 colectomies or more per hospital per year.[9]

PATIENT SELECTION

All patients included in the study were older than 18 years and had been discharged from a hospital included in the NIS during the 5-year period between 2001 and 2005. They had each undergone a colon resection at either a TH or a non-TH. We examined all elective colon resections with the exclusion of rectal procedures and those performed on an emergency basis. *International Classification of Diseases, Ninth Revision, Clinical Modification* classification codes pertaining to the colon used for inclusion criteria were the following: 45.71 (multiple segmental resection of large intestine), 45.72 (cecectomy), 45.73 (right hemicolectomy), 45.74 (resection of transverse colon), 45.75 (left hemicolectomy), 45.76 (sigmoidectomy), 45.79 (partial excision of large intestine), and 45.80 (total intra-abdominal colectomy).

OUTCOME VARIABLES

The primary outcome variable was in-hospital mortality. The secondary outcome variables were risk-adjusted LOS and total charges incurred during hospitalization. Frequencies and proportions were calculated for patient level, hospital level, and county level statistics in relation to the 3 outcome variables. Unadjusted and adjusted logistic regression analyses were used to estimate in-hospital mortality, while crude and adjusted linear regression analyses were used to estimate both LOS and total charges. We defined a TH in accordance with American Hospital Association and NIS definitions: it was a member of the Council of Teaching Hospitals (COTH) affiliated with a general surgery residency accredited by the Accreditation Council for Graduate Medical Education (ACGME) or an ACGME-accredited colorectal fellowship at the institution.[14-17] Patient level covariates used in adjustment in both logistic and linear regressions included age, sex, race, Charlson Index comorbidity score,[18] indication for surgery, and insurance status. Hospital level covariates used in adjustment included geographical region, institutional volume, and urban vs rural location. County-specific surgeon characteristics used in adjustment were derived from the American Medical Association Masterfile within the ARF and included average age of surgeons and proportion of colorectal board-certified surgeons within a county. Environmental or county-specific covariates used in adjustment included median income and percentage of county residents living below the federal poverty level. All statistical analyses were performed using Stata Intercooled software, version 10 (StataCorp, College Station, Texas). A list of the 48 ACGME-accredited US colorectal training fellowship programs was obtained from the American Society of Colon and Rectal Surgeons residency Web site.[19]

RESULTS

We identified a total of 115 250 patients between ages 29 and 93 years who had undergone colon resection and were eligible for inclusion in the study. Most were white women. The racial breakdown of the group is as follows: 67 841 whites (80.3%), 8331 blacks (9.9%), 4617 Hispanics (5.5%), 1786 Asians (2.1%), 197 Native Americans (0.2%), and 1731 patients of unknown race (2.1%). The median Charlson Index comorbidity score was 3 (interquartile range [IQR], 2-8) (**Table 1**).

Fewer patients underwent surgical resection in THs than in non-THs (46 656 vs 68 589) (**Table 2**). Of those patients included in the study, 4371 died while in the hospital (3.8%). Women had decreased odds of dying (odds ratio [OR], 0.77; 95% confidence interval [CI], 0.71-0.83) ($P=.03$) and increased odds of shorter LOS (by 0.2 days; 95% CI, 0.1-0.4 days) ($P<.001$) compared with men. After adjusting for patient, hospital, and county-level vari-

ables, we found that THs were associated with increased odds of operative mortality compared with non-THs (OR, 1.14; 95% CI, 1.01-1.29) (P=.03). The median LOS for all hospitals was 8 days (IQR, 6-12 days). After adjustment, we found that teaching hospitals were associated with a statistically significant increase in LOS (0.52 days; IQR, 0.18-0.85 days) (P=.003) compared with non-THs.

Median charges for colon resection were $33 611 (IQR, $21 817-$56 575). Teaching hospitals were associated with a trend toward an increase in total charges, though this was not statistically significant after adjustment (P=.36). To test the importance of the definition of a TH, a sensitivity analysis was performed using an alternative definition based on the presence of an ACGME-accredited colorectal fellowship. This involved the creation of a list of hospitals derived from the original list of 48 ACGME-accredited US colorectal training fellowship programs (obtained from the American Society of Colon and Rectal Surgeons) cross-referenced against the hospitals within the NIS. This separate analysis arrived at the same conclusions for both mortality and LOS and observed no difference for total charges.

Table 1. Patient Demographics of Study Population and Overall Hospital Characteristics for Colon Resection[a]

Characteristic	Finding
Patients, total No.	115 250
Race/ethnicity	
White	67 841/84 503 (80.3)
Black	8331/84 503 (9.9)
Hispanic	4617/84 503 (5.5)
Asian	1786/84 503 (2.1)
Native American	197/84 503 (0.2)
Unspecified	1731/84 503 (2.1)
Female sex	61 764/115 182 (53.6)
Age, median (IQR), y	71 (61-79)
Charlson Index comorbidity score, median (IQR)	3 (2-8)
Hospital characteristics	
Colon cancer resections, No. (%)	63 395 (55.0)
30-d mortality	4371/115 117 (3.8)
LOS, median (IQR), d	8 (6-12)
Total charges, median (IQR), $US	33 611.35 (21 817.22-56 575.57)

Abbreviations: IQR, interquartile range; LOS, length of stay.
[a] Unless otherwise indicated, data are reported as number of patients in the relevant category/number of patients possible in the category (percentage).

COMMENT

Complex surgical procedures performed at high-volume medical centers have an association with better outcomes,[4] which have been attributed to the availability and use of sophisticated clinical amenities and personnel, among other factors. However, most colon resections for both benign and malignant disease in the United States are performed in non-THs by general surgeons rather than board-certified colorectal surgeons.[8] This research suggests that patients undergoing oncology resections in THs may benefit from the availability and use of certain resources but that these resources may be of greater utility for higher-mortality resections than for less complex ones. Research conducted by Schrag et al[9] reaffirmed this notion. Overall mortality following colon resection in this study was lower (3.8%) than that reported by Dimick et al[3] for more complex resections (6.4% for pancreatic procedures, 6.0% for hepatic, and 8.7% for esophageal). These specified procedures benefit most from the adjunctive clinical resources that drive the volume-outcome relationship.[3]

Outcomes following complex surgery reflect the volume-outcome ratio that favors high-volume centers and in many cases THs.[4] Superior outcomes have thus been demonstrated in THs following pancreatic, hepatic, and esophageal cancer resections.[3] Ayanian and Weissman[20] used the Donabedian conceptual framework of structure, process, and outcome to elaborate on those processes of care within THs that yielded improved outcomes. Billingsley et al[21] postulated that the volume-outcome relationship was less a function of volume alone and more the result of the availability and use of the wide spectrum of clinical services that allowed prompt recognition and treatment of complica-

Table 2. Patient Demographics and Hospital Characteristics for Colon Resection, Stratified by Hospital Status[a]

Characteristic	Teaching Hospital (n=46 656)	Nonteaching Hospital (n=68 589)
Race ethnicity		
White	25 470/33 737 (75.5)	42 371/50 766 (83.5)
Black	4640/33 737 (13.8)	3691/50 766 (7.3)
Hispanic	1894/33 737 (5.6)	2723/50 766 (5.4)
Asian	835/33 737 (2.5)	951/50 766 (1.87)
Native American	54/33 737 (0.2)	143/50 766 (0.3)
Unspecified	844/33 737 (2.5)	887/50 766 (1.8)
Female	25 072/46 622 (53.8)	36 690/68 555 (53.5)
Age, median (IQR), y	70 (58-78)	72 (61-80)
Charlson Index comorbidity score, median (IQR)	3 (2-8)	3 (2-8)
Hospital characteristics		
Colon cancer resections, No. (%)	25 489 (54.6)	37 905 (55.3)
In-hospital mortality	1716/46 415 (3.9)	2655/68 497 (3.7)
Length of stay (LOS), median (IQR), d	8 (6-12)	8 (6-12)
Total charges, median (IQR), $US	33 640 (22 142-56 437)	33 596 (21 615-56 661)

Abbreviations: IQR, interquartile range; LOS, length of stay.
[a] Unless otherwise indicated, data are reported as number of patients in the relevant category/number of patients possible in the category (percentage).

tions.[21] It is likely that colon surgery generally, without the inclusion of cancer resections, displays a volume-outcome relationship similar to that of other complex surgical oncology procedures such as pancreatic and esophageal resections but does so in favor of non-THs rather than THs. The inclusion of colon resections for benign disease may, in this manner, allow volume to more clearly delineate the demarcation between THs and non-THs.

While the volume-outcome relationship may favor colon cancer resections performed in THs, this advantage might be lost when benign colon disease is factored into the equation. Ayanian and Weissman[20] highlighted the possibility that THs may offer a lower quality of care for common conditions. The inclusion of common benign disease might represent the tipping point at which both superior level of care and high volume shift away from TH in favor of non-TH settings. Where THs perform surgery in comparatively lower volume, they may also demonstrate comparatively poorer outcomes.

Laparoscopic cholecystectomies, as an example, are associated with better outcomes in non-THs.[22] Further research should concentrate on other surgical procedures used to treat common, benign, low-mortality conditions such as benign gallbladder (cholelithiasis) and esophageal (achalasia, hiatal hernia) disease. Teaching hospitals offer improved outcomes for complex oncologic surgical resections such as esophageal and pancreatic surgery but may offer worse outcomes for less complex surgery such as colon surgery, the bulk of which is performed at non-THs, which are less reliant on complex processes of care. We suspect that the inclusion of benign surgical disease with an attendant decrease in morbidity and mortality may be responsible for creating a tipping point that shifts the volume-outcome ratio in favor of non-THs.

While these findings might appear counterintuitive, they are not unprecedented. Khuri et al[13] also reported significantly higher complication rates and increased LOS following colectomy and cholecystectomies performed at THs. Dimick et al[3] similarly reported that esophageal resections performed at non-THs were associated with shorter LOS and, by inference, lower hospital charges. Yuan et al[15] also reported shorter LOS at non-THs. Ayanian et al[23] reported that THs had worse nursing care, and Epstein[24] and other investigators,[13,25-28] consistent with our findings, suggest that costs at THs are higher than those at non-THs. Teaching hospitals tend to be larger and more sophisticated than non-THs. The complex care processes in THs may serve as a source of complications as well as a remedy for them. The relative value of THs is perhaps best observed in the treatment of complex oncologic conditions with comparatively higher morbidity and mortality rates, tipping the risk-benefit ratio toward greater benefit. In the case of less specialized procedures, this benefit may be diminished. Studies that have reported better outcomes in THs, have also more commonly examined treatment of complex surgical oncologic disease or nonoperative medical conditions such as pneumonia, myocardial infarction,[29] and congestive heart failure.[17,30] Admittedly, some studies have shown no difference.[3,31-34] To the best of our knowledge, however, the present report is the first to explicitly examine the volume-outcome ratio as it pertains to resections for both benign and malignant disease of the colon.

With the potential for regionalization of care, such analyses should be taken into consideration because shifting noncomplex surgical disease treatment away from THs may have a negative impact on the training of surgeons, leaving them ill equipped for practice in non-THs. If an attempt at regionalization of colon surgery is made on the strength of previous reports that have examined outcomes only of resections for complex cancer performed in THs, an inappropriate generalization may be made that these improved outcomes also pertain to less complex resections. This may inadvertently result in the rerouting of most patients from non-THs to THs, overloading THs and subjecting patients to unexpected increases in mortality, LOS, and total charges. Conversely, if regionalization were to be based solely on minimum volume thresholds, the unintended consequence might be a reduction in the caseload of benign disease procedures performed by surgery residents (by moving these procedures away from THs) and the depletion of a valuable source of service, education, and revenue. Attempts at regionalization of colon surgery should thus ideally take both diagnosis and procedure into consideration, and not volume or outcome in isolation.

The present study is limited by its use of data abstracted from large administrative databases that lack clinical detail regarding the patient and disease. This limits the ability to accurately identify residual confounding or selection bias. The use of the ARF results in the inability to make causal inference without risk of ecological fallacy. This study is further limited by the inability to detect any refinements of care or examine the specific diagnoses for which the resections were performed. Therefore, little inference can be made regarding the relative influence of such clinical variables as staging of disease and/or utilization of adjuvant therapy and/or effect of adjuvant therapy on survival. Missing data may be attributed to variation in data collection at different hospitals around the country. Assuming that incomplete data acquisition occurred randomly, we believe that it would not alter overall outcome, but it illustrates yet another limitation of administrative data analysis.

However, the NIS database contains a representative sample of hospitals, allowing extrapolation of the results to the entire country. By using the NIS instead of Medicare claims data sources, the present study was able to capture patients undergoing surgical resection for benign inflammatory conditions such as Crohn disease, ulcerative colitis, and diverticulitis and for malignant disease such as hereditary nonpolyposis colorectal cancer and familial adenomatous polyposis. These conditions typically affect younger patients than those with sporadic colon cancer (age 37 vs 71 years, respectively) predominant in the Medicare population.

Lack of staging for malignant disease, nevertheless, may be of doubtful significance: previous reports have suggested that adjustment for cancer stage does not significantly change in-hospital mortality.[4,35] Furthermore, the limitations fail to detract from the likelihood that the inclusion of benign disease may tip the scales in favor of non-THs, which may serve as a volume outcome modifier.

A final limitation is the inability to determine the type of procedure performed, ie, laparoscopic vs open, and so

all resections were considered equivalent. We were unable to adjust for individual surgeon volume but adjusted for comorbidity using the Charlson Index score, a validated risk-adjustment tool.[5] Future research is required to further elucidate procedure type and surgeon volume in randomized trials comparing THs and non-THs and prospectively examining the processes of care that accompany colon resections and that may account for the differences we observed. As policymakers strive to establish quality measures and rationale for regionalization of surgical care, data gathered in this manner may be of great interest to patients, payers, and health care providers. These data might further allow the identification of a similar tipping point in other gastrointestinal surgical disease that allows a demarcation to guide the venues where individual surgical care may be most appropriately and efficiently rendered. The data may also serve as an impetus for THs to increase the volume of less specialized surgery to increase the caseload available for training purposes and simultaneously lower costs and improve outcomes in an exceedingly competitive medical marketplace.

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