Explaining the Volume-Cost Relationship for Cancer Surgery

by
Vivian Ho, PhD
James A. Baker III Institute for Public Policy, Rice University
Department of Economics, Rice University
Dept of Medicine, Baylor College of Medicine

Meei-Hsiang Ku-Goto, MA
James A. Baker III Institute for Public Policy, Rice University

Thomas Aloia, MD
The University of Texas M.D. Anderson Cancer Center

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ABSTRACT

Previous research found that surgeons performing more operations had lower hospital costs per patient for six different cancer surgeries. However, high hospital volume was associated with lower hospital costs for only one procedure, colectomy. This study aims to identify the reasons underlying the negative association between higher surgeon volume and patient costs; and why the association is weaker for hospital volume. We also aim to expand on previous analyses by examining both hospital and physician costs, and examining the relationship between provider volume and hospital profits. This study uses SEER-Medicare data for the years 2001 to 2005. Preliminary analyses indicate that the surgeon volume-cost relationship is precisely estimated for four different cancer resections, but the magnitude is relatively small. Higher surgeon volume is associated with lower Medicare reimbursements to physicians for colectomy and pancreatic resection. When we add several detailed hospital and surgeon characteristics and patient safety indicators, we are unable to "explain away" the observed volume-cost relationships. There is some evidence of a positive surgeon volume-profit relationship for colectomy and lobectomy. Our results suggest that some cost savings might be achieved by referring patients to high-volume surgeons, who tend to practice at high-volume hospitals. Lowering DRG reimbursements to discourage low-volume providers from operating does not appear to be viable, due to the relatively small magnitude of the volume-cost relationship and the relatively large number of hospitals willing to perform these operations at a loss. We have not yet identified potential best practices that could be disseminated to all providers, regardless of volume.

1. INTRODUCTION

The National Cancer Institute estimates that approximately 11.7 million Americans with a history of cancer were alive in January 2007, and approximately 1.6 million new cases are expected to be diagnosed in 2011 (1). The health care costs associated with treating these patients poses a tremendous burden to the health care system, reaching $102.8 billion in 2010. For the majority of solid tumor patients who present with early stage disease, surgery is a vital component of treatment. In many cases, surgery affords these patients the only possibility for cure. In addition, multimodality treatment strategies that include complex surgical resection are now able to prolong survival and quality of life for many patients with locally advanced, and even metastatic, cancers (ie. colorectal liver metastases).

Several previous studies have documented that patients who undergo complex surgery with high-volume surgeons or hospitals have lower risks of operative mortality than those who are cared for by lower-volume providers (2-5). This “volume-outcome” relationship has been noted for a range of cancer and non-cancer operations such as coronary artery bypass grafting, carotid endarterectomy, and total hip replacement. This relationship has been identified for complex cancer operations such as pancreatic resection, and for more commonly performed procedures such as colectomy (3, 6-9). For example, for pancreatic resection, risk-adjusted mortality rates at very-low-volume hospitals (those averaging <1 pancreatic resection per year) were 12.5 percent higher than at very high-volume hospitals (those averaging >16 pancreatic resections per year) between 1994 and 1999 (2). Many fewer studies have attempted to identify the underlying reasons for the relationship between provider volume and patient outcomes. For some operations, the surgeon's technical skill and discretion over specific intraoperative processes are likely important determinants of patient outcome. In other operations, hospital-based services (intensive care, pain management, respiratory care, and nursing care) are more likely to determine inpatient mortality (3).

Few studies have examined the association between case volume and patient costs. Some studies analyzed the association between hospital volume and costs, without adjusting for a potential association between surgeon volume and costs (10-12). Other studies examined the relationship between provider volume and hospital charges, even though charges may not reflect the true cost of providing care (13, 14). Charges are now more than twice the average reimbursement that hospitals receive for the services that they perform (15). Finally, some studies examined only one procedure, one U.S. state, or a socialized healthcare system (the UK) (13, 14, 16).

To address these shortcomings, we published a study that found that relative to low-volume surgeons, treatment by high-volume surgeons was associated with lower per-patient *hospital* costs for six different cancer resections. However, high hospital volume was associated with lower hospitals costs for only one procedure, colectomy (17). This study was conducted using hospital discharge data for the states of Florida, New Jersey, and New York between 1989 and 2000. Costs for each hospital stay were estimated by multiplying the reported patient charge in the discharge data by the hospital's cost-to-charge ratio in the same year as reported in its Medicare cost report. This same method is used by the Agency for Healthcare Research and Quality in providing estimates of inpatient costs for hospital stays in its Healthcare Cost and Utilization Project (HCUP) data files (18).

Not only was the association between higher surgeon volume and lower hospital costs statistically significant in our recent study, but the magnitude of the relationship was substantial. The average patient treated by surgeons who performed 5 or more esophagectomies cost $3,597 less than patients treated by surgeons who performed only 1 or 2 of these procedures in a year. The average patient treated by a surgeon who performed 5 or more pancreaticoduodenectomies a year during 1997-2000 cost $5,935 less than the average patient treated by a surgeon performing one per year. Identifying the underlying reasons for these

volume-cost associations may yield valuable information that could shape future process improvement efforts or recommendations regarding referral for complex cancer surgery, which could lead to lower costs.

We speculate that the association between higher surgeon volume and lower hospital costs could be due to differences in treatment in the operating room, as well as the perioperative environment (17). More surgeon experience may improve resource utilization in the OR, shorten operative times, and yield better surgical techniques which minimize costly complications. Shorter anesthetic times may reduce cognitive, cardiopulmonary, and thrombotic complications, lowering costs through shorter length of stay (19, 20). Higher volume surgeons may also become more efficient at moving uncomplicated cases to discharge, and in early identification and management of postoperative complications.

In contrast to the association between surgeon volume and lower costs, a significant association between higher hospital volume and lower costs was only identified for colectomy in our study. An absence of an association between higher hospital volume and lower costs for the other operations we studied is unexpected. Perhaps high-volume hospitals utilized more resources to achieve higher quality care, which raised costs. High-volume hospitals may have a broader range of specialists and technology-based services such as advanced intensive care units than smaller centers (3). High-volume hospitals may also have higher nurse-to-patient ratios. Therefore, there may be offsetting effects at high-volume hospitals, with lower costs due to fewer complications, but higher costs due to greater investment in capital and labor by the hospital to achieve better outcomes.

The absence of an association between higher hospital volume and lower costs is consistent with previous opinions that centralizing complex surgical procedures may save lives, but it will not reduce costs (21). Experts speculate that volume-based referral strategies would concentrate more care at teaching hospitals, which tend to deliver care more expensively than

do smaller, nonteaching hospitals. Moreover, volume-based referral may require high-volume centers to add capacity (operating rooms and beds), and incur workforce friction costs due to the need for more surgeons, anesthesiologists, and support staff. Nevertheless, friction costs and the costs of adding capacity are one-time costs, whose effect will dissipate over time. In addition, past studies do not consider the potential to restrain cost growth by reducing reimbursement rates to high-volume providers for performing profitable surgical procedures (21).

This study aims to identify the reasons underlying the negative association between higher surgeon volume and patient costs; and why the association is weaker for hospital volume. We also aim to expand on previous analyses by examining both hospital and physician costs, and examining the relationship between provider volume and hospital profits. This study uses SEER-Medicare data for the years 2001 to 2005.

Preliminary analyses indicate that the magnitude of the surgeon volume-cost relationship is relatively large for colectomy. This relationship is precisely estimated for three other cancer resections, but the magnitude is much smaller. Higher surgeon volume is associated with lower Medicare reimbursements for colectomy and pancreatic resection. When we add several detailed hospital and surgeon characteristics and patient safety indicators, we are unable to "explain away" the observed volume-cost relationships. There is some evidence of a positive surgeon volume-profit relationship for colectomy and lobectomy. Our results suggest that some cost savings could be achieved by referring patients to high-volume surgeons, who tend to practice at high-volume hospitals. Lowering DRG reimbursements to discourage low-volume providers from operating does not appear to be viable, due to the relatively small magnitude of the volume-cost relationship and the relatively large number of hospitals willing to perform these operations at a loss. We have not yet identified potential best practices that could be disseminated to all providers, regardless of volume.

2. APPROACH

We begin by estimating the volume-cost relationship, controlling for a range of patient characteristics that may influence costs, as well as the local area wage index for each hospital, which proxies for exogenous variation in labor costs. The regression takes the form:

$$(1) \qquad \ln\left(\frac{Hospital}{Costs} + \frac{Physician}{Costs}\right)_{ihst} = f\left(\frac{Surgeon}{Volume}_{ist}, \frac{Hospital}{Volume}_{iht}, X_{isht}, Wage_{iht}\ \tau_t, \upsilon_{iht}\right)$$

where the dependent variable is the natural log of hospital and physician costs for the entire stay for patient i, who received surgery at hospital h, in year t. Regressions will be estimated separately for each of the 6 cancer resections. The explanatory variables of interest are the number of resections of the same type performed by the patient's surgeon and hospital in the same calendar year. The regression includes a vector X_{iht} of patient characteristics, a wage index, and an error term υ_{iht}, which is assumed to be distributed iid.

Unlike previous studies of the volume-cost relationship, Equation (1) also contains a vector of year fixed effects τ_t, so that the coefficients on provider volume capture the "within-hospital" effects of variations in surgeon and hospital volume. These estimates are less likely to be confounded by unobserved characteristics among providers that may influence costs and are also associated with hospital volume. Our previous study of the volume-cost relationship used multilevel regression modeling which included surgeon and hospital level random effects and compared the costs of providers in the lowest volume tertile versus the highest tertile (17). The random effects approach is less robust to unobserved heterogeneity across hospitals. One cannot specify categorical volume variables (e.g. tertiles) when hospital fixed effects are included in the regressions. With these fixed effects, categorical volume variables would only represent the cost experience of hospitals that switched from one volume category to another during the sample period.

Therefore, surgeon and provider volume are specified continuously in this study. However, we test for a nonlinear relationship between provider volume and costs using fractional polynomials (22). Fractional polynomials express an explanatory variable in terms of either particular powers of X or as the natural log of X. The set of powers is restricted to (23). Data analysis indicates that including extra powers in the set is not worthwhile. Fractional polynomials have been found to provide greater flexibility in functional form than the family of conventional polynomial models.

We hypothesize a negative coefficient on surgeon volume in the regressions, for the reasons offered in the previous literature. The coefficient on hospital volume may or may not be negative. Increased hospital volume may yield economies of scale or reflect hospital-level learning effects. But these cost savings may be offset by costly investments in patient care at larger hospitals. The coefficient estimates may differ from those of our previous study, due to the inclusion of hospital fixed effects. We also estimate equation (1) using only the natural log of hospital costs as the dependent variable (as in our previous study); as well as another regression with physician costs as the dependent variable.

We then proceed to test whether the addition of a range of provider characteristics to equation (1) can "explain away" the estimated volume-cost relationship. That is, we add variables we hypothesize to underlie the volume-cost relationship and examine whether the coefficients on either surgeon or hospital volume decrease in magnitude or become insignificant. All regressions are estimated using Stata 10.0. The fractional polynomial commands in Stata do not include an option which would allow one to control for the clustering of standard errors for patients treated in the same hospital. Therefore, we begin by estimating fractional polynomial regressions for cost as a function of surgeon and provider volume, year, and hospital fixed effects. We then include the polynomial specifications suggested by these regressions in panel-data regressions with the other covariates that cluster standard errors at the hospital level.

We also estimate the association between provider volume and hospital profits for each of the cancer resections that we examine. Hospital profits per patient can be negative in many cases. Therefore, hospital profits per patient are specified as levels in these regressions, rather than natural logs.

3. DATA

The analysis requires a dataset that contains a large sample of hospitals that perform cancer surgery, which have varying levels of annual procedure volume, and unique physician identifiers, so that one can also track the number of cancer operations performed each year by surgeon. We analyze data from the SEER-Medicare database, which includes a combination of cancer registry data, including staging, with information on health care utilization from the Medicare claims data. We analyze the 2005 version of the database, which is the most recent data available. The database covers 26 percent of the U.S. population (24). Our analysis is based on patients diagnosed with cancer for the years 2001 through 2005. We analyze six cancer resections: colectomy (colon resection), rectal resection, pulmonary lobectomy, pneumonectomy, esophagectomy, and pancreaticoduodenectomy (pancreatic resection).

The dependent variable includes hospital costs per inpatient admission for cancer surgery. We examine the determinants of the cost of the entire inpatient stay; not just the cost of performing surgery. Provider volume may be associated with more efficient resource utilization in the operating room, but there may also be an association between case volume and post-operative outcomes such as complications and length of stay. For policy purposes, identifying strategies for controlling the cost of the entire patient stay will be most effective in restraining growth in health care costs.

The Medicare claims data provide detailed information on hospital charges by revenue center in the Medicare claims for each discharge. Charges adjusted by the All-Urban Consumer Price Index to reflect 2001 dollars. It is widely acknowledged that charge data are list prices,

which do not reflect substantial discounts obtained by Medicare, Medicaid, and private insurers (25). More importantly, charges are not equivalent to the economic costs of providing care. Instead, charges represent the amount that hospitals believe the least price-sensitive customer or group of consumers is willing to bear (26). Therefore, multiply patient charges by cost-to-charge ratios as the measure of hospital costs associated with each patient's hospital stay in this study. Cost-to-charge ratios are derived from the Medicare cost report for each hospital.

The advantages and disadvantages of using cost-to-charge ratios to estimate costs have been discussed in previous research (27). The ratio of cost to charges for each hospital may not provide an accurate correction for the specific costs associated with each cancer patient's hospital stay. Measurement error in the dependent variable costs could lead to larger error variance when estimating the association between volume and costs, which could lower the chance of finding a significant association between these two variables. However, measurement error in cost-to-charge ratios is likely to be uncorrelated with the independent variables in our regression analyses. In this case, the regression methods we plan to apply will yield unbiased and consistent estimators of the determinants of hospital costs (28). Moreover, even with the potential for measurement error, past studies using cost-to-charge ratios have found a precisely estimated association between hospital and/or surgeon volume and patient costs (17, 27, 29).

Physician costs will be measured using all physician billings to Medicare for the patient's hospital stay as reported in the Medicare Carrier claims files. These billings do not represent physicians' true marginal cost of providing services, because we lack global data on physicians' practice expenses (e.g. malpractice insurance, administrative costs, etc.) However, these billings represent the amount that Medicare (and ultimately taxpayers) pay for treating cancer patients. Therefore, understanding the determinants of physician payments is valuable for future attempts to control Medicare cost growth.

We will also estimate regressions with hospital profit as the dependent variable. Profit for each patient will be computed as the total reimbursement that the hospital received for

providing care to the patient, less hospital costs, which will be computed as described above. The total reimbursement received by the hospital can be derived from the MedPAR claims data. This amount is the sum of three variables in the MEDPAR files: The MedPAR DRG Price Amount, the DRG Outlier Approved Payment Amount, and the MEDPAR Total Pass Through Amount. The MedPAR DRG Price Amount is the amount that would have been paid to the hospital if no deductibles, coinsurance, primary payers, or outliers were involved. The DRG Outlier Approved Amount is the amount of additional payment approved due to an outlier situation over the DRG allowance for the stay. The DRG Pass Through Amount is the total of all claim pass through amounts for the stay. Included in the pass through amount are reimbursements for capital-related costs, direct medical education costs, and bad debts.

The patient characteristics that will be included in the regressions are listed below:

Patient Characteristics - X_{iht} **i=patient, h=hospital, t=year**
Indicators for sex, age category, race (0/1 dummies)
Income (in postal code of residence)
Indicators for components of Elixhauser comorbidity index (0/1 dummies)
Transfer patient (0/1 dummy)
Urgent/emergent admission (0/1 dummy)
Indicators for cancer stage (ICD-9-CM codes: nodal involvement 196.x, metastasis 197.x-198.x)
Indicators specific to cancer procedure

In subsequent specifications, we will add hospital and surgeon characteristics that may explain the volume-cost relationship. These variables include:

Hospital and Surgeon characteristics
Nurse-to-patient ratios
Hospital has CT Scanner
Hospital has Electron beam computed tomography (EBCT)
Hospital has Magnetic resonance imaging (MRI)
Hospital has Multi-slice spiral computed tomography
Hospital has Positron emission tomography
General surgeon / Surgical oncologist / Thoracic surgeon / other surgeon

Data for all of the hospital-level variables comes from the American Hospital Association Annual Survey of hospitals. Following previous studies, we calculate the number of full-time equivalent (FTE) registered nurses (RNs) and Licensed Practical Nurses (LPNs), divided by the adjusted

patient days for each hospital and year (30). The AHA calculates adjusted patient days as the sum of inpatient days and outpatient visits, weighted by revenue. Adjusted patient days are used, because the AHA does not report the number of nurses for inpatient versus outpatient care separately.

Given the demonstrated volume-outcome relationship found in the literature, it may be that high volume providers incur fewer complications during the hospital stay, which may lead to better outcomes and lower patient costs. Complications will be identified using the AHRQ Hospital-level Patient Safety Indicators (PSI) methodology (31). AHRQ has defined a list of 20 PSIs, along with corresponding ICD-9-CM codes, so that they can be readily identified in administrative data. These indicators focus on potentially preventable instances of complications and other iatrogenic events resulting from exposure to the health care system. The AHRQ developed the PSIs based on previous literature, clinician panels, expert coders, and empirical analyses. The AHRQ put these and other candidate measures through a process which evaluated these indicators based on face validity, precision, minimum bias, construct validity, potential to foster real quality improvement, and application, before specifying the final set of 20 PSIs. We will exclude four PSIs from our analysis, because they relate specifically to birth and obstetric care. The remaining 16 PSIs are listed below:

AHRQ Hospital-level Patient Safety Indicators

- Complications of anesthesia (PSI 1)
- Death in low mortality DRGs (PSI 2)
- Decubitus ulcer (PSI 3)
- Failure to rescue (PSI 4)
- Foreign body left in during procedure (PSI 5)
- Iatrogenic pneumothorax (PSI 6)
- Selected infections due to medical care (PSI 7)
- Postoperative hip fracture (PSI 8)
- Postoperative hemorrhage or hematoma (PSI 9)
- Postoperative physiologic and metabolic derangements (PSI 10)
- Postoperative respiratory failure (PSI 11)
- Postoperative pulmonary embolism or deep vein thrombosis (PSI 12)
- Postoperative sepsis (PSI 13)
- Postoperative wound dehiscence in abdominopelvic surgical patients (PSI 14)
- Accidental puncture and laceration (PSI 15)
- Transfusion reaction (PSI 16)

We are also interested in testing whether differences inprocesses of care explain differences in costs across high and low volume providers. Following previous research on the volume and process of care in high-risk cancer surgery for various cancers (31, 32), we will determine whether the following processes of care were used for each patient admission based on ICD-9-CM procedure codes and CPT codes in the claims data:

Processes of Care
Peri-operative care OR time Blood transfusion
Invasive hemodynamic monitoring Arterial line Central venous line Pulmonary artery catheter
Epidural analgesia (for pain management)
Specialist consultation after surgery

We are still in the process of coding these variables, so results including these variables are not reported in this manuscript.

4. RESULTS

Descriptive statistics for the five different cancer operations that we have analyzed so far are in Table 1. (We are still cleaning the dataset for rectal resection operations.) Patients treated by low and high volume providers are classified as those in the lowest and highest tertile of procedure volume respectively. In all but one case (surgeon volume for pneumonectomy), higher provider volume is associated with lower 30-day mortality. For esophagectomy and pancreatic resection, the differences in mortality by volume for both hospitals and surgeons are striking. For example, for both operations, 30-day mortality is 10 percent at low-volume hospitals and only 4 percent at high-volume hospitals.

For the procedures which are less frequently performed (pneumonectomy, esophagectomy, and pancreatic resection), low volume providers tend to operate on older

patients. In addition, patients treated by low volume hospitals and surgeons are more likely to be black, have two or more comorbidities recorded in their hospital claims data, and are more likely to have been admitted as an urgent or emergent case. These variables proxy for weaker patient health status, which is correlated with worse outcomes and perhaps greater resource utilization when in the hospital. Thus, it will be important to account for differences in patient casemix when estimating the volume-cost relationship.

Figure 1 presents unadjusted hospital costs by hospital and surgeon volume, with means again reported for the lowest and highest tertiles of volume. In nine of twelve cases, higher volume providers have lower costs per patient. The relative size of the bars in the graphs can be misleading, because the scale for costs is different for each operation. The largest cost differential is for pneumonectomy, where cost per patient is $8,929 higher in hospitals performing 1 to 2 procedures per year, versus facilities performing more than 5 annually. But the cost differential for low versus high volume hospitals is also subtantial for colectomy ($1,377), lobectomy (2,858) and pancreatic resection (2,637). The cost differential for low versus high volume surgeons exceeds $1,000 for only two cases: colectomy ($2,774) and pancreatic resection ($2,980).

Figure 2 presents unadjusted Medicare reimbursements to physicians by lowest and highest tertiles of hospital and surgeon volume. Low volume providers have higher costs relative to high volume providers in ten out of twelve cases. The largest cost differentials are for pancreatic resection, where physician billings are $826 higher in hospitals performing 5 or fewer operations per year, versus hospitals performing more than 15 resections annually. Surgeons performing one pancreatic resection per year bill $952 more per patient relative to surgeons performing three or more operations per year. We next test whether these observed differentials persist once we control for patient characteristics.

Table 2 presents regression estimates of the determinants of patient costs for each operation. The first column for each surgery reports the estimates of coefficients on provider volume when the dependent variable is reported hospital costs for the patient, combined with total Medicare physician billings during the patient's hospital stay. Colectomy was the only patient population for which the fractional polynomial estimation suggested a nonlinear relationship between provider volume and costs. The best fitting specification includes linear and quadratic values of hospital volume and the square root of surgeon volume.

For all five operations increased surgeon volume is associated with lower total costs of care, and the relationship is precisely estimated for each procedure except pneumonectomy. However, the magnitude of the volume effect implied by the coefficients on surgeon volume is relatively small. For example, if one considers an increase in volume for a surgeon representative of the lowest tertile relative to one in the highest tertile (from 2 to 10 colectomies per year), total costs are predicted to decrease 0.21% ($0.074*\sqrt{8}$). Mean total costs for colectomy are $19,879, so the implied reduction is only $42 per patient. For esophagectomy, which has the next largest coefficient and higher mean costs ($54,291), increasing volume from the lowest to the highest tertile of surgeon volume reduces costs by only $15.

The regression estimates in Table 2 suggest a precisely estimated association between hospital volume and total costs only for colectomy. The relationship is nonlinear, and we present a graph of the predicted relationship along with the residuals of total cost in Figure 3. The graph is in natural log scale, which masks potentially large differences in mean costs. For example, the inverse natural logs of 8.9 and 9.0 are $7,331 and $8,103 respectively. For colectomy, it appears that predicted costs are lower for patients in the lower tertile of hospital volume (1 to 35 per year), relative to many patients treated in the higher tertile of hospital volume (>65).

When we decompose total costs into hospital costs and physician payments, we find that the effects estimated for total costs are primarily driven by the relationship between provider volume and hospital costs. All of the volume coefficients that were precisely estimated for total

costs remain precisely estimated for the hospital cost regressions, and the magnitude of the coefficients is relatively similar. In contrast, when the regressions specific physician payments as the dependent variable, surgeon volume is associated with lower costs for only colectomy and pancreatic resection. For none of the operations do we find a tangible effect of hospital volume on physician reimbursement.

Table 3 presents results where the AHRQ patient safety indicators and surgeon specialty are added to the regressions. [*Note: The hospital nurse-to-patient ratio and the presence of a hospital CT, MRI, and/or PET scanner were mistakenly included in the regressions that were reported on in Table 2. However, these variables are not likely to explain the volume-cost relationship, because they were all imprecisely estimated.*] The first column for each operation reports the same coefficients on provider volume that were in Table 2. The second column then reports the estimates with PSI's and surgeon specialty added to the regressions. Perhaps surprisingly, we find little change in the coefficients on the hospital and surgeon volume variables when the PSIs and surgeon specialty are included. In each case the coefficients that were precisely estimated in Table 2 remain so in Table 3, and the magnitude of the coefficients is similar.

Some of the patient safety indicators were not observed for any patients receiving particular cancer operations. But for those cases in which complications were observed, they were overwhelmingly precisely estimated with relatively large magnitudes. For example, PSI 11, postoperative respiratory failure, was large and precisely estimated for 4 of the 5 operations and relatively common (1.63% of colectomy patients). PSI 15, accidental puncture or laceration, was also an important predictor of costs (2.08% of colectomy patients).

The effects of surgeon specialty were estimated using general surgeons as the excluded category from the regressions. We found little evidence that surgeon specialty influences total costs, although surgical oncologists performing esophagectomy appear to have substantially

lower costs per patient. This effect requires further investigation, because it is based on 26 esophagectomy patients receiving surgery from a surgical oncologist.

Table 4 presents regression estimates with hospital profits as the dependent variable. [*The fractional polynomial regressions are computationally intensive for regressions with large samples. Due to time constraints, we applied the same nonlinear or nonlinear specifications of volume for the profit regressions that were suggested by the total cost specifications.*] We report specifications with and without the indicators for PSIs and surgeon specialty, but the volume coefficients are quite similar in both specifications.

The regressions suggest a nonlinear relationship between hospital volume and profits per patient for colectomy. Higher hospital volume is significantly associated with higher profits for esophagectomy. The relationship between hospital volume and profits is much smaller and imprecisely estimated for the other procedures. We find that higher surgeon volume is associated with higher profits for colectomy and lobectomy, but not for the other procedures. Thus, there appears to be no systematic relationship between provider volume and profits that persists across the different types of surgical operations. The relatively large coefficient estimates for volume for colectomy and esophagectomy may result from the skewness in the profit data.

5. CONCLUSION

We find that the surgeon volume-cost relationship is precisely estimated for four different cancer resections, but the magnitude is relatively small. Some cost savings might be achieved by referring patients to high-volume surgeons, who tend to practice at high-volume hospitals. However, the cost savings are likely to be small, and could be offset by increased travel costs posed to patients living in sparsely populated areas. Lowering DRG reimbursements to discourage low-volume providers from operating does not appear to be viable either, due to the relatively small magnitude of the volume-cost relationship and the relatively large number of

hospitals willing to perform these operations at a loss. For example, 29 percent of patients receiving colectomy and 54 percent of patients undergoing esophagectomy generated a loss for hospitals. Profits were negative for a sizeable portion of patients for the most common and least common cancer operations in our dataset.

When we add several detailed hospital and surgeon characteristics and patient safety indicators, we are unable to "explain away" the observed volume-cost relationships. Thus, we have not yet identified potential areas that could be the focus of best practices that could be disseminated to all providers, regardless of volume.

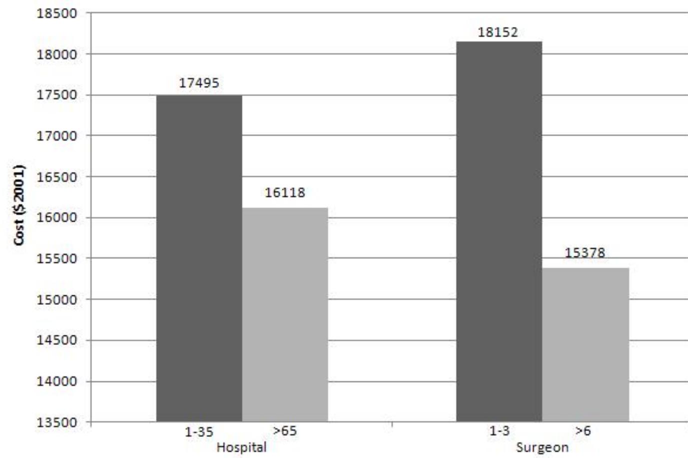
This analysis is highly preliminary, and there are a number of caveats. We are still in the process of data cleaning. The variables used in the analysis may be subject to measurement error, which would bias the coefficient estimates downwards. We must also code the variables measuring processes of care for each cancer operation.

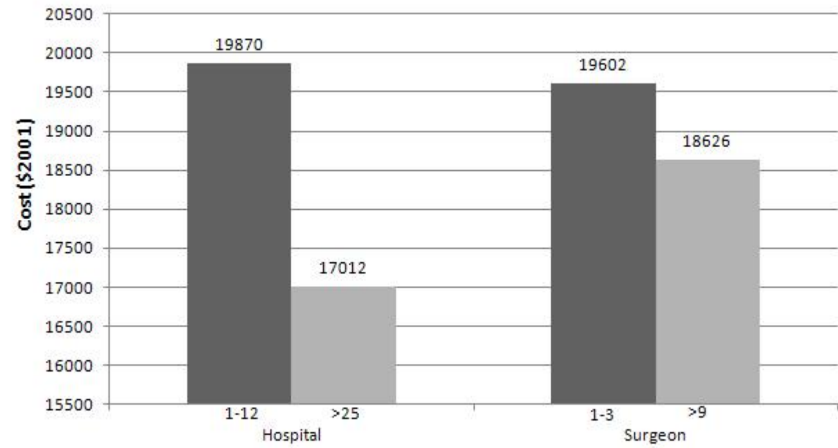
Our previous analysis found relatively large differences in hospital costs by surgeon volume, even after adjusting for patient characteristics and hospital teaching status. However, the previous study relied on random effects estimates, while this analysis used hospital fixed effects. The fixed effects approach is robust to unobserved differences across hospitals which are fixed over time. However, suppose one estimates a random effects model of the volume-cost relationship including only patient characteristics, and one finds that adding hospital and surgeon characteristics substantially reduces the magnitude of the coefficients on surgeon and/or hospital volume. Then these characteristics may be potential factors to focus on for quality improvement, and they could have a notable impact on cost reduction. We will also estimate random effects models in the future to test this hypothesis.

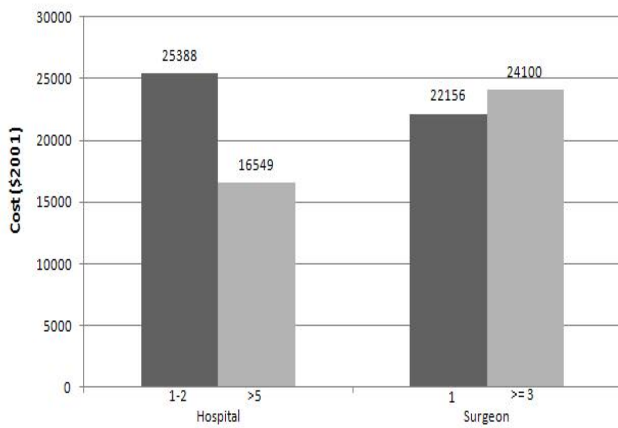
The sample size from the SEER-Medicare database is much smaller than what we obtained from four large U.S. states in our previous study. We have obtained a 100% sample of all MedPAR claims for patients receiving each of the six cancer operations we are studying,

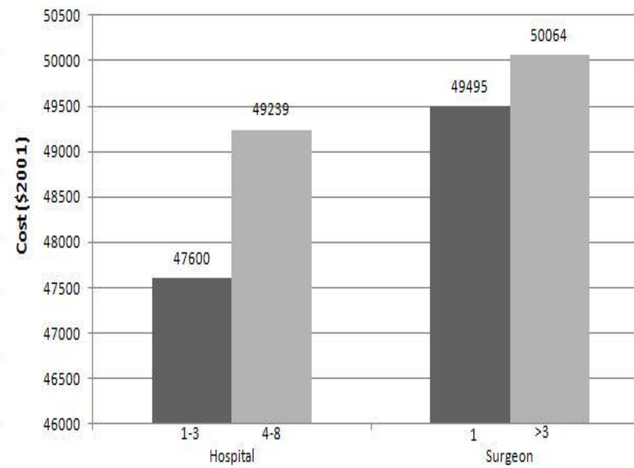
along with accompanying Part B physician claims data for patients identified in the MedPAR data to conduct a parallel analysis to the one reported here.

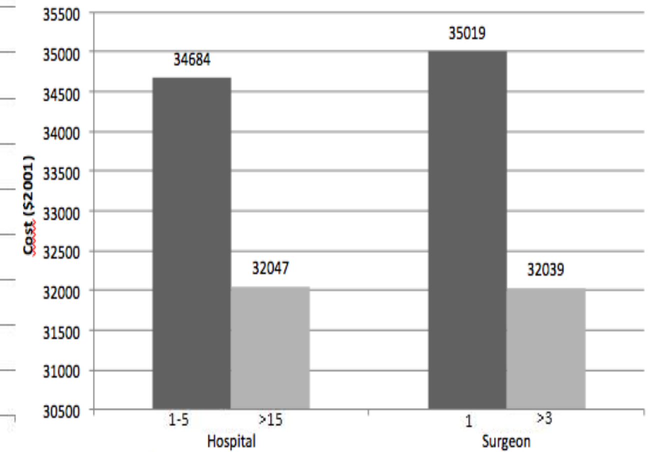
Figure 1: Hospital Costs by Hospital and Surgeon Volume











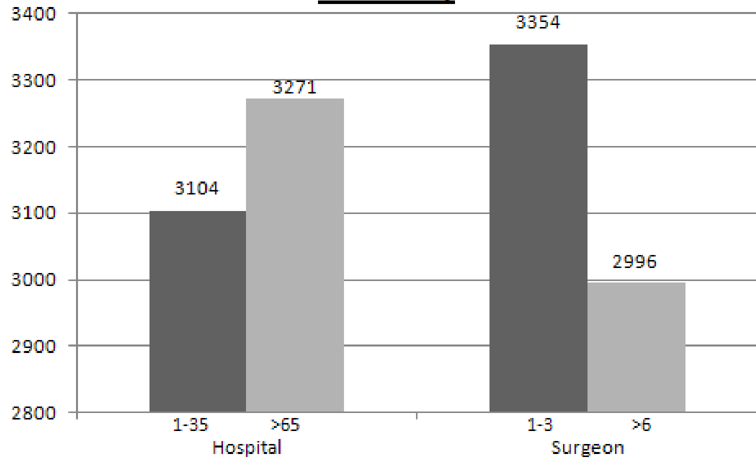
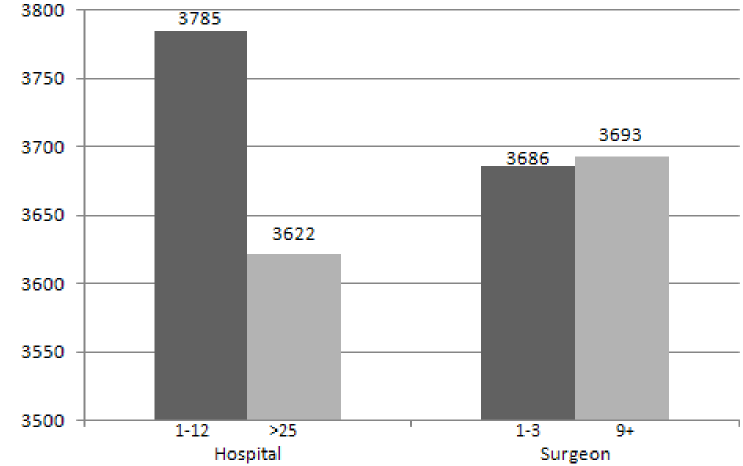
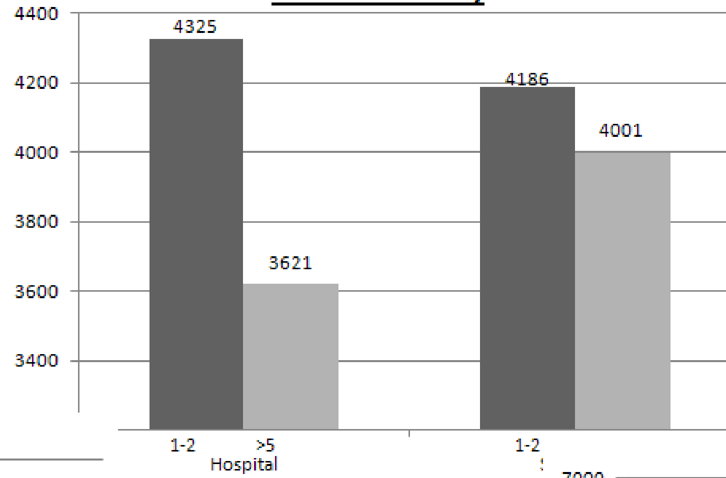
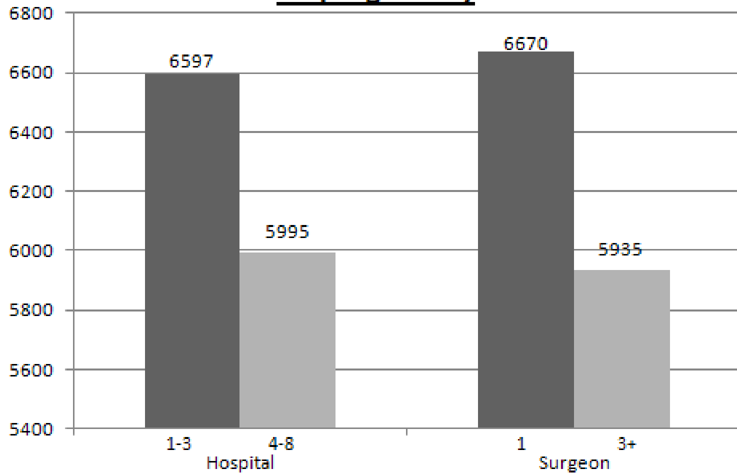
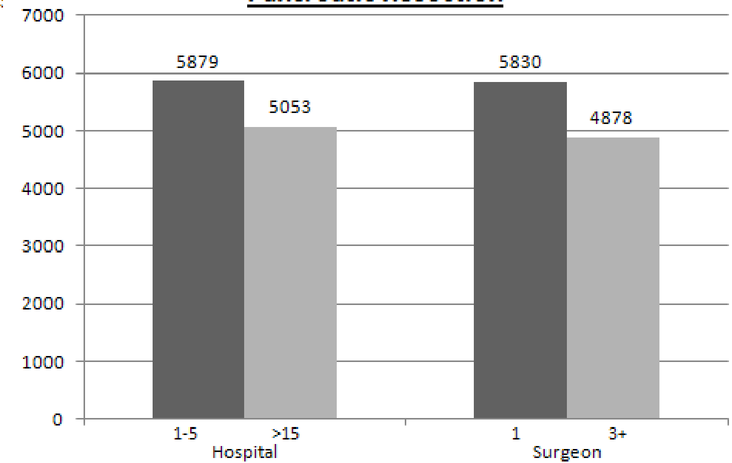


Figure 2: Physician Reimbursements by Hospital and Surgeon Volume









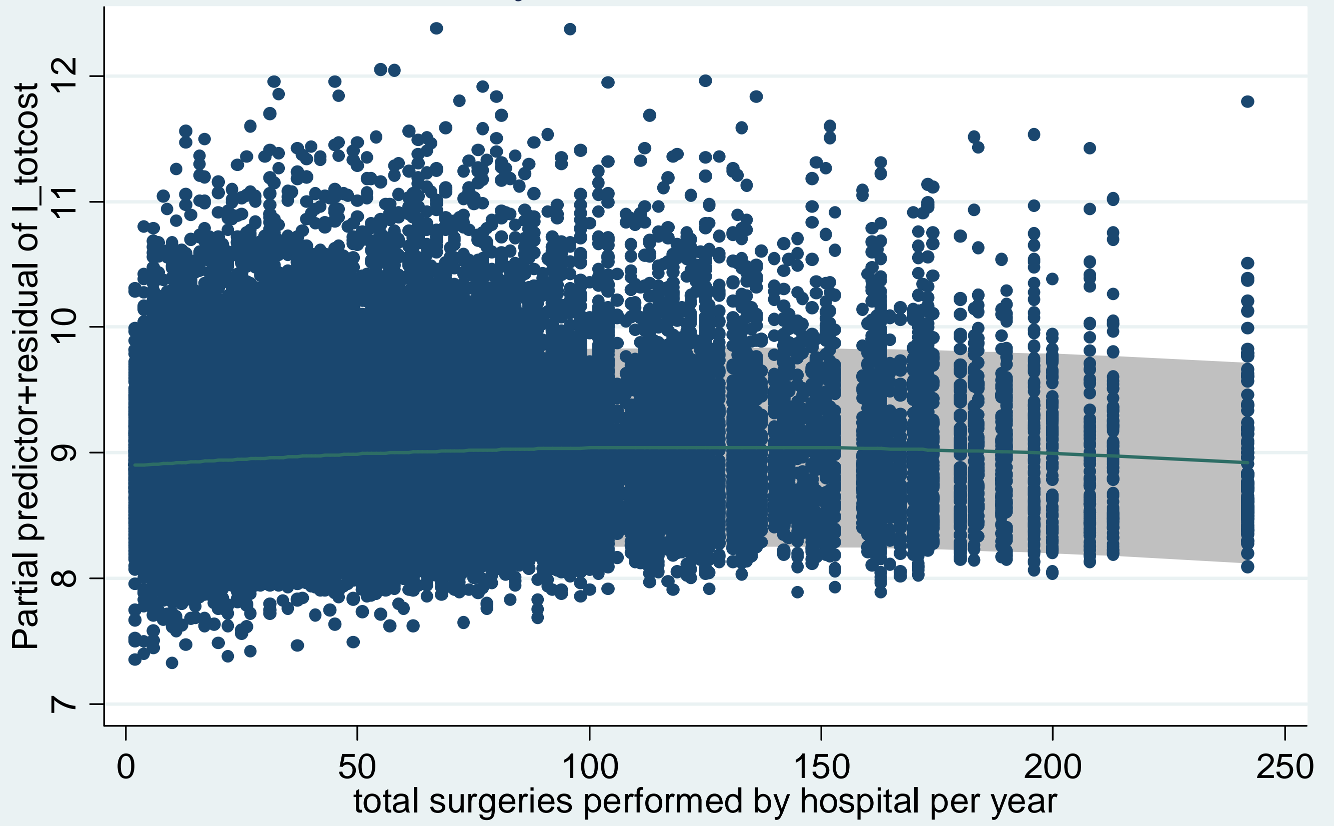


Figure 3: Fractional Polynomial (1 2),
adjusted for covariates
Partial predictor+residual of l_totcost
7
8
9
10
11
12
0
50
100
150
200
250
total surgeries performed by hospital per year

Table 1: Patient Characteristics by Volume

	Hospitals		Surgeons	
	Low Volume	High Volume	Low Volume	High Volume
Colectomy (N=43,231)				
30-day mortality	0.06	0.05	0.06	0.05
age 75+	0.64	0.67	0.66	0.66
black	0.08	0.08	0.09	0.07
2+ comorbidities	0.60	0.61	0.60	0.59
urgent admit	0.25	0.25	0.29	0.21
Lobectomy (N=12,330)				
30-day mortality	0.05	0.03	0.04	0.03
age 75+	0.45	0.47	0.44	0.47
black	0.06	0.04	0.06	0.05
2+ comorbidities	0.63	0.58	0.63	0.58
urgent admit	0.03	0.02	0.03	0.02
Pneumonectomy (N=680)				
30-day mortality	0.15	0.13	0.13	0.16
age 75+	0.38	0.28	0.34	0.30
black	0.05	0.05	0.05	0.07
2+ comorbidities	0.68	0.63	0.63	0.63
urgent admit	0.04	0.02	0.04	0.05
Esophagectomy (N=612)				
30-day mortality	0.10	0.04	0.08	0.04
age 75+	0.43	0.32	0.39	0.34
black	0.07	0.04	0.06	0.04
2+ comorbidities	0.56	0.51	0.54	0.54
urgent admit	0.07	0.01	0.05	0.03
Pancreatic Resection (N=1,618)				
30-day mortality	0.10	0.04	0.09	0.04
age 75+	0.46	0.46	0.45	0.44
black	0.07	0.05	0.07	0.06
2+ comorbidities	0.54	0.49	0.53	0.51
urgent admit	0.16	0.08	0.14	0.07

Table 2: Regression Estimates of the Determinants of Patient Costs[a]

	ln(Hospital + Physician)	ln(Hospital Costs)	ln(Physician Payments)	ln(Hospital + Physician)	ln(Hospital Costs)	ln(Physician Payments)
Colectomy[b] (N=43,231)						
Hospital volume	0.157***	0.178***	0.0656			
	(3.33)	(3.44)	(1.52)			
(Hospital volume)^2	-0.0659***	-0.0760***	-0.022			
	(-3.32)	(-3.43)	(-1.23)			
(Surgeon volume)$^{.5}$	-0.0740***	-0.0833***	-0.0238**			
	(-7.35)	(-7.60)	(-2.79)			
Lobectomy (N=12,330)				**Esophagectomy[c] (N=612)**		
Hospital Volume	-0.0000453	0.000137	-0.000631	0.00662	0.00718	-0.00178
	(-0.06)	(-0.16)	(-1.01)	(-1.32)	(-1.33)	(-0.32)
Surgeon Volume	-0.00151**	-0.00194***	0.000601	-0.0159*	-0.0190**	0.00399
	(-3.13)	(-3.63)	-1.66	(-2.32)	(-2.60)	(-0.60)
Pneumonectomy (N=680)				**Pancreatic Resection[d] (N=1,618)**		
Hospital Volume	-0.00947	-0.00966	-0.00831	0.00241	0.00238	0.00398
	(-0.98)	(-0.91)	(-1.24)	(-0.79)	(-0.73)	(-1.49)
Surgeon Volume	-0.000803	-0.00267	0.0056	-0.00949*	-0.0102*	-0.00695*
	(-0.09)	(-0.26)	(-0.88)	(-2.07)	(-2.08)	(-2.01)

[a] All regressions included age, sex, race, transfer patient, urgent/emergent admission, cancer stage, presence of Elixhauser-defined comorbidities, hospital ownership of CT scanner/MRI/PET, year, and hospital indicators. Mean nurse wages and the nurse-to-patient ratio were also included.

[b]Colectomy regressions included indicator total colectomy (vs. open and partial excision of large intestine).

[c]Esophagectomy included indicator for total esophagectomy (vs. partial).

[d]Pancreatic resection included indicators for total and partial pancreatectomies (vs. Whipple).

* p<0.05, ** p<0.01, ***p<.0001

Table 3: Regression estimates of the Determinants of ln(Hospital Costs + Physician Payments)

	Colectomy (N=43,231)				Lobectomy (N=12,330)				Pneumonectomy (N=680)			
	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t
Hospital volume	0.157***	(3.33)	0.164***	(3.65)	-4.53E-05	(-0.06)	-4.6E-05	(-0.06)	-0.00947	(-0.98)	-0.008	-0.99
(Hospital volume)^2	-0.066***	(-3.32)	-0.069	(-3.58)								
Surgeon volume					-0.0015**	(-3.13)	-0.0013**	(-2.93)	-0.0008	(-0.09)	-0.006	-0.65
(Surgeon volume)$^{.5}$	-0.074***	(-7.35)	-0.073***	(-7.45)								
psi03			0.317***	(9.31)			0.609***	-6.19			0.570**	2.61
psi04			0.223***	(6.81)			0.550***	(8.45)			0.696***	3.63
psi05												
psi06			0.475***	(6.78)								
psi07			0.398	(1.80)								
psi08			0.054	(0.18)			1.702***	(60.60)				
psi09			0.574***	(10.45)			0.432*	(2.20)				
psi10			0.658***	(7.56)			0.668***	(4.79)			-0.005	-0.03
psi11			0.651***	(22.26)			1.346***	25.16			1.336***	6.65
psi12			0.401***	(18.11)			0.501***	(8.70)			0.135	0.79
psi13			0.655***	(3.24)								
psi14			0.586***	(11.78)								
psi15			0.229***	(11.81)			0.284***	(6.64)			0.249**	3.18
Thoracic surgeon			0.014	(0.5)3			-0.003	(-0.16)			0.012	0.19
Surgical oncologist			0.024	(0.94)			0.064	(0.51)				
Other surgeon			-0.004	(-0.32)			-.043*	(-2.34)			-0.14	-1.45

Table 3 (continued)

	Esophagectomy (N=612)				Pancreatic Resection (N=1,618)			
Hospital volume	0.007	(1.32)	0.003	(0.79)	0.002	(0.79)	0.002	(0.81)
Surgeon volume	-0.016**	(-2.32)	-0.017**	(-2.65)	-0.010*	(-2.07)	-0.009*	(-2.32)
psi03			0.584***	(3.29)			0.174	(1.05)
psi04			0.719***	(6.06)			0.375*	(2.24)
psi05								
psi06							0.653*	(2.40)
psi07							-0.068	(-1.09)
psi08								
psi09			0.631***	(8.16)			0.341	(2.03)
psi10			-1.257***	(-5.68)			1.044***	(5.89)
psi11			0.738***	(9.94)			0.623	(7.46)
psi12			0.446	(3.16)			0.306***	(3.46)
psi13							-0.026	(-0.42)
psi14			-0.004	(-0.01)			0.014	(0.04)
psi15			0.280*	(2.30)			0.094	(1.17)
Thoracic surgeon			0.045	(0.53)			0.217	(1.09)
Surgical oncologist			-0.455*	(-2.25)			0.110	(1.89)
Other surgeon			-0.023	(-0.22)			0.019	(0.34)

Table 4: Regression estimates of the Determinants of Hospital Profits Colectomy Lobectomy Pneumonectomy Esophagectomy Pancreatic Resection

	Colectomy		Lobectomy		Pneumonectomy		Esophagectomy		Pancreatic Resection	
Hospital volume	-2459.2*	-2532.0*	-18.31	-16.87	52.06	63.57	2578.7***	2509.2***	5.501	3.843
	(-2.06)	(-2.13)	(-1.22)	(-1.13)	(0.38)	(0.53)	(4.02)	(5.45)	(0.05)	(0.04)
(Hospital volume)$_2$	931.8	963.4							204	209.1
	(1.62)	(1.67)							(1.45)	(1.59)
Surgeon Volume			26.08**	25.05**	151.9	168.9	187.4	411.1		
			(2.99)	(2.90)	(0.96)	(0.93)	(0.93)	-1.22		
(Surgeon volume).s	882.2***	871.7***								
	(4.98)	(4.96)								
psi03		-2927.8**		-13777.5***		-17793.5***		101703.2		-7844.8
		(-3.27)		(-5.57)		(-3.34)		(1.03)		(-1.73)
psi04		-3316.8***		-3387.3		-6756.3		33505.9		-12428.6
		(-3.83)		(-1.70)		(-1.76)		(1.96)		(-1.21)
psi05										
psi06		-4794.1**								-12579.3**
		(-2.83)								(-2.86)
psi07		5898.1								786.6
		(0.47)								(0.36)
psi08		6602.3		-47349.4***						
		(1.73)		(-80.67)						
psi09		-8978.2***		-204.6				-63367.8***		-8306.6*
		(-5.70)		(-0.09)				(-8.79)		(-2.04)
psi10		-7315.7		-4621.2		-5654.1		-8657.9		-33410.9**
		(-1.88)		(-0.68)		(-1.15)		(-0.29)		(-2.77)
psi11		-7459.8***		13673.4***		2828.6		7478.1		-9897.3***
		(-9.68)		-5.38		(-0.31)		(0.61)		(-3.39)
psi12		-4873.2***		-8302.4***		-14647.1*		-10058.4		-8637.0***
		(-9.62)		(-4.67)		(-2.52)		(-1.69)		(-3.63)
psi13		2299.3								5518.0**
		(0.17)								(2.82)
psi14		-5958.3**						-18581.9*		-6216.4
		(-3.11)						(-2.30)		(-1.74)
psi15		-1705.0***		-4765.9***		-4159.5		3204.9		2153.4
		(-3.92)		(-4.14)		(-1.83)		(0.55)		(0.65)
Thoracic surgeon		-626.3		-399.2		-263.8		-6784.3		8525.8***
		(-0.94)		(-1.20)		(-0.24)		(-1.00)		(4.85)
Surgical oncologist		-119.8		-3287.3				16382.7		-4682.2
		(-0.20)		(-0.81)				(1.43)		(-1.05)
Other surgeon		50.76		1178.8**		3938.7*		-14958.9		-751.6
		(0.17)		(2.67)		(2.00)		(-1.63)		(-0.42)

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