

# Surgeon Volume and Elective Resection for Colon Cancer: An Analysis of Outcomes and Use of Laparoscopy

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**BACKGROUND:** Surgeon volume may be an important predictor of quality and cost outcomes. We evaluated the association between surgeon volume and quality and cost of surgical care in patients with colon cancer.

**STUDY DESIGN:** We performed a retrospective study of patients who underwent resection for colon cancer, using data from the University HealthSystem Consortium from 2008 to 2011. Outcomes evaluated included use of laparoscopy, ICU admission, postoperative complications, length of stay, and total direct hospital costs by surgeon volume. Surgeon volume was categorized according to high (HVS), medium (MVS), and low (LVS) average annual volumes.

**RESULTS:** A total of 17,749 patients were included in this study. The average age of the cohort was 65 years and 51% of patients were female. After adjustment for potential confounders, compared with LVS, HVS and MVS were more likely to use laparoscopy (HVS, odds ratio [OR] 1.27, 95% CI 1.15, 1.39; MVS, OR 1.16 95% CI 1.65, 1.26). Postoperative complications were significantly lower in patients operated on by HVS than LVS (OR 0.77 95% CI 0.76, 0.91). The HVS patients were less likely to require reoperation than those in the LVS group (OR 0.70, 95% CI 0.53, 0.92) Total direct costs were \$927 (95% CI -\$1,567 to -\$287) lower in the HVS group compared with the LVS group.

**CONCLUSIONS:** Higher quality, lower cost care was achieved by HVS in patients undergoing surgery for colon cancer. An assessment of differences in processes of care by surgeon volume may help further define the mechanism for this observed association. (J Am Coll Surg 2014;218:1223–1230.

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Despite declines in the incidence rates of colorectal cancer over the last decade, it remains the third most common malignancy in the US.<sup>1</sup> Laparoscopic-assisted colectomy (LAC) was considered an acceptable approach for colon cancer resection after the Clinical Outcomes of Surgical Therapy (COST) trial demonstrated similar disease-free survival in patients undergoing LAC and open colectomy.<sup>2</sup>

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Multiple randomized controlled trials have either confirmed the findings of the COST trial, or demonstrated increased overall and disease-free survival with LAC.<sup>3,4</sup> Laparoscopic-assisted colectomy has also been associated with improved quality of life as well as fewer complications, decreased mortality, and lower costs.<sup>5</sup> Even though the use of laparoscopy has steadily increased over time,<sup>3</sup> it is still offered to only a minority of patients with CRC.<sup>6,7</sup>

Previous studies have analyzed morbidity and mortality outcomes in relation to surgeon and hospital volume in colorectal surgery, but the relationship between volume and use of LAC has not been well established.<sup>8</sup> Using data from the University HealthSystem Consortium (UHC), we examined LAC use and 30-day outcomes in patients undergoing surgery for colon cancer according to surgeon volume. We hypothesized that higher surgeon volume would be associated with higher use of LAC, lower complication rates, and lower costs, compared with lower volume surgeons, independent of hospital volume.

### Abbreviations and Acronyms

CRC	colorectal cancer
HVS	high volume surgeon
LAC	laparoscopic-assisted colectomy
LVS	low volume surgeon
MVS	medium volume surgeon
OR	odds ratio
UHC	University HealthSystem Consortium

## METHODS

### Source of data

The UHC database collects inpatient data from 116 participating academic medical centers and 276 of their affiliates, comprising nearly 95% of US nonprofit medical centers. The database includes all patients hospitalized at participating institutions. Variables collected include ICD-9 (International Classification of Diseases, 9th edition) codes for diagnoses and procedures, physician specialty, length of stay, risk-adjusted severity of illness scores, and hospital associated costs. The UHC converts hospital charges into cost estimates based on federal wage data for each hospital location, allowing for meaningful cost comparisons between centers, regardless of hospital location.

After exemption status by the IRB was received, the UHC database was queried for adult patients, 18 years or older, with ICD-9 diagnostic codes for colon or rectosigmoid cancers (153.0–153.4, 153.6–153.8, 154.0) present on admission between 2008 and 2011. These years were studied because they allowed for analysis of surgeon volume, as the unique surgeon identification numbers changed in 2012. To identify patients who underwent cancer resection, this cohort was limited to those with ICD-9 procedure codes for open and laparoscopic colectomy (45.71, 45.73–45.76, 45.79, 45.8, 45.81–45.82, 17.33–17.36, 17.39). Patients were excluded if they underwent both colon and mid- to lower-rectal resection in the same hospitalization, or if their hospitalization was urgent or emergent based on categorization in the database.

### Outcomes measures

The primary outcome of interest was the use of laparoscopy, which was determined by ICD-9 procedure codes for laparoscopic colectomy. Secondary outcomes were frequency of complications (eg, stroke, pneumonia, hemorrhage/hematoma, reopening of surgical wound, cellulitis, urinary tract infection, myocardial infarction, venous thromboembolism, sepsis), ICU admission rate after initial procedure, inpatient length of stay, and total

direct hospital costs. Postoperative complications were coded in the database based on risk pools according to procedure type by UHC. Reoperation was defined by ICD-9 procedure codes for exploratory laparotomy or laparoscopy (54.10, 54.11, 54.12, 54.19), small or large bowel resection (17.33–17.36, 17.39, 45.71, 45.73–45.76, 45.79, 45.8, 45.81–45.82, 48.42, 48.51, 48.52, 48.62, 48.63, 45.00, 45.00–45.02, 45.50–45.52, 45.61–45.63, 46.73), or stoma creation/revision (46.01, 46.03, 46.10, 46.11, 46.13, 46.20, 46.22, 46.23, 46.39) occurring at least 1 day after the primary procedure, including during any readmission stays. Additional covariates used for analysis included age, sex, race, comorbid diagnoses (based on ICD-9 diagnosis codes), 3M APR-DRG Admission Severity of Illness Score (3M Health Information Systems), and insurance status. Severity of illness was reclassified into low (minor and moderate) and high (major and extreme) for ease of analysis.

### Surgeon and hospital volume categories

Once the cohort was identified, unique physician identifiers were used to examine the distribution of yearly surgeon volume. Surgeons who performed less than 1 colectomy per year averaged over the 4-year study period were excluded. Surgeon volume was classified as high, medium, or low based on the observed distribution of average annual surgeon volume. High volume was defined as greater than or equal to the 90<sup>th</sup> percentile (>11 colectomies per year), medium volume between the 50<sup>th</sup> and 90<sup>th</sup> percentiles (5 to 11 colectomies per year), and low-volume as the 50<sup>th</sup> percentile or less (<5 colectomies per year). The 50<sup>th</sup> percentile cutoff for LVS was chosen instead of the 25<sup>th</sup> percentile to allow for similar numbers of patients in each group for analysis, in addition to the authors' decision that there was little clinical relevance for distinguishing between performing 2 colectomies per year (the 25<sup>th</sup> percentile cutoff) vs 4

**Table 1.** Summary of Surgeon and Hospital Volume Groups Over the Study Period

Variable	Low	Medium	High	Very high
Surgeons				
Definition of group*	<5	5–11	>11	–
Surgeons, n	1,274	379	64	–
Cases, <sup>†</sup> n	3,916	7,038	6,975	–
Hospitals				
Definition of group*	<9	9–18	19–37	>37
Hospitals, n	49	48	46	50
Cases, <sup>†</sup> n	575	2,033	4,046	11,095

\*Average number of colectomies for cancer per year.

<sup>†</sup>Total number of cases over the study period.

per year. Surgical specialty was not assessed in this study because some institutions classify their specialists as generalists. We elected not to make these comparisons because this misclassification may have skewed the results.

In order to account for the potentially confounding effects of hospital volume, a variable for hospital volume was created using unique, decrypted hospital identifiers. Hospital volume was categorized according to quartiles of average yearly volume into low (<9 colectomies per year), medium (9 to 18 colectomies per year), high (19 to 37 colectomies per year), and very high (>37 colectomies per year) volume (Table 1).

### Statistical analysis

Bivariate and multivariable regression analyses were used to evaluate differences in the primary and secondary outcomes according to surgeon volume while controlling for the effects of various potentially confounding variables. Differences in selected continuous variables were analyzed

by analysis of variance; differences in categorical variables were examined through the use of chi-square tests. Selection of covariates for use in the multivariable regression models was based on a priori knowledge and significant associations observed in our bivariate analyses. An interaction term for hospital volume and surgeon volume was found to be nonsignificant and was not included in the multivariable model. All analyses were conducted with the use of Stata IC version 12.1.

## RESULTS

### Patient and surgeon characteristics

A total of 17,749 adult men and women who underwent colectomy for cancer between 2008 and 2011 comprised the study sample. The average age of this population was 65 years, and 51% were women (Table 2). Among these patients, 6,795 (38%) underwent colectomy by a high-volume surgeon (HVS), 7,038 (40%) by a medium-volume

**Table 2.** Patient Demographics and Baseline Characteristics

Demographic and characteristics	Surgeon volume category*			p Value
	Low (n = 3,916)	Medium (n = 7,038)	High (n = 6,795)	
Age, y, mean (SD)	66 (13.5)	65 (13.7)	65 (13.8)	NS
Male, n (%)	1,902 (49)	3,445 (49)	3,414 (50)	NS
Race, n (%)				
White	2,808 (72)	5,178 (74)	4,989 (73)	NS
Black	539 (14)	1,007 (14)	817 (12)	<0.001
Hispanic	36 (1)	48 (1)	23 (<1)	<0.001
Asian	120 (3)	205 (3)	236 (3)	NS
Other	412 (8)	600 (9)	730 (11)	<0.001
Insurance status, n (%)				
Private	1,314 (33)	2,706 (39)	2,847 (42)	<0.001
Public	2,380 (61)	4,069 (58)	3,780 (55)	<0.001
Self-pay	24 (<1)	51 (<1)	45 (<1)	<0.001
Other	198 (5)	212 (3)	123 (2)	<0.001
Comorbidities, n (%)				
Hypertension	2,197 (56)	3,844 (54)	3,634 (54)	0.03
Diabetes	847 (22)	1,389 (20)	1,300 (19)	0.01
Anemia	856 (22)	1,448 (21)	1,220 (18)	<0.001
COPD	496 (13)	844 (13)	849 (13)	NS
Obesity	410 (10)	788 (11)	844 (12)	0.01
Congestive heart failure	214 (5)	357 (5)	331 (5)	NS
Depression	250 (6)	472 (7)	487 (7)	NS
Renal disease	222 (6)	373 (5)	408 (6)	NS
Peripheral vascular disease	177 (5)	268 (4)	271 (4)	NS
Liver disease	106 (3)	174 (3)	153 (2)	NS
Severity of illness category, n (%)				
Low (minor/moderate)	3,533 (90)	6,480 (92)	6,216 (91)	0.004
High (major/extreme)	383 (10)	558 (8)	579 (9)	0.004

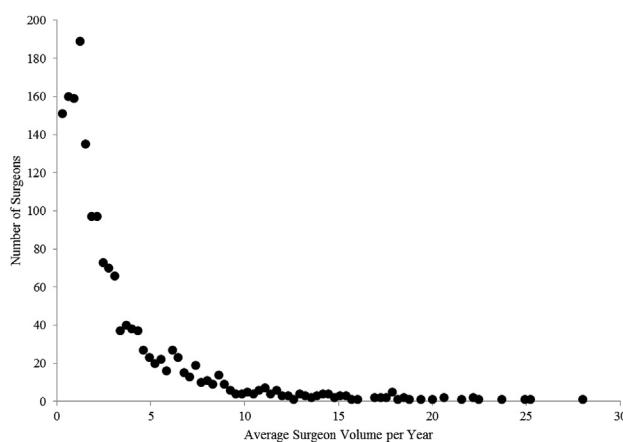
\*Low, <9 colectomies per year; medium, 9–18 colectomies per year; high, >18 colectomies per year.

surgeon (MVS), and 3,916 (22%) by a low-volume surgeon (LVS). The distribution of average annual surgeon volume was right skewed, with an overall median volume of 3.5 colectomies per year (Fig. 1). The median numbers of cases performed per year were: HVS group, 17; MVS group, 7; and LVS group, 2.

In examining differences in various baseline patient characteristics in our respective comparison groups, there was a greater proportion of black patients in the LVS and MVS vs HVS groups (Table 2). A considerably greater proportion of patients in the LVS group were publically insured than in the MVS and HVS groups. Baseline clinical characteristics were generally similar, although there were slightly higher proportions of hypertensive, diabetic, and anemic patients in the LVS group, and a trend toward more obese patients was observed with increasing surgeon volume. The vast majority of study patients presented with low severity of illness.

### Study outcomes

Between 2008 and 2011, there was an overall increase in the use of laparoscopy, with persistently higher rates in the HVS and MVS groups (Fig. 2). In 2011, rates of laparoscopy were 51% in the HVS group, 49% in the MVS group, and only 41% in the LVS group. Between 2010 and 2011, the biggest increase in laparoscopy use was in the LVS group. Complication rates were generally low and were slightly lower in HVS compared with MVS and LVS (7% vs. 8%) (Table 3). When limited to major and extreme severity of illness category, the difference in complication rates was more apparent, with a 14% complication rate among HVS and 16% and 22% in the MVS and LVS groups, respectively. Reoperation occurred in 4% of LVS patients, and 3% and 4% of the MVS and HVS patients.



**Figure 1.** Distribution of average surgeon volume per year.

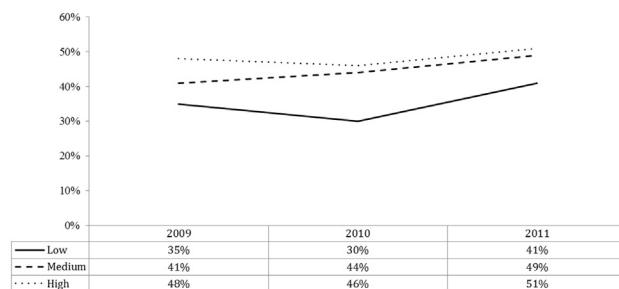
Nearly one-quarter of patients in the LVS group were admitted to the ICU postoperatively; however, only 18% of the MVS and 16% of HVS had a postoperative ICU stay. Median length of stay was 1 day longer in the LVS and MVS groups. The HVS patients had the lowest overall mean total direct cost, at \$13,100, a mean laparoscopic cost of \$10,895, and average open costs of \$15,192. As surgeon volume decreased, the costs for both LAC and open colectomy increased (Fig. 3).

After adjusting for relevant covariates, including hospital volume, the odds of LAC (vs open colectomy) were 16% higher for MVS compared with LVS and 27% higher when comparing HVS with LVS (Table 4). Patients operated on by HVS had about one-quarter fewer complications than LVS patients. The odds of reoperation were 30% less among HVS patients (vs LVS group). On adjusted analysis, higher surgeon volume was not found to be associated with ICU admission and length of stay. Finally, total direct costs were significantly lower for both MVS and HVS compared with LVS, regardless of how the procedure was performed (open or laparoscopic).

### DISCUSSION

This large observational study of adult men and women who underwent colectomy for colon cancer examined several health outcomes in relation to surgeon volume. Our results suggest higher rates of laparoscopy, fewer complications, and lower cost surgery was achieved by higher-volume surgeons. After adjustment for relevant confounders, both HVS and MVS were more likely to use laparoscopy than LVS. Lower complication rates were achieved by HVS, after adjusting for admission severity of illness. The LVS admitted more of their patients to the ICU after the procedure. Cost was lower for MVS and HVS, compared with LVS.

Colorectal cancer (CRC)-related care has a tremendous impact on health care costs. In 2010, the cost of treating



**Figure 2.** Trend in proportion of colectomies performed using laparoscopy by surgeon volume category.

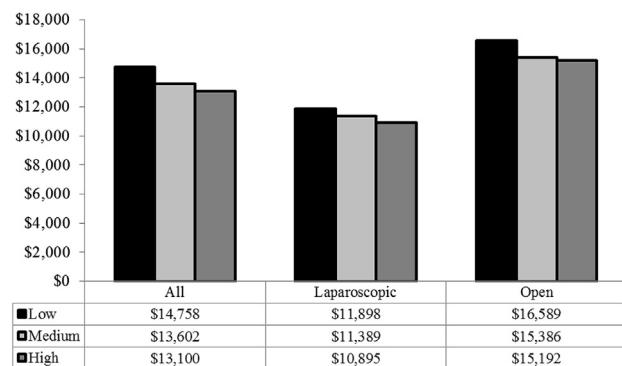
**Table 3.** Unadjusted Outcomes by Surgeon Volume Category

Outcome	Surgeon volume category*			p Value
	Low	Medium	High	
Colectomy type, n (%)				
Right	2,127 (54)	3,753 (53)	3,540 (52)	NS
Transverse	189 (5)	288 (4)	240 (4)	0.004
Left	439 (11)	809 (12)	829 (12)	NS
Sigmoid	796 (20)	1,463 (21)	1,416 (21)	NS
Total	116 (3)	297 (4)	351 (5)	<0.001
Other	249 (7)	428 (6)	419 (6)	NS
Any postoperative complication, n (%)	330 (8)	531 (8)	454 (7)	0.003
Complications if high severity of illness, n (%)	86 (22)	90 (16)	80 (14)	0.002
ICU admission, n (%)	904 (23)	1,254 (18)	1,107 (16)	<0.001
ICU admission if low severity of illness, n (%)	725 (21)	1,023 (16)	870 (14)	<0.001
Reoperation, n (%)	145 (4)	192 (3)	160 (2)	<0.001
Inpatient length of stay, d, mean (SD)	6 (7)	6 (7)	5 (9)	<0.001
Direct hospital cost, \$, mean (SD)	14,758 (16,323)	13,602 (14,541)	13,100 (14,196)	<0.001
Laparoscopic	11,898 (9,175)	11,389 (11,458)	10,895 (9,905)	<0.001
Open	16,589 (19,354)	15,386 (16,401)	15,192 (17,050)	<0.001

High severity of illness indicates major/extreme severity of illness; low severity of illness indicates minor/moderate severity of illness.

\*Low, <5 colectomies per year; medium, 5–11 colectomies per year; high, >11 colectomies per year.

CRC was estimated to be more than \$14 billion, nearly half of which was spent on patients in the first year after diagnosis.<sup>9</sup> Aging of the US population will likely lead to an increase in the number of patients with CRC and add to its financial burden. The Affordable Care Act (ACA),<sup>10</sup> passed in March 2010, demands low-cost care that maintains a high standard of quality. High-prevalence and high-cost diseases, like CRC, provide ideal targets for these reform efforts. In order to ensure policy changes are in the best interests of patients, quality indicators and their effects on cost need to be evaluated. This analysis of the relationship between surgeon-volume laparoscopy use, 30-day outcomes, and costs after elective colectomy for cancer was performed with that goal in mind.



**Figure 3.** Unadjusted mean overall (all), laparoscopic, and open total direct cost according to surgeon volume category.

### Laparoscopy use

Established improvements in morbidity, mortality, and quality of life led us to identify LAC as a quality indicator in surgery for colon cancer.<sup>5,11–16</sup> We demonstrated an overall rate of LAC use of 45% during the study period, with an increase from 42% to 48% between 2009 and 2011; these are higher than rates published from NSQIP in 2008 (34%), but similar to those from the Nationwide Inpatient Sample in 2009 (42.6%).<sup>7,17</sup> An important consideration for this difference is the use of Common Procedural Terminology (CPT) codes in NSQIP and ICD-9 procedure codes in the Nationwide Inpatient Sample and UHC. We showed higher rates of laparoscopy use for HVS and MVS compared with LVS. An explanation for our findings of lower LAC rates among LVS may be related to the well-established steep learning curves for laparoscopic colectomies.<sup>18,19</sup> Colectomies are likely a small portion of these surgeons' practices, and the surgeons are unable to dedicate the time and resources necessary for learning and adopting a new technique.

### Thirty-day outcomes

The association between improved outcomes and higher hospital or surgeon volume has been identified for many procedures, including colon cancer surgery.<sup>8</sup> The primary outcome of interest in previous studies analyzing the volume-outcome relationship in colon cancer patients has been all-cause mortality.<sup>18,20</sup> Mortality rates for elective colon resection are, however, low (1% to 2%), and

**Table 4.** Multivariable Analyses Assessing the Influence of Surgeon Volume on Outcomes

Variable	Laparoscopy	Complication	Reoperation	ICU admission	LOS, d	Cost, \$
	Odds ratio (95% CI)			Beta coefficient (95% CI)		
Surgeon volume category						
Low	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Medium	1.16 (1.06, 1.26)	0.89 (0.77, 1.03)	0.77 (0.60, 0.98)	0.89 (0.80, 1.00)	-0.05 (-0.34, 0.23)	-810 (-1,407, -213)
High	1.27 (1.15, 1.39)	0.77 (0.76, 0.91)	0.70 (0.53, 0.92)	0.98 (0.87, 1.10)	-0.01 (-0.31, 0.30)	-927 (-1,567, -287)
Hospital volume category						
Low	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Medium	1.62 (1.32, 2.00)	1.53 (1.04, 2.27)	1.09 (0.62, 1.94)	0.85 (0.68, 1.05)	0.48 (-0.17, 1.13)	1,097 (-334, 2,528)
High	1.89 (1.54, 2.31)	1.61 (1.10, 2.35)	1.02 (0.59, 1.79)	0.67 (0.54, 0.83)	0.39 (-0.21, 1.05)	2657 (1,279, 4,036)
Very high	2.02 (1.66, 2.47)	1.67 (1.16, 2.43)	0.96 (0.55, 1.66)	0.44 (0.35, 0.54)	0.18 (-0.44, 0.79)	1011 (-343, 2,367)
Age, per year increase	1.01 (1.00, 1.01)	0.99 (0.99, 1.00)	0.99 (0.98, 1.00)	1.01 (1.00, 1.01)	0.00 (-0.01, 0.01)	-25 (-46, -3)
Female (vs male)	1.08 (1.01, 1.14)	0.68 (0.60, 0.76)	0.72 (0.59, 0.87)	0.84 (0.77, 0.91)	-0.53 (-0.74, -0.33)	-1,212 (-1,647, -778)
Race						
White	Ref.	Ref.	-	Ref.	Ref.	Ref.
Black	0.95 (0.87, 1.04)	1.00 (0.85, 1.20)	-	0.83 (0.73, 0.94)	0.59 (0.29, 0.91)	535 (-127, 1,197)
Other	1.35 (1.23, 1.48)	1.00 (0.85, 1.20)	-	0.76 (0.68, 0.88)	0.30 (-0.01, 0.60)	38 (-613, 688)
Insurance status						
Private	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Public	0.82 (0.75, 0.89)	1.52 (1.30, 1.78)	1.16 (0.90, 1.49)	1.32 (118, 1.48)	0.58 (0.30, 0.86)	705 (119, 1,292)
Other	0.71 (0.60, 0.85)	1.08 (0.77, 1.51)	0.83 (0.48, 1.44)	1.21 (0.97, 1.51)	-0.02 (-0.60, 0.55)	-637 (-1,858, 584)
High severity of illness (vs low)	0.41 (0.37, 0.47)	2.42 (2.08, 2.83)	1.56 (1.20, 2.02)	2.83 (2.51, 3.19)	3.78 (3.40, 4.16)	7,154 (6,357, 7,951)
Laparoscopic (vs open)	-	0.57 (0.51, 0.66)	0.91 (0.74, 1.12)	0.44 (0.40, 0.48)	-2.12 (-2.33, -1.90)	-2,716 (-3,160, -2,273)
Procedure						
Total colectomy	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Left colectomy	1.32 (1.10, 1.58)	0.92 (0.66, 1.25)	0.57 (0.37, 0.88)	0.85 (0.68, 1.05)	-1.44 (-2.02, -0.86)	-2,134 (-3,357, -912)
Right colectomy	1.72 (1.47, 2.02)	0.88 (0.67, 1.16)	0.44 (0.30, 0.65)	0.69 (0.58, 0.85)	-1.88 (-2.40, -1.35)	-3,739 (-4,832, -2,639)
Transverse colectomy	0.94 (0.75, 1.17)	0.79 (0.53, 1.16)	0.52 (0.29, 0.94)	0.73 (0.56, 0.95)	-1.56 (2.28, -0.83)	-3608 (-5,124, -2,092)
Sigmoid colectomy	1.72 (1.46, 2.03)	0.77 (0.57, 1.03)	0.57 (0.37, 0.84)	0.66 (0.54, 0.81)	-2.23 (-2.76, -1.68)	-3,427 (-4,573, -2,281)
Other	0.52 (0.39, 0.70)	1.47 (0.98, 2.16)	1.32 (0.77, 2.25)	1.09 (0.81, 1.46)	0.42 (-0.44, 1.27)	1,925 (127, 3,733)
Postoperative complications (vs none)	-	-	15.38 (12.67, 18.67)	4.35 (3.84, 4.92)	9.18 (8.79, 9.58)	18,806 (17,968, 19,643)

LOS, length of stay; Ref., referent category.

the most important predictors of mortality are patient related, including older age and comorbidities, rather than systems-related factors.<sup>21,22</sup> Therefore, we focused our analyses on outcomes related to resource use and hospital-associated costs, rather than mortality. Consistent with previous studies, our data demonstrated lower post-operative complication rates, shorter length of stay, and lower costs in association with higher surgeon volume.<sup>23,24</sup>

Intensive care unit admission after elective procedures is a surrogate marker for excess resource use that has not been previously analyzed with respect to surgeon volume. The rate of ICU admission for patients with low severity of illness was 7% higher in the LVS group than in the HVS group. However, after adjustment for hospital volume, this difference was no longer seen. This may be explained by differences in patterns of care by hospital volume, in which low-volume surgeons may be operating at hospitals with lower thresholds for ICU admission after surgery.

### Study strengths and limitations

Compared with other studies that have previously used administrative data, we were able to provide data from a national cohort of patients, which may provide more generalizable results. Unique surgeon and hospital identifiers allowed for categorization of both surgeon and hospital volume directly, rather than using hospital volume as a surrogate marker for surgeon volume. Therefore, we were able to analyze differences in outcomes by surgeon volume while adjusting for the confounding influence of hospital volume. A unique aspect of our study is our categorization of surgeon volume. We believe our method of categorizing surgeon volume by distribution of the data, rather than quartiles of patients per category, allows for a more clinically relevant comparison of surgeon volume.

However, our study is not without limitations. First, it is susceptible to the pitfalls of using administrative claims data, including errors in coding and evidence of statistical significance regardless of clinical significance. To reduce the potential for bias toward high volume surgeons, surgeons who were documented as having performed the procedure less than once per year on average were excluded from the analysis. Second, given the nature of the data, analysis of the impact of surgeon volume on oncologic outcomes of interest, including nodal status, cancer-survival rates, and long-term outcomes, was not possible. Third, we were also unable to analyze anastomotic leak rates because this variable does not exist in UHC. Finally, while we were unable to account for selection bias, surgeon experience, and decision-making, we did adjust for admission severity of illness, which accounts for comorbidities that usually influence decisions in the pre-, intra-, and postoperative periods.

### CONCLUSIONS

At a time when health care reform aims to reduce health care costs in the US while maintaining quality care, analysis of quality and cost outcomes has high importance. Our results suggest higher quality, lower cost care can be achieved by surgeons performing a higher volume of colectomies for colon cancer, independent of hospital volume. Surgeon volume may be an important factor to consider when policies aimed at improving quality and reducing costs are developed. Processes of care after surgery for colon cancer need to be further studied to allow for implementation of interventions that will lead to improved outcomes in a cost-effective manner after surgery for colon cancer.

### Author Contributions

Study conception and design: Damle, Macomber, Sweeney, Sturrock, Maykel, Alavi

Acquisition of data: Damle, Macomber, Flahive, Santry

Analysis and interpretation of data: Damle, Flahive, Alavi

Drafting of manuscript: Damle, Davids, Alavi

Critical revision: Flahive, Davids, Sweeney, Sturrock, Maykel

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## Invited Commentary

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Since the relationship between the volume of surgical procedures and mortality was described by Luft and

colleagues in 1979, there has been increased focus on high-risk procedures such as pancreatectomy. This has led to a push to concentrate high-risk and relatively low-incidence surgical procedures into high-volume hospitals. But what about relatively common procedures, such as colorectal resection for cancer, one of the most common indications for resection? Colorectal cancer is relatively common, colectomy is a common operation, and presumably, expertise should be available at multiple centers and care accessible for the majority of patients.

Compared with other procedures, the risk of mortality after resection for colon cancer is low, and accordingly, Damle and colleagues examined other important factors including the use of laparoscopy, ICU admission, post-operative complications, length of stay, and direct hospital costs by surgeon volume in this review of 17,749 patients, from 2008 to 2011, using data from the University HealthSystem Consortium (UHC) database. Individual surgeon volume was examined and analyzed by low-volume surgeons (<5 colectomies a year), medium volume surgeons (5 to 11 colectomies per year), and high volume surgeons (>11 colectomies per year). Not surprisingly, high- and medium-volume surgeons were more likely to perform laparoscopic colectomy. In addition, postoperative complications were lower in high-volume compared with low-volume surgeons, and patients operated on by high-volume surgeons were less likely to require reoperation. Direct costs were lower in the high-volume surgeons compared with the low-volume surgeon group.

The authors provide us with a valuable contribution to the literature, but the billion dollar question is, of course, what is it about the added effect of high volume, either at the individual surgeon level or at the hospital level, that improves outcomes? Is it the nurse-to-patient ratio, the difference in experience of the surgical team, the role of residents or fellowship training programs, the experience of allied health professionals and extenders and/or other qualitative measures and additional infrastructure? Furthermore, what is the optimal surgical volume of colectomy to continue to maintain and continuously improve surgical skills? In addition, as the authors point out, administrative databases (such as the UHC database) do not include variables and/or standard definitions for important measures of the outcomes of resection, such as anastomotic leak. Because health care reform aims to optimize quality and decrease cost, further investigative efforts, beyond the scope of review of administrative databases, will be needed to answer these important questions raised by this article.