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Patient, hospital, and geographic disparities in laparoscopic surgery use among SEER-Medicare colon cancer patients

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Abstract

BACKGROUND—Surgical resection is the primary treatment for colon cancer, but utilization of laparoscopic approaches varies widely despite demonstrated short- and long-term benefits.

OBJECTIVE—To identify characteristics associated with laparoscopic colon cancer resection and quantify variation based on patient, hospital, and geographic characteristics.

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DESIGN—Bayesian cross-classified, multilevel logistic models calculated adjusted odds ratios and confidence intervals for patient, surgeon, hospital, and geographic characteristics and unexplained variability (predicted vs. observed values) using adjusted median odds ratios for hospitals and counties.

SETTINGS—Surveillance, Epidemiology, and End Results-Medicare claims database (2008–2011) supplemented with county-level American Community Survey (2008–2012) demographic data

PATIENTS—10,618 colon cancer resection patients 66 years old

INTERVENTION—none

MAIN OUTCOME MEASURES—Non-urgent/non-emergent resections for colon cancer patients 66 years old were classified as laparoscopic or open procedures

RESULTS—Patients resided in 579 counties and utilized 950 hospitals; 47% of patients underwent laparoscopic surgery. Medicare/Medicaid dual enrollment, age 85 years, higher tumor stage and grade were negatively associated with laparoscopic surgery receipt; proximal tumors and increasing hospital size and surgeon caseload were positively associated. Significant unexplained variability at the hospital (adjusted median odds ratio = 3.31, $P < 0.001$) and county (adjusted median odds ratio = 1.28, $P < 0.05$) levels remained after adjustment.

LIMITATIONS—Observational study lacking generalizability to younger patients without Medicare or those with Health Maintenance Organization coverage, dataset did not reflect national hospital studies or hospital volume, unable to account for specific types of comorbidities such as obesity, and broad categories for surgeon caseload.

CONCLUSIONS—Determining sources of hospital-level variation among poor insured patients may help increase laparoscopic resection to maximize health outcomes and reduce cost. See **Video Abstract** at <http://links.lww.com/DCR/AXXX>.

Keywords

Colon cancer; Disparity; Geographic variation; Hospital size; Laparoscopic resection utilization; Multilevel analysis; SEER-Medicare

Introduction

Minimally invasive laparoscopic surgery for colon cancer has been used more frequently for some patients after clinical trials demonstrated its safety and oncological similarity to open surgery. Short-term benefits of laparoscopic resection include reduced analgesia,¹ fewer complications,^{1–4} decreased post-operative intensive care/skilled nursing,^{3,4} and shorter length-of-stay^{1–6} without increased rates of readmission or emergency visits.⁷ Several,^{2,3,5,6,8} but not all,⁴ studies have documented decreased 30-day mortality. Compared to open resection, laparoscopic colectomy is associated with similar^{5,6,9–13} or better⁸ long-term oncological and survival outcomes and cost savings.^{4,14,15}

Despite these benefits, laparoscopic surgery has not been widely adopted for eligible colon cancer patients, and even among those who receive laparoscopic colectomy, unexplained

hospital-level variation in outcomes (hospital center effect) exists.¹⁶ Previous studies have shown extensive variability in laparoscopic surgery utilization based on characteristics of patients [e.g., age, gender, race/ethnicity, socioeconomic status (SES), payer/insurance type, disease stage, comorbidity], hospitals (e.g., size/volume, teaching hospital status, urban/rural, geographic region)^{3,5,8,17–21} and surgeon caseload.²² To our knowledge, no studies have examined small area variability (e.g., at the county level) in the use of laparoscopic surgery in the US. Moreover, no studies concurrently examined variation across patients, hospitals, and geography.

This study describes variability in use of laparoscopic (vs. open) surgery for colon cancer among Medicare patients. Identifying the level (patient, hospital, and/or geographic unit) at which variation is occurring and the characteristics associated with underutilization of laparoscopic surgery for colon cancer would help direct interventions aimed at decreasing disparities in availability and access—interventions that might have potential for cost savings and improving healthcare quality.

Materials and Methods

Data Sources

Data were from the most recent release of an existing linkage of the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) database with Medicare claims data (2008–2011), supplemented with county-level demographic data from the 2010 US Census and the 2008–2012 American Community Survey (ACS). SEER is a nationally representative collection of population-based cancer registries collecting demographic, diagnostic, initial treatment, and survival data for 28% of the US population.²³ This study included 17 SEER registries: Connecticut, Iowa, New Mexico, Utah, Hawaii, New Jersey, Kentucky, Louisiana, Detroit, San Francisco-Oakland, Atlanta, Seattle-Puget Sound, Rural Georgia, Greater Georgia, Los Angeles County, San Jose-Monterey, and Greater California. The Centers for Medicare and Medicaid Services (CMS) collect claims information for covered healthcare services from the time of an individual's Medicare enrollment until death. Use of the linked database provides detailed claims-related information such as physician- and hospital-level variables as well as the ascertainment of comorbidities prior to diagnosis which are unavailable through the SEER cancer registry. The Institutional Review Boards approved this study as non-human subjects research exempt from oversight.

Patient sample

Eligibility included patients aged 66 years and older who underwent non-urgent/non-emergent surgical resection within 90 days of diagnosis for a first primary in-situ or invasive colon cancer diagnosed during 2009–2011, who had both Medicare Parts A and B coverage during this period. Patients with unknown surgery type were excluded. Including patients aged 66+ years allowed for a complete year of claims data (from 2008 records) prior to diagnosis to determine comorbidities. Diagnosis during 2009–2011 was selected because the ICD-9 procedure codes for laparoscopic colon resection became available on October 1, 2008. We excluded patients who were members of a Health Maintenance Organization (HMO) or had incomplete Medicare Parts A and B coverage due to lack of claims data.

Similarly, patients identified by autopsy or death certificate were excluded from analysis. We identified urgent/emergent colon cancer patients based ICD-9 codes for bowel obstruction (56089, 5609), perforation (56983), hemorrhage (5693, 5789), peritonitis (5670, 5672, 5678, 5679), or emergency inpatient admission (see Text, Supplemental Digital Content 2, which details the exclusion criteria for urgent, emergent, and emergency procedures).²⁴

Type of surgery

Initial surgery was classified as laparoscopic, open, or converted-to-open (V64.4 and V64.41) based on ICD-9 procedure codes (see Table, Supplemental Digital Content 3, which lists the ICD-9 procedure codes used to identify surgery type) and CPT codes (see Table, Supplemental Digital Content 4, which lists the surgeon CPT codes used to identify surgery type).^{21,25,26} Surgery type was dichotomized for analysis based on intent-to-treat as laparoscopic, including converted-to-open, (vs. open) surgeries.

Covariates

Covariates were based upon patient, surgeon, hospital, and county characteristics thought to explain variability at different levels.^{27,28} Patient-level characteristics included: age, sex, race/ethnicity (excluding Alaska Natives due to few cases), number of comorbidities measured by the Elixhauser method²⁹ any use of Medicaid during diagnosis year (proxy measure for low income), American Joint Commission on Cancer (AJCC)³⁰ tumor stage, grade, location, and histology. Tumor location was defined as proximal colon (cecum, ascending), transverse colon (hepatic flexure, transverse colon, splenic flexure), or distal colon (descending colon, sigmoid colon, overlapping lesion, or colon NOS). Surgeon and hospital characteristics obtained from the CMS Healthcare Cost Report and Provider of Service files (2008–2011) included mean annual surgeon caseload of colon cancer resections for patients in this sample, regardless of surgery type or hospital affiliation, hospital size (total number of hospital beds), and hospital teaching status. County-level poverty was based on the percentage of the population living in poverty for each patient's county of residence at time of diagnosis using ACS data (2008–2012). The county urban-rural variable was based on census data using collapsed categories of the 2003 Rural/Urban Continuum Code. Patients with missing data were excluded listwise.

Statistical analysis

Chi-square tests were used to compare descriptive characteristics by surgery type. Mean annual surgeon caseload was treated as a hospital-level characteristic due to model complexity and based on the skewed distribution of the number of patients nested within surgeons. To account for lack of independence of patients within hospitals and within patient residential counties, we used a Bayesian cross-classified multilevel logistic model, which allows nesting within multiple separate, unrelated groups.³¹ Covariates were forced into the models to calculate adjusted odds ratios (aOR) and 95% confidence intervals (CI). Deviance Information Criterion was used to assess model fit, with lower values indicating better fit. WinBUGS (version 1.4.3, MRC, UK) was used to perform 5,000 burn-in iterations of the cross-classified Bayesian analysis, with an additional 5,000 iterations retained for parameter estimates.

To facilitate interpretation of the variance across hospitals and counties on a scale directly comparable to odds ratios for other covariates in the model, we calculated the median odds ratio (MOR).³² Based on the random effects variance component (V) from the regression model, $MOR = \exp(0.95 \sqrt{V})$ can be interpreted as the median value of the ratio of predicted odds of the outcome for two patients randomly selected from different hospitals (or counties) with equivalent covariates. An MOR of 1 indicates no variation in outcome across hospitals (or counties). Due to the 1-tailed testing of heterogeneity measures, 95% credible intervals (similar to confidence intervals using the Frequentist approach) are not reported and 1-tailed p-values are used to indicate statistical significance.³³

We also estimated variability in laparoscopic surgery utilization across hospitals and counties with at least 30 patients. Predicted probability of receiving laparoscopic surgery was computed for each patient using model coefficients. These individual predicted probabilities were then averaged for all patients treated at a particular hospital and residing in a particular county to create hospital- and county-level predicted values. These predicted values were compared to the observed values across hospitals and counties.

Results

Data were analyzed for 10,618 patients residing in 579 counties who underwent non-urgent/non-emergent colon cancer resection at 950 hospitals. Most patients were female (57.9%), white (84.0%), not dual enrolled in Medicaid (82.8%), and < 85 years (81.2%) (Table 1). AJCC Stage II tumors were the most common (33.2%). The majority of tumors were moderately differentiated (65.2%), in the proximal colon (55.4%), and non-mucinous adenocarcinoma (87.7%). Surgeons with annual caseloads <10 performed 43.4% of all the surgeries in this analysis. Most patients (63.9%) resided in counties with 10–19% poverty.

Among the 93.7% of patients for whom surgeon specialty was available, 98.6% had a single surgeon. Patients primarily saw general surgeons (72.6%), colorectal surgeons (22.1%) or surgical oncologists (2.0%).

Laparoscopic surgical use

Overall, laparoscopic surgery was used for 47% of all resections, including 484 converted surgeries. All covariates differed significantly by surgery type. Laparoscopic surgery rates were similar among men (49.3%) and women (46.2%). Among Whites, 47.8% of resections were laparoscopic, with 42.7% among Blacks and 49.8% among Other races. Laparoscopic resection rates were highest for patients with only 1 comorbidity (49.4%). Among Medicaid patients, 40.8% of resections were performed laparoscopically, compared to 48.9% among non-Medicaid patients. As age increased, laparoscopic surgery rates decreased, from 49.6% among patients aged 66–74 to 43.4% among patients aged 85+. As tumor stage increased, laparoscopic-resection rates decreased. As the number of hospital beds increased, so did the rate of laparoscopic surgery, from 38.9% in hospitals with fewer than 200 beds to 53.9% in hospitals with 500+ beds. Patients living in counties with >20% poverty rates had the lowest rates of laparoscopic resection (39.9%), as did patients in less urban areas (35.6%). Rates also differed by SEER area.

Adjusted Model

When adjusted, patients were 25% less likely to receive laparoscopic surgery if they were aged 85+ (vs. 66–74) and 41% more likely if they did not receive Medicaid (vs. Medicaid) (Table 2). Males were 14% more likely than females to receive laparoscopic resection. Race and number of comorbidities did not predict laparoscopic resection. Patients with proximal (vs. distal) tumors were 36% more likely to receive laparoscopic surgery, and patients with more advanced disease (stages II and III-IV each vs. stage 0-I) and more aggressive tumors (grade 3 and 4 vs. grade 1) were significantly less likely to undergo laparoscopic surgery. As hospital size increased, so did the odds of receiving laparoscopic surgery. Hospital teaching status was non-significant. Patients from counties with more than 20% of the population living in poverty (vs. <10%) were 35% less likely to receive laparoscopic surgery.

Multi-Level Variation

Due to missing data, 226 patients were excluded from cross-classified modeling ($n=10,392$). In unadjusted models, significant variation in laparoscopic surgery utilization existed at hospital ($MOR = 3.31$, $V = 1.58$, $p < 0.001$) and county ($MOR = 1.32$, $V = 0.09$, $p < .05$) levels (Table 3). When adjusted, hospital variation ($aMOR = 3.31$, $V = 1.58$, $p < 0.001$) remained larger than county-level variation ($aMOR = 1.28$, $V = 0.07$, $p < .05$).

Among the 85 hospitals with at least 30 incident colon cancer patients, the observed percentage who received laparoscopic surgery ranged from 4.4 to 94.0 (Table 4) while the predicted rate ranged from 8.1 to 91.3. Six hospitals had observed percentage of laparoscopic surgery use below the lower bound of the 1-tailed 95% credible interval of the predicted percentage (laparoscopic surgery use was lower than expected), while eight were above the upper bound (use was higher than expected).

Among the 76 counties with at least 30 new colon cancer patients, the observed percentage who received laparoscopic surgery ranged from 0.0 to 82.5 while the predicted rate ranged from 10.4 to 76.7. Four counties had observed percentage of laparoscopic surgery use below the lower bound of the 95% credible interval of the predicted percentage (use was lower than expected), while 11 were above the upper bound (use was higher than expected).

Discussion

We examined the role of patient, hospital and geographic variability in non-urgent/non-emergent laparoscopic resection for colon cancer. Use varied across hospitals, but less so across counties. When comparing observed and predicted values among hospitals and counties with at least 30 patients, patients in 8.9% of hospitals and 13.1% of counties received laparoscopic surgery below expected rates. At the patient level, sex, dual Medicare/Medicaid enrollment, older age, and tumor characteristics (stage, grade, proximal location) were significant predictors of laparoscopic surgery. Annual surgeon caseload, hospital size, and high county poverty were also significant.

Study limitations include those typical of observational studies, including an inability to account for factors not reflected in the database, such as patient preferences and other factors which may impact utilization of laparoscopic approaches. Although we used the most recent

release of the SEER-Medicare data set, there is an inherent time lag in using large linked data. As utilization continues to increase, more recent data may show higher proportions of colon cancer resections being performed laparoscopically. Additionally, this study lacks generalizability to patients without Medicare, including younger patients or those with HMO coverage. We also had to exclude the Alaska Native SEER registry due to low cell counts. SEER includes a nationally representative sample of cancer patients, but not hospitals. Colon cancer disproportionately affects older people,³⁴ so this study applies to the majority of colon cancer patients. HMO market penetration has been associated with increased likelihood of laparoscopic surgery use as well as lower overall costs,¹⁴ so our exclusion of patients with HMO coverage may underestimate laparoscopic use. However, Medicare Parts A and B provide complete claims data and therefore eliminate potential confounding due to different reimbursement plans. We were unable to examine the influence of specific comorbidities (e.g., obesity) that are difficult to identify using claims data and have been associated with increased odds of conversion to open surgery.^{35,36} Surgeon caseload was included as a hospital-level variable rather than being nested within hospital due to small numbers of patients for many providers and model complexity.

Our study extends knowledge by examining county-level geographic variation and by utilizing a Bayesian cross-classified multilevel model to quantify the variation in laparoscopic surgery use separately across hospitals and counties. Previously, geographic variation was examined at the census region²¹ and hospital referral region²⁶ in the US. Our model accounted for little of the county variation in our study, indicating that additional county-level factors are at work. A hot-spot analysis in Ontario, Canada found geographic variability at the neighborhood level (defined as 3-character postal forwarding sortation areas) associated with presence of minimally invasive surgery fellowship training facilities; 14% of the population resided in cold spots, which is similar to our finding of underutilization at the county level.³⁷ The ability to find geographic variation is related to the number of units examined. Smaller geographic divisions, such as census tracts, would have provided greater variability and may have resulted in different findings, but we were unable to utilize census tracts due to many tracts having fewer than five patients. Other studies found greater variability in colon cancer complications and 30-day mortality at the census-tract versus hospital level,^{27,28} but the current study found greater variation at the hospital versus county level, possibly due to the larger geographic unit (county) of measurement.

A previous study found surgeon caseload was positively associated with laparoscopic surgery.²² We also found that as surgeon caseload decreased, so did the odds of receiving laparoscopic resection. Less than 5% of patients in our study had surgery performed by surgeons with annual caseloads of 30+ (based on the study population) whereas 43% had surgeons with annual caseloads of less than 10. These patients were 60% less likely to undergo laparoscopic surgery compared to patients seeing surgeons with the highest caseload.

Our study supports prior research indicating that laparoscopic surgery is influenced by patient- and hospital-level factors.^{3,5,8,17-21} However, our study goes beyond previous studies to show that our proxy for individual-level low SES and county-level poverty (<10%

vs. 20%) were significantly associated with laparoscopic surgery. One possible explanation for these differences in utilization associated with poverty may be differential access to providers.³⁸ Even at high volume hospitals, socioeconomic disparities in utilization of minimally invasive colorectal surgery persist after controlling for factors such as comorbidities.³⁹

Larger hospital size was also significant in the adjusted model. Because we excluded urgent/emergent surgeries, we did not use critical access designation in the current study. Only 2.7% (n=281) of included patients had surgeries performed at critical access hospitals. Rather, we used total number of beds as an indicator of differences in hospital size. With over 23% of surgeries performed at hospitals with fewer than 200 beds, improving access to laparoscopic colon cancer resection could have significant cost savings and improvements in local healthcare quality. A previous study found near-universal access to laparoscopic equipment at hospitals filing claims with Medicare,²⁶ so hospital-level variation is not likely due to equipment access. Although larger hospitals were more likely to perform laparoscopic surgery to treat their colon cancer patients, none of the variables included in our model accounted for the variation across hospital, as indicated by the lack of change between the unadjusted and adjusted models.

More research is needed to identify modifiable factors with potential to correct this underutilization. Studies have suggested decision aids may help reduce regional variation in surgery type,²⁶ and practice guidelines have advocated for surgeon training, particularly at small, rural hospitals.³² Additionally, reimbursement through CMS value-based care models could incentivize use of laparoscopic surgery for colon cancer, which may reduce variability across hospitals. A possible solution to unwarranted variation (variation unexplained by disease, patient preference, or evidence-based care) in access to healthcare is to increase shared patient-physician decision making.⁴⁰ Patient education about initial screening referrals, selecting a treating physician, hospital quality, surgical options, and deciding where (which hospital) to have non-urgent/non-emergent colon cancer surgery are likely more important than the county of residence, although county variation was also significant. For example, patients should be educated about the potential health and cost benefits of laparoscopic resection and given referrals to surgeons who perform it on a regular basis or to hospitals with higher laparoscopic resection rates so patients can make informed treatment decisions based on their preferences and cost considerations. However, certain patients, particularly poor and/or rural patients enrolled in Medicare/Medicaid, may have fewer options about where to have surgery due to their financial and/or transportation constraints or to hospitals' policies for treating patients based on their health insurance status.

In summary, significant variability exists across hospitals, counties, and patients regarding the use of laparoscopic surgery for non-urgent/non-emergent colon cancer surgery; however, there is only limited county-level variability. Determining the sources of hospital-level variation and decreasing disparities in utilization at the patient level, particularly patients on Medicaid, are areas in which increased laparoscopic-surgery utilization could maximize patient outcomes and reduce healthcare costs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Patient, surgeon, hospital, and geographic characteristics by surgery type among SEER-Medicare colon cancer patients, 2009–2011

Variable Characteristics	Total patients N = 10,618 (%) ^a	Laparoscopic n = 5,040 (47%) ^b	Open n = 5,578 (53%) ^b	P
Patient Characteristics				
Sex **				0.002
Male	4471 (42.1)	2202 (49.3)	2269 (50.7)	
Female	6147 (57.9)	2838 (46.2)	3309 (53.8)	
Race **				0.009
White	8924 (84.0)	4262 (47.8)	4662 (52.2)	
African American	923 (8.7)	394 (42.7)	529 (57.3)	
Other/Unknown	771 (7.3)	384 (49.8)	387 (50.2)	
Comorbidity ³⁰ ***				0.001
0	2452 (23.1)	1197 (48.8)	1255 (51.2)	
1	3258 (30.7)	1608 (49.4)	1650 (50.6)	
2+	4908 (46.2)	2235 (45.5)	2673 (54.5)	
Medicaid (dual eligibility) ***				<0.0001
Yes	1831 (17.2)	747 (40.8)	1084 (59.2)	
No	8787 (82.8)	4293 (48.9)	4494 (51.1)	
Age group ***				<0.0001
66 – 74	3970 (37.4)	1971 (49.6)	1999 (50.4)	
75 – 84	4647 (43.8)	2201 (47.4)	2446 (52.6)	
85+	2001 (18.8)	868 (43.4)	1133 (56.6)	
AJCC tumor stage ***				<0.0001
0	189 (1.8)	113 (59.8)	76 (40.2)	
I	2803 (26.4)	1562 (55.7)	1241 (44.3)	
II	3523 (33.2)	1622 (46.0)	1901 (54.0)	
III	2813 (26.5)	1295 (46.0)	1518 (54.0)	
IV	1070 (10.1)	348 (32.5)	722 (67.5)	
Unknown	220 (2.1)	100 (45.4)	120 (54.6)	
Tumor grade ***				<0.0001
Well-differentiated	907 (8.5)	481 (53.0)	426 (47.0)	
Moderately differentiated	6922 (65.2)	3372 (48.7)	3550 (51.3)	
Poorly differentiated	2014 (19.0)	852 (42.3)	1162 (57.7)	
Undifferentiated	337 (3.2)	121 (35.9)	216 (64.1)	
Undetermined	437 (4.1)	213 (48.7)	224 (51.3)	
Tumor location ***				<0.0001
Proximal colon	5877 (55.4)	2952 (50.2)	2925 (47.8)	
Transverse colon	2062 (19.4)	883 (42.8)	1179 (57.2)	

Variable Characteristics	Total patients N = 10,618 (%) ^a	Laparoscopic n = 5,040 (47%) ^b	Open n = 5,578 (53%) ^b	P
Distal colon	2679 (25.2)	1205 (45.0)	1474 (55.0)	
Tumor histology**				0.014
Mucinous adenocarcinoma	1023 (9.6)	485 (47.4)	538 (52.6)	
Other adenocarcinoma	9309 (87.7)	4446 (47.8)	4863 (52.2)	
Non-adenocarcinoma	279 (2.6)	107 (38.4)	172 (61.6)	
Hospital Characteristics				
Mean annual surgeon caseload***				<0.0001
< 10	4607 (43.4)	1866 (40.5)	2741 (59.5)	
10 – 19	3086 (29.1)	1524 (49.4)	1562 (50.6)	
20 – 29	1264 (11.9)	726 (57.4)	538 (42.6)	
30+	507 (4.8)	323 (63.7)	184 (36.3)	
Unknown/Missing	1154 (10.9)	601 (52.1)	553 (47.9)	
Hospital size (no. beds)***				<0.0001
1 – 199	2494 (23.5)	970 (38.9)	1524 (61.1)	
200 – 349	3204 (30.2)	1520 (47.4)	1684 (52.6)	
350 – 499	2397 (22.6)	1190 (49.6)	1207 (50.4)	
500+	2523 (23.8)	1360 (53.9)	1163 (46.1)	
Teaching hospital***				<0.0001
Yes	5095 (48.0)	2554 (50.1)	2541 (49.9)	
No	4801 (45.2)	2104 (43.8)	2697 (56.2)	
Unknown	722 (6.8)	382 (52.9)	340 (47.1)	
Geographic Characteristics				
County-level poverty rate***				<0.0001
< 10%	2154 (20.3)	1072 (49.8)	1082 (50.2)	
10 – 19%	6789 (63.9)	3300 (48.6)	3489 (51.4)	
20%	1675 (15.8)	668 (39.9)	1007 (60.1)	
Urban/Rural***				<0.0001
Big Metro	5450 (51.3)	2726 (50.0)	2724 (50.0)	
Metro	3078 (29.0)	1541 (50.1)	1537 (49.9)	
Urban	680 (6.4)	256 (37.6)	424 (62.4)	
Less Urban	1148 (10.8)	409 (35.6)	739 (64.4)	
Rural	262 (2.5)	108 (41.2)	154 (58.8)	
SEER Registry***				<0.0001
Atlanta	267 (2.5)	137 (51.3)	130 (48.7)	
Connecticut	634 (6.0)	381 (60.1)	253 (39.9)	
Detroit	611 (5.8)	260 (42.6)	351 (57.4)	
Greater California	1740 (16.4)	925 (53.2)	815 (46.8)	
Greater Georgia	904 (8.5)	447 (49.4)	457 (50.6)	
Rural Georgia	23 (0.2)	12 (52.2)	11 (47.8)	

Variable Characteristics	Total patients N = 10,618 (%) ^a	Laparoscopic n = 5,040 (47%) ^b	Open n = 5,578 (53%) ^b	P
Hawaii	110 (1.0)	43 (39.1)	67 (60.9)	
Iowa	897 (8.5)	337 (37.6)	560 (62.4)	
Kentucky	938 (8.8)	320 (34.1)	618 (65.9)	
Los Angeles	695 (6.5)	338 (48.6)	357 (51.4)	
Louisiana	755 (7.1)	303 (40.1)	452 (60.9)	
New Jersey	1589 (15.0)	759 (47.8)	830 (52.2)	
New Mexico	225 (2.1)	119 (52.9)	106 (47.1)	
San Francisco	361 (3.4)	232 (64.3)	129 (35.7)	
San Jose	210 (2.0)	103 (49.0)	107 (51.0)	
Seattle	482 (4.5)	210 (43.6)	272 (56.4)	
Utah	177 (1.7)	114 (64.4)	63 (35.6)	

^aColumn percentages presented

^bRow percentages presented

* $P = 0.05$

** $P = 0.01$

*** $P = 0.001$

Table 2

Adjusted odds of receiving non-urgent laparoscopic surgery for colon cancer

Included Variables	aOR (95% CI) ^a
Individual-level Characteristics	
Sex	
Male	1.14 (1.04 – 1.26)
Female	Ref
Race	
White	Ref
African American	0.90 (0.75 – 1.07)
Other	1.21 (0.98 – 1.48)
Comorbidity (Elixhauser)	
0	Ref
1	1.05 (0.92 – 1.19)
2+	0.91 (0.80 – 1.02)
Medicaid (dual eligibility)	
Yes	Ref
No	1.41 (1.23 – 1.61)
Age group	
66 – 74	Ref
75 – 84	0.92 (0.82 – 1.02)
85+	0.75 (0.66 – 0.86)
AJCC tumor stage	
0 – I	Ref
II	0.66 (0.58 – 0.74)
III – IV	0.58 (0.51 – 0.65)
Tumor grade	
1 – Undifferentiated	Ref
2 – Poorly differentiated	0.88 (0.73 – 1.05)
3 – Moderately differentiated	0.70 (0.57 – 0.86)
4 – Well differentiated	0.58 (0.42 – 0.81)
Tumor location	
Proximal	1.36 (1.21 – 1.53)
Transverse	0.92 (0.80 – 1.06)
Distal	Ref
Tumor histology	
Mucinous adenocarcinoma	Ref
Other-adenocarcinoma	1.01 (0.87 – 1.18)
Non-adenocarcinoma	0.80 (0.57 – 1.14)
Hospital Characteristics	
Mean annual surgeon caseload	
1 – 9	0.40 (0.31 – 0.52)

Included Variables	aOR (95% CI) ^a
10 – 19	0.66 (0.51 – 0.86)
20 – 29	0.75 (0.56 – 0.99)
30+	Ref
Hospital size (no. beds)	
1 – 199	Ref
200 – 249	1.47 (1.12 – 1.91)
350 – 499	1.56 (1.14 – 2.14)
500+	1.87 (1.30 – 2.69)
Teaching hospital	
Yes	Ref
No	0.97 (0.77 – 1.21)
Geographic Characteristics	
% of population living in poverty	
0 – 9	Ref
10 – 19	0.92 (0.74 – 1.15)
20+	0.65 (0.50 – 0.86)

^a aOR: adjusted odds ratio; CI: confidence interval

Table 3

Unadjusted and adjusted^a hospital and county variability in laparoscopic surgery utilization in SEER-Medicare colon cancer patients

	Unadjusted		Adjusted	
	Hospital	County	Hospital	County
Variance	1.58 ($P < 0.001$)	0.09 ($P < 0.05$)	1.58 ($P < 0.001$)	0.07 ($P < 0.05$)
MOR ^b	3.31	1.32	3.31	1.28

^a Adjusted for sex, race, comorbidity, Medicaid, age, AJCC tumor stage, tumor grade, tumor location, tumor histology, mean annual surgeon caseload, hospital size, hospital teaching status, and county-level percentage of the population living in poverty

^b MOR: Median odds ratio

P-values based on 1-tailed tests

Observed and predicted percentage of patients who received laparoscopic surgery for colon cancer, by hospitals and counties with 30+ patients

Table 4

	Min	Mean	Median	Max	Number of units with observed % below 95% CI† of predicted	Number of units with observed % above 95% CI† of predicted
Hospital (n=85)						
Observed	4.4	52.0	53.1	94.0	6	8
Predicted	8.1	51.8	53.0	91.3		
County (n=76)						
Observed	0.0	51.1	51.3	82.5	4	11
Predicted	10.4	50.4	52.3	76.7		

[†]CI: credible interval, 1-tailed