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Utilization of Laparoscopic Colon Surgery in the Texas Inpatient Public Use Data File (PUDF)

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ABSTRACT

Background: Laparoscopic surgery has become the standard of care for the most common surgical procedures performed. However, laparoscopic techniques have not reached this same penetrance in colorectal surgery. We wanted to determine the percentage of colon operations performed in Texas that were done via laparoscopic, robotic and open techniques.

Methods: The Texas Inpatient Public Use Data File (PUDF) was queried using ICD-9-CM diagnostic and procedure codes to determine overall utilization of laparoscopic colectomies (LC) in Texas between 2013–14 for reporting facilities. We specifically looked at cost and the length of stay for LC, open colectomy (OC) and robotic assisted colectomy (RAC).

Results: In the state of Texas between 2013–14 there were 20,454 colectomies performed. Of these 12,328 (60.3%) were OC, 7,536 (36.8%) were LC, and 590 (3.9%) were RAC. Average total cost was $117,113 for OC, $75,741.9 for LC, and $81,996.2 for RAC. Average length of stay for each technique was 10.6 days for OC, 6.1 days for LC, and 5.1 days for RAC. The risk of a postoperative complication occurring was higher in the open procedure than a laparoscopic procedure.

Conclusions: LC accounted for only 36.8% of all colectomies performed in Texas between 2013–14. OC costs twice as much as LC and increased the length of stay by nearly 4 d. LC and RAC are both associated with significantly less cost and length of stay for patients undergoing surgery, while lowering perioperative complications.

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INTRODUCTION

Laparoscopic colon (LC) surgery has not yet reached the level of penetrance of other common operations, such as laparoscopic cholecystectomy. The laparoscopic approach has clear advantages compared to the open approach for cholecystectomy and this technique was readily adopted by surgeons.[1] In the past, there had been some concern over the oncological outcomes of laparoscopy in colon resection, but several large randomized controlled trials supported equivalent outcomes for laparoscopic and open colorectal cancer resections and have long since put that issue to rest.[2] However, laparoscopic surgery of the colon has had limited utilization throughout the country.[3,4] The reasons for this are not clearly elucidated.

There has been a shift in surgical research in the past decade. As a profession, surgeons are developing and participating in both large state or national administrative and clinical databases as part of ongoing quality improvement initiatives. These databases can be prospective, self reported clinical databases maintained by surgeons and their professional organizations such as the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program, or can be administrative databases or claims based databases that are regional or state specific such as the Texas Inpatient Public Use Discharge Data File (PUDF). Administrative databases collect much more data and focus on diagnostic and procedure coding as well as cost and demographics. Administrative databases are not as valuable for clinical information, such as complications, but are useful to study large heterogeneous populations. The primary aim of this study is to examine the rates of laparoscopic colon resections performed in Texas during the years of 2013–2014 and to compare the rates of LC, RAC and OC. Secondary outcomes include the characteristics of patients undergoing minimally invasive colon resections, length of stay, cost and complications.

METHODS

Database

The State of Texas maintains the Texas Hospital Inpatient Discharge Public Use Data File (PUDF) which collects hospital discharge data from all state licensed hospitals except those that are statutorily exempt from the reporting requirement.[5] The Texas PUDF also contains information such as International Classification of Diseases Clinical Modification 9 (ICD-9-CM) procedure and diagnosis codes. Up to 25 admission and discharge diagnoses are collected for each patient. The raw data was provided in a deidentified Health Insurance Portability and Accountability Act (HIPAA) compliant format. Exempt hospitals include those located in a county with a population less than 35,000, or those located in a county with a population more than 35,000 and with fewer than 100 licensed hospital beds and not located in an area that is delineated as an urbanized area by the United States Bureau of the Census. Exempt hospitals also include hospitals that do not seek government reimbursement and federal hospitals. A Data Use Agreement was obtained from the Texas Department of State Health Services.

Patient population

The Texas PUDF was queried using ICD-9-CM diagnostic codes for benign and malignant diseases of the colon. The inclusion criteria were the patients with the diagnosis codes for colonic disease (153, 153.1, 153.2, 153.3, 153.4, 153.5, 153.6, 153.7, 153.8, 153.9, 555.1, 556, 556.1, 556.2, 556.3, 556.4, 556.5, 556.6, 556.8, 556.9, 558, 558.1, 558.2, 558.3, 558.9, 562, 562.01, 562.11, 562.12, 562.13) which were then cross-referenced with the ICD-9-CM procedure codes that included LC resections (17.3, 17.31, 17.32, 17.33, 17.34, 17.35, 17.36, 17.39, 45.81) and OC (45.7, 45.71, 45.72, 45.73, 45.74, 45.75, 45.76, 45.79, 45.8, 45.82, 45.83). **Figure 1** shows the diagnosis codes and **Figure 2** shows the procedure codes. Robotic assisted cases are identified by the code 17.42. This inclusion criteria gave us the study population of patients that underwent colon resections for the years 2013 and 2014. These years were chosen because they were before the transition to ICD-10 codes in the third quarter of 2015, and we felt the coding would not initially be as accurate after this transition period. We also examined the other characteristics of this group such as demographics, length of stay and cost. Cost

ICD-9-CM	Diagnosis
153	Malignant neoplasm of the colon
153.1	Malignant neoplasm of transverse colon
153.2	Malignant of descending colon
153.3	Malignant of sigmoid colon
153.4	Malignant of cecum
153.5	Malignant of appendix
153.6	Malignant of ascending colon
153.7	Malignant of splenic flexure
153.8	Malignant of other specified site of large intestine
153.9	Malignant of colon, unspecified site
555.1	Regional enteritis of large intestine
556	Ulcerative colitis
556.1	Ulcerative (chronic) ileocolitis
556.2	Ulcerative proctitis
556.3	Ulcerative proctosigmoiditis
556.4	Psuedopolyposis of colon
556.5	Left sided ulcerative (chronic) colitis
556.6	Universal ulcerative (chronic) colitis
556.8	Other ulcerative colitis
556.9	Ulcerative colitis, unspecified
558	Other and unspecified nonifectious gastroenteritis and colitis
558.1	Gastroenteritis and colitis due to radiation
558.2	Toxic gastroenteritis and colitis
558.3	Allergic gastroenteritis and colitis
558.9	Other and unspecified nonifectious gastroenteritis and colitis
562	Diverticula of the intestine
562.01	Diverticulitis of small intestine (without mention of hemorhhage)
562.11	Diverticulitis of colon (without mention of hemorhhage)
562.12	Diverticulosis of colon with hemorhhage
562.13	Diverticulitis of colon with hemorhhage

Figure 1. ICD-9-CM diagnosis codes

ICD-9-CM	Procedure
17.3	Laparoscopic partial excision of large intestine
17.31	Laparoscopic multiple segmental resection of large inestine
17.32	Laparoscopic cecectomy
17.33	Laparoscopic right hemicolectomy
17.34	Laparoscopic resection of transverse colon
17.35	Laparoscopic left hemicolectomy
17.36	Laparoscopic sigmoidectomy
17.39	Other laparoscopic partial excision of large inestine
45.7	Open and other partial excision of large intestine
45.71	Open and other multiple segmental resection of large intestin
45.72	Open and other cecectomy
45.73	Open and other right hemicolectomy
45.74	Open and other resection of transverse colon
45.75	Open and other left hemicolectomy
45.76	Open and other sigmoidectomy
45.79	Other and unspecified partial excision of large intestine
45.8	Total intra-abdominal colectomy
45.81	Laparoscopic total intra-abdominal colectomy
45.82	Open total intra-abdominal colectomy
45.83	Other and unspecified total intra-abdominal colectomy
17.42	Laparoscopic robotic assisted procedure

Figure 2. ICD-9-CM procedure codes

is the total cost of the entire stay, it is not broken down by operating room costs, ward costs, etc., The length of stay is in days, and includes the time from admission to discharge, regardless of complications. The three study groups, OC, LC, and RAC, were analyzed for rates of perioperative complications. The perioperative complications reviewed were acute renal failure (ARF), progressive renal failure, coma for at least 24 h, stroke, shock, cardiac arrest, myocardial infarction (MI), pulmonary insufficiency, pneumonia (PNA), pulmonary embolism (PE), RBC transfusion, unplanned intubation, UTI, impaired wound healing, peripheral nerve damage, skin and soft tissue infection (SSI), sepsis, and death.

Statistical Analysis

Quantitative variables were summarized using mean and standard deviation (SD). Categorical variables were described using frequencies and proportions. The generalized linear model with family Poisson and link log was used to assess the differences in OC and LC. Prevalence ratio (PR) along with their 95% confidence intervals (CI) were reported. Cost analyses were carried out using the linear regression models on total charges. This was reported using the regression coefficients along with their 95% CI. P values less than five percent were considered statistically significant. All analyses were carried out using STATA v15.

RESULTS

In the State of Texas between 2013–14 there were 20,454 colectomies performed. Of these 12,328 (60.3%) were OC, 7,536 (36.8%) were LC, and 590 (3.9%) were RAC. There were 10,267 total cases done in 2013 and 10,187 in 2014. **Table 1** summarizes the demographics, such as age, gender, race, and common comorbidities of the entire cohort and of the three individual study groups. This table also notes the differences in average cost and length of stay for each study group. The most common age group was 45–64 y in each of the three study groups (OC 40%, LC 42.6% and RAC 48.3%) with significant differences between the groups ($P < .001$). There was an almost equal number of males to females (50.9%) in all three groups, despite significant differences between groups ($P < .001$). Whites made up most patients at 71.9%, followed by "other" at 18.6%, and African-Americans at 9.4%. Patients of Hispanic ethnicity made up 21.7% of the patients. There were statistical differences in the percentages of each racial category among the OC, LC, and RAC groups ($P < .001$). Diabetes mellitus was present in 19.4% of all patients and hypertension was present in 4.8% of all patients. Sleep apnea was present in 1.7% of all patients. The most common insurance in all three groups was "other," defined as private insurance, at 60.2%, followed by government aid (including Medicare and Medicaid) at 38.4%. Length of stay for open cases was 10.6 d, LC was 6.1 d and RAC was 5.1 d ($P < .001$). Average total cost was $117,113 for OC, $75,741.9 for LC, and $81,996.2 for RAC ($P < .001$).

Table 2 looks at prevalence ratios (PR) of OC vs LC regarding age, sex, race, length of stay and preoperative comorbidities. The study group receiving LC instead of OC had significantly higher prevalences of whites, non-Hispanics, and patients with above normal body mass index, hypertension, and/or sleep apnea. Using OC as the reference, white patients were more likely to undergo LC [PR 1.14, $P = .003$]. Obese patients were also more likely to undergo LC [PR 1.82, $P < .001$]. Meanwhile, OC was associated with higher prevalences of diabetes and HIV than was seen in the LC cohort. The OC study group also had a higher percentage of patients age 75 or above ($P < .001$). OC was associated with a higher prevalence of payment by government aid, while LC was associated with higher rates of payment by "other," namely private insurance.

Table 3 evaluated comorbidities in the study population. Postoperative complications that were statistically significantly different between OC, LC and RAC were ARF, cardiac arrest, coma, postoperative skin and soft tissue infections (SSI), postoperative MI, postoperative pneumonia (PNA), pulmonary embolism (PE) and postoperative sepsis. There was no significant difference between groups for rates of stroke, progressive renal failure, postoperative UTI and death. The three study groups, OC, LC, and RAC, were analyzed for rates of perioperative complications. There were no cases of pulmonary insufficiency, peripheral nerve damage, shock, RBC transfusion, or unplanned intubation in any of the three groups. Nine total complications were noted to be statistically more common in OC than LC or RAC, including ARF, coma, cardiac arrest, MI, PNA, PE, impaired wound healing, SSI, and sepsis. Postoperative ARF was most common in OC (1.5%) and least likely in RAC (0.3%), ($P = .003$). A postoperative coma lasting at least 24 h occurred in 0.1% of OCs, <0.01% of LCs, and in no RACs ($P = .017$). Postoperative cardiac arrest and MI were more common in OC at 1.3% than in LC (0.6%) or RAC (0.5%), ($P < .001$). A higher percentage of postoperative PNA was recorded for OC (1.4%) than for LC (0.7%) or RAC (1.0%), ($P < .001$). This data shows double the percentage of postop-

Table 1.
Summary of Selected Criteria of Entire Cohort, by Procedure Modality, from 2013–2014 (n = 20,454)

Factor	Entire Cohort	Open Colectomy	Laparoscopic Colectomy	Robotic Colectomy	*P*-value
N	**20454**	**12328**	**7536**	**590**	
MAJOR END POINTS					
Length of Stay (day), mean (SD)	8.8 (7.7)	10.6 (8.7)	6.1 (4.9)	5.1 (4.2)	<0.001
Total Charges ($), mean (SD)	1.0e+05 (1.1e+05)	1.2e+05 (1.3e+05)	75741.9 (59479.2)	81996.2 (49375.9)	<0.001
DEMOGRAPHICS					
Age (years)					<0.001
18–44	2468 (12.1%)	1419 (11.5%)	965 (12.8%)	84 (14.2%)	
45–64	8406 (41.1%)	4914 (39.9%)	3207 (42.6%)	285 (48.3%)	
65–74	5111 (25.0%)	3092 (25.1%)	1885 (25.0%)	134 (22.7%)	
75+	4469 (21.8%)	2903 (23.5%)	1479 (19.6%)	87 (14.7%)	
Gender					<0.001
Female	10404 (50.9%)	6213 (50.4%)	3879 (51.5%)	312 (52.9%)	
Male	9290 (45.4%)	5537 (44.9%)	3490 (46.3%)	263 (44.6%)	
Unknown	760 (3.7%)	578 (4.7%)	167 (2.2%)	15 (2.5%)	
Race					<0.001
Black	1923 (9.4%)	1238 (10.0%)	642 (8.5%)	43 (7.3%)	
White	14698 (71.9%)	8726 (70.8%)	5511 (73.1%)	461 (78.1%)	
Others* (other, Indian, Asian)	3800 (18.6%)	2341 (19.0%)	1373 (18.2%)	86 (14.6%)	
Invalid	33 (0.2%)	23 (0.2%)	10 (0.1%)	0 (0.0%)	
Insurance					<0.001
Government aid	7862 (38.4%)	5082 (41.2%)	2615 (34.7%)	165 (28.0%)	
Veterans, etc.	268 (1.3%)	165 (1.3%)	97 (1.3%)	6 (1.0%)	
Others	12316 (60.2%)	7074 (57.4%)	4823 (64.0%)	419 (71.0%)	
Unknown	8 (<1%)	7 (0.1%)	1 (<1%)	0 (0.0%)	
COMORBIDITIES					
Diabetes Mellitus					<0.001
No	16485 (80.6%)	9798 (79.5%)	6188 (82.1%)	499 (84.6%)	
Yes	3969 (19.4%)	2530 (20.5%)	1348 (17.9%)	91 (15.4%)	
Hypertension					0.020
No	19477 (95.2%)	11765 (95.4%)	7163 (95.1%)	549 (93.1%)	
Yes	977 (4.8%)	563 (4.6%)	373 (4.9%)	41 (6.9%)	
Sleep apnea					0.002
No	20115 (98.3%)	12154 (98.6%)	7386 (98.0%)	575 (97.5%)	
Yes	339 (1.7%)	174 (1.4%)	150 (2.0%)	15 (2.5%)	
YEAR					<0.001
2013	10267 (50.2%)	6331 (51.4%)	3713 (49.3%)	223 (37.8%)	
2014	10187 (49.8%)	5997 (48.6%)	3823 (50.7%)	367 (62.2%)	

Table 2.
Un-adjusted Association Between Laparoscopic and Open Colon Surgery and Selected Cofactors

Dependent Variable: Lap vs. Open (reference)	Un-adjusted	
Variable (s)	PR (95% CI)	*P*-value
Length of Stay	0.9 (0.89, 0.91)	<0.001
Age (years)		
18–44 (reference)		
45–64	0.98 (0.92, 1.04)	0.465
65–74	0.93 (0.86, 1)	0.049
75+	0.82 (0.76, 0.9)	<0.001
Gender		
Female (reference)		
Male	1 (0.96, 1.04)	0.884
Race		
Black (reference)		
White	1.14 (1.05, 1.24)	0.003
Others* (other, Indian, Asian)	1.08 (0.95, 1.22)	0.245
Invalid	0.85 (0.49, 1.48)	0.567
Ethnicity		
Hispanic origin (reference)		
Not Hispanic origin	1.16 (1.04, 1.29)	0.008
Invalid	1.2 (0.95, 1.51)	0.126
Insurance		
Government aid (reference)		
Veterans, etc.	1.09 (0.9, 1.3)	0.361
Others	1.2 (1.14, 1.27)	<0.001
Body mass index		
Underweight + Normal (reference)		
Overweight	1.42 (1.11, 1.8)	0.004
Obese	1.82 (1.49, 2.22)	<0.001
Morbidly obese	1.76 (1.46, 2.12)	<0.001
Diabetes mellitus		
No (reference)		
Yes	0.89 (0.85, 0.94)	<0.001
Hypertension		
No (reference)		
Yes	1.07 (0.97, 1.18)	0.166
Sleep apnea		
No (reference)		
Yes	1.23 (1.09, 1.39)	0.001
HIV and Alcohol Abuse		
No (reference)		
Yes	0.59 (0.52, 0.68)	<0.001
Study Year		
2013 (reference)		
2014	1.07 (1.03, 1.12)	0.001
Type of Neoplasm		
Benign (reference)		
Malignant	0.75 (0.65, 0.86)	<0.001

PR, prevalence risk; CI, confidence Interval.

erative PNA for OC versus LC. Similarly, the percentage of perioperative PE in OC (0.7%) was more than double that of LC (0.3%), ($P < .001$). LC and RAC showed similar rates of postoperative SSI, with 1.6% in LC and 1.7% in RAC, while 4.0% of OC cases were diagnosed with postoperative SSI, ($P < .001$). Impaired wound healing was not common overall, but appeared in 0.9% of OC cases, 0.1% of LC cases, and no RAC cases, ($P < .001$). The postoperative complication with the greatest difference in occurrences between groups was sepsis. OC had a postoperative sepsis rate of 12.9%, making sepsis the most common postoperative complication out of those we investigated. In contrast to the nearly 13% of OC patients that had postoperative sepsis, 2.3% of LC patients and 1.9% of RAC patients had the same complication.

Table 4 lists the unadjusted and adjusted PR for complications. After adjusting for age, gender, race, ethnicity, insurance, body mass index, hypertension, and year of operation; seven complications retained statistically significant different percentages of occurrence between OC & LC and/or between OC & RAC. These seven complications are delayed wound healing, postoperative SSI, coma, cardiac arrest, MI, PE, and stroke. Although ARF and postoperative PNA had significantly lower percentages of occurrence before adjustments, the significance of the decreased rates disappeared once adjustments were made. Delayed wound healing and postoperative skin and soft tissue infections

Table 3.
Postoperative Complications

Factor	Open	Lap	Robotic lap	*P*-value
N (%)	12328	7536	590	
Acute renal failure				0.003
No	12148 (98.5%)	7460 (99.0%)	588 (99.7%)	
Yes	180 (1.5%)	76 (1.0%)	2 (0.3%)	
Cardiac arrest				<0.001
No	12168 (98.7%)	7493 (99.4%)	587 (99.5%)	
Yes	160 (1.3%)	43 (0.6%)	3 (0.5%)	
Coma 24 hours				0.017
No	12312 (99.9%)	7535 (100.0%)	590 (100.0%)	
Yes	16 (0.1%)	1 (<1%)	0 (0.0%)	
Stroke				0.13
No	12322 (100.0%)	7535 (100.0%)	589 (99.8%)	
Yes	6 (<1%)	1 (<1%)	1 (0.2%)	
Surgical site infection				<0.001
No	11830 (96.0%)	7418 (98.4%)	580 (98.3%)	
Yes	498 (4.0%)	118 (1.6%)	10 (1.7%)	
Myocardial infarction				<0.001
No	12168 (98.7%)	7493 (99.4%)	587 (99.5%)	
Yes	160 (1.3%)	43 (0.6%)	3 (0.5%)	
Pulmonary insufficiency				
No	12328 (100.0%)	7536 (100.0%)	590 (100.0%)	
Pneumonia				<0.001
No	12159 (98.6%)	7482 (99.3%)	584 (99.0%)	
Yes	169 (1.4%)	54 (0.7%)	6 (1.0%)	
Peripheral nerve injury				
No	12328 (100.0%)	7536 (100.0%)	590 (100.0%)	
Progressive renal failure				0.87
No	12261 (99.5%)	7497 (99.5%)	586 (99.3%)	
Yes	67 (0.5%)	39 (0.5%)	4 (0.7%)	
Pulmonary embolism				<0.001
No	12238 (99.3%)	7515 (99.7%)	587 (99.5%)	
Yes	90 (0.7%)	21 (0.3%)	3 (0.5%)	
Shock				
No	12328 (100.0%)	7536 (100.0%)	590 (100.0%)	
RBC transfusion				
No	12328 (100.0%)	7536 (100.0%)	590 (100.0%)	
Unplanned intubation				
No	12328 (100.0%)	7536 (100.0%)	590 (100.0%)	

Table 3.
Continued

Factor	Open	Lap	Robotic lap	*P*-value
Postoperative urinary tract infection				0.87
No	12261 (99.5%)	7497 (99.5%)	586 (99.3%)	
Yes	67 (0.5%)	39 (0.5%)	4 (0.7%)	
Wound complication				<0.001
No	12223 (99.1%)	7525 (99.9%)	590 (100.0%)	
Yes	105 (0.9%)	11 (0.1%)	0 (0.0%)	
Death				0.72
No	12327 (100.0%)	7536 (100.0%)	590 (100.0%)	
Yes	1 (<1%)	0 (0.0%)	0 (0.0%)	
Sepsis				<0.001
No	10741 (87.1%)	7359 (97.7%)	579 (98.1%)	
Yes	1587 (12.9%)	177 (2.3%)	11 (1.9%)	

were statistically more prevalent in OC than in LC or in RAC, even after adjusting for the aforementioned demographics. Likewise, the prevalence of coma was significantly higher in OC when compared to LC (PR = 0.1, $P <$ .027) and to RAC (PR = 0). While cardiac arrest, MI, and PE did not show statistically significant differences in rates of occurrence between OC and RAC after adjustment, there were significantly more peri- or postoperative cardiac arrests, MIs, and PEs among OC patients than among LC patients, even after all adjustments ($P <$ .001 for all three LC). While a majority of the complications were found to be more prevalent in OC, the prevalence of stroke in RAC was more than three times that in OC ($P <$ .001). In contrast, the prevalence of stroke was statistically equivalent in OC and LC, even after adjustments, which may explain why the statistically significant difference in stroke rates among all three groups was not seen prior to adjustments.

DISCUSSION

This study would indicate that Texas lags behind other states in utilization of laparoscopic colon surgery. We found an overall rate of minimally invasive colectomies of nearly 40%, lower than the National Inpatient Sample, which had a rate of 55.4%.[6,7] While LC rates have increased over the years, laparoscopy has not reached the same level of penetrance in colon surgery as in other general surgery procedures. Previous studies have suggested multiple factors that are responsible for this trend.[8] As the use of laparoscopic colon surgery has been growing overall within the United States, it seems there is some variability on who gets laparoscopic surgery based on race. Bardakcioglu et al. showed that in addition to surgeon factors, socioeconomic factors play a role. This study, which sampled the National Inpatient Sample, showed that both being a Medicaid recipient and being African-American were significant factors in not having access to minimally invasive procedures.[9] In 1996, 86.5% of people undergoing LC were white and 8.4% were black, as compared to 2009 where 80.8% were white and 9.2% were black. The total number of LC operations increased by over 6,000 cases during this time, while the percentage of people undergoing surgery who are white decreased, but it was the "other" category that gained more percentage points during that time than blacks. Likewise, a more recent study using the National Cancer Database showed decreased odds of undergoing minimally invasive surgery in patients with lower socioeconomic status and in African-Americans.[10] The results of our study also showed these same factors decrease access to minimally invasive colon surgery in Texas, similar to the national database studies. Our study showed that whites had a greater chance of getting LC. Other authors have shown that being black is actually associated with decreased odds of having a minimally invasive technique performed. We found similar results for blacks and Hispanics in the present study.

When comparing LC to OC, studies have shown that while the length of the operation is longer, patients benefit from a quicker recovery and less days spent in the hospital. We

Table 4.
Postoperative Complications Adjusted For: Age, Gender, Race, Ethnicity, Insurance, Body Mass Index, Hypertension, and Operation year

	Unadjusted				Adjusted			
	PR	95% CI		*P*-value	PR	95% CI		*P*-value
Acute renal failure								
Laparoscopic (ref = Open)	0.69	0.51	0.93	0.016	0.78	0.58	1.05	0.098
Robotic (ref = Open)	0.23	0.06	0.94	0.041	0.27	0.07	1.08	0.065
Cardiac arrest								
Laparoscopic (ref = Open)	0.44	0.32	0.61	<0.001	0.48	0.34	0.68	<0.001
Robotic (ref = Open)	0.39	0.09	1.64	0.199	0.47	0.12	1.86	0.28
Coma 24 hours								
Laparoscopic (ref = Open)	0.10	0.01	0.77	0.027				
Robotic (ref = Open)	0.00	0.00	0.00	<0.001				
Stroke								
Laparoscopic (ref = Open)	0.27	0.03	2.28	0.231				
Robotic (ref = Open)	3.48	0.43	28.20	<0.001				
Surgical site infection								
Laparoscopic (ref = Open)	0.39	0.31	0.48	<0.001	0.39	0.31	0.49	<0.001
Robotic (ref = Open)	0.42	0.22	0.79	0.007	0.45	0.23	0.86	0.016
Myocardial infarction								
Laparoscopic (ref = Open)	0.44	0.32	0.61	<0.001	0.48	0.34	0.68	<0.001
Robotic (ref = Open)	0.39	0.09	1.64	0.20	0.47	0.12	1.86	0.28
Progressive renal failure								
Laparoscopic (ref = Open)	0.95	0.62	1.47	0.82	1.00	0.65	1.56	0.99
Robotic (ref = Open)	1.25	0.45	3.42	0.67	0.98	0.31	3.09	0.97
Pulmonary embolism								
Laparoscopic (ref = Open)	0.38	0.23	0.64	<0.001	0.38	0.22	0.65	<0.001
Robotic (ref = Open)	0.70	0.24	2.03	0.51	0.83	0.28	2.50	0.75
Urinary tract infection								
Laparoscopic (ref = Open)	0.95	0.62	1.47	0.82	1.00	0.65	1.56	0.99
Robotic (ref = Open)	1.25	0.45	3.42	0.69	0.98	0.31	3.09	0.97
Wound complication								
Laparoscopic (ref = Open)	0.17	0.09	0.34	<0.001	0.20	0.10	0.40	<0.001
Robotic (ref = Open)	0.00	0.00	0.00	<0.001	0.00	0.00	0.00	<0.001

found this to be true with a decrease by 4 d from OC to LC and 5 d from OC to RAC. Alkhamesi et al. highlighted this in a paper which analyzed costs of both OC and LC. They found shorter operative times for the OC group by an average of almost 2 h for left hemicolectomies, but an average LOS increase of 2–3 d when compared to the LC group. This extended LOS added up to an overall increased hospitalization cost of OC when compared to LC.[11] Similarly, Juo et al. published a study using the National Inpatient Sample evaluating outcomes and costs of 244,129 elective colon resections (OC, LC, and RAC). The study showed an average 2 d reduction in LOS when LC was compared to OC, with an average cost reduction of about $2000 per patient. The LC population also benefited from a five fold reduction in mortality, 13% less complications, and 9.5% less ostomies overall. These benefits were shared when the RAC data was compared to LC, with the only statistically significant finding being an overall hospitalization cost increase of RAC of $2881 over the LC patients.[12]

The study by Alkhamesi et al. showed that there were significantly higher postoperative complications with OC as compared to the minimally invasive cases.[11] Our study verifies this and shows higher rates in OC of sepsis and pneumonia. Other studies have demonstrated the decrease in pulmonary complications by using minimally invasive techniques.[13] The study by Juo et al. showed similar results with the addition of separating out LC and RAC from OC.[12] Furthermore, while the RAC had higher costs, it had the lowest postoperative complications. Our study showed significant decreases in postoperative complications including: kidney injury, cardiac arrest, surgical site infections, wound, and pulmonary embolism (during LC). In our study, RAC was associated with a higher risk of stroke. Minimally invasive techniques are the likely reason for the lower complications rates with regard to wounds and surgical site infections.

Overall, our results regarding LOS, cost and complications agree with the published literature. However, Texas does seem to be behind the rest of the country in the rates of utilization of minimally invasive colon surgery. As trainees graduate from residencies and fellowships today, they will be better trained in minimally invasive techniques and minimally invasive colectomies will become more common.[14,15] With the increasing prevalence of MIS operations and MIS-trained surgeons, we foresee that the percentages of LC and RAC will continue to increase.[16]

Strengths and Limitations

The main limitation of the Texas Inpatient PUDF is the lack of an unique identifier to follow individual patients over time. There are demographic limitations and rural areas may not submit data. Federal facilities and facilities that do not seek reimbursement from governmental sources are also exempt from reporting.[17] The state sets the parameters of the type of data to be collected, but there is no formal data collection training. This may lead to wide variances in the quality of the data.

Additionally, like many studies performed in the US, the cohort studied was largely white. The cohort had higher percentages of patients with private insurance, and lower percentages of patients with diabetes and/or hypertension than is seen in the general public. The demographic profile of the patients in this study results may have limited generalizability to the underrepresented populations and populations with higher rates of comorbidities.

While many of the limitations of this study relate to the Texas PUDF, this database also increases the strengths of this study. The ability to study millions of encounters per year through such a database enables researchers to ask broad questions about population based outcomes. There is a noticeable lack of granularity, but when these deficiencies are accounted for, we can still perform powerful studies.

CONCLUSIONS

Minimally invasive colectomies accounted for almost 40% of colectomies in Texas. LC accounted for 36.8% of all colectomies performed in Texas between 2013–14. OC costs twice as much as LC and is associated with an increased length of stay by nearly 4 d. LC and RAC are both associated with significantly less cost and length of stay for patients undergoing surgery, while not significantly increasing perioperative complications.

References:

1. Richardson WS, Fuhrman GS, Burch E, Bolton JS, Bowen JC. Outpatient laparoscopic cholecystectomy. Outcomes of 847 planned procedures. *Surg Endosc*. 2001;15(2):193–5.

2. Jayne DG, Guillou PJ, Thorpe H, et al.; UK MRC CLASICC Trial Group. Randomized trial of laparoscopic-assisted resection of colorectal carcinoma: 3-year results of the UK MRC CLASICC Trial Group. *J Clin Oncol*. 2007;25(21):3061–8.

3. Kemp JA, Finlayson SR. Nationwide trends in laparoscopic colectomy from 2000 to 2004. *Surg Endosc*. 2008;22(5):1181–7.

4. Langenfeld SJ, Thompson JS, Oleynikov D. Laparoscopic colon resection: is it being utilized? *Adv Surg*. 2013;47:29–43.

5. Texas Hospital Inpatient Public Use Data File, 2013 and 2014. Texas Department of State Health Services, Center for Health Statistics, Austin, TX. 2019.

6. Moghadamyeghaneh Z, Carmichael JC, Mills S, Pigazzi A, Nguyen NT, Stamos MJ. Variations in Laparoscopic Colectomy Utilization in the United States. *Dis Colon Rectum*. 2015;58(10):950–6.

7. Simorov A, Shaligram A, Shostrom V, Boilesen E, Thompson J, Oleynikov D. Laparoscopic colon resection trends in utilization and rate of conversion to open procedure: a national database review of academic medical centers. *Ann Surg*. 2012; 256(3):462–8.

8. Keller DS, Qiu J, Senagore AJ. Predicting opportunities to increase utilization of laparoscopy for rectal cancer. *Surg Endosc*. 2018;32(3):1556–1563.

9. Bardakcioglu O, Khan A, Aldridge C, Chen J. Growth of laparoscopic colectomy in the United States: analysis of regional and socioeconomic factors over time. *Ann Surg*. 2013;258(2):270–4.

10. Hawkins AT, Ford MM, Benjamin Hopkins M, et al. Barriers to laparoscopic colon resection for cancer: a national analysis. *Surg Endosc*. 2018;32(2):1035–1042.

11. Alkhamesi NA, Martin J, Schlachta CM. Cost-efficiency of laparoscopic versus open colon surgery in a tertiary care center. *Surg Endosc*. 2011;25(11):3061–8.

12. Juo YY, Hyder O, Haider AH, Camp M, Lidor A, Ahuja N. Is minimally invasive colon resection better than traditional approaches?: First comprehensive national examination with propensity score matching. *JAMA Surg*. 2014;149(2):177–84.

13. Sujatha-Bhaskar S, Alizadeh RF, Inaba CS, et al. Respiratory complications after colonic procedures in chronic obstructive pulmonary disease: does laparoscopy offer a benefit? *Surg Endosc*. 2018;32(3):1280–1285.

14. McCoy AC, Gasevic E, Szlabick RE, Sahmoun AE, Sticca RP. Are open abdominal procedures a thing of the past? An analysis of graduating general surgery residents' case logs from 2000 to 2011. *J Surg Educ*. 2013;70(6):683–9.

15. Collins D, Machairas N, Duchalais E, et al. Participation of Colon and Rectal Fellows in Robotic Rectal Cancer Surgery: Effect on Surgical Outcomes. *J Surg Educ*. 2018;75(2):465–470.

16. Accreditation Council for Graduate Medical Education. Minimum Case Numbers Review Committee for Colon and Rectal Surgery. Minimum Case Numbers Review Committee for Colon and Rectal Surgery. https://www.acgme.org/Portals/0/PFAssets/ProgramResources/060_CRS_Minimum_Case_Numbers.pdf?ver=2017–09-08–124846–337. Accessed Feb 12, 2019.

17. Texas Department of State Health Services. Inpatient Data Reporting Requirements. https://www.dshs.texas.gov/thcic/hospitals/HospitalReportingRequirements.shtm. Accessed Mar 7, 2019.