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Comparison of open, laparoscopic, and robotic approaches for total abdominal colectomy

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Abstract

Background The utilization of minimally invasive surgery is increasing in colorectal surgery. We sought to compare the outcomes of patients who underwent elective open, laparoscopic, and robotic total abdominal colectomy.

Methods

The NIS database was used to examine the clinical data of patients who underwent an elective total colectomy procedure during 2009–2012. Multivariate regression analysis was performed to compare the three surgical approaches.

Results

We sampled a total of 26,721 patients who underwent elective total colectomy. Of these, 16,780 (62.8 %) had an open operation, while 9934 (37.2 %) had a minimally invasive approach (9614 laparoscopic surgery, and 326 robotic surgery). The most common indication for an operation was ulcerative colitis (31 %). Patients who underwent open surgery had significantly higher mortality and morbidity compared to laparoscopic (AOR 2.48, 1.30, $P < 0.01$) and robotic approaches (AOR 1.04, 1.30, $P < 0.01$ and $P = 0.04$, respectively). There was no significant difference in mortality and morbidity between the laparoscopic and robotic approaches (AOR 0.96, 1.03, $P = 0.10$, $P = 0.78$). However, conversion rate of laparoscopic surgery to open was significantly higher than that of robotic approach (13.3 vs. 1.5 %, $P < 0.01$). Patients who underwent laparoscopic surgery had significantly lower total hospital charges compared to patients who underwent open surgery (mean difference = $21,489, $P < 0.01$). Also, total hospital charges for a robotic approach were significantly higher than for a laparoscopic approach (mean difference = $15,595, $P < 0.01$).

Conclusion

Minimally invasive approaches to total colectomy are safe, with the advantage of lower mortality and morbidity compared to an open approach. Although there was no significant difference in the morbidity between minimally invasive approaches, robotic surgery had a significantly lower conversion rate compared to laparoscopic approach. Total hospital charges are significantly higher in robotic surgery compared to laparoscopic approach.

Minimally invasive colorectal surgery began in 1990 [1]. Since that time, it has gained popularity and there have been numerous reports on the advantages of laparoscopy in colorectal surgery [1–4]. Lower mortality and morbidity rates and shorter hospitalization length have been cited as some of the advantages of a laparoscopic approach compared to an open approach in colorectal surgery [3–5]. Safety and feasibility of laparoscopic surgery in oncologic cases have been confirmed [5–7]. Over the past decade and a half, robotic surgery has been introduced to overcome some of the difficulties of laparoscopic surgery [8]. Three-dimensional visualization, easier suturing, more accurate identification of anatomic structures, more precise dissection, and less frequent conversion to open surgery have been purported as advantages of robotic surgery compared to a laparoscopic approach [9–11]. However, higher cost and longer operation time have been reported as disadvantages of robotic surgery compared to laparoscopic surgery [12–14]. Although the safety and benefits of laparoscopic colorectal surgery have been well established, the surgical literature regarding robotic total colectomy remains limited at this time and more studies are needed to define its role within colorectal surgery. Using a large national database, we aim to compare outcomes of open, laparoscopic, and robotic total colectomy.

Materials and methods

The study was conducted as a retrospective study utilizing data from the nationwide inpatient sample (NIS) database from 2009 through 2012. The NIS database is the largest inpatient care database in the USA, developed for the Healthcare Cost and Utilization Project (HCUP). NIS contains clinical and non-clinical data elements for each hospital stay including: primary and secondary diagnoses and procedures, patient demographic characteristics, hospital characteristics, total charges, length of stay, and severity and comorbidity measures [15]. NIS database informed consent is obtained from individual patients within the individual hospital's patient consent forms. For the purposes of this study, International Classification of Diseases, 9th Revision, clinical modifications (ICD-9-CM) procedure codes of 48.51–48.53 were pulled to select patients who underwent total colectomy during 2009–2012. The study was restricted to patients at least 18 years of age and electively admitted patients. Patients' diagnoses/indications of surgery were extracted using ICD-9-CM diagnosis codes from the database. Operations were divided into three groups of open, laparoscopic, and robotic surgery according to the appropriate ICD-9-CM procedure codes.

We used the inherent variables of NIS database in this study which include demographic data (age, sex, and race), comorbidities (such as hypertension, presence of metastatic cancer, and diabetes mellitus), hospitalization length, and total hospital charges. Endpoints of the study were mortality and postoperative complications according to the original variables of NIS database and ICD-9 diagnosis codes which were reported as the second to 25th diagnosis of patients in the database. The overall rates of each complication by surgical approaches were examined. Risk adjusted analysis was performed to compare the outcomes by surgical approaches.

Statistical analysis

All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) software, version 22 (SPSS Inc., Chicago, IL). The main analysis was multivariate analysis using logistic regression. Patient characteristics were compared among surgical approach groups with the Chi-squared test. For each outcome, the estimated adjusted odds ratio (AOR) with a 95 % confidence interval was calculated. Multivariate analysis was used to estimate risks of each postoperative complication by surgical approaches and compare surgical approaches. Adjustment was made for all variables of the study.

Results

We identified 26,721 patients who underwent elective total colectomy during 2009–2012. Of these, 62.8 % had open surgery, 36 % underwent surgery via a laparoscopic approach, and 1.2 % were treated via a robotic approach. The median patient age was 52 years; the majority of the patients were Caucasian (82 %) and female (50.1 %). Most common comorbidities included hypertension (32.3 %) and diabetes (13.1 %). The most common indication of surgery was ulcerative colitis (31 %) followed by colon cancer (22.3 %). Demographics and clinical characteristics of patients are shown in Table 1.

During the study period, there was a steady increase in rates of minimally invasive approaches. The rate of robotic surgery increased from 0.5 % in 2009 to 2.3 % in 2012. Similarly, the rate of laparoscopic surgery also increased during the study period, from 31.2 % in 2009 to 40.1 % in 2012. Likewise, the rate of open procedures decreased from 68.3 % in 2009 to 57.6 % in 2012. The overall conversion rate of minimally invasive approach to open was 13 %. Laparoscopic approach had significantly higher conversion rate compared to robotic approach (13.3 vs. 1.5 %, $P < 0.01$).

The mean hospitalization length for patients who underwent either minimally invasive approach was approximately 8 days. Conversely, patients who underwent open surgery had significantly longer mean hospitalization at 11 days (11 vs. 8 days, $P < 0.01$). The median total hospital charges for patients who underwent open, laparoscopic, and robotic approaches procedures were \$61,511, \$55,037, \$73,489, respectively. Patients who underwent open surgery had significantly higher total hospital charge compared to patients who underwent laparoscopic surgery (adjusted mean difference = \$21,489, CI 187,774–24,204, $P < 0.01$); there was no significant difference in hospital charges for patients who underwent robotic surgery and open surgery (adjusted mean difference = \$5672, CI 7927–19,272, $P = 0.41$). Also, patients treated via a robotic approach had higher mean total hospital charges compared to those undergoing laparoscopic surgery (adjusted mean difference = \$15,595, 95 % CI 9127–22,063, $P < 0.01$).

Table 1 Demographics and clinical characteristics of patients who underwent total colectomy

Variables	Open surgery (sample size = 16,780)	Laparoscopic surgery (sample size = 9614)	Robotic surgery (sample size = 326)
Age			
Mean, year	54 ± 17	48 ± 17	46 ± 18
Median, year	55	49	45
Sex			
Male	8743 (52.1 %)	4427 (46.1 %)	177 (51.1 %)
Race			
White	12,212 (81.9 %)	7058 (82.3 %)	221 (73 %)
Black or African-American	1131 (7.6 %)	526 (6.1 %)	10 (3.3 %)
Hispanic	777 (4.6 %)	488 (5.7 %)	20 (6.7 %)
Asian	171 (1.1 %)	56 (0.7 %)	16 (5.4 %)
Other	611 (4.1 %)	445 (5 %)	35 (11.6 %)
Comorbidity			
Hypertension	5825 (34.7 %)	2719 (28.3 %)	84 (25.8 %)
Diabetes mellitus	2562 (15.3 %)	914 (9.5 %)	15 (4.5 %)
Chronic pulmonary disease	2512 (15 %)	1166 (12.1 %)	24 (7.5 %)
Deficiency anemia	3145 (18.7 %)	1565 (16.3 %)	50 (15.4 %)
Renal failure	894 (5.3 %)	176 (1.8 %)	0
Congestive heart failure	749 (4.5 %)	164 (1.7 %)	0
Metastatic cancer	1441 (8.6 %)	303 (3.1 %)	35 (10.7 %)
Peripheral vascular disorders	735 (4.4 %)	146 (1.5 %)	*
Liver disease	529 (3.2 %)	121 (1.3 %)	*
Patient diagnosis			
Ulcerative colitis	5170 (30.8 %)	3005 (31.3 %)	116 (35.6 %)
Colorectal cancer	4040 (24.1 %)	1835 (19.1 %)	86 (26.3 %)
Crohn's disease	1392 (8.3 %)	735 (7.6 %)	35 (10.8 %)
Diverticulosis	185 (1.1 %)	72 (0.7 %)	0
Diverticulitis	230 (1.4 %)	297 (3.1 %)	0
Benign colorectal tumor	1226 (7.3 %)	1160 (12.1 %)	44 (13.6 %)
Functional disorders**	1174 (7 %)	1415 (14.7 %)	19 (5.9 %)
Other diagnosis	3363 (20 %)	1094 (11.4 %)	28 (8 %)

* The number is too small to report

** Includes: constipation, mega colon, neurologic bowel, and unspecified functional disorder of intestine

Tables 2, 3, 4 illustrate a comparison of open, laparoscopic, and robotic total colectomy in univariate and multivariate analyses. Overall mortality of all, open, laparoscopic, and robotic approaches was 3.1, 4.5, 0.8, and 0 %, respectively. Following multivariate analysis, both minimally invasive approaches had significantly lower mortality rate compared to open approach ($P < 0.01$). Overall, morbidity of all, open, laparoscopic, and robotic approaches was 29.5, 32.8, 24, and 23.9 %, respectively. Although both minimally invasive approaches had significantly lower morbidity rate compared to open approach, there was no significant difference in morbidity risk of laparoscopic approach compared to robotic approach (AOR 1.03, $P = 0.78$).

Discussion

Minimally invasive approaches to total colectomy are safe with a significantly lower mortality, morbidity, and hospitalization length compared to the open approach. Respective mortality rates of 4.5, 0.8, and 0 % for open, laparoscopic, and robotic total colectomy were demonstrated. A significantly lower mortality rate for minimally invasive approaches compared to open surgery has been reported previously [4]. Also, safe performance of laparoscopic resection for colorectal surgery has been reported in guidelines of Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) and the American Society of Colon and Rectal Surgeons (ASCRS) previously [16].

Table 2 Analysis for postoperative complications of laparoscopic and robotic approaches compared to open total colectomy (univariate analysis)

Complication	Open surgery (%)	Laparoscopic approach			Robotic approach		
		Rate (%)	OR and 95 % CI	*P* value	Rate (%)	OR and 95 % CI	*P* value
Mortality	4.5	0.8	0.17 (0.13–0.22)	<0.01	0	0.98 (0.97–0.98)	<0.01
Overall morbidity**	32.8	24	0.64 (0.61–0.68)	<0.01	23.9	0.64 (0.49–0.83)	<0.01
Prolonged ileus	16	13.9	0.84 (0.78–0.90)	<0.01	16	1.03 (0.77–1.39)	0.81
Hospitalization >30 days	4.1	1	0.22 (0.18–0.28)	<0.01	1.5	0.35 (0.14–0.87)	0.01
Pneumonia	3.2	0.7	0.21 (0.16–0.27)	<0.01	1.5	0.46 (0.19–1.13)	0.08
Wound infection	6.3	3.6	0.56 (0.49–0.63)	<0.01	4.3	0.66 (0.38–1.14)	0.13
Cardiac complications*	3.3	1.4	0.41 (0.34–0.50)	<0.01	1.5	0.46 (0.19–1.12)	0.08
Intra-abdominal abscess	3.3	1.8	0.52 (0.44–0.62)	<0.01	1.5	0.44 (0.18–1.09)	0.06
Respiratory failure	1.6	0.5	0.29 (0.21–0.39)	<0.01	0	0.98 (0.97–0.98)	0.02
Hemorrhagic complications	3.2	3.2	1 (0.86–1.15)	0.97	3	0.96 (0.51–1.82)	0.91
Wound disruption	1.8	1.1	0.63 (0.50–0.79)	<0.01	0	0.98 (0.97–0.98)	0.01
Deep vein thrombosis	1.2	0.5	0.43 (0.31–0.57)	<0.01	1.5	1.25 (0.51–3.07)	0.61
Central vascular accident	0.7	0.4	0.53 (0.36–0.78)	<0.01	0	0.98 (0.97–0.99)	0.13
Urinary tract infection	6.4	4.1	0.62 (0.55–0.70)	<0.01	6.1	0.96 (0.60–1.51)	0.86
Pulmonary embolism	0.7	0.4	0.52 (0.36–0.76)	<0.01	0	0.98 (0.97–0.99)	0.12
Septic shock	0.2	0.1	0.21 (0.08–0.53)	<0.01	0	0.98 (0.97–0.99)	0.37

* Includes: myocardial infarction, cardiac arrest, arrhythmia, and heart failure
** Includes prolonged ileus, hospitalization more than 30 days, pneumonia, wound infection, cardiac complications, intra-abdominal abscess, respiratory failure, hemorrhagic complications, wound disruption, deep vein thrombosis, central vascular accident, pulmonary embolism, and septic shock

Our study results demonstrate that minimally invasive approaches to total colectomy have significantly lower morbidity compared to the open approach. Lower morbidity rates of minimally invasive compared to open techniques in various colorectal procedures have been reported previously [3, 4, 17–20]. However, the inability to control for disease stage by the American Society of Anesthesiologists (ASA) score in patients undergoing open surgery with patients undergoing minimally invasive surgery makes it difficult to draw firm conclusions. In addition, critically ill patients more commonly underwent open surgery, and it is difficult to quantify feasibility and benefits of minimally invasive approaches in these situations. However, it is difficult to design a prospective case-matched study to compare outcomes of the three surgical approaches in three homogenous groups of patients, and retrospective studies with controlling perioperative factors are more accessible and realistic.

Minimally invasive approaches to total colectomy have shorter hospitalization length compared to open surgery. We found similar mean hospitalization length of 8 days for both laparoscopic and robotic approaches which was significantly shorter than the mean hospitalization length for patients who underwent open surgery (11 days). Further, the rate of prolonged hospitalization (longer than 30 days) was higher in open surgery compared to minimally invasive approaches. However, the patient and surgeon selection bias inherent in minimally invasive cases compared to the open approach makes it difficult to draw any firm conclusions. Further studies are required to compare hospitalization length of minimally invasive approaches with open approach in homogeneous groups of patients.

Similar to other studies evaluating the role of minimally invasive surgery, we noted an increase in utilization of laparoscopic and robotic approaches in total colectomy procedure over the course of the 4 years spanning the study from 31.7 % in 2009 to 42.4 % in 2012. However, the trend of utilization of minimally invasive approach in nonelectively admitted patients is unclear. Although some published articles report the feasibility of minimally invasive surgery in non-elective situations [21–23], further studies are required to investigate possibility and benefits of minimally invasive surgery in non-elective admitted patients who undergo total colectomy.

A robotic approach to a total colectomy appears to be a safe technique with the advantage of significantly lower conversion rate compared to the laparoscopic approach. Overall, there was no significant difference between the morbidity rates of laparoscopic and robotic approaches to total colectomy, while both approaches also had similar lengths of stay. However, total hospital charges for patients who underwent robotic surgery were significantly higher than for those undergoing laparoscopic surgery. Similar observations have been reported for segmental colectomy previously [24, 25]. Davis et al. [24] studied 25,758 segmental colectomy procedures and reported increased percase hospital costs for robotic-assisted procedures with the similar hospitalization length and postoperative complications compared to laparoscopic approach. It seems that the robotic approach may increase feasibility of minimally invasive approach to a total colectomy for selected patients with similar short-term outcomes compared to a laparoscopic approach. More randomized controlled trials investigating long-term oncological outcomes and cost-effectiveness of robotic surgery compared to laparoscopic approach are currently ongoing.

Table 3 Risk-adjusted analysis for postoperative complications of minimally invasive approaches compared to open total colectomy (multivariate analysis)

Complication	Open surgery (%)	Laparoscopic approach			Robotic approach		
		Rate (%)	AOR and 95 % CI	*P* value	Rate (%)	AOR and 95 % CI	*P* value
Mortality	4.5	0.8	0.40 (0.31–0.51)	<0.01	0	*	–
Overall morbidity***	32.8	24	0.76 (0.72–0.81)	<0.01	23.9	0.76 (0.58–0.99)	0.04
Prolonged ileus	16	13.9	0.91 (0.85–0.99)	0.02	16	1.12(0.82-1.51)	0.46
Hospitalization >30 days	4.1	1	0.37 (0.29–0.46)	<0.01	1.5	0.79 (0.30–2.06)	0.63
Pneumonia	3.2	0.7	0.36 (0.27–0.47)	<0.01	1.5	1.02(0.39-2.63)	0.96
Wound infection	6.3	3.6	0.64 (0.56–0.72)	<0.01	4.3	0.66 (0.38–1.14)	0.13
Cardiac complications**	3.3	1.4	0.62 (0.51–0.76)	<0.01	1.5	0.76 (0.30–1.87)	0.55
Intra-abdominal abscess	3.3	1.8	0.65 (0.54–0.78)	<0.01	1.5	0.51 (0.20–1.31)	0.16
Respiratory failure	1.6	0.5	0.49 (0.35–0.68)	<0.01	0	*	–
Hemorrhagic complications	3.2	3.2	1.21 (0.94–1.41)	0.05	3	1.13 (0.58–2.19)	0.71
Wound disruption	1.8	1.1	0.85 (0.67–1.07)	0.18	0	*	–
Deep vein thrombosis	1.2	0.5	0.55 (0.40–0.77)	<0.01	1.5	1.70 (0.67–4.27)	0.25
Central vascular accident	0.7	0.4	0.73 (0.49–1.09)	0.13	0	*	–
Urinary tract infection	6.4	4.1	0.72 (0.64–0.82)	<0.01	6.1	1.09 (0.68–1.74)	0.70
Pulmonary embolism	0.7	0.4	0.79 (0.53–1.17)	0.24	0	*	–
Septic shock	0.2	0.1	0.43 (0.16–1.12)	0.08	0	*	–

* Unable to calculate because of no events in the robotic surgery group
** Includes: myocardial infarction, cardiac arrest, arrhythmia, and heart failure

*** Includes prolonged ileus, hospitalization more than 30 days, pneumonia, wound infection, cardiac complications, intra-abdominal abscess, respiratory failure, hemorrhagic complications, wound disruption, deep vein thrombosis, central vascular accident, pulmonary embolism, and septic shock

The robotic approach to total colectomy has four times lower conversion rate to open compared to the laparoscopic approach (13.3 vs. 1.5 %, $P < 0.01$). Previously published articles reported similar results in partial colectomy and rectal resections [26, 27]. However, due to the limited number of robotic procedures in our study, the lower conversion rate in robotic cases could be skewed by the sample size. Also, we did not have any detailed information regarding the potential use of laparoscopy for portions of the ‘‘robotic’’ procedures. Nevertheless, the lower conversion rate in robotic compared to laparoscopic approach may be influenced by technological advantages of the robotic system which may provide accurate identification of anatomic structures due to the three-dimensional visualization, and reported easier suturing and dissection in robotic approach compared to laparoscopic approach [9–11]. The benefit of the lower conversion rate in the robotic approach is concomitant with the disadvantages of longer operation time and the time a robotic total colectomy would require for triple docking [28]. Also, following multivariate analysis, there was no significant difference in morbidity of the two minimally invasive approaches. Similar results were reported for other colorectal procedures previously [20, 24].

There is not any significant difference in hemorrhagic complications of different surgical approaches to total colectomy. Rates of postoperative hemorrhagic complications for open, laparoscopic, and robotic total colectomy were 3.2, 3.2, and 3 %, respectively, in our study. However, we found a lower rate of accidental puncture or laceration of bowel during robotic compared to laparoscopic procedure (2.2 vs. 0 %, $P < 0.01$). This could be related to the technological advantages of the robotic system compared to laparoscopic approach [9, 29].

Table 4 Analysis for postoperative complications of robotic approach compared to laparoscopic total colectomy

Complication	Laparoscopic surgery (%)	Robotic surgery (%)	Univariate analysis		Multivariate analysis	
			AOR and 95 % CI	*P* value	AOR and 95 % CI	*P* value
Mortality	0.8	0	0.96 (0.96–0.97)	0.10	*	–
Overall morbidity***	24	23.9	0.99 (0.77–1.29)	0.99	1.03 (0.79–1.36)	0.78
Accidental puncture****	2.2	0	0.96 (0.96–0.97)	<0.01	*	–
Prolonged ileus	13.9	16	1.22 (0.90–1.64)	0.18	1.26 (0.92–1.72)	0.14
Wound infection	3.6	4.3	1.18 (0.68–2.05)	0.53	1.45 (0.82–2.54)	0.19
Hemorrhagic complications	3.2	3	0.96 (0.50–1.82)	0.90	1.07 (0.54–2.09)	0.83
Hospitalization >30 days	1	1.5	1.59 (0.64–3.93)	0.31	1.87 (0.69–5.10)	0.21
Intra-abdominal abscess	1.8	1.5	0.85 (0.34–2.08)	0.72	0.73 (0.28–1.91)	0.52
Cardiac complications**	1.4	1.5	1.11 (0.45–2.73)	0.82	1.45 (0.57–3.65)	0.42
Pneumonia	0.7	1.5	2.18 (0.87–5.44)	0.08	3.22 (0.99–8.95)	0.06
Wound disruption	1.1	0	0.96 (0.96–0.97)	0.05	*	–
Deep vein thrombosis	0.5	1.5	2.97 (1.18–7.52)	0.01	2.67 (0.92–7.78)	0.07
Respiratory failure	0.5	0	0.96 (0.96–0.97)	0.21	*	–
Pulmonary embolism	0.4	0	0.96 (0.96–0.97)	0.26	*	–
Urinary tract infection	4.4	6.1	1.53 (0.96–2.44)	0.06	1.69 (0.99–2.73)	0.06
Central vascular accident	0.4	0	0.96 (0.96–0.97)	0.27	*	–
Septic shock	0.1	0	0.96 (0.96–0.97)	0.68	*	–

* Unable to calculate because of no events in the robotic surgery group
** Includes: myocardial infarction, cardiac arrest, arrhythmia, and heart failure
*** Includes prolonged ileus, hospitalization more than 30 days, pneumonia, wound infection, cardiac complications, intra-abdominal abscess, respiratory failure, hemorrhagic complications, wound disruption, deep vein thrombosis, central vascular accident, pulmonary embolism, and septic shock
**** Accidental puncture or laceration of bowel during a procedure

Study limitations

The main limitation of the study, as with all database studies, is that it is a retrospective evaluation which makes it difficult to draw firm conclusions. We compared outcomes of patients who underwent the three approaches of open, laparoscopic, and robotic total colectomy, but these groups were not three homogeneous groups of patients. The study data were extracted from a large national database, and wide variation in hospital setting, hospital quality, and surgeons' expertise in our database may have affected some of the indices, such as the operation time and conversion rate. In addition, our study intended to investigate outcomes of total colectomy by surgical approaches. However, factors such as the operation duration and docking time could not be evaluated [14, 28]. Also, we did not have any information regarding specifics of the surgical technique, for example if the robotic procedures were performed purely robotically or if some portions were performed laparoscopically while only selected portions were performed robotically (hybrid approach). We evaluated total hospital charges of patients who underwent open, laparoscopic, and robotic total colectomy. However, we did not have any detailed information regarding hospital costs. In order to have homogeneous groups of patients, we excluded patients who underwent emergent/urgent total colectomy from the study. However, we could not adjust our results with disease stage by ASA score. Despite these limitations, this study is one of the first studies comparing open, laparoscopic, and robotic approaches to total colectomy procedure.

Conclusion

Minimally invasive approaches to abdominal colectomy are feasible and safe with a significantly lower mortality, morbidity, and hospitalization length compared to the open approach. Laparoscopic surgery significantly decreases hospital charges of patients compared to open surgery and robotic surgery. Among both minimally invasive approaches, there was no significant difference in morbidity of robotic and laparoscopic approaches to total colectomy. However, the robotic approach increases the feasibility of minimally invasive surgery for total colectomy. Total hospital charges for patients who underwent robotic surgery were significantly higher than for laparoscopic surgery. However, the inability to control for disease stage in patients undergoing open surgery with patients undergoing minimally invasive surgery makes it difficult to draw firm conclusions.

Compliance with ethical standards

Disclosures Dr. Stamos has received educational Grants and speaker fees paid to the Department of Surgery, University of California, Irvine, from Ethicon, Gore, Covidien, and Olympus. Dr. Mills and Dr. Carmichael received Ethicon educational Grants paid to the Department of Surgery, University of California, Irvine. Dr. Pigazzi is a consultant for Intuitive Surgical and has also received consultancy fees and educational Grants paid to the Department of Surgery, University of California, Irvine. Dr. Moghadamyeghaneh and Dr. Hanna have no disclosures. Dr. Moghadamyeghaneh had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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