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RESEARCH

Oncologic outcomes for robotic versus laparoscopic colectomy for colon cancer: an ACS-NSQIP analysis

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Abstract

Robotic colectomy has been associated with comparable or improved short-term morbidity and mortality when compared to laparoscopic colectomy, including shorter length of stay. In this study, we sought to understand oncologic advantages for robotic as compared to laparoscopic colectomy in colon cancer. We analyzed the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) participant user files for all elective colon cancer cases from 1/2016 through 12/2021 performed with minimally invasive surgical techniques (robotic and laparoscopic). We calculated relative risks (RR) through Poisson Regression models and treatment effect coefficients by propensity-score match, after adjusting for age, BMI, ASA scores, mechanical and antibiotic bowel preparation, emergency surgery, race, gender, smoking status, hypertension and diabetes mellitus. Analyzed outcomes included rate of chemotherapy initiation within 90 days of surgery, number of harvested lymph nodes, any occurrence of intraoperative or postoperative blood transfusion, and the need for ostomy. During the study period, 44,745 patients underwent minimally invasive colectomy for colon cancer; 39,614 in the laparoscopic cohort and 7,831 in the robotic cohort. After adjusting for confounders, robotic colectomy was associated with a significant increase in the likelihood for initating chemotherapy within 90 days (RR 1.98, 95% CI {1.86—2.10}, $p<0.001$). The robotic-treated patients had a significantly more lymph nodes harvested, a significant decrease in the need for intraperative or postoperative blood transfusion (RR 0.64, 95% CI {0.57–0.71}, $p<0.001$) and a significant reduction in the need for ostomy formation (RR 0.26, 95% CI {0.22–0.30}, $p<0.001$). As a retrospective and non-randomized study, residual bias and confouding variables are likely to exist. The study is also subject to coding incompleteness and inaccuracies. We also do not have additional context on potential factors that might influence time to chemotherapy. In addition, there is no information on surgeon or hospital volume, which can be associated with outcomes. Robotic colectomy for colon cancer was associated with significant improvement in the rate of chemotherapy initiation within 90 days, a significant reduction in need for blood transfusions, and a lower likelihood of receiving an ostomy when compared to laparoscopic colectomy procedures. The data reveal substantial short-term gains in oncologic outcomes for colon cancer performed with robotic techniques.

Keywords Colectomy · Colon cancer · Colorectal · Robotic · Laparoscopic · Minimmaly invasive surgery

Introduction

Adoption of robotic surgery continues to grow across specialties at an accelerated pace. As the robotic technology has continued to progress, improvements have been made with significant impact on colorectal procedures. These improvements include 3D high-definition visualization, wristed instrumentation, integrated table motion, increased-angle robotic staplers [1], enhanced imaging, and multi-quadrant access within the abdomen. These technologic advancements have paralleled an increased adoption of robotic colorectal procedures as well as the adoption of more intracorporeal anastomosis techniques [2].

The current literature has demonstrated the safety and efficacy of robotic colectomy procedures in comparison to laparoscopic. Many studies have even show improved perioperative outcomes between robotic and laparoscopic

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colectomy procedures [3], including reduced length of stay, reduced opioid use, less blood loss, fewer complications, and reduced conversion rates [4–7]. However, the comparison of oncologic outcomes has been inconsistently reported for colon cancer. It is important that we understand how the improved perioperative outcomes translate to oncologic outcomes as well.

Over time, an increase in time to treatment for many solid organ cancers has been observed [8]. It has also been well documented that delays in time to initial treatment, as well as time to adjuvant therapy, have been associated with increased mortality [9] for colon cancer. Considering the potential improvements in surgical recovery associated with the robotic approach, we sought to understand if this translates to quicker initiation of chemotherapy after surgery. The objective of our study was to provide a real world comparison of the oncologic outcomes between robotic and laparoscopic colon-cancer procedures through the ACS-NSQIP database.

Methods

Study oversight

The data in this study were de-identified and thus were exempt from formal review by our Institutional Review Board.

Cohort abstraction

We abstracted data from the ACS-NSQIP participant user files from 1/2016 through 12/2021 [10]. First, we identified all patients who underwent surgery at participating NSQIP hospitals and collected the data for the procedure targeted colectomy files with primary indication of colon cancer. We included only patients treated with minimally invasive (laparoscopic or robotic) colectomy. We included all cases in which robotic and laparoscopic surgery were included for the overall analysis, according to NSQIP built-in classification for surgical approach. NSQIP codes cases as purely robotic as well as robotic with open assist and robotic with unplanned conversion. We included all approaches as an overall "intention to treat" robotic colectomy approach cohort. Similarly, the laparoscopic group included case codes as purely laparoscopic as well as laparoscopic with open assist or unplanned conversion. To improve the homogeneity of our cohort, we excluded natural orifice transluminal endoscopic surgery (NOTES), single incision laparoscopy surgery (SILS), and hybrid procedures.

Left versus right colectomy

Patients who underwent a right-sided colectomy were defined as those patients who had a partial colectomy with ileocolic anastomosis (CPT code 44,160 or 44,205). Patients who underwent left-sided colectomy were defined as those who had a partial colectomy with anastomosis (CPT codes 44,140, 44,204, 44,145, or 44,207) [11]. Due to misclassification regarding segmental colectomies, we also included a segmental colectomy subgroup (CPT codes 44,140 and 44,204) solely for the purpose of multivariate analysis.

Covariates

Trained clinical research abstractors collected the covariates of age, gender, body mass index (BMI), presence of diabetes mellitus with and without insulin use, hypertension, smoking history, use of steroids, and history of heart failure. American Society of Anesthesiologists (ASA) scores were also abstracted and adjusted for.

Unmeasured confounders

Due to the observational nature of the study, we added the analysis of E-values for our primary outcomes. E-value is a novel statistical tool that indicates the minimum strength of association, on the risk ratio scale, that an unmeasured confounder would need to have with both the intervention and the outcome to fully negate the study's conclusion. A higher E-value suggests that it would take a very strong unmeasured confounder to nullify the observed effect, implying that the observed association is more robust. A lower E-value means that a relatively weak unmeasured confounder could potentially explain away the observed association, implying that the association might be more vulnerable to bias. [12] For example, an E-value of 5 means that a possible confounder would have to increase the likelihood of the outcome fivefold to invalidate the results.

Intraoperative outcomes

Our intraoperative outcomes included rate of ostomy creation, intra-operative and post-operative blood loss, total operative time, and total hospital length of stay.

Postopertive outcomes

Our included postoperative outcomes were the overall 30-day mortality the rate of chemotherapy initiated within

90 days of surgery, number of harvested lymph nodes, and all-cause morbidity.

All-cause morbidity included all patients who experienced any episode of return to the operating room, myocardial infarction, deep vein thrombosis, pneumonia, acute renal failure, cardiac arrest, urinary tract infection, wound disruption, pulmonary embolism, progression of renal failure, and postoperative sepsis. This all-cause morbidity outcome has been validated in previous studies using the NSQIP (13.14), and was included in our pre-specified statistical analysis plan (SAP) [15].

Statistical analysis

We aggregated the data to compare robotic versus laparoscopic colectomy outcomes. We performed univariate analysis incorporating $\chi 2$ tests, Fisher exact tests, and independent-sample *t tests* to compare patient baseline characteristics by time to intervention. Chi-squared risk ratios were used for categorical data. Next, our multivariable analyses used Poisson regression models to estimate relative risks adjusted for potential confounders, including demographic (age, gender, BMI), patient risk factors (diabetes mellitus, hypertension, smoking status, heart failure, ASA score), and indication for surgery (inflammatory bowel disease, colon cancer and diverticular disease) and for NSQIP bult-in score of estimated probability of morbidity. The reporting of this study conforms to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines. Our SAP was published as a pre-specified SAP [15].

Results

Cohort

The NSQIP registered 219,981 patients with colectomy procedures from 1/1/2016 through 12/31/2021. After excluding all cases with indications for surgery not defined as colorectal cancer, the analysis was limited to a study population of 90,050 patients. Of the 59,932 patients in the oncologic minimally invasive cohort 12,334 cases were robotic, and 47,598 cases were laparoscopic. As compared to laparoscopic colectomy, robotic patients were significantly older, more likely to be male, and presented a higher incidence of smoking, hypertension, diabetes and ASA 2 or higher scores. Demographic results are summarized in Table 1.

Intraoperative outcomes

Blood transfusions

Blood loss was measured by the need for intra-operative or early postoperative transfusion. In the laparoscopic cohort, blood transfusion was recorded in 6.05% of patients compared to 4.33% in the robotic cohort. Blood transfusions were significantly reduced with a robotic approach, even after adjusting for multiple confounders {adjusted RR: 0.81 (95% CI 0.73–0.89), $p < 0.001$}.

Operative time and length of stay

The median operative time for the robotic approach was 225 min (IQR 173–299), as compared to a median of 166 min in the laparoscopic group (IQR 122–226). Robotic approach was associated with a significant increase in total operative

Table 1 Demographic Characteristics

	Laparoscopic	Robotic	*p* value
Median age (IQR)	67 (56–75)	63 (53–72)	< 0.001
Pathologic status			
T1	10.55%	11.34%	0.409
T2	16.61%	19.36%	0.04
T3	46.55%	44.10%	0.001
T4a	8.76%	6.44%	0.034
T4b	2.76%	2.16%	0.587
N1	3.6%	3.9%	0.154
M0	52.4%	51.3%	0.023
ASA Score			
ASA 1 or 2	37.03%	38.26%	0.046
Right colon	16.31%	14.15%	0.081
Median estimated probability of morbidity (IQR)	9.10% (6.81–12.79)	8.75% (6.62–11.61)	< 0.001

time ($p < 0.001$). In addition, the robotic approach was associated with a significant reduction in total length of stay of approximately 1 day ($p < 0.001$). The median length of stay in the robotic group was 3 days (IQR 2–5) and 4 days in the laparoscopic cohort (IQR 3–6), $p < 0.001$.

Ostomy creation

Ostomy creation (either colostomy or ileostomy) was recorded in 1.8% of patients in the robotic cohort and in 2.2% of the laparoscopic cohort. After adjusting for multiple confounders, the robotic approach was associated with a significant reduction in ostomy creation {RR 0.69, 95% IC (0.59–0.79), $p < 0.001$} Table 2.

Postoperative outcomes

Overall morbidity

Overall medical-related morbidity had an incidence of 13.90% in the laparoscopic cohort and 9.77% in the robotic cohort. The robotic approach was associated with a significant reduction in the incidence of postoperative morbidity, even after adjusting for multiple confounders (adjustedRR 0.87, 95% CI{0.83–0.93}, $p < 0.001$). The estimated E-value for this analysis was 10.

Overall mortality

Any cause 30-day mortality was significantly reduced with robotic approach, both in crude analysis and after adjusting for multiple confounders. The absolute incidence of mortality was 1.8% in the laparoscopic group and 1% in the robotic group (adjusted RR 0.66 (0.54–0.81), $p < 0.001$). The estimated E-value for this analysis was 4.05.

Chemotherapy initiation

The rate of chemotherapy initiation within 90-days of surgery was 9.17% in the laparoscopic group and 19.24% in the robotic group. Robotic approach was associated with a significant increase in the rate of early chemotherapy initiation, even after adjusting for multiple covariates {adjusted RR 2.01 (95% CI 1.91–2.12, $p < 0.001$}. The estimated E-value for this outcome was 3.02.

Harvested lymph nodes

We compared the mean number of harvested lymph nodes in both robotic and laparoscopic approaches. The median number of harvested lymph nodes in the robotic cohort was 21 (IQR 16–29) and 19 in the laparoscopic cohort (IQR 14–25). After multivariate regression, we observed a significantly more nodes harvested by robotic approach {Coef 1.18, 95% CI(+ 0.67 −/ + 1.68). $p < 0.001$}.

Discussion

Our study analyzed the ACS-NSQIP database to compare the oncologic outcomes of robotic and laparoscopic elective colectomy procedures for patients with colon cancer. By examining the years of 2016 through 2021, we sought to provide a real world perspective of modern oncologic minimally invasive surgery. We found that the robotic approach for colon-cancer procedures was associated with a significant

Table 2 Oncologic and Surgical outcomes

	Incidence in laparoscopic cohort	Incidence in robotic cohort	Adjusted relative risks	95% CI	p value		
Overall mortality	1.8%	1.00%	0.76	0.59–0.97	0.029		
Clinical morbidity	13.90%	9.77%	0.87	0.83–0.93	< 0.001		
Blood transfusion	6.05%	4.33%	0.81	0.73–0.89	< 0.001		
Ostomy confection	2.2%	1.8%	0.69	0.59–0.79	< 0.001		
Early chemotherapy initiation	19.24%	9.17%	2.22	2.11–2.34	< 0.001		
	Median laparoscopic	Interquartile range	Median robotic	Interquartile range	Adjusted coefficient	95% CI	p value
Operative time	166 min	122–226	225 min	173–299	62.60	+ 60.48 to + 64.70	< 0.001
Length of stay	4 days	3–6	3 days	2–5	– 0.67	– 0.87 to – 0.47	< 0.001
Number of harvested lymph nodes	19	14–25	21	16–29	1.18	+ 0.67 to + 1.68	< 0.001

decrease in overall 30-day mortality and clinical-related morbidity, early initiation of chemotherapy, reduced need for ostomy creation, and a significant decrease in blood transfusion, when compared to laparoscopic colectomy. Although these results are short and intermediate-term in nature, they may extrapolate to long term oncologic benefits to those colon-cancer patients treated with robotic approaches.

A recent analysis of ACS-NSQIP data from 2013 through 2018 revealed an increased adoption of robotics for elective colectomy procedures while rates of both laparoscopy and open procedures declined [16]. The shift appeared to be predominantly a shift from open to minimally invasive modalities. However, over the last few years, a decline in laparoscopy was also observed. The trend in robotic adoption observed persisted across diagnoses and high-risk patient categories. In parallel with this trend, a decreasing trend of overall complications, surgical complications, and hospital length of stay was observed. 17 These differences in traditional surgical outcomes favor a robotic approach, yet the impact of robotics on oncologic outcomes is largely unclear.

The present study shows results consistent with a recent analysis of the same database [18]. In a large sample of colectomy patients across different indications, the robotic approach was associated with significant reductions in length of stay, ostomy confection and medical-related morbidity. Our data show that these benefits are also significant in the population diagnosed with colorectal cancer.

This study is necessary given the concerns related to minimally invasive surgery described in other cancers [19–21]. In a study of the National Cancer Database from the American College of Surgeons and The American Cancer Society, epidemiologic review of early stage cervical cancer revealed inferior results of minimally invasive surgery compared to open surgery. This study pointed to potential oncologic disadvantages to minimal access surgery and was initially extrapolated to all minimally invasive surgery, including robotic and laparoscopic. It even prompted an FDA warning around the application of robotics in cancer-related procedures. However, retrospective data from the MEMORY Study, a multicentered collaborative, revealed no difference in oncologic outcomes of minimally invasive (primarily robotic) compared to open radical hysterectomy for cervical cancer [22]. In addition, the RECOURSE trial, a systematic review and meta-analysis on surgical procedures for endometrial, cervical, prostate, lung, and rectal cancers, observed comparable or favorable survival outcomes between robotic and laparoscopic/open modalities.

We did find a significant improvement in 30-day all cause mortality for robotic patients in comparison to laparoscopic. A prior NSQIP analysis on right colon-cancer outcomes specifically demonstrated no significant differences between robotic and laparoscopic patients, however only years 2012–2014 were examined. Our study provides a significantly more updated perspective on the impact of robotic technology as well as the growing collective experience with this approach. Further prospective studies [23] are enrolling but the oncologic outcomes of robotics in colon surgery are less clearly understood.

We revealed a significant increase in the likelihood of initiating adjuvant chemotherapy within 90-days of surgery when robotic techniques were used. Although the existing literature has demonstrated an association between minimally invasive surgical modalities with a reduced likelihood of delay in adjuvant chemotherapy [24]. Timely initiation of chemotherapy is crucial in the setting of adjuvant treatment, as the literature points to ineffectiveness of chemotherapy if treatment begins 4 months after surgery [25]. This is also a significant indication of how the robotic approach can impact the timeliness of cancer treatment, given the observed reduction in hospital length of stay.

Our study also observed a significant reduction in need for intraoperative or postoperative blood transfusions for robotic patients when compared to laparoscopic patients. This result is consistent with the existing literature [26] and is of particular importance considering the negative impact of blood transfusions on colorectal cancer recurrence and mortality [27]. It has been postulated that perioperative transfusions in cancer patients weaken the immune system permitting reduced cancer control. Much of these results may be related to unchecked circulatory tumor cell spread.

A further advantage of the robotic approach in comparison to laparoscopy that was observed is the reduction in ostomy formation. This difference may be attributable to the enabling dissection capability of the robotic platform. The avoidance of an ostomy has a profound impact on quality of life for patients, as well as subsequent hospital admissions attributable to stoma complications and the additional burden of ostomy takedown procedure as well. Further investigation into the contributing variables to the differences in ostomy creation are warranted. A possible explanation for this observed reduction is increase in the safety of surgeons regarding the quality and viability of the anastomosis, leading to a decrease in the need for diverting ileostomies [28].

Finally, robotic approach was associated with a significant increase in lymph-node harvests when compared to laparoscopic colectomy. This increase was significant even after multivariate analysis, and falls in line with the current medical literature. A likely explanation for this fact is that robotic approach permits more radical lymphadenectomy with greater rates of Complete Mesocolic Excision. The relevancy of this finding lies in the fact that complete mesocolic excision permits through lymph-node basin evaluation which may be associated with improved disease-free survival. (29).

Our study has limitation related to the inherent nature of retrospective and non-randomized study. There is the potential for selection bias related to the non-random distribution of patients. In addition, we were unable to obtain other process measures of oncologic quality such as circumferential margins, distal margins, etc., nor do we have all the clinical details such as stage or other treatment available through independent chart extraction. Also of note, the definition of the chemotherapy initiation outcome is subject by misclassification within NSQIP, by including neoadjuvancy cases as early chemotherapy. Due to the format of data classification on NSQIP, this is a relevant limitation to our early chemotherapy initiation finding. We also do not have data on surgeon experience with each modality or hospital volume, both of which we know to influence patient outcomes. We also acknowledge that there are a number of variables that can influence the time to initiation of chemotherapy and ostomy formation that are unrelated to surgical modality and cannot be controlled for in our study.

In conclusion, our analysis reveals the oncologic benefits of robotics for colon-cancer patients. Surgical procedures are often curative for patients with colon cancer, thus methods to reduce surgical sequelae are of significant long-term benefit to the patient. Our data indeed confirm reduction in morbidity, blood transfusions, adequate lymph node yield, improved length-of-stay, and early initiation of chemotherapy for robotic colectomy patients. These outcomes gains may be associated with overall long term oncologic benefits.

Author contributions Dr Leite wrote the main manuscript text and conducted statistical analysis Dr Araujo and dr Ricciardi revised the final manuscript Dr Callado prepared the table Ms. Bossie contributed in the literature review for the manuscript.

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Data availability Public access.

Declarations

Conflict of interests Ms Bossie serves as a medical science liaison for Intuitive Inc. She did not have access to the database, results or statistical analysis process. Her role was of literature review and manuscript draft, per compliance policy. The remainder authors have no conflicts of interest to report.

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