# Surgical and medical outcomes in robotic compared to laparoscopic colectomy global prospective cohort from the American college of surgeons national surgical quality improvement program

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## Abstract

**Background** Evidence regarding the outcomes benefits of robotic approach, when compared to a laparoscopic approach, in colectomy remain limited.

**Objective** This study aimed to analyze the value of robotic approach compared to laparoscopic approach in minimally invasive colectomy.

**Design** Cohort study of the National Surgical Quality Improvement Program (NSQIP).

**Setting** This study included data from the NSQIP from 1/2016 to 12/2021.

**Patient** Adult patients undergoing minimally invasive (laparoscopic or robotic) colorectal surgery.

**Intervention** Robotic versus laparoscopic colectomy.

**Outcome measures** Risk ratios for the incidence of medical and surgical morbidity and overall mortality.

**Results** Compared to laparoscopic, robotic colectomy was associated with a significant decrease in postoperative morbidity [RR 0.84 (95%CI 0.72–0.96), $P < 0.001$], a significant reduction in postoperative mortality [RR 0.83 (95%CI 0.79–0.90), $P$ 0.010)], and in post operative ileus [RR: 0.80 (95%CI 0.75–0.84), $P < 0.001$]. Yet, robotic approach was associated with a significant increase in total operative time despite a significant decrease in total length of stay. No benefit was observed regarding anastomotic leak.

**Limitations** Observational nature of the study cannot exclude residual bias.

**Conclusions** In this prospective cohort from the NSQIP, robotic colectomy was associated with a significant reduction in postoperative ileus, unplanned conversion to open surgery, morbidity, and overall mortality when compared to laparoscopic colectomy.

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Robotic surgery has been rapidly incorporated into surgical practice over the last 30 years. [1, 2] in many surgical fields, including colorectal procedures. While initial reports have suggested potential benefits, such as reduced incidence of postoperative ileus [3] and shorter hospital stays, the evidence supporting these claims remains inconclusive when adjusting for confounding factors [4, 5]. Moreover, relevant outcomes of surgical success, including anastomotic leak rates and overall mortality, have shown comparable results between robotic and laparoscopic approaches (3.4) The benefits of robotic approach over laparoscopic approach in colectomy has presented equivocal surgical and medical outcomes in previous studies. A recent analysis of a large national database [6] has shown similar surgical outcomes for robotic colectomy in colon cancer, though the findings were partially influenced by inclusion of early years of robotic adoption in medical practice. To address this relevant question, we abstracted a prospective collected cohort using the American Colleges of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) across multiple indications for colectomy. We hypothesized that robotic colectomy could present improved morbidity and mortality when compared to laparoscopic approaches.

## Methods

### Study oversight—IRB exemption

The data in these studies 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. First, we identified all patients who underwent surgery at participating NSQIP hospitals and collected the data for the procedure targeted colectomy files. We included only patients treated with minimally invasive (laparoscopic or robotic) colectomy. We included all cases in which robotic and laparoscopic surgery was included for the overall analysis. We also included cases with unplanned conversion to open surgery as an "intention to treat"population, as well as cases with planned open assist.

### 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 44160 or 44205). Patients who underwent left-sided colectomy were defined as those who had a partial colectomy with anastomosis (CPT codes 44140, 44204, 44145 or 44207). Due to misclassification

regarding segmental colectomies, we also included a segmental colectomy subgroup (CPT codes 44140 and 44204) for the purpose of multivariate analysis.

### Interventions

The intervention for this study was surgical approach to colectomy (either robotic or laparoscopic). The 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.

### 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.

### Primary outcomes

Our primary outcomes were all-cause morbidity, as well as overall 30 days mortality. 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, superficial and deep surgical site infection and postoperative sepsis. This all-cause morbidity outcome has been validated in previous studies using the NSQIP [7], and was included in our pre-specified statistical analysis plan [8].

### Secondary outcomes

Our secondary outcomes included the incidence of postoperative ileus, total operative time, total length of in -hospital stay, rate of unplanned conversion to open surgery.

### Statistical analysis

We aggregated the data to compare robotic versus laparoscopic colectomy. 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, weight), patient risk factors (diabetes mellitus, hypertension, smoking status, heart failure) ASA scores, indication for surgery (Inflammatory Bowel Disease, Colon Cancer and Diverticular Disease) and surgical intervention (right, left colectomy and segmental colectomy), emergency vs elective and specialty of surgical provider. We also conducted propensity-score match analysis for our primary outcomes with treatment effect logistic models to obtain coefficients paired by the same demographics and risk factors as our Poisson Regression, using Probit Regression Module. All the analysis were conducted on STATA 18 Standard Edition.

The reporting of this study conforms to the strengthening the reporting of observational studies in epidemiology (STROBE) reporting guidelines. Our statistical analysis plan was published as a pre-specified statistical analysis plan (SAP) [8].

## Results

### Cohort

The NSQIP registered 219,981 patients with colectomy procedures from 1/1/2016 to 12/31/2021. After excluding open surgery cases our "intention to treat minimally invasive" cohort—including cases of unplanned conversion to open surgery comprised 132,071 patients.

### Robotic and laparoscopic colectomy cohorts

Of the 132,071 patients in the minimally invasive cohort 25,175 cases were robotic, and 106,896 cases were laparoscopic. As compared to laparoscopic colectomy, robotic patients were significantly older, male and presented a higher proportion of cases with smoking, hypertension, diabetes and ASA 2 or higher scores. Demographic results are summarized in Table 1. The most frequent indication for surgery was colon cancer in both cohorts, although we noted proportionately more cancer cases in the robotic patients.

### Overall mortality

Any cause 30 days mortality was significantly reduced with robotic approach, both in crude analysis and after adjusting for multiple confounders. The absolute incidence of mortality was around 2% in the laparoscopic group and 1.8% in the robotic group (RR 0.83 (95%CI 0.79–0.90), P 0.010). Absolute incidences are presented on Table 2.

**Table 1** Demographic characteristics in laparoscopic X robotic colectomy

|  | Intention to treat robotic | Intention to treat laparoscopic | P value |
|---|---|---|---|
| Number of patients | 25,175 | 106,896 |  |
| Mean age (sd) | 60.60 (13.19) | 60.33 (15.24) | 0.007 |
| Male sex | 49.02% | 48.24% | < 0.001 |
| Smokers | 14.67% | 14.55% | < 0.001 |
| Hypertension | 48.36% | 45.15% | < 0.001 |
| Diabetes | 16.07% | 14.78% | < 0.001 |
| ASA 1 | 1.39% | 2.20% | < 0.001 |
| Indications |  |  |  |
| Colon cancer | 47.66% | 42.44% | < 0.001 |
| Acute diverticulitis | 6.61% | 5.79% | < 0.001 |
| Crohn's disease | 2.38% | 6.59% | < 0.001 |

*SD* standard deviation, *ASA* American Society of Anesthesiology Score

### Morbidity

We also analyzed the outcome of any-cause 30 day morbidity. Robotic approach was associated with a significant reduction in all-cause morbidity, after adjusting for multiple confounders {adjusted RR: 0.84 (95%CI 0.72–0.96), $P < 0.001$}. Absolute incidences are presented in Table 2.

### Ileus

A total of 14,001 patients experienced postoperative ileus, 10.97% in the laparoscopic colectomy group and 9.03% in the robotic group. The incidence of ileus was significantly reduced with a robotic approach, even after adjusting for multiple confounders {adjusted RR: 0.83 (95%CI 0.79–0.87), $P < 0.001$}.

### Anastomotic leak

A total of 3403 patients experienced an anastomotic leak, 2.5% in the laparoscopic cohort and 2.7% in the robotic cohort. There was no statistically significant difference in the incidence of anastomotic leak in the crude analysis {RR:1.10 (95%CI 0.96–1.15), $P = 0.2$}, and after adjusting for multiple confounders {RR:1.05 (95%CI 0.95–1.17), $P = 0.309$}. We also stratified leak incidence by BMI status—as previous studies have noticed significant advantages for robotic colectomy in the obese population [9]. We did not find evidence for effect modification by BMI in the anastomotic leak subgroup. The primary outcomes are presented in Table 2.

**Table 2** Results—robotic x laparoscopic colectomy

| | Number of events | Incidence (laparo-scopic) | Incidence (robotic) | Relative risks and 95%CI | *P*-value | Propensity-score match coefficients | *P*-value |
|---|---|---|---|---|---|---|---|
| Primary outcomes | | | | | | | |
| All cause medical morbidity | 8968 | 7.73% | 6.60% | 0.84 (0.72–0.96) | <0.001 | 0.99, (− 0.17 to − 0.21) | 0.013 |
| All cause mortality | 26,588 | 2.5% | 1.8% | 0.83 (0.79–0.90) | 0.003 | − 0.16, (− 0.19 to − 0.13) | <0.001 |
| Secondary outcomes | | | | | | | |
| Ileus | 12,656 | 11.11% | 8.36% | 0.783 (0.79–0.87) | <0.001 | | |
| Anastomotic leak | 3100 | 2.58% | 2.72% | 1.05 (0.96–1.17 | 0.309 | | |
| Ostomy creation | 22,902 | 4.37% | 2.30% | 0.56 (0.51–0.61) | <0.001 | | |
| Mean operative time (minutes), SD | | 177 (84) | 236 (97) | | <0.001 | | |
| Lenght of stay days (SD) | | 5.07 (8.53) | 4.12 (6.90) | | <0.001 | | |
| Unplanned conversion rate (SD) | 21,819 | 12.64 (0.25) | 6.12 (0.08) | | <0.001 | | |

*SD* standard deviation

## Operative time and length of stay

Robotic approach was associated with a significant increase in total operative time ($P < 0.001$), with a mean increase of 12 min. On the contrary, a robotic approach was associated with a significant reduction in total length of stay, of approximately 1 day ($P < 0.001$). We analyzed the trend over time for operative duration in robotic colectomy using the Jonckheere–Terpstra test for trends and linear regression models, with no evidence of decrease in additional operative time over the years of analysis.

## Unplanned conversion rate

Unplanned conversion to open surgery was significantly reduced in robotic approach when compared to laparoscopic approach (12.6% vs. 6.1%, $P < 0.001$).

### Propensity-score match analysis

Due to the observational nature of our study, we decided to run Propensity-score match analysis—analysis for our primary outcomes. Robotic Approach was still associated with a significant reduction in mortality (Coef—0.99, 95%CI {− 0.17 to − 0.21}. *P* 0.013) and medical-related morbidity (Coef—0.16, 95%CI {− 0.19 to − 0.13}, $P < 0.001$).

## Discussion

In this global prospective cohort study of 219,981 patients treated from 1/2016 through 12/2021 using the American college of surgeons national surgical quality improvement program, robotic colectomy was associated with a significant reduction in overall mortality, a significant reduction in all-cause morbidity, a significant reduction in length of stay, and significant reduction in postoperative ileus and ostomy creation when compared to a laparoscopic approach. These results were statistically significant in the crude and adjusted analysis and indicate signficant immediate advantages to robotic procedures.

Previous studies have shown improved surgical and medical outcomes with robotic approaches (3–5). However, these results lost significance after adjusting for standard covariates, and limiting analysis to particular populations. The most consistent findings across prior observational trials was the reduction in total length of stay, at the expense of an increase in total operative time. Our present cohort includes a much larger sample size, including the last 6 available years in the ACS—NSQIP database. In addition, other studies utilized administrative data, whereas NSQIP is clinical in nature, with validated outcomes.

As previously described, we noted an increase in total operative time with robotic colectomy. We conducted

analysis of temporal trends within the NSQIP database, hypothesizing that additional operative time could be reduced as surgeons became more efficient with a robotic approach. On the contrary, we found evidence of the opposite effect: a trend towards increased operative time with a robotic approach. Although operative time may be prolonged, it should not be necessarily considered as an adverse outcome. Interestingly, there is evidence from one cohort study [10] indicating that a longer operative time was not associated with poorer outcomes in the setting of minimally invasive surgery. Also, the definition of operative time in NSQIP database includes set up time for the robot, and does not reflect only procedural time per se. Hence, it is essential to consider the context and individual patient characteristics when evaluating the significance of a prolonged operative time. Further research is needed to address this important topic to help explain the additional time for robotic procedures and the lack of improved efficiency with time.

We did not identify a difference in anastomotic leak between laparoscopic and robotic colectomy. A lack of difference was noted regardless of BMI categories. We conducted further analyses to assess whether indication for colectomy may be influential in the anastomotic leak rates by diagnostic category. Results were similar between laparoscopic and robotic approach colectomy in colon cancer, inflammatory bowel disease, and diverticular disease. These results may be explained by similar anastomotic methods or stapling technologies regardless of indication. Also, we could not adjust for the use of indocyanine green in anatomic perfusion tests due to lack of this report in our database.

We found a significant reduction in overall mortality with robotic approaches to colectomy when compared to laparoscopic colectomy. This result must be considered with the understanding that the robotic colectomy population was significantly older and more morbid than the laparoscopic group, with a significantly higher cancer prevalence. Even after adjusting for multiple confounders, the mortality results were highly significant indicating a superiority of robotic surgery over laparoscopic surgery. Previous studies have failed to demonstrate a mortality benefit with robotic approaches in colectomy [11, 12]. The likely improvement in mortality is likely related to overall similar reduction in morbidity.

Our study has several limitations. We can not adjust for possible confounders as surgical expertise and hospital volume or teaching facility. Also, although we adjudged for multiple different indications (IBD, cancer, diverticular disease) the influence of surgical complexity in the presented outcomes is also a possible bias. Also, the literature shows that NSQIP may misidentify ostomy creation [13], specially diverting loop ileostomy. Thus, we could not accurately report on ostomy creation differences across groups.

Additionally, our analysis was also limited by the lack of financial data in the NSQIP database, which could bring about relevant analysis. Institutional protocols differences and discharge criteria could not be adjusted for. Finally, due to the observational nature of the study, the risk of residual bias cannot be excluded. However, compared to previous publications, our work has several strengths. First, our data from the ACS-NSQIP has a prospective design and is in clinical in nature, lowering limitations of observational design. Also, we are presenting a very large sample, comprising the last five available years of the NSQIP cohort. Because adverse outcomes in contemporary minimal invasive colectomy are rare, previous studies may have been underpowered to detect significant differences in robotic colectomy.

## Conclusions

In summary, in this global prospective cohort using ACS-NSQIP data, robotic colectomy was associated with a reduced incidence of ileus, morbidity and overall short-term (30 days) mortality when compared to laparoscopic colectomy. It was also associated with a reduced total length of stay, ostomy creation, at the expense of longer operative times.

## Declarations

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