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RESEARCH

Feasibility of robotic multivisceral resections in colorectal cancer patients: a NSQIP-based study

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Abstract

Multivisceral robotic surgery may be an alternative to sequential procedures in select patients with colorectal cancer who are diagnosed with synchronous lesions or in those who require additional procedures at the time of resection. The aim of this study was to assess utilization of the robot for multivisceral resections and compare the surgical outcomes of this approach to laparoscopic resections. Adult colorectal surgery patients who underwent a colectomy or proctectomy and a concurrent abdominal surgery procedure in the American College of Surgeons NSQIP database (2016–2021) were included. The primary outcomes were 30-day postoperative overall and serious morbidity. Factors associated with morbidity were assessed using a multivariable logistic regression. Of the 3875 patients who underwent simultaneous multivisceral resections, 397 (10.3%) underwent a robotic approach and 962 (24.8%) a laparoscopic approach. Gynecological procedures (38%) comprised the largest proportion of concurrent procedures followed by hepatic resections (18%). On unadjusted analysis, rates of overall morbidity (25.4% vs. 30.0%) and serious morbidity (12.1% vs 12.0%) did not differ between the robotic and laparoscopic approach groups, respectively. The rate of conversion to open was lower for the robotic compared to laparoscopic approach (9.3% vs. 28.8%, $p < 0.001$), and length of stay was shorter (4 vs. 5, $p < 0.001$). On adjusted analysis, there was no significant difference in overall (OR 0.87, 95% CI 0.65–1.16, $p = 0.34$) or serious morbidity (OR 1.12, 95% CI 0.75–1.65, $p = 0.59$) between the two approaches even after concurrent procedure risk stratification. Robotic multivisceral resections can be performed with acceptable overall and serious morbidity in select patients with colorectal cancer. Rates of conversion and length of stay may be decreased with a robotic approach, and future research is needed to determine the optimal operative approach in this patient population.

Keywords Colorectal surgery · Colorectal cancer · Robotic surgery · Multivisceral resections

Introduction

Over the last decade, the robotic system has been increasingly utilized in a variety of surgical specialties, including urology, gynecology, and general surgery disciplines, such as colorectal surgery and surgical oncology [1]. Numerous studies have shown that the robotic platform is safe, both from a patient, and when applicable, an oncologic perspective [2, 3]. As more disciplines adopt a robotic approach, the feasibility and potential benefit of utilizing the platform for more complex operations has come into question. One population that could particularly benefit from the robotic approach is patients with synchronous colorectal metastases requiring multivisceral resections at the time of the primary tumor operation.

Colorectal cancer is the third most common cancer worldwide, and approximately 20–25% of patients present with metastatic disease at the time of diagnosis [4, 5]. Numerous small institutional studies have demonstrated the feasibility of simultaneous robotic resection of colorectal liver metastases (CRLM) and the primary tumor [6–9]; however, reports of the application of the robot in other multivisceral resections are limited to small case studies [10–15]. To our knowledge, no study has utilized a large national database

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to investigate the frequency and outcomes of full robotic multivisceral resections for colorectal cancer.

The aim of this retrospective study was to 1) report on the frequency of robotic multivisceral resections for colorectal cancer, and 2) compare the outcomes from these procedures to laparoscopic multivisceral resections. The authors hypothesize that although the number of full robotic multivisceral resections for colorectal cancer is small, it is increasing since the introduction of the robotic platform, and outcomes are comparable to laparoscopic multivisceral resections.

Materials and methods

Data source

This was a retrospective analysis using the 2016–2021 American College of Surgeons National Surgical Quality Improvement Project (ASC-NSQIP) database, including the Procedure Targeted Colectomy and Proctectomy participant use data files. ACS-NSQIP is a nationally validated, risk-adjusted, outcomes-based program that collects data of patients undergoing surgery from over 700 participating member hospitals of varying size and academic affiliation for the primary purpose of measuring and improving surgical quality care [16]. Surgical clinical reviewers at participating hospitals capture and abstract data from clinical records in a standardized format per ACS-NSQIP protocol. This program employs a prospective, systematic data collection of over 150 preoperative and intraoperative variables, as well as 30-day postoperative morbidity and mortality. The historical development and the current details of ACS-NSQIP are described elsewhere [16, 17]. This study was deemed exempt by the Institutional Review Board of the Johns Hopkins University School of Medicine.

Study population

Patients $\geq$ 18 years of age diagnosed with colorectal cancer who underwent a colectomy or proctectomy (designated as the primary procedure code) and a concurrent abdominal surgical procedure were included. Colon and rectal cancer diagnoses were identified using International Classification of Diseases, 9th and 10th Revision (ICD-9/10) codes, and procedures were identified using Current Procedural Terminology (CPT) codes (Supplemental Tables 1, 2, 3). Patients who underwent emergency procedures, had a malignant bowel obstruction, and were either American Society of Anesthesiology (ASA) class V or had missing ASA information were excluded. Furthermore, patients who did not undergo a robotic, laparoscopic, or planned open procedure or who had missing data on operative approach were also excluded. Per the NSQIP data dictionary, and instructions to surgical clinical reviewers, the operative approach that is entered into NSQIP is the final approach found on the operative report at the conclusion of the case. Based on the instructions provided, a case that includes a planned diagnostic laparoscopy followed by an open procedure would be entered as an "open (planned)" approach and not a "laparoscopic w/unplanned conversion to open".

Baseline characteristics of patients

NSQIP-defined patient demographics and clinical characteristics were reported for three operative approach categories: combined robotic, combined laparoscopic, and combined open surgery procedures. An intent-to-treat approach was utilized based on the original planned operative approach for each patient. Demographic characteristics included age (categorized as < 50, 50–59, 60–69, $\geq$ 70 years old), sex, and race (white, black, other [American Indian/Alaskan Native, Native Hawaiian/Pacific Islander, Asian], unknown). Clinical characteristics included the ASA risk classification (I–II, III, IV), obesity (defined as BMI $\geq$ 30 kg/m^2), and preoperative comorbidities, including: current history of smoking (within one year of the operation), history of chronic obstructive pulmonary disease (COPD), and disseminated cancer.

Concurrent procedures

Concurrent procedures were assigned a priori a high- or low-surgical risk designation based on the specific type of procedure performed (Supplemental Table 2). Consensus on the assignment of high and low risk to each concurrent procedure was reached among three authors (SNR, SYC, CA). Patients were designated as undergoing a high-risk combined procedure if the concurrent abdominal procedure was considered high-risk. Operative characteristics included concurrent abdominal surgical procedure (categorized as hepatic resection, cholecystectomy, gynecologic, gastrectomy, nephrectomy, prostatectomy, and cystectomy) and risk of procedure (Supplemental Table 2). There were multiple patients who underwent more than one additional procedure. Patients who underwent both a hepatic resection and cholecystectomy ($n=136$) were analyzed as part of the hepatic resection group. Patients who underwent a prostatectomy and cystectomy ($n=86$) were analyzed as part of the cystectomy group. Other patients who had more than one major concurrent procedure were excluded from the analysis ($n=144$).

Outcomes

The primary outcomes were 30-day postoperative overall and serious morbidity. Overall morbidity was defined as an occurrence of any of the following complications: wound infection (composite of superficial surgical-site infection (SSI), deep incisional SSI, and wound dehiscence), pneumonia, urinary tract infection (UTI), venous thromboembolism (VTE), cardiac complication, shock/sepsis, unplanned intubation, bleeding requiring transfusion, renal complication, on ventilator > 48 hours, organ/space surgical-site infection (SSI), and anastomotic leak. Serious morbidity was defined using the Clavien–Dindo classification of surgical complications. Consistent with prior literature, a grade III or IV complication was classified as a serious morbidity (cardiac complication, shock/sepsis, unplanned intubation, renal complication, on ventilator > 48 hours, organ/space SSI, and reoperation) [18]. Secondary outcomes included prolonged postoperative ileus, conversion to open, 30-day readmission, reoperation, 30-day mortality, length of stay (LOS, calculated as days from procedure to discharge), and operative time.

Statistical analysis

Patient baseline characteristics and outcomes were compared between the robotic and laparoscopic surgical groups using Pearson's chi-squared test or Fisher's exact test (when appropriate) for categorical variables, and Wilcoxon rank-sum test for continuous variables. Multivariable logistic regression analysis was used to identify factors associated with overall and serious morbidity and to assess the impact of surgical operative approach on morbidity. Odds ratios (OR) and 95% confidence intervals (CI) were reported. Logistic regression models for overall and serious morbidity were adjusted for clinically relevant variables chosen a priori and included age, sex, race, ASA classification, obesity, smoking, COPD, disseminated cancer, concurrent procedure risk level, and concurrent procedure type. Statistical significance was indicated by $p < 0.05$. All data analyses and management were performed using Stata/MP version 17.0 (StataCorp LP, College Station, TX, USA).

Results

Study population

A total of 3875 patients were identified, including 397 (10.2%) who underwent combined robotic procedures, 962 (24.8%) who underwent combined laparoscopic procedures, and 2516 (65.0%) who underwent combined open procedures (Fig. 1).

The overall median age was 59 years (IQR: 50–68). The majority of patients were female (61.1%) and white (66.3%). In comparison to patients who underwent combined laparoscopic procedures, patients who underwent robotic surgery procedures tended to be younger (59 vs. 61 years old; $p = 0.009$), more frequently white ($p = < 0.001$), had a lower ASA classification ($p = 0.036$), and less frequently smokers

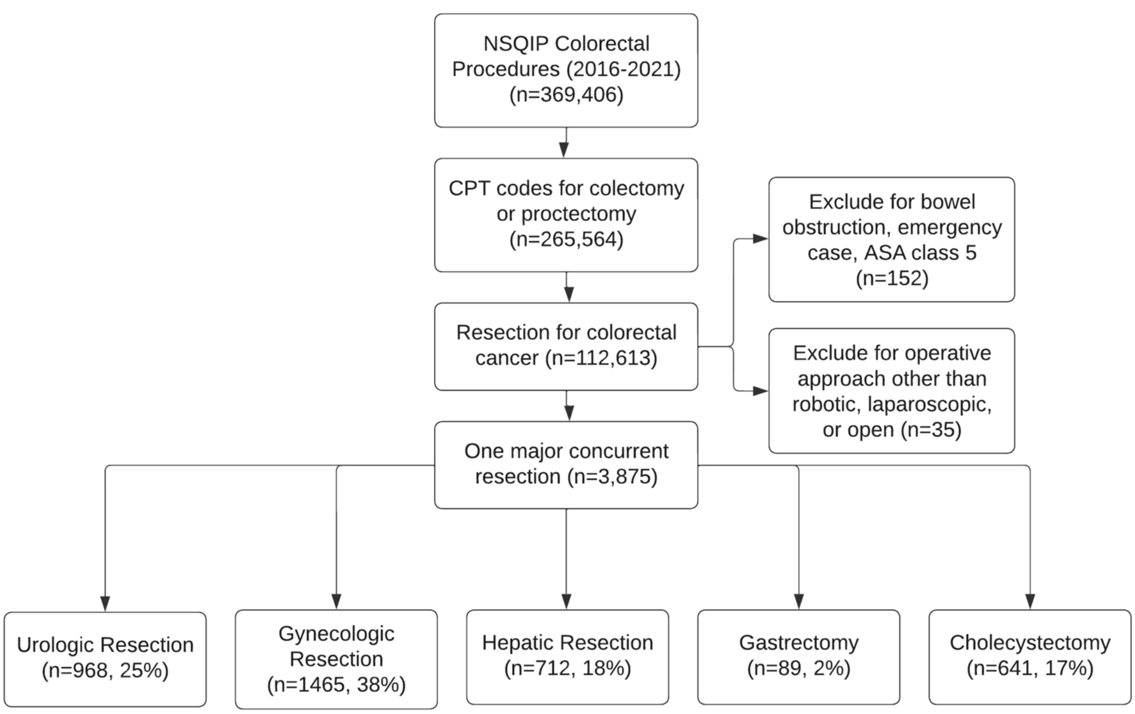

Fig. 1 Patient selection schematic of final cohort based on exclusions

($p = 0.004$) (Table 1). The two groups did not differ in rates of COPD or obesity at time of surgery, or the percentage of high-risk concurrent procedures performed (Table 1).

Types of concurrent procedures

In all three operative approach categories, gynecological procedures were the most frequently performed concurrent procedure (37.8%). This was followed by hepatic resections (18.4%) and cystectomies (16.6%) in both the laparoscopic and robotic groups (Table 2).

Compared to the laparoscopic group, the robotic concurrent group had a significantly higher percentage of gynecological procedures (54.9% vs. 46.3%, $p = 0.004$) and prostatectomies (7.8% vs 1.6%, $p < 0.001$) and a lower rate of hepatic resections (14.4% vs 20.4%, $p = 0.011$) and cholecystectomies (2.8% vs 9.6%, $p < 0.001$). A total abdominal hysterectomy was the most common concurrent procedure, performed in 39% of robotic cases and 29% of laparoscopic cases. This was followed by a partial hepatic lobectomy which was performed in 14% of robotic cases and 22% of laparoscopic cases. Details regarding other commonly performed procedures are found in Table 3.

Unadjusted outcomes

On unadjusted analysis, patients who underwent combined robotic procedures had no significant differences in 30-day

Table 1 Demographic, clinical, and operative characteristics stratified by operative approach

Characteristic, *n* (%)	Total 3875	Robotic 397 (10.3)	Laparoscopic 962 (24.8)	Open 2516 (65.0)	*p-value R vs L*[a]
Age group (years)					
< 50	791 (20.4)	97 (24.4)	200 (20.8)	494 (19.6)	0.063
50–59	952 (24.6)	103 (25.9)	235 (24.4)	614 (24.4)	
60–69	1068 (27.6)	112 (28.2)	255 (26.5)	701 (27.9)	
≥ 70	1064 (27.5)	85 (21.4)	272 (28.3)	707 (28.1)	
Age, median (IQR)	59 (50,68)	59 (50,68)	61 (51,71)	62 (52,71)	0.009
Sex					
Male	1506 (38.9)	125 (31.5)	313 (32.5)	1068 (42.5)	0.706
Female	2369 (61.1)	272 (68.5)	649 (67.5)	1448 (57.6)	
Race					
White	2564 (66.3)	289 (73.4)	631 (65.7)	1644 (65.5)	< 0.001
Black	379 (9.8)	37 (9.4)	91 (9.5)	251 (10.0)	
Other	236 (6.1)	38 (9.6)	64 (6.7)	134 (5.3)	
Unknown	687 (17.8)	30 (7.6)	175 (18.2)	482 (19.2)	
ASA classification					
I–II	1074 (27.7)	159 (40.1)	324 (33.7)	591 (23.5)	0.036
III	2514 (64.9)	223 (56.2)	580 (60.3)	1711 (68.0)	
IV	287 (7.4)	15 (3.8)	58 (6.0)	214 (8.5)	
BMI ≥ 30	1229 (31.9)	141 (35.5)	350 (36.6)	738 (29.5)	0.713
Current smoker	642 (16.6)	44 (11.1)	167 (17.4)	431 (17.1)	0.004
Hx of COPD	120 (3.1)	9 (2.3)	36 (3.7)	75 (3.0)	0.167
Disseminated cancer	1465 (37.8)	94 (23.7)	274 (28.5)	1097 (43.6)	0.070
Risk of procedure (high)		46 (11.6)	105 (0.9)		0.720
Concurrent procedure					
Hepatic resection	712 (18.4)	57 (14.4)	196 (20.4)	459 (18.2)	< 0.001
Gynecological	1465 (37.8)	218 (54.9)	445 (46.3)	828 (31.9)	
Gastrectomy	89 (2.3)	3 (0.8)	24 (2.5)	63 (2.5)	
Cholecystectomy	641 (16.5)	11 (2.8)	93 (9.6)	538 (21.4)	
Nephrectomy	201 (5.2)	37 (9.3)	72 (7.5)	92 (3.7)	
Prostatectomy	123 (3.2)	31 (7.8)	15 (1.6)	77 (3.1)	
Cystectomy	644 (16.6)	40 (10.1)	119 (12.4)	485 (19.3)	

IQR Interquartile Range; *ASA* American Society of Anesthesiologists; *BMI* Body Mass Index; *CHF* Congestive Heart Failure; *COPD* Chronic Obstructive Pulmonary Disease

[a]Robotic resections compared to laparoscopic group

Table 2 Concurrent procedures by approach and procedure

Concurrent procedure type	Total 3875	Robotic 397 (10.3)	Laparoscopic 962 (24.8)	Open 2516 (65.0)
Gynecologic	1465 (37.8)	218 (54.9)	445 (46.3)	828 (31.9)
Hepatic resection	712 (18.4)	57 (14.4)	196 (20.4)	459 (18.2)
Cystectomy	644 (16.6)	40 (10.1)	119 (12.4)	485 (19.3)
Cholecystectomy	641 (16.5)	11 (2.8)	92 (9.6)	538 (21.4)
Nephrectomy	201 (5.2)	37 (9.3)	72 (7.5)	92 (3.7)
Prostatectomy	123 (3.2)	31 (7.8)	15 (1.6)	77 (3.1)
Gastrectomy	89 (2.3)	3 (0.8)	23 (2.4)	63 (2.5)

Table 3 Most common concurrent procedures

Concurrent procedure type, *n* (%)	Robotic 397	Laparoscopic 962
Gynecologic		
Total abdominal hysterectomy[a]	155 (39.0)	275 (28.6)
Partial or total oophorectomy[b]	20 (5.0)	66 (6.9)
Hepatic resection		
Partial lobectomy[c]	56 (14.1)	210 (21.8)
Urologic		
Partial nephrectomy[d]	17 (4.3)	15 (1.6)
Radical nephrectomy[e]	16 (4.0)	39 (4.1)
Partial cystectomy[f]	18 (4.5)	68 (7.1)

[a]CPT code 58150 and 58571 [b]CPT code 58940 [c]CPT code 47120 [d]CPT code 50543 [e]CPT codes 50545 and 50546 [f]CPT code 51550

overall (25.4% vs. 30.0%, $p=0.088$) or serious morbidity (12.1% vs. 12.0%, $p=0.944$) than those who underwent combined laparoscopic procedures (Table 4).

Patients who underwent combined robotic procedures had lower rates of shock/sepsis (2.8% vs. 5.3%, $p=0.042$), bleeding requiring transfusion (12.3% vs. 16.9%, $p=0.034$), and ileus (12.1% vs. 16.9%, $p=0.027$) compared to those who underwent combined laparoscopic procedures. However, patients who had robotic procedures did have higher rates of UTI (4.8% vs. 26%, $p=0.038$). There was a significantly lower rate of conversion to open in the robotic group than the laparoscopic group (9.3% vs. 28.8%, $p<0.001$). Combined robotic surgery patients also had a shorter median LOS (4 vs. 5 days, p<0.001), but longer median operative time (373 vs. 285 minutes, p<0.001). Rates of 30-day anastomotic leak, readmission, reoperation, and mortality were comparable between the two operative approach groups.

Factors associated with 30-day overall and serious morbidity

Multivariable logistic regression analysis demonstrated that there were no significant differences in overall or serious morbidity between patients who underwent combined robotic procedures or combined laparoscopic procedures (Table 5).

For these patients, age ≥ 70 (OR: 1.62, 95% CI [1.11–2.34], $p=0.012$), ASA class III and IV (ASA III: OR: 1.34, 95% CI [1.01–1.77], $p=0.040$, ASA IV: OR: 3.62, 95% CI [2.10–6.25], $p<0.001$), other race (OR:1.82, 95% CI [1.15–2.88], $p=0.011$), current smoker (OR: 1.49, 95% CI [1.06–2.08], $p=0.020$), and a high-risk concurrent procedure (OR: 1.65, 95% CI [1.04–2.64], $p=0.035$) were associated with increased odds of overall morbidity. Factors associated with increased odds of serious morbidity included age ≥ 70 (OR: 1.85, 95% CI [1.12–3.06], $p=0.017$), ASA class IV (OR: 2.18, 95% CI [1.11–4.26], $p=0.023$), and current smoker (OR: 1.70, 95% CI [1.10–2.64], $p=0.018$). Female sex was associated with decreased odds of serious morbidity (OR: 0.57, 95% CI: 0.35–0.92], $p=0.022$).

Discussion

Since the introduction of the robotic surgery platform over 30 years ago, utilization has continued to expand. As surgeons across a wide variety of specialties grow more comfortable with this technique, questions remain about the feasibility and benefits of complex multivisceral, multidisciplinary robotic surgeries. This is of particular importance in patients with CRC, as many patients who undergo surgery may present with synchronous metastases requiring combined resections of the primary tumor and the metastatic disease. Given that the median age at CRC diagnosis is 66 years in men and 69 years in women, some patients may have other surgical procedures that might be indicated at the time of surgery, such as a hysterectomy or cholecystectomy [19]. To our knowledge, this study is the first to utilize the ACS-NSQIP database to examine the outcomes of robotic multivisceral resections for CRC. Our findings highlight the following: 1) in a large national database robotic and laparoscopic resections make up 35% of multivisceral resections in CRC patients; 2) robotic multivisceral resections have similar outcomes when compared to laparoscopic resections; and 3) robotic multivisceral resections may have

Table 4 30-day post-operative outcomes stratified by operative approach

Outcome (%)	Total 1359	Robotic 397 (10.3)	Lap 962 (24.8)	*p* *R vs L*[a]
Overall morbidity[b]	390 (28.7)	101 (25.4)	289 (30.0)	0.088
Wound infection[c]	59 (4.3)	11 (2.8)	48 (5.0)	0.068
Pneumonia	16 (1.2)	4 (1.0)	12 (1.3)	0.999
UTI	44 (3.2)	19 (4.8)	25 (2.6)	0.038
VTE	30 (2.2)	5 (1.3)	25 (2.6)	0.126
Cardiac	12 (0.9)	2 (0.5)	10 (1.0)	0.526
Shock/sepsis	62 (4.6)	11 (2.8)	51 (5.3)	0.042
Re-intubation	11 (0.8)	6 (1.5)	5 (0.5)	0.091
Bleeding requiring transfusion	212 (15.6)	49 (12.3)	163 (16.9)	0.034
Renal Complication	18 (1.3)	5 (1.3)	13 (1.4)	0.893
On ventilator > 48 h	11 (0.8)	4 (1.0)	7 (0.7)	0.740
Organ/space infection	80 (5.9)	24 (6.1)	56 (5.8)	0.873
Anastomotic leak[d]	49 (3.6)	14 (3.5)	35 (3.6)	0.930
Serious morbidity[e]	163 (12.0)	48 (12.1)	115 (12.0)	0.944
Conversion to open	314 (23.1)	37 (9.3)	277 (28.8)	< 0.001
Readmission	166 (12.2)	49 (12.3)	117 (12.2)	0.926
Reoperation	62 (4.6)	17 (4.3)	45 (4.7)	0.751
Mortality	13 (1.0)	4 (1.0)	9 (0.9)	0.999
Prolonged postoperative ileus[f]	210 (15.5)	48 (12.1)	162 (16.9)	0.027
LOS (days), median (IQR)	5 (3,7)	4 (3,7)	5 (4,8)	< 0.001
Operative time, median (IQR)	307 (226,413)	373 (288,483)	285 (210,380)	< 0.001

UTI urinary tract infection; *VTE* venous thromboembolic event; *hrs* hours; *LOS* length of stay; *IQR* interquartile range

[a]Comparison of outcomes between robotic and laparoscopic resections. [b]Overall morbidity composite of wound infection, pneumonia, urinary tract infection, VTE, cardiac complication, shock/sepsis, unplanned intubation, bleeding transfusion, renal complication, on ventilator > 48 h, organ space SSI, and anastomotic leak. [c]Includes superficial surgical-site infection (SSI), deep incisional SSI, and dehiscence of wound. [d]Missing anastomotic leak data for 1 robotic case and 1 laparoscopic case. [e]Clavien–Dindo III–IV: cardiac complication, shock/sepsis, unplanned intubation, renal complication, on ventilator > 48 h, organ/space SSI, and reoperation. [f]Missing postoperative ileus data for 1 robotic case and 1 laparoscopic case. Abbreviations: LOS, Length of Hospital Stay; IQR, Interquartile Range

Table 5 Multivariable logistic regression assessing the association between operative approach and morbidity

	Unadjusted analysis		Adjusted analysis	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Overall morbidity[a]				
Operative approach				
Lap	Reference		Reference	
Robotic	0.79 (0.61, 1.03)	0.085	0.87 (0.65, 1.16)	0.343
Serious morbidity[a]				
Operative approach				
Lap	Reference		Reference	
Robotic	1.00 (0.70, 1.44)	0.961	1.12 (0.75, 1.65)	0.586

OR Odds ratio, *CI* Confidence interval

[a]Adjusted for age, sex, race, ASA classification, obesity, smoking, hx of COPD, disseminated cancer, risk of concurrent procedure, and type of concurrent procedure

added benefits when compared to laparoscopic resections including decreased LOS and decreased rates of conversion to open. However, future studies are needed in order to determine the optimal operative approach in this complex surgical population.

Our findings are consistent with prior reports on robotic multivisceral resections that have also demonstrated the feasibility of multivisceral robotic resections [6–8, 10–15]. A recent single institutional study reported on 11 cases of full multivisceral robotic abdominal surgery, with a range of procedures including a nephrectomy, hysterectomy with salpingo-oophorectomy, and an adrenalectomy. The authors reported no intraoperative complications or conversions to open with a similar morbidity rate to that reported in this study [12]. A review article found that over the last 15 years (2005–2020) 26 papers on the topic of robotic multivisceral resections have been published (10 case series and 16 case reports) comprising a total of 156 combined multivisceral robotic procedures. The number of dockings in this review ranged from 1 to 3, and complications were reported in 15 of the 156 cases [12]. Though our study may include some of these cases, our sample size of 397 patients further strengthens the conclusions of these smaller case series that a combined robotic approach can be performed with acceptable rates of morbidity.

There are several benefits of a multivisceral combined approach for patients who would normally have two isolated surgeries. These include the potential for less psychological and physiologic stress related to separate operations, a single recovery period, and possibly decreasing complications related to two separate surgeries. Additionally, in our study we found that robotic multivisceral procedures did not increase readmission or reoperation rates compared to a laparoscopic approach. In some circumstances, the robotic platform may be the preferred approach, particularly in surgeries involving pelvic dissection where it can provide superior visualization, such as in a total mesorectal excision [20]. While concerns about the feasibility of multivisceral resections may have prevented the robotic platform from being utilized, or led surgeons to seek alternative approaches, our study demonstrates that surgeons across the country are already utilizing the robotic approach for a wide variety of procedures.

While this study focuses on the surgical outcomes of robotic multivisceral procedures, the indications and sustainability of these complex surgeries should also be considered. Although we report that robotic patients had a shorter LOS, the robotic platform is associated with a higher overall cost of surgery and increased utilization of operative time and thus personnel. Some reports have estimated the cost of robotic surgery is nearly 1.3–2.5 times higher than that of laparoscopic surgery [21, 22]. Preoperative planning, including staff training to increase efficiency in assisting at the bedside, can help decrease this time, but this is likely only possible at centers with multiple consoles and experienced, high-volume surgeons. Additionally, an important consideration is the possibility that some combinations of multivisceral surgeries could lead to increases in morbidity compared to isolated resections, which may delay future oncologic care. A recent study on simultaneous colorectal primary tumor and CRLM showed that any surgical morbidity that resulted in a delay or failure to receive planned chemotherapy was associated with worse overall survival [23]. Our study did not compare the morbidity rates of the multivisceral surgeries to isolated surgeries, but this could be an area of future study.

This present study is not without limitations. ACS-NSQIP is a national, standardized, multi-institutional database that focuses on measuring surgical quality of care but does not include hospital-specific variables. As a result, details regarding hospital-specific perioperative practices such as enhanced recovery after surgery (ERAS) protocols, are unavailable. Additionally, we cannot comment on which centers, and as a result which surgeons, are performing these combined resections and whether they are in select regions of the U.S. or more widespread. Additionally, the dataset does not collect granular cancer-related data beyond 30 days. As a result, the impact of morbidity and LOS on receiving adjuvant therapy, disease-free survival, and overall survival cannot be assessed. Due to the limited number of simultaneous resections, we are also unable to comment on the procedure-specific risks of select combinations of resections, and cannot determine if complications were related to the additional procedure or to the primary colorectal operation. Despite these limitations, our study is currently the largest report on robotic multivisceral resections. Even with using an "intent-to-treat" approach for a more conservative analysis between robotic and laparoscopic patients, we were able to demonstrate the safety of the robotic platform.

This study is the largest report of complete robotic multivisceral resections in colorectal cancer patients. We demonstrate that in this patient cohort, a robotic approach was safe and led to no increased risk of overall or serious morbidity compared to a laparoscopic approach. We show that patients who undergo multivisceral robotic resections have lower rates of conversion to open and shorter LOS than laparoscopic resections. Results from this study can be utilized to more accurately counsel patients on postoperative outcomes and specific complications following multivisceral surgeries, and to advocate for increased research into determining the optimal operative approach for complex multidisciplinary multivisceral surgeries.

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Author's contributions SNR and CA designed and directed the project. MS was responsible for data extraction and statistical analysis. SNR, JZD, and SYC wrote the main manuscript text. SNR and MS prepared the tables and figures. All authors (SNR, SYC, JZD, MS, BS, JEE, CA) reviewed and provided edits for the final manuscript.

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Declarations

Conflict of interest The authors of this paper (Shannon N Radomski, Sophia Y Chen, Joy Zhou Done, Miloslawa Stem, Bashar Safar, Jonathan E Efron, and Chady Atallah) have no relevant financial or non-financial interests to disclose.

Ethical approval This study was reviewed and approved by the Institutional Review Board of the Johns Hopkins University School of Medicine.

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