Journal of Robotic Surgery (2023) 17:1071–1076
https://doi.org/10.1007/s11701-022-01514-6

RESEARCH

Safe implementation of robotic right colectomy with intracorporeal anastomosis

E. Van Eetvelde[1] · S. Violon[1] · N. Poortmans[1] · J. Stijns[1] · M. Duinslaeger[1] · M. Vanhoeij[1] · R. Buyl[2] · D. Jacobs-Tulleneers-Thevissen[1]

Received: 15 June 2022 / Accepted: 18 December 2022 / Published online: 25 December 2022

Abstract
The robotic platform can overcome technical difficulties associated with laparoscopic colon surgery. Transitioning from laparoscopic right colectomy with extracorporeal anastomosis (ECA) to robotic right colectomy with intracorporeal anastomosis (ICA) is associated with a learning phase. This study aimed at determining the length of this learning phase and its associated morbidity. We retrospectively analyzed all laparoscopic right colectomies with ECA ($n = 38$) and robotic right colectomies with ICA ($n = 67$) for (pre)malignant lesions performed by a single surgeon between January 2014 and December 2020. CUSUM-plot analysis of total procedure time was used for learning curve determination of robotic colectomies. Non-parametric tests were used for statistical analysis. Compared to laparoscopy, the learning phase robotic right colectomies ($n = 35$) had longer procedure times ($p < 0.001$) but no differences in anastomotic leakage rate, length of stay or 30-day morbidity. Conversion rate was reduced from 16 to 3 percent in the robotic group. This study provides evidence that robotic right colectomy with ICA can be safely implemented without increasing morbidity.

Keywords Colon cancer · Robotic surgery · Intracorporeal anastomosis · Learning curve analysis · Right colectomy

Introduction

Minimally invasive surgery (MIS) is becoming the gold standard in the treatment of colon cancer because of demonstrated benefits in postoperative recovery, pain and length of stay with comparable long-term oncological outcomes as for open surgery [1–4]. However, laparoscopic colon surgery requires a high degree of technical skills, especially in case of resection of locally advanced tumors, tumors at the hepatic flexure and proximal transverse colon or in the presence of extensive adhesions. These difficulties are associated with increased risk of conversion or not even considered for a laparoscopy at all.

The robotic platform is associated with a stable 3D view, an extra operative arm under the surgeon's control and an increased dexterity thanks to articulating instruments. It therefore offers all advantages of MIS while decreasing the technical difficulties associated with laparoscopy, leading to significantly lower conversion rates [5]. It can also facilitate the use of an intracorporeal anastomosis which has a number of advantages over extracorporeal anastomosis including faster recovery of bowel function, decreased incidence of incisional hernias and reduction in surgical site infections [6].

These advantages of the robotic platform led us to initiate a robotic program for colon surgery at our institution. Since implementing this approach in our practice required a new set of skills, we used the standard right colectomy, a procedure considered representative of establishing a learning curve for robotic colorectal surgery [7], to evaluate its safety.

The current study determined a learning curve for the implementation of robotic right colectomy with ICA for right-sided colon tumors. We used conversion rate and postoperative morbidity to compare the safety of implementing robotic surgery in comparison with laparoscopic right colectomy with ECA, which was the standard in our practice.

E. Van Eetvelde and S. Violon contributed equally to this study.

✉ E. Van Eetvelde
ellen.vaneetvelde@uzbrussel.be

1 Department of Surgery, Vrije Universiteit Brussel (VUB), Universitair Ziekenhuis Brussel (UZ Brussel), Laarbeeklaan 101, 1090 Brussels, Belgium

2 Biostatistics and Medical Informatics, Vrije Universiteit Brussel (VUB), Laarbeeklaan 103, 1090 Brussels, Belgium

Methods

Patient selection and data collection

Since the start of our robotic colorectal surgery program, data on patient demographics, clinical variables, procedure details and postoperative outcomes of all robotic colorectal resections have been prospectively collected for quality control and safety analysis in an anonymized database. Data on laparoscopic right colectomies were retrospectively collected from the electronic patient files of our hospital and added to our database.

From this data collection all consecutive laparoscopic and robotic standard right colectomies performed for (pre) malignant lesions between January 2014 and December 2020 by a single surgeon (EVE) were retrospectively analyzed. All laparoscopic procedures involved an extracorporeal anastomosis (ECA), while an intracorporeal anastomosis (ICA) was used in the robotic cases. Surgery for inflammatory bowel disease, redo-surgery, major concomitant surgery and emergency surgery were excluded from analysis, as were patients undergoing a robotic complete mesocolic resection with D3 resection that was stepwise implemented after establishing the learning curve.

Data analyzed included preoperative patient characteristics [age, gender, body mass index (BMI), American Society of Anesthesiology Score (ASA), Charlson comorbidity index, previous abdominal surgery], intraoperative details [total procedure time, conversion to laparotomy (and reason for conversion)] and postoperative outcome [length of stay, 30-day complication rate according to the Clavien–Dindo classification [8] and 90-day mortality]. Anastomotic leak was defined as a radiologically diagnosed intraperitoneal fluid collection or overt leak, requiring CT-guided drainage or reoperation and was reported separately. Peri-operative outcome variables were used for safety analysis of different study groups.

The study protocol was reviewed and approved by the ethics committee of our institution (B.U.N. 143201837797).

Surgical procedures for right colectomy

Laparoscopic right colectomy was performed using a medial to lateral approach with ligation of the ileocolic vessels followed by complete mobilization of the colon. The mesentery of the terminal ileum and colon (including the right colic vessels and the right branch of the middle colic vessels) was transected after externalization of the colon through an abdominal incision with wound protector, and an ECA was made.

Robotic standard right colectomy was performed using the da Vinci Xi Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA, USA) after laparoscopic exploration, adhesiolysis, and positioning of the small bowel to the left side. A suprapubic bottom-up approach was implemented for bowel mobilization taking care to preserve the mesocolonic window. Mobilization was followed by ligation of the ileocolic vessels, ligation of the right branch of the middle colic artery and division of the remaining mesentery without bowel externalization. To determine the transection level of both bowel segments we evaluated vascularization by indocyanine green angiography (Firefly™ Fluorescent Imaging, Intuitive Surgical, Inc.). Bowel segments were transected using a robotic stapler and a mechanical isoperistaltic side-to-side anastomosis was created. The remaining enterotomy was closed with a running suture. After undocking the robot, the specimen was retrieved via a Pfannenstiel incision with wound protector.

Learning curve analysis

Cumulative sum (CUSUM) of total procedure time of all consecutive standard robotic right colectomies with ICA for (pre)malignant lesions since the start of our program until December 2020 was performed for learning curve analysis. Total procedure time is defined as the time between the first incision until skin closure and includes laparoscopic exploration, docking time as well as console time. When using chronologically arranged data, this method allows learning curve analysis thanks to its ability to reveal rapid trend changes in data sets [9].

Statistical analysis

Individual patient and operative characteristics were stored in our password protected Microsoft Excel database (Microsoft Corp., Redmond, WA, USA). Results are presented as median (range) or percentage if not otherwise specified. Statistical analysis was performed using SPSS (IBM, Armonk, NY, USA) and Prism 9 for macOS (GraphPad Software, San Diego, CA, USA). Non-parametric tests [two tailed Mann–Whitney *U* (MWU) test or Kruskall-Wallis test for continuous variables and Chi-squared test/Fisher's exact test when appropriate for categorical variables] were used for analysis. Statistical significance was assumed at $p < 0.05$.

Results

Determination of a learning curve for robotic right colectomy

During the study period, 67 robotic standard right colectomies with intracorporeal anastomosis were performed at our center. We used total procedure time of these cases to create a CUSUM plot for learning curve analysis (Fig. 1). The initial learning phase of the plot (phase 1) consists of 11 cases, after which a first decrease in the slope is observed. After 35 cases, the second phase (consolidation phase) of the CUSUM plot turns into a negative slope, indicating the end of the learning phase and the start of the experienced phase (phase 3). A positive slope during phase 1, followed by a plateau for phase 2 and a negative slope during phase 3 was confirmed by linear regression testing (Fig. 1). When using console time as alternative variable for learning curve analysis, the learning phase ended after 29 cases (data not shown).

Safety of implementation of robotic standard right colectomy

Baseline patient and tumor characteristics of the 35 patients that underwent a robotic colectomy during initial learning phase 1 and consolidation phase 2 of the learning curve are summarized in Table 1 and compared to our last cohort of 38 patients that underwent a laparoscopic right colectomy. We could not identify any significant differences in patient body mass index (BMI) or comorbidities although patients treated by robotic surgery were older and tended to be more frequently classified as American Society of Anesthesiologists class III or IV. There were no differences in surgical indication or tumor stage.

Total procedure time was significantly longer in the robotic cases when compared to laparoscopy.

Peri- and postoperative outcome variables were used as safety measure for both procedures and are shown in Table 1. There was no difference in 30-day morbidity. There was no difference in anastomotic leakage rate between robotic and laparoscopic cases. The length of stay was statistically significantly shorter in the robotic group when compared to the laparoscopic group. Robotic right colectomy was associated with a reduction in conversion rate from 16 to 3 percent. There was one 90 day mortality in the robotic group (3%) while this was not the case in the laparoscopy-treated patients.

Outcome of robotic right colectomy beyond the learning phase

After initiating the experienced phase (from case 36), there was a significant reduction in total operative time

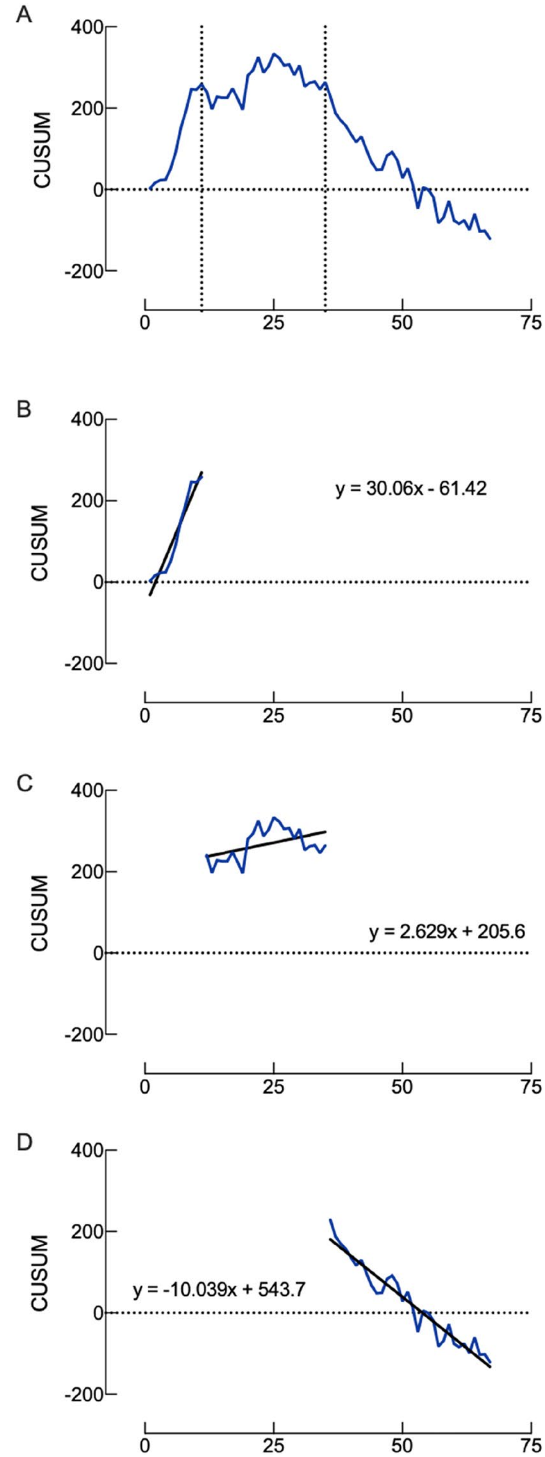

Fig. 1 Total procedure time of robotic right colectomy represented as CUSUM plot and showing three phases—initial learning phase (phase 1), stabilization phase (phase 2) and experienced phase (phase 3)—of the learning curve separated by dotted lines (**A**), and lines of best fit for the initial learning phase 1 (**B**), the stabilization phase 2 (**C**) and the experienced phase 3 (**D**)

Table 1 Patient characteristics and peri-operative outcome

	L-RHC	Learning R-RHC	*p	R-RHC	$p
n	38	35		32	
Patient characteristics					
Gender male [n (%)]	17 (44.7)	19 (54, 3)	0.828	19 (59.4)	0.831
Age (years)	70 (44–91)	79 (47–97)	0.028	73 (26–91)	0.198
BMI (kg/m^2)	25 (17–35)	26 (18–46)	0.647	28 (18–41)	0.055
ASA [n (%)]			0.061		0.223
I–II	22 (57.9)	12 (34.3)		16 (50.0)	
III–IV	16 (42.1)	23 (65.7)		16 (50.0)	
Charlson comorbidity index	5 (2–9)	6 (1–10)	0.175	5 (1–11)	0.272
Previous abdominal surgery [n (%)]	20 (52.6)	16 (45.7)	0.642	21 (65.6)	0.141
Tumor histology and stage					
Adenocarcinoma [n (%)]	24 (63.2)	23 (65.7)	> 0.999	18 (56.3)	0.462
Stage 1	8	11		8	
Stage 2	7	9		6	
Stage 3	8	3		2	
Stage 4	1	0		2	
Lymph node yield (n)	16 (11–27)	14 (5–24)	0.160	14 (9–20)	0.481
Procedure details					
Total Procedure time (min)	104 (66–247)	148 (90–225)	< 0.001	122 (78–193)	0.010
Console time (min)	NA	94 (52–139)	NA	82 (47–137)	0.063
Peri-operative outcome					
Conversion to laparotomy [n (%)]	6 (15.8)	1 (2.9)	0.109	0 (0)	> 0.999
Reason for conversion (n)					
Tumor size/invasion abdominal wall	3	0		–	
Adhesions	3	0		–	
Bleeding	0	1		–	
Estimated blood loss (ml)	ND	30 (5–300)		30 (3–200)	0.582
Length of stay (days)	7 (4–88)	6 (2–65)	0.027	5 (3–22)	0.037
30-day morbidity [n (%)]	10 (26.3)	7 (20)	0.588	5 (15.6)	0.755
Clavien–Dindo grade I–II	7	3		3	
Clavien–Dindo grade III–IV	3	4		2	
Anastomotic leakage [n (%)]	2 (5.3)	0 (0)	0.494	0	> 0.999
90-day mortality [n (%)]	0 (0)	1 (2.9)	0.480	0	> 0.999

Baseline characteristics and peri-operative outcome of patients undergoing laparoscopic right colectomy (L-RHC), robotic right colectomy during learning phase 1 and 2 (learning R-RHC) and after establishing the learning curve (R-RHC). Data are represented as median (range) unless otherwise specified

NA not applicable, *ND* not determined

*Versus laparoscopic right colectomy

$Versus learning phase robotic right colectomy

for patients undergoing robotic right colectomy with intracorporeal anastomosis (Table 1). While console time also tended to be shorter, this difference was not significant. None of the procedures performed after completing the learning phase had to be converted to open surgery. We observed no mortality, but major postoperative morbidity was reduced from 11 to 6 percent. Median length of stay significantly decreased from 6 to 5 days.

Discussion and conclusions

Despite the fact that minimally invasive surgery for right-sided colon cancer has a variety of benefits for the patient with at least equivalent oncological outcomes [1, 3], open surgery is still widely performed [10]. A recent international survey demonstrated that laparoscopic right colectomy with ICA is performed in a minority of cases [11]. This is mainly attributed to technical challenges associated with laparoscopy. The robotic platform might help overcome these technical difficulties thanks to articulated instruments improving dexterity and a stable 3D view in combination with an additional arm that further aids exposure of the surgical field and allows precise dissection [12, 13].

This prompted us to initiate a robotic colorectal surgery program at our center. Since this technique requires a specific set of skills for the surgeon and operating team, patient morbidity and peri- and postoperative outcomes throughout its learning phase were studied and compared with preceding laparoscopic cases. To our knowledge, the present study is one of the first to perform such an assessment for robotic right colectomy with ICA using the da Vinci Xi system.

CUSUM analysis of total procedure time of all first consecutive robotic right colectomies was used to determine the length of the learning phase. It is considered a valuable tool for this purpose in different types of surgery, including colorectal robotic procedures [14–16] and compares sequential changes in total procedure time to their average. Data are represented in a CUSUM plot from which three different stages of surgical experience can be deduced. In our study, the total learning phase was completed after 35 patients. This is at variance with other authors that report a consolidation of the learning phase after 68 or 90 cases respectively [17, 18]. We were not able to identify patient or tumor characteristics attributing to these differences but patient characteristics, postoperative outcome and complication rate might be of added value to the learning curve analysis. However, this would make this analysis more complex [19] and given the low number of adverse events reported in our series also make such a risk-adjusted CUSUM analysis difficult to interpret.

We used peri-operative outcome and conversion rate of the 35 learning phase cases to evaluate the safety of implementing the robotic platform for right colectomy and compared it to the last cohort of 38 patients undergoing laparoscopy. While peri-operative morbidity was comparable in both groups, there was a significantly shorter length of stay for patients undergoing robotic surgery. This reflects a faster recovery from surgery and can at least partially be attributed to the ICA that was performed in patients undergoing robotic right colectomy while all laparoscopically treated patients had extracorporeal anastomosis [20]. A recent meta-analysis also favored ICA over ECA because of faster bowel function recovery, lower anastomotic leakage rate and less surgical site infections; however, most cited studies were retrospective [6]. We hope that the Mircast study, an ongoing prospective observational cohort study comparing intra- and extracorporeal anastomosis, will provide more evidence [21].

Even during the learning phase we observed a significant reduction in conversion rate (from 15.8 to 2.3%) in the robotic group compared to laparoscopy, to a level as low as previously reported for robotic right colectomy [22–24]. This reduction might be explained by the reasons for conversion, which were predominantly related to tumor characteristics ($n = 3$) and adhesions ($n = 3$) during laparoscopy, while bleeding was the cause in the robotic surgery group ($n = 1$). This observation is in line with reported differences in risk factors between laparoscopic and robotic colon procedures that can lead to unplanned conversion to open surgery [25].

Our reported initial experience with robotic surgery confirms that this technique can be safely implemented in a colorectal surgery practice without increasing risk for perioperative complications, even during the learning phase.

Author contributions Conceptualization: EVE and DJ-T-T; Methodology: EVE and RB; Formal analysis and investigation: SV and RB; Writing—original draft preparation: SV, NP and JS; Writing—review and editing: EVE, MV and MD; Supervision: DJ-T-T. All authors read and approved the final manuscript.

Funding This study did not benefit from any external funding.

Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest E. Van Eetvelde performs proctoring and consulting activities for Intuitive Surgical, Inc., a private company, and received a research grant from the same company. All other authors declare no conflict of interest.

Clinical trial registration A clinical trial registration is not applicable for this retrospective study.

Ethics approval The study was evaluated and approved by the committee for medical ethics of the UZ Brussel and VUB (B.U.N. 143201837797).

Patient consent Retrospective studies are exempted from obtaining written informed consent. Use of collected data was approved by the medical ethics committee of UZ Brussel and VUB.

References

1. Guillou PJ, Quirke P, Thorpe H et al (2005) Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicentre, randomised controlled trial. Lancet 365:1718–1726. https://doi.org/10.1016/s0140-6736(05)66545-2
2. Green BL, Marshall HC, Collinson F et al (2013) Long-term follow-up of the medical research council CLASICC trial of conventional versus laparoscopically assisted resection in colorectal cancer. Brit J Surg 100:75–82. https://doi.org/10.1002/bjs.8945
3. Veldkamp R, Kuhry E, Hop W et al (2005) Laparoscopic surgery versus open surgery for colon cancer: short-term outcomes of a

randomised trial. Lancet Oncol 6:477–484. https://doi.org/10.1016/s1470-2045(05)70221-7
4. Fleshman J, Sargent DJ, Green E et al (2007) Laparoscopic colectomy for cancer is not inferior to open surgery based on 5-year data from the COST study group trial. Trans Meet Am Surg Assoc 125:312–321. https://doi.org/10.1097/sla.0b013e318155a762
5. Waters PS, Cheung FP, Peacock O et al (2020) Successful patient-oriented surgical outcomes in robotic vs laparoscopic right hemicolectomy for cancer – a systematic review. Colorectal Dis 22:488–499. https://doi.org/10.1111/codi.14822
6. Emile SH, Elfeki H, Shalaby M et al (2019) Intracorporeal versus extracorporeal anastomosis in minimally invasive right colectomy: an updated systematic review and meta-analysis. Tech Coloproctol 23:1023–1035. https://doi.org/10.1007/s10151-019-02079-7
7. Raimondi P, Marchegiani F, Cieri M et al (2018) Is right colectomy a complete learning procedure for a robotic surgical program? J Robotic Surg 12:147–155. https://doi.org/10.1007/s11701-017-0711-3
8. Dindo D, Demartines N, Clavien P-A (2004) Classification of surgical complications. Ann Surg 240:205–213. https://doi.org/10.1097/01.sla.0000133083.54934.ae
9. Wohl H (1977) The Cusum plot: its utility in the analysis of clinical data. New Engl J Med 296:1044–1045. https://doi.org/10.1056/nejm197705052961806
10. Leersum NJV, Snijders HS, Henneman D et al (2013) The Dutch surgical colorectal audit. European J Surg Oncol Ejso 39:1063–1070. https://doi.org/10.1016/j.ejso.2013.05.008
11. Al-Taher M, Okamoto N, Mutter D et al (2022) International survey among surgeons on laparoscopic right hemicolectomy: the gap between guidelines and reality. Surg Endosc. https://doi.org/10.1007/s00464-022-09044-w
12. Spinoglio G, Bianchi PP, Marano A et al (2018) Robotic versus laparoscopic right colectomy with complete mesocolic excision for the treatment of colon cancer: perioperative outcomes and 5-year survival in a consecutive series of 202 patients. Ann Surg Oncol 25:3580–3586. https://doi.org/10.1245/s10434-018-6752-7
13. Siddiqi N, Stefan S, Jootun R et al (2021) Robotic complete mesocolic excision (CME) is a safe and feasible option for right colonic cancers: short and midterm results from a single-centre experience. Surg Endosc. https://doi.org/10.1007/s00464-020-08194-z
14. Pernar LIM, Robertson FC, Tavakkoli A et al (2017) An appraisal of the learning curve in robotic general surgery. Surg Endosc 31:4583–4596. https://doi.org/10.1007/s00464-017-5520-2
15. Yamaguchi T, Kinugasa Y, Shiomi A et al (2015) Learning curve for robotic-assisted surgery for rectal cancer: use of the cumulative sum method. Surg Endosc 29:1679–1685. https://doi.org/10.1007/s00464-014-3855-5
16. Parascandola SA, Horsey ML, Hota S et al (2021) The robotic colorectal experience: an outcomes and learning curve analysis of 502 patients. Colorectal Dis 23:226–236. https://doi.org/10.1111/codi.15398
17. Tang B, Liang Y, Shi J, Li T (2022) Learning curve of robotic right hemicolectomy. J Gastrointest Surg 26:2215–2217. https://doi.org/10.1007/s11605-022-05343-8
18. Parisi A, Scrucca L, Desiderio J et al (2017) Robotic right hemicolectomy: analysis of 108 consecutive procedures and multidimensional assessment of the learning curve. Surg Oncol 26:28–36. https://doi.org/10.1016/j.suronc.2016.12.005
19. Wong SW, Crowe P (2022) Factors affecting the learning curve in robotic colorectal surgery. J Robotic Surg. https://doi.org/10.1007/s11701-022-01373-1
20. Saleh NB, Voron T, De'Angelis N, et al (2020) Intracorporeal versus extracorporeal anastomosis in laparoscopic right hemicolectomy: results from the CLIMHET study group. Tech Coloproctol 24:585–592. https://doi.org/10.1007/s10151-020-02202-z
21. Ruiz MG, Bianchi PP, Chaudhri S et al (2020) Minimally invasive right colectomy anastomosis study (MIRCAST): protocol for an observational cohort study of surgical complications using four surgical techniques for anastomosis in patients with a right colon tumor. Bmc Surg 20:151. https://doi.org/10.1186/s12893-020-00803-x
22. Bianchi PP, Salaj A, Giuliani G et al (2021) Feasibility of robotic right colectomy with complete mesocolic excision and intracorporeal anastomosis: short-term outcomes of 161 consecutive patients. Updat Surg 73:1065–1072. https://doi.org/10.1007/s13304-021-01001-x
23. Gerbaud F, Valverde A, Danoussou D et al (2019) Experience with transitioning from laparoscopic to robotic right colectomy. JSLS J Soc Laparoendosc Surg. https://doi.org/10.4293/jsls.2019.00044
24. Blumberg D (2019) Robotic colectomy with intracorporeal anastomosis is feasible with no operative conversions during the learning curve for an experienced laparoscopic surgeon developing a robotics program. J Robotic Surg 13:545–555. https://doi.org/10.1007/s11701-018-0895-1
25. Bhama AR, Wafa AM, Ferraro J et al (2016) Comparison of risk factors for unplanned conversion from laparoscopic and robotic to open colorectal surgery using the Michigan surgical quality collaborative (MSQC) database. J Gastrointest Surg 20:1223–1230. https://doi.org/10.1007/s11605-016-3090-6