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An initial experience with 85 consecutive robotic-assisted rectal dissections: improved operating times and lower costs with experience

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Abstract

Background Data are limited about the robotic platform in rectal dissections, and its use may be perceived as prohibitively expensive or difficult to learn. We report our experience with the initial robotic-assisted rectal dissections performed by a single surgeon, assessing learning curve and cost.

Methods Following IRB approval, a retrospective chart review was conducted of the first 85 robotic-assisted rectal dissections performed by a single surgeon between 9/1/2010 and 12/31/2012. Patient demographic, clinicopathologic, procedure, and outcome data were gathered. Cost data were obtained from the University HealthSystem Consortium (UHC) database. The first 43 cases (Time 1) were compared to the next 42 cases (Time 2) using multivariate linear and logistic regression models.

Results Indications for surgery were cancer for 51 patients (60 %), inflammatory bowel disease for 18 (21 %), and rectal prolapse for 16 (19 %). The most common procedures were low anterior resection (n = 25, 29 %) and abdominoperineal resection (n = 21, 25 %). The patient body mass index (BMI) was statistically different between the two patient groups (Time 1, 26.1 kg/m^2 vs. Time 2, 29.4 kg/m^2, $p = 0.02$). Complication and conversion rates did not differ between the groups. Mean operating time was significantly shorter for Time 2 (267 min vs. 224 min, $p = 0.049$) and remained significant in multivariate analysis. Though not reaching statistical significance, the mean observed direct hospital cost decreased ($17,349 for Time 1 vs. $13,680 for Time 2, $p = 0.2$). The observed/expected cost ratio significantly decreased (1.47 for Time 1 vs. 1.05 for Time 2, $p = 0.007$) but did not remain statistically significant in multivariate analyses.

Conclusions Over the series, we demonstrated a significant improvement in operating times. Though not statistically significant, direct hospital costs trended down over time. Studies of larger patient groups are needed to confirm these findings and to correlate them with procedure volume to better define the learning curve process.

Keywords Robotic surgery · Colorectal surgery · Rectal cancer · Rectal prolapse · Inflammatory bowel disease

Minimally invasive approaches to the surgical management of colorectal disease and cancer have been broadly accepted with new techniques being explored on various fronts. Robotic and robotic-assisted laparoscopic colorectal dissection is one such area and has garnered much excitement and criticism since its first description [1, 2]. Recent literature focusing on robotic dissection for rectal cancer has shown improved conversion rates and decreased blood loss when compared to traditional laparoscopy [3–5]. Despite these improved clinical outcomes and the surgeon-related benefits such as the surgeon-controlled camera platform and ergonomic console, wide adaption of the technology has not been achieved [6].

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The focus of the colorectal robotic literature has largely been on rectal cancer due to the potential for improved oncologic dissection afforded by the tremor-resistant articulating instrumentation and improved optics. Robotic dissections for benign rectal disease, rectal prolapse, and inflammatory bowel disease, however, are not as well described [7, 8].

In this series, we employed the robotic approach for both rectal cancer and benign rectal dissections. Our goal was to assess the learning curve and safety of our initial robotic rectal dissections and to analyze cost.

Materials and methods

A retrospective chart review was conducted of the first 85 robotic pelvic dissections performed between 9/1/2010 and 12/31/2012. Cases were analyzed by time period with Time 1 comprising the first 43 cases from 9/1/2010 to 12/31/2011 and Time 2 comprising the second 42 cases from 1/1/2012 through 12/31/2012. Data were obtained via chart review and from American College of Surgeons-National Surgical Quality Improvement Program (ACS-NSQIP) and the University HealthSystem Consortium (UHC) databases [9, 10]. All procedures were performed by a single surgeon (J.B.) at the University of Iowa Hospitals and Clinics. The operating surgeon was a fellowship-trained colorectal surgeon with 1 year of staff-level experience in laparoscopic pelvic dissection at the start of this study; the cases in this series represent the initial robotic rectal dissections performed by this surgeon. This review was approved by the University of Iowa Institutional Review Board.

Patients were selected for a robotic approach based on surgeon discretion and informed consent. Indications for surgery were rectal carcinoma, rectal prolapse, and inflammatory bowel disease. Patients were routinely offered a robotic procedure unless they had a history of laparotomy for abdominopelvic surgery, where a minimally invasive approach was considered to be at prohibitive risk for conversion. Other contraindications for the robotic approach are detailed below.

Rectal carcinoma was defined as tumors within 15 cm of the anal verge on rigid proctosigmoidoscopy. Patients were staged and treated with neoadjuvant chemoradiotherapy in accordance with the American Society of Colon and Rectal Surgeons (ASCRS) Practice Parameters [11]. Those requiring hysterectomy, salpingo-oophorectomy, or partial vaginectomy were offered a combined en bloc robotic resection with the assistance of Gynecology Oncology surgeons. Patients requiring concomitant bladder or prostate resection due to local invasion were not offered robotic resection. Rectal prolapse patients were recommended robotic rectopexy when deemed medically fit for abdominal repair. Patients with complex pelvic prolapse were offered robotic rectopexy in combination with perineorrhaphy performed by Urogynecology surgeons. Individuals with extreme age or comorbidities were recommended to undergo perineal proctectomy. Patients indicated for proctectomy due to failure of medical management or dysplasia in Crohn's disease and Ulcerative Colitis were offered a robotic rectal dissection with concomitant laparoscopic abdominal colectomy and restorative ileal pouch reconstruction as needed.

Robotic rectal dissections were performed in a technique adapted from published reports [12, 13]. Abdominal colectomy, including ileal mobilization for J-pouch reconstruction when indicated, ligation of the inferior mesenteric artery, and splenic flexure mobilization were performed laparoscopically as previously described [14]. Robotic docking was performed off the left hip of the patient in a "side docking" manner designed to give access to the anus and perineum. Docking times were not recorded separately from operating times if less than 5 min. A four-robotic-arm technique was used with trocar sites located in each abdominal quadrant. An assistant port was placed in the right upper quadrant and the camera port at the superior portion of the umbilicus. The robotic mesorectal dissection was performed with the robotic cautery shears. Dissection was carried to the level of the anal canal for restorative proctectomy and the level of the levator musculature for extra-levator abdominal perineal dissection. Division of the low rectum was performed with a laparoscopic stapler, and a double-stapled technique was used for low rectal or coloanal anastomosis. A hand sewn coloanal anastomosis with perineal specimen extraction was performed in one rectal cancer patient. Low rectal, coloanal, and ileal J-pouch-to-anal anastomoses were diverted with a loop ileostomy. For rectopexy, a posterior and anterior dissection was completed, but only the right rectal stalk was taken. The rectopexy suture was accomplished robotically with a non-absorbable heavy suture.

Patients were admitted following surgery and managed according to our institutional Enhanced Recovery Pathway regardless of operative approach. The tenets of the pathway are similar to those published elsewhere [15].

Cost data were obtained from the UHC database. In analyzing cost data, we evaluated both the observed and expected costs. Observed direct hospital costs are based on the actual charges from our hospital and our centers for medicare and medicaid services (CMS) cost-to-charge ratio for the most current year available. Expected costs were obtained from the UHC database. UHC calculates a risk-adjusted expected cost based on factors including patient demographics, comorbidities, and the Medicare Severity-Diagnosis Related Group (MS-DRG) Model. As the robotic platform is maintained for surgical services other than

Table 1 Demographic and clinical variables for all patients undergoing robotic-assisted rectal dissection by time period ($n = 85$)

Characteristic	Time 1 $n = 43$ n (%)[a]	Time 2 $n = 42$ n (%)[a]	p value
Age in years, Mean ± SD	57.0 ± 15.1	57.6 ± 17.0	0.9
Body mass index in kg/m^2, Mean ± SD	26.1 ± 5.4	29.4 ± 7.3	**0.02**
Male gender	27 (63.0 %)	24 (57.1 %)	0.6
White race	33 (76.7 %)	42 (100 %)	**0.002**
Recent history of smoking	17 (39.9 %)	6 (14.3 %)	**0.009**
ASA Classification			0.5
1–2	29 (67.4 %)	31 (73.8 %)	
3	14 (32.6 %)	11 (26.2 %)	
Comorbidity			
Diabetes mellitus	6 (14.0 %)	7 (16.3 %)	0.7
Congestive heart failure	0	3 (7.1 %)	0.1
Chronic obstructive pulmonary disease	3 (7.0 %)	2 (4.8 %)	1
Previous abdominal surgery	24 (55.8 %)	21 (50.0 %)	0.6
Pre-operative steroid use	5 (11.6 %)	4 (9.5 %)	1
Indication for Surgery			0.4
Cancer	25 (58.1 %)	26 (61.9 %)	
Inflammatory bowel disease	12 (27.9 %)	6 (14.3 %)	
Crohn's disease	2 (4.7 %)	2 (4.8 %)	
Ulcerative Colitis	10 (23.2 %)	4 (9.5 %)	
Prolapse	6 (14.0 %)	10 (23.8 %)	
Surgical procedure			0.06
Low anterior resection ± loop ileostomy	8 (18.6 %)	17 (40.4 %)	
Abdominoperineal resection	11 (25.6 %)	10 (23.8 %)	
Rectopexy	6 (14.0 %)	10 (23.8 %)	
Proctectomy, j-pouch, loop ileostomy	7 (16.3 %)	3 (7.1 %)	
Total proctocolectomy ± end ileostomy	4 (9.3 %)	1 (2.4 %)	
Proctectomy, coloanal anastomosis, loop ileostomy	4 (9.3 %)	0	
Hartmann's procedure	2 (4.7 %)	0	
Total proctocolectomy, j-pouch, loop ileostomy	1 (2.3 %)	1 (2.4 %)	
Follow-up in months, Mean ± SD	11.0 ± 7.5	4.4 ± 3.8	**<0.0001**

Bold values are statistically significant

ASA American Society of Anesthesiologists

[a] n (%) presented unless otherwise specified

colorectal surgery, the purchase and maintenance of the robot platform was considered an indirect cost and not factored into the direct cost analysis.

Chi square tests and Fisher's exact tests for categorical variables and t-tests for continuous variables were used to compare Time 1 versus Time 2 groups on demographic variables, clinical characteristics, and outcomes of interest. Outcomes were assessed by time period and indication for surgery. Generalized linear models were used to assess the multivariate relationship between demographic variables, clinical characteristics, and outcomes including procedure time, estimated blood loss, length of stay, and cost. Logistic regression was used to model the multivariate relationship between demographic variables, patient characteristics, and outcomes including conversion to open procedure and occurrence of surgical complications. In both the linear and logistic models, time period, indication for surgery, age, and BMI were considered the core variables and were forced into final models. In addition, all variables listed in Table 1 were considered for inclusion into the final models. Final models were developed using a backward selection process to retain all variables with an adjusted p value of less than 0.05. Adjusted means were computed for continuous outcome variables, and odds ratios with 95 % confidence intervals were calculated for binary outcome variables. All statistical analyses were performed in SAS v9.3 (Cary, NC).

Results

Over a 27-month period, 85 consecutive robotic pelvic dissections were performed. Patient characteristics and comorbidities, indications for surgery, and procedures performed were compared between Time 1 versus Time 2 as shown in Table 1. The two groups did not vary significantly by mean age, gender, and severity of illness as indicated by the American Society of Anesthesiologist (ASA) classification, or comorbidities. There was a statistically significant difference in mean body mass index (BMI), with the latter group having a mean BMI of 29.4 versus 26.1 for the earlier group. Time 2 had a significantly lower rate of smoking and significantly higher percentage of White patients. The differences in BMI, smoking, and race were not due to any explicit inclusion or exclusion criteria.

The primary indication for the procedures performed was malignancy, with 58 % of the first group and 62 % of the second group undergoing surgery for rectal cancer. There were no statistically significant differences in the indication for surgery in Time 1 versus Time 2 or in the procedures performed. Mean follow-up significantly varied between the groups, with the latter group having a shorter follow-up than the earlier group.

Table 2 shows surgical outcomes by time period. The procedure time was significantly lower in the Time 2 group (mean of 224.4 min versus 266.9 min, $p = 0.049$). On

Table 2 Univariate and multivariate analysis of surgical outcomes by time period for all patients (n = 85)

Outcome	Univariate Analysis			Multivariate Analysis		
	Time 1 $n = 43$ Mean ± SD	Time 2 $n = 42$	p value	Time 1 $n = 43$ Adjusted Mean	Time 2 $n = 42$	p value
Procedure time, minutes	266.9 ± 94.5	224.4 ± 101.8	**0.049**	254.8	212.1	**0.03**
Cost, dollars						
Observed	17,349 ± 15,246	13,680 ± 6,225	0.2	20,286	18,046	0.40
Expected	11,163 ± 2,401	13,000 ± 4,818	**0.03**	11,029	12,468	0.06
Observed/Expected	1.47 ± 0.92	1.05 ± 0.29	**0.007**	1.62	1.37	0.10
Estimated blood loss, mL	213 ± 193	222 ± 295	0.9			
Number of lymph nodes[a]	11.8 ± 6.2	20 ± 13.3	**0.0096**			
Days to normal diet	3.8 ± 3.1	3.6 ± 4.2	0.9			
Length of stay, days	8.3 ± 10.2	5.9 ± 4.4	0.2			
n (%)						
Conversion to open	8 (18.6 %)	8 (19.0 %)	1			
Perioperative transfusion	6 (14.0 %)	2 (4.8 %)	0.3			
Superficial surgical site infection	9 (21.4 %)	5 (11.9 %)	0.2			
Anastomotic leak/pelvic abscess	7 (16.2 %)	4 (9.5 %)	0.7			
Deep vein thrombosis	2 (4.8 %)	0	0.5			
Post-operative ileus	11 (26.2 %)	10 (23.8 %)	0.8			
High output ileostomy	4 (9.5 %)	5 (11.9 %)	0.7			
Urinary tract infection	5 (11.9 %)	9 (21.4 %)	0.2			

Bold values are statistically significant

[a] For cancer cases only, therefore not analyzed on multivariate analysis

multivariate analysis, after controlling for surgical indication, age, BMI, and smoking status, this difference remained significant. Of note, procedure time did not include docking time; docking time is not recorded unless it exceeds 5 min, and there were only five cases, all within Time 1 group, whose docking times were recorded.

Table 2 also demonstrates that the observed mean direct hospital cost was higher in the Time 1 group ($17,349 ± 15,246 versus $13,680 ± 6,225), though this did not reach significance ($p = 0.2$). The ratio of observed to expected costs, a comparison of actual direct hospital cost divided by the expected cost as calculated by UHC, was significantly lower in the Time 2 group (1.47 for Time 1 versus 1.05 for Time 2, $p = 0.007$). The difference in observed/expected costs on multivariate analysis did not remain statistically significant.

Estimated blood loss, number of days until patients tolerated a general diet, and length of stay did not vary significantly between the groups on uni- or multivariate analysis, nor did the conversion rate, rate of surgical site infection, or rate of anastomotic leak. Anastomotic leaks and pelvic abscesses were broadly grouped together and included NSQIP-defined deep surgical site infection and organ space infections. Of the 14 patients with a superficial surgical site infection, five had undergone surgery for IBD (four in Time 1, one in Time 2); nine had surgery for cancer (five in Time 1, four in Time 2). Seven of the 11 patients having an anastomotic leak or pelvic abscess were in the malignancy group (four in Time 1, three in Time 2), and the other four had surgery for IBD (three in Time 1, one in Time 2). Four patients required pelvic drain placement by interventional radiology for the treatment of pelvic abscess; one patient required a perineal wound debridement due to breakdown and infection in the malignancy group. Seven of eight patients requiring transfusion were in the malignancy group.

To evaluate whether the aforementioned surgical outcomes such as procedure time and cost varied by surgical indication, we performed a univariate analysis of these outcomes of interest as stratified by indication, shown in Table 3. Procedure time demonstrated a trend toward decreasing over time for each surgical indication but did not reach statistical significance. Direct costs observed for IBD cases showed a trend toward decreasing though this was not statistically significant ($19,278 ± 13,404 vs. $13,413 ± 2,504, $p = 0.06$). However, the ratio of observed to expected costs for IBD-related rectal dissections did significantly decrease over time (1.8 ± 0.8 vs. 1.2 ± 0.1, $p = 0.02$). Length of stay was also significantly decreased over time for IBD cases (9.3 ± 5.3 days vs. 5.3 ± 1.2 days, $p = 0.03$).

Procedure time can be influenced by a number of factors, most clearly by the procedure performed. However,

Table 3 Univariate analysis of selected surgical outcomes by indication for surgery and time period

Outcome, Mean ± SD	Cancer n = 51			Inflammatory Bowel Disease n = 18			Prolapse n = 16		
	Time 1 n = 25	Time 2 n = 26	p value	Time 1 n = 12	Time 2 n = 6	p value	Time 1 n = 6	Time 2 n = 10	p value
Procedure time, minutes	275.1 ± 88.8	258.6 ± 91.6	0.5	293.2 ± 95.7	264.7 ± 93.6	0.6	180 ± 82.6	111 ± 16.7	0.1
Cost, dollars									
Observed	18,590 ± 18,154	15,872 ± 6,202	0.5	19,278 ± 13,404	13,413 ± 2,504	0.06	6,515 ± 1,643	6,759 ± 1,190	0.8
Expected	11,805 ± 2,644	14,486 ± 5,297	**0.03**	10,721 ± 1,701	11,262 ± 2,231	0.6	9,015 ± 535	9,474 ± 756	0.3
Observed/Expected	1.5 ± 1.0	1.1 ± 0.3	0.1	1.8 ± 0.8	1.2 ± 0.1	**0.02**	0.73 ± 0.18	0.71 ± 0.63	0.9
EBL, mL	223 ± 189	248 ± 294	0.7	252 ± 193	447 ± 367	0.2	99 ± 197	19 ± 14	0.4
Days to normal diet	3.9 ± 3.3	4.7 ±5.0	0.5	4.7 ± 2.9	3.0 ± 0.6	0.08	1.3 ± 0.5	1.3 ± 0.5	0.9
LOS, days	9.4 ± 12.4	7.7 ± 4.5	0.5	9.3 ± 5.3	5.3 ± 1.2	**0.03**	1.5 ± 0.5	1.8 ± 1.0	0.5

Bold values are statistically significant

EBL estimated blood loss. *LOS* length of stay

the time to complete a procedure is also a measure of one's facility in performing that procedure and thus is a rough surrogate for the learning curve. To reduce the heterogeneity of procedures performed while still evaluating a large sample, we plotted the operative time of the procedures performed for malignancy (n = 51). While there were several outliers that skewed the regression line, there was a clear trend toward decreasing operating time (Fig. 1).

Discussion

We present experience with the initial 85 robotic rectal dissections performed by a single surgeon for benign and malignant indications. Our results demonstrate significant improvement in operating time with experience and evidence of improved direct hospital costs, potentially due in part to these reductions in operating time. Complications and conversions remained stable throughout the learning curve illustrating the safety and feasibility of this approach.

We observed a statistically significant decrease in operating time between the two groups of patients. One concern about this observation is that the second group had a greater proportion of rectal prolapse cases which are shorter than the more complex cases performed for rectal cancer. However, even after controlling for factors including surgical indication, the decrease in procedure time remained statistically significant. This decrease in procedure time occurred despite a potentially more technically challenging cohort (as evidenced by significantly higher mean BMI in the latter group). Additionally, this improvement in procedure time was due to greater speed within the cases, not due to setup time, as docking time was under 5 min for all but the first five cases.

Proponents of robotic surgery cite an abbreviated learning curve when compared to that experienced by the laparoscopic naïve surgeon learning laparoscopy [16–18]. The literature addressing case volume needed for mastery of robotic techniques is unsettled, with necessary projected case volumes ranging from 15–25 cases into the hundreds for colorectal surgery [17, 18]. The designs of these studies vary and are subject to surgeon and institutional bias. We evaluated operating time in part as a surrogate for measuring the learning curve. In assessing our own learning curve, an additional detailed analysis of trends in operating time was performed with case volume divided in quartiles, as well as groups of 10 cases, and no clear inflection points were observed in these smaller groupings. Data were therefore presented as Time 1 versus Time 2 to maximize power to detect differences in outcomes, and the scatter plot (Fig. 1) was provided to show the overall trend by time. Also the improved lymph node harvest in Time 2 was observed, which could be evidence of the operating

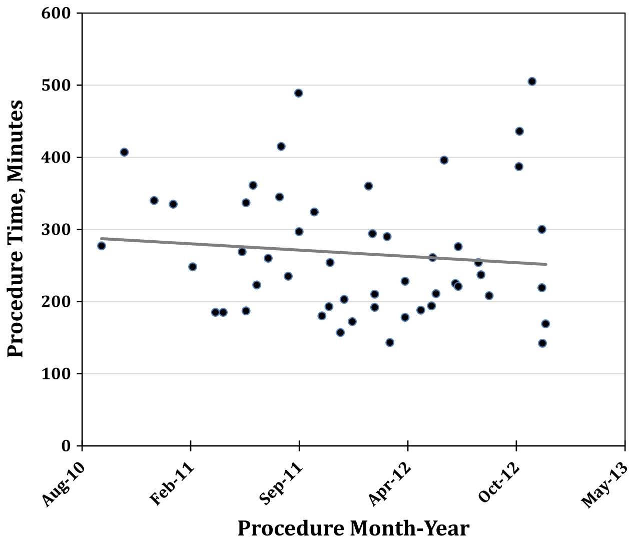

Fig. 1 Trend in procedure time for robotic-assisted rectal dissection performed for malignancy ($n = 51$)

surgeon's laparoscopic learning curve as these cases were performed relatively early in his career. Importantly, throughout the series, lymph node harvest was adequate for staging. Due to the heterogeneity of the procedures performed throughout the series as well as the differences in group characteristics such as BMI and smoking history, it is difficult to elucidate learning curve inflection points at a more granular level, and the absolute number of cases required for proficiency has yet to be defined. While understanding that our method is subject to many of the same limitations as other published learning curve analyses, we consider our results comparable.

One of the major concerns of the robotic platform is its cost. Important trends in cost over time were observed in this series. First, on univariate analysis, direct hospital costs were significantly improved between Time 1 and Time 2 as indicated by the observed/expected cost ratio. This ratio was designed to correct observed costs for patient-specific factors that increase cost outside of the surgical technique employed. The reasons for this decrease in cost are likely multifactorial, but decreased operating time and length of stay are likely two major contributors. This is exemplified in part in Table 3, where the IBD group showed a significant decrease in observed/expected cost ratios along with a significant decrease in length of stay from Time 1 to Time 2.

The literature on robotics and cost almost invariably concludes that robotic colorectal surgery is more expensive when compared to open and traditional laparoscopy [19, 20]. In recent review, only one of five series that analyzed cost was from United States institutions [6, 21]. The most robust analyses from the United States have involved national data using the healthcare cost and utilization project Nationwide Inpatient Sample (NIS) database. Limitations of the NIS data include the lack of case-specific information, institution- or surgeon-specific clinical practice, coding error or bias, and the possibility that many institutions contribute relatively few cases leading to learning curve related cost elevations. Due to the heavy investment in the robotic approach, a suitable comparison group for cost and outcomes was not available in our series. However, use of the UHC database afforded us standardized expected and observed cost data. While the accuracy of data is dependent on appropriate clinical documentation and coding, the methodology is designed to prepare institutions for future pay-for-performance initiatives and thus is fairly robust.

Given the criticisms of the robotic platform, it is important to review what it has to offer: improved 3-dimensional optics and surgeon-controlled camera platform, tremor reducing and endo-wristed instrumentation facilitating dissections in challenging spaces such as the pelvis, fixed third-arm retraction, and the ergonomic surgeon console. These are the cornerstones of the robotic platform and have been realized to varying degrees by different surgical specialties [16, 21–23]. For this author, the most useful advantages of the robotic approach were the fixed third-arm retraction and surgeon-controlled camera platform.

Limitations of our analysis include its retrospective nature, the lack of a comparison group, and the potential for selection bias inherent in a single surgeon case series. Additionally, the small sample size and heterogeneous case mix make it challenging to detect clear patterns across the groups. Although the diverse nature of the indications and procedures performed confounds some of the analysis, this may also strengthen our contribution, as the reports on benign indications for robotic rectal dissection are limited. Additionally, we believe that this experience contributes to the literature demonstrating robotics as a feasible tool in minimally invasive rectal surgery, even for those with limited previous robotic experience. Future studies need to be designed to assess profitability, cost, patient outcomes, and number of cases needed to attain proficiency, with head-to-head comparisons to open and traditional laparoscopic approaches.

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References

1. Weber PA, Merola S, Wasielewski A, Ballantyne GH (2002) Telerobotic-assisted laparoscopic right and sigmoid colectomies for benign disease. Dis Colon Rectum 45:1689–1694 discussion 1695–1686

2. Pigazzi A, Ellenhorn JD, Ballantyne GH, Paz IB (2006) Robotic-assisted laparoscopic low anterior resection with total mesorectal excision for rectal cancer. Surg Endosc 20:1521–1525
3. Memon S, Heriot AG, Murphy DG, Bressel M, Lynch AC (2012) Robotic versus laparoscopic proctectomy for rectal cancer: a meta-analysis. Ann Surg Oncol 19:2095–2101
4. Yang Y, Wang F, Zhang P, Shi C, Zou Y, Qin H, Ma Y (2012) Robot-assisted versus conventional laparoscopic surgery for colorectal disease, focusing on rectal cancer: a meta-analysis. Ann Surg Oncol 19:3727–3736
5. Trastulli S, Farinella E, Cirocchi R, Cavaliere D, Avenia N, Sciannameo F, Gulla N, Noya G, Boselli C (2012) Robotic resection compared with laparoscopic rectal resection for cancer: systematic review and meta-analysis of short-term outcome. Colorectal Dis 14:e134–e156
6. Halabi WJ, Kang CY, Jafari MD, Nguyen VQ, Carmichael JC, Mills S, Stamos MJ, Pigazzi A (2013) Robotic-assisted colorectal surgery in the United States: a nationwide analysis of trends and outcomes. World J Surg 37:2782–2790
7. Miller AT, Berian JR, Rubin M, Hurst RD, Fichera A, Umanskiy K (2012) Robotic-assisted proctectomy for inflammatory bowel disease: a case-matched comparison of laparoscopic and robotic technique. J Gastrointest Surg 16:587–594
8. Perrenot C, Germain A, Scherrer ML, Ayav A, Brunaud L, Bresler L (2013) Long-term outcomes of robot-assisted laparoscopic rectopexy for rectal prolapse. Dis Colon Rectum 56:909–914
9. American College of Surgeons National Surgical Quality Improvement Program. Available at: http://site.acsnsqip.org; Accessed April 20, 2014
10. University HealthSystem Consortium. Available at: https://www.uhc.edu; Accessed April 20, 2014
11. Monson JR, Weiser MR, Buie WD, Chang GJ, Rafferty JF, Buie WD, Rafferty J, Standards Practice Task Force of the American Society of C, Rectal S (2013) Practice parameters for the management of rectal cancer (revised). Dis Colon Rectum 56:535–550
12. deSouza AL, Prasad LM, Ricci J, Park JJ, Marecik SJ, Zimmern A, Blumetti J, Abcarian H (2011) A comparison of open and robotic total mesorectal excision for rectal adenocarcinoma. Dis Colon Rectum 54:275–282
13. Peterson CY, McLemore EC, Horgan S, Talamini MA, Ramamoorthy SL (2012) Technical aspects of robotic proctectomy. Surg Laparosc Endosc Percutan Tech 22:189–193
14. Byrn J (2012) Technical considerations in laparoscopic total proctocolectomy. Surg Laparosc Endosc Percutan Tech 22:180–182
15. Gustafsson UO, Scott MJ, Schwenk W, Demartines N, Roulin D, Francis N, McNaught CE, Macfie J, Liberman AS, Soop M, Hill A, Kennedy RH, Lobo DN, Fearon K, Ljungqvist O, Enhanced Recovery After Surgery Society fPC, European Society for Clinical N, Metabolism, International Association for Surgical M, Nutrition (2013) Guidelines for perioperative care in elective colonic surgery: Enhanced Recovery After Surgery (ERAS((R))) Society recommendations. World J Surg 37:259–284
16. Ma J, Shukla PJ, Milsom JW (2011) The evolving role of robotic colorectal surgery. Dis Colon Rectum 54:376 author reply 376–377
17. Patel CB, Ragupathi M, Ramos-Valadez DI, Haas EM (2011) A three-arm (laparoscopic, hand-assisted, and robotic) matched-case analysis of intraoperative and postoperative outcomes in minimally invasive colorectal surgery. Dis Colon Rectum 54:144–150
18. Sng KK, Hara M, Shin JW, Yoo BE, Yang KS, Kim SH (2013) The multiphasic learning curve for robot-assisted rectal surgery. Surg Endosc 27:3297–3307
19. Salman M, Bell T, Martin J, Bhuva K, Grim R, Ahuja V (2013) Use, cost, complications, and mortality of robotic versus nonrobotic general surgery procedures based on a nationwide database. Am Surg 79:553–560
20. Barbash GI, Glied SA (2010) New technology and health care costs–the case of robot-assisted surgery. N Engl J Med 363:701–704
21. Scarpinata R, Aly EH (2013) Does robotic rectal cancer surgery offer improved early postoperative outcomes? Dis Colon Rectum 56:253–262
22. Wexner SD, Bergamaschi R, Lacy A, Udo J, Brolmann H, Kennedy RH, John H (2009) The current status of robotic pelvic surgery: results of a multinational interdisciplinary consensus conference. Surg Endosc 23:438–443
23. Pigazzi A, Garcia-Aguilar J (2010) Robotic colorectal surgery: for whom and for what? Dis Colon Rectum 53:969–970