Review Article

Ewha Med J 2022;45(4):e10
https://doi.org/10.12771/emj.2022.e10
eISSN 2234-2591

Robot-Assisted Colorectal Surgery

Young Il Kim

Division of Colon and Rectal Surgery, Department of Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea

Received Sep 30, 2022
Accepted Oct 4, 2022

Corresponding author
Young Il Kim
Division of Colon and Rectal Surgery, Department of Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul 05505, Korea
Tel: 82-2-3010-1206
E-mail: illie@amc.seoul.kr

Key Words
Robot surgical procedures; Colonic neoplasms; Rectal neoplasms; Colorectal disease

Minimally invasive surgery for colorectal disease has now become the standard treatment in Republic of Korea. However, there are limitations to the laparoscopic approach, such as an unstable camera support, a limited range of motion, and poor ergonomics. Recent advances in technology have led to the introduction of robotic surgical systems in colorectal surgery to overcome these shortcomings. Robot-assisted colorectal surgery has clear advantages in many aspects. Surgery involving the rectum benefits the most among colorectal diseases owing to technical difficulties in rectum dissection. The concept of robotic surgery is not different from laparoscopic surgery in that it is a minimally invasive surgery, and abundant research demonstrates comparable results from both modalities for postoperative complications, oncological outcomes, and functional outcomes. However, the cost of robot-assisted surgery limits surgeons to performing robotic surgeries in only selected cases. Improvements regarding cost-effectiveness and more convincing studies that support benefits of robotic surgery are needed to popularize robot-assisted colorectal surgery.

Introduction

Since the introduction of laparoscopic colorectal surgery in the early 1990s, minimally invasive surgery (MIS) for colorectal disease has now become the standard treatment in Republic of Korea (Korea). While the MIS approach was applied for less than 50% of colorectal cancer patients in 2008, it increased to nearly 80% in 2018 [1]. Important randomized controlled trials (RCTs) have presented evidence that laparoscopic surgery is feasible oncologically and technically [2–4]. MIS provides a faster recovery, less postoperative pain, and a reduced risk of surgical site infection compared to open surgery with comparable survival outcomes [5–7]. However, there are limitations to the laparoscopic approach, such as an unstable camera support, a limited range of motion owing to the rigid straight surgical equipment, and poor ergonomics. Constant efforts are ongoing to overcome these problems, and recent advances in technology have led to the introduction of robotic surgical systems in colorectal surgery.

The concept of modern robots first appeared in 1921 where the word "robot" was used in the play R.U.R.: Rossum's Universal Robots by a Czech novelist Karel Capek. Robot means forced labor in the Czech language [8]. This nomenclature seems well defined in that one of the key advantages of robotic surgery is to aid surgeons during physically demanding procedures. Robotic assistance provides an immersive 3-dimensional view that the operator can control without any additional human assistance, while manipulating articulated surgical instruments for a much more versatile movement. The first robot-assisted surgery performed for colorectal disease was in 2001 with the

Da Vinci telerobotic surgical system. The feasibility of robotic colorectal surgery has been validated by many studies since then and it is now practiced worldwide for various colorectal diseases; malignancies, benign lesions and inflammatory bowel diseases (IBD). This article reviews the clinical impacts of applying robotic surgical systems to treating colorectal diseases.

Current Evidence for Robotic Surgery in Colorectal Diseases

Specific features of robot-assisted surgery led to variations in the extent of application of the robotic system according to the target organ. Even though the colon and rectum are both a continuation of the large bowel, each organ has a distinct anatomy and thus benefits from robot-assisted surgery differently. Also, the diverse spectrum of colorectal diseases (malignant, benign, IBD, etc.) presents dissimilar practices and indications for adapting robotic surgery.

1. Rectal cancer

The most widely appreciated site for the application of robotic systems is the rectum. This is due to the anatomical characteristics of the rectum. The rectum is located in a confined compartment constituted by the sacral promontory posteriorly, genitourinary organs anteriorly, and pelvic floor muscles laterally. The bony structure of the pelvis forms a narrow canal, and this feature is particularly prominent in male patients. Operating in such environment is challenging and surgeons often experience limitations of their rigid laparoscopic instruments. Manipulating the rectum in such a narrow pelvis for traction, especially with a bulky tumor, is time consuming and causes surgeons to become exhausted. There are several studies that demonstrated a longer operation time, a worse quality of total mesorectal excision, and a higher rate of postoperative morbidities in patients with a narrow pelvis or a bulky tumor when operated on laparoscopically [9–12].

Robot-assisted surgery provides a comfortable environment for surgeons. The fully wristed robot instruments and stable 3-dimensional camera vision that can be controlled by the operator enables a much more versatile movement in narrow spaces [13]. The difficulty of the pelvic anatomy does not result in an overtly prolonged operation time, and Baek et al. reported a shorter operation time even in patients with a narrow pelvis when using a robotic system [14]. This advantage of robotic surgery for rectal cancer also leads to better preservation of urinary and sexual functions. Identifying pelvic autonomic nerves and not damaging the nerves is extremely important during total mesorectal excision for rectal cancer [15]. The nerves are at risk of transection or thermal injury during the ligation of the inferior mesenteric artery, dissection of the mesorectum at the level of the sacral promontory, and dissection of the antero-lateral planes of the rectoprostatic/rectovaginal (Denonvilliers') fascia. Although a laparoscopic camera provides a more magnified vision compared to open surgery, the robotic system is equipped with an immersive 3-dimensional camera, which allows for identification and direct observation of these important structures in greater detail. Previous studies have shown higher rates of preserved physiological functions after robot-assisted rectal surgery compared to laparoscopic surgery [16].

All of these benefits of robotic systems would not be acceptable without oncological safety. A series of RCTs from various centers worldwide, along with numerous retrospective studies over the past 20 years of clinical practice, have presented unified results of comparable survival outcomes of robot-assisted rectal cancer surgery with laparoscopic surgery (Table 1) [17–21]. Confidence from accumulated experience has led to the adaption of robotic surgery to even more complicated and advanced cases of rectal cancer [22–26].

https://doi.org/10.12771/emj.2022.e10

Table 1. Studies validating robot-assisted surgery for rectal cancer

Study [Ref.]	Design	Diagnosis	Operation	Study arms	Sample size	Conclusion
Baik et al., 2009 [17]	Prospective	Rectal cancer	Low anterior resection	Robot	56	Lower conversion rate and serious complication rate in robot group.
				Laparoscope	57	
Patriti et al., 2009 [18]	Case-matched	Rectal cancer	All rectal resection (LAR, ISR, APR)	Robot	29	Lower conversion rate in robot group, comparable OS and DFS.
				Laparoscope	37	
Jayne et al., 2017 [19]	RCT	Rectal cancer	All rectal resection (AR, LAR, APR)	Robot	236	Comparable conversion rate, CRM, and sexual/urinary functions.
				Laparoscope	230	
Kim et al., 2018 [20]	RCT	Rectal cancer	All rectal resection (LAR, APR, Hartmann)	Robot	66	Comparable TME quality, postoperative morbidity, bowel function recovery, QoL.
				Laparoscope	73	
Kim et al., 2017 [21]	Retrospective, PPM	Rectal cancer	All rectal resection	Robot	224	Favorable 5-year OS, CSS, DFS in the robot group.
			(AR, LAR, ISR, APR)	Laparoscope	224	

LAR, low anterior resection; ISR, intersphincteric resection; APR, abdominoperineal resection; OS, overall survival; DFS, disease-free survival; RCT, randomized controlled trial; AR, anterior resection; CRM, circumferential resection margin; TME, total mesorectal excision; QoL, quality of life; PPM, propensity score matching; CSS, cancer-specific survival.

2. Colon cancer

Surgery for colon cancer is not fundamentally different from rectal cancer in that the principle concept is to excise the mesocolon along with the draining vessels and lymphatics from the primary tumor, defined as complete mesocolic excision. This surgical objective is equivalent to TME for rectal cancer and is known to be essential for an optimal survival outcome [27,28]. However, the anatomical distinction between the colon and rectum makes surgery on the colon less challenging; nevertheless, it requires additional caution during dissection. The colon is not confined within a limited compartment, and the surgical field is much broader and more open. Basically, the whole intraperitoneal space can be used to manipulate the instruments. Therefore, the advantages of robotic surgery may not be as prominent during colon resection.

This is supported by a RCT from Park et al., which compared robotic-assisted colectomy with traditional laparoscopic-assisted colectomy in right-sided colon cancer [29]. The length of hospital-stay, postoperative morbidity, and the number of harvested lymph nodes were comparable between the two groups, but the operation time was significantly longer in the robot-assisted colectomy group (195 min versus 130 min, P<0.001). The overall medical cost was also significantly higher in the robot-assisted surgery group and there were no benefits in the long-term survival outcomes [30]. Choi et al. concluded that there were no clinical benefits of robot surgery in right-sided colon cancer that outweighs the high costs [1]. However, to date, there are not enough studies with a large sample size and statistical power to strongly contraindicate robot-assisted colectomy.

Recent technological advances in robotic systems have led to the development of single-platform robot systems since 2018 (da Vinci SP) (Fig. 1). The operator can perform reduced port surgeries more comfortably with fully wristed robotic instruments through a single-port compared to the conventional single-incision laparoscopic surgery. Single-incision laparoscopic surgery is known to be beneficial in terms of cosmetic aspects but it is usually only used for

Fig. 1. Da Vinci robot surgical systems, (A) X system, (B) Xi system, and (C) SP system. Constant improvement of the technology has expanded the use of robot-assisted surgery in colorectal diseases.

highly selected patients due to technical difficulties [31]. The utility of a robotic system for single-port surgery may become a safer and more practical approach for surgeons to perform colon cancer resection [32–34].

3. Ventral rectopexy

The perineal or a transabdominal approach are both available treatment modalities for pelvic organ prolapses. In particular, abdominal ventral mesh rectopexy is an effective approach for treating rectal prolapse and MIS has shown benefits of a low complication rate and recurrence rate, with improved symptoms of fecal incontinence and obstructed defecation syndrome [35–37]. The key procedures of ventral mesh rectopexy are similar to rectum resection in that the dissection of the rectum down to the rectovaginal or rectoprostatic septum is essential. Therefore, patients indicated for ventral mesh rectopexy can also benefit from robot-assisted surgery, similar to patients with rectal cancer. Theoretically, suturing the mesh to the anterior wall of the lower rectum can be performed readily with the fully wristed robotic instruments.

A RCT comparing robot-assisted ventral mesh rectopexy (RVMR) to laparoscopic ventral mesh rectopexy demonstrated no difference in operation time or postoperative complications. The RVMR group showed a trend of less residual rectocele postoperatively in terms of amount and size [38]. However, there are mixed results regarding the operation time in retrospective studies and RVMR should be applied to selected patients depending on the cost-effectiveness and surgeon compatibility [39,40].

4. Inflammatory bowel disease

Extensive studies still need to be conducted to prove the feasibility of robotic surgery in IBD patients. A retrospective study analyzed the perioperative outcomes of 108 patients with Crohn's disease who received robotic-assisted ileocolic resection and compared the results to open cases. The robot-assisted cases had a significantly shorter hospital stay by 2 days ($P<0.0001$) with a lower 30-day complication rate (24% versus 38%, $P=0.039$), but they required a mean of 60 min additional operation time ($P<0.0001$) [41].

Two case-matched comparison studies of robotic versus laparoscopic proctectomy for IBD patients presented similar complication rates, short-term functional results, conversion rate, and length of stay for both groups, but the robotic group had a longer operative time [42,43]. Robot-

https://doi.org/10.12771/emj.2022.e10

assisted surgery can have advantages in pelvic nerve preservation during proctectomy, but further research is warranted as surgeons adapt to robotic surgery for IBDs [44].

Cost-Effectiveness of Robot-Assisted Surgery

The biggest obstacle to the nationwide adaption of robot-assisted colorectal surgery in Korea is the cost benefit ratio. Since the first approval of robot-assisted surgery in the year 2005 by the Ministry of Food and Drug Safety of Korea, robot surgery has been classified as non-reimbursable. All citizens of Korea are obligated to obtain national health insurance and essential medical services are generally covered by this national health insurance system. While robot-assisted surgery has been praised for its minimally invasive approach and shortened hospital stay, its cost-effectiveness has been considered unclear for coverage by the national health insurance system. This results in a roughly 2- to 4-fold higher operative cost for patients receiving robot-assisted surgery compared to laparoscopic surgery in Korea [45,46]. The national insurance policy differs in each country but robotic surgery is universally accepted to be more expensive compared to laparoscopic surgery (Table 2) [19,30,45–48]. This is the core issue why robot-assisted surgery, while presenting comparable postoperative outcomes and survival outcomes to laparoscopic surgery, still cannot be the standard treatment for colorectal diseases.

Conclusion

Robot-assisted colorectal surgery has clear advantages in many aspects. Surgery involving the rectum benefits the most among colorectal diseases owing to technical difficulties in rectum dissection. The fundamental concept of robotic surgery is not that different from laparoscopic surgery in that it is a minimally invasive approach, and abundant research demonstrates comparable results from both modalities for postoperative complications, oncological outcomes, and functional outcomes.

However, the cost of robot-assisted surgery limits surgeons to performing robotic surgeries in only selected cases. Currently, few patients meet the indications to justify the high costs of

Table 2. Studies analyzing cost of robot-assisted surgery for colorectal disease

Study (Ref.)	Design	Diagnosis	Operation	Study arms	Costs	P-value
Baek et al., 2012 [45]	Retrospective	Rectal cancer	All rectal rection (AR, LAR, ISR, APR, TPC)	Robot	$14,647	0.001
				Laparoscope	$9,978	
Park et al., 2015 [46]	Prospective	Rectal cancer	LAR	Robot	$12,742	<0.001
				Laparoscope	$10,101	
Jayne et al., 2017 [19]	RCT	Rectal cancer	All rectal resection (AR, LAR, APR)	Robot	$13,668	0.02
				Laparoscope	$12 556	
Morelli et al., 2016 [48]	Retrospective	Rectal cancer	All rectal resection (AR, LAR, ISR, APR)	Robot	Euro 12,283	<0.001
				Laparoscope	Euro 7,619	
Park et al., 2019 [30]	RCT	Colon cancer	Right colectomy	Robot	$12,235	0.013
				Laparoscope	$10,320	

AR, anterior resection; LAR, low anterior resection; ISR, intersphincteric resection; APR, abdominoperineal resection; TPC, total proctocolectomy; RCT, randomized controlled trial.

https://doi.org/10.12771/emj.2022.e10

robot-assisted surgery. Further advances in robotic surgical systems may improve the cost-effectiveness of robotic surgery and influence national insurance policies to provide a more comprehensive indication criterion for applying robot-assisted surgery in colorectal diseases.

Acknowledgements

Not applicable.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

ORCID iD

Young Il Kim : https://orcid.org/0000-0002-0212-9196

Author Contribution

The article is prepared by a single author.

Ethics Approval and Consent to Participate

Not applicable.

References

1. Choi GS. Minimally invasive surgery for colorectal cancer, a look back to look forward: a personal history. *J Minim Invasive Surg* 2022;25(2):41-48.
2. Buunen M, Veldkamp R, Hop WC, Kuhry E, Jeekel J, Haglind E, et al. Survival after laparoscopic surgery versus open surgery for colon cancer: long-term outcome of a randomised clinical trial. *Lancet Oncol* 2009;10(1):44-52.
3. Jeong SY, Park JW, Nam BH, Kim S, Kang SB, Lim SB, et al. Open versus laparoscopic surgery for mid-rectal or low-rectal cancer after neoadjuvant chemoradiotherapy (COREAN trial): survival outcomes of an open-label, non-inferiority, randomised controlled trial. *Lancet Oncol* 2014;15(7):767-774.
4. Jaap Bonjer H, Deijen CL, Abis GA, Cuesta MA, van der Pas MHGM, de Lange-de Klerk ESM, et al. A randomized trial of laparoscopic versus open surgery for rectal cancer. *N Engl J Med* 2015;372(14):1324-1332.
5. Guillou PJ, Quirke P, Thorpe H, Walker J, Jayne DG, Smith AMH, et al. Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicentre, randomised controlled trial. *Lancet* 2005;365(9472):1718-1726.
6. Nelson H, Sargent DJ, Wieand HS, Fleshman J, Anvari M, Stryker SJ, et al. A comparison of laparoscopically assisted and open colectomy for colon cancer. *N Engl J Med* 2004;350(20):2050-2059.
7. Lohsiriwat V. High compliance with surgical site infection (SSI) prevention bundle reduces incisional SSI after colorectal surgery. *Ann Coloproctol* 2021;37(3):146-152.
8. Moore EJ. Robotic surgery [Internet]. Encyclopedia Britannica; 2018 [cited 2021 Mar 09]. Available from: https://www.britannica.com/science/robotic-surgery
9. Akiyoshi T, Kuroyanagi H, Oya M, Konishi T, Fukuda M, Fujimoto Y, et al. Factors affecting the difficulty of laparoscopic total mesorectal excision with double stapling technique anastomosis for low rectal cancer. *Surgery* 2009;146(3):483-489.
10. Kim JY, Kim YW, Kim NK, Hur H, Lee KY, Min BS, et al. Pelvic anatomy as a factor in laparoscopic rectal surgery: a prospective study. *Surg Laparosc Endosc Percutan Tech* 2011;21(5):334-339.
11. Baik SH, Kim NK, Lee KY, Sohn SK, Cho CH, Kim MJ, et al. Factors influencing pathologic results after total mesorectal excision for rectal cancer: analysis of consecutive 100 cases. *Ann Surg Oncol* 2008;15(3):721-728.
12. Nasir IUI, Shah MF, Panteleimonitis S, Figueiredo N, Parvaiz A. Spotlight on laparoscopy in the surgical resection of locally advanced rectal cancer: multicenter propensity score match study. *Ann Coloproctol* 2022;38(4):307-313.
13. Jang JH, Kim CN. Robotic total mesorectal excision for rectal cancer: current evidences and future perspectives. *Ann Coloproctol* 2020;36(5):293-303.
14. Baek SJ, Kim CH, Cho MS, Bae SU, Hur H, Min BS, et al. Robotic surgery for rectal cancer can overcome difficulties associated with pelvic anatomy. *Surg Endosc* 2015;29(6):1419-1424.
15. Varela C, Kim NK. Surgical treatment of low-lying rectal cancer: updates. *Ann Coloproctol* 2021;37(6):395-424.
16. Wang G, Wang Z, Jiang Z, Liu J, Zhao J, Li J. Male urinary and sexual function after robotic pelvic autonomic nerve-preserving surgery for rectal cancer. *Int J Med Robot Comput Assist Surg* 2016;13(1):e1725.
17. Baik SH, Kwon HY, Kim JS, Hur H, Sohn SK, Cho CH, et al. Robotic versus laparoscopic low anterior resection of rectal cancer: short-term outcome of a prospective comparative study. *Ann Surg Oncol* 2009;16(6):1480-1487.
18. Patriti A, Ceccarelli G, Bartoli A, Spaziani A, Biancafarina A, Casciola L. Short- and medium-term outcome of robot-assisted and traditional laparoscopic rectal resection. *J Soc Laprosc Robot Surg* 2009;13(2):176-183.
19. Jayne D, Pigazzi A, Marshall H, Croft J, Corrigan N, Copeland J, et al. Effect of robotic-assisted vs conventional laparoscopic surgery on risk of conversion to open laparotomy among patients undergoing resection for rectal cancer: the ROLARR

randomized clinical trial. *J Am Med Assoc* 2017;318(16):1569-1580.
20. Kim MJ, Park SC, Park JW, Chang HJ, Kim DY, Nam BH, et al. Robot-assisted versus laparoscopic surgery for rectal cancer: a phase II open label prospective randomized controlled trial. *Ann Surg* 2018;267(2):243-251.
21. Kim J, Baek SJ, Kang DW, Roh YE, Lee JW, Kwak HD, et al. Robotic resection is a good prognostic factor in rectal cancer compared with laparoscopic resection: long-term survival analysis using propensity score matching. *Dis Colon Rectum* 2017;60(3):266-273.
22. Yang SY, Kim NK. Robotic partial excision of levator-ani muscle for locally advanced low rectal cancer invading ipsilateral pelvic floor. *Ann Coloproctol* 2020;36(6):415-416.
23. Piozzi GN, Kim SH. Robotic intersphincteric resection for low rectal cancer: technical controversies and a systematic review on the perioperative, oncological, and functional outcomes. *Ann Coloproctol* 2021;37(6):351-367.
24. Leong QM, Son DN, Cho JS, Baek SJ, Kwak JM, Amar AH, et al. Robot-assisted intersphincteric resection for low rectal cancer: technique and short-term outcome for 29 consecutive patients. *Surg Endosc* 2011;25(9):2987-2992.
25. Kim JC, Lee JL, Kim CW, Kim JR, Kim J, Park SH. Technical, functional, and oncological validity of robot-assisted total-intersphincteric resection (T-ISR) for lower rectal cancer. *Eur J Surg Oncol* 2022. https://doi.org/10.1016/j.ejso.2022.07.010
26. Bae JH, Koh W, Kim HH, Lee YS. Standardized step-by-step technique using surgical landmarks in robotic lateral pelvic lymph node dissection. *Ann Coloproctol* 2021;37(1):58-60.
27. Son GM, Lee IY, Lee YS, Kye BH, Cho HM, Jang JH, et al. Is laparoscopic complete mesocolic excision and central vascular ligation really necessary for all patients with right-sided colon cancer? *Ann Coloproctol* 2021;37(6):434-444.
28. Conti C, Pedrazzani C, Turri G, Fernandes E, Lazzarini E, De Luca R, et al. Comparison of short-term results after laparoscopic complete mesocolic excision and standard colectomy for right-sided colon cancer: analysis of a western center cohort. *Ann Coloproctol* 2021;37(3):166-173.
29. Park JS, Choi GS, Park SY, Kim HJ, Ryuk JP. Randomized clinical trial of robot-assisted versus standard laparoscopic right colectomy. *Br J Surg* 2012;99(9):1219-1226.
30. Park JS, Kang H, Park SY, Kim HJ, Woo IT, Park IK, et al. Long-term oncologic after robotic versus laparoscopic right colectomy: a prospective randomized study. *Surg Endosc* 2019;33(9):2975-2981.
31. Kim WJ, Jin HY, Lee H, Bae JH, Koh W, Mun JY, et al. Comparing the postoperative outcomes of single-incision laparoscopic appendectomy and three port appendectomy with enhanced recovery after surgery protocol for acute appendicitis: a propensity score matching analysis. *Ann Coloproctol* 2021;37(4):232-238.
32. Bae SU, Jegon WK, Baek SK. Single plus one-port robotic surgery using the da Vinci single-site platform versus conventional multi-port laparoscopic surgery for left-sided colon cancer. *Wideochir Inne Tech Maloinwazyjne* 2022;17(1):179-187.
33. Hirano Y, Kondo H, Yamaguchi S. Robot-assisted surgery with Senhance robotic system for colon cancer: our original single-incision plus 2-port procedure and a review of the literature. *Tech Coloproctol* 2021;25(4):467-471.
34. Song SH, Kim HJ, Choi GS, Park JS, Park SY, Lee SM, et al. Initial experience with a suprapubic single-port robotic right hemicolectomy in patients with colon cancer. *Tech Coloproctol* 2021;25(9):1065-1071.
35. Campagna G, Panico G, Caramazza D, Anchora LP, Parello A, Gallucci V, et al. Laparoscopic sacrocolpopexy plus ventral rectopexy as combined treatment for multicompartment pelvic organ prolapse. *Tech Coloproctol* 2020;24(6):573-584.
36. Rajasingh CM, Gurland BH. Best approaches to rectal prolapse. *Ann Laparosc Endosc Surg* 2022;7:12.
37. Tsunoda A, Takahashi T, Sato K, Kusanagi H. Factors predicting the presence of concomitant enterocele and rectocele in female patients with external rectal prolapse. *Ann Coloproctol* 2021;37(4):218-224.
38. Mäkelä-Kaikkonen J, Rautio T, Pääkkö E, Biancari F, Ohtonen P, Mäkelä J. Robot-assisted vs laparoscopic ventral rectopexy for external or internal rectal prolapse and enterocele: a randomized controlled trial. *Colorectal Dis* 2016;18(10):1010-1015.
39. Ramage L, Georgiou P, Tekkis P, Tan E. Is robotic ventral mesh rectopexy better than laparoscopy in the treatment of rectal prolapse and obstructed defecation? A meta-analysis. *Tech Coloproctol* 2015;19(7):381-389.
40. Rondelli F, Bugiantella W, Villa F, Sanguinetti A, Boni M, Mariani E, et al. Robot-assisted or conventional laparoscoic rectopexy for rectal prolapse? Systematic review and meta-analysis. *Int J Surg* 2014;12(Suppl 2):S153-S159.
41. Raskin ER, Gorrepati ML, Mehendale S, Gaertner WB. Robotic-assisted ileocolic resection for Crohn's disease: outcomes from an early national experience. *J Robot Surg* 2019;13(3):429-434.
42. Miller AT, Berian JR, Rubin M, Hurst RD, Fichera A, Umanskiy K. Robotic-assisted proctectomy for inflammatory bowel disease: a case-matched comparison of laparoscopic and robotic technique. *J Gastrointest Surg* 2012;16(3):587-594.
43. Rencuzogullari A, Gorgun E, Costedio M, Aytac E, Kessler H, Abbas MA, et al. Case-matched comparison of robotic versus laparoscopic proctectomy for inflammatory bowel disease. *Surg Laparosc Endosc Percutan Tech* 2016;26(3):e37-e40.
44. Sapci I, Gorgun E. Minimally invasive surgery in complex Crohn's disease. *Clin Colon Rectal Surg* 2019;32(4):300-304.
45. Baek SJ, Kim SH, Cho JS, Shin JW, Kim J. Robotic versus conventional laparoscopic surgery for rectal cancer: a cost analysis from a single institute in Korea. *World J Surg* 2012;36(11):2722-2729.
46. Park EJ, Cho MS, Baek SJ, Hur H, Min BS, Baik SH, et al. Long-term oncologic outcomes of robotic low anterior resection for rectal cancer: a comparative study with laparoscopic surgery. *Ann Surg* 2015;261(1):129-137.
47. Jeon Y, Park EJ, Baik SH. Robotic surgery for rectal cancer and cost-effectiveness. *J Minim Invasive Surg* 2019;22(4):139-149.
48. Morelli L, Guadagni S, Lorenzoni V, Di Franco G, Cobuccio L, Palmeri M, et al. Robot-assisted versus laparoscopic rectal resection for cancer in a single surgeon's experience: a cost analysis covering the initial 50 robotic cases with the da Vinci Si. *Int J Colorectal Dis* 2016;31(9):1639-1648.