Review Article

A review on robotic surgery in rectal cancer

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Abstract: Robotic surgery has the upper hand when compared to the laparoscopic approach in terms of superior visualisation, flexibility in movement, steadiness and accessibility to confined anatomical spaces. Nevertheless, limitations still exist with regards to cost, reduced tactile sensation, time-consuming setup and a significant learning curve to achieve. Although studies have shown better or at least comparable outcomes between the robotic and laparoscopic approach, the limitations mentioned result in poor penetrance among centres and surgeons. Advancements in robotic surgery technology and attaining the acquired skillset will translate into better clinical outcomes for patients.

Keywords: Robotic surgery; robotic-assisted surgery; rectal dissection; total mesorectal excision (TME); minimally invasive surgery (MIS)

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Introduction

Robotic surgery in the field of colorectal has been around since 2001. The first published experience was reported in 2002, where two colonic resections were performed on benign cases. With the rapid advancement in the field of medical science, there is definite potential for robotic surgery to overcome some of the limitations of conventional laparoscopic surgery.

Rectal dissection has always been a challenge due to its confined location and various dimensions of the rectum and mesorectum. Since it was described in 1982, total mesorectal excision (TME) has been the gold standard of rectal cancer surgery (1). In order to obtain good quality TME, a precise sharp dissection must be performed along the avascular plane while encompassing the entire mesorectum, which bears potential malignant lymph nodes (2).

Worldwide, laparoscopic surgery has been acknowledged as a safe and effective modality of rectal cancer surgery (3). However, a randomised controlled multicentre trial has recently suggested that the use of laparoscopic surgery in T3/T4 tumours may result in incomplete resection, affecting the oncological outcome in this group of patients (3).

The challenges of an incomplete TME in laparoscopic surgery are often encountered when faced with anatomical difficulties i.e., a narrowed male pelvis; bulky tumours and obese patients. Robotic rectal surgery, with superior visualisation and agility of its EndoWrist® (Intuitive Surgical Inc., Sunnyvale, CA, USA), might be the answer to this predicament.

This review will shed light on the potential benefits, clinical outcomes and pitfalls of robotic rectal surgery.

Surgical techniques

The da Vinci® robotic system (Intuitive Surgical Inc., Sunnyvale, CA, USA) is widely used in robotic rectal surgery. Robotic rectal surgery can generally be performed in two ways—the hybrid technique or the totally robotic technique (4).

The hybrid technique comprises of standard laparoscopic isolation and ligation of the inferior mesenteric vessels, mobilisation of the left colon and splenic flexure take down. The robotic system is then brought in to complete the pelvic dissection for TME. Distal rectal dissection can be performed laparoscopically or via robotics.

The totally robotic technique is typically a two-stage or three-stage procedure depending on the number of times the robotic cart is repositioned. A desirable single-stage totally robotic technique in which the robotic cart remains stationary throughout the surgery, has been described (5). Only the robotic arms were repositioned from the colonic phase to the pelvic and TME phase.

Potential benefits

Superior visualization

Minimally invasive surgery (MIS) would not have been successful if not for the technology that permits indirect viewing of the operating field either on a monitor or console. The quality and steadiness of the images produced are paramount to excellent surgical dissection.

Laparoscopic surgery gives a conventional 2-dimensional (2D) view, whilst robotic surgery produces a 3-dimensional (3D) image. This confers the added advantage to the surgeon by allowing better judgement in terms of depth and spatial relationships (6). The relative anatomy between important structures will be more apparent, thus allowing meticulous dissection.

With the advent of 3D vision systems in conventional laparoscopic surgery, some parties question the necessity for a robotic system. Furthermore, the usage of conventional laparoscopy with 3D images was comparable to robotic surgery in terms of short-term operative outcomes (7). We believe, however, that a mounted 3D camera system eliminates unavoidable assistant drawbacks such as fatigue or inexperience, thus producing impeccable steady images throughout surgery.

Enhanced motion

A limited range of movement as a result of the rigid design of conventional laparoscopic instruments beckons for the need of a more versatile appliance. The answer to this was the development of the EndoWrist®, an intuitive robotic instrument which mimics the human wrist. The motion is totally regulated by the surgeon's hand and finger movement (8). The system provides improved dexterity, seven degrees of freedom and motion scaling, while eliminating physiological tremor (9). This avoids iatrogenic injuries and improves peri-operative outcomes (10).

Ergonomics

Laparoscopic surgery has been related to an increased musculoskeletal discomfort for the surgeon, with studies reporting a rate of 73–87% (11). Ergonomic stress was believed to be a compounding factor. In laparoscopic surgery, the substantial use of muscles of the upper torso is associated with more fatigue (11). In robotic surgery, the surgeon is seated within the console, with an armrest in place. This ergonomic design reduces musculoskeletal discomfort.

Achievable learning curve

In general a learning curve can be ascertained from two methods; observation of a consecutive case series and cumulative sum (CUSUM) analysis.

In the first method, a consecutive case series is split into smaller segments i.e., quartiles. A univariate analysis will be performed to compare the means of these quartiles. Most publications look into decreased operative times, complications and estimated blood loss as indicators of improvement (12-14).

In the CUSUM analysis, the learning curve is divided into three phases (15,16). Bokhari *et al.* (16) and Yamaguchi *et al.* (17) described the initial phase (phase I) as a phase comprising of 15 and 25 cases respectively. As the surgeon becomes more experienced, they reach a plateau in the learning curve (phase II). Subsequent cases will be represented in phase III of the curve.

Interestingly, a study has reported that novice rectal surgeons—with limited experience of less than five cases in open/laparoscopic low rectal cancer resection—were able to achieve a similar learning curve in robotic-assisted low rectal resection (18). This faster learning curve may be compensated by their experience in other forms of minimally invasive colonic resection.

It should be reiterated that robotic surgery is technically demanding. We therefore propose a formal form of training in rectal dissection before undertaking robotic rectal surgery. This is best achieved through the proctorship of cases within a robotic rectal cancer surgery setting.

Clinical outcomes

The use of robotics for the treatment of rectal cancer has recently shown to be feasible, and numerous studies have looked into the short- and long-term clinical outcomes of robotic rectal surgery. The short-term outcomes that have been studied include the conversion rate, estimated blood loss, length of hospital stay, functional outcomes and post-operative complications. In the long-term, the oncological outcomes in robotic rectal surgery are discussed.

Conversion rate

Conversion to open surgery is an important predictor of the feasibility of minimally invasive approaches (19). Most studies report rates of conversion of 10–20% in laparoscopic low anterior resection (19). In robotic rectal surgery however, data with regards to conversion rate remains inconsistent.

A recent nationwide analysis showed a significant reduction of conversion for robotic versus laparoscopic rectal resections (5.38% *vs*. 13.38%). Similar findings were presented in other studies, where robotic surgery was shown to have lower or even a zero conversion rate (20-22). Despite this, other studies found no difference in conversion rates between robotic and laparoscopic surgery (23-26).

The on-going ROLARR (Robotic versus Laparoscopic Resection for Rectal Cancer) trial, that has now completed the phase of patient recruitment, aims to compare multiple outcomes between robotic and laparoscopic surgery. Conversion rate to open surgery is the primary endpoint of this study. Early reports have criticised the study design of this trial with regards to this primary endpoint, as a high assumption of 25% was hypothesised in the laparoscopic group. Due to this postulation, this study has failed to detect a clinically relevant difference in terms of conversion rate between robotic and laparoscopic surgery (robotic 8.1% *vs*. laparoscopic 12.2%; odds ratio 0.61, 95% CI: 0.31–1.21, P=0.158) (27).

Causes of conversion are multifactorial, but can be simply classified into patient factors and tumour characteristics. The most common cause for conversion was the inability to perform pelvic dissection satisfactorily; attributed to obesity or a narrow pelvis (28). Other reasons for conversion included presence of adhesions, excessive bleeding and bowel dilatation.

Estimated blood loss

A systemic review of 21 studies showed the amount of blood loss was only ranging from 16 to 400 mL for colorectal robotic surgery (29). A recent case-controlled analysis comparing TME between robotic and laparoscopic methods did not show any significant difference in the amount of blood loss (30). A separate meta-analysis review reaffirmed these findings (31).

Length of stay (LOS)

The LOS for robotic surgery was either similar (7) or shorter compared to laparoscopic surgery. The mean LOS differed between studies, with some reporting a mean LOS of approximately 5–7 days, while others quoting a post-operative LOS of 9–12 days (22,32,33). These findings are not unexpected, as both modalities are minimally invasive.

Postoperative complications

With regards to postoperative complications, again, many studies have shown similar or lower rates compared with laparoscopic surgery. Among the complications reported were anastomotic leakage, surgical site infection and ileus. Anastomotic leakage is a common postoperative complication after MIS, at a rate of 5–11% (5,8,34-36). In a meta-analysis review, Trastulli *et al*. (26) showed a lower leak rate with robotic resection.

The advantages of robotic surgery that were discussed earlier, including superior visualisation systems and enhanced motion allow for more precise dissection, thus resulting in favourable postoperative outcomes.

Preservation of function

When performing rectal cancer surgery, preservation of sexual function and urinary continence are essential, particularly as indicators of postoperative quality of life. The main cause of genitourinary dysfunction is injury to the hypogastric and/or sacral splanchnic nerves during surgery. These essential nerves are preserved when there is good visualisation and precise dissection that to our knowledge can best be achieved by robotic TME.

Most studies use the International Index of Erectile Function (IIEF) and International Prostate Symptoms Score (IPSS) to determine sexual and urinary function respectively. An IIEF score of less than 10 is defined as having sexual dysfunction whereas an IPSS score of more than 8 as urinary dysfunction.

In a recent prospective study, it was concluded that there was no difference in sexual dysfunction in open *vs*. robotic TME (37). In terms of urinary function, it was noted that patients who underwent open surgery suffered from urinary dysfunction in the first 3 months following surgery, but were able to regain their baseline function within a 3 to 12 months follow-up period (37). Another paper that discussed genitourinary outcomes in laparoscopic *vs*. robotic TME found that robotic TME for rectal cancer was associated with earlier recovery of normal voiding and sexual function compared to patients who underwent laparoscopic TME (38).

Survival rate

With regards to short-term oncologic outcomes, Baek *et al*. (39) reported that the 3-year overall survival (OS) rate after robotic surgery was 96.2% with a 3-year disease free survival (DFS) rate of 73.7%. This was found over a mean 20.2-month follow-up period. Pigazzi *et al*. (28) reported similar figures in his multicentric study, with a 3-year OS of 97% and a 3-year DFS of 77.6%. The mean follow-up rate in this study was 17.4 months. Both studies did not report any isolated loco-regional recurrence, but there were patients who developed distant metastasis, with or without local recurrence.

Long term OS rate was comparable between laparoscopic and robotic rectal surgery. At least two publications (25,33), have reported similar 5-year OS rates; 93.1% and 93.5% respectively in the laparoscopic arm, and 92.2% and 92.8% respectively in the robotic arm. A 5-year DFS rate was higher in the robotic group for both studies, at about 81%; 78% in the laparoscopic group. These values, however, did not translate into any significant difference between the OS and DFS rates between the two arms. Park *et al*. (33) showed a cumulative local recurrence of only 2.3% in the robotic group with no involvement of port and wound site.

It was initially hypothesised that robotic surgery, with its precise TME would improve survival rate. However, as evidenced by various studies looking into the short- and long-term OS and DFS rates, it appears that robotic surgery does not produce superior results compared to conventional laparoscopic technique.

Pitfalls

Technical limitations

Tissue handling is an important aspect in surgery. In laparoscopic surgery, there is presence of tactile feedback. In robotic surgery however, the surgeon has to rely more on visual cues to know how much force to exert in handling delicate tissue. As the tactile feedback is not apparent, sensation of pressure, vibration and sheer force are being masked. This leads to tissue injuries in inexperienced hands. In addition, robotic arm collisions can occur as a result of unplanned placement of working ports and the inability of the surgeon to visualise the movements of robotic arms during surgery.

Cost

Cost is a major issue and becomes a hindrance for new technology to flourish. In robotic surgery the cost comprises the robotic appliance, annual maintenance and changing of ancillary equipment.

The robotic systems typically costs anywhere between $1–$2.3 million. As a result of the steep price of equipment, patients who opt for MIS have to pay more when robotic surgery is performed. The charges range from $7,150 to $10,700 for robotic surgery, a 7- to 10-fold increase compared to laparoscopic surgery ($1,240) (40). Inevitably, total hospital charges were noted to be 1.5 times higher in the robotic group ($14,647 *vs*. $9,978). Furthermore, authors also reported a significantly lowered hospital profit (40).

Whether the high cost associated with robotic surgery translates into better clinical outcomes is yet to be proven in a cost-effectiveness study. To date, there are limited publications on this issue. A recent study by Kim *et al*. concluded that there was no evidence of cost-effectiveness of robotic surgery compared with laparoscopic surgery in 30 days. However, the functional i.e., sexual and bladder functions, and long-term outcomes were not analysed to give a more comprehensive understanding on the economical worth of robotic surgery (41).

With the increased awareness of the advantages that robotic colorectal surgery has to offer, coupled with competitive industry players, we are optimistic that there will be reductions in cost in the new future, making this modality more appealing for the masses.

What the future holds

Advancement in robotic systems will be apparent in years to come. Currently the fourth generation da Vinci® surgical system, the Xi® has revolutionised robotic surgery with its multiple enhancements and upgrades. Simpler docking, laser guided port placement and mounted robotic arms on a rotated-boom are among the key features in this new system. This is claimed to ease a single-stage fully robotic rectal dissection i.e., splenic flexure and pelvic dissection.

In the reported early experience performing rectal dissection with the da Vinci Xi®, there were no apparent intraoperative and postoperative complications. In addition, no conversion to open surgery has been reported (42).

Already, there are several novel technologies that have been incorporated to complement the existing robotic system. One such example is the da Vinci EndoWrist® Stapler 45 with its SmartClamp® feedback. This application allows for full range of motion while providing adequate tissue compression based on tissue thickness during stapling. Whether this advancement translates into better clinical outcomes, particularly in terms of anastomotic leak, is yet to be studied (43).

Another fascinating addition is the FireFly® Fluorescence Imaging application. The integration of this equipment, which utilises near-infrared technology, provides real-time, image-guided identification of key anatomical landmarks. This assists in better oncological resection, i.e., identification and preservation of anatomical structures, lymph node dissection, differentiating malignancy from normal tissue, and assessing organ and tissue perfusion (44,45).

Numerous research and technology groups are working towards transforming the robotic system that we use today. Concurrent with the growth in the fields of artificial intelligence, nanotechnology and communication systems, it is promising that our current robotic surgical systems will undergo revolutionary changes over the next few decades (46-48).

Conclusions

Patient safety is central to modern surgical treatment. With MIS making headway, it is promising that robotic surgery will provide the next major breakthrough in the treatment of rectal cancer. As of today, robotic systems have already revolutionised the surgical field, proving its advantage over laparoscopic techniques in terms of superior visualisation, enhanced motion, ergonomics and comparable clinical outcomes.

Before robotic rectal surgery is widely adopted however, the long-term prospects need to be better established. At present, the Robotic versus Laparoscopic Resection for Rectal cancer (ROLARR) trial is underway. Believed to be a robust study comprising of about 20 centres and involving eight countries, this study that is estimated to be completed by mid-2018 will address not just the short- and long-term clinical outcomes, but also the economical feasibility of robotic rectal surgery. It will be interesting to see if this trial changes the standard of care for rectal cancer surgery in the future. As an old saying goes—little do we know what the future holds.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

References

1. Heald RJ, Husband EM, Ryall RD. The mesorectum in rectal cancer surgery--the clue to pelvic recurrence? Br J Surg 1982;69:613-6.
2. Lichliter WE. Techniques in total mesorectal excision surgery. Clin Colon Rectal Surg 2015;28:21-7.
3. Bonjer HJ, Deijen CL, Abis GA, et al. A randomized trial of laparoscopic versus open surgery for rectal cancer. N Engl J Med 2015;372:1324-32.
4. Aly EH. Robotic colorectal surgery: summary of the current evidence. Int J Colorectal Dis 2014;29:1-8.
5. Choi DJ, Kim SH, Lee PJ, et al. Single-stage totally robotic dissection for rectal cancer surgery: technique and short-term outcome in 50 consecutive patients. Dis Colon Rectum 2009;52:1824-30.
6. Chmarra MK, Kolkman W, Jansen FW, et al. The influence of experience and camera holding on laparoscopic instrument movements measured with the TrEndo tracking system. Surg Endosc 2007;21:2069-75.
7. Guerrieri M, Campagnacci R, Sperti P, et al. Totally robotic vs 3D laparoscopic colectomy: A single centers preliminary experience. World J Gastroenterol 2015;21:13152-9.
8. Baik SH, Kwon HY, Kim JS, et al. Robotic versus laparoscopic low anterior resection of rectal cancer: short-term outcome of a prospective comparative study. Ann Surg Oncol 2009;16:1480-7.
9. Moorthy K, Munz Y, Dosis A, et al. Dexterity enhancement with robotic surgery. Surg Endosc 2004;18:790-5.
10. Park S, Kim NK. The Role of Robotic Surgery for

Rectal Cancer: Overcoming Technical Challenges in Laparoscopic Surgery by Advanced Techniques. J Korean Med Sci 2015;30:837-46.
11. Zihni AM, Ohu I, Cavallo JA, et al. Ergonomic analysis of robot-assisted and traditional laparoscopic procedures. Surg Endosc 2014;28:3379-84.
12. Tsao AK, Smaldone MD, Averch TD, et al. Robot-assisted laparoscopic prostatectomy: the first 100 patients-improving patient safety and outcomes. J Endourol 2009;23:481-4.
13. Kim YW, Lee HM, Kim NK, et al. The learning curve for robot-assisted total mesorectal excision for rectal cancer. Surg Laparosc Endosc Percutan Tech 2012;22:400-5.
14. Akmal Y, Baek JH, McKenzie S, et al. Robot-assisted total mesorectal excision: is there a learning curve? Surg Endosc 2012;26:2471-6.
15. Sng KK, Hara M, Shin JW, et al. The multiphasic learning curve for robot-assisted rectal surgery. Surg Endosc 2013;27:3297-307.
16. Bokhari MB, Patel CB, Ramos-Valadez DI, et al. Learning curve for robotic-assisted laparoscopic colorectal surgery. Surg Endosc 2011;25:855-60.
17. Yamaguchi T, Kinugasa Y, Shiomi A, et al. Learning curve for robotic-assisted surgery for rectal cancer: use of the cumulative sum method. Surg Endosc 2015;29:1679-85.
18. Foo CC, Law WL. The Learning Curve of Robotic-Assisted Low Rectal Resection of a Novice Rectal Surgeon. World J Surg 2016;40:456-62.
19. Collinson FJ, Jayne DG, Pigazzi A, et al. An international, multicentre, prospective, randomised, controlled, unblinded, parallel-group trial of robotic-assisted versus standard laparoscopic surgery for the curative treatment of rectal cancer. Int J Colorectal Dis 2012;27:233-41.
20. Liao G, Zhao Z, Lin S, et al. Robotic-assisted versus laparoscopic colorectal surgery: a meta-analysis of four randomized controlled trials. World J Surg Oncol 2014;12:122.
21. Lin S, Jiang HG, Chen ZH, et al. Meta-analysis of robotic and laparoscopic surgery for treatment of rectal cancer. World J Gastroenterol 2011;17:5214-20.
22. Sawada H, Egi H, Hattori M, et al. Initial experiences of robotic versus conventional laparoscopic surgery for colorectal cancer, focusing on short-term outcomes: a matched case-control study. World J Surg Oncol 2015;13:103.
23. Bianchi PP, Ceriani C, Locatelli A, et al. Robotic versus laparoscopic total mesorectal excision for rectal cancer: a comparative analysis of oncological safety and short-term outcomes. Surg Endosc 2010;24:2888-94.
24. Park JS, Choi GS, Lim KH, et al. Robotic-assisted versus laparoscopic surgery for low rectal cancer: case-matched analysis of short-term outcomes. Ann Surg Oncol 2010;17:3195-202.
25. Cho MS, Baek SJ, Hur H, et al. Short and long-term outcomes of robotic versus laparoscopic total mesorectal excision for rectal cancer: a case-matched retrospective study. Medicine (Baltimore) 2015;94:e522.
26. Trastulli S, Farinella E, Cirocchi R, et al. Robotic resection compared with laparoscopic rectal resection for cancer: systematic review and meta-analysis of short-term outcome. Colorectal Dis 2012;14:e134-56.
27. Jayne DG. On behalf of the ROLARR trial. Astract presented at the 23rd International Congress of the European Association for Endoscopis Surgery (EAES), Bucharest, Romania. June 3-6, 2015.
28. Pigazzi A, Luca F, Patriti A, et al. Multicentric study on robotic tumor-specific mesorectal excision for the treatment of rectal cancer. Ann Surg Oncol 2010;17:1614-20.
29. AlAsari S, Min BS. Robotic Colorectal Surgery: A Systemic Review. ISRN Surg 2012;2012:293894.
30. Allemann P, Duvoisin C, Di Mare L, et al. Robotic-Assisted Surgery Improves the Quality of Total Mesorectal Excision for Rectal Cancer Compared to Laparoscopy: Results of a Case-Controlled Analysis. World J Surg 2016;40:1010-6.
31. Lee SH, Lim S, Kim JH, et al. Robotic versus conventional laparoscopic surgery for rectal cancer: systematic review and meta-analysis. Ann Surg Treat Res 2015;89:190-201.
32. Colombo PE, Bertrand MM, Alline M, et al. Robotic Versus Laparoscopic Total Mesorectal Excision (TME) for Sphincter-Saving Surgery: Is There Any Difference in the Transanal TME Rectal Approach? : A Single-Center Series of 120 Consecutive Patients. Ann Surg Oncol 2015. [Epub ahead of print].
33. Park EJ, Cho MS, Baek SJ, et al. Long-term oncologic outcomes of robotic low anterior resection for rectal cancer: a comparative study with laparoscopic surgery. Ann Surg 2015;261:129-37.
34. Hellan M, Anderson C, Ellenhorn JD, et al. Short-term outcomes after robotic-assisted total mesorectal excision for rectal cancer. Ann Surg Oncol 2007;14:3168-73.
35. Ng KH, Lim YK, Ho KS, et al. Robotic-assisted surgery for low rectal dissection: from better views to better outcome. Singapore Med J 2009;50:763-7.
36. Zimmern A, Prasad L, Desouza A, et al. Robotic colon and rectal surgery: a series of 131 cases. World J Surg

2010;34:1954-8.
37. Ozeki S, Maeda K, Hanai T, et al. Effects of robotic rectal surgery on sexual and urinary function. Surg Today 2016;46:491-500.
38. Kim JY, Kim NK, Lee KY, et al. A comparative study of voiding and sexual function after total mesorectal excision with autonomic nerve preservation for rectal cancer: laparoscopic versus robotic surgery. Ann Surg Oncol 2012;19:2485-93.
39. Baek JH, McKenzie S, Garcia-Aguilar J, et al. Oncologic outcomes of robotic-assisted total mesorectal excision for the treatment of rectal cancer. Ann Surg 2010;251:882-6.
40. Baek SJ, Kim SH, Cho JS, et al. Robotic versus conventional laparoscopic surgery for rectal cancer: a cost analysis from a single institute in Korea. World J Surg 2012;36:2722-9.
41. Kim CW, Baik SH, Roh YH, et al. Cost-effectiveness of robotic surgery for rectal cancer focusing on short-term outcomes: a propensity score-matching analysis. Medicine (Baltimore) 2015;94:e823.
42. Morelli L, Guadagni S, Di Franco G, et al. Use of the new Da Vinci Xi during robotic rectal resection for cancer: technical considerations and early experience. Int J Colorectal Dis 2015;30:1281-3.
43. Intuitive surgical brings stapler instrumentation to da Vinci robotic-assisted surgical systems in the U.S., Europe & Asia. Available online: https://globenewswire.com/news-release/2015/07/14/751891/10141572/en/Intuitive-Surgical-Brings-Stapler-Instrumentation-to-da-Vinci-Robotic-Assisted-Surgical-Systems-in-the-U-S-Europe-Asia.html (accessed 30 January 2016).
44. Daskalaki D, Aguilera F, Patton K, et al. Fluorescence in robotic surgery. J Surg Oncol 2015;112:250-6.
45. Bae SU, Min BS, Kim NK. Robotic Low Ligation of the Inferior Mesenteric Artery for Rectal Cancer Using the Firefly Technique. Yonsei Med J 2015;56:1028-35.
46. Camarillo DB, Krummel TM, Salisbury JK Jr. Robotic technology in surgery: past, present, and future. Am J Surg 2004;188:2S-15S.
47. Tiwari MM, Reynoso JF, Lehman AC, et al. In vivo miniature robots for natural orifice surgery: State of the art and future perspectives. World J Gastrointest Surg 2010;2:217-23.
48. Rentschler ME, Dumpert J, Platt SR, et al. Natural orifice surgery with an endoluminal mobile robot. Surg Endosc 2007;21:1212-5.

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