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The MicroHand S robotic-assisted versus Da Vinci robotic-assisted radical resection for patients with sigmoid colon cancer: a single-center retrospective study

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Abstract

Background Sigmoid colon cancer is a lethal disease and has a strong indication for surgery. Robotic-assisted surgery is one of the promising alternative treatment for this disease. Nowadays, the MicroHand S surgical system and the Da Vinci surgical system have been assembled in China. However, there is still no report to study the therapeutic effects of the two robotic-assisted surgical systems. Thus, the purpose of this study was to compare clinical and economic outcomes of patients with sigmoid colon cancer undergoing robot-assisted radical surgery via The MicroHand S or Da Vinci surgical system.
Methods The clinical data of 45 patients with sigmoid colon cancer undergoing the MicroHand S or Da Vinci robotic-assisted surgery at The Third Xiangya Hospital of Central South University from January 2017 to January 2019 were retrospectively analyzed.
Results Twenty-one patients received MicroHand S robotic-assisted radical surgery and 24 patients received Da Vinci robot-assisted radical surgery. No significant differences were observed in terms of operation time, number of lymph node harvested, blood loss, intestinal exhaust time, time of oral feeding resumption, volume of abdominal cavity 24-h drainage, hospital stay, complication and rate of conversion, removal time of drainage tube and catheter between MicroHand S and Da Vinci group. However, the MicroHand S group had significantly lower hospitalization costs ($P=0.002$) and shorter time to get out of bed after surgery ($P=0.04$). In addition, no recurrence and metastases were observed in both groups during the follow-up.
Conclusions In patients with sigmoid colon cancer, the Da Vinci surgical system did not show obvious clinical advantages compared to the MicroHand S surgical system in surgical outcomes. However, the MicroHand S surgical platform showed advantages in terms of the hospitalization costs and length of postoperative bedtime. The outcome of this study will probably result in a shift to the MicroHand S surgical system as treatment preference in China.

Keywords Sigmoid colon cancer · Robotic-assisted surgery · The MicroHand S robot · The Da Vinci robot · Surgical outcomes

Colorectal cancer (CRC) is a common malignant tumor of the digestive system. It is the fourth most common cancer diagnosed among adults and the second leading cause of death related to cancer [1] in the United States. Surgery is the cornerstone of treatment for CRC [2], but traditional open abdominal incision is associated with significant morbidity and long period of convalescence. Therefore, patients and providers are both increasingly interested in the utilization, safety, and efficacy of minimally invasive surgery (MIS). Since the first successful incorporation of laparoscopy in colorectal surgery in 1991, MIS has yielded many tremendous developments in the field of colorectal cancer [3]. Recently, robotic-assisted surgery has revolutionized and has expanded the field of MIS beyond laparoscopic

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surgery [4]. Robotic-assisted surgery has gradually become the predominant MIS approach for CRC [5, 6] since 2009.

The Da Vinci surgical system was approved by the United States Food and Drug Administration (FDA) in 2000 [7]. This system provides enhanced, controlled three-dimensional high-definition vision, giving the visual field of operation a true sense of depth, seven degrees of freedom, and tremor elimination with improved dexterity. Weber et al. first performed robotic colorectal surgery in 2002 [8, 9]. Then D'Annibale et al. reported several cases treated via robotic-assisted colorectal surgery and concluded that a robotic system might be useful for procedures such as dissection of the inferior mesenteric artery and denitrification of the nerve plexus [10].

Currently, the Da Vinci robotic-assisted surgical system has been known as the most advanced surgical system all over the world. The number of Da Vinci robotic-assisted surgery is growing strongly in mainland China and the average amount of surgery performed by each robot is far ahead of that in other developed countries, which is twice the world's average rate of utilization in a few large medical centers in China. However, just about 70 the Da Vinci surgical robots have equipped in mainland China so far, the popularity of the Da Vinci robotic surgery system is far from enough in mainland China because of extremely high cost. Therefore, China has developed our own robotic-assisted surgical system (The "MicroHand S" surgical system, developed jointly by Central South University and Tianjin University) recent years and completed the first surgery of general surgery at The Third Xiangya Hospital in 2014. Therefore, there has been two robotic-assisted surgical system applied in China, The Da Vinci surgical system and the MicroHand S surgical system, but currently no clear evidence of clinical information is available regarding minimally invasive surgery between these two different robotic-assisted surgical systems. The Da Vinci surgical system and the MicroHand S surgical system in The Third Xiangya Hospital of Central South University have been used for radical surgery for colorectal cancer since 2016. To date, 45 cases of robotic-assisted radical surgery for sigmoid colon cancer have been completed. As such, we did this single-center retrospective study to explore clinical and economic outcomes of patients with sigmoid colon cancer undergoing robotic-assisted radical surgery via The MicroHand S or Da Vinci surgical system.

Materials and methods

Patient and data

In this single-center retrospective trial, 45 patients who pathologically confirmed sigmoid colon cancer at the Department of General Surgery, The Third Xiangya Hospital of Central South University, undergoing radical resection of sigmoid colon cancer, by either The Da Vinci surgical system ($n=24$) or MicroHand S surgical system ($n=21$) between January 2017 and January 2019 were included.

Inclusion criteria: (1) Adult patients (age from 18 to 80). (2) Colonoscopy biopsy confirmed sigmoid colon cancer. (3) No distant metastasis (including pelvic cavity, peritoneum, liver, lung, brain, bone, etc.) determined by Ultrasound or CT. (4) Not receive radiotherapy and chemotherapy before surgery. (5) No history of other malignant tumors or associated with other organ dysfunction. (6) Willing to choose robot surgery. Exclusion criteria: (1) Partial resection. (2) Multiple colorectal malignancies. (3) Combined with other sites of colectomy or other adjacent organ resection. (4) American Society of Anesthesiologists (ASA) Classification > Level III.

Clinical data including demographic baseline characteristics, operation time, number of lymph node harvested, intraoperative blood loss, intestinal exhaust time, time of oral feeding resumption, abdominal cavity 24-h drainage volume, removal time of drainage tube, removal time of catheter, hospital stay, Visual Analogue Score, the time to get out of bed after surgery, hospitalization costs, complication, and the rate of conversion were collected.

All operations were performed by the same well-experienced and qualified surgical team (who have done more than 100 cases of robotic-assisted General Surgery such as gastric and colorectal cancer radical surgery) of the Department of General Surgery, The Third Xiangya Hospital, Central South University. All of the work was reviewed and approved by the Medical Council's ethics committee of The Third Xiangya Hospital of Central South University (D14002 and Clinical Trials. gov No. NCT02752698). All patients or their legal representatives had signed the informed consent before enrollment. According to Chinese law, this work was regarded as quality-assured activity.

Robot-assisted surgical techniques

The "MicroHand S" surgical system consists of three parts: the doctor's console, the patient's console, and the accessories (Fig. 1).

The doctor's console includes the engine base, column, armrest, main mechanical arm (left/right main arm), image display device, and the control system, and completes function such as acquiring information of doctor's movement, boosting robotic arm lifting, and adjusting height of armrest. The patient's console includes engine base, lifting column, suspension arm, and electrical control system of slave robotic arm (left/right slave arm), and performs function as follow: master–slave communication (between the doctor's console and the patient's console), adjustment of lifting column, holdup of electric push rod of the base and

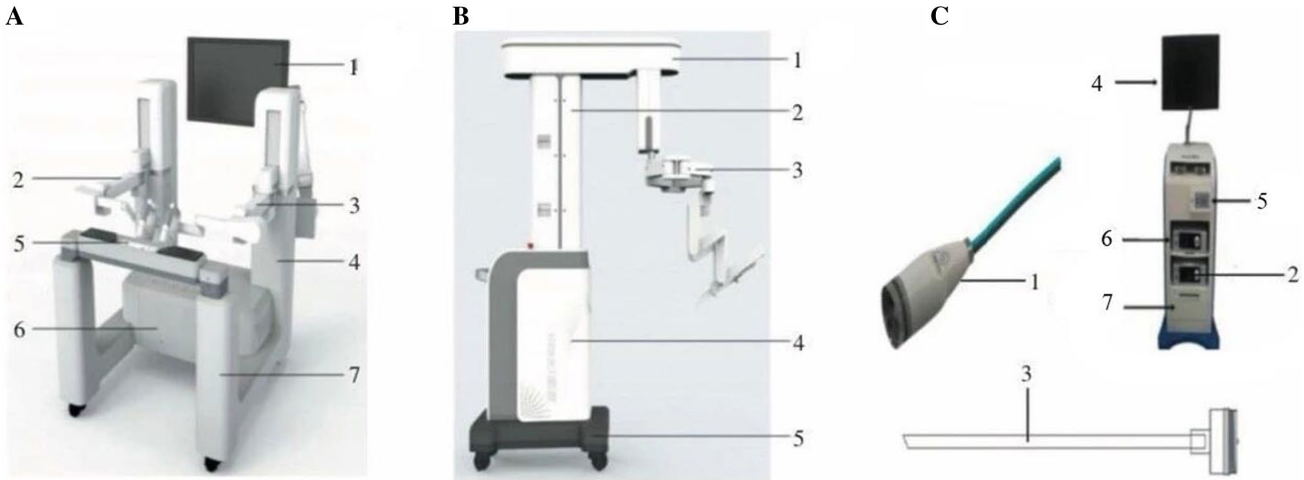

Fig. 1 The "MicroHand S" surgical system. **A** The doctor's console: 1, image display device; 2, left main arm; 3, right main arm; 4, engine base; 5, armrest; 6, control system; 7, column. **B** The patient's console: 1, suspension arm; 2, lifting columns; 3, slave arm; 4, electrical control system; 5, engine base. **C** Three-dimensional laparoscopy and camera system: 1, camera module; 2, ergonomics car and display; 3, three-dimensional laparoscopy; 4, image display unit; 5, control panel; 6, cold light; 7, locker. Refer Guohui et al. [29]

warning sound, etc. Accessories include three-dimensional laparoscopic and camera system, surgical instruments, sterile protective covers, and trocars.

Robot-assisted surgery were performed as follows: Patients were in the lithotomy position, a 12-mm right supraumbilical port was used to establish a pneumoperitoneum, then the peritoneum was accessed and the robotic camera (named the observational port) were inserted. Two abdominal 8-mm ports were placed at the umbilical level of double lower abdomen, which were 8 cm from the observational port, and another one 5 mm-incision were cut at the right upper abdomen for the fourth operational port (five puncture ports were selected for "The MicroHand S" robotic-assisted surgery, including a 12 mm trocar, placed in a three-dimensional laparoscope; two 10 mm "MicroHand S" dedicated trocar, using for connecting to the left and right arms, a 12 mm trocar and a 5 mm trocar as auxiliary operating hole. The incisions were respectively located in upper umbilicus, left lower abdomen, right lower abdomen and left and right front line at the umbilical level). After that the operating instrument was placed, intra-abdominal condition was routinely probed to determine the location of the tumor. During the process of anatomy, the inferior mesenteric arteriovenous and superior rectal arteries and veins were first dissected, then the inferior mesenteric arteriovenous and rectal superior arteriovenous were disconnected from the root and the titanium clip was attached. The rooted peritoneums were cut on both sides of the sigmoid mesenteric until to the upper end of the rectum from left to right, and then they were dissipated downward to the lower edge of the mass about 5 cm. A 5 cm-diameter incision in the lower left abdomen against the Mc Burney point was made, the sigmoid colon was pulled out of the incision, then the specimen was removed between 5 cm at the lower end of the mass and descending colon (10 cm from the mass), and closed respectively by the clamp. The descending colon and the upper rectum were anastomosed on the colonic band with the Johnson 60-cut closure, and the stump was closed and the abdomen was also closed.

Statistical analysis

Patients characteristics were summarized with frequencies and percentages (for categorical variables) or with mean values ± standard deviation. SPSS 22.0 software was used for data analysis. The measurement data was tested by t test and the counting data was tested by χ^2 test. $P < 0.05$ showed significant difference.

Results

Forty-five patients with sigmoid colon cancer were included from January 2017 to January 2019, 21 patients received MicroHand S robotic-assisted radical surgery and 24 patients received Da Vinci robotic-assisted radical surgery respectively. The patient's general information including age, gender, body mass index (BMI), maximum diameter of tumor, clinical stage, pathological type, ASA Grade, tumor markers (CEA, CA-199) had no significant difference ($P > 0.05$). Baseline characteristics were equally distributed between groups (Table 1).

No significant difference was observed in operation time, number of node harvested, intraoperative blood loss, intestinal

Table 1 Baseline characteristics

Variables	MicroHand S group ($n=21$)	Da Vinci group ($n=24$)	T/χ^2	P
Sex				
Male	12(57.1)	13(54.2)	0.040	0.841
Female	9(42.9)	11(45.8)		
Age	65.43 ± 9.38	59 ± 12.74	1.903	0.064
Maximum diameter of tumor	4.39 ± 1.86	4.44 ± 0.95	−0.109	0.914
BMI (kg/m^2)	22.85 ± 3.14	22.43 ± 3.95	0.385	0.702
Clinical stage			0.068	0.795
I	2(9.5)	0(0.0)	5.858	0.098
II	10(47.6)	7(29.2)		
III	8(38.1)	11(45.8)		
IV	1(4.8)	6(25.0)		
Pathological type				
Highly differentiated adenocarcinoma	9(42.9)	10(41.7)	0.010	0.995
Medium differentiated adenocarcinoma	7(33.3)	8(33.3)		
Poor differentiated adenocarcinoma	5(23.8)	6(25)		
ASA score				
I	2(9.5)	3(12.5)	0.222	1.000
II	12(57.1)	13(54.2)		
III	7(33.3)	8(33.3)		
CEA				
Normal	8(38.1)	10(41.7)	0.060	0.807
Up	13(61.9)	14(58.3)		
CA19-9				
Normal	9(42.9)	16(66.7)	2.571	0.109
Up	12(57.1)	8(33.3)		

Values are presented as mean ± standard deviation, or n (%)

ASA American Society of Anesthesiologists, *BMI* body mass index

exhaust time, time of oral feeding resumption, abdominal cavity 24-h drainage volume, removal time of drainage tube, removal time of catheter, hospital stay, Visual Analogue Score, complication, and the rate of conversion to open surgery between groups. However, the time to get out of bed was shorter [(2.14 ± 0.36) vs. (2.42 ± 0.50) days, $P=0.04$)] in the "MicroHand S" group than that in the Da Vinci group. More importantly, the hospitalization costs was significantly lower [(81719.48) ± (17388.81) vs. (107081.21 ± 30969.83) ¥, $P=0.002$] in the "MicroHand S" group compared to that in the Da Vinci group (Tables 2, 3).

The follow-up period was 4–24 months, with a median follow-up time of 15 months. During the follow-up period, no recurrence (at the primary site) and metastases was observed both groups.

Discussion

Robotic-assisted surgery has advantages such as less intraoperative bleeding, rapid postoperative recovery, and radical cure [11], compared to the traditional open surgery or laparoscopic surgery. Because of extremely expensive price of Da Vinci surgical system and the increasing demand for clinical application for robotic-assisted surgery, we have developed our own robotic-assisted surgical system—the "MicroHand S" surgical system (developed jointly by Central South University and Tianjin University) in China and completed clinical phase I study at The Third Xiangya Hospital. We performed a study to explore the clinical efficacy of two surgical systems (The

Table 2 Comparison of main clinical variables between the two groups

Variables	MicroHand S group ($n=21$)	Da Vinci group ($n=24$)	T/χ^2	P
Operation time (min)		241.71 ± 49.18	− 0.566	0.574
Number of lymph node harvested (*n*)	14.19 ± 5.86	14.08 ± 8.57	0.048	0.962
Intraoperative blood loss (ml)	118.57 ± 55.43	256.67 ± 444.36	− 1.509	0.144
Intestinal exhaust time (day)	4.33 ± 1.68	4.62 ± 1.86	− 0.548	0.586
Time of oral feeding resumption (day)	6.38 ± 2.56	5.71 ± 2.46	0.898	0.374
Time to get out of bed (day)	2.14 ± 0.36	2.42 ± 0.50	− 2.119	0.040*
Abdominal cavity 24-h drainage volume (ml)	120 ± 53.85	171.67 ± 113.58	− 1.904	0.064
Time of drainage tube removal (day)	7.81 ± 2.09	8.46 ± 0.78	− 1.344	0.191
Time of removal of catheter (day)	3.19 ± 1.17	2.92 ± 1.86	0.598	0.553
Hospital stay (day)	9.14 ± 1.59	9.79 ± 1.84	− 1.256	0.216
Hospitalization costs (¥)	81719.48 ± 17388.81	107081.21 ± 30969.83	− 3.320	0.002*
VAS				
First day after surgery	3.67 ± 0.66	3.92 ± 0.65	− 1.276	0.209
Second day after surgery	3.48 ± 0.51	3.58 ± 0.5	− 0.707	0.484
Third day after surgery	2.1 ± 0.62	2.25 ± 0.61	− 0.841	0.405
Conversion to open				
Yes	1(4.8)	2(8.3)	< 0.001	1.000
No	20(95.2)	22(91.7)		

Values are presented as mean ± standard deviation,or *n* (%)

VAS visual analogue score

*Statistically significant

Table 3 Comparison of complications between the two groups

Variables	MicroHand S group ($n=21$)	Da Vinci group ($n=24$)	χ^2	P
Hemorrhage	1(4.8)	2(8.3)	< 0.001	1.000
Incision infectin	1(4.8)	1(4.2)	< 0.001	1.000
Anastomotic leak	2(9.5)	1(4.2)	0.014	0.905
Intestinal obstruction	0(0.0)	1(4.2)	< 0.001	1.000
Total	4(19.0)	5(20.8)	< 0.001	1.000

Values are presented as mean ± standard deviation, or *n* (%)

Da Vinci surgical system and the "MicroHand S" surgical system) for radical resection in sigmoid colon cancer. Current experience has shown that the first laparoscopic colorectal surgery is best to start with sigmoidectomy. It is safe and reliable for surgical robots to apply for colorectal resection at the junction between rectal and sigmoid colon [12] and it has advantages in controlling intraoperative bleeding, reducing the rate of conversion, shortening the postoperative hospital stay. What's more, while intestine is located in the peritoneum, the process of free and ligation for vascular is relatively easy and the visual field does not move too much [13] for robotic-assisted surgery. Therefore, the selection of sigmoid colon cancer as the initial robotic-assisted colorectal surgery in our center was also based on those considerations above.

In our study, no significant differences were observed in operation time, number of lymph node harvested, intraoperative blood loss, intestinal exhaust time, time of oral feeding resumption, abdominal cavity 24-h drainage volume, removal time of drainage tube, removal time of catheter, hospital stay, complication, and the rate of conversion between groups. While the time to get out of bed after surgery was shorter in the "MicroHand S" group than that in the Da Vinci group, those factors are important indicators reflecting the clinical effect of surgery and the concepts recommended by Enhanced recovery after surgery (ERAS).

ERAS is a multidisciplinary and multi-modal approach to taking care of individuals undergoing surgery through implementation of evidence-based perioperative practices, it aims to maintain physiologic function, reduce pain, enhance early mobilization and facilitate early oral nutrition postoperatively by reducing perioperative stress [14–16]. It was developed initially for elective colorectal surgery [17]. The concept and pathway of ERAS have been widely accepted and proved to be beneficial in terms of improving postoperative outcomes in China. Early postoperative activities can promote recovery of multiple systems such as respiratory, gastrointestinal and musculoskeletal system etc. And help prevent lung infection, pressure sores and deep vein thrombosis of lower extremities [18].

As far as perioperative complications, including hemorrhage, incision infection, anastomotic leak, intestinal obstruction, there was no significant difference between two groups. The "MicroHand S" group was better than the Da Vinci group regarding early ambulation of ERAS and did not increase the incidence of complications.

The hospitalization costs were significantly lower in the MicroHand S group than that in Da Vinci group in our study. The application of Da Vinci robotic-assisted surgery for complex operations in colonic oncology can be facilitated for its main advantages [19]. However, robotic-assisted approach has been challenged because of the high costs of the Da Vinci robotic platform [20–23]. The only commercially available robotic equipment (da Vinci®, Intuitive Surgical Inc. CA, USA) is characterized by high cost, including the cost of equipment, acquisition, training, maintenance of the robotic system. We believed that the absence of competition in the market of robotic equipment is one of the most important factors for the high costs of robotic instrumentation [24]. The question must be answered if such a belief is correct, especially in developing China with extremely uneven economic development. The emergence of this new robotic-assisted surgery platform with completely independent intellectual property rights, the "MicroHand S" robotic-assisted surgical system, is good news for reducing costs of robot-assisted surgery in China. Our research showed that the cost of hospitalization for each patient in the "MicroHand S" group is nearly 20,000 ¥ lower than that of Da Vinci surgical group, while 20,000 ¥ is a huge expense for the majority of Chinese families in developing countries. It is believed that the cost of robot-assisted surgery will definitely drop significantly with the widespread use of "MicroHand S" surgical system, which is more conducive to the promotion and application of robotic-assisted system. It can be expected to break the monopoly of robotic-assisted surgical technology around the world in the near future.

The rate of conversion to open surgery was up to 8.3% in the Da Vinci group in our study, while 4.8% in MicroHand S group, but no significant difference was observed between two groups. Robotic-assisted colorectal surgery, compared with conventional laparoscopic surgery, did reduce the risk of conversion [25], but it still had certain rate of conversion, which was to 1.5–7.7% [26, 27]. Guend's data suggested that establishing a robotic-assisted colorectal cancer surgery program require approximately 75 cases. Once a program was well established, the learning curve was shorter and surgeons required fewer cases (25–30) to reach proficiency [28]. The rate of conversion was up to 8.3% in the Da Vinci group, slightly higher than existing reported data. Maybe it was in acceptable range, but our learning curve has been met, one reason may be that the size of sample enrolled was relatively small.

During follow-up time, no recurrence (at the primary site) and metastases was observed both groups. It seem that no significant trend of differences were founded in tumor free survival between groups, but the follow-up time was relatively short, the difference were not enough for statistical analysis. Currently, it should be regarded as no trend of differences regarding to disease-free survival, however, further research is needed.

Our study has some limitations. Firstly, as mentioned above, our sample size was still relatively small. Second, this is just a single-center respective study, because "MicroHand S" surgical robotic system only has been assembled in our hospital currently, multicenter randomized trials are needed for further research. Third, given that the follow-up time is relatively short, long-term follow-up results should be especially focused on disease-free survival and overall survival, making data more comprehensive and reliable.

In conclusion, we found that Da Vinci surgical system did not show the significant clinical advantages as the most advanced robotic-assisted surgical platform in the world today compared to the MicroHand S surgical system in surgical outcomes for patients with sigmoid colon cancer. However, the MicroHand S surgical platform showed advantages in terms of the hospitalization costs and length of postoperative bedtime. The outcome of this study will probably result in a shift to the MicroHand S surgical system as treatment preference in China.

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Compliance with ethical standards

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References

1. Wolf A et al (2018) Colorectal cancer screening for average-risk adults: 2018 guideline update from the American Cancer Society. CA Cancer J Clin 68(4):250–281
2. Pox C, Aretz S, Bischoff SC et al (2013) S3-guideline colorectal cancer version 1.0. Z Für Gastroenterol 51(8):753–854
3. Jacobs M, Verdeja JC, Goldstein HS (1991) Minimally invasive colon resection (laparoscopic colectomy). Surg Laparosc Endosc Percutaneous Tech 1(3):144–150
4. Corcione F, Esposito C, Cuccurullo D et al (2005) Advantages and limits of robot-assisted laparoscopic surgery: preliminary experience. Surg Endosc 19(1):117–119

5. Selby LV, Dematteo RP, Tholey RM et al (2017) Evolving application of minimally invasive cancer operations at a tertiary cancer center. J Surg Oncol 115(4):365–370
6. Jensen CC, Madoff RD (2016) Value of robotic colorectal surgery. Br J Surg 103(1):12–13
7. Mak TWC, Lee JFY, Futaba K et al (2014) Robotic surgery for rectal cancer: a systematic review of current practice. World J Gastrointest Oncol 6(6):184–193
8. Merola S, Wasielewski A, Ballantyne GH et al (2002) Telerobotic-assisted laparoscopic right and sigmoid colectomies for benign disease. Dis Colon Rectum 45(12):1689–1694
9. Hashizume M, Shimada M, Tomikawa M et al (2002) Early experiences of endoscopic procedures in general surgery assisted by a computer-enhanced surgical system. Surg Endosc Other Interv Tech 16(8):1187–1191
10. Annibale Annibale D', Pernazza G, Monsellato I et al (2013) Total mesorectal excision: a comparison of oncological and functional outcomes between robotic and laparoscopic surgery for rectal cancer. Surg Endosc Other Interv Tech 27(6):1887–1895
11. Yang SX et al (2018) Security and radical assessment in open, laparoscopic, robotic colorectal cancer surgery: a comparative study. Technol Cancer Res Treat. https://doi.org/10.1177/1533033818794160
12. Kai Shen, Fan Liu, Bin Liang et al (2017) A comparative study of Da Vinci robotic surgery system and laparoscopic treatment of colorectal cancer. Chin J Gen Surg 32(10):813
13. Tsai KY, Kiu KT, Huang MT et al (2016) The learning carve for laparoscopic colectomy in colorectal cancer at a new regional hospital. Asian J Surg 39(1):34–40
14. Ljungqvist O, Scott M, Fearon KC (2017) Enhanced recovery after surgery: a review. JAMA Surg 152(3):292–298
15. Meyer LA, Javier L, Iniesta MD et al (2018) Effect of an enhanced recovery after surgery program on opioid use and patient-reported outcomes. Obstet Gynecol 132(2):281–290
16. Thorell A, Mac Cormick AD, Awad S et al (2016) Guidelines for perioperative care in bariatric surgery: enhanced recovery after surgery (ERAS) society recommendations. World J Surg 40(9):2065–2083
17. Fearon KC, Ljungqvist O, Von Meyenfeldt M et al (2005) Enhanced recovery after surgery: a consensus review of clinical care for patients undergoing colonic resection. Clin Nutr 24(3):466–477
18. Wei Chen, Yajin Chen, Hailong Dong et al (2018) Chinese expert consensus and path management guide for accelerated rehabilitation surgery. Chin J Pract Surg 1:1–20
19. Gkegkes I, Mamais I, Iavazzo C (2016) Robotics in general surgery: a systematic cost assessment. J Minim Access Surg 13(4):243
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. Park JY, Jo MJ, Nam BH et al (2012) Surgical stress after robot-assisted distal gastrectomy and its economic implications. Br J Surg 99:1554–1561
22. Strong VE, Forde KA, MacFadyen BV et al (2014) Ethical considerations regarding the implementation of new technologies and techniques in surgery. Surg Endosc 28:2272–2276
23. Kneuertz PJ et al (2019) Hospital cost and clinical effectiveness of robotic-assisted versus video-assisted thoracoscopic and open lobectomy: a propensity score-weighted comparison. J Thorac Cardiovasc Surg 157(5):2018–2026
24. Iavazzo C, Gkegkes ID (2017) Cost-benefit analysis of robotic surgery in gynaecological oncology. Best Pract Res Clin Obstet Gynaecol 45:7–18
25. Cleary RK, Mullard AJ, Ferraro J et al (2017) The cost of conversion in robotic and laparoscopic colorectal surgery. Surg Endosc 32(3):1515–1524
26. Lee YF, Albright J, Akram WM et al (2018) Unplanned robotic-assisted conversion-to-open colorectal surgery is associated with adverse outcomes. J Gastrointest Surg 22(6):1059–1067
27. 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(6):1223–1230
28. Guend H, Widmar M, Patel S et al (2017) Developing a robotic colorectal cancer surgery program: understanding institutional and individual learning curves. Surg Endosc 31(7):2820–2828
29. Guohui W, Bo Y, Yong L et al (2019) Clinical phase I study of domestic surgical robots (report of 103 cases). Chin J Pract Surg 39(8):840–843