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Minimally invasive surgery for colorectal cancer, a look back to look forward: a personal history

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While laparoscopic colonoscopy was reported by several surgeons in the early 1990s, laparoscopic colorectal surgery has been attempted sporadically since 1992 in Korea. Then, in 2000, the Korean Laparoscopic Colorectal Surgery Study Group was established. Didactic lectures, videos, and live surgery by the early pioneers of this group inspired and helped many surgeons initiate the laparoscopic approach to the treatment of colorectal disease. As a result, the penetration rate of minimally invasive colorectal cancer surgery nationwide is increasing to 80% in 2018. As a witness on this journey, I would like to share my personal minimally invasive colorectal cancer surgery history and perspectives on future surgery in this field.

Keywords: Colorectal neoplasms, Minimally invasive surgical procedures, Laparoscopy, Robotic surgical procedures, Korea

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INTRODUCTION

While laparoscopic colonoscopy was reported by several surgeons in the early 1990s, laparoscopic colorectal surgery has been attempted sporadically since 1992 in Korea. In 2000, the Korean Laparoscopic Colorectal Surgery Study Group was established. Didactic lectures, videos, and live surgery by the early pioneers of this group inspired and helped many surgeons initiate use of the laparoscopic approach for the treatment of colorectal disease. As a result, the penetration rate of minimally invasive colorectal cancer surgery nationwide increased to 80% in 2018. As a witness to this journey, I would like to share my personal minimally invasive colorectal cancer surgery history and perspectives on future surgery in this field (Fig. 1).

MAIN SUBJECTS

Laparoscopic colorectal surgery in Korea: humble beginning but prosperous

There is no doubt that the Korean Laparoscopic Colorectal Surgery Study Group (the first Chairman, Jun-Gi Kim), launched in 2000 by several founding members, laid the foundation for laparoscopic colorectal cancer surgery in Korea [1]. During its first

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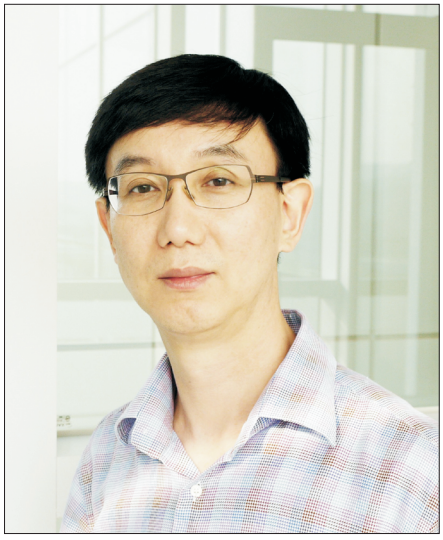

Fig. 1. The 18th president of the Korean Society of Endoscopic & Laparoscopic Surgeons, Professor Gyu-Seog Choi.

few years, the group attracted the attention of young surgeons after bimonthly meetings with live demonstrations, didactic lectures, and videos, and its active membership grew exponentially to over 100 members. As a result, recent laparoscopic penetration rates for colorectal cancer treatment are approximately 85% and 75% for rectal and colon cancers, respectively (Fig. 2). Considering that open surgery is unavoidable in advanced cases, these rates have already reached their peak. Personally, I started performing laparoscopic surgery in a small communal hospital in 1994 and performed several colorectal surgeries, particularly right hemicolectomy, low anterior resection, and abdominoperineal resection. I joined Kyungpook National University Hospital as faculty in the Department of Surgery in 1996. Then, fortunately, I continued to develop minimally invasive surgery. After 25 years of working in the Colorectal Surgery Department, now more than 95% of colorectal cancer surgeries can be performed by minimally invasive approaches, either laparoscopically or robotically. I am also honored and grateful for the opportunity to serve as the president of the Korean Society of Endoscopic & Laparoscopic Surgeons for 1 year.

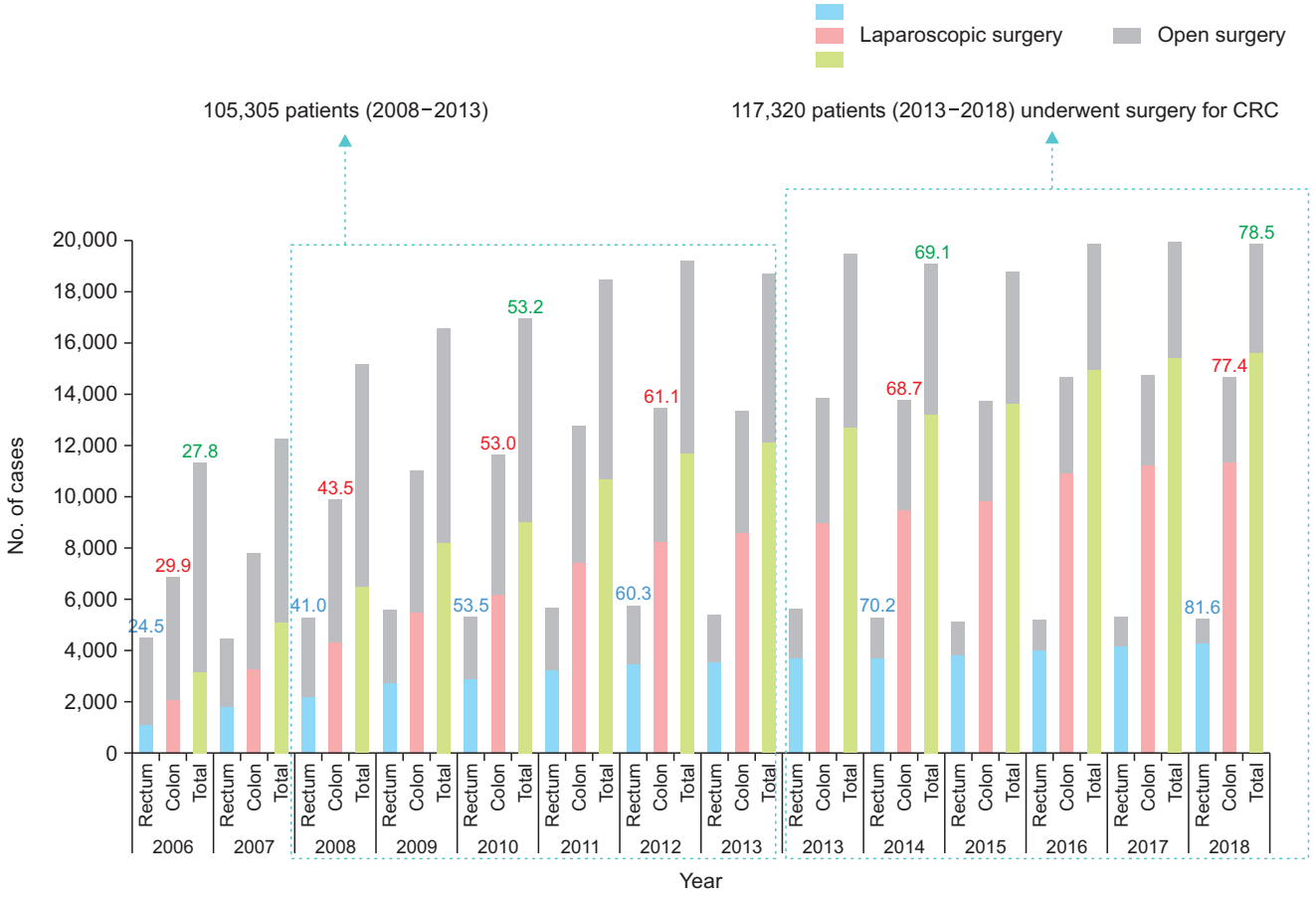

Fig. 2. The laparoscopic penetration rate for colorectal cancer (CRC) in Korea, 2006–2018; in courtesy of Sun-Jin Park (Editor-in-chief of *Journal of Minimally Invasive Surgery*).

Learning curve

The acquisition of new skills in surgery inevitably requires a period of learning. In the early days of laparoscopic surgery, the relatively steep learning curve was taken for granted. Therefore, we attempted to determine the learning curve for competency in performing laparoscopic colorectal surgery for 1,014 patients in the first 10 years [2]. We categorized patients into nine periods according to the number of surgeries performed. The operative time continuously decreased for right hemicolectomy (216 minutes vs. 150 minutes) and anterior resection (214.8 minutes vs. 147.7 minutes), whereas for low anterior resection it did not change over many periods and then significantly decreased after the ninth period (221.3 minutes vs. 176.4 minutes). The rate of anastomotic leakage and open conversion significantly decreased after 200 and 100 cases, respectively. The number of harvested lymph nodes stabilized for right hemicolectomy after 200 cases, whereas it stabilized after the initial 20 cases for left colon and rectal cancer. Overall, the disease recurrence rate was 16% to 25%. For rectal cancer, the local recurrence rate was the highest (12%) in the fourth period and decreased thereafter to approximately 3%.

We separately analyzed 381 laparoscopic rectal cancer surgeries and found that the operative time decreased significantly after 90 surgeries [3]. The overall anastomotic leakage rate was 3.7%; it was 14.6% for the first 50 patients and 5.4% for the following 40 cases. The overall conversion rate was 2.9% and was 4% to 6% during the first and second periods but decreased thereafter. For patients with stage I to III tumors, the local recurrence rate was 8.9% initially and decreased to 1.4% after the second period. The cumulative incidence of local recurrence decreased to less than 7% after 120 cases and to less than 5% after 180 cases.

Initial oncologic results

Over time, the oncologic safety of laparoscopic colon surgery has been confirmed by several randomized clinical trials. However, for rectal cancer, its oncologic outcomes had not initially been elucidated. We reported the long-term results of laparoscopic rectal cancer surgery compared with open surgery using a propensity score matching analysis (n = 812) [4]. There were no significant differences in the mortality, morbidity, or pathological quality in the two groups. The 3-year local recurrence rate (3.8% in the laparoscopic group [LAP group] and 5.9% in the open surgery group [OS group], $p = 0.089$) and disease-free survival rate (80.5% in the LAP group and 82.9% in the OS group, $p = 0.516$) for all tumor stages were similar between the groups. We concluded that laparoscopic rectal resection for rectal cancer is feasible and safe and has acceptable oncologic outcomes.

In the following year, a collaboration between our institute and Kyoto University gave rise to a study on intermediate oncological outcomes for laparoscopic versus open intersphincteric resection (ISR), which is a more complex procedure in rectal cancer management [5]. A total of 80 patients in the OS group and 130 in the LAP group were compared. The major complication rates were similar in the LAP and OS groups (5.4% vs. 3.8%, respectively; $p = 0.428$). However, the LAP group had a shorter hospital stay and time for bowel movement than the OS group. In the LAP group, the operative time was 16 minutes shorter ($p = 0.230$), and there was less intraoperative blood loss ($p = 0.002$). The local recurrence rates were similar in the two groups (LAP group, 2.6% vs. OS group, 7.7%; $p = 0.184$). The combined 3-year disease-free survival for all stages was 82.1% in the LAP group and 77.0% in the OS group ($p = 0.523$). We concluded that laparoscopic ISR can be performed safely and offers a minimally invasive sphincter-sparing alternative. The intermediate-term outcomes of the LAP group seemed to be equivalent to those achieved in the OS group.

Extended indications

With the accumulation of experience and the wide spread of laparoscopic surgery, we ambitiously extended the indications for laparoscopy to the more complicated clinical situations listed below.

Laparoscopic management of obstructive colon cancer

In general, obstructive colon cancer had been managed by open staged or one-stage surgery and was considered a contraindication for laparoscopy in the early period of laparoscopic surgery. In addition, a self-expandable metallic stent (SEMS) was used mainly for palliation of obstructive colorectal cancer. We adopted the SEMS technique as a bridge to laparoscopic surgery in the early 2000s; open surgery with intraoperative colon lavage (OLAV) had previously been a routine procedure for obstructive colon cancer. We evaluated the operative outcomes of 25 patients who underwent preoperative stenting and elective laparoscopic surgical treatment (SLAP group) and 70 patients who underwent emergency OLAV (OLAV group) [6]. In the SLAP group, a primary anastomosis was possible in all patients, and a diverting stoma was needed in one patient. The operative time was shorter in the SLAP group (198.53 minutes vs. 262.17 minutes, $p = 0.002$). The tumor size, number of retrieved lymph nodes, and pathological stage were similar in both groups. The rate of anastomotic failure was similar, and postoperative complications occurred less in the SLAP group (5.9% vs. 31.4%, $p = 0.034$). The overall postoperative recovery was quicker in the SLAP group.

We followed up this cohort for 51 months (range, 4–139 months) and found that perineural invasion of the primary tumor was more frequent in the SLAP group (76% vs. 51.4%, $p = 0.033$) [7]. However, there were no significant differences between

groups in the 5-year overall survival rates (SLAP group, 67.2% vs. OLAV group, 61.6%; $p = 0.385$). The 5-year disease-free survival rates were also similar between groups (SLAP group, 61.2% vs. OLAV group, 60.0%; $p = 0.932$).

Simultaneous laparoscopic multivisceral resection

We evaluated the short-term outcomes of 93 simultaneous laparoscopic surgeries combined with resection for synchronous lesions in patients with colorectal cancer, and the remaining 1,090 cases were included in a non-combined group [8]. As expected, the operative time was significantly longer in the combined group. Nonetheless, the other intraoperative complications and open conversion rates were similar in both groups. The rate of postoperative morbidity in the combined group was also similar to that in the non-combined group (combined, 15.1% vs. non-combined, 13.5%; $p = 0.667$). The oncological safety for the colon and synchronous lesions was determined in the combined group. Thus, our conclusion was that simultaneous laparoscopic multiple organ resection combined with colorectal cancer is a safe and feasible option in selected patients.

Extramesocolic/mesorectal lymph node dissection

Resection of lymph nodes up to the D3 level (near the origin of named vessels) is commonly recommended for advanced colorectal cancer as well as total mesocolic or mesorectal excision (TME) in a package. However, surgical dissection beyond these apical nodes has long been a controversy in terms of its oncologic benefits and technical feasibility. We started performing laparoscopic lateral pelvic node dissection (LPND) in 2003 and published the initial results [9]. Sixteen consecutive laparoscopic TME procedures with selective LPND were performed for patients with suspicion of lateral pelvic node (LPN) metastasis. In brief, no open conversion, a mean operative time of 321.9 minutes, a mean number of harvested LPNs of 9.1, a metastatic rate of 56.2%, and a mean hospital stay of 9.9 days were found. The postoperative mortality and morbidity were 0% and 31.2%, respectively. Recently, robotic surgery has been the main approach for this difficult procedure, and the results will be described in more detail.

The other site of extramesocolic/mesorectal lymph node dissection is the paraaortic lymph nodes (PaLNs). A total of 40 patients underwent laparoscopic PaLN dissection with a mean operative time of 192.3 minutes, minimal blood loss, no open conversion, and a postoperative complication rate of 15% [10]. Sixteen patients (40.0%) had pathologically positive lymph nodes. In patients with metastatic PaLNs, the 3-year overall survival rate and disease-free survival rate were 65.7% and 40.2%, respectively.

Laparoscopic cytoreductive surgery and intraperitoneal chemotherapy for peritoneal metastasis of colorectal cancer

A combination of cytoreductive surgery (CRS) and intraperitoneal chemotherapy (IPC) +/– systemic chemotherapy is arguably the only method with a survival benefit for patients with colorectal cancer with peritoneal metastasis. Disease extent and surgical completeness are regarded as the most important prognostic factors. Laparoscopic CRS is a challenging and rarely reported surgical procedure. Between November 2004 and February 2010, 29 patients underwent CRS and early postoperative IPC; 15 patients underwent laparoscopic surgery, and 14 underwent open surgery [11]. Synchronous peritoneal carcinomatosis was found more commonly in the LAP group, and a higher Gilly stage of peritoneal carcinomatosis was found more frequently in the OS group. There were fewer complications and a shorter hospital stay in the LAP group. However, the outcomes for patients who underwent the combined treatment were similar between the two groups with respect to the completeness of cytoreduction, operative morbidity, and overall survival. The LAP group had a cytoreduction completeness of 86.7% and an operative morbidity of 13.3%. Operative mortality occurred in one patient after open surgery.

With a peritoneal cancer index of ≤10 in the following study (42 patients who underwent laparoscopic surgery and 21 who underwent open surgery) [12], complete cytoreduction was achieved in all patients in the LAP group and in 19 patients (91%) in the OS group ($p = 0.042$). The mean hospital stay was shorter, and the use of postoperative narcotics was significantly less frequent in the LAP group. The type of surgery (open surgery vs. laparoscopic surgery) was not related to survival outcomes. Therefore, with careful selection by experienced laparoscopic surgeons, laparoscopic CRS was technically feasible and safe to treat patients with colorectal cancer with limited peritoneal metastases.

Efforts for lesser and lesser invasive surgery

On the other hand, a movement to maximize the advantages of minimally invasive surgery by minimizing the invasiveness of surgery has led to single-incision laparoscopic surgery (SILS), natural orifice translumenal endoscopic surgery (NOTES), and natural orifice specimen extraction (NOSE). In 2006, Woo Yong Lee, Seung Yong Jeong, Dae Kyung Sohn, and myself attended a NOTES meeting in Boston and subsequently organized The Korean Noscar Surgery Study Group. We enthusiastically conducted workshops and several preclinical trials but realized that it was too early to apply NOTES in patients due to lack of formidable technologies and instruments at that time. Therefore, our institute turned to NOSE which seemed, we believed, to be more practical to afford similar benefits to NOTES to patients with the compromise of a few more incisions.

Consequently, we developed total laparoscopic colectomy with transvaginal anastomosis and extraction of specimens in female patients with right-sided colon cancer [13]. We reported the initial clinical results in a series of 14 consecutive patients [13]. The median operative time was 150 minutes (range, 110–330 minutes). No patient experienced complications directly associated with the transvaginal approach, nor did any patient have an infection or prolonged spotting from the extraction site postoperatively. Recovery after the procedure was rapid, and the median hospital stay was 7.0 days (range, 6–12 days). With a median follow-up of 34 months, one patient experienced distant metastasis (7.1%). In selected cases, this technique is feasible and reproducible and may be an alternative for treatment of women with right-sided colon cancer. In a subsequent comparative study of NOSE vs. conventional laparoscopic surgery with 34 patients in each group, the postoperative recovery was quicker, and the pathological results were similar [13]. After a median follow-up of 23 months (range, 5–40 months), there was no transvaginal access-site recurrence or posterior colpotomy-related complications. NOSE was associated with significantly better cosmetic results ($p = 0.037$).

Similarly, we attempted NOSE for selected patients with rectal cancer and reported its long-term oncologic outcomes after reviewing 844 patients (163 NOSE group and 681 conventional LAP group) [14,15]. After propensity score matching, each group included 138 patients with a median follow-up of 57.7 months; the 5-year local recurrence rate for all tumor stages was 4.1% in the NOSE group and 3.0% in the conventional LAP group ($p = 0.355$). The 5-year disease-free survival rates were similar as 89.3% and 87.3%, respectively ($p = 0.639$).

Robotic surgery

A surgical robot was installed in our unit in 2007. We applied this robotic system in various kinds of colorectal surgeries. However, we focused on rectal cancer surgery, especially in complex cases, rather than colon cancer surgery (Fig. 3).

Right-sided colon cancer

The advantages of robotic surgery in right colectomy might be insufficient to justify the higher costs of robotic surgical systems. We conducted a randomized clinical trial to compare the outcomes of robotic-assisted colectomy (RAC) with those of traditional laparoscopic-assisted colectomy (LAC) in patients with right-sided colon cancer [16]. A total of 70 patients were included. The length of hospital stay (primary endpoint), surgical complications, and the number of harvested lymph nodes were not different in the two groups. However, the duration of surgery was longer in the RAC group (195 minutes vs. 130 minutes, $p < 0.001$), and overall hospital costs were significantly higher for RAC (US $12,235 vs. US $10,320, $p = 0.013$). Therefore, we concluded that RAC was feasible but provided no benefit to justify the greater cost.

In the long-term oncologic outcomes of this study [17], the combined 5-year disease-free survival rate for all tumor stages was 77.4% (95% confidence interval [CI], 60.6%–92.1%) in the RAC group and 83.6% (95% CI, 72.1%–97.0%) in the LAC group ($p = 0.442$). The combined 5-year overall survival rates for all stages were 91.1% (95% CI, 78.8%–100%) in the RAC group and 91.0% (95% CI, 81.3%–100%) in the LAC group ($p = 0.678$). We confirmed the clinical benefits of RAC that could translate to a decrease in expenditures.

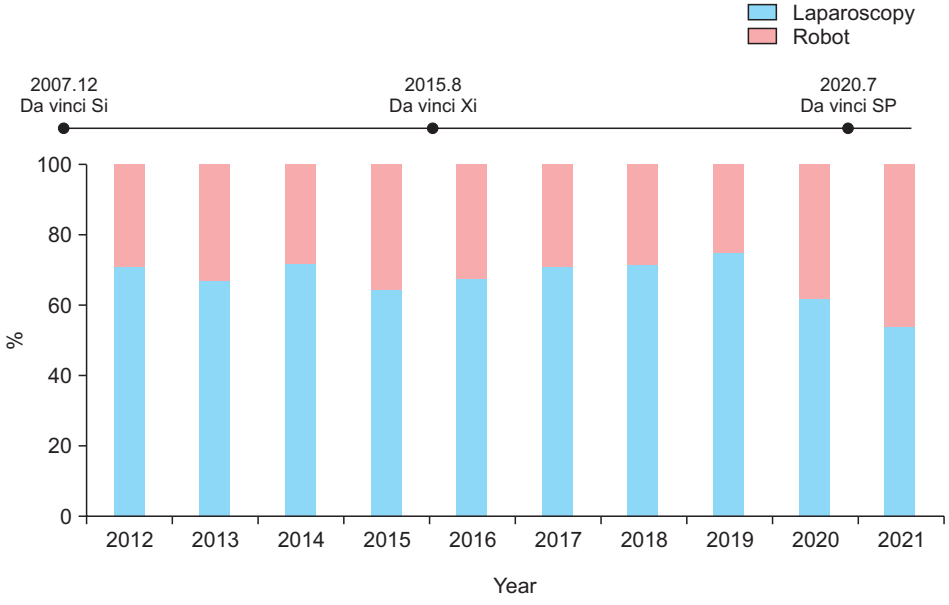

Fig. 3. The proportion of robotic surgery for colorectal cancer in Kyungpook National University Chilgok Hospital.

Rectal cancer

We started using robotic TME for the treatment of rectal cancer in 2007. We compared the short-term outcomes for open, laparoscopic, and robot-assisted rectal resection. A total of 263 patients with rectal cancer were classified into an OS group (n = 88), a LAP group (n = 123), and a robot-assisted group (RAP group, n = 52) and evaluated [18]. The mean operative time was 233.8 minutes for the OS group, 158.1 minutes for the LAP group, and 232.6 minutes for the RAP group ($p < 0.001$). Patients from the LAP and RAP groups recovered significantly faster than did those from the OS group ($p < 0.05$). The specimen quality with a distal resection margin, harvested lymph nodes, and circumferential margin, did not differ among the three groups. The overall complication rates were 20.5%, 12.2%, and 19.2% in the OS, LAP, and RAP groups, respectively ($p = 0.229$). We concluded that the robotic system provided no significant short-term clinical benefit over the conventional laparoscopic approach. Recently, we investigated 415 patients with laparoscopic and 118 patients with robotic low anterior resection for stage I to III mid/low rectal cancer [19]. During a median follow-up of 54.1 months, the 5-year disease-free survival rate was 80.5% in the LAP group and 87.6% in the robotic group ($p = 0.118$). The 5-year distant recurrence rates were significantly lower in the robotic group (19.0% vs. 10.0%, $p = 0.048$), but the 5-year local recurrence rates were similar in the two groups (4.2% vs. 3.7%, $p = 0.846$). In a subgroup of patients who received preoperative chemoradiation (CRT) and had ypT3/4 tumors, the 5-year distant recurrence and local recurrence rates were 44.8% and 5.0%, respectively, in the LAP group and 9.8% and 9.8%, respectively, in the robotic group ($p = 0.014$ and $p = 0.597$). We concluded that robotic surgery for mid/low rectal cancer shows similar long-term oncologic outcomes to laparoscopic surgery but is beneficial to a certain group of patients with advanced rectal cancer with a poor response to neoadjuvant CRT.

Intersphincteric resection

On behalf of the Korean Laparoscopic Colorectal Surgery Study Group, patients who underwent robotic or laparoscopic ISR with coloanal anastomosis between 2008 and May 2011 from seven institutions were retrospectively analyzed [20]. Propensity score analyses were performed to compare outcomes for groups in a 1:1 case-matched cohort, and 106 patients in each group were evaluated. The overall conversion rate to open surgery was 0.9% in the robotic ISR group and 1.9% in the laparoscopic ISR group. Nine patients (8.5%) in the LAP group and three (2.8%) in the robotic ISR group still had a stoma at the last follow-up visit ($p = 0.075$). The total mean hospital costs were significantly higher for robotic ISR (€12,757 vs. €9,223 for laparoscopic ISR, $p = 0.037$). The overall 3-year local recurrence rates were similar in the two groups (6.7% for robotic and 5.7% for laparoscopic resection, $p = 0.935$). The combined 3-year disease-free survival rates were 89.6% (95% CI, 84.1%–95.9%) and 90.5% (95% CI, 85.4%–96.6%) for the robotic and LAP groups, respectively ($p = 0.298$). We suggested that robotic ISR for rectal cancer has reasonable oncological outcomes but is currently too expensive with no short-term advantages.

Functional outcomes

Urinary and sexual dysfunction are complications of rectal cancer surgery. Based on our initial experiences, we compared 32 men who underwent robotic TME with matched patients who underwent laparoscopic TME [21]. The International Prostatic Symptom Score (IPSS) for urinary function did not differ between the two groups, but the mean five-item version of the International Index of Erectile Function (IIEF-5) scale was significantly higher in the robotic TME group at 6 months than in the laparoscopic TME group (14.1 ± 6.1 vs. 9.4 ± 6.6, $p = 0.024$). The interval decrease in IIEF-5 scores was significantly higher in the laparoscopic TME group than in the robotic TME group at 6 months (4.9 ± 4.5 vs. 9.2 ± 4.7, $p = 0.030$). This result was confirmed again when we compared patients undergoing laparoscopic or robotic TME for rectal cancer between 2009 and 2013 via a propensity score matching analysis [22]. The global health status/quality of life (QoL) was similar between the two groups for 130 matched pairs, but the robotic group showed better role, emotional, and social functioning and experienced less fatigue and financial difficulty. The IPSS in men increased postoperatively, with significantly less impairment in the robotic TME group at 6 months. These scores were comparable to the preoperative scores at 6 months in the robotic group and at 12 months in the LAP group. Of 48 sexually active men in each group, the IIEF-5 scores decreased postoperatively, returning to preoperative levels at 6 months in the robotic group and at 12 months in the LAP group. The robotic approach for TME was associated with less impairment of urinary and sexual function; the QoL was comparable to the laparoscopic approach.

The usefulness of fluorescence and three-dimensional computed tomography reconstruction

Near-infrared fluorescence imaging (FI) with indocyanine green (ICG) in surgical fields provides real-time information regarding blood or lymphatic flow. We mainly adopted this technique in visualizing lymph nodes in advanced colorectal cancers to confirm complete dissection of nonvisible lymph nodes during the conventional procedure.

Right-sided colon cancer

We adopted FI for right-sided colon cancer to improve the radicality of lymph node dissection. A 1:2 matched case-control study

included 25 patients undergoing FI-guided laparoscopic surgery and 50 patients undergoing conventional laparoscopic surgery [23]. The numbers of harvested pericolic and intermediate lymph nodes were not different between the two groups. Significantly more central lymph nodes (14 vs. 7, $p < 0.001$) and total harvested lymph nodes (39 vs. 30, $p = 0.003$) were removed in the fluorescence group than in the conventional group. The number of metastatic lymph nodes was not significantly different between the two groups. Therefore, oncologic value of this technique seems not clear.

Lateral pelvic node dissection

LPND is the most technically demanding procedure and has a possibility of incomplete dissection. Therefore, we adopted FI to confirm the completeness of LPND. Detailed methods of ICG injection including the time, dose, site, and surgical procedures are demonstrated in a video [24]. For more advanced methods to complete dissection of LPNs, we added three-dimensional (3D) lymphovascular reconstruction to FI [25]. This dual-image guided technique was adopted in 10 patients who underwent TME with LPND after preoperative CRT. All index LPNs (suspicious metastatic LPNs) among ICG-bearing lymph nodes were clearly identified intraoperatively by matching with their corresponding 3D images. Pathologic LPN metastasis was confirmed in four patients (40.0%) and in five of the 15 dissected pelvic sidewalls (33.0%). All metastatic LPNs were identified among index LPNs. Four (80.0%) of the five metastatic LPNs were located in the internal iliac area. We are further evaluating the long-term oncologic outcomes to determine the real impact of dual-image guidance in LPND.

Single-port robotic surgery

The da Vinci single-port (SP) system is designed to facilitate single-incision robotic surgery, and we adopted this technique in July 2020. We developed surgical techniques for the treatment of colon and rectal cancer, including robotic trocar position, docking, and detailed surgical steps.

Right-sided colon cancer: suprapubic right hemicolectomy

An SP robotic colectomy via a suprapubic approach was developed [26]. All procedures including colon mobilization, D3 lymphadenectomy, and intracorporeal anastomosis were completed using the SP robotic platform through a mini transverse suprapubic incision. In a total of five patients, the median total operative time was 160 minutes. The median docking time was 4 minutes 40 seconds, and the median console time was 105 minutes. There were no conversions to multiport or open surgeries. The median hospital stay was 7 days, and the median number of harvested lymph nodes was 41.

Rectal cancer: total mesorectal excision

A novel surgical technique of SP robotic TME was developed [27]. A single transverse incision was made in the right lower quadrant, and one 5-mm laparoscopic assistant port was placed in the right upper quadrant. All procedures including inferior mesenteric artery ligation, colonic mobilization, TME, and anastomosis were completed using the SP robotic system. In a total of five patients, a single docking was conducted, and the median docking time was 4 minutes 20 seconds. The median total operative time was 195 minutes, and the median time of pelvic dissection was 45 minutes. All patients had circumferential and distal tumor-free resection margins. The median duration of hospital stay was 7 days. Therefore, our initial experiences with SP robotic right colectomy and rectal resection were safe and feasible.

FUTURE PERSPECTIVES IN COLORECTAL SURGERY

In my personal opinion, colorectal surgery of the future will be a combination of better vision, more sophisticated robotics, and artificial intelligence (AI). In minimally invasive surgery, surgical vision is evolving into 3D, high-definition surgical vision. Recently, virtual augmentation and navigation systems are also ready for use in clinical settings. In addition, tumor-specific fluorescence has been developed to visualize the invisible. Regarding surgical robots, many manufacturers have developed various surgical robot platforms to increase versatility and freedom of movement and miniaturize them to access the internal space of the human body. The most surprising thing is that AI is evolving at a rate that is beyond our imagination. As a futurist said, when the singularity arrives, who knows if robots powered by AI and super-vision will perform autonomous operations, and professional surgeons may no longer exist. However, I always pray that human effort will be used to better the life of mankind as they have done so far.

NOTES

Conflict of interest

The author has no conflicts of interest to declare.

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