Original Article

Benefits of Three-dimensional Video System in Laparoscopic Colorectal Surgery: A Comparative Study of Reduced Port versus Conventional Approach

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Key Words
Reduced port laparoscopic surgery; Three-dimensional video system; Colorectal surgery

Purpose. Reduced port laparoscopic surgery application to colorectal cancer remains debatable because of questions on its feasibility and lack of benefits. Our study aimed to compare the overall characteristics with those of conventional laparoscopic colectomy and explored the effect of the three-dimensional video system

Methods. This single-center, retrospective cohort study included patients who underwent laparoscopic resection for colorectal cancer between November 2017 and August 2021. Detailed information was retrieved from the Kaohsiung Veterans General Hospital.

Results. In total, 509 patients underwent reduced port laparoscopic surgery and 197 underwent conventional Multiple-port laparoscopic surgery. The reduced port and the 3D group had shorter operative times (217.57 vs. 289.93 minutes, 223.29 vs. 257.36 minutes, respectively; both $p < 0.001$) but harvested more lymph nodes (24.92 vs. 22.6 lymph nodes harvested, $p = 0.0097$; 25.57 vs. 22.52 lymph nodes harvested, $p = 0.0003$). The pathological and oncological outcomes were not statistically significant. The reduced port group had a smaller maximum Visual Analogue Scale score (2.79 vs. 3.35, $p = 0.0012$) and fewer postoperative complications (0.3 vs. 0.85, $p = 0.0002$).

Conclusions. Reduced port laparoscopic surgery has advantages in terms of reduced operating time, lower Visual Analogue Scale scores, more harvested lymph nodes, and fewer complications. It is worthy to attempt with three-dimensional video system assisted.

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Laparoscopic colorectal surgery is now well-established, and when compared with open surgery, results in short-term benefits while maintaining equivalent long-term outcomes.[1] Studies have described that reducing the number of ports in the procedure does not affect its safety, but further enhances the advantages of laparoscopy over traditional open surgery.[2,3] Many surgeons have challenged the importance of the use of additional trocars. Single-incision surgery was introduced in the late 1990s, after the development of special instruments designed for single-port surgery. First, simple procedures such as hyster-

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ectomy, appendectomy, and cholecystectomy were attempted.[4-6] Single-incision laparoscopic surgery (SILS) for colectomy was first reported by Remzi and Bucher in 2008.[7,8] However, SILS is not very popular among surgeons due to the technical demand, selectivity of patients, and lack of dramatic clinical advantages, as seen in the advent of the laparoscopic technique over open surgery.[9]

Therefore, some surgeons advocate for the concept of "reduced port" which requires fewer trocars compared to conventional laparoscopic colectomy. Reduced port laparoscopic surgery (RPLS) was deemed the "bridge" between SILS and conventional laparoscopic colectomy.[10-12]

However, RPLS application to colorectal cancer remains debatable because of questions on its feasibility and lack of benefits. Our study aimed to compare the overall characteristics of RPLS colectomy with those of conventional laparoscopic colectomy. We also explored the effect of the three-dimensional video system on the quality of the stereoscopic view and ability to perform RPLS, shortening the learning curve required for surgeons to effectively use these methods.

Methods and Materials

We conducted a retrospective cohort study of 712 patients diagnosed with colorectal cancer who underwent laparoscopic colectomy and proctectomy at Kaohsiung Veterans General Hospital over 4 years from November 2017 to April 2021. The inclusion criteria were (1) pathological diagnosis of colorectal cancer and (2) laparoscopic colectomy. The exclusion criteria were (1) converted to exploratory surgery for any reason and (2) missing data (Figs. 1, 2). Information was collected from individual medical records. Retrospectively reviewed data contained demographic information, such as age, sex, body mass index (BMI), American Society of Anesthesiologist (ASA) score, preoperative carcinoembryonic antigen level, and past abdominal surgical history. Perioperative characteristics such as operation time, three-dimensional (3D) video system or traditional two-dimensional (2D) video system, trocar number, blood loss amount, tumor size, surgical margin, number of harvested lymph nodes, and pathological stage were also included. Postoperative characteristics included the visual analog scale (VAS) score, time to flatus, length of hospitalization, complication rate, and recurrence rate.

We defined RPLS as surgeries with total trocar numbers ≤ 3, and multiple-port laparoscopic surgery (MPLS) as surgeries with total trocar numbers > 3. Patients were categorized into three groups each based on their body mass indexes (BMIs) (< 18.5, 18.5-24, and > 24 kg/m^2) to analyze the impact of BMI on surgical outcome, and according to tumor location (rectum, left side colon, and right side colon) to evaluate the difference between tumor locations and surgical methods.

Statistical analysis was conducted using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). For comparative statistics, Chi-square test, ANOVA and Tukey's HSD were used. Statistical significance was set at $p < 0.05$.

Results

Between November 2017 and August 2021, 712

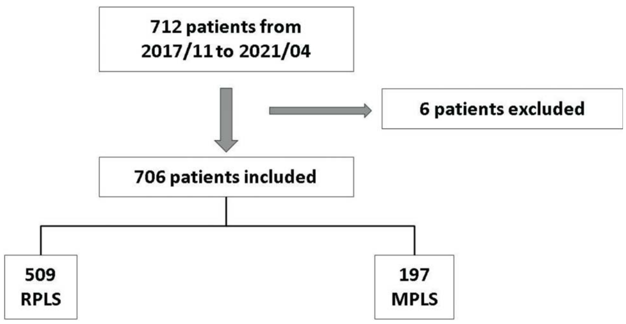

Fig. 1. Study flow chart (RPLS versus MPLS).

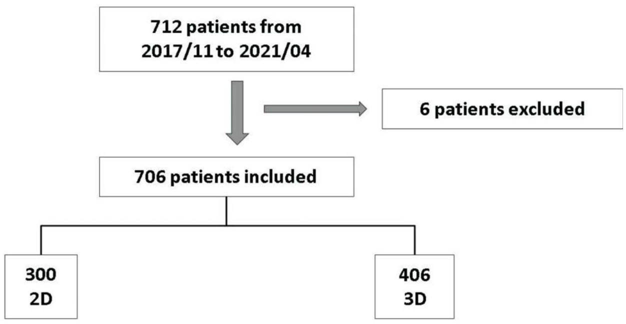

Fig. 2. Study flow chart (2D versus 3D).

patients who underwent laparoscopic colectomy were identified retrospectively. Six patients were excluded owing to missing data or conversion to open surgery.

Baseline characteristics

Patient demographics are presented in Table 1. In total, 197 patients underwent RPLS and 509 underwent conventional MPLS. A total of 406 patients underwent laparoscopic colectomy with the assistance of a 3D video system, and 300 patients underwent laparoscopic colectomy with a traditional 2D video system.

The demographic data observed between the two groups showed no statistical significance, except for mean age and history of abdominal surgery. Patients in the RPLS (63.26 vs. 65.76 years, $p = 0.017$) and 3D video system groups (62.86 vs. 65.44 years, $p = 0.017$) were younger in age as compared to patients in the MPLS and 2D video system groups. Fewer patients in the RPLS group had previously undergone abdominal surgery (79 [15.52%] vs. 67 [34.1%] patients, $p < 0.001$).

Perioperative outcomes

Perioperative data are listed in Table 2, which reveals differences in the operative time and number of harvested lymph nodes between the groups. The RPLS group and the 3D group had shorter operative times (217.57 vs. 289.93 minutes, 223.29 vs. 257.36 minutes, respectively; both $p < 0.001$) but harvested more lymph nodes (24.92 vs. 22.6 lymph nodes harvested, $p = 0.0097$; 25.57 vs. 22.52 lymph nodes harvested, $p = 0.0003$).

Pathologic and oncologic outcomes

The pathological and oncological outcomes are presented in Table 3. The differences in pathological

Table 1. Patients' characteristics

Variable*	RPLS versus MPLS			2D versus 3D		
	RPLS (n = 509)	MPLS (n = 197)	*p*-value†	2D (n = 300)	3D (n = 406)	*p*-value†
Age (year)	63.26 ± 13.36	65.76 ± 12.07	0.0170	65.44 ± 13.15	62.86 ± 12.89	0.0170
Sex			0.3980			0.4862
Male	274 (53.83)	113 (57.36)		169 (56.33)	218 (53.69)	
Female	235 (46.17)	84 (42.64)		131 (43.67)	188 (46.31)	
BMI (kg/m^2)	24.07 ± 3.95	24.27 ± 9.47		24.33 ± 7.97	23.97 ± 4.01	
ASA PS classification			0.6350			0.0936
I-II	424 (83.30)	167 (84.77)		243 (81.00)	348 (85.71)	
III	85 (16.70)	30 (15.23)		57 (19.00)	58 (14.29)	
History of abdominal surgery	79 (15.52)	67 (34.01)	< 0.001	62 (20.67)	84 (20.69)	0.9941
Preoperative	163.14 ± 1,604.31	55.11 ± 343.28	0.1600	101.77 ± 602.58	155.80 ± 1,734.43	0.1600

ASA, American Society of Anesthesiologist; BMI, body mass index; MPLS, multiple-port laparoscopic surgery; RPLS, reduced port laparoscopic surgery.

Table 2. Perioperative results

Variable*	RPLS versus MPLS			2D versus 3D		
	RPLS (n = 509)	MPLS (n = 197)	*p*-value†	2D (n = 300)	3D (n = 406)	*p*-value†
Operative time (min)	217.57 ± 74.33	289.93 ± 113.82	< 0.001	257.36 ± 98.80	223.29 ± 85.65	< 0.001
Estimated blood loss (mL)	89.30 ± 639.92	90.71 ± 161.18	0.9633	80.83 ± 145.08	96.24 ± 714.54	0.6726
Tumor size (cm)	3.91 ± 2.21	3.93 ± 2.31	0.9458	3.93 ± 2.24	3.91 ± 2.24	0.8783
Proximal resection margin (cm)	12.10 ± 6.02	12.18 ± 6.21	0.8664	12.77 ± 6.63	11.64 ± 5.58	0.0163
Distal resection margin (cm)	8.14 ± 6.36	8.39 ± 6.31	0.6330	8.11 ± 6.56	8.28 ± 6.19	0.7177
No. of harvested lymph nodes	24.92 ± 11.45	22.60 ± 10.29	0.0097	22.52 ± 10.78	25.57 ± 11.31	0.0003
No. of positive lymph nodes	1.93 ± 3.68	2.02 ± 3.50	0.7701	1.91 ± 3.36	1.99 ± 3.82	0.7769

MPLS, multiple-port laparoscopic surgery; RPLS, reduced port laparoscopic surgery.

and oncological outcomes between the two groups, including the depth of invasion, regional lymph node metastasis, distant metastasis, lymphatic invasion, and perineural invasion, were not statistically significant.

Short-term outcomes

In terms of short-term outcomes, the RPLS group had a smaller maximum VAS score (2.97 vs. 3.35, p = 0.0012) and fewer postoperative complications (0.3 vs. 0.85, p = 0.0002) than in the MPLS group (Table 4). There were no statistically significant differences in the time to first flatus or length of hospital stay. In contrast, the 3D model group had a smaller maximum VAS score (3.02 vs. 3.29, p = 0.0211), but no statistically significant differences in terms of other short-term outcomes compared to the 2D model group.

We categorized the eligible patients according to their BMIs and analyzed the impact of BMI on surgical outcomes. No significant differences were found in operative time (243.6, 232.8, and 253.54 min, respectively; p = 0.845), complication rates (14.3%, 13.5%, and 16.7%, respectively; p = 0.637), or time to flatus (3.78, 3.72, and 3.82 days, respectively; p =

Table 3. Pathologic data

Variable*	RPLS versus MPLS			2D versus 3D		
	RPLS (n = 509)	MPLS (n = 197)	p-value†	2D (n = 300)	3D (n = 406)	p-value†
Depth of invasion			0.7455			0.7330
T1-2	151 (29.67)	56 (28.43)		90 (30.00)	117 (28.82)	
T3-4	358 (70.33)	141 (71.57)		210 (70.00)	289 (71.18)	
Lymph node metastasis			0.8073			0.1717
Negative	248 (48.72)	98 (49.75)		156 (52.00)	190 (46.80)	
Positive	261 (51.28)	99 (50.25)		144 (48.00)	216 (53.20)	
Distant			0.3518			0.2743
M0	389 (76.42)	157 (79.70)		226 (75.33)	320 (78.82)	
M1	120 (23.58)	40 (20.30)		74 (24.67)	86 (21.18)	
Lymphatic invasion			0.6422			0.6437
Negative	335 (65.82)	126 (63.96)		193 (64.33)	268 (66.01)	
Positive	174 (34.18)	71 (36.04)		107 (35.67)	138 (33.99)	
Perineural invasion			0.6619			0.4933
Negative	443 (87.03)	169 (85.79)		257 (85.67)	355 (87.44)	
Positive	66 (12.97)	28 (14.21)		43 (14.33)	51 (12.56)	

MPLS, multiple-port laparoscopic surgery; RPLS, reduced port laparoscopic surgery.

Table 4. Short-term surgical outcomes

Variable*	RPLS versus MPLS			2D versus 3D		
	RPLS (n = 509)	MPLS (n = 197)	p-value†	2D (n = 300)	3D (n = 406)	p-value†
Maximum VAS score	2.97 ± 1.17	3.35 ± 1.25	0.0012	3.29 ± 1.30	3.02 ± 1.15	0.0211
Time to first flatus (day)	3.76 ± 1.61	3.67 ± 1.58	0.5349	3.66 ± 1.62	3.77 ± 1.58	0.4946
Hospital stay (day)	13.09 ± 9.08	14.63 ± 9.83	0.0571	14.21 ± 10.41	13.00 ± 8.40	0.0999
Postoperative complications	0.30 ± 1.10	0.85 ± 1.95	0.0002	0.50 ± 1.53	0.41 ± 1.32	0.4342
Complication grade			< 0.0001			0.6010
None	455 (64.45)	151 (21.39)		252 (35.69)	354 (50.14)	
I	17 (2.41)	20 (2.83)		18 (2.55)	19 (2.69)	
II	11 (1.56)	16 (2.27)		15 (2.12)	12 (1.70)	
III	21 (2.97)	7 (0.99)		12 (1.70)	16 (2.27)	
IV	5 (0.71)	3 (0.42)		3 (0.42)	5 (0.71)	

MPLS, multiple-port laparoscopic surgery; RPLS, reduced port laparoscopic surgery; VAS, visual analog scale.

0.58) among the three groups.

These patients were also classified according to different tumor locations, indicative of different surgical methods. No significant differences were found in the proportion of RPLS (54.1%, 52.4%, and 61.7%, respectively; $p = 0.138$) or the 2D system (41.4%, 45%, and 40.5%, respectively; $p = 0.565$) among the groups. Less operative time with the RPLS method was observed in all three groups (212 vs. 303.6 min; 193 vs. 264.1 min; and 206.8 vs. 272.5 min, respectively; all $p < 0.005$). In addition, less blood loss (53 vs. 86 mL, RPLS vs. MPLS, $p = 0.007$) was observed with the RPLS method in the right side colon group. No statistically significant differences were found in other indexes between the RPLS and MPLS techniques, irrespective of the tumor location or surgical method.

Discussion

Compared with open surgery, laparoscopic colorectal surgery has equal safety and feasibility with a better cosmetic appearance and quicker recovery. With the increasing use of trocars in surgery, complications such as postoperative incisional pain, incision-related wound infections, bleeding, hernia, and metastasis have become common.[13-15] Reducing the number of trocars has been attempted for many years, but its feasibility and necessity have been challenged.

In our hospital, two types of colorectal surgeons were recruited: those performing RPLS and those performing MPLS. The trocar position was determined according to the surgeon's preference and the tumor characteristics. Most RPLS used a 12-mm trocar for the scope held by the cameraman via the umbilical wound, with 12- and 5-mm trocars for laparoscopic scissors, graspers, or other laparoscopic instruments held by the operator (Figs. 3, 4). Therefore, no assistant port was needed in the RPLS, and no additional instruments were manipulated by the assistant.

The results of our study showed that RPLS did not compromise early surgical outcomes. In contrast, RPLS had the advantages of a reduced operating time, lower VAS score, more harvested lymph nodes, and fewer complications than in surgeries that used more trocars. Using fewer instruments results in better oncological outcomes and efficiency. We assume that immature assistants may interfere with the surgeon and cause iatrogenic injury owing to their unfamiliarity with laparoscopic instruments and the lack of stereoscopic and inappropriate traction. Therefore, improved perioperative or oncological outcomes were not observed when more trocars were used.

The most controversial aspect of RPLS was its feasibility. Owing to fewer instruments, both hands of the operator needed to be multifunctional, especially the left hand, which provided adequate traction and revealed the correct plane during dissection. There are several ways to perform this procedure, which requires extensive knowledge and experience regarding anatomy and colorectal surgery. Therefore, RPLS is not

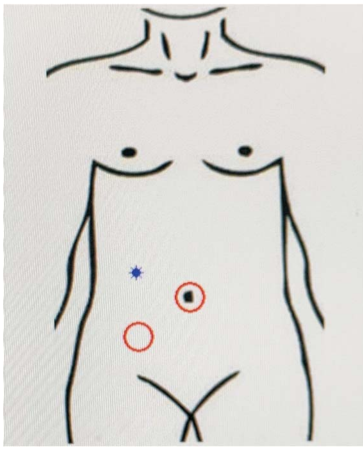

Fig. 3. Trocar position (Left side colon and rectum).

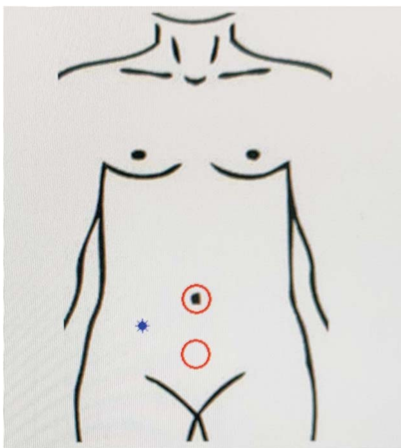

Fig. 4. Trocar position (Right side colon).

feasible for most colorectal surgeons, especially beginners. In our hospital, RPLS is still performed by only a few senior surgeons having > 10 years of experience in laparoscopic surgery.

A better stereoscopic view may help in narrowing the gap between RPLS and MPLS. In our study, we explored if a 3D video system could be used for colorectal surgery. Our results are promising, as they showed reduced operating time, lower VAS score, and more harvested lymph nodes in 3D video systems than the 2D systems. We believe that the 3D video system will play a major role in laparoscopic surgery and may shorten the learning curve of surgical interventions. In addition, with the more widespread use of 3D video systems in recent years, we can acquire more data, especially on the surgery performed by junior surgeons. Therefore, the impact of 3D video systems on the learning curve of laparoscopic colorectal surgery will be further assessed in our future study.

This study had a limitation. Selection bias could not be avoided, as the data were collected retrospectively.

Our results demonstrated no statistically significant differences between RPLS and MPLS in BMI, ASA score, tumor size, and clinical stage. Only age and abdominal surgical history of the patient seemed to affect the surgeon's choice of RPLS. We can assume that RPLS is not as highly selected as SILS and the proportion of RPLS did not vary among different tumor locations and surgical methods. In addition, the sample size in our study was relatively large compared to that of previous studies.

Conclusion

RPLS has advantages in terms of reduced operating time, lower VAS scores, more harvested lymph nodes, and fewer complications. RPLS was also similar to MPLS for all other variables. Fewer trocars, one surgeon, and one cameraman were needed, which meant better resource management. Considering the financial effects and the above advantages, performing RPLS is worthy of attempts by experienced surgeons.

Sources of Financial Support

There are no conflicts of interest to declare.

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原　　著

應用 3D 影像系統於大腸直腸癌手術之益處 — 減孔腹腔鏡手術與傳統腹腔鏡手術之比較研究

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目的　減孔腹腔鏡手術應用於大腸直腸癌手術因可行性及缺少益處仍未普及，此篇研究探討減孔腹腔鏡手術與傳統多孔手術之各項特徵比較。

方法　這是一篇回顧性單中心研究，包括 2017 年十一月至 2021 年八月進行腹腔鏡大腸直腸癌手術治療的病患，資料取自於高雄榮民總醫院大腸直腸外科。

結果　研究收錄 509 位接受減孔腹腔鏡手術的病患以及 197 位接受多孔腹腔鏡手術的病患，減孔腹腔鏡及 3D 影像系統有較短手術時間 (217.57 vs. 289.93, 223.29 vs. 257.36, $p < 0.001$)，並在術中取得更多淋巴結 (24.92 vs. 22.6, $p = 0.0097$; 25.57 vs. 22.52, $p = 0.0003$)。在病理及腫瘤學預後兩組無統計差異。減孔腹腔鏡亦有較少術後疼痛 (2.79 vs. 3.35, $p = 0.0012$) 及併發症 (0.3 vs. 0.85, $p = 0.0002$)。

結論　減孔腹腔鏡手術具有較短手術時間、取得更多淋巴結、較少術後疼痛及併發症之優勢，值得外科醫師在 3D 影像系統的協助下嘗試。

關鍵詞　減孔腹腔鏡手術、3D 影像系統、大腸直腸癌手術。