Original Article

Comparison of Surgical Outcomes and Safety between Three- and Two-Dimensional Laparoscopy in Colorectal Cancer Surgery

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Key Words
3-D imaging;
Colorectal cancer;
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Laparoscopy

Background. 3D HD (high definition) image system for laparoscopic surgery had been introduced to Taiwan for years, this study was aimed to evaluate the safety, efficacy and short-term outcome in patients received colorectal cancer surgery via this assisted medical system in our hospital.
Methods. From January 2014 to December 2018, 275 patients underwent laparoscopic colorectal surgeries through 3D HD (n = 111) and 2D HD (n = 164) real-time image system. Surgical safety, efficacy and short outcome were evaluated.
Results. The 3D HD laparoscopic surgery group has significantly less operative time (206 vs. 242 minutes, $p = 0.0004$), less length of postoperative hospital stay (7.8 vs. 11 days, $p = 0.038$), lower major morbidity rate (5.6% vs. 14.6%, $p = 0.016$) and lower leakage rate (2.8% vs. 9.1%, $p = 0.034$). The groups had similar tumor resection margin (5.0 vs. 4.2 cm, $p = 0.38$) and numbers of lymph nodes harvested (19.0 vs. 19.6, $p = 0.57$). Though there were no significant differences in perioperative blood loss (94 vs. 115 c.c., $p = 0.355$), conversion (2.8% vs. 4.3%, $p = 0.496$), and 30-day mortality (0.9% vs. 3.6%, $p = 0.154$), relative risk reductions were observed.
Conclusions. The 3D imaging system is a safe and feasible equipment, and the short outcomes are equivalent and better than 2D imaging systems. It may be beneficial due to less operative time, less major morbidity rate and less leakage rate.
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For years, laparoscopic surgery has been the standard surgical procedure in colorectal cancers with only a few contraindications, such as severe cardiovascular disease and hemodynamic instability. Moreover, it has more benefits compared to open surgery, including a decrease in postoperative pain, subsequent adverse cardiovascular effects, and esthetic sequels, while having relatively similar oncological outcomes.[2,5] However, the small port limits the movement of the instruments and vision of the surgeons, which increases operative time, surgical technique difficulty, and off-camera damage otherwise absent during the open surgeries.

Traditional laparoscopic systems can only provide indirect field-limited monocular vision for surgeons, which causes a loss of binocular depth on a two-di-

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mensional (2D) display and visual misperceptions.[9] It may also enhance surgeon fatigue and increase intracorporeal suturing difficulty. Briefly, the greatest challenge for laparoscopic surgeons has been eye-hand coordination within a three-dimensional (3D) scene on a 2D display.[8]

The recent development of 3D high-definition imaging systems has allowed surgeons to gain a better view of the surgical field, thereby decreasing the adverse effects of traditional laparoscopic surgery.[11] A 3D imaging system provides depth perception and correct dimensional measurements of the operative field and anatomical sites, which translates to better laparoscopic dissection, tissue cutting, and, more importantly, intracorporeal suturing. Surgeons are thus able to conduct quicker and smoother procedures, with the patients also benefiting from the more efficient and delicate surgical interventions.[16]

To date, only a few small studies have investigated 3D imaging system-assisted laparoscopic procedures in patients with colorectal cancer. Moreover, only a few studies have compared 3D and 2D imaging systems. Thus, the present study aimed to compare the safety, efficacy, and short-term outcomes of 3D and 2D imaging system-assisted laparoscopic surgeries in patients with colorectal cancers.

Materials and Methods

Patient selection

From January 2014 to December 2018, a total of 299 patients underwent multi-port laparoscopic colectomy or proctectomy for colorectal cancer in a regional teaching hospital at eastern Taiwan. Those who underwent single-port laparoscopic surgery (n = 9), synchronous resection for metastasis to other organs, such as the liver and lungs (n = 8), subtotal colectomy (n = 3), and abdominoperineal resection (n = 2) were excluded. Patients who had extremely high perioperative risk [American Society of Anesthesiologists (ASA) score > 4)] (n = 2) were also excluded[12] (Fig. 1). Accordingly, 275 consecutive patients with colorectal cancer who underwent multi-port laparoscopic surgeries were retrospectively reviewed using data obtained from the oncological database. All patients received standard preoperative cancer evaluation. This study had been approved by our hospital's local review board.

Preoperative management

All patients underwent pelvic magnetic resonance imaging (rectal cancer only); chest, abdominal, and pelvic computed tomography (CT), and a total colonoscopy before the surgery.[7] Preoperative examinations, including complete electrocardiography, chest radiography, blood cell counts, and electrolyte tests, were performed routinely. All patients also received preoperative anesthesia evaluation (ASA scoring) by anesthesiologist a day before the surgery. Patients with rectal cancer who had a T3/T4 tumor or positive lymph node involvement received preoperative long-course concurrent chemoradiotherapy (50.4 Gy over 5 weeks and 5-FU regimen) followed by surgery 8 to 10 weeks later.[13]

Surgical procedure

General anesthesia was used for all patients who underwent surgery. Laparoscopic surgical procedures, including radical right hemicolectomy, left hemicolectomy, anterior resection, and low anterior resec-

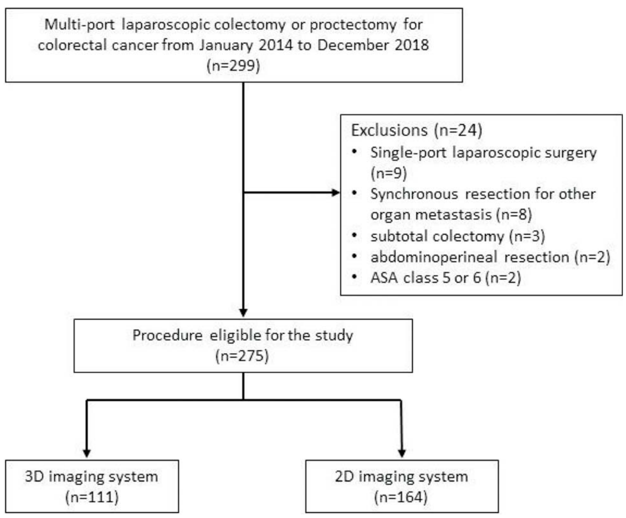

Fig. 1. Flow diagram of study participants, including exclusion criterias.

tion, were selected based on tumor locations and performed by three skilled surgeons at our hospital. IMAGE 1S™ 3D TC-302 with a TH-100 IMAGE 1S™ H3-Z Three-clip FULL HD camera head (KARL STORZ Endoskope) was use for all 3D imaging-assisted laparoscopic surgeries. All 2D imaging laparoscopic surgeries were performed using IMAGE 1S™ TC-300 with an EndoCAMeleon® telescope (KARL STORZ Endoskope). The operative time, defined as the duration from the start of procedure until its completion, was determined for each surgery.[4] Perioperative blood loss was also calculated after each procedure. In cases where laparoscopic surgery was extremely difficult, conversion to open surgery was inevitable and was decided by surgeon during the surgery.

Radical right and left hemicolectomy

One 10-mm umbilical port was placed under direct vision, and three other ports (one 12-mm and two 5-mm ports) were placed at the right and left upper and lower quadrants. Patients were placed in the lithotomy-Trendelenburg position. Dissection began at the transverse colon, and the lesser sac was entered. The hepatic flexure or splenic flexure was taken down via medial-to-lateral methods. The left or right paracolic gutter was also dissected until the left or right colon was completed mobilized. The root of the ileocolic vessels and right branch of the middle colic vessels were transected during right hemicolectomy, whereas the left colic vessels and left branch of the middle colic vessels were transected during left hemicolectomy. The affected colon was transected with a safety margin of at least 5 cm, and the terminal ileum was also transected during right hemicolectomy. Mesocolic lymph nodes of the affected colon were removed and harvested. The specimen was then retracted through a 3- to 5-cm extended umbilical wound using a 4-cm wound protector. The hand-sewn method for colon anastomosis was performed routinely.

Radical anterior resection and low anterior resection

Patients were placed in the lithotomy-Trendelenburg and right lateral tilt position. One 10-mm umbilical port was placed under direct vision, and three other ports (one 12-mm and two 5-mm ports) were placed at right and left upper and lower quadrants. The fourth 5-mm trocar was placed at the suprapubic area if necessary. Dissection began at the sacral promontory. Left paracolic gutter and mesocolic dissection was performed through the medial-to-lateral approach. The root of the inferior mesenteric vessels was transected above the level of the left colic vessels (high ligation). The splenic flexure was taken down routinely. The rectum was fully mobilized until level with the pelvic floor while preserving the proper rectal fascia. The rectum was cut using a 45- or 60-mm Medtronic Endo GIA™. The specimen was retracted through a 3- to 5-cm extended umbilical wound using a 2 to 6-cm wound protector. The anastomosis was closed using a 27- to 33-mm ETHICON Circular Stapler.

Postoperative care and outcome measurements

Patients were transferred to the ward after surgery until discharged from the hospital. The length of hospital stay was also recorded. Postoperative mortality included all deaths occurring before hospital discharge or postoperative day (POD) 30.[15] Morbidity included all complications occurring after the surgeries and before POD 30. Anastomosis and ureter injuries were confirmed through CT scans.[13] Tumor size, number of lymph nodes harvested, and pathological staging were evaluated and recorded by a pathologist.

Statistical analysis

Quantitative variables expressed as means were compared by using t-tests, while quantitative variables expressed as rates (%) were compared by using Chi-square tests. A p value of < 0.05 was considered statistically significant. Statistical analysis was performed using IBM SPSS statistics Release 22.0.0.0 64bit version. Risk calculations, such as odds ratio, relative risk, and numbers needed to treat, were also included for comparison of short-term outcomes.

Results

Preoperative data

Patient characteristics are presented in Table 1. A total of 275 patients underwent either 3D (n = 111) or 2D (n = 164) imaging-assisted multi-port laparoscopic surgeries for colorectal cancer from January 2014 to December 2018. Subjects had a median age of 69.7 years, with a majority being male (n = 160, 58.3%). Patients in 3D group were significantly older than those in 2D group (73.1 vs. 67.9 years old; $p = 0.005$). However, no significant differences in gender and pathological cancer staging were observed between both groups, though more subjects were ASA class 3 (60.6% vs. 49.4%) and 4 (10.8% vs. 3.0%) in the 3D group ($p = 0.045$).

Intraoperative data

Intraoperative data are detailed in Table 2. Four types of surgeries were performed in this study, including radical right hemicolectomy (n = 76), radical left hemicolectomy (n = 31), radical anterior resection (n = 96), and radical low anterior resection (n = 72). No significant differences in all surgeries were observed between both groups ($p = 0.52$). The 3D group had a significantly shorter mean operative time (207 vs. 243 min; $p = 0.04$) but a slightly longer mean tumor resection margin than the 2D group (5.0 vs. 4.2 cm; $p = 0.38$). No significant differences in the mean number of lymph nodes harvested (19.0 vs. 19.6; $p = 0.57$) and mean intraoperative blood loss (94.4 vs. 114.8 cm^3; $p = 0.355$) were observer between both groups.

Table 1. Preoperative data

	Total patients (n = 275)	3D group (n = 111)	2D group (n = 164)	*p*
Age, mean (year old)	--	73.1	67.9	0.005
Gender (male), n (%)	160 (58.3%)	63 (56.3%)	97 (58.9%)	0.69
Pathological TNM staging				0.71
0, n (%)	14 (5.2%)	6 (5.6%)	8 (4.9%)	--
I, n (%)	46 (16.7%)	22 (19.7%)	24 (14.6%)	--
II, n (%)	87 (31.5%)	36 (32.4%)	51 (31.1%)	--
III, n (%)	100 (36.4%)	38 (33.8%)	62 (37.8%)	--
IV, n (%)	28 (10.2%)	9 (8.5%)	19 (11.6%)	--
ASA classification				0.003
1, n (%)	9 (3.3%)	2 (1.8%)	7 (4.3%)	--
2, n (%)	101 (36.7%)	30 (26.8%)	71 (43.3%)	--
3, n (%)	148 (53.8%)	67 (60.6%)	81 (49.4%)	--
4, n (%)	17 (6.2%)	12 (10.8%)	5 (3.0%)	--

Table 2. Intraoperative data

	Total patients (n = 275)	3D group (n = 111)	2D group (n = 164)	*p*
Operative procedure				0.19
RH, n (%)	76 (27.6%)	26 (23.4%)	50 (30.5%)	--
LH, n (%)	31 (11.3%)	20 (18,0%)	11 (6.7%)	--
AR, n (%)	96 (34.9%)	34 (30.6%)	62 (37.8%)	--
LAR, n (%)	72 (26.2%)	31 (28.0%)	41 (25.0%)	--
Operative time, mean (min.)	--	206.8	242.5	0.004
Tumor resection margin, mean (cm)	--	5.0	4.2	0.38
LNs harvested, mean, n	--	19.0	19.6	0.57
Blood loss, mean (c.c.)	--	94.4	114.8	0.35

RH, radical right hemicolectomy; LH, radical left hemicolectomy; AR, radical anterior resection; LAR, radical low anterior resection; LNs, lymph nodes.

Postoperative outcomes

Postoperative outcomes are outlined in Table 3. The 3D group had a significantly shorter mean length of postoperative hospital stay than the 2D group (7.8 vs. 11.0 days; $p = 0.027$). A total of 6 (5.6%) patients in the 3D group and 24 (14.6%) in the 2D group exhibited morbidity, the major cause of which was anastomosis leakage in both groups (n = 3 vs. n = 15). One patient died 7 days after 3D imaging-assisted laparoscopic radical right hemicolectomy because of postoperative anastomosis leakage with septic shock. Moreover, six patients died after 2D imaging-assisted laparoscopic surgery, among whom two died due to acute myocardial infraction, one due to cerebral vascular accident, one due to sudden cardiac arrest, and two due to septic shock after anastomosis leakage. Conversions to open surgery totaled three and seven in the 3D and 2D group, respectively. Moreover, two patients suffered anastomotic leakages observed in the 3D group, both of whom underwent laparoscopic low anterior resection. Meanwhile, 18 patients suffered leakages in the 2D group, among whom 14 underwent laparoscopic low anterior resection, three underwent laparoscopic radical anterior resection, and the last one underwent laparoscopic radical right hemicolectomy. Compared with the 2D group, the 3D group has a significantly lower major morbidity rate (5.6% vs. 14.6%, $p = 0.016$) and lower anastomotic leakage rate (2.8% vs. 9.1%, $p = 0.034$). No significant differences in the conversion rate (2.8% vs. 4.3%; $p = 0.74$), and overall morbidity rate (5.6% vs. 14.6%; $p = 0.13$) were observed between both groups.

Discussion

The loss of binocular depth with 2D displays has been a considerable challenge for surgeons given that human vision is naturally 3D. Being forced to observe images on a 2D display may easily cause unnecessary tissue damage during surgery. This also requires increased hand-eye coordination and cooperation between surgeons and surgical assistants.[9,17] The new 3D system has two separate lenses and two cameras within one single laparoscope similar to human eyes. This provides surgeons with good depth perception and is valuable for surgical techniques that demand a higher degree of spatial perception, such as intracorporeal suturing.[13]

Our results showed that the 3D group had shorter mean operative time than the 2D group (206.8 vs. 242.5 min; $p = 0.004$). Similarly, Kanaji S. et al. reported significantly decreased operative time with 3D imaging-assisted-total gastrectomy.[12] Other studies conducted by Fanfani F. et al. and Lara-Dominguez et al. also found similar results in gynecological surgeries.[16,18] Moreover, recent studies have revealed several advantages for 3D imaging-assisted laparoscopic surgery over 2D surgery in rectal tumor resection.[21] Accordingly, the better spatial vision and high-definition images provided by 3D imaging systems allows for the recognition of adjacent organs and prevention of severe tissue damage.

Our results showed the postoperative hospital stay in the 3D group was 3 days shorter than that in 2D group (7.8 vs. 11.0 days; $p = 0.027$). Our hospital had been utilizing 3D imaging laparoscopy since early 2016, while most of the 2D imaging laparoscopic surgeries were performed before 2015. Moreover, our hospital had introduced and practiced early feeding and early postoperative rehabilitation within the last 2 years, which may have been the reason for the shorter length of hospital stay.

The present study showed no significant differences in mortality rate or conversion rate between the

Table 3. Postoperative outcome

	Total Patients (n = 275)	3D group (n = 111)	2D group (n = 164)	*p*
Postoperative hospital stay, mean (day)	--	7.8	11.0	0.038
Conversion to open, n (%)	10 (4.0%)	3 (2.8%)	7 (4.3%)	0.496
Total morbidity, n (%)	30 (10.9%)	6 (5.6%)	24 (14.6%)	0.016
Anastomosis leakage, n (%)	18 (6.5%)	3 (2.8%)	15 (9.1%)	0.034
Mortality, n (%)	7 (2.6%)	1 (0.9%)	6 (3.6%)	0.154

3D and 2D groups. However, absolute values were better in the 3D group than in the 2D group as shown in Table 3. This may be attributed to improvements in not only surgical technique but also postoperative quality of care. The improvement in surgical device, such as replacing 2D with 3D imaging system, may not solely account for the decrease in morbidity or mortality. As discussed previously, the introduction of 3D imaging laparoscopy, as well as postoperative care quality and early feeding, at our hospital since early 2016 may have been one factor contributing to better postoperative outcomes.[21] Further studies with larges sample size would be needed to confirm these postoperative outcomes.

Concerning postoperative outcomes, the 3D group exhibit a lower rate of anastomosis leakage and major morbidity. At our facility, intracorporeal sutures for bowel anastomosis have been performed using Medtronic Endo GIA™ and the ETHICON Circular Stapler. Accordingly, the anastomosis leakage rates in the 3D group with such medical devices have been low (2.8%) for skillful surgeons. However, the leakage rate was high (9.1%) in 2D group. It may be attributed to the learning curve that the most anastomosis leakages happened in 2014 and 2015, and the 3D imaging system had been utilized since 2016.

This study also observed similar oncological resection criteria in the 3D and 2D groups after comparing the number of lymph nodes harvested and safety margins for tumor resection. This showed that the use of a 3D imaging system did not modify the oncological principles of surgery. A highly experienced and skilled surgeon who is familiar with surgical anatomy may overcome the disadvantages offered by a 2D imaging system.[19,20] However, variations have been present in real human anatomy. A high-definition 3D imaging system provides more accurate visualization of fine organ structures, thereby decreasing the probability of severe tissue damage during the operation and the associated postoperative complications. Several studies have revealed that 3D imaging systems require a significantly shorter operative time, and, more importantly, has a shallow learning curve.[9,11,15] Although no significant differences in other parameters had been observed between both groups included herein, the 3D group still exhibited better absolute values compared to the 2D group. Nonetheless, a larger sample size might have provided different results, definitively confirming the advantage 3D imaging systems have over 2D imaging systems.

Although 3D imaging systems provide many benefits for laparoscopic surgery, it also carries some disadvantages, such as monitor color distortion and eye strain, headaches, dizziness, and physical discomfort the operator, for which reason some surgeons have refused to utilize 3D imaging systems until present.[21] Moreover, the performance and outcomes following 3D and 2D imaging-assisted laparoscopic surgeries have differed by on a little among highly experienced and skilled surgeons.[11,17]

Some limitations of the present study are worth noting. First, given that our hospital had been utilizing a 3D imaging system since early 2016, all laparoscopic surgeries performed before 2015 were equipped with only a 2D imaging system. Second, the follow-up duration herein was relatively short. Further research with long-term outcomes, including cancer prognosis, is thus needed.

Conclusion

The present study showed that 3D imaging-assisted laparoscopic surgery by skilled surgeons is feasible and safe given that it shares better short-term surgical outcomes, such as lower major morbidity rate and lower anastomosis leakage rate. The decrease in length of hospital stay or other benefits may be attributed to the postoperative early feeding and the improvement in surgical technique. It still supports that 3D imaging laparoscopy is beneficial in colorectal surgeries.

Conflicts of Interest Statement

The authors have no conflicts of interest.

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原　著

3D 與 2D 腹腔鏡大腸直腸癌手術於安全性與預後之比較

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目的　腹腔鏡大腸直腸手術近年來在台灣已被廣泛使用，而 3D 立體腹腔鏡技術亦日漸普及。本研究報告此技術於本院使用之安全性與預後評估。

方法　本研究回溯性收集自 2014 年 1 月至 2018 年 12 月，共 275 位接受 3D (111 位) 及 2D (164 位) 腹腔鏡大腸直腸切除術之病患，進行評估並比較安全性、效果及短期預後之差異。

結果　兩者病患基本資料無差異。3D 立體腹腔鏡手術之手術時間較短 (206 分鐘 vs. 242 分鐘)，術後住院日數亦較短 (7.8 日 vs. 11 日)。而術後併發症率 (5.6% vs. 14.6%)，及接口滲漏率 (2.8% vs. 9.1%) 亦明顯較低。但 3D 及 2D 腹腔鏡手術病患，兩者之間無腫瘤大小、淋巴結廓清數量之差異。而在短期預後方面，兩者之術後出血量，轉換開腹率，及術後 30 日死亡率均無統計學上之差異。

結論　3D 立體腹腔鏡手術為一種安全及可接受的手術技術。

關鍵詞　3D 立體影像、大腸直腸癌、大腸直腸手術、腹腔鏡微創手術。