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DYNAMIC MANUSCRIPT

Surgical technique of robotic D3 lymph node dissection around the inferior mesenteric artery with preservation of the left colic artery and autonomic nerves for the treatment of distal rectal cancer

Jin-Tung Liang · Hong-Shiee Lai

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Abstract
Background Our objective was to evaluate the quality of surgery regarding application of the robotic approach to perform D3 lymph node dissection over the inferior mesenteric artery (IMA) with preservation of the left colic artery (LCA) and autonomic nerves for the treatment of distal rectal cancer, which has not been reported before, although it has been successfully performed by some surgeons laparoscopically.
Methods Patients with distal rectal cancer posing risk factors for anastomotic leakage were recruited and underwent the present robotic procedure, which was standardized and presented in the attached video file. Patients' surgical outcomes were prospectively evaluated.
Results A total of 26 patients with distal rectal cancer were operated on via the present robotic approach. The number of cleared lymph nodes was 26.1 ± 7.2 (range 10–44). The operation time was 307.3 ± 74.1 min (including docking time). The blood loss was 190.5 ± 225.8 ml. Anastomotic leakage occurred in one (1/16, 6 %) patient without preoperative chemoradiation therapy, and wound infection of port sites was detected in two (2/26, 7.6 %) patients. The patients had quick convalescence, as evaluated by the recovery of flatus passage (48.0 ± 12.0 h), hospitalization (14.6 ± 4.8 days), and degree of postoperative pain (2.5 ± 0.5, visual analog scale). The median duration for indwelling urine Foley catheter was 6.0 days (range 3.0–28). The voiding function after removal of the urine Foley catheter was good (International Prostate Score Symptom [IPSS] 0–7) in 22 (84.6 %) patients, fair (IPSS 8–14) in three (11.5 %), and poor (IPSS 15–35) in one (3.8 %). The median time of return to partial activity, full activity, and work was 2.0, 4.0, and 6.0 weeks, respectively.
Conclusions By using the three-armed Da Vinci® robotic system in our clinical setting, quality surgery of the D3 lymph node dissection around the IMA with preservation of the LCA and autonomic nerves, in which the adequacy of lymph node harvest and the security of blood supply over distal colon were juggled, can be achieved for patients with distal rectal cancer posing risk factors of anastomotic failure.

Keywords Robotic surgery · LCA preservation · D3 lymphadenectomy · Rectal cancer

During surgery for rectal cancer, there has been a differentiation between a high versus low ligation of the inferior mesenteric artery (IMA) related to whether or not the ligation is above (high ligation) or below (low ligation) the left colic artery (LCA). Surgeons favoring high ligation stress the technical merits, which include the following: it allows for more adequate lymph node harvest due to more extensive dissection of the lymphatic basin around the root of the IMA; a more complete mobilization of the left colon is made possible by the transection of the IMA flush with the abdominal aorta and can facilitate a tension-free and safer low pelvic or anal anastomosis. In contrast, the advocates of low ligation maintain that the level of IMA ligation actually has no effect on patient survival despite

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J.-T. Liang (✉) · H.-S. Lai
Division of Colorectal Surgery, Department of Surgery, National Taiwan University Hospital and College of Medicine, No. 7, Chung-Shan South Road, Taipei, Taiwan, ROC
e-mail: jintung@ntu.edu.tw

that the number of lymph nodes harvested may increase after high ligation of the IMA; high ligation and division of the IMA proximal to the LCA may compromise the blood supply of the left colon, which can increase surgical morbidity, especially in patients with evidence or suspicion of mesenteric vascular disease, obesity, old age with major underlying comorbidities; and moreover, extensive dissection of lymphatic tissues over the root of the IMA may inevitably injure the autonomic nerve plexus, which can thereafter impair the genitourinary function of patients [1]. In our view, the adequacy of lymph node harvest and the security of blood supply over the distal colon can be juggled if we employ the technique of lymph node dissection around the IMA with simultaneous preservation of the IMA and LCA.

In a literature review, we found that the above-mentioned lymph node dissection around the IMA with preservation of the LCA has been performed laparoscopically by some surgeons for the treatment of rectosigmoid cancer [2, 3]. However, to the best of our knowledge, the robotic approach in performing such procedures has not been reported before. Herein, we present the technical details regarding application of the three-armed da Vinci® robotic approach to lymph node dissection around the IMA with preservation of the LCA and autonomic nerves for the treatment of distal rectal cancer in high-risk patients with comorbidities. We hypothesized that, taking advantage of the surgical precision and stability provided by the da Vinci® robotic system, we can achieve satisfactory oncological clearance and better functional recovery for patients with low rectal cancer requiring total mesorectal excision (TME) with low colorectal anastomosis.

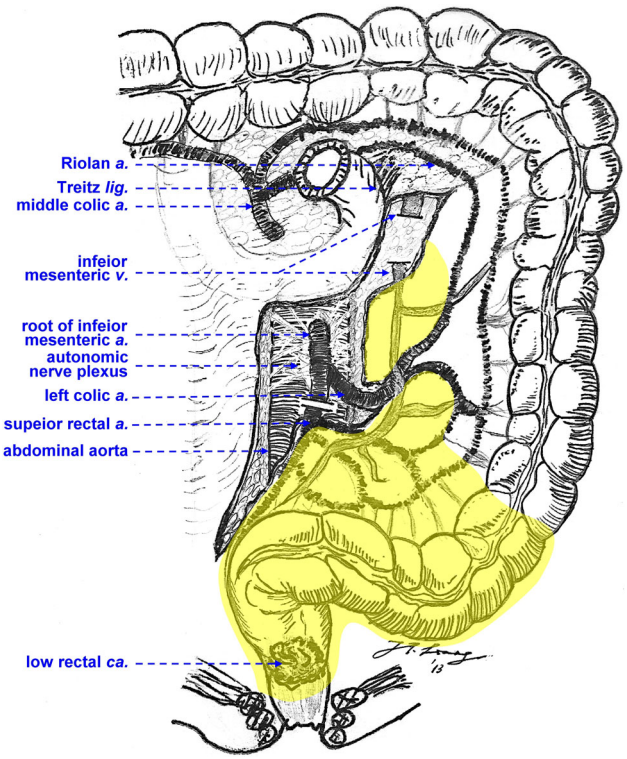


Fig. 1 Surgical anatomy and the extent of dissection (*yellow shadow*) during the robotic D3 lymph node dissection around the IMA with preservation of the LCA and autonomic nerves for the treatment of distal rectal cancer. *IMA* inferior mesenteric artery, *LCA* left colic artery (Color figure online)

Patients and methods

Patient selection

High-risk morbidity patients with distal rectal cancer, defined as tumors below the pelvic peritoneal reflection, were recruited and underwent this surgical procedure: the robotic approach for TME of rectal cancer with lymph node dissection around the IMA plus simultaneous preservation of the LCA and the autonomic nerve plexus. Body mass index (BMI) more than 30 kg/m^2, age older than 80 years, and evident pre-operative comorbidity, including pulmonary dysfunction (lung emphysema, obstructive lung disease), cardiovascular disease (coronary arteriosclerosis, arrhythmia, heart failure, hypertension), renal insufficiency (serum creatinine >2.0 mg/dl), diabetes mellitus (necessity for preoperative drug treatment), and arterial circulation disturbance (occlusion of arterial vessels of limb, cerebral ischemia in patient's history), were considered to be high-risk factors for surgical morbidity for patients in undergoing this procedure [4–6].

Surgical strategy

The extent of dissection is highlighted in Figs. 1 and 2. The harvested lymph nodes were mapped according to Japanese guidelines, in which lymph nodes over the root of the IMA were defined as N3 lymph node, and therefore the extent of D3 lymph node dissection for rectosigmoid cancer was from the level of the IMA flush with the abdominal aorta to the branching of the LCA [7].

Robotic surgical procedures

Port configuration

Five abdominal ports were set (Fig. 3a): 12-mm camera port placed 3 cm to the right and 3 cm above the umbilicus; 12-mm port right lower quadrant (mid-clavicular line) through which is telescoped an 8-mm robotic port designated as R1 for the right robotic working arm (the 8-mm port can be removed to place an endostapler); 8-mm port

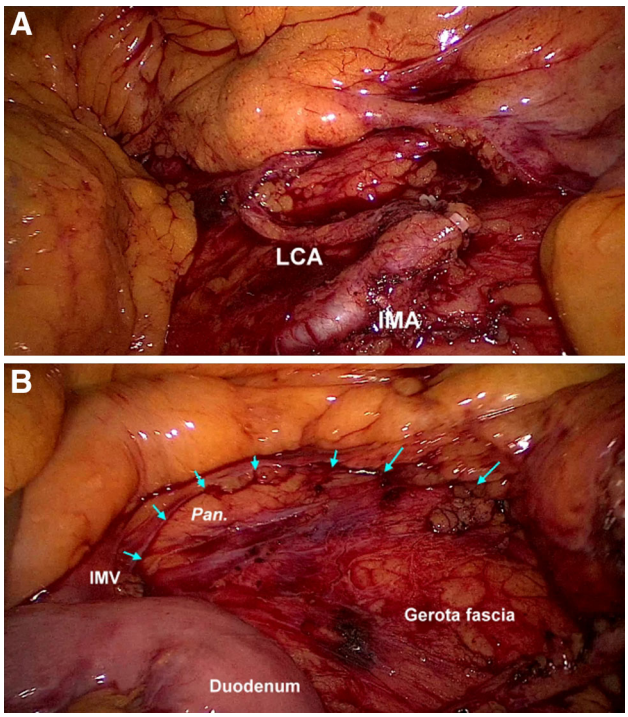


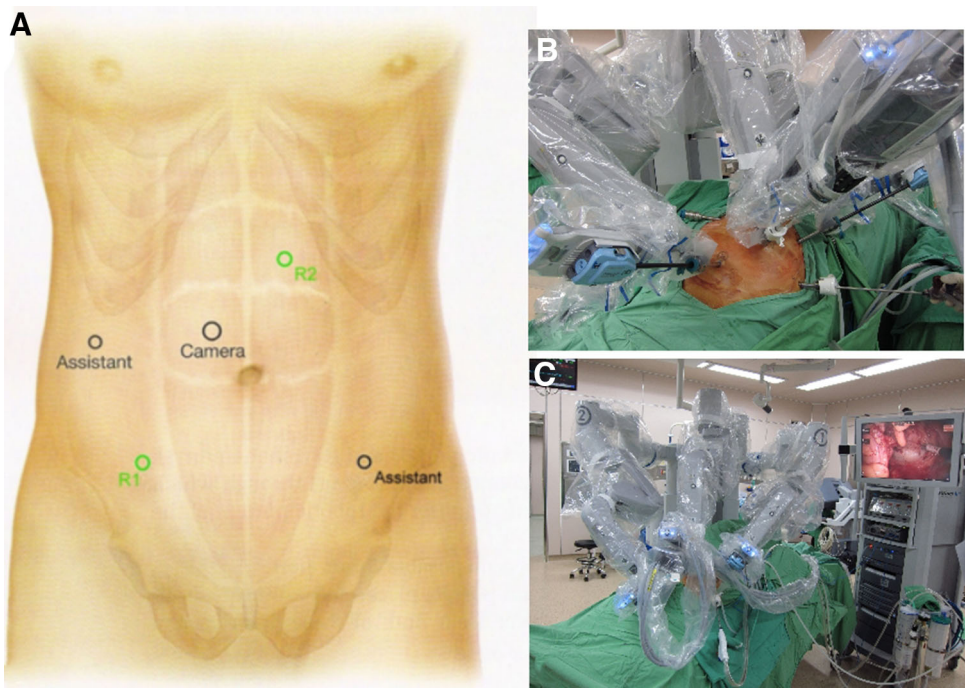
Fig. 2 Laparoscopic view of the related anatomic structures after full implementation of the surgical blueprint. **a** Complete D3 lymph node dissection with preservation of the LCA and pre-aortic autonomic nerve plexus. **b** The IMV was ligated flush with the lower border of pancreas (*Pan.*), and an additional wedge-shaped excision of the mesentery lateral to the IMV was conducted to ensure more radical excision of the mesenteric lymphatic basin of rectosigmoid cancer (*arrow*). *IMV* inferior mesenteric vein, *LCA* left colic artery

left upper quadrant just to the right of the mid-clavicular line midway between umbilicus and left subcostal region designated as R2 for the left robotic working arm; 12-mm assistant port right lateral mid-abdomen for retracting and suctioning by an assistant; 8-mm port left lower quadrant placed at the same height and position as the right lower quadrant port for counter-traction by another assistant (Fig. 3b). The robotic cart was placed in the left hip position (Fig. 3c). During the entire procedure, each robotic working arm and assistant instrument was inserted through its respective uniform abdomen port cited above, and the position of the robotic cart remained unchanged.

Surgical procedures

The robotic dissection sequence was similar to that of laparoscopic TME, as described in our previous publication [8, 9] and as follows: (i) the inferior mesenteric vein (IMV) was clipped and transected at the lower border of the pancreas (Fig. 4a and video file 1: IMV ligation); (ii) the origin of the IMA from the abdominal aorta and the junction of the IMA and LCA was explored. Lympho-adipose tissues around this area were skeletonized to facilitate complete N3 and N2 lymph node dissection, with the preservation of the sympathetic nerve plexus encircling the IMA (Fig. 4b and video file 2: IMA stripping); (iii) the LCA and superior rectal artery (SRA) were identified and transected just below the junction of the IMA and the LCA (Fig. 4c, d, e); (iv) upward skeletonization along the

Fig. 3 Design of port sites and the configurations of robotic arms



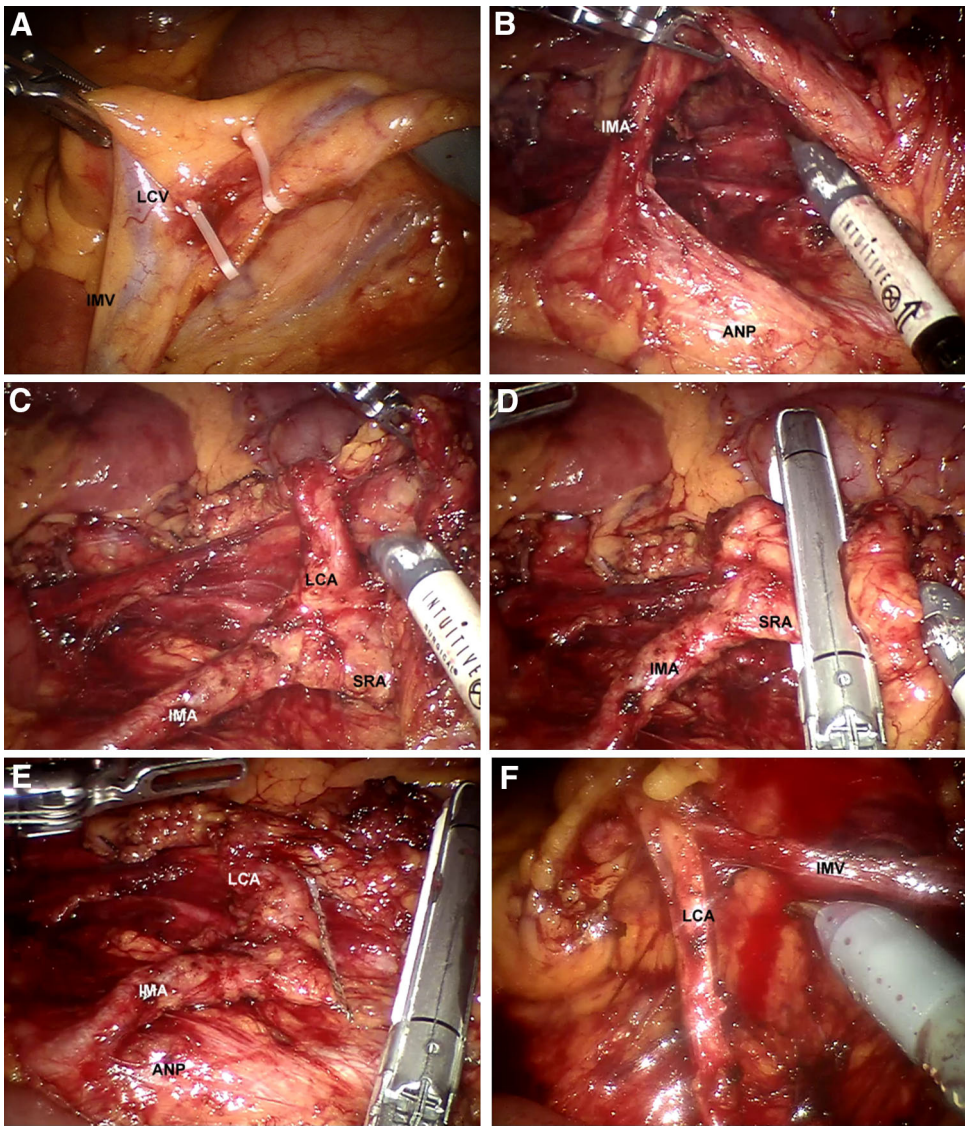


Fig. 4 **a** Ligate the IMV distal to its confluence with the LCV; **b** strip the IMA root with preservation of the pre-aortic ANP; **c** upward skeletonization of the LCA with identification of the SRA; **d**, **e** transection of the SRA just distal to the origin of the LCA with an endostapler; **f** separate the intertwining of the LCA and the distal IMV. *ANP* autonomic nerve plexus, *IMA* inferior mesenteric artery, *IMV* inferior mesenteric vein, *LCA* left colic artery, *LCV* left colic vein, *SRA* superior rectal artery

ascending branch of the LCA was performed, with separation of the intertwining between the ascending branch of the LCA and IMV (Fig. 4f) and wedge excision of the mesentery lateral to proximal IMV (video file 3: LCA stripping); (v) medial-to-lateral retro-mesenteric dissection was conducted along the pre-aortic plane and Gerota fascia, followed by lysis of the lateral colonic attachments upward to the colonic splenic flexure to facilitate the complete mobilization of the sigmoid and descending colon; (vi) dissection of the pre-sacral fascia downward to the ano-coccygeal rhaphae, with preservation of the paired hypogastric nerves and pelvic autonomic nerve plexi (video file 4: rectal mobilization); (vii) the peritoneal reflection was incised laterally and then anteriorly and the rectum and the vagina/prostate was separated circumferentially to the level of the levators with appreciation of Denonvilliers' fascia, followed by transection of the distal rectum at a level flush with the levator ani muscle.

Thereafter, the robotic cart was replaced by a traditional laparoscopic system, the proximal bowel segment was exteriorized and transected, and subsequently the bowel continuity was reconstructed by side-to-end colorectal anastomosis. For selected patients, an ileostoma was created at the left abdominal quadrant via extension of the wound over the left assistant port.

Evaluation of surgical outcomes

Anastomotic leakage was defined by the presence of clinical features of peritonitis and bowel contents in the drainage.

Urinary function was evaluated based on a questionnaire-based interview of patients preoperatively and 3 months after surgery. In patients with major surgical complications (e.g. anastomotic leakage), urinary function were evaluated 3 months after recovery from surgical

morbidity (i.e. 3 months after closure of the dysfunctioning ileostoma). The preoperative functional questionnaire was based on the recollection of function before the development of symptoms of rectosigmoid cancer. A urine Foley catheter was routinely inserted for patients immediately before the operation. In the postoperative period, the date for removal of the Foley catheter and the nature of any voiding problems, such as those requiring re-catheterization, were recorded. The duration of indwelling urine Foley catheter was counted from insertion to its removal. The questionnaire was based on the International Prostate Symptom Score (IPSS), the parameters of which included incomplete bladder emptying, frequency, intermittency, urgency, weak stream, straining, and nocturia. Further subdivisions were added to the seven items [10]. The scoring system for voiding function described above was based on a 0–5 scale, as follows: 0 = not at all; 1 = less than one time in five; 2 = less than half the time; 3 = about half the time; 4 = more than half the time; 5 = almost always. The IPSS was calculated by adding the item scores. We ranked urinary function as 'good' (IPSS 0–7); 'fair' (IPSS 8–14), and 'poor' (IPSS 15–35). Any voiding problems that recovered within 3 months after operation was considered as transient bladder voiding dysfunction, otherwise they were deemed persistent.

Results

A total of 26 patients with distal rectal cancer were accrued and underwent robotic lymph node dissection around the IMA with preservation of the LCA between February and December 2012, under the ethical approval of the clinical trial in the National Taiwan University Hospital. Mean (±standard deviation [SD]) age was 59.3 ± 13.1 years (range 37–88). There were eight females and 18 males. BMI was 28.2 ± 3.0 kg/m^2 (range 19.1–34.8). Physical status (American Society of Anesthesiology classification) was class I in two, class II in seven, and class III in 17 patients. The main reason for the present 26 patients who were considered as high risk for anastomotic leakage, with necessity for preservation of the LCA, included pulmonary dysfunction (lung emphysema, obstructive lung disease) in four patients, cardiovascular disease (coronary arteriosclerosis, arrhythmia, heart failure, hypertension) in six, renal insufficiency (serum creatinine >2.0 mg/dl) in two, diabetes mellitus (necessity of preoperative drug treatment) in seven, arterial circulation disturbance (occlusion of arterial vessels of limb, cerebral ischemia in patient's history) in two, BMI >30 kg/m^2 in two, and age >80 years in three patients.

Ten patients were undergoing preoperative chemoradiation therapy (CCRT) and 16 received surgical intervention directly. The pathologic TNM stage was four patients with complete response after CCRT (stage 0), one with stage I, two with stage II, and three with stage III. In patients without preoperative CCRT, the pathologic stage was stage I in one; stage II in six, and stage III in nine. For patients undergoing preoperative CCRT, defunctioning ileostomy was a routine procedure.

The number of cleared lymph nodes was 26.1 ± 7.2 (range 10–44). The operation time was 307.3 ± 74.1 min (range 180–420) (including docking time). The blood loss was 190.5 ± 225.8 ml (range 50–800). There was no surgical mortality. However, anastomotic leakage occurred in one patient (1/16, 6 %) without preoperative CCRT, and wound infection of port sites was detected in two patients (2/26, 7.6 %). The patients convalesced quickly, as evaluated by the recovery of flatus passage (48.0 ± 12.0 h, range 24–120), hospitalization (14.6 ± 4.8 days, range 7–28), and degree of postoperative pain (2.5 ± 0.5 visual analog scale, range 2.0–8.0). The median time for the removal of the Foley catheter was 6 days (range 3–28). Preoperatively, the baseline urinary function of all patients was ranked as good (IPSS 0–7). However, after removal of the urine Foley catheter postoperatively, the ranks of IPSS were changed to good in 22 patients (84.6 %), fair (IPSS 8–14) in three (11.5 %), and poor (IPSS 15–35) in one (3.8 %). There was no significant difference in pre- and postoperative IPSS score (3.40 ± 1.84 vs. 3.74 ± 2.92, $p = 0.075$, paired t test) in patients with successful nerve-preserving surgery. The fair or poor bladder function in four patients was transient dysfunction and patients recovered thereafter. The median time of return to partial activity, full activity, and work was 2.0, 4.0, and 6.0 weeks, respectively. Besides the expenses covered by the National Bureau of Health Insurance of Taiwan, the consumable payment by patients undergoing robotic TME for rectal cancer was NT$180,000.00 ± 3000.00 ($US1 = NT$29).

Discussion

The present study demonstrates that, with the surgical precision offered by the three-armed Da Vinci® robotic system in our clinical setting, D3 lymph node dissection with preservation of the LCA can be performed with good technical efficiency, quick functional recovery, and mild disability for patients with distal rectal cancer requiring TME and posing risk factors for colorectal anastomotic leakage [4–6]. The surgical outcomes of the present case series are consistent with our hypothesis that by maintaining the blood supply to the proximal colon, anastomotic failure can be prevented for the surgery of distal rectal cancer requiring a very low colorectal anastomosis, especially for patients with

risky comorbidities. In this study, we routinely performed defunctioning ileostomy for patients ($N = 10$) with rectal cancer after preoperative CCRT, and the colorectal anastomosis of all patients were well protected and, their ileostoma was closed 3 months after the TME surgery. In contrast, in patients without preoperative CCRT ($N = 16$), anastomotic leakage was detected in one obese patient, whose anastomotic failure was due to failure of the circular stapler but not from ischemia. Compared with other reported series' based on patients with low and moderate risk [4–6], the leakage rate of 6 % in the present case series of high-risk patients was favorable. However, it may be challenged that the preservation of the LCA may inevitably limit the pull-down of the proximal bowel segment to the low pelvic level to facilitate a tension-free colorectal anastomosis, and thus paradoxically increase the risk of anastomotic leakage. We found that such a problem can be circumvented if the IMV is ligated at a high level flush with the lower border of the pancreas and the lateral attachments of descending colon are mobilized to the level of the splenic flexure, both of which were routine procedures in this study.

The present study shows that lymph node dissection over the root of the IMA and LCA can achieve an adequate harvest of lymph nodes, which implies that the present surgical technique, in which the LCA was preserved, did not compromise the oncologic efficacy for the treatment of low rectal cancer. However, D3 lymph node dissection over the IMA and LCA poses several technical tips that need to be further addressed. First, although the average length between the origin of the IMA and that of the LCA has been estimated to be 4.0 cm [2], there can be a large distance in some cases, which can make lymph node dissection around the IMA difficult until the LCA is recognized. Second, as shown in the attached video (video file 3 and Fig. 4f), the ascending branch of LCA usually intertwines very closely with the IMV, and it was remarkable that the surgical stability (tremor elimination and motion scaling) provided by the robotic arms can make the skeletonization of such small vessels a precise procedure. Third, after high ligation and transection of the IMV at the low border of the pancreas, some surgeons favor an additional dissection of the mesentery lateral to the IMV in order to achieve more radical excision of the mesenteric lymphatic basin of rectosigmoid cancer. However, because of the anatomic proximity, extreme caution should be taken at this point to prevent the inadvertent injury of the Riolan vascular branch (Fig. 1), the ascending branches of the LCA, or even the marginal artery of Drummond.

In the present case series, we routinely made a complete mobilization of the left colon up to the colonic splenic flexure, without re-docking of the robotic cart. In our experience, Taiwanese patients rarely presented with extreme habitus (very tall or very high BMI), and therefore the entire extent of dissection can be achieved with three robotic arms and without any change of position of the robotic cart. In our method, the use of three robotic arms can translate into savings one-fourth of the robotic consumables expenses, compared with the standard four-arm robotic approach; and single docking of the robotic cart can translate into a more simple and time-saving entire surgical procedure, as compared with the multiple docking method. With the above-mentioned dual technical benefits, the present three-armed single-docking method can be recommended to patients with rectal cancer requiring a TME with low colorectal anastomosis, if the patient's body habitus is within the normal limits.

In the present study, the preservation of autonomic nerve function was evaluated solely by bladder function. This is because preoperative sexual dysfunction is very common in patient subsets with high-risk comorbidities.

In conclusion, the present study indicates that robotic D3 lymph node dissection with preservation of the LCA can be a treatment option for rectal cancer patients, especially those with comorbidities that risk anastomotic failure. The present preliminary results should facilitate further randomized prospective studies in a cohort of patients treated either with standard high ligation of the IMA or the present surgical technique, especially in the context that both surgical procedures were performed robotically.

Disclosure The authors, Dr. Jin-Tung Liang and Dr. Hong-Shiee Lai have no conflicts of interest or financial ties to disclose.

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