Surgical Endoscopy (2019) 33:309–314
https://doi.org/10.1007/s00464-018-6302-1

DYNAMIC MANUSCRIPT

Application of ultrasonography to high-tie and low-tie vascular ligation of the inferior mesenteric artery in laparoscopic colorectal cancer surgery: technical notes

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Received: 15 April 2018 / Accepted: 18 June 2018 / Published online: 25 June 2018

Abstract

Background Two ligation techniques can be applied in laparoscopy for left-sided colorectal cancer: (1) high-tie (HT), transection at the level of the inferior mesenteric artery (IMA); and (2) low-tie (LT), transection below the IMA, at the level of superior rectal artery (SRA), preserving the left colic artery (LCA). However, even with preoperative images, it can still be a challenge to identify these structures due to intraoperative individual conditions. In this study, we assess the use intraoperative ultrasonography (IOUS) to aid us in identifying the IMA and its branches to the SRA, LCA, and sigmoid artery.

Methods We performed IOUS in 18 patients diagnosed with left-sided colorectal cancer. Preoperatively, a three-dimensional computed tomography (3D-CT) angiography was obtained in majority of the patients, to visualize the IMA and its branches. Two patients were contraindicated to receive a contrast study, hence, was unable to undergo 3D-CT angiography. The resected specimen was grossly examined for the study. The bifurcation types were identified and compared using different modalities: preoperative 3D-CT, IOUS, and gross examination of the resected specimen.

Results The branching of the IMA revealed by IOUS was consistent to the findings preoperatively by the 3D-CT and post-operatively by the resected specimen. The IOUS result of the two patients without preoperative 3D-CT evaluation was also consistent with the post-operative bifurcation type.

Conclusions IOUS is an easy and feasible modality which aids in detecting the branching of the IMA during LT and HT ligation in laparoscopic left-sided colorectal surgery. It can serve as an adjunct modality for 3D-CT angiography and can also be considered a safe alternative option for cases wherein 3D-CT angiography is unavailable.

Keywords Intraoperative ultrasonography · Laparoscopic colorectal surgery · Vascular ligation · Low-tie transection · High-tie transection · Colorectal cancer

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00464-018-6302-1) contains supplementary material, which is available to authorized users.

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Colorectal cancer is the third most common cancer of both sexes in the United States. Surgical treatment for colorectal cancer is based on en bloc removal of the tumor with the adjacent intestine and mesentery, including blood vessels, lymphatic vessels, and lymph nodes along the blood vessels [1]. Metastatic nodal involvement is an independent and important prognostic factor [2]. Two ligation techniques can be used to remove the mesentery with regional lymph nodes: (1) high-tie (HT) transection of the vessels corresponds to division of the inferior mesenteric artery (IMA) close to the aorta; and (2) low-tie (LT) transection of the vessels corresponds to division of the superior rectal artery (SRA) below the origin of the left colic artery (LCA). The branching pattern of the IMA varies among individuals. Thus, it is very important to identify these variations to ensure successful HT and LT transection during left-sided colorectal operations.

Laparoscopic surgery for colorectal cancer has become a standard procedure in some institutions around the world. At the same time, advancement in imaging modalities has allowed for accurate preoperative vascular reconstruction using three-dimensional computed tomography (3D-CT) angiography, which provides helpful information to determine the optimal ligation level of the IMA [3, 4]. But compared to the open technique, it is much more challenging to identify the bifurcation of the LCA in laparoscopic surgery especially in patients with obesity and adhesions, even if preoperative 3D-CT angiography is available. Thus, intraoperative ultrasonography (IOUS) can help identify the branching of the IMA in certain conditions. We report our experience with IOUS for HT and LT transection during laparoscopic surgery in patients with left-sided colorectal cancer.

Materials and methods

Between January and December 2017, 18 patients diagnosed with pathologically proven left-sided colon cancer underwent laparoscopic colon resection of the said tumors with IOUS, at Kyushu University Hospital, Fukuoka, Japan. 14 of these patients were assigned to HT transections for advanced left-sided colorectal cancer, while the remaining 4 had LT transections for early cancer. Preoperative 3D-CT angiography (Aquilion One, Toshiba Medical Systems, Japan) was performed in majority of the patients. High-quality 3D image analysis system (Synapse Vincent, Fuji Film Co., Ltd., Tokyo, Japan) was used to assess and analyze the 3D images of the IMA and its tributaries.

Laparoscopic surgery for left-sided colorectal cancer was performed on all patients using a standardized technique previously reported [5]. A total of five ports were placed, one 12-mm umbilical port for the camera; another 12-mm port for the surgeon's right hand located at the right lower abdomen; and the remaining three 5-mm ports for the surgeon's left hand and the assistant's both hands placed symmetrically forming an imaginary square (Fig. 1).

Initially, the dissection is approached medially dividing the descending and sigmoid mesentery from the prehypogastric nerve fascia up to the root of the IMA and left-lateral side. The vascular pedicle of the IMA is lifted by the assistant's left hand in the lateral–ventral direction. The sigmoid mesentery is laid out horizontally by the assistant's right hand in the left-lateral direction. The laparoscopic ultrasonography probe is inserted via the 12-mm port (UST-5550® and ProSound Alpha 10®; Hitachi Healthcare Americas, OH), and the descending and sigmoid mesentery is scanned from the root of the IMA towards the periphery. The course of the IMA pedicle, LCA, sigmoid artery (SA), and SRA are scanned. Based on these findings, the IMA was divided on the central side and peripheral side of the LCA bifurcation in HT transection and LT transection, respectively. Representative images are shown in Fig. 2. IOUS was applied in an 80-year-old male with rectal cancer who underwent HT transection.

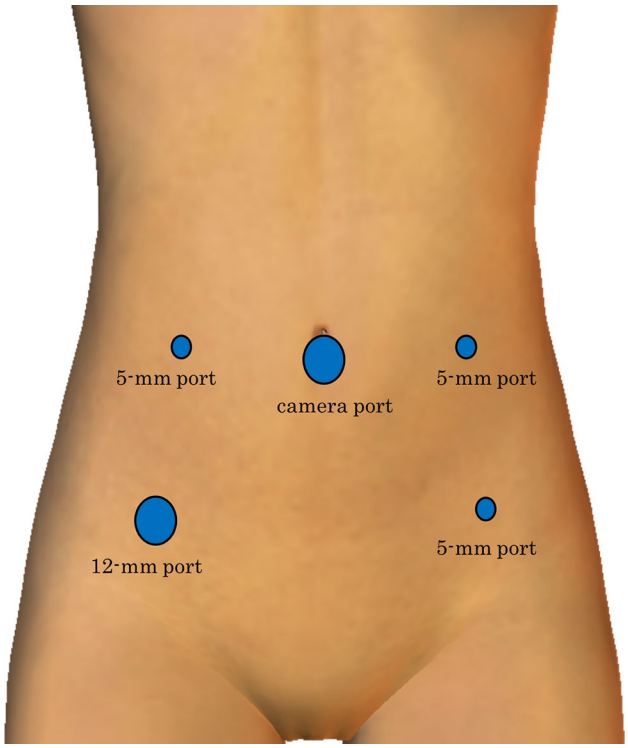

Fig. 1 A 12-mm camera port was placed via the vertical umbilical incision. Another 12-mm port was placed in the right lower abdomen. The other three 5-mm ports were symmetrically placed in the right lateral abdominal, left-lateral abdominal, and left lower abdominal regions in a square position. The operator stood on the right side of the patient

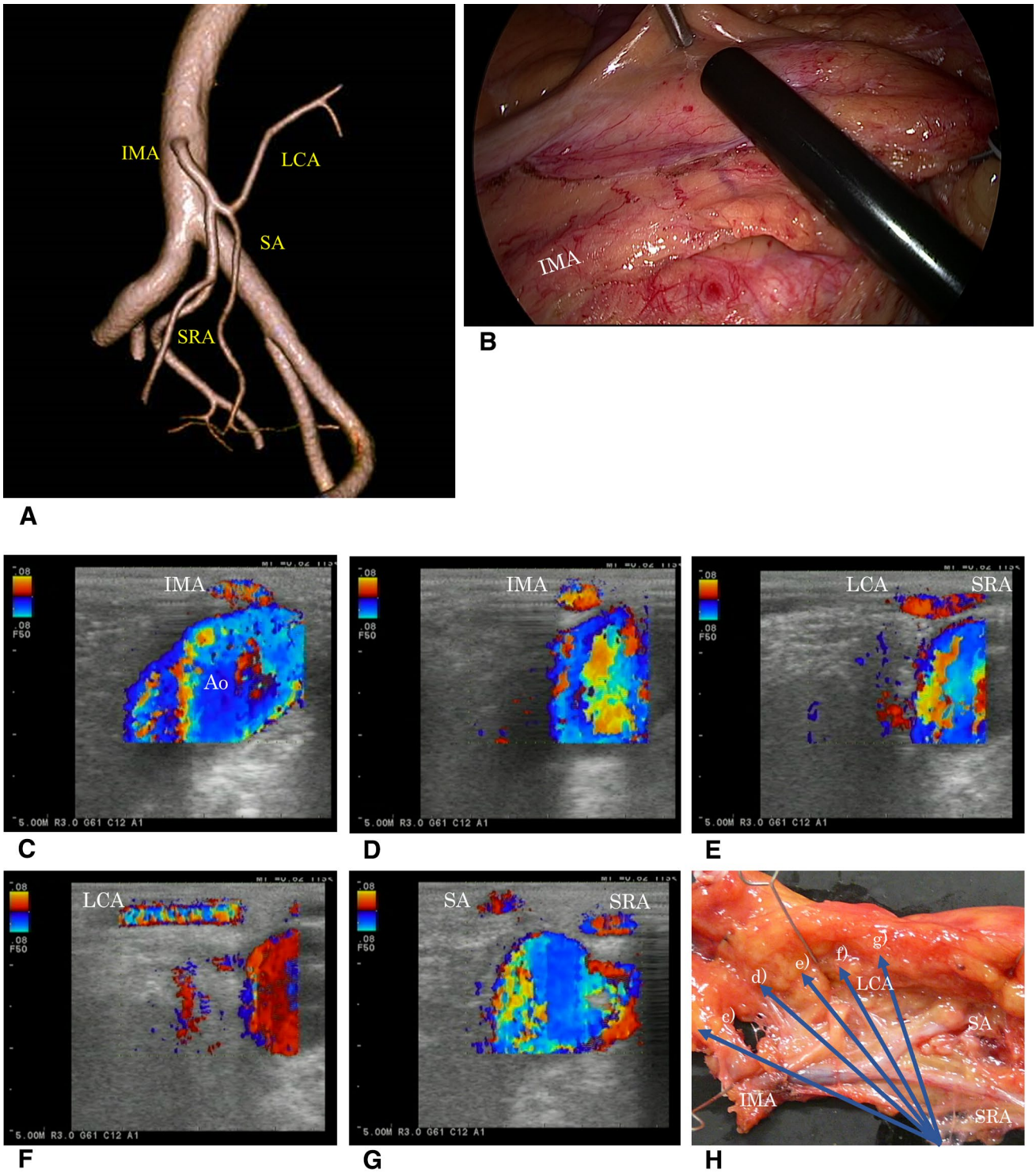

Fig. 2 **A** 3D-CT angiography shows that the LCA and SA have a common trunk. **B** The IMA is scanned from its root toward the periphery using the IOUS probe. **C–G** IOUS images from the root of the IMA toward the peripheral direction are shown in series. **H** A resected specimen reveals the branching of the IMA. Blue arrows indicate the probe directions corresponding to each IOUS image (**C–G**). *3D-CT* three-dimensional CT, *LCA* left colic artery, *SA* sigmoid artery, *IMA* inferior mesenteric artery, *IOUS* intraoperative ultrasonography

The anatomical variations of the IMA bifurcation were divided into three patterns based on the definition reported by Murono et al. [3] and Yada et al. [6] with minor modifications: (1) type 1, the LCA arose independently from the SA; (2) type 2, the LCA and SA arose from the IMA at the same point; and (3) type 3, the LCA and SA had a common trunk. Lastly, the HT resected specimens were grossly examined and analyzed. The perioperative findings of each case were tabulated and compared to identify differences among the modalities. This retrospective study was approved by the ethics committee of the Kyushu University Hospital.

Results

A total of 18 patients underwent laparoscopic left-sided colon resection with IOUS during the study period. 14 patients underwent HT, while LT for the remaining 4 patients. Majority of the patients were male ($n=10$), with an overall median age of 63.5 years (range 40–85 years). The median BMI of the cohort was 22 kg/m^2 (range 16–29 kg/m^2). In terms of intraoperative adhesions, majority of the patients had no or minimal adhesions; only one case was found to have severe adhesion. Specific procedures done were as follows: eight low anterior resection, five sigmoidectomy, four abdominoperineal resection, and one intersphincteric resection (Table 1).

The bifurcation type was also tallied using different modes (3D-CT, IOUS, and gross specimen examination). The most common type was type 1 ($n=8$), followed by type 2 ($n=5$), type 3 ($n=3$), and unclassified ($n=2$). Among the HT group, two cases failed to undergo 3D-CT reconstruction due to medical contraindication to receive contrast, which pertains to the "unclassified" type in the table. Complete information on the course of branching of the IMA was obtained from the gross examination of the resected specimens of the HT patients. The results gathered on the type of bifurcation using different modalities (3D-CT and IOUS only for LT patients) were consistent across the table (Table 2).

The video clip (Video S1) showed the application of IOUS in LT transection. The SRA was successfully divided and transected according to the information obtained by IOUS. In addition, 3D-CT angiography and IOUS both detected type 2 bifurcation of the IMA.

Discussion

Generally, IOUS in colorectal surgery has been applied for detection of synchronous liver metastasis; it showed advantage over other imaging modalities done preoperatively [7]. This study expands the application of IOUS in laparoscopic left-sided colorectal surgery by aiding the operator in identifying the IMA and its branches when doing a HT or LT transection. In open surgery, IMA can easily be located through palpation, but with the increasing use of laparoscopy in colorectal surgery, laparoscopic ultrasound plays an important role in the clinical setting.

The benefits or disadvantages between HT and LT for left-sided colorectal tumor surgery are still a controversial debate. Globally, ligation of the IMA at the origin is not routinely done. One of the benefits of doing HT is that it improves nodes harvest and gives a more accurate staging. Although HT transection significantly reduces perfusion of the proximal colon limb, it is often preferred as a

Table 1 Characteristics of the patients

Characteristics	Overall ($n=18$)	High tie ($n=14$)	Low tie ($n=4$)
Age, median, range, years	64.6 (40–85)	65.4 (40–85)	62.0 (53–75)
Sex			
Male	11	9	2
Female	7	5	2
BMI, median, range, kg/m^2	21.9 (16–29)	22.2 (16–29)	20.8 (18–24)
Procedure			
LAR	8	6	2
APR	4	3	1
Sigmoidectomy	5	4	1
ISR	1	1	0
Adhesion			
None	9	6	3
Mild	8	7	1
Severe	1	1	0

BMI body mass index, *LAR* low anterior resection, *APR* abdominoperitoneal resection, *ISR* intersphincteric resection

Table 2 List of all cases and their corresponding type of bifurcation using 3D-CT, IOUS, and GSE

Case	Transection technique	BMI (kg/m^2)	3D-CT	IOUS	GSE
1	High tie	21	Type 1	Type 1	Type 1
2	High tie	22	Type 1	Type 1	Type 1
3	High tie	21	Type 2	Type 2	Type 2
4	High tie	28	Unclassified[a]	Type 2	Type 2
5	High tie	28	Type 1	Type 1	Type 1
6	High tie	23	Type 1	Type 1	Type 1
7	High tie	16	Unclassified[a]	Type 1	Type 1
8	High tie	16	Type 2	Type 2	Type 2
9	High tie	19	Type 2	Type 2	Type 2
10	High tie	22	Type 3	Type 3	Type 3
11	High tie	18	Type 3	Type 3	Type 3
12	High tie	26	Type 1	Type 1	Type 1
13	High tie	22	Type 2	Type 2	Type 2
14	High tie	29	Type 1	Type 1	Type 1
15	Low tie	24	Type 2	Type 2	Not examined
16	Low tie	18	Type 1	Type 1	Not examined
17	Low tie	20	Type 1	Type 1	Not examined
18	Low tie	21	Type 3	Type 3	Not examined

BMI body mass index, *IOUS* intraoperative ultrasonography, *GSE* gross examination of the resected specimen

[a]3D-CT angiography not done

prerequisite for a tension-free anastomosis because it provides a longer colon length [8]. A tension-free anastomosis with a well-vascularized proximal colon limb is necessary to prevent anastomotic leakage. Generally, two factors may contribute to anastomotic leakage: first, poor vascularization of the proximal limb of the colon; and second, tension in the anastomosis. However, Rutegard et al. found no difference in the rate of symptomatic anastomotic leakage between HT and LT transection in their large retrospective study [9]. The oncological superiority of the survival benefits attributable to HT transection has remained controversial in comparative studies of HT versus LT techniques [2].

In this study, it is important to recognize the branching of the IMA in HT and LT transection for left-sided colorectal cancer. The bifurcation of the LCA is easily visualized and accessed by IOUS, because the probe can be scanned parallel to the LCA using the operator's right-hand port. A preoperative 3D-CT angiography provides accurate and objective information; however, in cases wherein it is unavailable or a contrast study is contraindicated in a patient (i.e., chronic renal disease, allergy), IOUS is a good alternative to visualize the vascular anatomy. At the same time, IOUS can aid in challenging intraoperative and real-time factors that can affect the identification of IMA, such as unrecognized anomalies, vascular effect of pneumoperitoneum (vasoconstriction), vessel tension, and amount of visceral fat. Since no discrepancy was seen in the bifurcation types between modalities (3D-CT, IOUS, and examined specimen) in this study, IOUS is an acceptable modality to detect the LCA in various conditions.

We do recognize that our study has several limitations. First, it is a non-randomized, non-blinded study. The operators knew the findings of 3D-CT angiography preoperatively. Therefore, IOUS findings might be influenced by the preconceived knowledge. However, in two patients without preoperative 3D-CT angiography, the IOUS findings were consistent with the examined resected specimen. Second, all patients included in the study were relatively lean, mean BMI of 21.5 kg/m^2. However, the IOUS images were clear and appraisable in three patients with BMI over 27. Even with these known limitations, the technique and result on the use of IOUS in laparoscopic left-sided colorectal are still notable and may be considered for certain cases.

In conclusion, our case series demonstrated that IOUS for HT and LT transection during laparoscopic operations is a safe, feasible, and reproducible technique. IOUS can serve as an adjunct modality for 3D-CT angiography. At the same time, it can also be considered as an alternative option for cases wherein 3D-CT angiography is unavailable.

Author contribution YS, SN, KN, HF, and TM conception and design; YS, SN, KN, HF, and TM acquisition of data; YS, SN, KN, HF, and TM analysis and interpretation of data; YS, VVV, KO, TO, and MN drafting the article or revising it critically for important intellectual content; YS, SN, KN, HF, VVV, KO, TM, TO, and MN final approval of the version to be published. YS thought up this technique. YS and SN are the operation attending surgeons in the video.

Compliance with ethical standards

Disclosures Yoshihiko Sadakari, Shuntaro Nagai, Vittoria Vanessa Velasquez, Kinuko Nagayoshi, Hayato Fujita, Kenoki Ohuchida, Tatsuya Manabe, Takao Ohtsuka, and Masafumi Nakamura have no conflicts of interest or financial ties to disclose.

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