

The impact of three-dimensional reconstruction on laparoscopic-assisted surgery for right-sided colon cancer

Ryoichi Miyamoto, Sosuke Tadano, Naoki Sano, Satoshi Inagawa, Shinya Adachi, Masayoshi Yamamoto

Department of Gastroenterological Surgery, Tsukuba Medical Center Hospital, Tsukuba, Ibaraki, Japan

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Abstract

Introduction: During laparoscopic-assisted colorectal surgery (LACS) for right-sided colon cancer patients, we performed three-dimensional (3D) surgical simulation to investigate vascular anatomy, including the ileocolic artery (ICA), right colic artery (RCA) and superior mesenteric vein (SMV).

Aim: We also used 3D imaging to examine the shortest distance from the root of the ileocolic vein (ICV) to the gastrocolic trunk (GCT).

Material and methods: We analyzed 46 right-sided colon cancer patients who underwent 3D-simulated LACS. We also examined a control group of 20 right-sided colon cancer patients who underwent LACS without 3D imaging. Patients who received such assessments were classified into the following two groups based on the vessel arrangement patterns of the ICA and SMV: the type A group, in which the ICA crosses anterior to the SMV, and the type B group, in which the ICA crosses posterior to the SMV. The shortest length from the root of the ICV to the GCT (D mm) was measured via 3D imaging. Patient characteristics and perioperative outcomes for these three groups were compared.

Results: The mean D mm for all cases was 29.2 ± 5.21 mm. Mean D mm values for the type A and type B groups were 27.8 ± 4.21 and 30.5 ± 5.53 mm, respectively. Intraoperative blood loss was lower in the type A group (41.8 ± 27.5 g) and the type B group (44.5 ± 31.6 g) than that in the control group (86.8 ± 27.5 g) ($p = 0.013$).

Conclusions: 3D imaging was useful for understanding anatomical relationships during LACS.

Key words: three-dimensional surgical simulation, laparoscopic-assisted colorectal surgery, right-sided colon cancer.

Introduction

Laparoscopic-assisted colorectal surgery (LACS) is currently a common surgical procedure for colorectal cancer patients. For right-sided colon cancer, an understanding of vascular anatomy, including the ileocolic artery (ICA), the ileocolic vein (ICV), the right colic artery (RCA), and the gastrocolic trunk (GCT), is important for D3 lymph node dissection and reducing intraoperative blood loss. In particular, the relationship between the superior mesenteric vein (SMV) and these two arteries is important because these two arteries should be dissected proximal to

the point at which they cross the SMV. Furthermore, the vascular sheath of the SMV must be peeled off from the root of the ICV to the root of the GCT for D3 lymph node dissection [1, 2].

Laparoscopic dissection of lymph nodes while taking into account the aforementioned vessel arrangement is technically demanding and time consuming [3, 4]. One reason for this is that several vessel arrangement patterns exist among the ICA, ICV, RCA, GCT, and SMV. Previous studies have reported that the ICA crosses the SMV anteriorly in 20.8–52% of cases and posteriorly in 48–79.2% of cases [1, 5, 6]. Furthermore, it has been reported

Address for correspondence

Ryoichi Miyamoto, Department of Gastroenterological Surgery, Tsukuba Medical Center Hospital, 1-3-1 Amakubo, Tsukuba, Ibaraki 305-8558, Japan, phone: +81 298 51 3511, fax: +81 298 51 3512, e-mail: goodfirst883@gmail.com

that the RCA branches from the SMV in 30–38% of cases [5, 7, 8]. Previous studies also reported that the SMV arrangement pattern could be classified by 3DCT angiography [9, 10]. In terms of arrangement pattern including the ICV to GCT, the shortest distance between these two vessels is often unclear, especially in laparoscopic surgery. Therefore, it is very difficult to appreciate the precise anatomical variations and relationships associated with the aforementioned vessel arrangement. Another factor that impedes laparoscopic identification of vessel arrangement is the difficulty inherent in determining the surgical anatomy using laparoscopy. We could not directly manipulate lesions using this approach. To solve these problems, we used reconstructed three-dimensional (3D) imaging during laparoscopic-assisted surgery, including LACS [11, 12]. The reconstructed 3D image could easily be observed from any angle. By predicting the direction from which the laparoscope will observe abdominal organs or vessel arrangements, a 3D image indicating the field of view of the laparoscope can be reconstructed.

Aim

In the present study, we examined the 3D simulated vessel arrangement pattern among the ICA, ICV, RCA, and SMV, and the distance from the root of the ICV to the GCT using 3D imaging. Furthermore, we evaluated the extent to which their anatomical variations affected perioperative outcomes.

Material and methods

Reconstructed 3D images used in the present study

We used a workstation (Virtual Place Advance 300, AZE, Ltd., Tokyo, Japan) to construct 3D images from multidetector computed tomography (MDCT) images. This software offers a standardized analysis of 3D anatomy based on two-dimensional MDCT imaging. A preoperative conference based on the resulting 3D images allowed for the interpretation of 3D anatomical images from any laparoscopic view and the sharing of these anatomical images with surgical staff [1–3]. Furthermore, during the actual surgery, the surgical staff was able to view the preoperative 3D images on a large display, which facilitated discussion of the vessel arrangement pattern.

Classification of the 3D simulated vessel arrangement pattern among the ICA, RCA and SMV

According to the 3D simulated anatomical relationships between the ICA and SMV, the arrangement of these vessels could definitively be classified into the following two groups: the ICA crossing anterior to the SMV (type A) and the ICA crossing posterior to the SMV (type B) (Photos 1 A, B). The ICA and RCA were defined as arteries that feed the cecum and ascending colon, respectively (Photo 1 A).

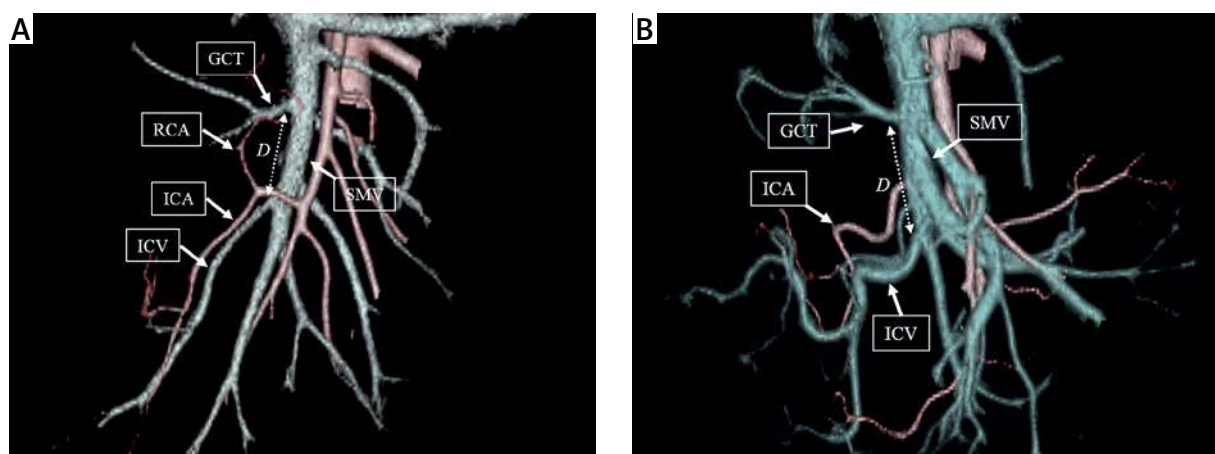


Photo 1. A reconstructed 3D image indicating the arrangement of various vessels is shown. The shortest length from the root of the ICV to the GCT (D mm) was respectively measured using a reconstructed 3D image. **A** – The ICA crosses anterior to the SMV (type A), **B** – The ICA crosses posterior to the SMV (type B)
 ICA – ileocolic artery, ICV – ileocolic vein, RCA – right colic artery, GCT – gastrocolic trunk, SMV – superior mesenteric vein.

Measurement of the distance from the ICV to the GCT

To examine the shortest distance between the ICV and the GCT, which was observed in actual operative laparoscopic findings (Photo 2), this shortest length “*D* mm” was measured using 3D imaging (Photos 1 A, B). Furthermore, this measured length was compared between the type A and B groups.

Patient characteristics and perioperative outcomes

We retrospectively analyzed 46 right-sided colon cancer patients who underwent LACS using reconstructed 3D images at Tsukuba Medical Center Hospital between December 2010 and December 2016. We also examined a control group of 20 right-sided colon cancer patients who underwent LACS without a preoperative 3D assessment of vascularity. These patients could not undergo MDCT imaging with contrast media due to severe renal dysfunction or an allergy to contrast media.

Preoperative informed consent was obtained from the patients. When performing LACS on patients with colorectal cancer, we excluded patients with a tumor size > 5 cm and patients for whom there was suspicion that the primary tumor had invaded another organ. We also excluded patients with a severe comorbidity such as low cardiopulmonary function.

The following perioperative outcomes were compared among the control group and the two groups defined based on crossing patterns of the ICA and SMV: conversion rate, operation time, intraoperative blood loss, length of postoperative hospital stay and postoperative complications. Postoperative complications were graded using the Clavien-Dindo classification system [13].

In terms of our operative technique, dissection of the intestine and lymph nodes was accomplished laparoscopically, and minilaparotomy or a laparoscopic double-stapling technique using a surgical stapler was used for anastomosis.

Statistical analysis

As appropriate, correlations among the three groups were analyzed using Bonferroni tests. Correlations between the two groups were analyzed using the χ^2 test or Fisher’s exact test as appropriate.

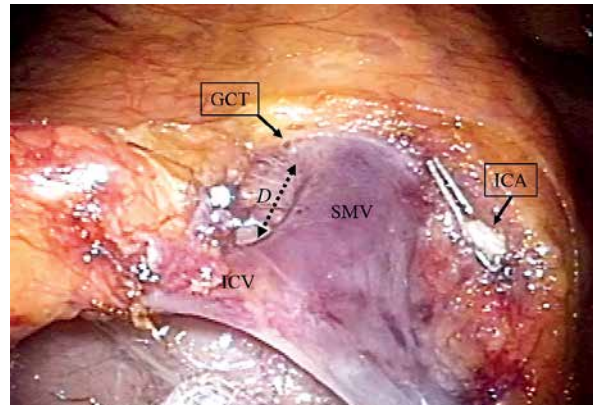


Photo 2. *D* mm was defined as the shortest length from the root of the ICV to the GCT based on actual operative laparoscopic findings. This case corresponds to type A in our classification, and this view represents that the vascular sheath of the SMV was peeled off from the root of the ICV to the root of the GCT

ICA – ileocolic artery, ICV – ileocolic vein, GCT – gastrocolic trunk, SMV – superior mesenteric vein.

Statistical analyses were performed using a statistical analysis software package (SPSS, version 21; IBM, Armonk, NY), with a value of $p < 0.05$ regarded as significant.

Results

3D simulated vessel arrangement pattern among the ICA, RCA and SMV

The 3D surgical simulation clearly indicated the ICA and SMV arrangement in all cases. The ICA crossed anterior to the SMV in 24 (52%) cases, and it crossed posterior to the SMV in 22 (48%) cases. Branching of the RCA from the SMV was observed in 11 (23%) cases.

Patient backgrounds and perioperative outcomes

No significant differences in the following patient characteristics were found among the three groups: age, sex ratio, body mass index (BMI), American Society of Anesthesiologists (ASA) score, prior history of abdominal surgery, location of primary disease, histopathological differentiation and stage (Table I).

Intraoperative blood loss was lower in the type A group (41.8 ± 27.5 g) and the type B group (44.5

Table I. Patient background data

Factors	Control (n = 20)	Type A (n = 24)	Type B (n = 22)	P-value
Age	69 (42–81)	65 (31–82)	68 (35–83)	0.511
Sex ratio (male : female)	12 : 8	14 : 10	12 : 10	0.385
BMI [kg/m ²]	21.7 ±2.15	23.7 ±3.05	24.7 ±2.25	0.169
ASA score	2.11 ±0.75	2.01 ±0.65	2.15 ±0.45	0.133
History of abdominal surgery	2 (10%)	3 (12%)	1 (4.5%)	
Location:				
C	2 (10%)	8 (33%)	7 (32%)	
A	10 (50%)	15 (63%)	13 (29%)	0.313
T	8 (40%)	1 (4%)	2 (9%)	
Histology:				
Well diff	15 (75%)	14 (58%)	12 (55%)	
Moderate diff	5 (25%)	10 (42%)	9 (41%)	0.153
Poorly diff	0	0	1 (4%)	
Stage (UICC7 th):				
0	2 (10%)	1 (4%)	1 (5%)	
I	6 (30%)	8 (33%)	6 (27%)	
IIA, IIB, IIC	8 (40%)	9 (38%)	7 (32%)	0.553
IIIA, IIIB, IIIC	4 (20%)	6 (25%)	7 (32%)	
IVA, IVB	0	0	1 (5%)	

BMI – body mass index, ASA – American Society of Anesthesiology, C – cecum, A – ascending colon, T – transverse colon, diff – differentiated, UICC – Union for International Cancer Control.

±31.6 g) than that in the control group (86.8 ±27.5 g) ($p = 0.013$). However, a comparison of perioperative outcomes did not reveal significant differences among the three groups with respect to conversion cases, operating time, length of postoperative hospital stay, or grade III–V postoperative complications (Table II).

Table II. Postoperative complications between three groups

Factors	Control (n = 20)	Type A (n = 24)	Type B (n = 22)	P-value
Conversion case	1 (5%)	1 (4%)	0	0.221
Operating time [min]	253 ±44.4	243 ±38.4	224 ±35.5	0.117
Intraoperative blood loss [g]	86.8 ±27.5	41.8 ±27.5	44.5 ±31.6	0.013
Length of postoperative hospital stay [days]	11 (9–14)	10 (9–13)	8 (6–11)	0.252
Postoperative complications (≥ Clavien-Dindo grade III)	1 (5%)	1 (4%)	0	0.211

Distance from the ICV to the GCT for the two groups

The mean D mm for all cases was 29.2 ± 5.21 . The mean D mm from the ICV to the GCT in types A and B was 27.8 ± 4.21 and 30.5 ± 5.53 mm, respectively. There was no significant difference between the two types (Table III).

Discussion

During LACS, the reconstructed 3D images facilitated our understanding of the anatomical relationships between and the vessel arrangement of the ICA, RCA and SMV. Furthermore, the findings of the present study clearly indicated no significant difference in the specific distance from the ICV to the GCT between the two groups. These findings were helpful, and the anatomical images could be shared with surgical staff to promote a safe and rapid operation, especially with regard to LACS.

Significantly less intraoperative blood loss was observed for the type A and type B groups than for the control group. Thus, an improved preoperative understanding of relevant 3D anatomy, including the arrangement of vessels and the tumor, and the sharing of 3D images with the surgical staff were assumed to contribute to the safety of laparoscopic-assisted surgery for right-sided colon cancer. Our 3D reconstruction technique was hypothesized to be particularly useful for highly obese patients. A strong relationship between obesity and intraoperative blood loss in patients has been widely discussed [14, 15]. When operating, we found that surgical anatomy was more difficult to grasp for highly obese patients than for patients with low degrees of obesity. Furthermore, high-fat tissue can be easily lacerated during surgery. These disadvantages are hypothesized to result in greater intraoperative bleeding for highly obese patients than for other patients. Although the mean BMI value for our cohort showed that most of the included patients were not obese, we theorized that our 3D reconstruction technique would allow us to grasp the precise 3D anatomy of a highly obese patient, including the arrangement of vessels and the colorectal tumor, during laparoscopic operations on the right colon. In fact, our previous study indicated that for gastric cancer surgery, preoperative 3D reconstruction significantly reduced intraoperative blood loss for highly obese patients [12].

Considering that major bleeding mainly occurs from the laceration of fragile veins including the ICV and the GCT, more emphasis should be placed on precise recognition of SMV anatomy. In fact, the present study also revealed the distance from the ICV to the GCT to be independent of the vessel arrangement pattern including the ICA and ICV. When applying the reconstructed 3D images to LACS for right-sided colon cancer patients, we assumed that this technique

Table III. Distance from the ICV to the GCT between two groups

Branching type	No. of patient	D, mean \pm SD [mm]	P-value
Type A	24 (52%)	27.8 \pm 4.21	
Type B	22 (48%)	30.5 \pm 5.53	0.433
All	46	29.2 \pm 5.21	

ICV – iliocolic vein, GCT – gastrocolic trunk.

would be useful for recognizing the vessel arrangements among the ICA, ICV, RCA, GCT and SMV. These results may contribute to safe and rapid surgery and a reduction of intraoperative blood loss.

Our surgical concept for treating right-sided colon cancer is based on performing a surgical procedure known as D3 dissection. Several reports have discussed the significance of thorough lymph node dissection up to the root of the ICA proximal to the point at which the ICA crosses the SMV [16, 17]. However, obtaining a 3D anatomical image of the ICA and SMV when dissecting around the ICA during laparoscopic surgery has been difficult. Therefore, we assumed that the present reconstructed 3D image would facilitate recognition of the vascular anatomical relationship between the root of the ICA and SMV. This surgical technique is based on oncological tissue planes and results in a colon and mesocolon specimen lined with the intact fascial coverage of the tumor and containing all blood vessels, lymphatic vessels, lymph nodes and surrounding soft tissue, which may contain disseminated cancer cells. Several previous reports have indicated that employing these procedures contributes to good long-term outcomes for the treatment of right-sided colon cancer [15–18].

Preoperative 3D simulation for LACS is now an essential modality for performing safe and rapid surgery. Hirai *et al.* [3] clarified the anatomic relationship among the ICA, RCA and SMV using 3D images. We also applied 3D imaging during LACS [11]. The reconstructed 3D image could easily be observed from any angle. After predicting the direction of laparoscopic observation of the abdominal organs, a 3D image can be reconstructed for the field of view of the laparoscope [19]. Our prior study, which involved the use of 3D images, demonstrated that left coronary artery (LCA) branching patterns could be classified into three groups and that the specific distances from the inferior mesenteric artery (IMA) to the LCA branch

and the inferior mesenteric vein (IMV) did not significantly differ across these three groups [11].

The present findings of the anatomical relationship between the ICA and SMV differ from previous reports. Spasojevic *et al.* and autopsy studies have reported that the ICA tends to cross the SMV anteriorly in 20.8–36.7% of cases and posteriorly in 63.3–79.2%, whereas in the present study, the ICA tended to cross the SMV anteriorly in 53% of cases and posteriorly in 47% of cases [1, 5, 6]. We assumed that this discrepancy might be attributed to ethnicity. Similarly to the present report, Hirai *et al.* [3] also reported that the ICA crossed the SMV anteriorly in 52% of cases and posteriorly in 48% of cases in a Japanese cohort.

Conclusions

The present 3D simulation technique was useful for determining the relative positions of the ICA and SMV during LACS. Furthermore, we also revealed that the shortest distance from the ICA to the GCT was independent of the vessel arrangement pattern between the ICA and ICV. We propose the use of this 3D imaging technique as a novel modality for preoperative assessment and safe intraoperative navigation during LACS.

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Conflict of interest

The authors declare no conflict of interest.

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