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FULL PAPER

The variations of the middle colic vein tributaries: depiction by three-dimensional CT angiography

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Objective: Laparoscopic transverse colectomy is challenging owing to technical difficulties in identifying an adequate dissection plane, ligating and dissecting lymph nodes around the middle colic vessels. One of the reasons for the technical difficulties is the complex relationship between the middle colic vein (MCV) and its tributary. So, defining the venous anatomy around the MCV before laparoscopic surgery seems important to avoid massive bleeding. The purpose of this study was to evaluate the depiction rate and variation of the MCV and its tributaries on three-dimensional CT angiography (3DCTA).

Methods: This study included 331 patients (203 males and 128 females) scheduled for laparoscopic surgery between June 2010 and April 2012. Most of the patients had gastric or colorectal cancer. Patients who needed emergency surgeries for obstruction or perforation were excluded. 3DCTA with an i.v. contrast medium was performed

immediately following the administration of effervescent granules or room air insufflation. We assessed variations of the MCV tributaries using transaxial, multiplanar reconstructed images and volume-rendering images.

Results: The MCV could be identified in all patients. The MCVs drained into the superior mesenteric vein in 62.5% of patients, gastrocolic trunk of Henle in 29.3% of patients, inferior mesenteric vein in 4.8% of patients, splenic vein in 2.7% of patients and jejunal vein in 0.6% of patients.

Conclusion: 3DCTA is useful in evaluating the anatomic variants of the MCV in pre-operative planning for laparoscopic surgery.

Advances in knowledge: Use of 3DCTA for the recognition of the anatomic complexity around the MCV and its tributary plays an important role in pre-operative planning for optimal patient outcome.

INTRODUCTION

Laparoscopic surgery has been widely accepted as an alternative to open surgery for colon cancer. However, transverse colectomy is challenging owing to the difficulty in deciding the appropriate operative procedure and extent of lymph node dissection, as well as the technical difficulties in the laparoscopic identification of an adequate dissection plane, ligation and lymph node dissection around the middle colic vessels.¹ For safer laparoscopic transverse colectomy, it seems important to know the venous anatomy around the middle colic vein (MCV) beforehand to avoid massive bleeding from tearing of the veins.¹

Three-dimensional CT angiography (3DCTA) is useful in pre-operatively identifying the arterial and venous anatomies.^{2–5} Although there have been previous studies of vascular anatomy, few have addressed the venous anatomy

around the superior mesenteric vein (SMV), particularly the tributary of the MCV; to our knowledge, there have been few *in vivo* studies with a sufficiently large number of patients.^{2,3,6}

Previous studies have demonstrated that the relationship between the MCV and its tributaries is complex. In the present study, therefore, we performed 3DCTA with gastrointestinal distention for all patients scheduled to undergo gastrectomy or colectomy, excluding those who needed emergency surgery, and assessed the MCV tributary variation.

METHODS AND MATERIALS

Patients

Between June 2010 and April 2012, 331 consecutive patients (203 males and 128 females; mean age 67 years; range, 29–90 years) scheduled for laparoscopic surgery in our institution were included in this study. Patients who needed emergency surgery for obstruction or perforation

Table 1. Summary of patient diseases

Disease	<i>n</i>
Gastric cancer	113
U	14
M	62
L	18
UM/MU	3
ML/LM	14
MUL/LMU	2
Gastric submucosal tumour	4
U	1
M	3
Colorectal cancer	199
Ascending colon	31
Caecum	17
Transverse colon	22
Descending colon	16
Sigmoid colon	52
Rectum	54
Ascending and sigmoid colon	1
Ileocaecum	2
Appendix	2
Ascending and descending colon	1
Sigmoid and rectum	1
Gastric (ML) and ascending colon cancer	1
Gastric (M) and transverse colon cancer	1
Others	13
Anal canal cancer	1
Rectal carcinoid tumour	1
Appendix of suspicious for malignancy	1
Extragastrintestinal stromal tumour	1
Lymph node dissection post-sigmoid colectomy	1
Cyst of the diaphragm	1
Liver tumour	1
Sigmoid volvulus	1
Ovarian cancer	1
Duodenal cancer	1
Bile duct cancer	1
Median arcuate ligament syndrome	1
Sarcoma of the mesentery	1

L, lower part of the stomach; M, middle part of the stomach; U, upper part of the stomach.⁷

When involving multiple parts, all parts were recorded in the order of degree of involvement e.g. UM or MUL.

were excluded. Written informed consent for the examination was obtained from all patients. The institutional review board approved this retrospective study. The summary of the patients is shown in Table 1. The disease was gastric cancer in 113 (34.1%) patients, colorectal cancer in 199 (60.1%) patients and both gastric and colon cancers in 2 (0.6%) patients.

Preparation

Distention of the stomach or colon was performed to enable a clear view of the courses of the surrounding arteries and veins in all patients. The colon had to be thoroughly cleaned to depict the bowel lining clearly. The patients scheduled to undergo colectomy were instructed to take inspection diet (FG-two☆®; Fushimi Pharmaceutical Co., Ltd., Kagawa, Japan; and Enimaclin®; Horii Pharmaceutical Ind., Ltd., Osaka, Japan) for 2 days prior to the examination. In the evening before the examination, they took purgative agents such as magnesium citrate (Magcorol P®; Horii Pharmaceutical Co., Ltd, Tokyo, Japan), sennoside A and B calcium (Sennoside Tab., Taisho Pharmaceutical Co., Ltd., Tokyo, Japan) and sodium picosulfate hydrate (Laxisoberon, Pfizer Japan Inc., Tokyo, Japan).

The patients were placed in a right decubitus position and room air was insufflated through a rubber catheter (diameter: 8.5 mm) (Izumo-Health, Co., Ltd, Nagano, Japan) inserted into the rectum until they felt uncomfortable distension; the patients were encouraged to keep the gas in the rectum. Carbon dioxide insufflation is widely used in the USA and Europe in CT colonography, but such a system had not been approved in Japan until August 2011. In our institution, it became available in May 2012. So, room air was used in our study. After the colon was inflated, the catheter was left in the rectum. Patients with intestinal obstruction due to colorectal cancer did not undergo air insufflation owing to the risk of perforation, based on assessment by a gastroenterologist or surgeon. The patients scheduled to undergo gastrectomy fasted starting 4 h prior to the examination and took 5.0 g of effervescent granules (Baryace®, Fushimi Pharmaceutical Co., Ltd, Kagawa, Japan) just before the examination for inflation of the stomach.

Imaging data acquisition and reconstruction protocol

A 64-detector row CT scanner (Light Speed VCT Vision; GE Healthcare, Milwaukee, WI, or Aquilion 64; Toshiba Medical Systems, Tokyo, Japan) was used. Scanning parameters were as follows: tube voltage, 120 kV; tube rotation speed, 0.4 s for Light Speed VCT Vision and 0.5 s for Aquilion 64; pitch factor, 0.984 and 0.703, respectively; collimation 64 × 0.625 mm and 64 × 0.5 mm, respectively; slice thickness, 0.5 mm for both; reconstruction kernel, STANDARD and FC13, respectively. Dynamic contrast-enhanced CT was performed using a bolus tracking technique, where a region of interest was placed on the abdominal aorta at the level of the root of the celiac artery and the trigger threshold inside the region of interest was set at 100 HU higher than the baseline. The first arterial phase scan was started immediately after the threshold was achieved following administration of a contrast material. The second portal phase images were obtained 25 s after the first arterial phase, and the third venous phase images were obtained 40 and 50 s after the second phase for patients weighing <60 kg and 60 kg or more,

Figure 1. A 69-year-old male with gastric cancer before laparoscopy-assisted total gastrectomy. (a, b) Transaxial and (c) coronal multiplanar reconstruction and maximum intensity projection images clearly showing the middle colic vein (MCV) draining into the superior mesenteric vein (SMV). (d) CT angiographic reconstruction using volume rendering showing the MCV draining into the SMV. GCT, gastrocolic trunk.

respectively. The data set was reconstructed with 0.625-mm section thickness and 0.625-mm increment for Light Speed VCT Vision and with 0.5-mm section thickness and 0.5-mm increment for Aquilion 64 and then processed using three-dimensional (3D) multiplanar reconstruction (MPR) with thin-slab maximum intensity projection in the coronal plane with 3-mm thickness and 2-mm increment and volume-rendering technique on a workstation (Ziostation; Zio Software, Tokyo, Japan).

Contrast material

To obtain dynamic contrast-enhanced CT images, a non-ionic iodinated contrast agent was injected through a 20-gauge catheter into a vein in the antecubital fossa. For patients weighing

<55 kg, 300 mgI/ml of iohexol (Omnipaque 300®; Daiichi Sankyo Co., Ltd., Tokyo, Japan) was used and for those weighing 55–65 kg, 350 mgI/ml of iomeprol (Iomeron® 350; Eisai Co., Ltd., Tokyo, Japan) was used. They were infused rapidly at 4.5 ml s^{-1} using an automated injector (Dual Shot GX; Nemoto Kyorindo, Tokyo, Japan) in a total volume of 100 ml, followed by a 30-ml saline flush. For patients weighing 65 kg or more, 300 mgI/ml of Omnipaque 300® was infused at 5.0 ml s^{-1} in a total volume of 150 ml, followed by a 30-ml saline flush.

Image analysis

The MCV was defined as the tributary from the marginal veins of the transverse colon. When the MCV showed insufficient

Figure 2. A 39-year-old female with gastric cancer before laparoscopy-assisted distal gastrectomy. (a) Transaxial and (b) coronal multiplanar reconstruction and maximum intensity projection images clearly showing the middle colic vein (MCV) draining into the gastrocolic trunk (GCT) of Henle. (c) CT angiographic reconstruction using volume rendering showing the MCV draining into the GCT of Henle. SMV, superior mesenteric vein.

Figure 3. A 90-year-old male with gastric cancer before laparoscopy-assisted distal gastrectomy. (a, b) Transaxial images clearly showing the middle colic vein (MCV) draining into the inferior mesenteric vein (IMV). (c) CT angiographic reconstruction using volume rendering showing the MCV draining into the IMV. SMV, superior mesenteric vein.

enhancement in the portal phase, venous phase images were used. The MCV was confirmed by the finding of running parallel with the middle colic artery (MCA) in the arterial phase. Two radiologists with 30 and 4 years' experience in diagnostic radiology evaluated the transaxial, 3D MPR with maximum intensity projection and volume-rendering images on the portal phase images in combination with the arterial and venous phase images. The MCV was identified as a vein which flowed back from the transverse colon and accompanied the MCA, and then, types of tributaries of the MCV were classified by a discussion.

Literature review

Previous reports on MCV tributaries were searched in PubMed using various combinations of the following keywords: computed tomography, CT angiography, middle colic vein, three dimensional, transverse, colon, laparoscopic, laparoscopy, colectomy, surgery, anatomy, preoperative, vascular, mesocolon, mesenteric vein, variation and tributary. The obtained data were compared with those of the present study.

RESULTS

The MCV could be identified in all patients, and its tributaries were classified into five types. The MCV drained into the SMV [207 (62.5%) of 331 patients] (Figure 1), the gastrocolic trunk of Henle [97 (29.3%) of 331 patients] (Figure 2), the inferior mesenteric vein (IMV) [16 (4.8%) of 331 patients] (Figure 3),

the splenic vein (SV) [9 (2.7%) of 331 patients] (Figure 4) or the jejunal vein (JV) [2 (0.6%) of 331 patients] (Figure 5).

Table 2 shows a summary of the present results and those of previous studies. The most common type was the MCV draining into the SMV, followed by the type draining into the gastrocolic trunk of Henle. In previous studies, the percentage of the MCV draining into the SMV, gastrocolic trunk of Henle, IMV, SV and JV was 68–89%, 11–23%, 0–11%, 0–3% and 0–6%, respectively.^{2,3,6,8,9}

DISCUSSION

Currently, the use of laparoscopic surgery for colorectal cancer has been accepted based on several prospective randomized controlled studies and meta-analysis of several trials showing that its safety and efficacy are similar to those of open surgery.^{10–14} However, because laparoscopic surgery for transverse colon cancer was considered to be difficult owing to anatomical complexity, it was excluded from prior randomized controlled trials.^{1,15} Laparoscopic transverse colectomy tends to be more difficult for patients who are severely obese and for patients with severe adhesions.¹⁵ On the other hand, laparoscopic surgery is superior to open surgery in terms of good visibility of the operative field owing to the magnifying effect.^{16,17} The magnifying effect may allow for sufficiently experienced surgeons to reduce injury to vessels and vital structures and offset the difficulty of transverse colectomy. 3DCTA

Figure 4. A 59-year-old male with descending colon cancer before laparoscopic colectomy. (a) Transaxial and (b) coronal multiplanar reconstruction and maximum intensity projection images clearly showing the middle colic vein (MCV) draining into the splenic vein (SV). (c) CT angiographic reconstruction using volume rendering showing the MCV draining into the SV. SMV, superior mesenteric vein.

Figure 5. A 78-year-old male with gastric cancer before laparoscopy-assisted distal gastrectomy. (a) Transaxial and (b) coronal multiplanar reconstruction and maximum intensity projection images clearly showing the middle colic vein (MCV) draining into the jejunal vein (JV). (c) CT angiographic reconstruction using volume rendering showing the MCV draining into the JV. SMV, superior mesenteric vein.

before laparoscopic surgery helped achieve safe ligation of the vessels and dissection of the lymph nodes.^{4,5} Pre-operative evaluation of 3D portography allowed for decreased operation

time and blood loss with laparoscopic surgery.³ Thus, the combination of 3DCTA and the good visibility of laparoscopy may be beneficial for difficult operations.

Table 2. Summary of previous studies on middle colic vein (MCV) drainage

First author (References)	Number of patients with MCV (%)	Modality	Veins into which the MCV drained <i>n</i> (%)					Notes PSPDV
			SMV	GCT	IMV	SV	JV	
Ibukuro et al (1996) ⁶	36/50 (72)	CT	27 (75)	5 (14)	4 (11)	0 (0)	0 (0)	1 (3)
Yamaguchi et al (2002) ⁸	58/58 (100)	Cadavers	49 (84)	7 (12)	1 (2)	2 (3)	0 (0)	Main MCV ^a 1 MCV, <i>n</i> = 22 (38%) Multiple <i>n</i> = 36 (62%) 2 MCVs, <i>n</i> = 29 (50%) 3 MCVs, <i>n</i> = 7 (12%)
Jin et al (2006) ⁹	9/9 (100)	Cadavers	8 (89)	1 (11)	0 (0)	0 (0)	0 (0)	–
Sakaguchi et al (2010) ²	96/102 (94)	CT	SMV left trunk					Total <i>n</i> = 107 (single and multiple type) 1 MCV <i>n</i> = 86 (84%), multiple <i>n</i> = 10 (10%) 2 MCVs, <i>n</i> = 9 (2%) 3 MCVs, <i>n</i> = 1 (1%)
			77 (72)	21 (20)	9 (8)			
			62 (72)	20 (23)	4 (5)			
Ogino et al (2014) ³	81/81 (100)	CT	55 (68)	16 (20)	4 (5)	1 (1)	5 (6)	Main MCV ^a 1 MCV, <i>n</i> = 40 (49%), 2 MCVs, <i>n</i> = 37 (46%), 3 MCVs, <i>n</i> = 4 (5%)
This study	331/331 (100)	CT	207 (63)	97 (29)	16 (5)	9 (3)	2 (1)	–

GCT, gastroduodenal trunk of Henle; IMV, inferior mesenteric vein; JV, jejunal vein; PSPDV, posterior superior pancreaticoduodenal vein; SMV, superior mesenteric vein; SV, splenic vein.

^aWhen >2 MCVs were present, the thickest vein was defined as the main vein.

Figure 6. Schematic illustration showing the anatomy around the middle colic vein (MCV). (1) gastrocolic mesocolon; (2) transverse mesocolon; (3) transverse colon; (4) middle colic artery; (5) MCV; (6) superior mesenteric artery; (7) superior mesenteric vein; (8) gastrocolic trunk; (9) right gastroepiploic vein; (10) right gastroepiploic artery; (11) pancreas; (12) splenic vein; (13) duodenum.

In embryology, the transverse mesocolon is fused with various fascias until 20 weeks of gestation. The peritonea at the attachment site are fused together and degenerate to form a membranous connective tissue called the fusion fascia. The MCV passes between the layers of the transverse mesocolon (Figure 6).^{18,19} In laparoscopic transverse colectomy, surgeons must identify and dissect the correct layer of the fusion fascia for complete dissection of the lymph nodes at the root of the MCA (Figure 7). Also, surgeons should take care not to injure vital organs adjacent to the MCVs, such as the pancreas and duodenum, and avoid tearing of the veins around the SMV and massive bleeding owing to excessive traction of the transverse mesocolon.¹ To avoid these complications, we considered that pre-operative identification of the MCV and its tributaries using 3DCTA should be helpful, after discussion with our surgeons.

Few studies have been published regarding the venous anatomy around the SMV, particularly the tributaries of the MCV.^{2,3,6,8,9} While two of the five studies could not identify the MCV in every patient, we identified the MCV in all patients and classified its tributary into five types. We filled the gastrointestinal tract with adequate air to distend the mesenteries, which allowed for easy tracing of the vessels. This technique, coupled with the use of various imaging techniques including MPR, may have contributed to the 100% identification success rate of the MCVs in the present study. In previous studies, the most commonly identified type was the MCV that drained into the SMV, followed by the MCV that drained into the gastrocolic trunk of Henle. Although we observed the same tendency, compared with previous studies, the present study showed the lowest frequency of the MCV draining into the SMV (63%) and the highest frequency of the MCV draining into the gastrocolic trunk of Henle (29%). Our study included the

largest number of patients, and this may, in part, account for the differences in frequencies. The inclusion of thin MCVs in other studies may have also contributed to the differences in reported frequencies,^{2,3,8} whereas only the thickest main MCV was investigated in the present study. In a previous study that investigated a single MCV, the frequency of the MCV draining into

Figure 7. View after complete dissection of lymph nodes at the root of the middle colic artery (MCA) in laparoscopic transverse colectomy. The middle colic vein (MCV) drained into the superior mesenteric vein (SMV). The red dashed line shows the area of the radical dissection. The pancreas and important vessels are close to the area. Owing to the magnifying effect, an adequate dissection plane and lymph nodes are clearly identified and resected. GCT, gastrocolic trunk; IMV, inferior mesenteric vein; SMA, superior mesenteric artery.

the gastrocolic trunk of Henle was 23%,² which is the closest value to what was observed in the present study (29%). Few patients had MCVs that drained into the IMV or SV. Furthermore, only 2 (0.6%) patients had MCVs draining into the JV. This information may be helpful for surgeons to avoid incorrectly dissecting the gastrocolic trunk of Henle during transverse colectomy.

One of the limitations of this study is that all the patients were Japanese. There may be some racial differences in the anatomy of the veins around the MCV. Owing to the retrospective nature of this study, we were also unable to confirm the MCV tributaries for all cases during surgery. In addition, how 3DCTA may have contributed to the improvement of safety, such as reduction of operation time or reduction of blood loss, was not evaluated. Although there have been previous studies on the multiplicity of MCVs,^{2,3,5} we attempted to

identify only the thickest, main MCV; thin tributary veins are not considered to be clinically important, because injury of the small vessels may not cause massive bleeding and even when bleeding occurs, it could be stopped immediately, and the main thick MCV is important as a source of massive bleeding during surgery.

CONCLUSION

Identification of the MCV tributary is useful for lymph node dissection around the SMA and the SMV, as well as for the dissection of the MCV during transverse colectomy. It may also be helpful in assessing the tributary of the MCV for patients who are severely obese and for patients with severe adhesions. Use of 3DCTA for the recognition of the anatomic complexity around the MCV and its tributaries plays an important role in pre-operative planning for optimal patient outcome.

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