Int Surg 2018;**103**:15–20
DOI: 10.9738/INTSURG-D-16-00217.1

Preoperative Evaluation of Blood Vessel Anatomy Using 3-Dimensional Computed Tomography for Laparoscopic Surgery of Transverse Colon Cancer

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This study describes the efficacy of the evaluation of blood vessel anatomy by 3-dimensional computed tomography (3D-CT) for laparoscopic surgery for transverse colon cancer (TCC). A total of 102 patients with TCC were examined by preoperative 3D-CT to clarify their blood vessel anatomy at Tokyo Medical University Hospital between January 2010 and December 2015, before undergoing laparoscopic surgery using the obtained 3D-CT data. Regarding blood vessel variation, the middle colic artery (MCA) was present in all patients (100%). The common duct type was observed in 89 patients (87.3%), and a type of branch separate from the superior mesenteric artery was observed in 13 patients (12.7%). The accessory MCA was present in 25 patients (24.5%). The middle colic vein was present in all patients (100%), and it drained into the following vessels: the superior mesenteric vein, gastrocolic trunk, first jejunal vein, and inferior mesenteric vein [67 (65.8%), 25 (24.5%) 8 (7.8%), and 2 (1.9%) patients, respectively]. Regarding the surgical outcome, the bleeding volume was 43 g, the operative time was 218 minutes, the number of harvested lymph nodes was 21, the proximal resection margin was 164 mm, the distal resection margin was 105 mm, and the length of postoperative hospital stay was 10 days. Although complicated variations and anomalies in the MCA and the contiguous veins were observed, preoperative 3D-CT will be useful for surgeons performing laparoscopic surgery on patients with TCC.

Key words: Transverse colon cancer – Laparoscopic surgery – 3D-CT – Middle colic artery

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In large-scale randomized, controlled trials of laparoscopic colectomy,[1–3] the reasons given for excluding transverse colon cancer (TCC) include its anatomic characteristic of being in close proximity to important organs, such as the pancreas and duodenum; the difficulty in reflecting the hepatic flexure and the splenic flexure; and the difficulty in performing central ligation of the middle colic artery (MCA).[4,5] These underlying factors result in a large amount of variation in the MCA as well as the complexity of the associated veins. In addition, because the incidence of TCC is low (10%)[6,7] compared with other colon cancers, to our knowledge, there have been very few studies[8,9] published to date on vessel anatomy, which is essential information for laparoscopic central ligation of the MCA in TCC.

Therefore, in the present study we evaluated variations and anomalies in the MCA and analyzed their contiguous veins in TCC patients, by creating preoperative 3-dimensional computed tomography (3D-CT) images.

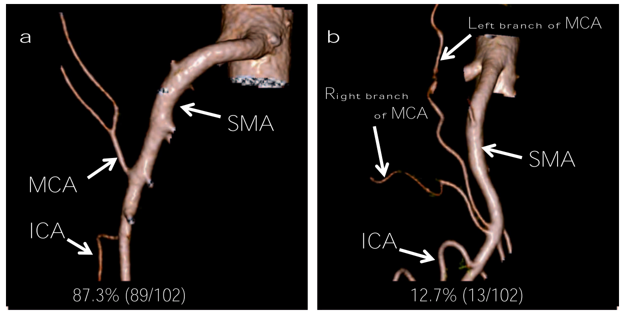

Fig. 1 Three-dimensional CT images displaying flow variations of the MCA. (a) The common duct type, in which the left and right branches of the MCA have a common vessel, was observed in 89 patients (87.3%). (b) A type of MCA in which the left and right branches do not arise from a common duct, but rather branch separately from the SMA, was observed in 13 patients (12.7%).

Materials and Methods

Patients

A total of 102 colon cancer patients (60 men and 42 women; mean age ± SD, 68.8 ± 11.8 years) who underwent preoperative 3D-CT at Tokyo Medical University Hospital between January 2010 and December 2015, before undergoing laparoscopic surgery using the collected 3D-CT data were analyzed. Informed consent was obtained from all participants, and the ethics committee of Tokyo Medical University Hospital approved the study.

3D-CT

A 64-row multidetector CT device (GE Healthcare, Little Chalfont, United Kingdom) was used to image 1-mm–thick slices by intravenously injecting (via a 30-second rapid injection) the nonionic contrast medium iopamidol in doses of 600 mg/kg using automatic syringes. Ten seconds after the CT value for the superior mesenteric artery (SMA), which was set as the region of interest, reached 100 Hounsfield units, arterial phase imaging was started, and 25 seconds after its completion, portal phase imaging was started. Vessel data were imported into a 3D image analysis (system volume analyzer) workstation (Synapse VINCENT, Fujifilm, Tokyo, Japan), bone components and areas containing organs not required for analysis were removed, and the SMA and superior mesenteric vein (SMV), as well as the other vessels of interest, were specifically targeted. However, because the software has limited ability to automatically detect blood vessels, the technician reconstructed detailed vessel images by reviewing the horizontal-slice database and plotting and tracing the small blood vessels in 1-mm slices.

Definition of blood vessels

The MCA is defined as the blood vessel that arises from the first branch on the right side of the SMA and supplies the transverse colon.[10] The accessory middle colic artery (AMCA) is defined as the blood vessel that arises from the SMA more proximally than the first jejunal artery and meets the marginal artery at the splenic flexure.[11] The middle colic vein (MCV) is defined as the largest vessel formed from the marginal veins that drain the transverse mesocolon,[12] and all of the other veins are known as accessory middle colic veins (AMCVs).[12] The gastrocolic trunk (GCT) is defined as the venous trunk that drains into the SMV from the right side and which functions as the common vein into which the MCV, AMCV, right gastroepiploic vein, and anterior superior pancreaticoduodenal vein drain.[13]

Results

Blood vessel variation

MCA

The MCA was present in all patients (100%). After the MCA branched off the right side of the SMA, it went toward the transverse mesocolon (Fig. 1a). The

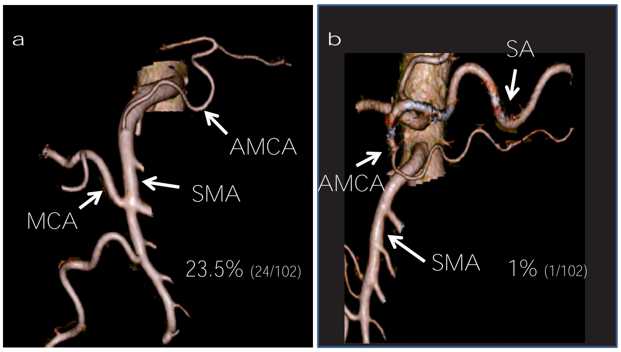

Fig. 2 Three-dimensional CT images displaying flow variations of the AMCA. (a) In most patients, the AMCA arose from the SMA (23.5%). (b) In 1 patient, the AMCA arose from the splenic artery (1%).

common duct type, in which the left and right branches of the MCA have a common vessel, was observed in 89 patients (87.3%). The common duct was found to be 28.7 ±15.4 mm in length. Normally, the MCA branches off the SMA 9.7 ± 11.0 mm from the caudal side of the GCT, but in 10 patients (9.8%), the MCA was found to branch off the SMA on the cranial side of the GCT. A type of MCA in which the left and right branches do not arise from a common duct, but rather branch separately from the SMA, was observed in 13 patients (12.7%; Fig. 1b).

AMCA
The AMCA was present in 25 patients (24.5%). It was found to run along the transverse mesocolon toward the splenic flexure and branch off the SMA 16.5 ± 12.5 mm from the cranial side of the GCT. In 24 patients (23.5%) it branched off the SMA (Fig. 2a), and in 1 patient (1%) it branched off the splenic artery (Fig. 2b).

MCV
The MCV was present in all patients (100%) and was observed to drain into the following vessels: the SMV in 67 patients (65.8%), the GCT in 25 patients (24.5%), the first jejunal vein (J1V) in 8 patients (7.8%), and the inferior mesenteric vein in 2 patients (1.9%; Fig. 3). The most commonly observed type of MCV, which drains into the SMV, was located 10.0 ± 5.8 mm from the cranial side of the GCT.

AMCV
The AMCV was present in 45 patients (44.1%). It was a single vessel in 40 patients (39.2%) and a double vessel in 5 patients (4.9%). The AMCV was observed to drain into the following vessels: the GCT in 34 patients (33.3%), the SMV in 9 patients (8.8%), and the splenic vein in 1 patient (0.9%).

GCT
The GCT was present in 98 patients (96.0%; Fig. 4). The MCV or AMCV, right gastroepiploic vein, and anterior superior pancreaticoduodenal vein merged to form the venous trunk and directly connected to the SMV from the right side. The GCT was absent in 4 patients.

Surgical outcome

The median bleeding volume was 49.2 ± 56.0 g, operative time was 217.5 ± 48.5 minutes, number of harvested lymph nodes was 21.0 ± 11.4, proximal resection margin was 164.4 ± 78.5 mm, distal resection margin was 113.0 ± 111.0 mm, and length of postoperative hospital stay was 10.0 ± 2.8 days. Laparoscopic surgery for TCC was performed without conversion to open surgery in all patients.

Discussion

In recent years, research has shown that complete mesocolic excision (CME) leads to a 7% to 15% improvement in the 5-year survival rates of patients with colon cancer,[14,15] and as a result, the importance of CME is now widely recognized. In many

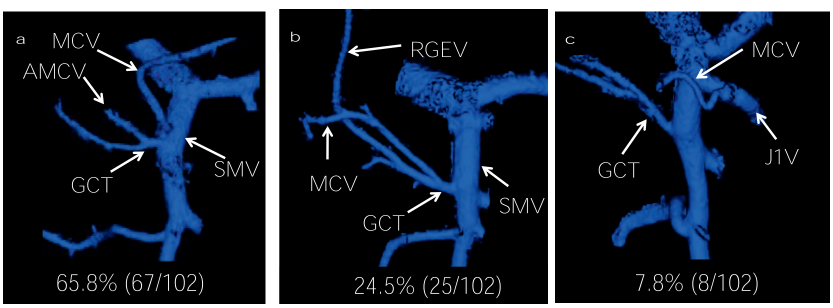

Fig. 3 Three-dimensional CT images displaying flow variations of the MCV. (a) The MCV drained directly into the SMV (65.8%). (b) The MCV drained into the GCT (24.5%). (c) The MCV drained into the J1V (7.8%).

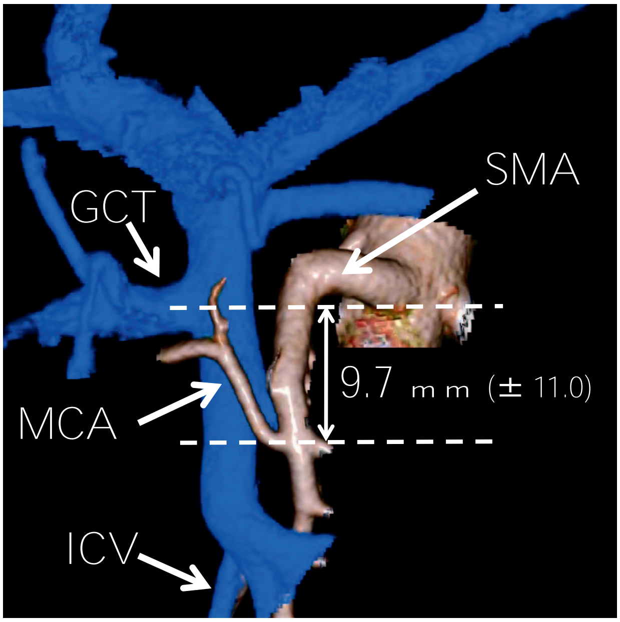

Fig. 4 Three-dimensional CT image of the GCT. The GCT was observed in 98 patients (96%). The MCA branched off the SMA 9.7 ±11.0 mm from the caudal side of the GCT.

cases of advanced TCC, the MCA is the main feeding artery, making central ligation of the MCA an essential procedure of CME. Thus, it is important to have detailed knowledge of the variations and anomalies of the MCA. In addition, because it is more difficult to obtain a bird's eye view during laparoscopic surgery than during open surgery, the ability to identify the drainage patterns and numbers of contiguous veins will increase the safety of central ligation procedures performed on the MCA. The effectiveness of laparoscopic surgery for advanced TCC has already been reported.[16,17] Kawamoto *et al*[9] recently reported a case in which adequate lymph node dissection was performed for TCC using 3D-CT, and hence its use is likely to increase in the future. Therefore, we evaluated variations and anomalies in the MCA of TCC patients, and analyzed their contiguous veins by creating 3D-CT images.

Research has shown that the MCA is absent in 3% to 5% of patients,[18] but in our present study, it was observed in all patients. In patients with little visceral fat, laparoscopic surgeons can easily see the blood vessels. However, in patients in whom a large amount of visceral fat prevents identification of the root of the MCA, laparoscopic surgery is performed based on blood vessel data constructed using 3D-CT in the following way.

First, when performing lymph node dissection of the blood vessels, which have many variations and accompanying anomalies, it is important to use landmark veins that drain into the SMV and can be dissected easily and with reliable reproducibility. When an inferior approach is taken from the caudal side of the transverse colon to the front of the cranial side of the SMV, the GCT, which drains into the SMV from the right side of the inferior edge of the pancreas, is the most important landmark. The GCT is a venous trunk that is consistently formed from the confluence of the MCV or AMCV, the right gastroepiploic vein, and the anterior superior pancreaticoduodenal vein, and drains into the SMV from the right side.[13] In this study, the GCT was present in 96% of the patients. In contrast, the MCV has a large number of anomalies, and in comparison with the GCT, it drains into the SMV separately in a smaller percentage of patients.[13] Likewise, in the present study, the GCT was present in 65.8% of patients, indicating that the GCT is a reliable landmark. Second, the MCA is located 9.7 ± 11.0 mm to the caudal side of the GCT (Fig. 4), which means that if the peritoneum of the transverse mesocolon is carefully dissected toward the splenic flexure, the root of the MCA, where it branches off the SMA, can be safely identified. However, in the present study, the MCA was located on the cranial side of the GCT in 9.8% (10 of 102) of the patients, indicating that care is required in identifying the MCA in each individual patient. Third, after identifying the root of the MCA, the next important step is to understand its branching pattern. Resection of the most common type of MCA, the common duct type (87.3%; Fig. 1a), leads to complete central ligation, but in cases of the separated type (12.7%; Fig. 1b), in which the left and right branches of the MCA are distinct, resection of just 1 of the 2 branches leads to an incomplete CME. Detailed knowledge of the vessel anatomy prior to the start of surgery enables reliable performance of central ligation on both the left and right branches, which then leads to successful completion of CME.

On the other hand, there are patients in whom lymph node dissection is anatomically difficult. In 3 patients (2.9%), the thick J1V drained into the SMV from the left side, and the MCA root was hidden behind the J1V (Fig. 5a and 5b). Because this condition makes central ligation of the MCA impossible, the J1V must be dissected, and the caudal end must be reflected in to expose the MCA

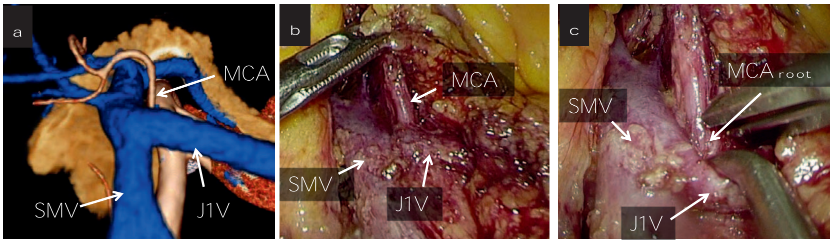

Fig. 5 A rare case in which the thick J1V drains into the SMV from the left side, and the MCA root is hidden behind the J1V. (a) A 3D-CT image displaying the MCA root behind the J1V, which extended transversely. (b) Intraoperative findings for the same patient. The actual anatomic relationship of the blood vessels corresponded with that displayed on the 3D-CT image. (c) Dissecting the J1V and pulling it to a posterior position exposed the MCA root, which enabled successful resection.

root to enable central ligation (Fig. 5c). In cases such as this in which central ligation is difficult, there is a risk of bleeding. Therefore, the laparoscopic surgeon must have an extremely high level of technical skill. Thus, to reliably and safely perform CME, the surgeon must become familiar with the anatomy of the region prior to surgery using 3D-CT and must plan a surgical strategy accordingly.

The presence of an AMCA requires extra care during surgery. Studies[11,19,20] have indicated that an AMCA is observed in 8% to 49.2% of cases. In the present study, the AMCA was present in 24.5% of the patients (Fig. 2a); it was located 16.5 ± 12.5 mm from the cranial side of the GCT, which is used as the landmark, and branched off the SMA. In 1 patient it branched off the splenic artery (Fig. 2b). Determining whether the AMCA is present prior to surgery will enable the surgeon to avoid unexpected bleeding[21] when reflecting the splenic flexure. In addition, to reliably perform lymph node dissection, it is important to use 3D-CT to determine the positional relationship of the cancer and the AMCA, because in cases of distal side TCC, the AMCA is the main feeding artery.

During central ligation of the MCA, successful CME also relies on accurate determination of the veins that require processing. Studies[12,13] have reported that the MCV is always present and exhibits the most variable drainage patterns. Although in the present study the MCV was observed in all patients, the vessels it drained into varied considerably among the patients. The MCV drained into the SMV in 65.8% of the patients (Fig. 3a). Other vessels that the MCV drained into included the GCT (Fig. 3b), the J1V (Fig. 3c), and the inferior mesenteric vein in 24.5%, 7.8%, and 1.9% of the patients, respectively. The AMCV is sometimes listed as the superior right colic vein[13] and the accessory right colic vein,[22] and was reported to be observed in 75% of patients.[13] In our present study, it was observed in 44.1% of the patients. The AMCV originated mainly from the marginal veins near the hepatic flexure of the transverse colon and showed a large amount of variation in the vessels into which it drained. In the highest number of patients (33.3%), the AMCV drained into the GCT, followed by into the SMV (4.0%) and into the splenic vein (0.98%). In addition, in 4.9% of the patients, a double-vessel AMCV was observed, which requires care when dissecting in the vicinity of the GCT. Although vessel dissection is a simple procedure, because vessel walls are fragile, carelessness during surgery can lead to bleeding. Research[23] has shown that there is a 16.4% risk of bleeding from the veins associated with the GCT. Because severe bleeding from these veins may require conversion from laparoscopic surgery to open surgery, we believe that the safe performance of CME requires the preoperative use of 3D-CT to determine the variations in the GCT, which is used as a landmark; the distance between the blood vessels; and which and how many vessels will require processing.

In this study, the patients did not experience any major complications, such as excessive blood loss or other organ damage, and none of the cases were converted to open surgery. Although the National Comprehensive Cancer Network[24] recommends the removal of 12 lymph nodes in surgery, the median number of harvested lymph nodes was 21, which was much greater than the recommended number. Curative surgery was performed on all of the patients.

In conclusion, although patients can have complicated variations and anomalies in the MCA and contiguous veins, we believe that laparoscopic surgery for advanced TCC can be safely and reliably performed using the data observed from preoperative 3D-CT.

Acknowledgments

All of the authors have no disclosures, and none have received any financial support.

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