Surgical and Radiologic Anatomy (2018) 40:423–429
https://doi.org/10.1007/s00276-018-1994-4

ORIGINAL ARTICLE

Anatomy of the right colic vein and pancreaticoduodenal branches: a surgical landmark for laparoscopic complete mesocolic excision of the right colon

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Received: 26 August 2017 / Accepted: 20 February 2018 / Published online: 26 February 2018

Abstract

Purpose Knowledge of mesenteric venous anatomy is important to safely perform laparoscopic complete mesocolic excision (CME) of the right colon. Despite their previously reported diversity, consistent features of the right colonic and pancreatic veins can be discerned. The objective of this study was to evaluate anatomical consistency of the right colic vein (RCV) and the pancreaticoduodenal vein associated with the colic vein (PDV-C).

Methods This study included 125 consecutive patients undergoing contrast-enhanced multidetector-row CT of the abdomen. Images of 100 of these cases were retrospectively reviewed for the positioning of the colonic, gastric and pancreatic veins associated with the superior mesenteric vein (SMV). RCV were classified as three types: Type-I, running on the ventral aspect of the pancreatic head and draining into the right lateral wall of the SMV; Type-II, running apart from the pancreatic head and directly draining into the SMV; and Type-III, draining into the tributaries of the SMV.

Results The RCV was identified in 88% of cases, in which the frequencies of Type-I, -II and -III anatomies were 84.1, 9.1, and 6.8%, respectively. All of the Type-I RCVs formed a common trunk with other veins, including the gastroepiploic vein (93.2%) and the superior RCV (59.5%). The PDV-C joined the RCV in 63.5% of the Type-I cases.

Conclusions Anatomical consistency of the RCV together with the PDV-C is present in the majority of cases. Our findings support the view that the appearance of the veins is a useful landmark for laparoscopic CME of the right colon.

Keywords Colectomy · Dissection · Laparoscopy · Mesenteric veins · Mesocolon

Introduction

Evidence is accumulating that complete mesocolic excision (CME) with central vascular ligation can result in improved oncological outcomes for colon cancer patients [3, 6, 14, 18], and the feasibility of laparoscopic CME is being increasingly recognized [5, 20, 21]. On the other hand, the procedure is possibly associated with a higher risk of vessel-related complications [2, 5]. Indeed, meticulous dissection close to the superior mesenteric vein (SMV) is required to safely perform CME of the right colon, as its tributaries are vulnerable to damage by inadvertent traction. Therefore, much effort has been devoted to classification of the venous anatomy of the right colonic and peripancreatic area, mainly focused on the gastrocolic trunk (GCT) [1, 8–10, 12, 13, 15, 16, 19]. These studies have unanimously concluded that the confluence patterns of the mesenteric venous tributaries are complex and vary from one individual to the next.

There are several reports describing surgical procedures for laparoscopic right hemicolectomy with CME [5, 20, 21]. Effective landmarks guiding dissection, as well as a better understanding of the complex and variable anatomy, are crucial to compensate for the inherent drawbacks of laparoscopic surgery, such as the limited operative field of view and lack of tactile sensation. The structure of the ileocolic vein (ICV) with its convergence to the SMV has been shown to be consistent and, therefore, can serve as an important landmark in laparoscopic procedures [12, 15, 19]. At the same time, some recent studies have presented intraoperative pictures of other right colonic veins as typical anatomy to explain the procedure of laparoscopic surgery [1, 20, 21],

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despite their previously reported diversity. In those images, a consistent feature of the right colic vein (RCV) can be discerned, as demonstrated in a previous radiological study [7], namely, that it runs horizontally along the ventral aspect of the pancreatic head, joining the pancreaticoduodenal vein (PDV) and draining into the right lateral wall of the SMV.

In the present study, we evaluate the inter-individual consistency of these anatomical characteristics of the RCV together with the PDV by reviewing images of multidetector-row CT (MDCT), to address the issue of whether this venous structure can be taken as a useful landmark for laparoscopic CME of the right colon.

Materials and methods

Patients

This study included 125 consecutive patients undergoing contrast-enhanced MDCT for abdomen in January 2016 at Aichi Medical University Hospital. 25 patients were excluded because of prior upper abdominal surgery (four gastrectomies, two right hemicolectomies, five pancreaticoduodenectomies), or poor visualization of the mesenteric vessels (14 cases). The reasons for these unsatisfactory images were as follows: seven cases of inadequate contrast enhancement, two cases of flattened SMV, and five cases of local disease or intervention, including pancreatic cancer, pancreatitis with pseudocyst, portal vein obstruction, large cyst of the right kidney, and the presence of an aortic stent.

We retrospectively reviewed CT scans of the remaining 100 patients regarding the anatomy of the colonic, gastric and pancreatic veins associated with the SMV. Axial views of 2-mm slices were carefully inspected to identify the vessels in the phase when the mesenteric veins were clearly delineated by contrast enhancement. When necessary, multiplanar reconstruction or multi-dimensional images were used to confirm the location and spatial relationship of the vessels. The study protocol was approved by the institutional review board of Aichi Medical University Hospital.

Computed tomography protocol

All CT examinations were performed using a 16-detector row CT scanner (SOMATOM Definition AS, SIEMENS, Tokyo Japan). The technical parameters of CT exams were as follows: tube voltage 100 or 120KV, tube current determined by Automatic Exposure Control systems, matrix 512 × 512, slice thickness 0.5 mm, collimation 64 × 0.5 mm, pitch 0.8, gantry rotation time 0.5 s, and field of view 30–40cm. Each patient fasted prior to imaging. For contrast-enhanced CT, a nonionic contrast agent (350 mg or 300 mg I/ml Omnipaque, Daiichi-Sankyo Pharmaceutical, Tokyo, Japan) was infused rapidly at a rate of 600 mg I/Kg for 30 s using an automated injector.

Classification of mesenteric vein tributaries

The right colic vein (RCV), superior right colic vein (SRCV), and middle colic vein (MCV) were defined as those draining from the marginal vein of the ascending colon, the hepatic flexure of the colon, and the transverse colon, respectively [10, 15, 19]. In some previous studies, the SRCV has been termed the "accessory right colic vein" [14] or "accessory middle colic vein" [19]. The vein running along the right gastroepiploic artery was designated the right gastroepiploic vein (RGEV). The presence or absence of these colic and gastric veins in the MDCT images was recorded. In addition, visualization of the PDV and the site where it terminated were noted. The PDV joining the RGEV was designated the anterior superior pancreaticoduodenal vein (ASPDV). The PDV flowing into or running adjacent to the colic veins, except for the obvious ASPDV, was termed the PDV associated with the colic vein (PDV-C).

Definition of the types of RCV

The anatomical forms of the RCV visualized by MDCT were classified into three types. In Type-I cases, the RCV ran horizontally along the ventral aspect of the pancreatic head, draining into the right lateral wall of the SMV. Figure 1 shows a representative Type-I case. Type-II was defined as a venous form running apart from and caudal to the pancreatic head, directly draining into the SMV (Fig. 2). Type-III was

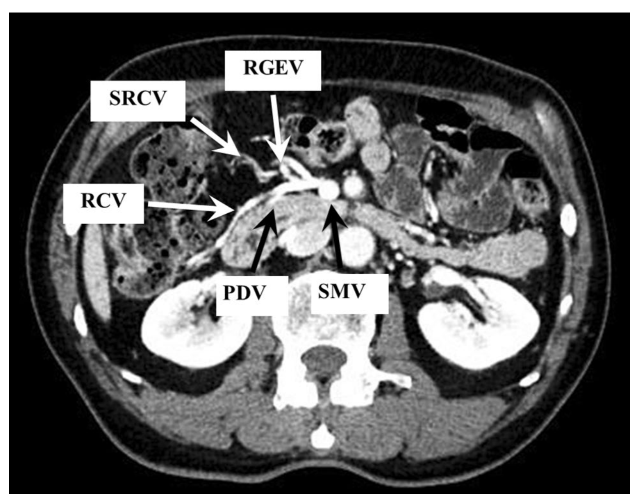

Fig. 1 CT image of a representative Type-I right colic vein (RCV). The RCV runs horizontally along the ventral aspect of the pancreatic head, draining into the right lateral wall of the superior mesenteric vein (SMV). The pancreaticoduodenal vein (PDV), right gastroepiploic vein (RGEV), and superior right colic vein (SRCV) participate in the common trunk

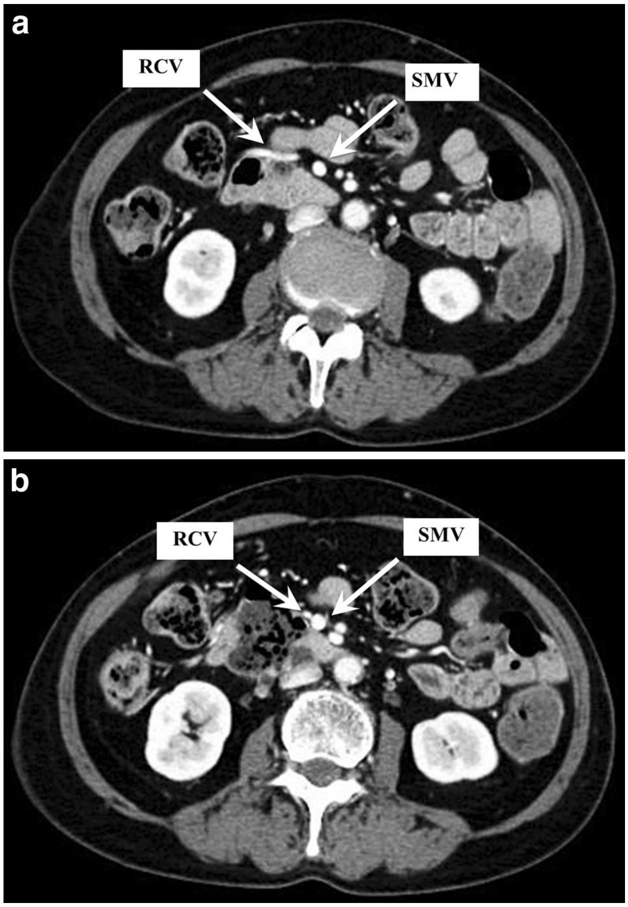

Fig. 2 CT image of a representative Type-II right colic vein (RCV). The RCV runs horizontally along the ventral aspect of the duodenum (distanced from and caudal to the pancreatic head) (**a**), directly draining into the superior mesenteric vein (SMV) (**b**)

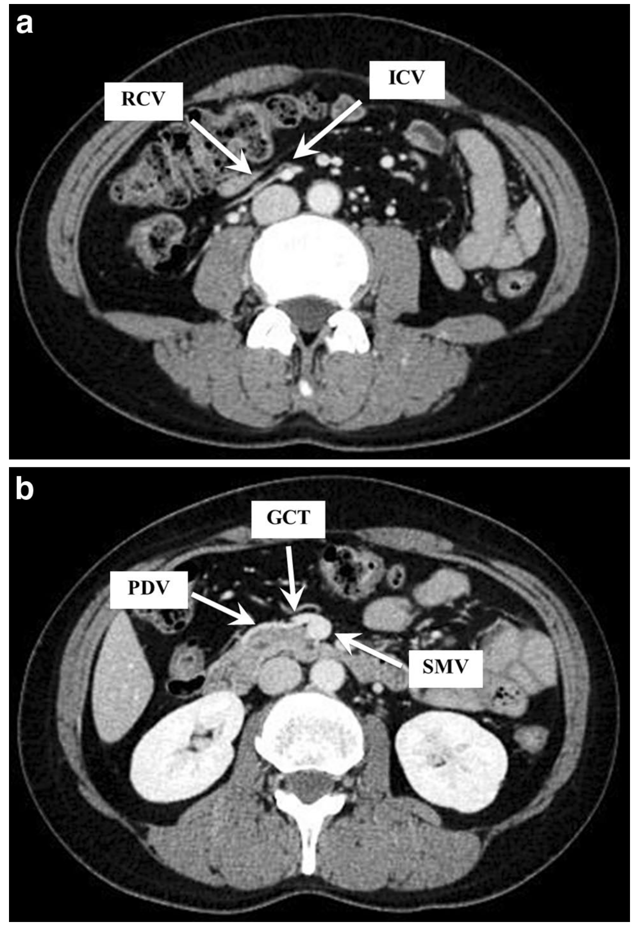

Fig. 3 CT image of a representative Type-III right colic vein (RCV). The RCV drains into the tributary (ICV: ileocolic vein) of the superior mesenteric vein (SMV) (**a**). The pancreatic head and the associated vessels (PDV: pancreaticoduodenal vein and GCT: gastrocolic trunk) are found distanced from and cranial to the RCV (**b**)

defined as a form draining into the tributaries of the SMV (such as ICV or MCV) (Fig. 3).

Draining angle of the colic veins

The draining angle of the root of the RCV and the MCV, as determined from the positive *X* axis of the horizontal line in an axial plane was measured as shown in Fig. 4. That the patient was in the supine position was confirmed by the position of the bilateral superior-anterior iliac processes.

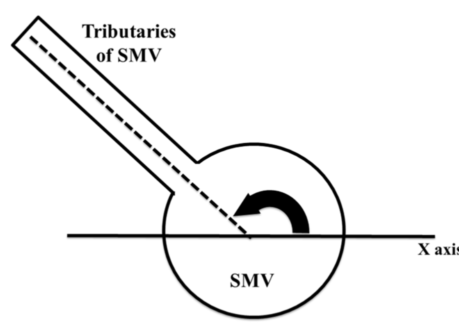

Fig. 4 Drainage angle of the root of the right colic vein (RCV) and the middle colic vein (MCV) into the superior mesenteric vein (SMV), estimated from the positive *X* axis of the horizontal line in the axial plane (arrow)

Point of confluence of the RCV/MCV on the circumference of the SMV

The center of the SMV was identified by the intersection of horizontal and longitudinal lines at the point of maximal diameter in the axial plane. A line was drawn from the center of the SMV to the midpoint of the width of the confluence. The position of confluence of the RCV/MCV on

Table 1 Visualization of the colonic, gastric and pancreatic veins associated with SMV as assessed by MDCT

	RCV	PDV-C	SRCV	ASPDV	RGEV	MCV
Number of identified cases/total	88/100	63/100	76/100	35/100	99/100	90/100
%	88	63	76	35	99	90

SMV superior mesenteric vein, *MDCT* multidetector-row CT, *RCV* right colic vein, *PDV-C* pancreaticoduodenal vein associated with the colic vein, *SRCV* superior right colic vein, *ASPDV* anterior superior pancreaticoduodenal vein, *RGEV* right gastroepiploic vein, *MCV* middle colic vein

Table 2 Confluence types of the RCV

Type	I	II	III
Number of identified cases/total	74/88	8/88	6/88
%	84.1	9.1	6.9

Type-I: RCV running horizontally along the ventral aspect of the pancreas head. Type-II: RCV running apart from the pancreas head and directly draining into the SMV. Type III: RCV draining into the tributaries of the SMV such as the ICV or MCV

RCV right colic vein, *SMV* superior mesenteric vein, *ICV* ileocolic vein, *MCV* middle colic vein

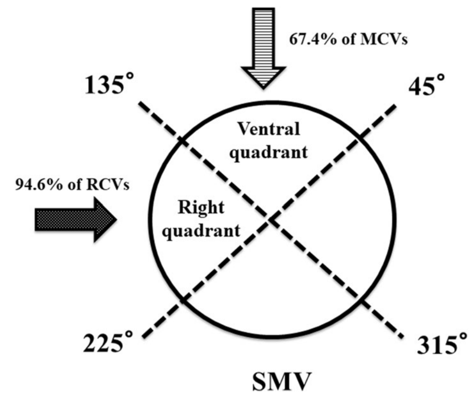

Fig. 5 The point of confluence of the right colic vein (RCV) and the middle colic vein (MCV) on the circumference of the superior mesenteric vein (SMV) shown by four divided quadrants. 94.6% of RCVs terminate at the right lateral quadrant of the SMV, while 67.4% of MCVs flow into the ventral quadrant of the SMV

the circumference of the SMV was measured as an angle of this line as determined from the positive *X* axis of the horizontal line.

Statistics

The values quantified are expressed as mean ± standard deviation for continuous data and as number with percentage for categorical data.

Results

The patient population consisted of 65 males (65%) and 35 females (35%), with a mean age of 65 ± 15 years (median: 68 years, range 17–93). The reasons for performing abdominal contrast-enhanced MDCT were periodic follow-up after surgery for malignant tumors (55 cases), evaluation of the effect of chemotherapy and/or radiotherapy (14 cases), investigation before surgery (20 cases), or were for diagnostic purposes (11 cases).

Visualization of the colonic, gastric and pancreatic veins associated with the SMV is summarized in Table 1. Each vessel was identified at the following frequencies: RCV, 88%; PDV-C, 63%; SRCV, 76%; ASPDV, 35%; RGEV, 99% and MCV, 90%. For the 88% of identified RCVs, the frequencies of Type-I, -II and -III anatomies were 84.1% ($n = 74$), 9.1% ($n = 8$), and 6.8% ($n = 6$), respectively (Table 2). All Type-I RCVs formed a common trunk with other veins, including the RGEV ($n = 69$, 93.2%), the SRCV ($n = 44$, 59.5%), and the MCV ($n = 2$, 2.7%). In 47 Type-I cases (63.5%), the PDV-C draining into the RCV was identified as a component of the common trunk.

The mean drainage angle of the RCV into the SMV was 168 ± 21°, and that of the MCV was 74 ± 37°. The point of confluence of the RCV and MCV on the circumference of the SMV is shown in Fig. 5. The Type-I RCV joined the right lateral quadrant of the SMV in 70 cases (94.6%), while the MCV joined the ventral quadrant of the SMV in 58 cases (67.4%).

The PDV-C was identified in 63 cases of which 47 (74.6%) exhibited a PDV-C draining into the RCV; all of these were Type-I. The PDV-C independently draining into the SMV was observed in 11 cases (17.5%), and into the SRCV in 5 (7.9%).

Next, the point of confluence of the PDV-C with the RCV was examined in relation to the junction with the RGEV, as shown in Fig. 6. The PDV-Cs joining the RCV which is not associated with the RGEV (3 cases) were excluded, leaving 44 cases of the PDV-C identified in Type-I cases classified into three groups. In 21 cases (47.7%), PDV-Cs were observed to drain into the site of the RCV distal to the junction with the RGEV. A further 12 (27.3%) drained into the RCV at the same level as the junction, and the remaining 11 (25.0%) drained into the RCV proximal to the junction (Table 3).

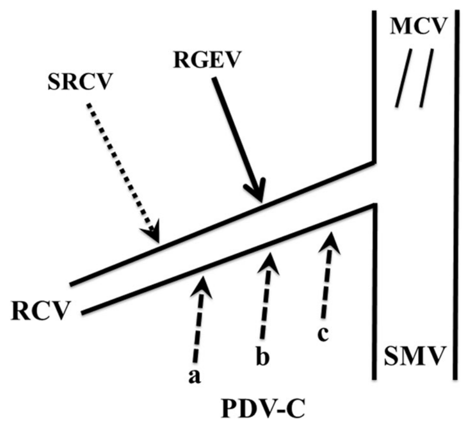

Fig. 6 Schema showing a typical confluence pattern of the superior mesenteric vein (SMV) with its tributaries, when the Type-I right colic vein (RCV) of is highlighted. The place where the pancreaticoduodenal vein associated with the colic vein (PDV-C) terminates is classified into three patterns in this study: **a** distal to the right gastroepiploic vein (RGEV) confluence, **b** at the level of the RGEV confluence, **c** proximal to the RGEV confluence. SRCV, superior right colic vein

Table 3 Site of termination of the PDV-C on the Type-I RCV in relation to the RGEV confluence

Terminating site	Distal	Same level	Proximal
Number of identified cases/total	21/44	12/44	11/44
%	47.7	27.3	25.0

PDV-C pancreaticoduodenal vein associated with colic vein, *RCV* right colic vein, *RGEV* right gastroepiploic vein

Discussion

There has been a great deal of interest in the venous anatomy that is relevant for surgery for right-sided colon cancer. Many studies, based on cadaveric dissections as well as radiological and intraoperative findings, have precisely classified the confluence pattern of colonic veins [1, 8–10, 12, 13, 15, 16, 19]. Their observations were specifically focused on formation of the GCT and its components, demonstrating complex and variable patterns of the mesenteric venous tributaries. Confusingly, inconsistent detection rates of the veins draining from the right colon have been reported using different nomenclatures, although each vessel was defined according to its colon drainage area. Furthermore, few published studies have described the PDV in relation to the colic veins [5].

A perspective from the caudal-to-cranial view of the mesenteric vessels reveals that a characteristic form of the RCV may emerge as shown in studies of laparoscopic right hemicolectomy applying CME [1, 13, 20, 21]. The present study, by reviewing contrast-enhanced MDCT, represents a first attempt to evaluate what is consistent in the anatomy of the RCV, especially whether it runs horizontally along the ventral aspect of the pancreatic head, joins the PDV, and terminates at the right lateral wall of the SMV. Anatomical images of the right colonic veins would be easier to assess and of more practical value, if the form of the RCV could be highlighted in the complex anatomy of the venous tributaries (Fig. 6).

Numerous studies which examined the anatomy of the GCT reported a wide range of detection rates of the trunk itself (46–94%) in addition to a variety of drainage patterns of its components [4, 11, 13, 15, 16, 19]. Our observations confirm that the RCV transversely drains into the right lateral side of the SMV in contrast to the ventrally rising MCV. Furthermore, the RCV was found to form a common trunk with the RGEV in the majority of cases. These characteristics from the viewpoint of the RCV clearly correspond to well-known features of the GCT.

The detection rates of the RCV (43–94%) were also highly variable in previous studies [13, 15, 16, 19]. Some of the discrepant results may be due to the use of confusing terminology for the right colonic veins, the difficulty in distinguishing the RCV from the SRCV, and the diversity of tributaries of the GCT. In the present study, the RCV was identified in 88% of cases; in 84% of those was located on the pancreatic head forming a common trunk, and drained separately into the SMV apart from the pancreas only in 9% of those. These findings are largely consistent with a recent study by Ogino et al. [15], except for the more frequent detection of the SRCV (76% vs 24%) in our study.

An interesting aspect of this study is that a majority of the PDV-Cs end at a type-I RCV. In addition, the PDV-C was found to join the RCV at different levels. It is notable that 47.7% of the PDV-Cs joined the RCV before forming a common trunk with the RGEV, whereas 27.3% joined the RCV at the level of the junction with the RGEV, giving rise to the appearance of a tripod. Indeed, the tripod type is likely to correspond to the ASPDV, which has been recognized as a component of the GCT or RGEV [4, 13, 20, 21]. Nonetheless, the relationship between the PDV and the colic veins had not been clarified in these previous studies. Because there is risk of hemorrhage caused by damage to the short and fragile pancreatic veins during laparoscopic CME of the right colon [5], it is important to be aware of the anatomy of the PDV-C in the individual patient when the mesenteric dissection is extended up to the root of the right colic vessels along the SMV.

There are some limitations to our study. The characteristic form of the RCV is not as consistent as that of the ICV. Thus, it is undoubtedly important to be aware of mesenteric venous variants, including confluence patterns of the CGT, to safely perform laparoscopic CME.

Preoperative evaluation for variation of venous anatomy in each individual is of the utmost importance to avoid bleeding, as previous studies have emphasized. An interesting issue is raised from the findings of this study, namely whether the colonic lymphatic pathway and distribution of lymph nodes vary according to the difference in confluence pattern of the venous tributaries. However, a definitive answer is not readily available.

Studies on the colonic lymphatic drainage system indicate that the main lymph nodes of the right colon lie anterior to the superior mesenteric vein [17]. CME for right colon cancer aims at the dissection of the mesocolic plane and central ligation not only of the supplying arteries but also of the draining veins at their roots, ensuring clearance of all associated lymph nodes [6]. The procedure is possibly associated with a higher risk of vessel-related complications [2, 5]. Major bleeding results mainly from laceration of the fragile venous tributaries of the SMV, which is potentially devastating. Furthermore, blood obscuring of the surgical field, by which recognition of the vessels or dissecting layers becomes difficult, may hamper optimal oncological resection. These veins must be identified and dissected carefully to avoid hemorrhage. Nonetheless, it is sometimes challenging to identify the vessels in the surgical field, especially when using a laparoscopic approach or when the area is covered by thick fat tissues. Therefore, an improved understanding of the mesenteric venous anatomy can contribute to safe and precise dissection along the SMV.

In conclusion, anatomical consistency of the RCV and PDV is present in the diverse right colonic vessels. Our findings support the view that the appearance of the veins is a useful landmark for laparoscopic CME of the right colon. Our concept for the anatomy of the right colonic veins may help identify vessels on preoperative examination as well as during surgical dissection, and consequently contribute to successful management of carcinoma of the right colon.

Acknowledgements We are grateful to Takahiro Hashimoto in the Division of Mathematics, Aichi Medical University for valuable comments on the manuscript. We are also grateful to Toyohiro Ohta in the Department of Radiology, Aichi Medical University for valuable comments on radiological methods.

Funding None.

Compliance with ethical standards

Ethical approval The study protocol was approved by the institutional review board of Aichi Medical University Hospital.

Conflict of interest Osawa T, Komatsu S, Ishiguro S and Sano T have no conflict of interest to declare.

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