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SPECIAL SECTION: RECTAL CANCER

Complete mesocolic excision and central vascular ligation for right colon cancer: an introduction for abdominal radiologists

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Abstract

Objective To provide an overview of complete mesocolic excision, along with a review of the relevant vascular anatomy and locoregional staging concepts, for abdominal radiologists.

Results Complete mesocolic excision (CME) with central vascular ligation (CVL) for colon cancer has emerged as a technique that has growing interest in surgical oncology. Specific anatomic considerations and patterns of nodal spread have thus gained clinical significance, and should be familiar to abdominal radiologists. This review article provides an overview of CME with CVL, and discusses some of the important anatomic considerations in patients with colon cancer that are relevant to radiologists.

Conclusion Knowledge of CME with CVL and the relevant anatomic and staging considerations is important for abdominal radiologists, as this surgical technique becomes increasingly utilized.

Keywords Colon cancer · Colorectal cancer · Complete mesocolic excision · Central vascular ligation

Introduction

When the concept of total mesorectal excision (TME) for rectal cancer was introduced in 1986 [1], few could have predicted the wide-reaching impact it would have on the surgical treatment of patients with rectal cancer. The concept of resecting a patient's rectal tumor en bloc, along with the entire rectum and mesorectum, along with the growing role of neoadjuvant radiation therapy, has decreased local recurrence rates and likely improved overall survival for those without systemic metastases [2]. Because of these improved outcomes, over the past three decades TME has become the standard of care for patients with rectal cancer. In line with this, the staging of rectal cancer patients using MRI has also evolved and now guides therapy. A standardized approach to performing and reporting MRI examinations for rectal cancer has been developed [3] with high levels of consensus among experts in the field, providing uniformity in baseline staging and post-treatment evaluation of rectal cancer patients [4].

Since TME has resulted in a beneficial shift in the surgical management of patients with rectal cancer, others have more recently expanded its concept to the resection of colon cancer. In 2009, Hohenberger et al. described a standardized surgical technique for colectomy, i.e., complete mesocolic excision with central ligation (CME with CVL) [5]. In that analysis of 1329 patients treated over a 30-year period, CME with CVL reduced local recurrence rates at 5 years from 6.5 to 3.6% and improved 5-year survival rates to 89.1% from 82.1%. Since then, there has been a growing interest in CME with CVL in the surgical literature, and the surgical technique has become more common in clinical practice. Although there are no randomized data at this point, there is some evidence already that CME with CVL is associated with improved disease-free survival for patients with stage I–III colon cancer [6]. Despite the early promising data in the literature, it is worth emphasizing that compared to the evidence for improved outcomes in TME, the current evidence supporting CME with CVL is less robust at this point.

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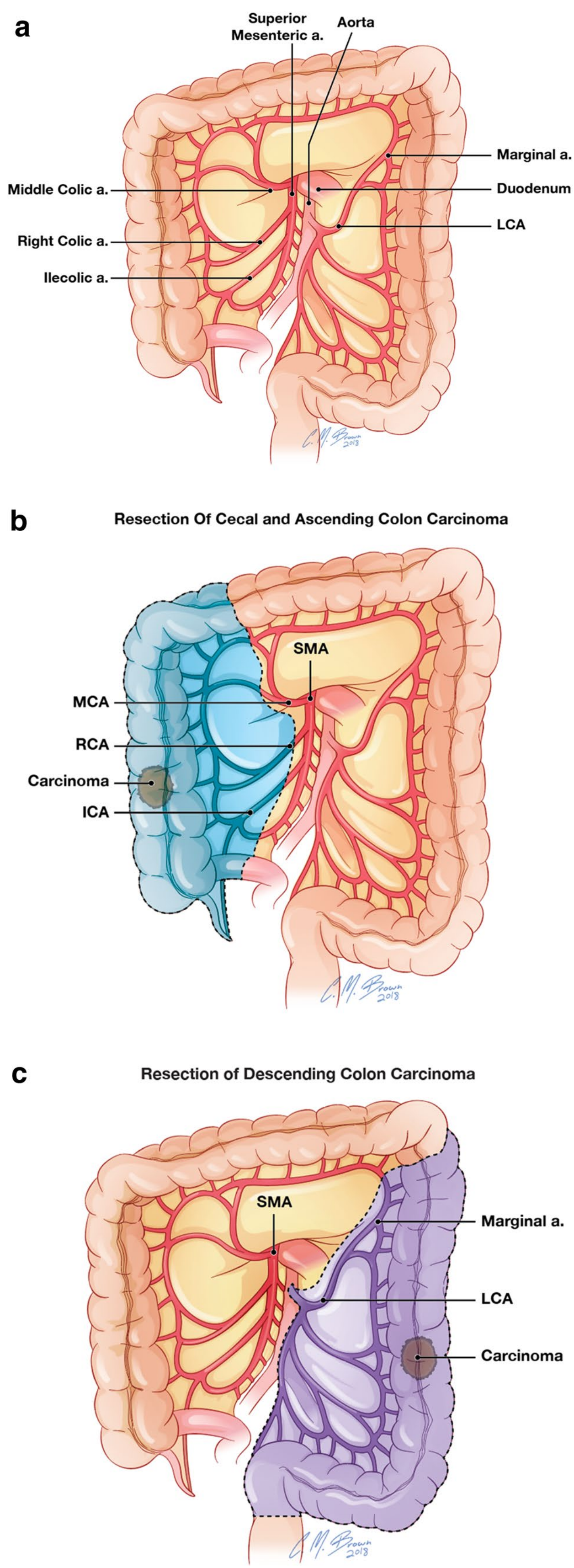

Fig. 1 **a** Overview of standard arterial anatomy of the colon. The superior mesenteric artery (SMA) gives rise to the ileocolic artery (ICA), right colic artery (RCA), and middle colic artery (MCA). The inferior mesenteric artery [23] gives rise to the left colic artery (LCA), supplying the left colon from the splenic flexure to the upper rectum. The right- and left-sided arterial supply is integrated by the marginal artery of Drummond. **b** Diagram showing standard vascular supply to the right colon, with an ascending colonic mass. **c** Diagram showing standard vascular supply to the left colon, with a descending colonic mass. Illustrations by Christopher M. Brown

Just as rectal MRI is now reported with regard to surgical planning for TME, there is now evolving as an important role for the abdominal radiologist in the reporting of preoperative computed tomography (CT) [7] scans for patients with colon cancer who will undergo CME with CVL. This article will review the surgical concepts behind CME with CVL, pertinent anatomy, and vascular variations (Figs. 1, 2).

Variant arterial anatomy

The arterial anatomy of the right colon and its variations has been widely reported in the literature as assessed with cadaveric specimens, surgical studies, and diagnostic imaging.

Negoi et al. [8] summarized the common arterial anatomic variations relevant to CME with CVL in a recent meta-analysis. In 6090 specimens, the ileocolic artery (ICA) was commonly present (pooled prevalence of 99.8%) along with the ileocolic vein (ICV) (pooled prevalence of 99.7%), with the ICA tending to course posterior to the ICV (57.4% of cases). The middle colic artery (MCA) was also commonly present (pooled prevalence of 94.6%), with the majority presenting as a single trunk (88.4% of cases) while the remainder demonstrated two or three MCA vessels arising from the superior mesenteric artery (SMA). The MCA most often originated from the SMA (78.7% of cases) or right colic artery (RCA) (17.8% of cases), but it can also originate from a variety of other arteries (each in less than 1% of cases). The RCA was the least commonly present artery (pooled prevalence of 60.1%). Its course was typically anterior to the superior mesenteric vein (SMV) (89.4% of cases), in contrast to the arterial–venous relationship of the ICA and ICV, where the artery usually courses posterior to the vein. When present, the RCA most often arose from the SMA (70.8% of cases) and less commonly from the MCA (15.4% of cases) or ICA (13.8% of cases) (Figs. 3, 4, 5, 6).

Measuring the length of certain vessels, e.g., the ICA, may be of importance in the future. Some authors have suggested that the length of the resected mesenteric pedicle may have an effect on locoregional recurrence rates [9]. It has been shown that CME with CVL produces longer specimens compared with traditional operations [10], but whether or not the surgical specimen length affects the prognostic value

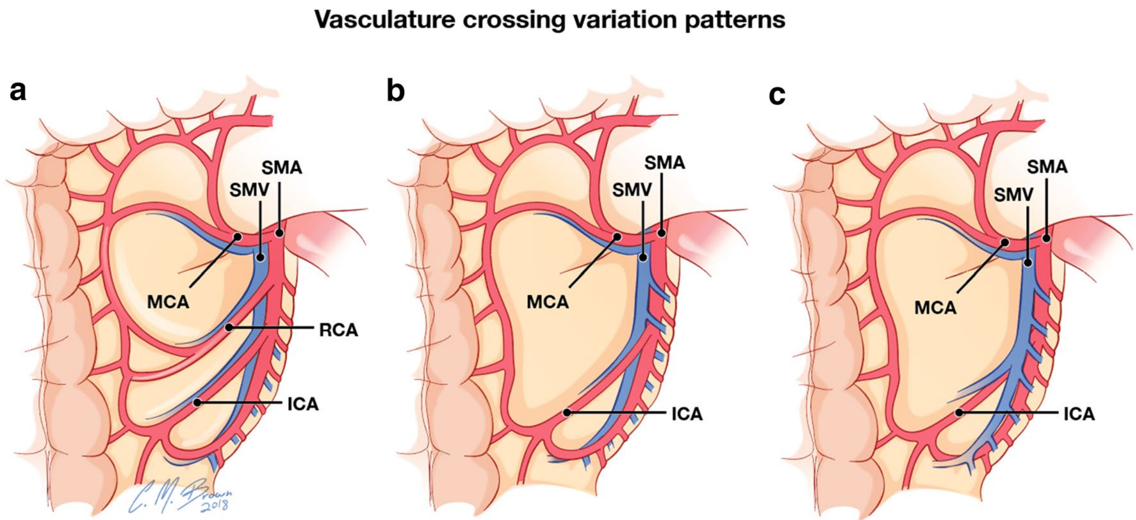

Fig. 2 Diagram showing variant anatomy and antero-posterior relationship of right-sided arteries and veins. **a** The right colic artery (RCA) is present (60.1% of cases) and courses anterior to the superior mesenteric vein (SMV) (89.4% of the time). **b** The RCA is absent and the ileocolic artery (ICA) is anterior to the ileocolic vein (ICV) (42.6% of the time). **c** The ICA is shown in its more common relationship, posterior to the ICV (57.4% of cases). Illustrations by Christopher M. Brown

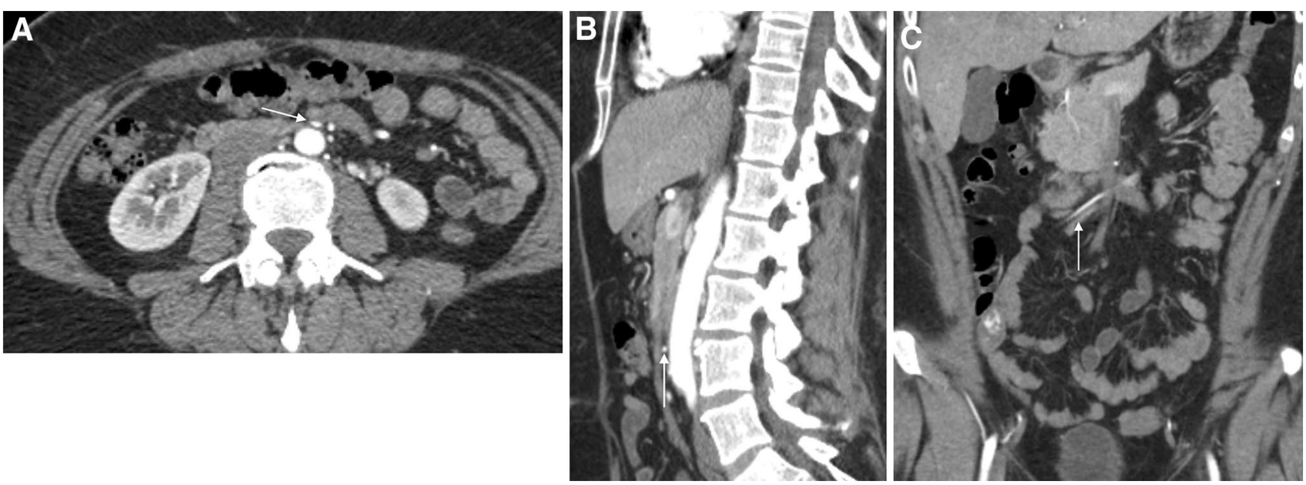

Fig. 3 Right colic artery coursing posterior to the superior mesenteric vein. Axial, sagittal, and coronal contrast-enhanced CT images show the RCA (arrows) positioned posterior to the SMV

of the ratio of positive lymph nodes in colon cancer has not been proven [11].

Variant venous anatomy

Familiarity with the colonic vascular anatomy as well as its common variations is important for the pre-operative planning of patients undergoing CME with CVL. This is particularly important when surgeons are planning to perform laparoscopic CME with CVL, which has comparable and sometimes superior outcomes to open surgical resection [7, 12, 13]. Visualization of the anatomy and vascular variations may be more difficult in a laparoscopic procedure, and hemorrhage caused by accidental injury to aberrant vessels can lead to conversion to an open operation. The radiologist can play an integral part in surgical planning by identifying and describing the relevant vascular anatomy and, thus, potentially minimizing non-intentional vascular injuries during laparoscopic CME with CVL.

The venous drainage of the right colon is particularly complex, with a number of variations involving the gastrocolic trunk of Henle (GTH) that have been studied in cadavers during surgery and via 3D reconstruction using

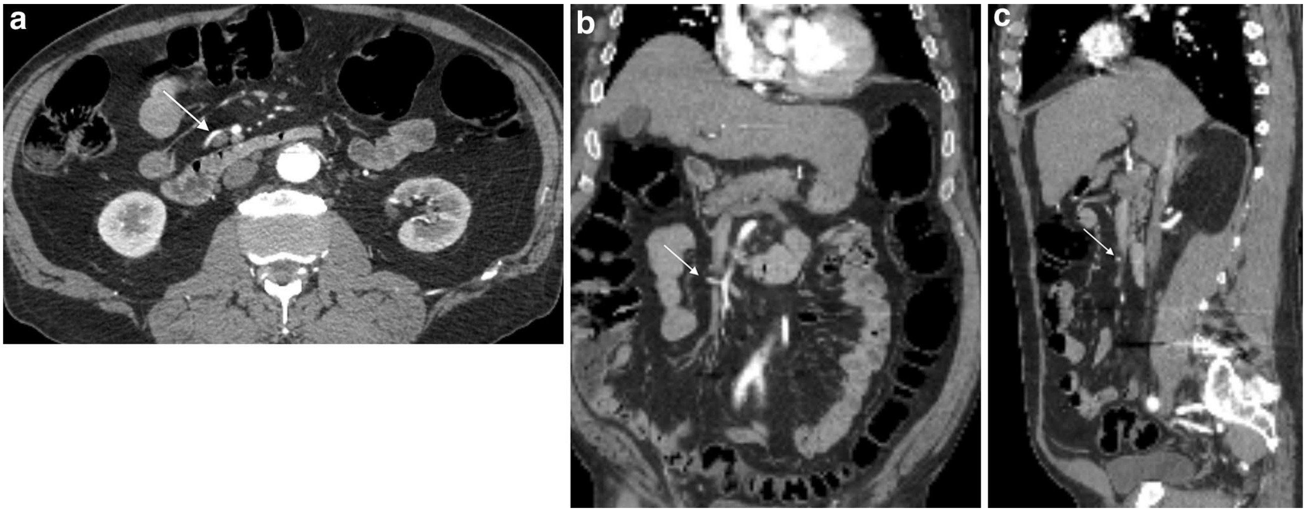

Fig. 4 Right colic artery coursing anterior to the superior mesenteric vein. Axial, sagittal, and coronal contrast-enhanced CT images show the RCA (arrows) positioned anterior to the SMV

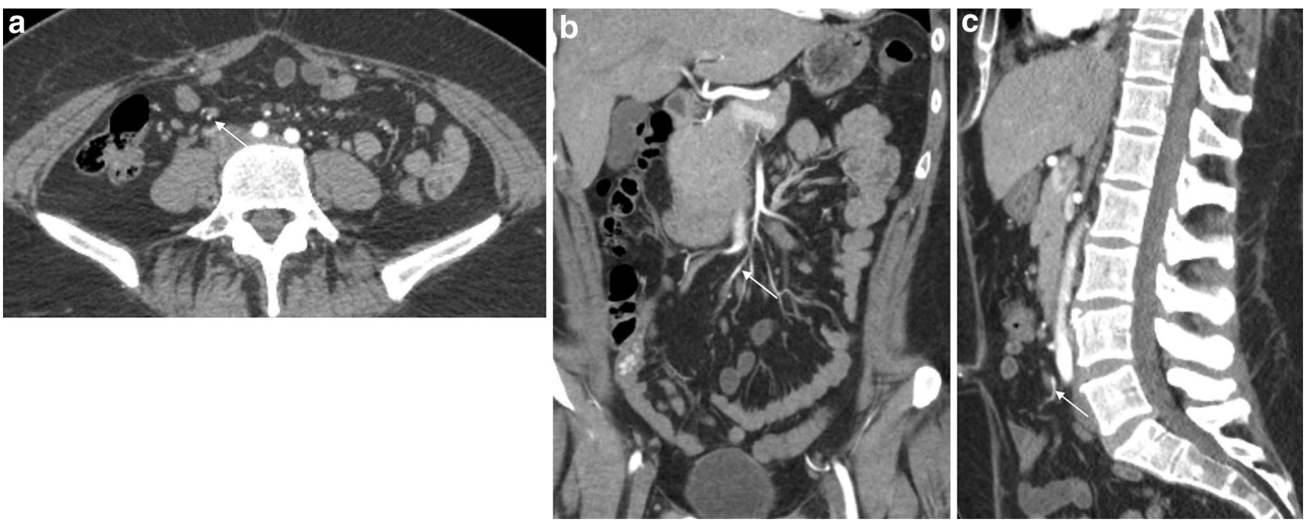

Fig. 5 Ileocolic artery coursing posterior to the ileocolic vein. Axial, sagittal, and coronal contrast-enhanced CT images show the ICA (arrows) posterior to the SMV

computed tomography [7, 14]. The GTH was originally described as a venous structure that merges venous drainage from the stomach and colon, namely the right gastroepiploic vein (RGEV) and super right colic vein (SRCV) [14]. The GTH subsequently drains into the superior mesenteric vein (SMV). In the literature, the GTH is identified approximately 80% of the time and has several variations in which the RCV may have between two to four tributary vessels [14]. For the purposes of radiologic evaluation, it may be most practical to describe the GTH as the confluence of the RGEV and dominant veins draining the right colon.

Regarding the nomenclature of tributaries from the right colon, the RCV is defined as the vein formed by marginal vessels along the ascending colon. The middle colic vein (MCV) is comprised of marginal vessels along the transverse colon. When more than one RCV or MCV is present, the largest diameter vein is the named vessel (RCV or MCV), and the smaller vessel is the accessory (aRCV or aMCV) [14].

Lymph nodes

Currently, the diagnostic accuracy for assessing nodal metastases in colon cancer is suboptimal on CT. A recent review article by Nerad et al. found that the pooled sensitivity and

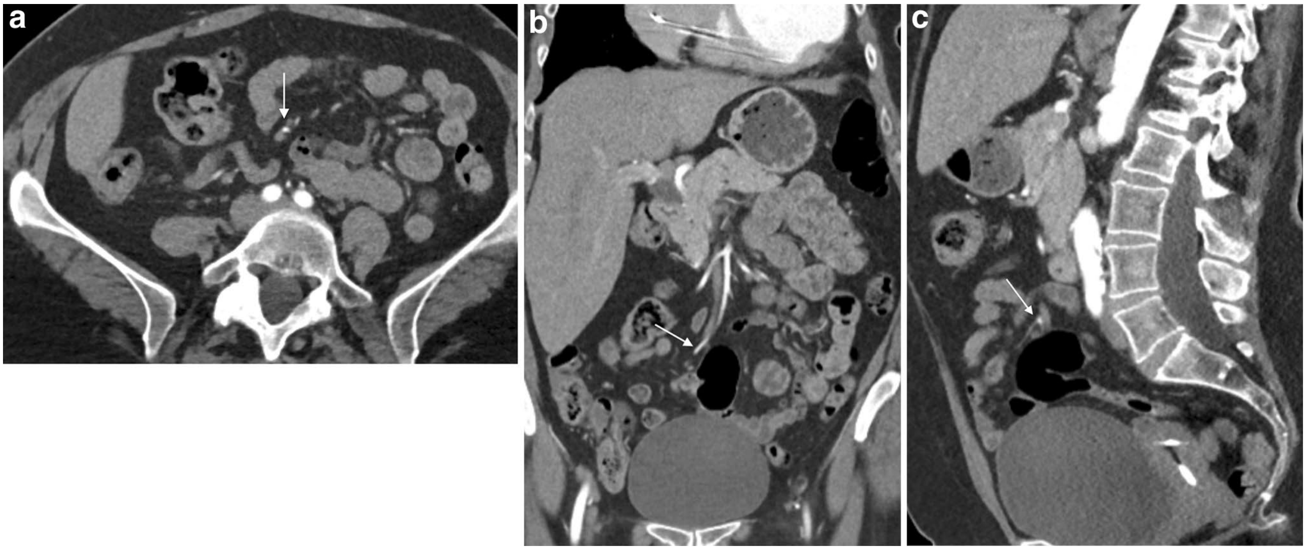

Fig. 6 Ileocolic artery coursing anterior to the ileocolic vein. Axial, sagittal, and coronal contrast-enhanced CT images show the ICA (arrows) anterior to the SMV

pooled specificity of CT from the published literature were 71% (95% CI 59, 81%) and 67% (95% CI 46, 83%), respectively [15]. Part of the challenge is the lack of precise node-for-node comparison between imaging and pathology in colon cancer, which is challenging due to the mobile nature of the mesentery. Despite this, familiarity with the known pattern of nodal spread in colon cancer is important when performing imaging for initial staging (Fig. 7).

A recent review article by Bertelsen et al. [16] focused on the currently available literature describing the patterns of lymph node metastases in colon cancer. The authors examined 47 studies that presented heterogeneity with regard to methodology and anatomic definitions. Despite these limitations, they concluded that central mesocolic lymph node metastases were present in 1–22% of right-sided colon cancers. In the sigmoid colon, nodal metastases were present in ≤ 12% of cancers. Aside from this recent comprehensive review, a few additional individual studies are worth noting.

Unique patterns of lymph node metastases have been reported in cancers of the transverse colon, including in the hepatic and splenic flexures. Perrakis et al. [17] reported lymph node metastases in the infrapancreatic lymph node region and in the gastroepiploic region in 19.2% and 15.4% of patients with transverse colon cancer, respectively, though their cohort of 26 patients was small. Bertelsen et al. [18] reported that in 98 patients with cancer in the region of the transverse colon or flexures, among the 35% with mesocolic nodal metastases, 12% had gastrocolic nodal metastases, whereas no other patients in the study cohort had gastrocolic nodal metastases, indicating that gastrocolic nodal metastases are more likely to occur when mesocolic nodal metastases are seen. The radiologist should be aware of these additional potential sites of nodal metastases in cases of cancer involving the transverse colon and flexures, particularly when additional suspicious mesocolic nodes are present (Figs. 8, 9).

Benz et al. [19] found that in a group of 51 patients with right-sided colon cancer (cT1–3) who underwent CME with CVL, 25.5% of patients had nodal metastases including 5.8% with central nodal metastases. Interestingly, their cohort had one case of isolated central nodal metastasis without additional mesocolic nodal metastases. This suggests that in a small number of patients it may be necessary to look at nodes more central in the upper abdomen, even when mesocolic nodes adjacent to the primary tumor appear normal.

The prognostic implications of nodal metastases in colon cancer are relevant with regard to overall survival and disease-free survival at 5 years. Nagasaki et al. [20] looked at the outcomes for 446 patients with T3 colon cancer, with specific attention to metastases in pericolic nodes, intermediate nodes, or main nodes classified according to the Japanese Society for Cancer of the Colon and Rectum classification. They found that in patients with N1 (1–3 metastatic nodes) or N2 (4 or more metastatic nodes), recurrence-free survival was significantly improved when metastatic nodes were isolated to the pericolic location as opposed to intermediate or main nodal stations: 84.4% versus 71.5% and 72.6% versus 53.1%, respectively.

By becoming familiar with patterns of nodal metastases and the prognostic implications, radiologists can communicate more effectively with the treating surgeon.

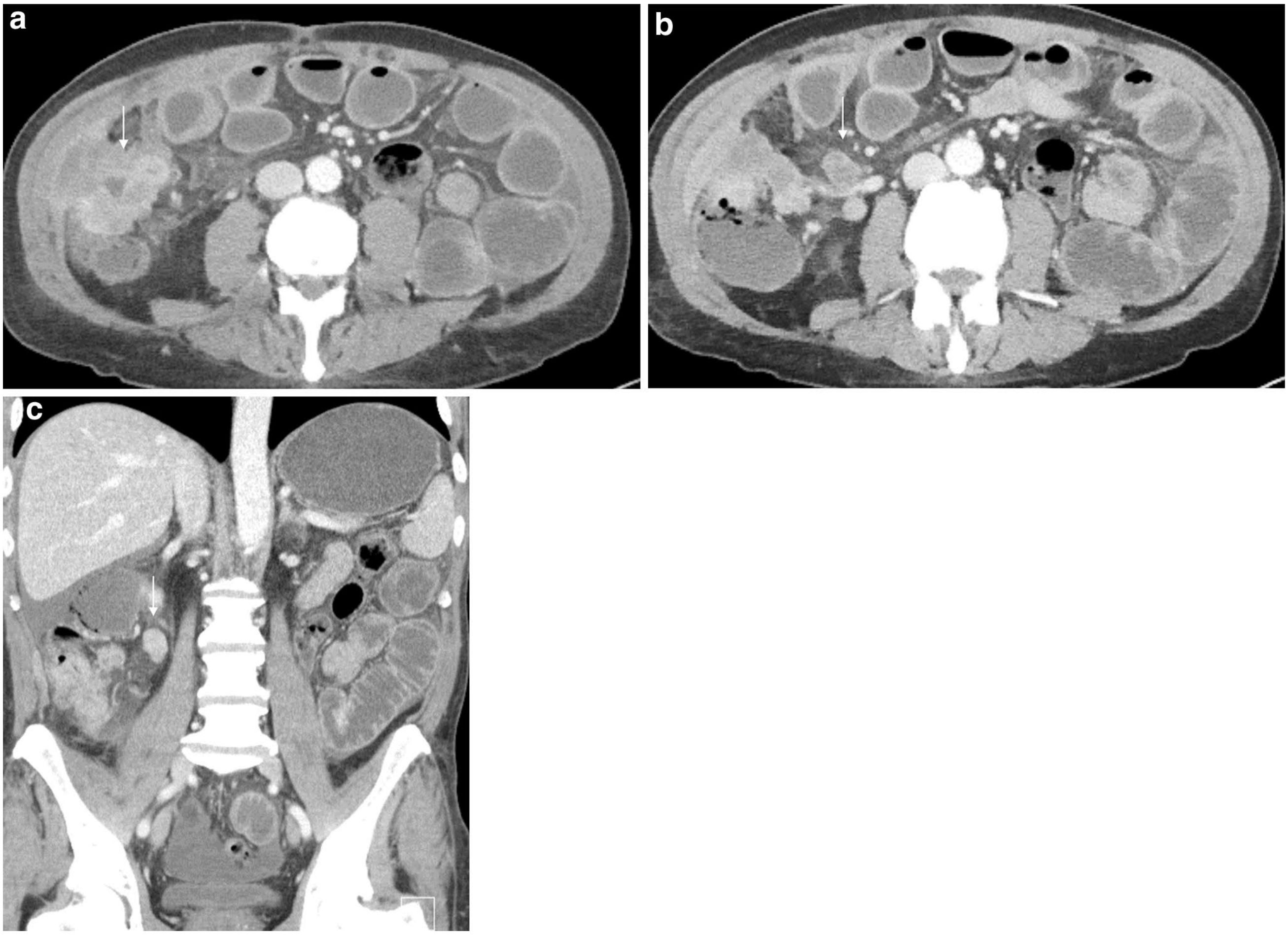

Fig. 7 Axial and coronal contrast-enhanced CT images show a large mass (**a**, arrow) in the ascending colon, with an enlarged ileocolic lymph node (**b** and **c**, arrows)

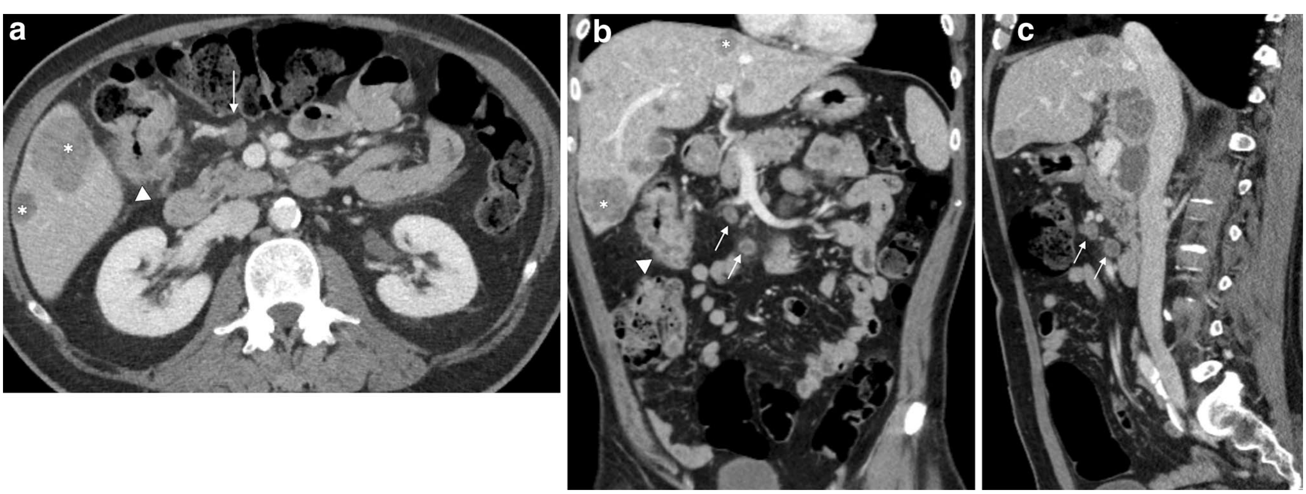

Fig. 8 Axial, coronal, and sagittal contrast-enhanced CT images show a mass in the hepatic flexure (arrowheads) with adenopathy in the root of the mesentery (arrows), as well as hepatic metastases (asterisk)

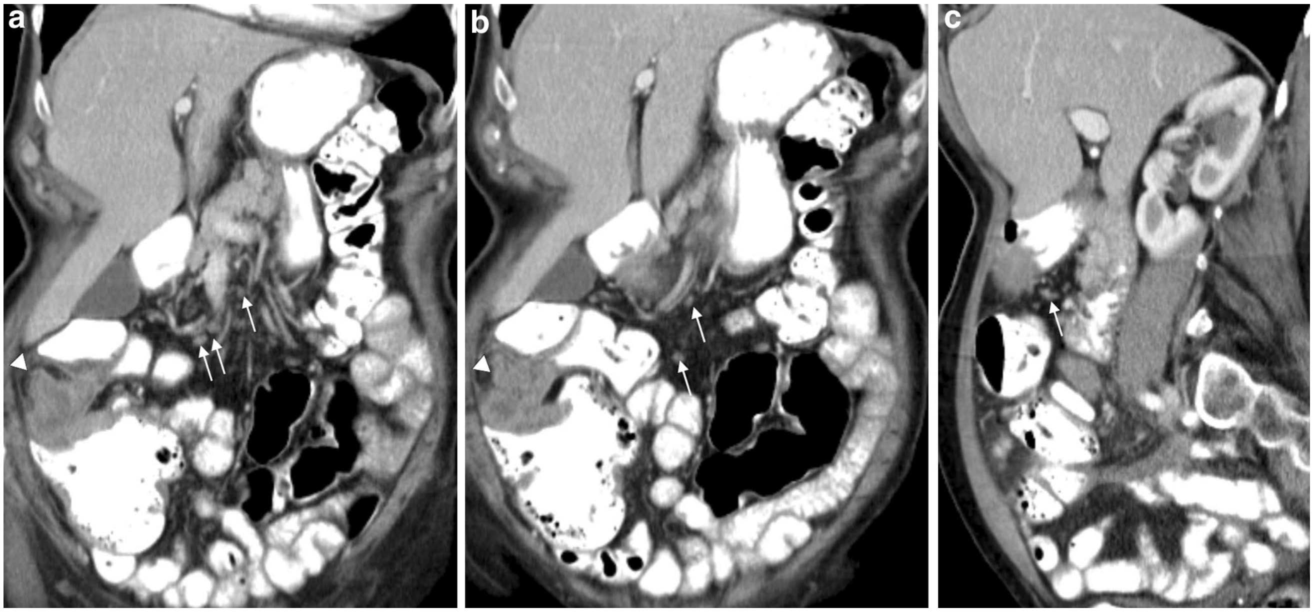

Fig. 9 Coronal and sagittal contrast-enhanced CT images show a mass in the hepatic flexure/proximal transverse colon (**a** and **b**, arrowheads) with cluster of small mesocolic nodes (**b**, arrows) and moderately suspicious gastrocolic adenopathy (**c**, arrow)

Concept of CME

The concept of CME includes surgical dissection along the embryological planes between the visceral and parietal fascia around the colon (Toldt's space), central vascular ligation of supplying vessels, and complete removal of the lymph nodes. The procedure may involve mobilizing the duodenum and pancreatic head for an optimal exposure of the mesenteric root and the SMA/SMV and to allow the excision of tumor along the mesenteric envelope and complete removal of lymphatic, vascular, and neural tissues. All nodes are removed in the longitudinal (pericolic, D1) and central (mesenteric D2/extended D3) direction. An ideal excision ascertains adequate (5–10 cm) bowel margins, and maximum lymph node harvest and excision with intact fascial layers are correlated with improved prognosis and improved survival.

Pre-operative evaluation of vascular anatomy with computed tomography

There is the potential to improve surgical outcomes in CME with CVL using pre-operative multidetector computed tomography (MDCT). Graf et al. first described CT for the evaluation of mesenteric venous anatomy in 1997 [21]. Since then, a modest number of studies were published specifically examining MDCT for the evaluation of mesenteric vasculature relevant to CME with CVL [22–24]. The ability to create 3-dimensional (3D) reformats of the mesenteric vessels while removing extraneous soft tissue structures allows the radiologist, and thus the surgeon, to easily understand the variant vascular anatomy for a given patient.

Sakaguchi et al. [22] created 3D vascular reformats for 102 patients with abdominal malignancy to assess their arterial and portal venous anatomy. They created separate arterial and venous 3D reconstructions from triple-phase CT (early arterial, late arterial, and early portal venous phase) and fused them using post-processing software. The resulting images were useful but the process was time consuming, requiring between 35 and 78 min to make images for each case. Although they examined a range of abdominal cancers, the data are relevant to CME with CVL. In their cohort, the GTH was identified in most cases (77.5%) and was most commonly formed by the confluence of the RGEV and SRCV (41.2%). The second most common type was formed by the confluence of the RGEV and the SRCV, plus either the MCV, RCV, or both the MCV and RCV (33.3%). Other variations in which the GTH formed with the RGEV and colic veins, but not the SRCV, were rare [22] (Fig. 10).

Miyazawa et al. [24] looked at pre-operative MDCT scans to evaluate the GTH in patients prior to pancreaticoduodenectomy. Their classification varied in that it included the anterior superior pancreaticoduodenal vein (ASPDV) as a tributary to the GTH in all variations, along with the RGEV. Their study found that the breakdown of GTH drainage was from one colic vein (71%), two colic veins (20%), no colic vein (7%), and three colic veins (2%).

Lastly, Ogino et al. [23] examined 3D reformats from pre-operative CT scans in 81 patients who underwent

Fig. 10 Multiplanar reformatted image from a contrast-enhanced CT showing the gastrocolic trunk of Henle (GTH). A: superior mesenteric vein; B: middle colic vein; C: gastrocolic trunk; D: right gastroepiploic vein; E: anterosuperior pancreaticoduodenal vein; F: superior right colic; G: right colic vein

laparoscopic CME with CVL. They reported the presence of a single RCV in 88% of patients and an accessory RCV (aRCV) in 6% of patients. Interestingly, the SRCV was identified in only 21% of the patients. The MCV was identified in all cases, with variable drainage into the SMV (68%), GTH (20%), jejunal vein (6%), inferior mesenteric vein (5%), and splenic vein (1%). They noted that in prior studies [25, 26], bleeding caused conversion to open surgery in 1%–2% of cases for laparoscopic right hemicolectomy, whereas in their study that included pre-operative analysis of the vasculature, all cases were completed via laparoscopy. It is not appropriate to draw further conclusions from this single cohort that did not have a control group, but the implication is that this type of 3D modeling prior to surgery may impact surgical outcomes.

Suffice to say, there is a wide range of complex venous variations that can be identified on CT prior to surgery. Rather than memorizing rates of incidence, it is more useful to be familiar with the patterns that can exist in order to identify the most relevant vascular anatomy prior to surgery (Table 1).

Summary

Complete mesocolic excision with central vascular ligation has emerged as a promising surgical operation for colon cancer and is becoming more common in clinical practice. The radiologist's role in pre-operative evaluation and surgical planning has the potential to impact surgical planning and patient outcomes. Familiarity with arterial and venous variations not traditionally considered in patients with colon cancer, as well as patterns of nodal spread of metastases, is important to optimize the upfront evaluation of colon cancer patients. Although some studies have examined the role of CT imaging specifically as pertains to CME with CVL, additional research is needed to further evaluate the role of CT in surgical planning with ultimate goal of the standardization of imaging protocols, terminology, and structured reporting.

Table 1 Elements to consider including in the report for CT abdomen and pelvis in staging of colon cancer

Body of report	
Location of tumor	Cecum/Ascending/Hepatic Flexure/Transverse/ Splenic Flexure/Descending/Sigmoid
Size (if measurable)	Size in cm
Suspicious mesocolic lymph nodes	If yes, give size and location
Suspicious central mesenteric lymph nodes	If yes, give size and location
If mass is in the transverse colon, suspicious gastro-hepatic nodes?	Yes/no
Relationship of the right colic artery to the superior mesenteric vein	Anterior/posterior
Relationship of the ileocolic artery to the ileocolic vein	Anterior/posterior
Peritoneal deposits	Yes/No If yes, location and size (up to 2 examples)
Impression of report	
CT stage	ctT []N []M []

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