Received:
28 May 2018

Revised:
19 October 2018

Accepted:
04 March 2019

<https://doi.org/10.1259/bjr.20180478>

Cite this article as:

Yedururi S, Kang HS, Cox VL, Chawla S, Le O, Loyer EM, et al. Tumor thrombus in the venous drainage pathways of primary, recurrent and metastatic disease on routine oncologic imaging studies: beyond hepatocellular and renal cell carcinomas. *Br J Radiol* 2019; **92**: 20180478.

PICTORIAL REVIEW

Tumor thrombus in the venous drainage pathways of primary, recurrent and metastatic disease on routine oncologic imaging studies: beyond hepatocellular and renal cell carcinomas

SIREESHA YEDURURI, MBBS, HYUNSEON KANG, MD, PhD, VERONICA L COX, MD, SUMEDHA CHAWLA, MBBS, OTT LE, MD, EVELYNE M LOYER, MD and LEONARDO MARCAL, MD

Department of Diagnostic Radiology, University of Texas MD Anderson Cancer Center Houston, Texas, USA

Address correspondence to: Dr Sireesha Yedururi
E-mail: syedururi@mdanderson.org

ABSTRACT

Radiologists routinely evaluate for tumor thrombus in the portal and hepatic veins in patients with hepatocellular carcinoma and in the renal vein and inferior vena cava in patients with renal cell carcinoma. However, tumor thrombus occurs in association with numerous other tumor types, e.g. colorectal carcinoma and pancreatic neuroendocrine tumor. Furthermore tumor thrombi are not limited to the primary tumor but also seen with local recurrence and metastatic disease. While less recognized, these thrombi nevertheless affect patterns of recurrence and prognosis. Their detection is critical for accurate local staging and early detection of local recurrence and metastatic disease. The purpose of this pictorial review is to draw the attention of radiologists to the less familiar manifestations of tumor thrombus, review the imaging findings and illustrate the clinical significance of these thrombi.

INTRODUCTION

Hematogenous dissemination is a common route of spread of malignancy as tumor cells disseminate via the splanchnic, systemic or pulmonary circulation. It can either be occult on cross-sectional imaging or be seen as direct venous extension of tumor, a tumor embolus or a combination of both. While radiologists are familiar with tumor thrombus associated with hepatocellular carcinoma (HCC) and renal cell carcinoma (RCC), tumor thrombus in the setting of other tumor types such as colorectal carcinoma and pancreatic neuroendocrine tumor is often less appreciated. Detection of tumor thrombi is critical for local staging and affects patterns of recurrence and prognosis.

At surgical resection of RCC, invasion rates of 4, 24.4 and 18.1% have been reported in the inferior vena cava (IVC), renal vein and major renal vein branches, respectively, and shown to be associated with poor prognosis.¹ In HCC, invasion rates of 24 and 9% have been reported in the portal and hepatic veins respectively at surgical resection, and both have been found to be poor prognostic factors.² At surgical resection for colorectal carcinoma, vascular invasion was reported in 23% of patients, and this again was a significant poor prognostic indicator.³ In rectal cancer,

high-resolution MRI is increasingly used for staging, and radiologists routinely evaluate for the presence of extramural venous invasion. A 35% prevalence of extramural vascular invasion, characterized by a dilated and tortuous vessel filled with tumor signal has been reported on MRI, and found to be associated with a five-fold increase in the rate of synchronous metastatic disease and almost four-fold risk of developing metastatic disease after surgery.⁴ In patients with nonfunctioning pancreatic neuroendocrine tumors, a 33% incidence of venous tumor thrombus on CT was reported.⁵ Less well-known associations have been described with gastric and other gastrointestinal malignancies,^{6,7} uterine leiomyosarcoma,⁸ Wilms tumor,⁹ primary and metastatic osteosarcoma,^{10,11} metastatic melanoma¹² and adrenal cortical carcinoma.¹³ The incidence of tumor thrombus as reported in the literature is summarized in Table 1.

Definition and detection of tumor thrombus:

Radiologists routinely evaluate for tumor thrombus in the portal and hepatic veins in patients with HCC and in the renal vein and IVC in patients with RCC, but may be less likely to do so in tumor types infrequently associated with tumor thrombus or when the venous extension affects small

Table 1. Incidence of tumor thrombus in different primary tumors

Type of primary tumor	Method of confirmation	Study	No. of patients	Reported incidence of tumor thrombus and involved veins	
Renal cell carcinoma	Surgical resection	Hoehn et al ¹	426	4%,	IVC
				24.4%	Main renal vein
				18.1%	Major renal vein branches
Hepatocellular carcinoma	Surgical resection	Ikai et al ²	12,118	24%	Portal vein
				9%	Hepatic vein
Colorectal carcinoma	Surgical resection	Betge et al ³	381	23%	Both intramural and extramural veins
Rectal cancer	MRI	Siddiqui et al ⁴	1262	35%	Extramural veins
Non-functional pancreatic neuroendocrine tumors	CT and/or surgical resection	Balachandran et al ⁵	88	33%	Splenic vein, SMV, portal, jejunal and gastroduodenal veins
Gastric cancer	CT	Kim et al ⁶	153	23%	Perigastric vessels
Pelvic osteosarcoma	Surgical resection and/or follow up imaging	Yedururi et al ¹¹	39	57%	CFV, IIV, CIV, IVC and RA
Wilms tumor	Pre-therapy imaging or at surgery	Shamberger et al ⁹	2731	6%	IVC and RA

CFV, common femoral vein; CIV, common iliac vein; EIV, external iliac vein; IIV, internal iliac vein; IVC, inferior vena cava; RA, right atrium; SMV, superior mesenteric vein.

vessels. These tumor thrombi can be seen either directly extending from the tumor or as a non-contiguous tumor embolus along the vascular drainage pathways. The purpose of this illustrative article is to increase awareness that tumor thrombus occurs in tumors other than HCC and RCC and that tumor thrombus occurs not only in the veins draining the primary tumor but also with those draining local recurrence and metastases. Owing to the overlap in the use of the terms “vascular invasion”, “venous invasion”, “vascular involvement” and “vascular occlusion”,⁵ we used the term “tumor thrombus” which implies tumor inside the lumen of the vessel. Note is made that the terms “vascular invasion”, “venous invasion” or “vascular involvement” have been used interchangeably for encasement of the vessel or vein by the tumor (with or without extrinsic compression) and intraluminal tumor thrombus. Vascular occlusion can result from either extrinsic compression or intraluminal tumor. We have identified tumor thrombus in the venous drainage pathways on CT, MRI and PET/CT studies. Majority of these studies were acquired with routine protocols and a few of them with dedicated liver, pancreas or renal mass protocols. The tumor thrombus typically follows the enhancement or MR signal or FDG uptake characteristics of the primary tumor. The phase/modality providing optimal conspicuity of the primary tumor is generally also the one where tumor thrombus is best seen, consequently there is no need for any specific technique to visualize a tumor thrombus. Instead, identification of dilated and tortuous vessels in the venous drainage pathways with intraluminal contents showing imaging characteristics similar to the adjacent tumor is key to diagnosing tumor thrombus. Detection of tumor thrombus in small vessels can be challenging, progressive enlargement of the caliber of involved vessels in comparison with prior studies or asymmetry with normal side-when applicable can help.

Further characterization of tumor thrombus:

Differentiating tumor thrombus from bland thrombus is crucial for patient management and can be challenging.^{10,14} A tumor thrombus forms from contiguous tumor growth into the veins draining the tumor or can be seen non-contiguously in the veins draining the tumor and usually results in expansion of the vein. It is characterized on cross-sectional imaging by attenuation (CT) or signal (MRI) similar to that of the adjacent tumor. These thrombi are characterized by the presence of enhancement on CT or MRI, pulsatile waveforms on spectral Doppler imaging,¹⁵ ¹⁸F FDG uptake on PET/CT for tumors that are metabolically active¹⁶ and restricted diffusion for tumors that show restricted diffusion.¹⁷ Bland thrombus in contrast, develop as a consequence of the mass effect of the tumor resulting in venous occlusion or narrowing with impaired venous flow. This is seen in veins obstructed by the tumor and typically does not enhance. Expansion of the vessel can occur during the acute phase. Bland thrombus often resolves completely or partially, and chronic thrombosis results in decreased caliber of the involved vessel. At times, it is impossible to differentiate tumor thrombus from bland thrombus on a single study, and temporal evolution of the thrombus on serial imaging studies can aid diagnosis. Tumor thrombus should be considered when the thrombus within a vein draining the tumor persists despite anticoagulation therapy¹⁰ or improved with effective chemotherapy. The differences between tumor thrombus and bland thrombus are summarized in Table 2. Intravascular tumor embolus in the distal pulmonary arteries can be mistaken for mucus plugging. The key differentiating feature is that tumor emboli are typically accompanied by air filled bronchi¹⁸ and conversely mucus plugging is accompanied by vessels.

Table 2. Differentiating between tumor thrombus and bland thrombus

Tumor thrombus	Bland thrombus
Typically located within the downstream veins <i>i.e.</i> the veins draining the tumor	Typically located within the upstream veins, <i>i.e.</i> the veins obstructed by the tumor
Can extend directly from the tumor	Does not show direct extension of the tumor
Expands the lumen and may be nodular or beaded.	Expands the lumen in the acute phase and narrows or occludes the lumen in the chronic phase.
Persists despite anticoagulation in the absence of treatment for tumor	Resolves or improves with anticoagulation
Enhancement on CT or MRI for tumors that enhance	No enhancement
May show pulsatile waveforms on spectral Doppler imaging (a specific but not sensitive finding)	No show pulsatile waveforms
FDG uptake on PET/CT for tumors that are metabolically active	No FDG uptake
Restricted diffusion for tumors that show restricted diffusion.	No restricted diffusion

FDG, fludeoxyglucose.

Table 3. Imaging of tumor thromboembolism

Type of malignancy: any tumor that can spread hematogenously.	<ul style="list-style-type: none"> Well known: hepatocellular carcinoma Renal cell carcinoma Pancreatic neuroendocrine tumors Colorectal carcinoma Less known: Adrenal cortical carcinoma Hepatoblastoma Head and neck squamous cell carcinoma, Testicular germ cell tumor Cholangiocarcinoma Urothelial carcinoma Sarcomas Pheochromocytoma Pancreatic adenocarcinoma
Sites	<ul style="list-style-type: none"> Veins draining the primary tumor Veins draining local recurrence Veins draining metastatic disease Tumor emboli in the pulmonary arteries from tumor thrombi draining into the systemic veins
Characteristic imaging findings	<ul style="list-style-type: none"> Dilated, tortuous and beaded vessel either in direct contiguity with the tumor or in the venous drainage pathways of tumor. Intraluminal contents show imaging characteristics (enhancement, MR signal, FDG tracer uptake and pulsatile waveforms of spectral Doppler) similar to adjacent tumor. Tumor emboli in the small distal pulmonary arteries are seen as dilated tubular branching opacities.
Clinical significance of accurate detection and interpretation	<ul style="list-style-type: none"> Delineate the extent of disease and improve staging accuracy Predict the sites of spread of malignancy Early detection of recurrence and metastatic disease Avoids misinterpreting tumor thromboembolism as bland thromboembolism

Overview of hematogenous spread correlating with basic anatomy and physiology

Hematogenous spread can be occult or overt on imaging. The location of the primary tumor tends to determine the sites of distant metastatic disease. The initial sites of hematogenous spread are the liver for most gastrointestinal primary tumors (except for lower rectal tumors) and the lungs for most other primary tumors (including breast, melanoma, sarcomas and lower rectal tumors). Liver metastases can subsequently drain into the hepatic veins and spread to the lungs. Lung metastases can further drain into the pulmonary veins and potentially disseminate to the rest of the body via the systemic circulation. Tumor in the veins draining these systemic metastases can potentially commence the next cycle of metastatic spread to the lung or liver. Primary lung malignancies can either drain into the right heart via the systemic veins (bronchial veins and superior vena cava), leading to further spread within the lungs, or drain into the left heart via the pulmonary veins, potentially

Figure 1. Axial pre-contrast (a), arterial phase (b), portal venous phase (c) and delayed (d) CT images of the abdomen in a 76-year-old male with pancreatic neuroendocrine tumor depict an arterially enhancing mass with washout on the delayed phase in the pancreatic tail (arrowheads) and tumor thrombus in the splenic vein (arrows) with similar enhancement and washout characteristics.

leading to systemic spread to the rest of the body. This explains why systemic spread to the brain and adrenal gland is more commonly seen with lung cancer than with other malignancies, particularly gastrointestinal malignancies. Morgan-Parkes has reviewed the mechanisms, pathways and cascades of metastases describing the multistep process of hematogenous spread where liver and lung act as initial sites of metastatic disease and then as source of further hematogenous dissemination of malignancy.¹⁹ This pictorial review illustrates the continuous, multistep process of hematogenous dissemination and how liver, lung and systemic metastases are associated with different prognoses. Understanding the pattern of hematogenous spread of malignancy and the associated imaging findings improves the accuracy of local staging and helps predict the sites of spread of malignancy, thus facilitating early diagnosis of recurrence.

Figure 2. Coronal post-contrast CT images of the abdomen and pelvis (a, b) in a 47-year-old male with sigmoid colon adenocarcinoma (arrowhead) and tumor thrombus within the dilated and tortuous draining veins (straight arrow). Multifocal liver metastatic disease is also seen (curved arrows).

Figure 3. Coronal post-contrast CT images of the abdomen (a, b) in a 68-year-old male with gastric adenocarcinoma (arrowhead) who had recently completed palliative radiotherapy to the primary tumor. A slowly growing tumor thrombus is seen extending from dilated and tortuous perigastric veins and left gastric vein and further into the main portal vein (arrows). This finding prompted a more careful search for liver metastasis, and a new subtle liver metastasis was identified (not shown).

ILLUSTRATIVE REVIEW

The cases described below illustrate the typical imaging findings of tumor thrombus, diagnostic challenges and the implications of accurate diagnosis and misdiagnosis (summarized in Table 3). The first step in the diagnosis of tumor thrombus is the identification of a dilated and tortuous vessel either in direct continuity with the tumor or along the venous draining pathways. The next step is further characterization of the intraluminal contents and differentiation from bland thrombus. If the thrombus is located in the veins draining the tumor and the imaging characteristics of the intraluminal contents are similar to those of the primary tumor, then it is a tumor thrombus. The next step is to search for metastatic spread along the venous drainage pathways.

Tumor thrombus in the veins draining the primary tumor:

In our experience, in addition to HCC and RCC tumor thrombus is frequently associated with pancreatic neuroendocrine tumors (Figure 1) and colorectal adenocarcinomas (Figure 2). Less often, we have seen tumor thrombus in patients with gastric adenocarcinoma (Figure 3), adrenal cortical carcinoma (Figure 4), hepatoblastoma (Figure 5), tonsillar squamous cell carcinoma (Figure 6), testicular germ cell tumor (Figure 7),

Figure 4. Coronal (a) and axial (b) post-contrast CT images of the abdomen in a 36-year-old male with left adrenal cortical carcinoma show a large heterogeneous left adrenal mass (arrowheads) with a large tumor thrombus in the left renal vein and IVC (white arrows). A liver metastasis is also present (curved arrow). Non-enhancing bland thrombus is seen in the infrarenal IVC (black arrow). IVC, inferior vena cava.

Figure 5. Axial post-contrast CT image of the abdomen (a) and coronal post-contrast CT image of the chest (b) in a 5-year-old boy with hepatoblastoma show large infiltrative mass in the right lobe of the liver (arrowheads) with large tumor thrombus in the IVC extending into the right atrium (arrows). IVC, inferior vena cava.

cholangiocarcinoma (Figure 8), urothelial carcinoma (Figure 9), sarcomas such as leiomyosarcoma (Figure 10) and paratesticular dedifferentiated liposarcoma (Figure 11) and other tumors, such as pheochromocytoma, pancreatic adenocarcinoma, Ewing sarcoma and alveolar soft part sarcoma (not shown). Direct contiguous extension of the primary tumors into the draining veins (Figures 1–5, 7, 9 and 11) and noncontiguous involvement of the venous drainage pathways (Figures 6, 8 and 10) are both illustrated. Tumor thrombi are not only seen at presentation, but can develop at any stage of disease. Figure 3 illustrates gastric adenocarcinoma with a tumor thrombus in the left gastric and portal veins concomitant with progression of the primary tumor, following completion of palliative radiation therapy. If the primary tumor shows arterial enhancement with wash-out on the portal venous and delayed phases, the tumor thrombus typically shows the same characteristics (e.g. pancreatic neuroendocrine tumor shown in Figure 1). If the primary tumor does not show arterial enhancement but shows more delayed enhancement, the tumor thrombus also typically shows delayed enhancement (e.g. intrahepatic cholangiocarcinoma in Figure 8). If the primary tumor does not show enhancement, the tumor thrombus

Figure 6. Axial post-contrast CT (a, b), corresponding fused PET/CT (c,d) and sagittal post-contrast CT (e) images of the head and neck in a 52-year-old male depict FDG-avid squamous cell carcinoma of the right tonsil (arrowheads), malignant right upper jugular node (curved arrows) and tumor thrombus in the draining vein extending into the right internal jugular vein (straight arrows). Spectral Doppler imaging (f) of the vein shows pulsatile waveforms confirming tumor thrombus. FDG, fludeoxyglucose; PET, positron emission tomography.

Figure 7. Coronal post-contrast CT abdomen and pelvis images (a–c) and axial chest CT image (lung window) (d) in an 18-year-old male with newly diagnosed right testicular germ cell tumor illustrate right testicular mass (arrowhead), tumor thrombus in the right testicular vein and IVC (straight arrows) and lung metastasis (curved arrow). IVC, inferior vena cava.

typically does not show enhancement either. Tumor thrombus detection does not require special technique and can be seen on routine CT abdomen and pelvis acquired during the portal venous phase (e.g. sigmoid colon adenocarcinoma in Figure 2, gastric adenocarcinoma in Figure 3, adrenal cortical carcinoma in Figure 4, hepatoblastoma in Figure 5, testicular germ cell

Figure 8. Axial pre-contrast (a), arterial phase (b), portal venous phase (c) and delayed (d) CT images of the abdomen in a 76-year-old male with multifocal cholangiocarcinoma with a dominant lesion in the left liver (arrowheads) and tumor thrombus in the left (not shown), right and main portal veins (arrows) with delayed enhancement pattern similar to the primary tumor.

Figure 9. Axial post-contrast CT image of the abdomen in delayed phase (a) in a 68-year-old male with poorly differentiated urothelial carcinoma of the right renal pelvis shows an infiltrative right renal mass (arrowhead) with tumor thrombus in the right renal vein and IVC (straight arrow). Axial (b) and coronal (c) post-contrast CT images of the chest show tumor embolism in the left lower lobe segmental pulmonary artery (straight arrows) and peripheral pulmonary metastasis (curved arrows) in the same segment. IVC, inferior vena cava.

tumor in Figure 7, uterine leiomyosarcoma in Figure 10 and paratesticular dedifferentiated liposarcoma in Figure 11). In contrast, bland thrombus does not show any enhancement, is typically located in the upstream veins obstructed by the tumor (e.g. infrarenal IVC thrombus in adrenal cortical carcinoma shown in Figure 4a). In our experience, if the primary tumor is FDG avid, the tumor thrombus is typically FDG avid (e.g. tonsillar squamous cell carcinoma in Figure 6) and conversely if the primary tumor does not show FDG uptake, tumor thrombus typically does not show FDG uptake. Spectral Doppler imaging of internal jugular venous thrombus in this patient with tonsillar primary confirmed pulsatile waveforms (Figure 6f) which is highly specific, but moderately sensitive for tumor thrombus.^{10,14,15} Identification of tumor thrombus in the testicular vein and IVC in the patient with testicular germ cell tumor (Figure 7) has led to a change in surgical treatment planning with involvement of

Figure 10. Coronal post-contrast CT image of the abdomen and pelvis in a 61-year-old female with resected uterine leiomyosarcoma shows tumor thrombus within the left gonadal vein extending into the left renal vein (arrows).

Figure 11. Transverse ultrasound image of the right scrotum (a) and coronal post-contrast CT image of the pelvis (b) in a 56-year-old male with right paratesticular dedifferentiated liposarcoma (arrowheads) show dilated and tortuous right gonadal vein with tumor thrombus (arrow in b). The paratesticular mass was resected before obtaining the chest CT image. Follow-up chest CT (lung window) Figure 4 months later (c, d) depict multiple lung metastases, predominantly in the form of beaded and tortuous distal pulmonary vessels (arrows in c, d).

vascular surgeons during retroperitoneal lymph node resection allowing for complete resection.

Tumor thrombus and emboli as early imaging indicator for metastatic disease: In our experience, recognition of tumor thrombus increases confidence in the interpretation of subtle lesions developed in the organs downstream to the thrombus. Identification of the tumor thrombus in the draining gastric and portal veins in the patient with gastric adenocarcinoma (Figure 3) increased

Figure 12. Axial T_2 weighted MR image of the pelvis in a 4-year-old boy previously treated for sacrococcygeal teratoma (a) shows recurrent tumor in the right posterior pelvic musculature (arrowheads) associated with a dilated and thrombosed draining vein (arrow). Axial chest CT (lung window) image (b) shows one of the few new lung nodules (arrow) that are most consistent with metastases given the thrombus in the draining vein. Follow-up chest CT (not shown) confirmed progression of these lung nodules.

Figure 13. Axial (a) chest CT, coronal T_2 weighted MRI and axial post-contrast T_1 weighted MR images in a 17-year-old girl with right humerus osteosarcoma, 10 months after completing treatment, including chemotherapy and radical resection with reconstruction, show a recurrent sub pectoral mass (arrowhead) and tumor thrombus within the right subclavian vein and innominate vein (arrows). These findings were later confirmed at surgical resection.

suspicion of liver metastasis, allowing for early diagnosis of a subtle liver metastasis. In the distal pulmonary arteries, tumor embolism can be seen as dilated and beaded distal pulmonary vessels and can be potentially misinterpreted as inflammatory or non-specific opacities. This finding can be one the earliest imaging findings of metastatic disease to the lungs (Figure 11c, d), before the development of overt nodular metastases.^{10,18} Tumor embolism into the central pulmonary vessels can mimic bland or septic pulmonary embolism which may be difficult to distinguish on initial study. Clinical context and follow-up imaging may provide clue to the diagnosis.

Tumor thrombus in the veins draining local recurrence:

Figure 12 illustrates a patient with recurrent sacrococcygeal teratoma on pelvic MRI with a subtle tumor thrombus in the draining vein seen as a tortuous, tubular T2 hyperintense small vein, directly extending from the recurrent tumor with signal characteristics similar to the adjacent recurrence and early lung metastases. This is another illustration of the value of recognition of tumor thrombus in the early detection of metastasis. The presence of tumor in the draining vein increased the likelihood that otherwise indeterminate lung nodules are metastatic.

Figure 14. Axial post-contrast chest CT in a 58-year-old male with metastatic hepatocellular carcinoma in the left lower lobe mass (white arrows) that directly extends into the left inferior pulmonary vein and left atrium (black arrow).

Figure 15. Coronal post-contrast CT images of the abdomen and pelvis (a, b) in a 54-year-old female with metastatic melanoma to the small bowel (arrowheads) show tumor thrombus in the draining mesenteric veins (arrow in a) and a tumor embolism within the portal vein (arrow in b). The tumor thrombus in the small draining mesenteric vein was not recognized and the portal venous thrombus was misinterpreted as bland thrombus. The small bowel metastases was resected due to gastrointestinal bleeding and the patient was anticoagulated for presumed bland portal vein thrombosis. Follow-up coronal post-contrast CT images of the abdomen and pelvis 4 months later (c, d) show progressive tumor thrombus in the portal vein and mesenteric veins (arrows) and new liver metastases (curved arrows).

Figure 13 illustrates a patient with recurrent osteosarcoma in the right subpectoral region and a pathologically proven tumor thrombus within the right subclavian and innominate veins. On T_2 weighted MR images, the tumor thrombus in the right subclavian vein lacks the typical flow void and is hyperintense similar to the adjacent subpectoral recurrence. On contrast enhanced T_1 weighted MRI, the tumor thrombus shows enhancement. The recognition of this tumor thrombus allowed for optimal surgical planning involving vascular surgeons.

Tumor thrombus in the veins draining metastatic disease

Metastatic disease can be associated with tumor thrombus in the draining vein and be source of tumor emboli. Figure 14 illustrates lung metastases from HCC directly extending into the pulmonary vein and left heart. Spread to the left heart increases the risk for widespread tumor dissemination via the systemic circulation.¹⁰ Figure 15 illustrates metastatic melanoma in the small bowel with tumor thrombus in a small mesenteric vein and tumor embolism in the portal vein. The tumor in the mesenteric vein was not recognized and tumor embolism in the portal vein was misinterpreted as bland thrombus. The patient subsequently underwent surgical resection of small bowel metastasis, was anticoagulated for portal vein thrombosis and did not receive any chemotherapy until the follow-up imaging 4 months later showed progression of the thrombus in the portal vein and superior mesenteric vein (Figure 15c, d) with new liver metastases.

This case emphasizes the importance of accurate characterization of thrombosis in patient treated for malignancy.

CONCLUSION

Tumor thrombus can develop with tumors other than HCC and RCC and is also seen with local recurrence and metastatic disease. Systematic search for tumor thrombus increases the likely hood of detection. Characterization relies on the demonstration that the attenuation, pattern of enhancement or metabolic activity of the tumor thrombus are similar to the primary

tumor. In difficult cases characterization may be achieved only at follow-up imaging. The diagnosis of tumor thrombus is critical for accurate local staging, early detection of recurrence and as a result significantly impact management and prognosis.

ACKNOWLEDGMENT

The authors thank Ms. Sunita Patterson, in the Department of Scientific Publications at MD Anderson Cancer Center for editing this manuscript. We also thank Ms. Kelly Kage for editing the images.

REFERENCES

1. Hoehn W, Hermanek P. Invasion of veins in renal cell carcinoma - frequency, correlation and prognosis. *Eur Urol* 1983; **9**: 276–80. doi: <https://doi.org/10.1159/000474103>
2. Ikai I, Arai S, Kojiro M, Ichida T, Makuuchi M, Matsuyama Y, et al. Reevaluation of prognostic factors for survival after liver resection in patients with hepatocellular carcinoma in a Japanese nationwide survey. *Cancer* 2004; **101**: 796–802. doi: <https://doi.org/10.1002/cncr.20426>
3. Betge J, Pollheimer MJ, Lindtner RA, Kornprat P, Schlemmer A, Rehak P, et al. Intramural and extramural vascular invasion in colorectal cancer: prognostic significance and quality of pathology reporting. *Cancer* 2012; **118**: 628–38. doi: <https://doi.org/10.1002/cncr.26310>
4. Siddiqui MRS, Simillis C, Hunter C, Chand M, Bhoday J, Garant A, et al. A meta-analysis comparing the risk of metastases in patients with rectal cancer and MRI-detected extramural vascular invasion (mrEMVI) vs mrEMVI-negative cases. *Br J Cancer* 2017; **116**: 1513–9. doi: <https://doi.org/10.1038/bjc.2017.99>
5. Balachandran A, Tamm EP, Bhosale PR, Katz MH, Fleming JB, Yao JC, et al. Venous tumor thrombus in nonfunctional pancreatic neuroendocrine tumors. *AJR Am J Roentgenol* 2012; **199**: 602–8. doi: <https://doi.org/10.2214/AJR.11.7058>
6. Kim TU, Kim S, Lee NK, Kim HJ, Han GJ, Lee JW, et al. Prognostic value of computed Tomography-Detected extramural venous invasion to predict disease-free survival in patients with gastric cancer. *J Comput Assist Tomogr* 2017; **41**: 430–6. doi: <https://doi.org/10.1097/RCT.0000000000000543>
7. Tan CH, Vikram R, Boonsirikamchai P, Bhosale P, Marcal L, Faria S, et al. Extramural venous invasion by gastrointestinal malignancies: CT appearances. *Abdom Imaging* 2011; **36**: 491–502. doi: <https://doi.org/10.1007/s00261-010-9667-8>
8. McDonald DK, Kalva SP, Fan C-M, Vasilyev A. Leiomyosarcoma of the uterus with intravascular tumor extension and pulmonary tumor embolism. *Cardiovasc Intervent Radiol* 2007; **30**: 140–2. doi: <https://doi.org/10.1007/s00270-006-0118-4>
9. Shamberger RC, Ritchey ML, Haase GM, Bergemann TL, Loecheit-Yoshioka T, Breslow NE, et al. Intravascular extension of Wilms tumor. *Ann Surg* 2001; **234**: 116–21. doi: <https://doi.org/10.1097/00000658-200107000-00017>
10. Yedururi S, Morani AC, Gladish GW, Vallabhaneni S, Anderson PM, Hughes D, et al. Cardiovascular involvement by osteosarcoma: an analysis of 20 patients. *Pediatr Radiol* 2016; **46**: 21–33. doi: <https://doi.org/10.1007/s00247-015-3449-y>
11. Yedururi S, Chawla S, Amini B, Wei W, Salem UI, Morani AC, et al. Tumor thrombus in the large veins draining primary pelvic osteosarcoma on cross sectional imaging. *Eur J Radiol* 2018; **105**: 49–55. doi: <https://doi.org/10.1016/j.ejrad.2018.05.021>
12. Klatte T, Rao JY, Ribas A, Pantuck AJ. Metastatic melanoma to the kidney presenting with renal vein tumor thrombus. *Urology* 2007; **69**: 982.e7–982.e9. doi: <https://doi.org/10.1016/j.urology.2007.02.032>
13. Annamaria P, Silvia P, Bernardo C, Alessandro DL, Antonino M, Antonio B, et al. Adrenocortical carcinoma with inferior vena cava, left renal vein and right atrium tumor thrombus extension. *Int J Surg Case Rep* 2015; **15**: 137–9. doi: <https://doi.org/10.1016/j.ijscr.2015.07.008>
14. Rohatgi S, Howard SA, Tirumani SH, Ramaiya NH, Krajewski KM. Multimodality imaging of tumour thrombus. *Can Assoc Radiol J* 2015; **66**: 121–9. doi: <https://doi.org/10.1016/j.carj.2014.11.001>
15. Dodd GD, Memel DS, Baron RL, Eichner L, Santiguida LA. Portal vein thrombosis in patients with cirrhosis: does sonographic detection of intrathrombus flow allow differentiation of benign and malignant thrombus? *AJR Am J Roentgenol* 1995; **165**: 573–7. doi: <https://doi.org/10.2214/ajr.165.3.7645473>
16. Sharma P, Kumar R, Jeph S, Karunanithi S, Naswa N, Gupta A, et al. 18F-FDG PET-CT in the diagnosis of tumor thrombus: can it be differentiated from benign thrombus? *Nucl Med Commun* 2011; **32**: 782–8. doi: <https://doi.org/10.1097/MNM.0b013e32834774c8>
17. Catalano OA, Choy G, Zhu A, Hahn PE, Sahani DV. Differentiation of malignant thrombus from Bland thrombus of the portal vein in patients with hepatocellular carcinoma: application of diffusion-weighted MR imaging. *Radiology* 2010; **254**: 154–62. doi: <https://doi.org/10.1148/radiol.09090304>
18. Shepard JA, Moore EH, Templeton PA, McCloud TC. Pulmonary intravascular tumor emboli: dilated and beaded peripheral pulmonary arteries at CT. *Radiology* 1993; **187**: 797–801. doi: <https://doi.org/10.1148/radiology.187.3.8497633>
19. Morgan-Parkes JH. Metastases: mechanisms, pathways, and cascades. *AJR Am J Roentgenol* 1995; **164**: 1075–82. doi: <https://doi.org/10.2214/ajr.164.5.7717206>