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Nuances of the unenhanced abdominal CT: careful inspection discloses critical findings

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Abstract

Patients who have unenhanced abdominal CT scans are often critically ill. The unenhanced CT may reveal many unsuspected subtle abnormalities in the lower chest, abdomen, and pelvis and accordingly warrants careful attention. This article reviews unenhanced CT findings in the setting of pulmonary embolus, acute aortic syndromes, mesenteric and deep venous thrombosis, gastrointestinal hemorrhage, pancreatitis and its complications, as well as pyelonephritis.

Key words: Unenhanced CT—Venous thrombus—Gastrointestinal bleeding—Hemorrhage—Pulmonary embolism—Pancreatitis

MDCT of the abdomen and pelvis is ideally performed using IV contrast to maximize lesion detection and characterization. However, patients with acute symptomatology, including emergency department or critically ill patients, may not be able to receive IV contrast because of renal insufficiency, allergy, lack of IV access, or other contraindications. In these cases, abnormal findings are often more difficult to appreciate. Utilization of non-contrast CT is expanding, particularly within the emergency department. Despite diagnostic limitations, unenhanced CT may be seen as a way to complete imaging sooner, avoid potential risks of contrast exposure, and potentially offer cost savings to patients and the healthcare system [1]. The purpose of this article is to demonstrate subtle findings indicative of pathology on an unenhanced abdominal CT.

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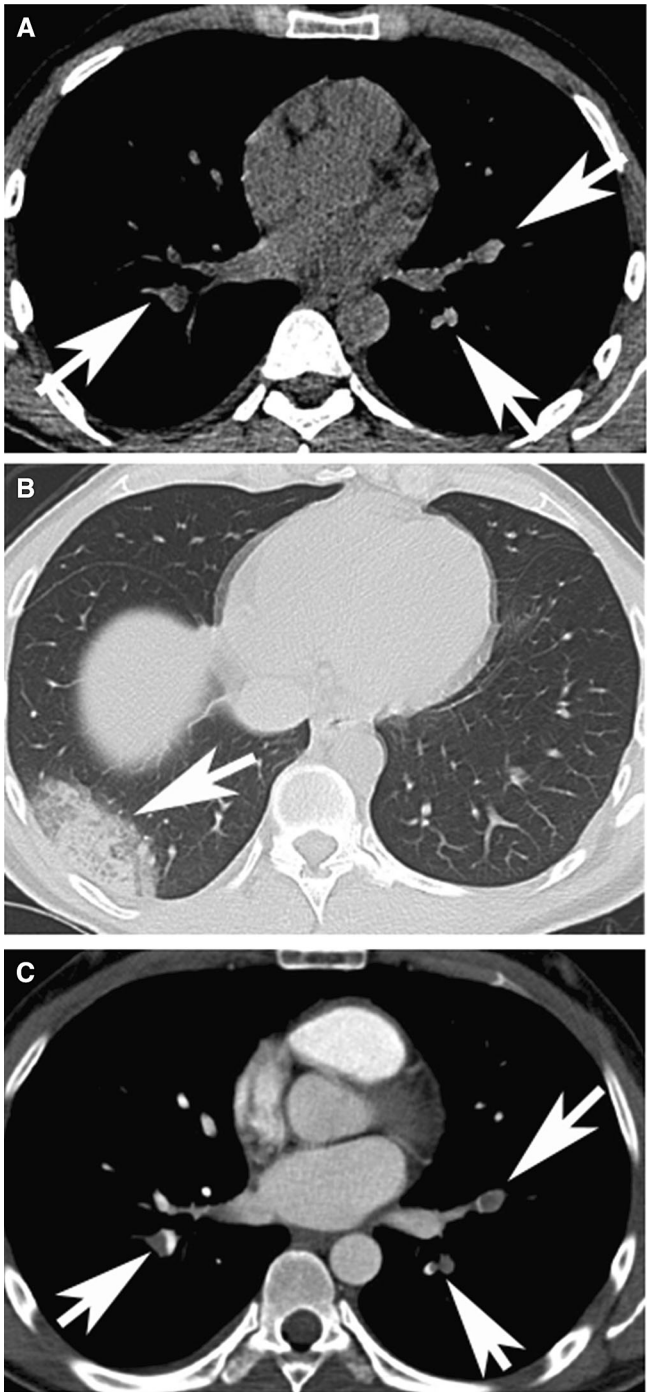
Thrombotic/hemorrhagic pathologies

Pulmonary embolism

The most widely used first line imaging tool for the diagnosis of acute pulmonary embolism is contrast-enhanced CT pulmonary angiography (CTPA) [2]. CTPA is accurate for the diagnosis of pulmonary embolism with sensitivities ranging from 66% to 93% and high specificity, generally considered greater than 90% [3, 4]. On enhanced CT scan, pulmonary embolism is diagnosed by visualization of a complete or partial intraluminal filling defect surrounded by the contrast-enhanced blood pool within the pulmonary arteries [5]. Unenhanced CT is often performed in neutropenic oncology patients, in patients with elevated serum creatinine levels, those allergic to intravenous contrast material, or as part of another CT scan protocol such as spine imaging. In these patients, acute pulmonary embolism in the lower lobes may be an incidentally detected abnormality on unenhanced abdominal CT. Ancillary findings on unenhanced CT that suggest the diagnosis of pulmonary embolism include wedge-shaped subpleural pulmonary consolidation (pulmonary infarct), dilated central or segmental pulmonary arteries, oligemia, or pleural effusion; however, these are non-specific [6], and 29% of patients with acute pulmonary embolism have no lung parenchymal abnormality on CT [7].

The diagnosis of acute pulmonary embolism by unenhanced CT is uncommon with few cases in the literature, all identified in retrospective review [8–12]. In previous reports, clot CT density was influenced by the patient's hematocrit level at time of imaging and the age of pulmonary artery clot: acute clot appeared hyperattenuating compared with the blood pool and subacute clot appearing hypoattenuating [8, 9]. Narrow window widths aid in the visualization of pulmonary artery clot; the average density difference between the clot and the blood pool in one study was 30 Hounsfield units [8]. Hyperdensity of the central pulmonary arteries is reported to be 67% sensitive and 99% specific for pul-



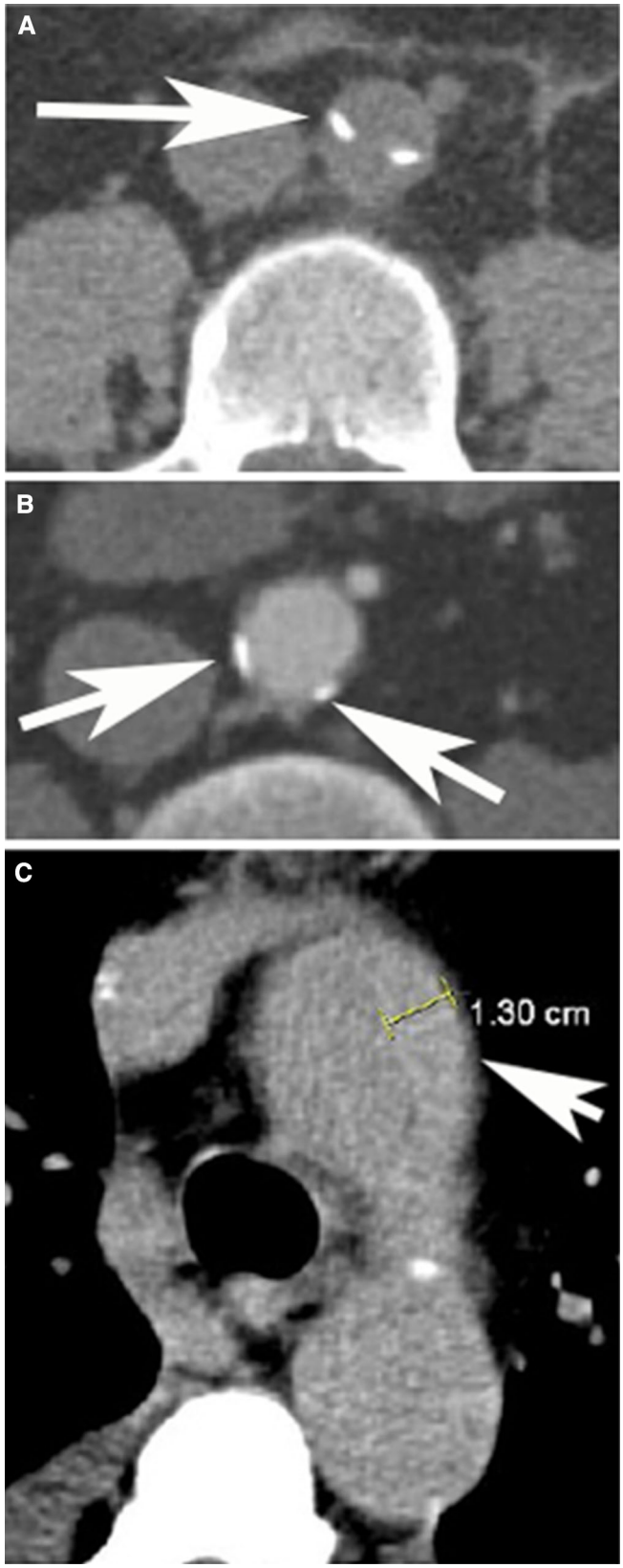


Fig. 1. 26-year-old man with shortness of breath. Bilateral lower lobe segmental pulmonary embolus (*arrows* in **A**) seen on non-contrast exam with corresponding right lower lobe peripheral consolidation from pulmonary infarction (*arrows* in **B**), findings confirmed on contrast-enhanced scan (*arrows* in **C**). If pulmonary embolism is not suspected, pulmonary infarct may be mistaken for pneumonia.

◀ **Fig. 2.** 55-year-old man with Marfan syndrome post-aortic root repair. Follow-up non-contrast CT shows displaced intimal calcifications in the abdominal aorta (*arrows* in **A**) when compared to baseline (*arrows* in **B**). Images through the chest demonstrate intramural hematoma (*arrows* in **C**).

monary embolus on unenhanced CT with decreased reliability in the peripheral pulmonary arteries [12]. Prospective diagnosis of lower lobe pulmonary embolism on unenhanced CT is challenging (Fig. 1); however, with careful attention to the pulmonary arteries and the secondary lung parenchymal findings, this important diagnosis can be identified in select cases.

Acute aortic syndromes

Unenhanced CT is often included as part of the chest imaging protocol if intramural hematoma is suspected. The contrast-enhanced CTA is optimal for identifying acute aortic syndromes, including dissection, penetrating ulcer, pseudoaneurysm, or rupture. In patients who have acute aortic syndrome and have received contrast-enhanced CT, the literature is controversial as to whether a non-contrast acquisition improves diagnostic accuracy [13, 14]. In patients with prior aortic surgical or endovascular repair, a non-contrast CT as part of a multiphase protocol facilitates distinction of calcification or surgical material from endoleak or pseudoaneurysm [15, 16].

When IV contrast in contraindicated, unenhanced CT may still demonstrate critical aortic pathology. In a recent investigation, the reported sensitivity of unenhanced CT alone was 89% with a specificity of 100% for the detection of acute aortic syndromes [17]. Specific findings of acute aortic syndromes on unenhanced CT were enlarged aortic diameters, high-density pericardial effusions, and hemomediastinum; other findings include crescentic mural aortic high attenuation thickening, displaced intimal calcifications, or complex or simple density pleural fluid [17]. Careful attention to the aortic wall morphology on unenhanced CT can reveal findings indicative of acute aortic syndrome (Fig. 2).

Iliac and femoral deep vein thrombus

Iliac and femoral deep venous thrombosis is a commonly encountered clinical problem that, in the majority of patients with the appropriate history, is initially diagnosed by ultrasound. Ultrasound was shown to be equivalent to CT venography for the diagnosis of deep venous thrombus and has replaced CT venography in the PIOPED II algorithm because of its lack of pelvic radiation and lower cost [18, 19]. Cancer patients have an increased risk of deep venous thrombosis, and this finding is often incidental on a CT exam performed for other reasons, in particular, follow-up exams for treatment response [20, 21]. In patients who are unable to receive IV contrast material, careful attention to the unenhanced CT may disclose high-density acute clot in the pelvic and lower extremity veins in the setting of

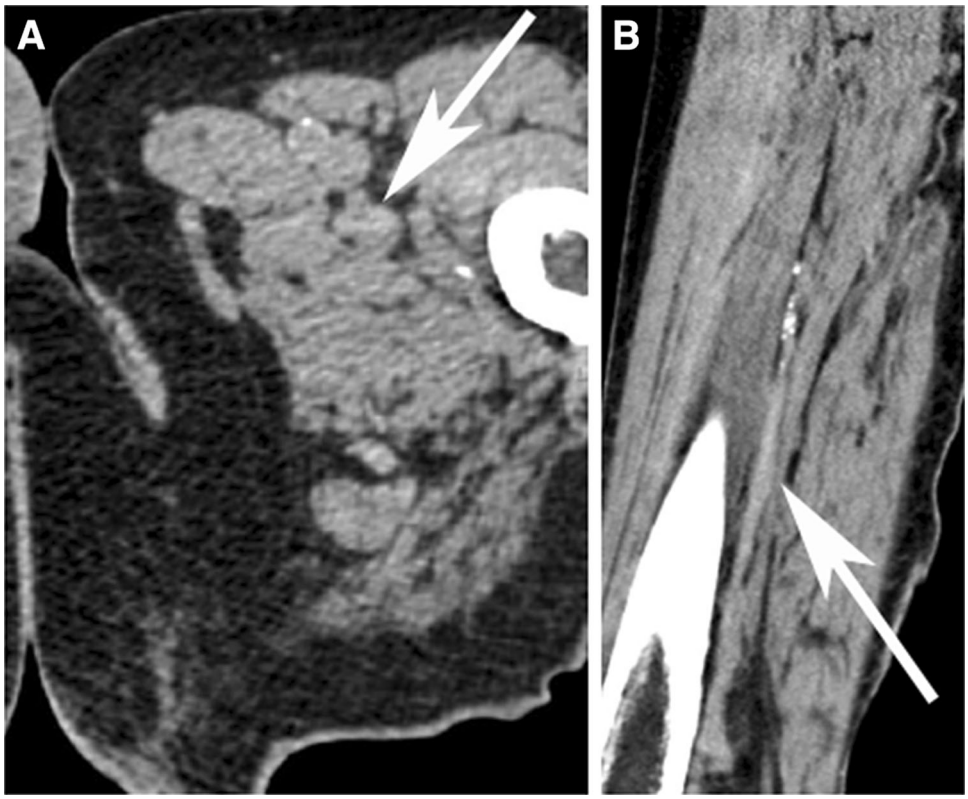


Fig. 3. 87-year-old man with left lower extremity pain. Non-contrast axial CT showed hyperdensity in the lumen of the proximal left deep femoral vein (*arrows* in **A**) extending distally on sagittal images (*arrows* in **B**).

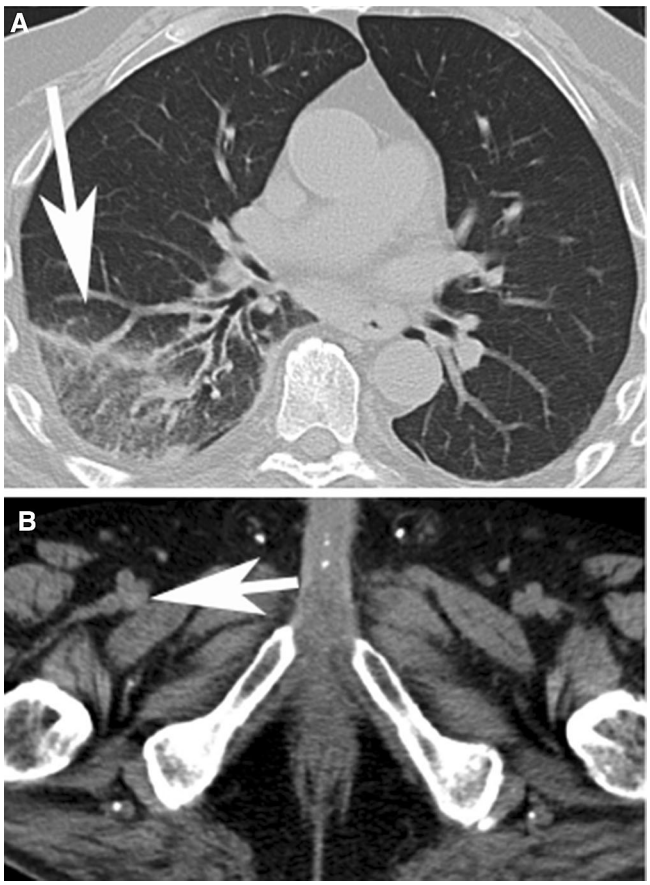


Fig. 4. 73-year-old man with renal failure and new peripheral right lower lobe consolidation due to pulmonary infarct (*arrows* in **A**) that was initially misdiagnosed as pneumonia. This patient also had a right lower extremity DVT seen on pelvic CT (*arrows* in **B**) and confirmed by ultrasound.

acute deep venous thrombosis (Fig. 3). It is important to search for subtle lower extremity deep venous thrombosis on the inferior slices of an abdominal CT scan through proximal lower extremity veins, especially in oncology patients or those with new peripheral consolidation reflecting pulmonary infarct (Fig. 4). Recognizing the CT appearance of a pulmonary infarct, a peripheral opacity with mixed ground glass and solid components, is equally important.

Portal and mesenteric vein thrombus

Portal and mesenteric venous thrombosis is a common and potentially very serious abnormality where early clinical diagnosis is important because of the associated risks of bowel ischemia and peritonitis. Thrombosis of the mesenteric venous system can readily be identified with contrast-enhanced CT; however, it is important to pay careful attention to the non-contrast CT as this has been shown to be both sensitive (78%) and highly specific (97%) for thrombus detection [22]. The ''hyperdense

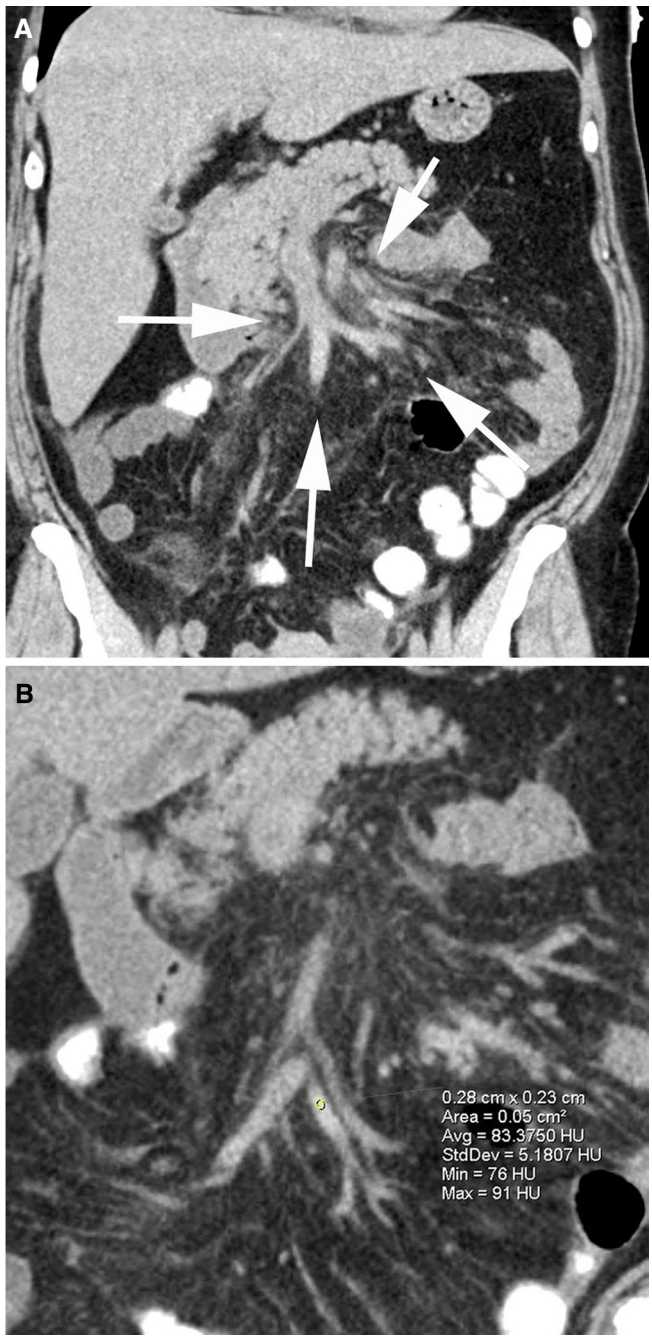


Fig. 5. 62-year-old woman 1-day status post-bowel resection surgery. Coronal MPRs from non-contrast CT reveals hyperdense clot within the superior mesenteric vein and branches with associated mesenteric stranding (*arrows* in **A**). Density of acute clot in small SMV branch exceeds 80 HU (**B**). The presence of acute thrombus was confirmed with ultrasound (not shown).

vessel sign'' on non-contrast CT (Fig. 5) reflects acute intraluminal clotted blood products with decreased intraluminal water content and is better visualized with narrow window settings [22, 23]. Cancer patients are especially in increased risk of thrombosis of the mesen-

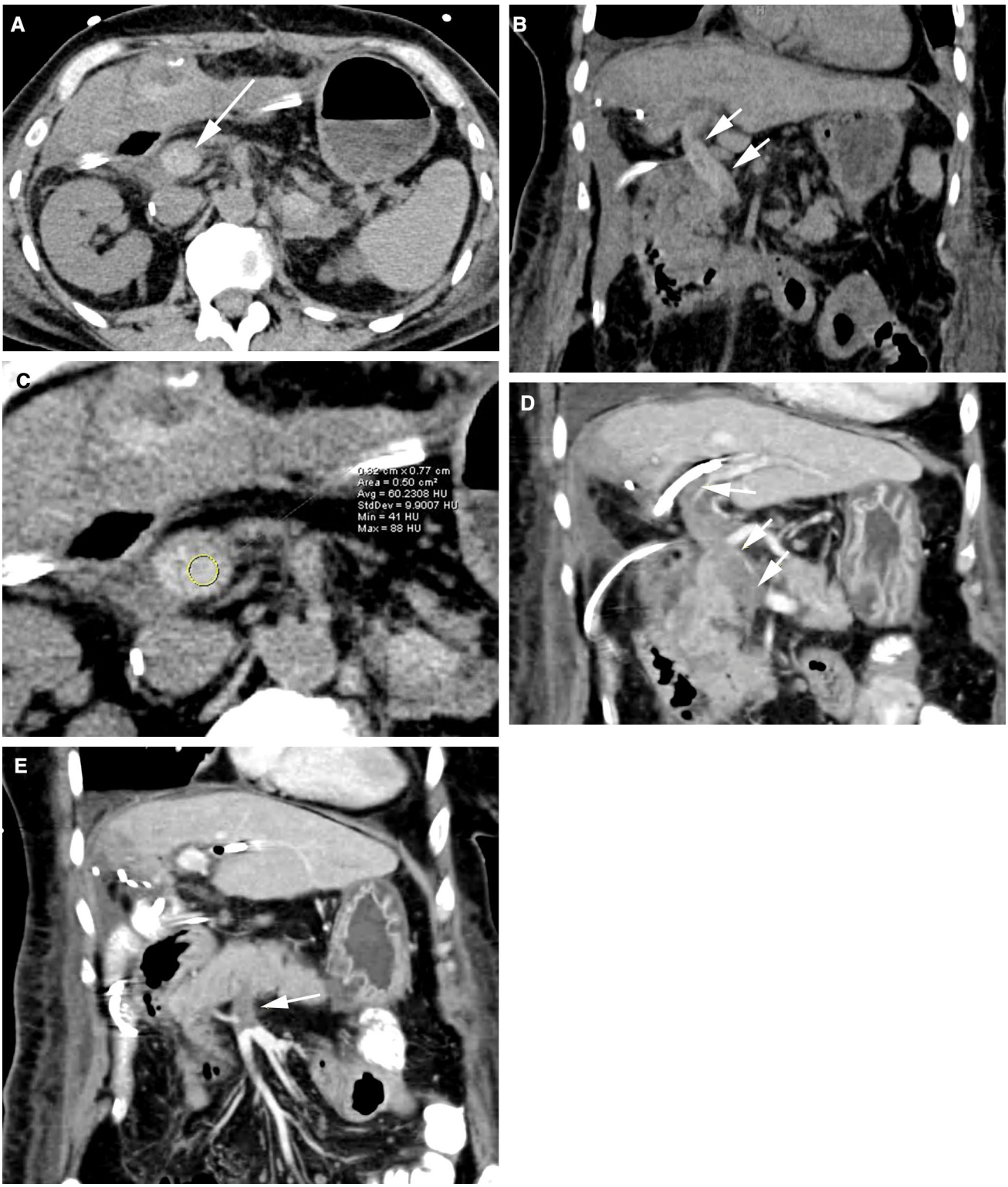


Fig. 6. 68-year-old woman status hepatic resection and post-portal vein reconstruction surgery, with acute portal and superior mesenteric vein thrombus (*arrows* in **A**, **B**) on non-contrast axial (**A** and **C**) and coronal (**B**) CT images. Note attenuation of 60 HU on precontrast (**C**). Finding confirmed by IV contrast-enhanced coronal CT (*arrows* in **D**, **E**).

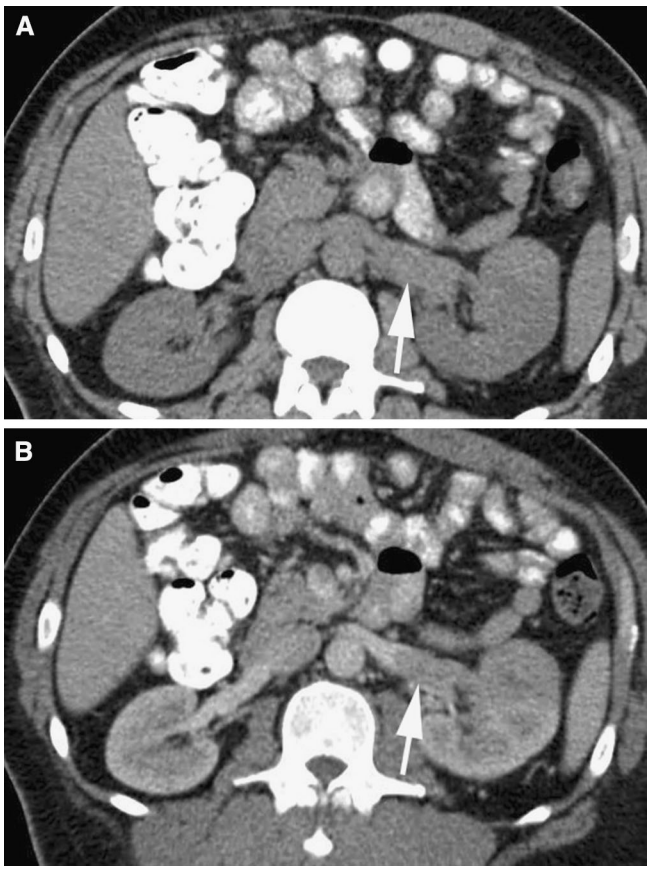


Fig. 7. 48-year-old man with sarcoma metastatic to left kidney and associated renal vein thrombosis. Note expansion of the left renal vein (*arrow*) on precontrast axial CT (**A**), due to thrombus (*arrow*) elucidated after IV contrast administration (**B**).

teric vasculature (Fig. 6) and this finding is often incidental [20]. Thrombosis on unenhanced abdominal CT was most commonly identified in the portal vein, splenic vein, and superior mesenteric vein in one series [22].

Renal vein thrombus

Renal vein thrombosis may present as either acutely symptomatic or may be asymptomatic until complications such as worsening renal function or pulmonary embolism arise. Renal vein thrombosis is most commonly seen in patients with nephrotic syndrome, less commonly in patients with history of trauma, infection, or malignancy [24]. While most cases (2/3) are bilateral, the left renal vein (Fig. 7) is more commonly affected than the right when it is unilateral [24]. CT scan with IV contrast is the currently recommended diagnostic test; however, the diagnosis can also be made by ultrasound and MRA [24]. Renal vein thrombosis is less common than other causes of thrombosis, comprising 1.9% of patients in a series of patients with known abdominal venous thrombosis [22]. Identification of thrombus within the renal vein can be made by the ''hyperdense vessel sign'' on unenhanced CT, and this diagnosis should be sought by the radiologist, especially in patients with worsening renal function or a renal cell carcinoma.

Gastrointestinal hemorrhage

MDCT is increasing being used to diagnose patients with acute gastrointestinal hemorrhage, especially in the emergency department, due to its accuracy, rapidity, and lack of patient preparation [25]. In a recent meta-analysis, CT angiography is 85% sensitive and 92% specific for the detection of gastrointestinal bleeding with greater accuracy in patients with higher rates of bleeding or active bleeding [25]. Diagnosis of active gastrointestinal (GI) bleeding hinges on IV contrast administration, with dual phase IV contrast-enhanced CT advocated [26]. Nonetheless, in patients who cannot receive IV contrast, hyperattenuating material may be seen on non-contrast CT within the wall or bowel lumen in the setting of acute GI hemorrhage. Intraluminal hemorrhage should be suspected when the intraluminal fluid attenuation is increased but the patient was not administered oral contrast or a medication that contains calcium or components that would increase the density of intraluminal fluid (Fig. 8) [27]. High-density fluid may be the only evidence of gastrointestinal hemorrhage on non-contrast CT, or on IV contrast-enhanced CT when the bleeding has stopped or the rate does not reach the CTA detection threshold of 0.3–0.5 mL/min [27]. A high-density ''sentinel clot'' may also be seen reflecting the higher density of clotted blood adjacent to the site of bleeding (Figs. 8, 9) verses the lower density unclotted blood farther from the bleeding source [27]. Hyperdensity of the bowel wall on unenhanced CT is another sign in patients with bowel wall hematomas with intramural hemorrhage [28, 29].

It is important to evaluate the bowel wall and contents on unenhanced CT with narrow window settings to detect unsuspected gastrointestinal hemorrhage [27]. A potential diagnostic pitfall is preexisting intraluminal high attenuation material such as oral contrast, foreign bodies, opaque pills, surgical clips, suture material, and barium contrast in diverticula [27]. Comparison with prior imaging and clinical history may be helpful to differentiate some causes of intraluminal high attenuation including recent contrast administration, history of foreign body ingestion, or recent surgery.

Hematuria

Various acute renal pathologies can cause hematuria. On a non-contrast CT, the cause may not be elucidated if it does not alter the contour of the kidney or col-

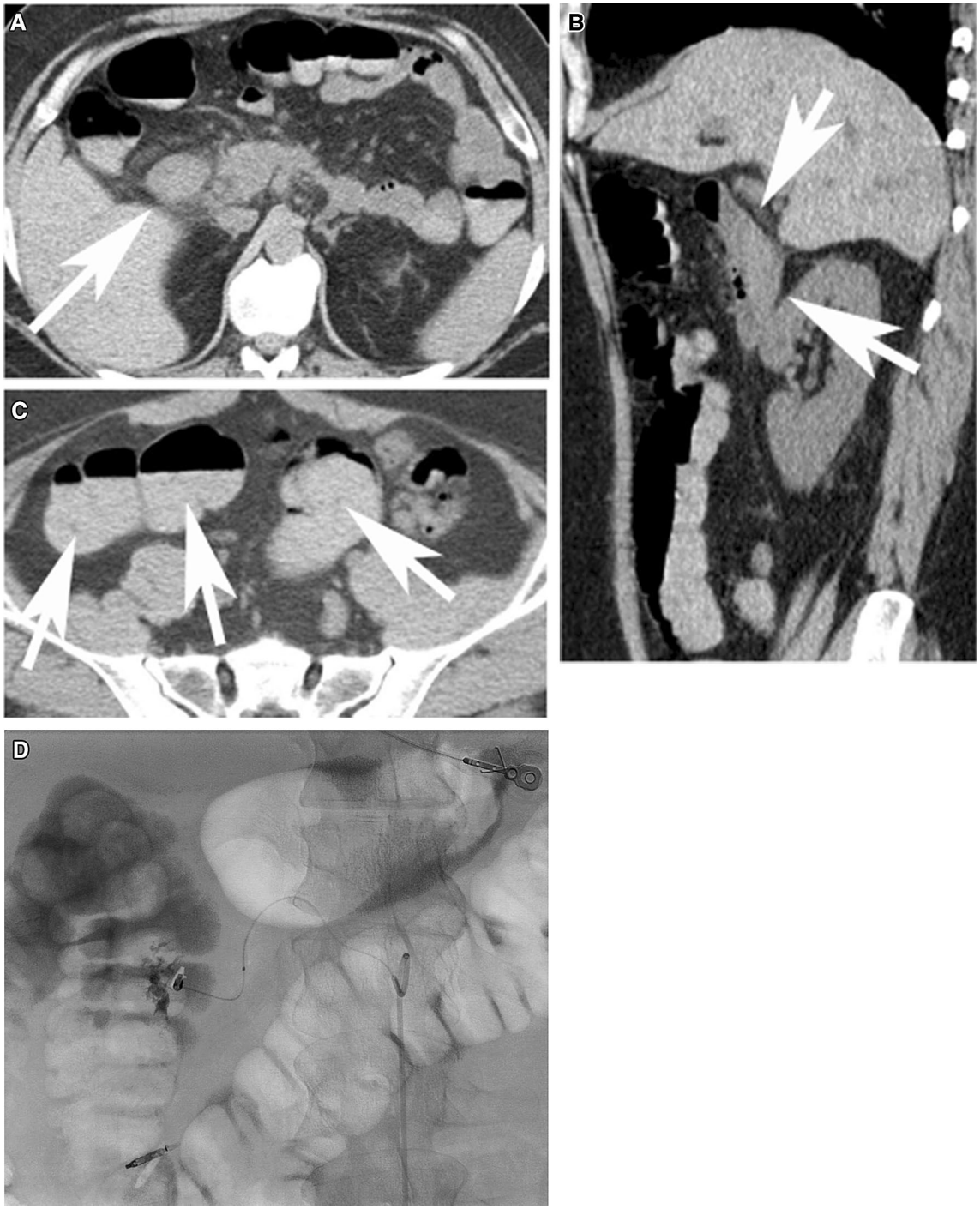


Fig. 8. 50-year-old man with anemia post-bone marrow transplant. Non-IV contrast axial (**A**, **C**) and sagittal (**B**) CT images with no oral contrast show mesenteric stranding adjacent to the duodenum, where there is acute hemorrhage in the wall or lumen (*arrows* in **A**, **B**) and high-density blood distending the colon (*arrows* in **C**). Endoscopy revealed bleeding duodenal ulcer. Hemorrhage could not be controlled endoscopically, necessitating interventional embolization (**D**).

lecting system. Nonetheless, hemorrhage may be seen within the collecting system (Fig. 10) and should prompt additional diagnostic measures including IV contrast-enhanced CT or MRI and cystoscopy or ureteroscopy if necessary.

Inflammatory conditions

Complications of pancreatitis

Contrast-enhanced CT is considered the imaging test of choice for evaluation of acute pancreatitis and its com-

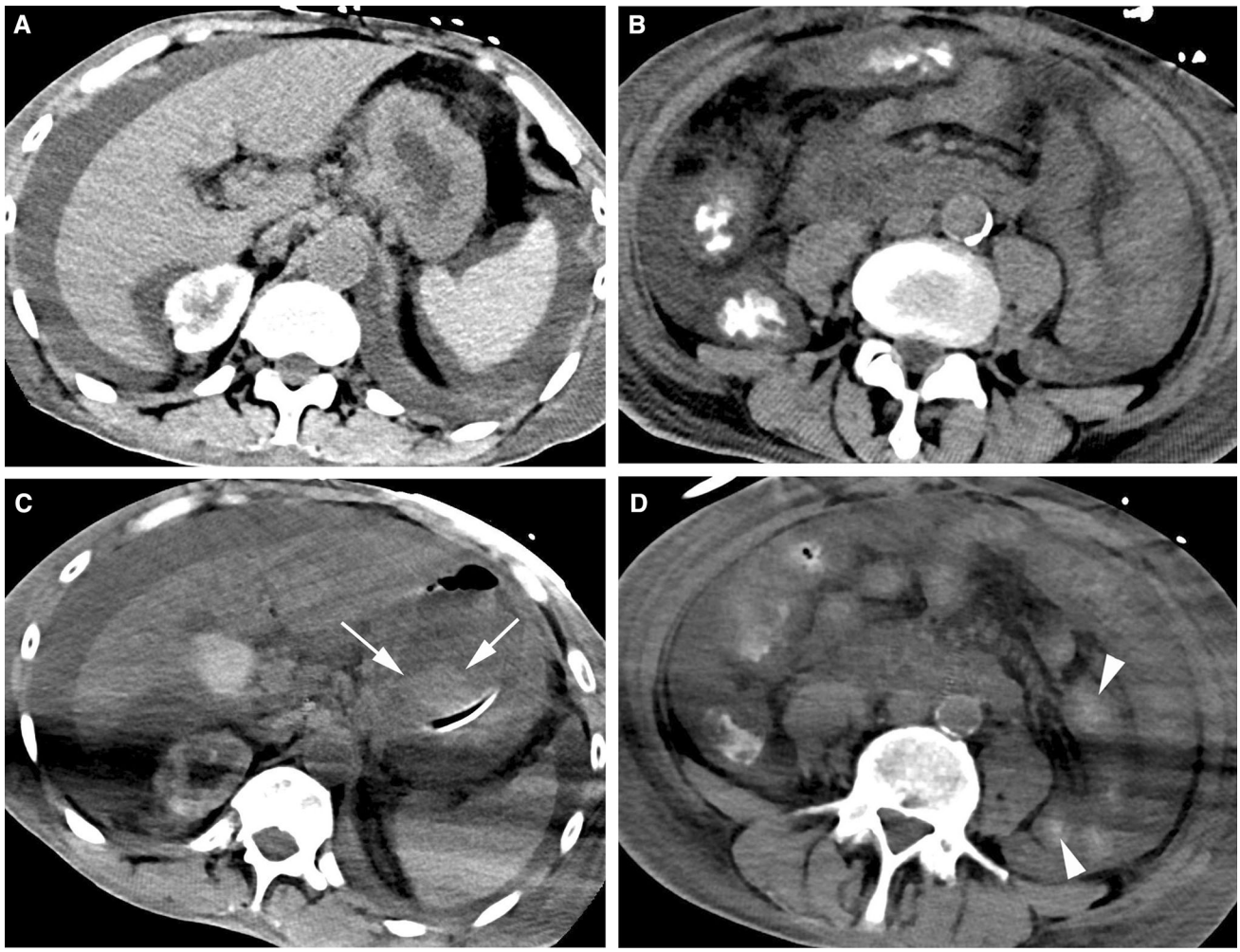
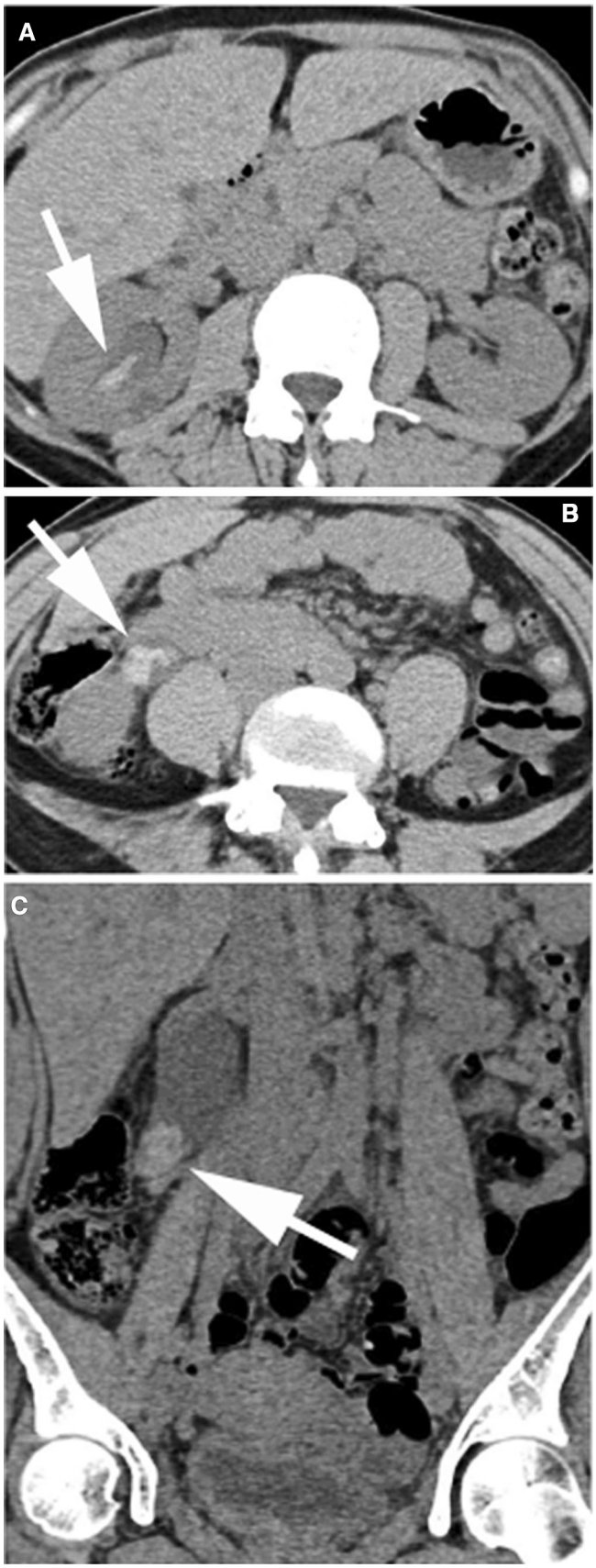


Fig. 9. 71-year-old man with dropping hematocrit. Non-contrast CT on prior day (**A**, **B**) shows collapsed stomach and no oral contrast in proximal small bowel (retained contrast from prior imaging in the large bowel and renal parenchyma is also noted). Subsequent CT without oral or IV contrast performed to evaluate for cause of declining hematocrit (**C**, **D**) shows new gastric distention with soft-tissue density mass (*arrow*) and fluid in the gastric lumen reflecting acute hematoma. Note new high attenuation fluid (*arrowhead*) in the proximal small bowel, also intraluminal hemorrhage.

plications [30]. Pancreatitis and its complications may be an unsuspected diagnosis in patients imaged with unenhanced CT for other indications. Alternatively, follow-up exams to assess for the complications of pancreatitis may be performed without contrast in cases of a contraindication. Pancreatitis on unenhanced CT (Fig. 11) is suggested by pancreatic enlargement, peripancreatic inflammation and fat stranding, and peripancreatic fluid collections, indicators of acute pancreatitis [31].

Complications of acute pancreatitis are best evaluated with IV contrast enhanced CT, and include peripancreatic fluid collections, infection of pancreatic necrosis, pseudocyst formation, and vascular complications such as thrombosis and pseudoaneurysm formation. Infected pancreatic necrosis can be seen in up to 30% of patients and is associated with multi-organ failure [32]. On unenhanced CT, infected necrosis appears as a thick-walled fluid collection containing gas. Peripancreatic fluid collections may also be seen on unenhanced CT, and the presence of gas within the fluid collection is suggestive of an infection. At 4 weeks after symptom onset, a pseudocyst may be visualized on unenhanced CT as a rounded or oval fluid collection with a well-defined wall; wall thickening and gas suggest the presence of an infection and further assessment is warranted [32, 33]. Unenhanced CT may depict a pseudoaneurysm as a high-density structure if it is thrombosed, or can show surrounding hemorrhage (Fig. 12), which should raise suspicion for a pseudoaneurysm and prompt IV contrast-enhanced imaging. As discussed previously, thrombosis of the mesenteric vasculature is also a potential complication of pancreatitis. Other findings that may suggest the etiology pancreatitis can be visualized on unenhanced CT such as gallstones within a dilated common bile duct in cases of gallstone pancreatitis [34].



◀**Fig. 10.** 38-year-old woman with hematuria. Unenhanced axial (**A**, **B**) and coronal (**C**) CT show hemorrhage into right renal collecting system (*arrows* in **A**) and into the moderately dilated right proximal ureter (*arrows* in **B** and **C**).

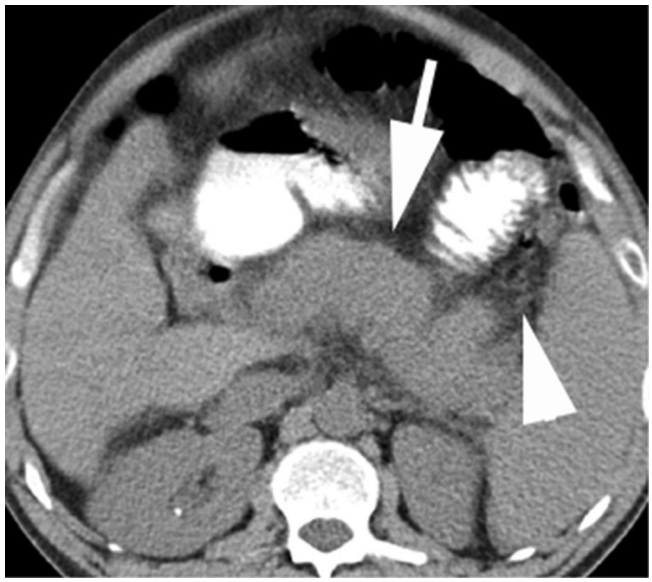


Fig. 11. 45-year-old man with history of pancreatitis with acute abdominal pain. On non-contrast CT, there is diffuse pancreatic enlargement with stranding of the peripancreatic mesentery (*arrows*).

Pyelonephritis

Acute pyelonephritis is a clinical diagnosis that can cause flank pain; imaging is usually performed to assess for complications or in patients with inadequate treatment response. If CT is performed, contrast-enhanced late venous phase is best to define the extent of disease [35]. In patients with abnormal renal function or in whom pyelonephritis is not suspected clinically, an unenhanced CT may be the initial diagnostic test. On unenhanced CT patients with moderate to severe acute pyelonephritis may have asymmetric perinephric stranding and mild renal enlargement (Fig. 13); patients with mild disease may have no findings on unenhanced CT [36, 37]. It is important for the radiologist to recognize the findings of acute pyelonephritis on unenhanced CT, so that confirmatory laboratory analyses are conducted in the appropriate clinical setting.

Conclusion

Subtle abnormalities in the lower chest, abdomen, and pelvis on unenhanced CT can provide important diagnostic information in patients who are otherwise unable to undergo CT with intravenous contrast. Despite the importance of IV contrast for optimal quality abdominal

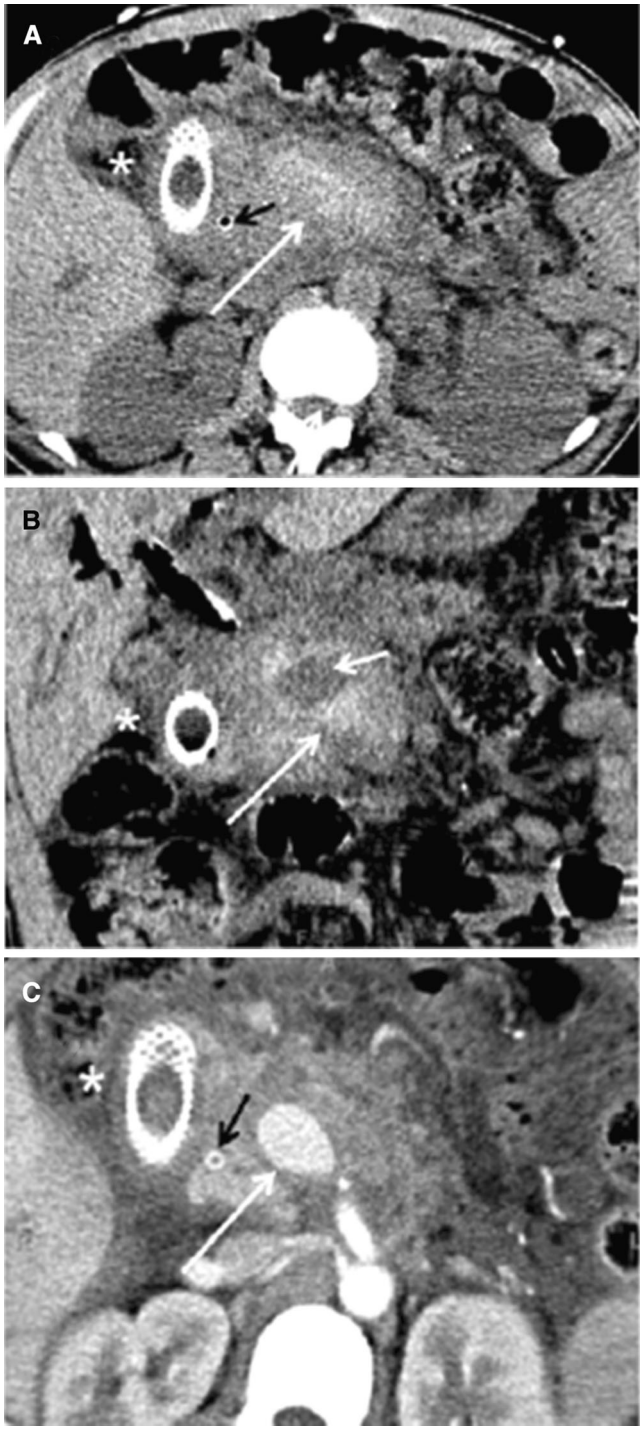


Fig. 12. 40-year-old man with pseudoaneurysm that developed within a pancreatic pseudocyst, visualized on non-contrast CT. Non-contrast CT in axial (**A**) and coronal (**B**) planes demonstrate clot (*long white arrow*) as hyperdense material within pseudocyst-pseudoaneurysm. Perfused portion of pseudoaneurysm is seen as less dense component (**B**, *short white arrow*). Contrast-enhanced images (**C**, *long white arrow*) show the perfused pseudoaneurysm initially detected as hypoattenuating on unenhanced images. Duodenal stent (*asterisk*) and common bile duct stent also seen (*short black arrow*). Reproduced with permission from Verde et al. [38]

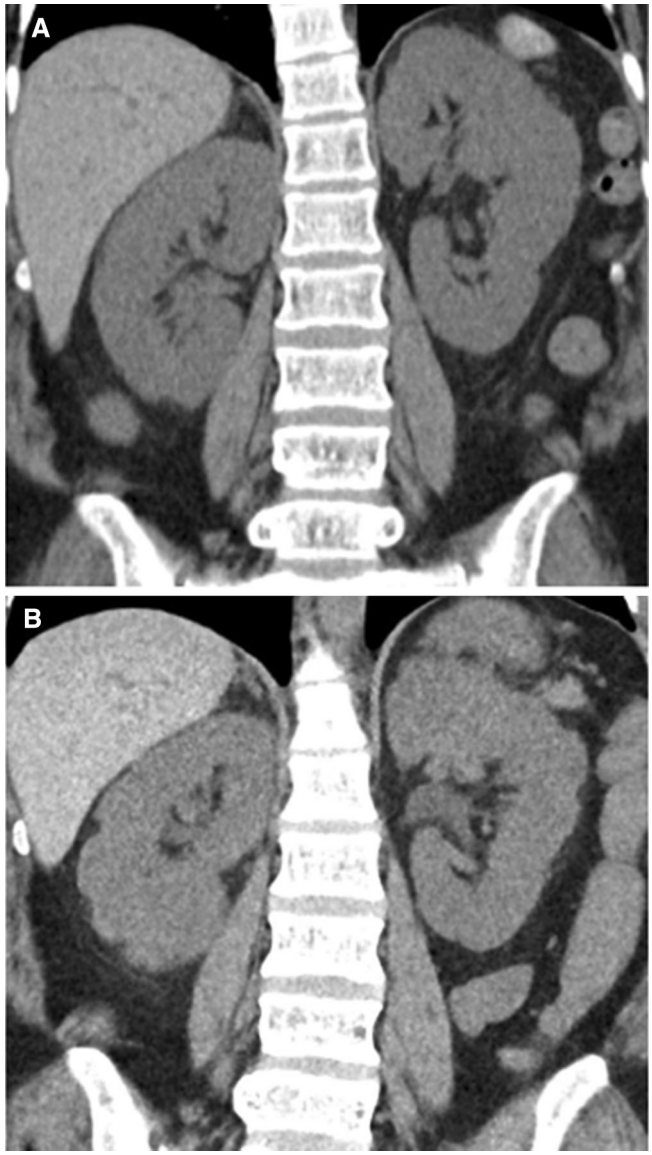


Fig. 13. 34-year-old woman with flank pain and acute renal failure. The left kidney is enlarged with subtle new perinephric stranding (**A**) when compared to baseline (**B**) in this patient with acute pyelonephritis.

CT imaging, non-contrast scans are often the only exams performed on critically ill patients who may be unable to receive other imaging tests. The unenhanced CT may not be ideal; however, it is important for the interpreting radiologist search for these subtle findings on abdominal CT without IV contrast, as they can dramatically alter patient management.

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