Computed tomography angiography concept in gastrointestinal bleeding

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Abstract

Acute GI bleeding is a common cause of both Emergency Department visits and hospitalizations in the United States, and can have a high morbidity and mortality if not treated rapidly. Imaging is playing an increasing role in both the diagnosis and management of GI bleeding. In particular, CT angiography is a promising initial test for acute gastrointestinal bleeding as it is universally available, can be performed rapidly, and may provide diagnostic information to guide management. The purpose of this review is to provide an overview of the uses of imaging in the diagnosis and management of acute GI bleeding, with a focus on CT angiography.

Key words: gastrointestinal bleeding; CT; abdominal imaging

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Introduction

Gastrointestinal bleeding (GIB) is a symptom of many digestive and/or systemic disorders or drug side effects, which can appear suddenly (i.e., acute forms) or can occur as a chronic/recurrent course. Acute gastrointestinal (GI) bleeding is a common cause of both emergency department visits and hospital admissions, leading to 375 hospitalizations per 100,000 individuals per year in the United States (1). If acute GI bleeding is not diagnosed promptly and adequately treated, morbidity and mortality are high (2), reaching 40% in hemodynamically unstable patients(3). Diagnosis and treatment requires a multidisciplinary approach that may involve diagnostic and interventional radiology, emergency medicine, internal medicine, gastroenterology, and general surgery. Imaging is playing a growing role in the management of acute GI bleeding by localizing the source of bleeding, differentiating the underlying disease processes, and aiding decisions to proceed to endovascular therapies to treat many causes of GI bleeding.

Clinical Presentation

The clinical evaluation and appropriate triage of patients with acute gastrointestinal bleeding can be difficult. The manifestation of bleeding with haematemesis, coffee grounds vomiting, or the presence of a substantial amount of blood or coffee grounds-like material in the nasogastric tube aspirate indicate a proximal source of bleeding. Melaena generally indicates a proximal source of bleeding but can occur with slight bleeding lesions of the small intestine or proximal colon. Haematochezia generally indicates mild blood loss from the colon or anorectal area, whereas severe bleeding from the distal GI tract is defined as rectorrhagia. Maroon-coloured stools can be seen when the source of bleeding is located in the ileum or proximal colon (2).

Distinguishing between upper and lower GI bleeding based solely upon clinical history and physical examination is difficult, as there is significant overlap in the clinical presentation. Most (75%) cases of GI bleeding have an upper GI tract source. Patients with upper GI bleeding classically present with hematemesis (vomiting bright red blood), "coffee ground" emesis (vomiting darker blood that has been partially digested), or melena (passage of dark feces containing digested blood), though patients can present with hematochezia (passage of bright red blood per rectum) in cases of brisk upper GI bleeding with rapid transit time. Conversely, patients with lower GI bleeding classically present with hematochezia, but may also present with melena. Although nasogastric tube aspiration can be assessed for the presence of blood, it is neither sensitive nor specific for diagnosis of an upper GI source, so diagnostic imaging and endoscopy are often relied upon to determine the source of bleeding. In patients presenting acutely to the emergency (4).

Diagnostic Pathway

After the haemodynamic stabilisation of the patient, if required, finding the source of the bleeding in the upper or lower gastrointestinal tract is important as this affects the correct diagnostic pathway. In general, patients with suspected UGIB are triaged for upper GI endoscopy, while those with suspected LGIB and also patients with suspected SBB/MGIB (if the previous two causes are excluded) are more frequently evaluated with4 imaging or endoscopy of the lower GI tract depending on the various clinical scenarios (Figure 1) (3).

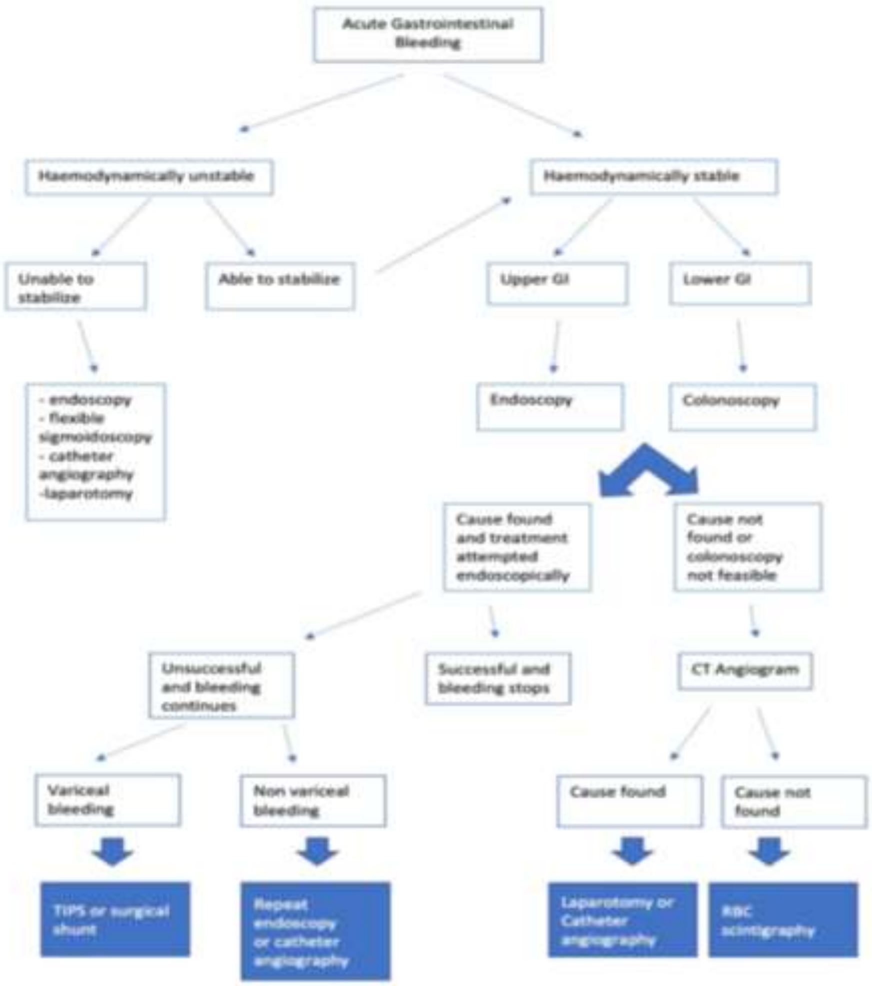


Figure.1: Therapeutic.andanddiagnosticflowflowchartchartofofaapatientpatientwithwithgastrointestinalbleeding.

Diagnostic Modalities

Upper Endoscopy and Colonoscopy

Endoscopy is often the first line diagnostic and therapeutic modality in patients with acute GI bleeding, particularly if there is a suspected upper GI source. Endoscopy is highly sensitive and specific for acute upper GI bleeding with sensitivity of up to 98% and specificity of up to 100% (9). Endoscopy and colonoscopy provide direct visualization of the mucosa to identify the source of bleeding, enable application of hemostatic therapy, and can be used for tissue sampling in cases of suspected malignancy. However, endoscopy and colonoscopy have a number of limitations. They may not be readily available in the emergency room setting. For patients with high-volume bleeding, it may be impossible to adequately visualize the source of hemorrhage with endoscopy. In addition, for those with lower GI tract bleeding, endoscopy is unable to assess the majority of the small bowel distal to the ligament of Treitz and provides limited visualization of the distal duodenum. Bowel preparation for colonoscopy can take 3-5 hours, which may not be possible in patients with acute colonic hemorrhage who are clinically unstable. Even with adequate bowel preparation, sensitivity and specificity of colonoscopy in acute lower GI bleeding has been shown to be lower than that of MDCT (5).

Video capsule endoscopy is a technique that has been shown to be beneficial in evaluation of obscure GI bleeding (persistent bleeding with negative upper and lower endoscopy). Recently, some researchers have evaluated capsule endoscopy in assessment of acute upper GI bleeding in emergency department patients as a method to triage patients. Although this approach shows promise, capsule endoscopy is not currently considered a suitable substitute for endoscopy (6).

Radionuclide imaging

Radionuclide imaging for GI bleeding is generally performed with technetium-99m tagged red blood cells (RBC), with initial injection of radiotracer and subsequent gamma camera imaging. GI bleeding can be diagnosed when radiotracer activity is visualized outside of normal areas of blood pool, which either focally intensifies or moves over time in an antegrade or retrograde fashion (7) (Figure 2).

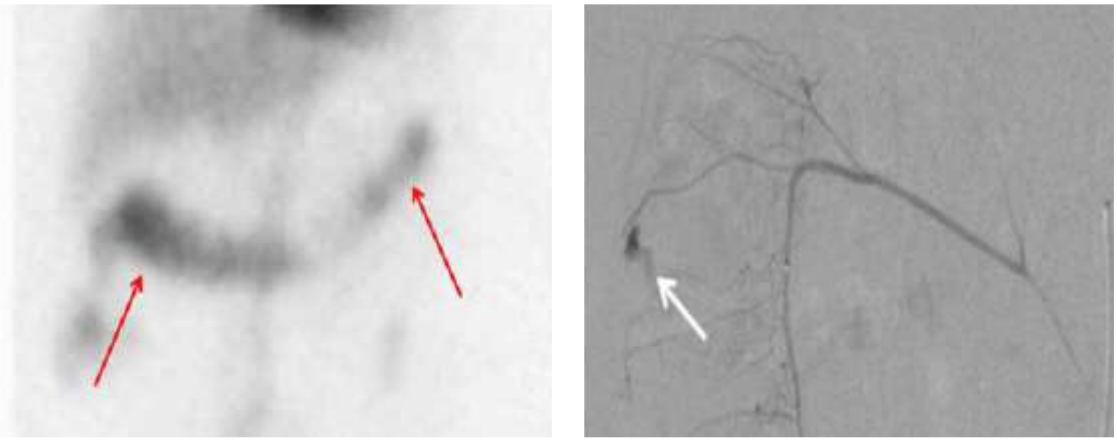


Figure 2. Tagged RBC images in a 78-year-old female with bright red blood per rectum demonstrate accumulation of radiotracer within the transverse colon (A, red arrows). Selective catheter angiography of a branch of the right colic artery (B) shows brisk contrast extravasation (white arrow) into the lumen of the cecum, which was subsequently treated with coil embolization

Radionuclide studies have the advantage of being highly sensitive, detecting rates of bleeding as low as 0.05-0.1 ml/min (8). In addition, scintigraphy can assess for bleeding over a prolonged period of time, and can detect both arterial and venous hemorrhage. However, due to their prolonged imaging times, these studies are not ideal for clinically unstable patients. In addition, radionuclide imaging may have limited availability in the acute care setting, particularly overnight. Radionuclide scans also often cannot provide precise anatomic localization of the site of active bleeding (9); this, in combination with their high sensitivity, could potentially lead to some positive radionuclide scans that are followed by negative endoscopy or catheter angiography (10).

Catheter angiography

Catheter angiography is considered the first line imaging and treatment modality for unstable patients with lower GI bleeding, patients following a failed upper or lower endoscopy, and patients with lower GI bleeding with a source of bleeding visualized on an additional imaging modality. For a known source of GI bleeding, selective catheter angiography of the bleeding artery and embolization can be performed (Figure 2). For an unknown bleeding source, angiography is generally performed of the celiac, SMA, and IMA vessels. Bleeding can be diagnosed confidently when active extravasation of contrast material into the bowel lumen is visualized (Figure 2), and embolization can be performed if active extravasation is visualized. In addition, for patients with upper GI bleeding, prophylactic embolization can be performed even if a site of bleeding is not identified, most commonly of the gastroduodenal artery (GDA). This has been shown to be effective, particularly in patients with large volume upper GI bleeding refractory to endoscopic treatment(11).

Angiography has a high spatial resolution, can detect rates of bleeding as low as 0.5 ml/min, and has the added major advantage of allowing for treatment of GI bleeding. The primary disadvantage of catheter angiography is that it is an invasive and time-consuming procedure with a potentially high radiation dose. In addition, patients may have falsely negative studies if GI bleeding is intermittent and they are not actively bleeding during the angiogram (12).

Multidetector CT Angiography

MDCT angiography has increasingly been adopted for the diagnosis of acute GI bleeding. Because CT can be acquired rapidly and is nearly universally available in the acute setting, it may be an ideal initial diagnostic test for hemodynamically stable patients with acute GI bleeding, as well as patients awaiting catheter angiography or endoscopy. CTA has the advantage of being able to precisely localize the source of arterial and venous GI bleeding, and to diagnose underlying pathology that may be the cause of bleeding to direct future management. In particular, CTA can uniquely diagnose causes of GI bleeding that are not within the gastrointestinal tract, such as hemobilia. In addition, CTA can delineate the underlying vascular anatomy prior to embolization, and characterize any anatomical variants that may impact management. Disadvantages of CTA include decreased sensitivity relative to radionuclide imaging, relatively high radiation dose, and the need for intravenous contrast. Due to the short acquisition time, false negative results can occur if the patient is not bleeding at the time of the scan (13).

CT Technique

Specific CTA protocols in patients with suspected GI bleeding will vary between vendors and institutions. In general, CTA for GI bleeding is performed as a three-phase examination, including non-contrast, arterial, and venous phase imaging. For all phases, the scan range should include the complete abdomen and pelvis (from the diaphragms to below the inferior pubic rami). Arterial phase images are obtained with bolus tracking at the abdominal aorta (150 HU threshold), with venous phase imaging obtained at 70-90 seconds following contrast injection. 100-125 mL intravenous contrast (with an iodine concentration of 300 mg per mL or greater) is administered at a rate of 4-5 mL/sec, followed by 40-50 mL of saline at the same rate. Oral contrast is not administered, as positive contrast agents would obscure intravenous contrast extravasation into the bowel lumen, and negative or neutral contrast agents would dilute the extravasated intravenous contrast. Non-contrast imaging is incorporated to ensure that pre-existing hyperdense ingested material within the bowel lumen can be differentiated from active hemorrhage during the scan. Images can be reconstructed at 5 mm thickness for non-contrast images and 1.25 mm for arterial and venous phase images. Multiplanar reformation (MPR) images in the sagittal and coronal planes are reconstructed for all phases. Maximum intensity projection (MIP) images in the sagittal and coronal planes are also performed for arterial and venous phase images, to increase conspicuity of hemorrhage and delineate vascular anatomy (14).

Imaging Findings and Diagnostic Pitfalls

The critical imaging finding of GI bleeding is active extravasation of intravenous contrast into the bowel lumen. This can be diagnosed with CTA when an intraluminal focus of high attenuation (> 90 HU) is seen on arterial phase images ("contrast blush") that is not present on non-contrast images (Figure 3). On portal venous phase images, this extravasation should change in appearance and generally moves distally within the bowel lumen. The extravasation itself can have a variety of imaging appearances depending on the underlying physiology, including a linear "jet" of contrast, "cloudlike" morphology, circular configuration, or a contrast-fluid level (15).

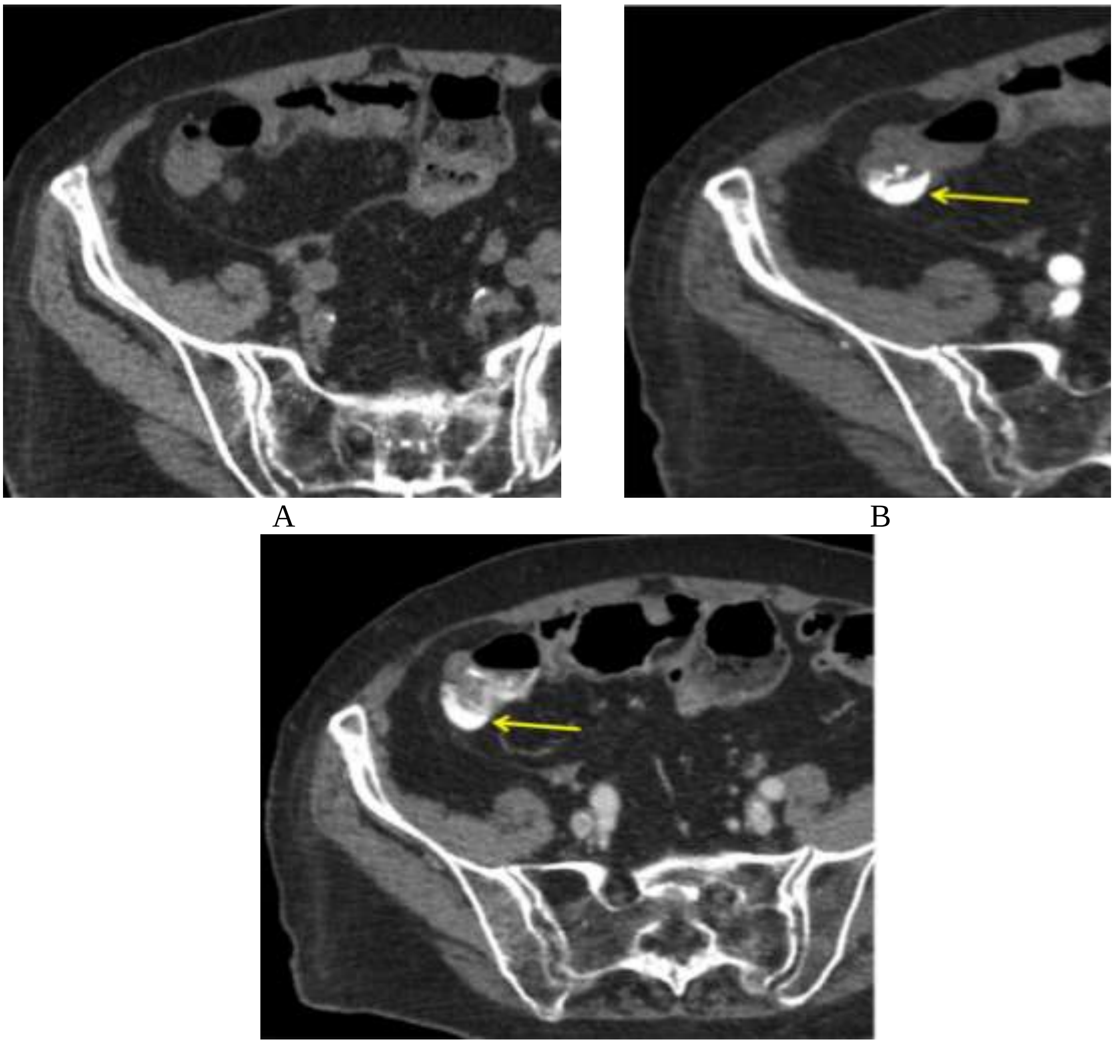
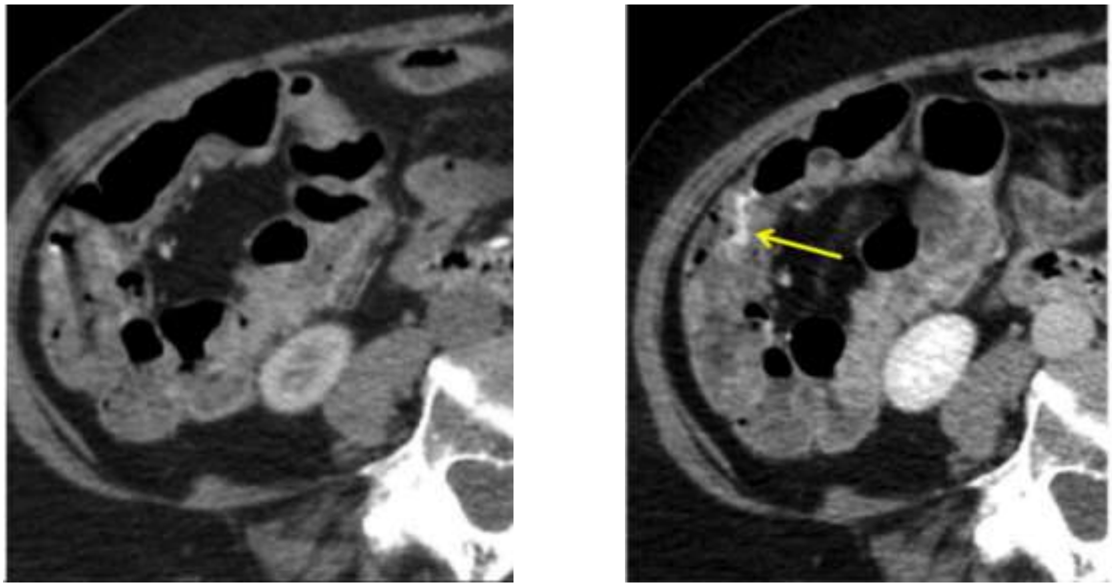


Figure 3. Diverticular hemorrhage in a 77-year-old male. There is no hyperattenuating material within the bowel lumen on the non-contrast scan (A). There is active extravasation of contrast (yellow arrows) into the lumen of the right colon on arterial phase image (B), which evolves in morphology at the portal venous phase (C).

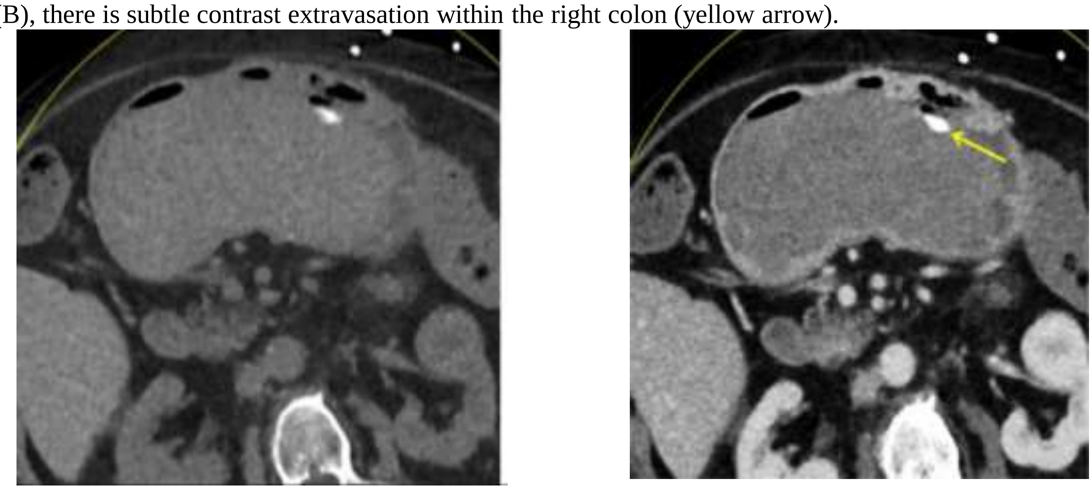
There are several important variations in the imaging appearance of GI bleeding to be familiar with. In patients with slow or delayed bleeding, extravasation may be present only on the portal venous phase images, as there is greater accumulation of blood within the bowel lumen on delayed images (Figure 4). In patients with recent bleeding who are not actively bleeding at the time of imaging, CT may only reveal hyperdense clot within the bowel lumen without active extravasation (Figure 5). The site of clot of the highest attenuation has been deemed the "sentinel clot," which is closest to the site of active bleeding. For all patients with GI bleeding, MIP images must be screened carefully, as they may identify subtle bleeding that can be overlooked on source images, can visualize underlying vascular malformations, and can delineate underlying vascular anatomy prior to angiography (Figure 6) (16).

Recognition of potential diagnostic pitfalls is important when interpreting CT angiograms for active GI bleeding. Fluid distension of bowel loops may dilute contrast extravasation, potentially causing a false negative result. High-density material within or near the bowel lumen, including surgical clips, ingested material, and fecaliths, can be mistaken for hemorrhage without a non-contrast scan (Figures 5). Cone-beam artifacts can also lead to the false appearance of high density within the bowel lumen (17).



A B

Figure 4. 83-year-old female with delayed diverticular bleeding. On axial arterial phase CT images, no hyperattenuating material is present within the bowel lumen. On subsequent portal venous phase image (B), there is subtle contrast extravasation within the right colon (yellow arrow).



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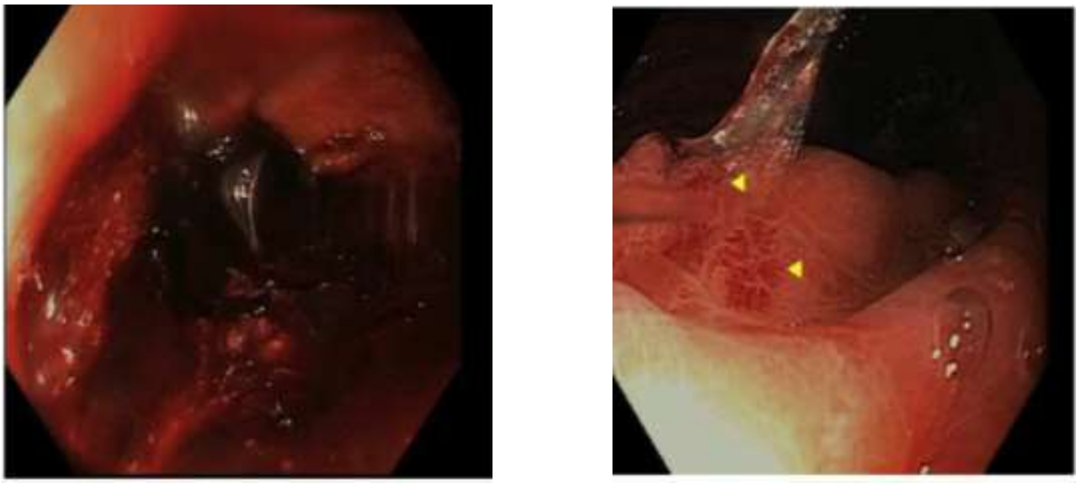


C D

Figure 5. 73-year-old female with hematemesis and bright red blood per rectum who underwent dual energy CT. Virtual non-contrast (A) and portal venous phase (B) images demonstrate a large volume of hyperdense clot within the gastric lumen. No active extravasation is seen, however there is an ingested pill within the stomach (yellow arrow). Subsequent endoscopy confirmed a large volume of blood within the stomach (C), as well as multiple bleeding arterio-venous malformations (yellow arrowheads, D).

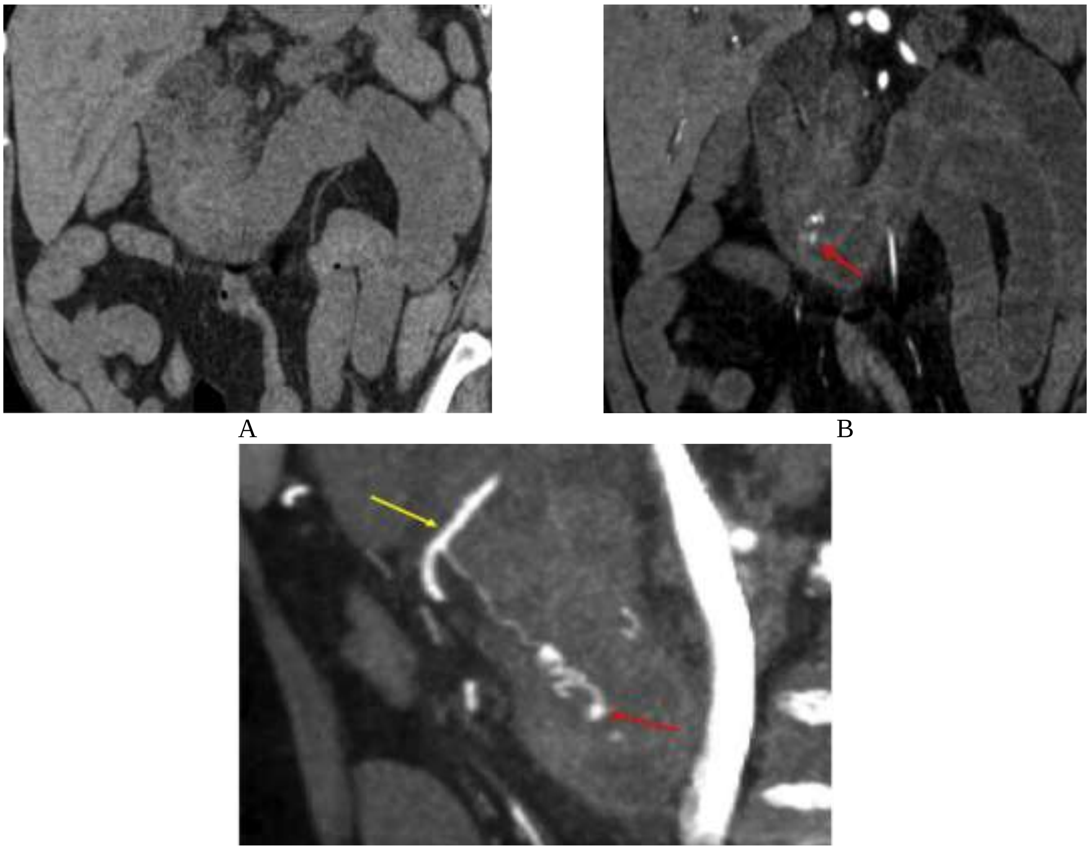


Figure 6. 70-year-old male with bleeding following endoscopy. On coronal non-contrast images (A), there is no hyperattenuating material within the bowel lumen. On coronal arterial phase images (B), active extravasation of intravenous contrast into the second and third portions of the duodenum is seen (red arrow). On sagittal maximum intensity projection images (C), the active extravasation (red arrow) can be seen arising from a branch of the gastroduodenal artery (yellow arrow).

Efficacy of MDCT Angiography in Evaluating Acute GI Bleeding

Several studies have evaluated the rate of bleeding that can be detected with MDCT; for example, in one study, Dobritz et al used an experimental model and showed that rates of bleeding above 0.25 ml/min could be detected by MDCT with a sensitivity of 97% and specificity of 100% using arterial and portal venous phase images (18). A large body of research has examined the diagnostic performance of CT angiography in the assessment of acute GI bleeding. For example, in a prospective study, Marti et al performed CTA in 47 patients with acute lower gastrointestinal bleeding and found a sensitivity of 100%, specificity of 96%, and accuracy of 93%. Kennedy and colleagues evaluated 86 CT angiograms in 74 patients, and found a sensitivity of 79% and a specificity of 95% (19). Similar findings have been reported in multiple additional studies assessing CTA for upper and lower GI bleeding. While sensitivity and specificity of CTA in GI bleeding vary between studies, Garcia-Blazquez and colleagues found that CTA had a sensitivity of 85.2% and specificity of 92.1% in detecting GI bleeding in a systematic review and meta-analysis of 22 papers including 672 patients with acute GI bleeding (20). The sensitivity of CTA in determining the underlying etiology of bleeding has also been reported to be above 90% in multiple studies. For patients with lower GI bleeding, those with a negative CTA have been shown to be unlikely to develop recurrent bleeding; therefore, patients with lower GI bleeding and a negative CTA may not need subsequent angiography (21).

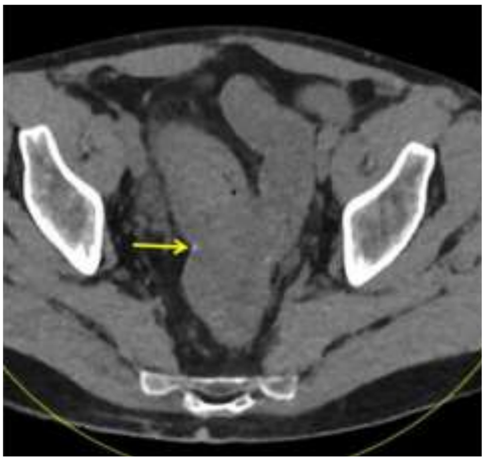
Dose Reduction

As a three-phase CT examination, radiation dose is a potential concern for GI bleeding CTA scans. There are many alterations that can be made to CT protocols to reduce radiation dose. Because non-contrast images for GI bleeding scans are performed to assess for high density ingested material within the bowel, they can be obtained at a very low dose to accomplish this diagnostic task (22). Advances in CT technology including automatic tube voltage selection and iterative reconstruction have allowed for further radiation dose reductions for abdominal CT imaging (23). some authors have suggested that radiation dose could be further conserved in CTA for GI bleeding by eliminating either the arterial or portal venous phase. For example, in a study performed by Kim et al, two readers evaluated CTA scans in 46 patients with acute GI bleeding by reviewing arterial, portal venous, and combined data sets independently, and found no added diagnostic value between the three datasets (24).

New Directions: Dual Energy CT

Dual energy CT (DECT) is an emerging technology of promise in the assessment of GI bleeding. While conventional CT imaging uses a single x-ray spectrum, DECT acquires data at two different x-ray spectra: lower energy at 80 or 100 kV and higher energy at 140 kV. This allows materials with different kV-dependent x-ray absorption behaviors, such as iodine and calcium, to be differentiated or quantified using DECT post-processing techniques. DECT post-processing can be used to create virtual non-contrast (VNC) images with iodine subtracted from the image, as well as iodine maps to depict iodine content, both of which can be useful in the assessment of GI bleeding (Figure 7). The use of VNC images can obviate the need for a non-contrast phase, substantially reducing patient radiation dose. In a recent study 112 consecutive patients with suspected GI bleeding underwent dual energy CT angiography. The authors found that substituting virtual non-contrast imaging for true non-contrast imaging did not impact diagnostic performance in detection of GI bleeding, and allowed for a radiation dose reduction of roughly 30%.

A


B


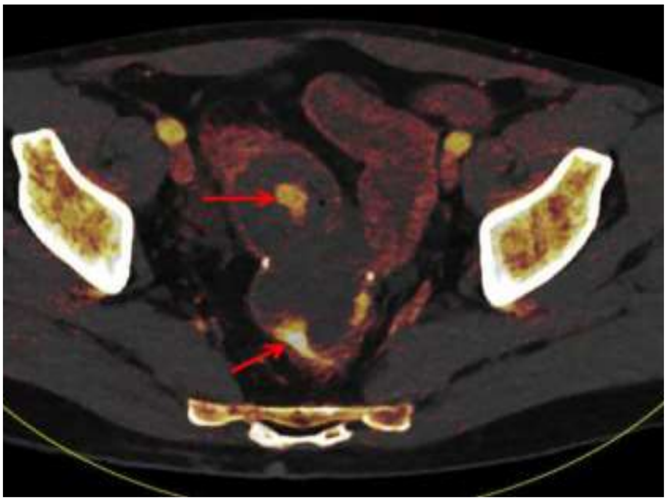

C

Figure 7. 51-year-old male with prior colectomy for Clostridium Difficile colitis presenting with rectal bleeding. "Mixed" image from a dual energy CT scan in the portal venous phase (A) shows hyperattenuating material within the distal small bowel and rectum (red arrows). On the virtual non-contrast image (B), this material is not present within the bowel lumen, showing that this is not ingested material. The anastomotic suture material remains visible on the VNC image (yellow arrow). On iodine overlay image (C) with iodine content color-coded in orange, the hyperattenuating material within the bowel lumen demonstrates iodine content, further confirming that this represents active extravasation.

Conclusion

Imaging is playing a growing role in the diagnosis and management of patients with acute GI bleeding. CT angiography is promising as a first line diagnostic modality in many patients in the acute care setting, as it is a test that is widely available and can be performed rapidly. CTA findings can help to further guide endoscopic, endovascular, or surgical management. Advances in CT technology, including the emergence of dual energy CT, will allow for these scans to be performed at a lower dose. Radiologists should be aware of the appropriate uses of CTA and other imaging modalities in patients.

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