Multidetector CT Angiography for Acute Gastrointestinal Bleeding: Technique and Findings

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Acute gastrointestinal bleeding is a common reason for emergency department admissions and an important cause of morbidity and mortality. Factors that complicate its clinical management include patient debility due to comorbidities; intermittence of hemorrhage; and multiple sites of simultaneous bleeding. Its management, therefore, must be multidisciplinary and include emergency physicians, gastroenterologists, and surgeons, as well as radiologists for diagnostic imaging and interventional therapy. Upper gastrointestinal tract bleeding is usually managed endoscopically, with radiologic intervention reserved as an alternative to be used if endoscopic therapy fails. Endoscopy is often less successful in the management of acute lower gastrointestinal tract bleeding, where colonoscopy may be more effective. The merits of performing bowel cleansing before colonoscopy in such cases might be offset by the resultant increase in response time and should be weighed carefully against the deficits in visualization and diagnostic accuracy that would result from performing colonoscopy without bowel preparation. In recent years, multidetector computed tomographic (CT) angiography has gained acceptance as a first-line option for the diagnosis and management of lower gastrointestinal tract bleeding. In selected cases of upper gastrointestinal tract bleeding, CT angiography also provides accurate information about the presence or absence of active bleeding, its source, and its cause. This information helps shorten the total diagnostic time and minimizes or eliminates the need for more expensive and more invasive procedures.
Introduction

Acute gastrointestinal bleeding is a common, potentially life-threatening condition responsible for 1%–2% of all hospital admissions (1), with the estimated rate in the United States reaching 375 admissions per 100,000 persons per year in some series (2–4). Acute gastrointestinal bleeding is more common in men than women (M/F ratio, 2:1). The incidence increases with age, with 70% of patients older than 65 years (1,5). In addition, acute gastrointestinal bleeding frequently occurs as a complication in critically ill adults who are admitted with other primary diagnoses and complicates their clinical course (1). Mortality ranges between 19% and 40% and increases with (a) older age, (b) the presence of shock, and (c) associated underlying comorbidities (6–8). Variceal hemorrhage is associated with a mortality rate of 15%–40%, a rate higher than that from other causes of acute gastrointestinal bleeding (1,9).

The framework for triage of patients with gastrointestinal bleeding varies on the basis of its source—upper or lower gastrointestinal tract—with important differences in terms of epidemiology, clinical management, and prognosis (10,11). Compared with lower gastrointestinal tract bleeding, upper gastrointestinal tract bleeding tends to affect younger people. Because the rate of occurrence of lower gastrointestinal tract bleeding events increases with age, hospitalizations that are due to gastrointestinal bleeding in the elderly are more likely to be caused by lesions of the lower gastrointestinal tract (12). Moreover, better control of peptic ulcers secondary to Helicobacter pylori infection, the increasing use of gastroprotection, and the progressive aging of Western populations, combined with an increased use of antithrombotic therapy and anticoagulant therapy, are changing the epidemiology of hospitalizations for gastrointestinal bleeding. In the findings from recent studies, investigators have pointed out that the rates of hospitalization for patients with upper and those with lower gastrointestinal tract bleeding are becoming similar, with poorer outcomes and higher resource utilization for lower gastrointestinal tract bleeding events (3,13).

Identification of the source and cause of bleeding helps guide therapeutic decisions, and for years, clinical management has been focused mainly on endoscopic findings. Endoscopy represents a safe and effective method for the diagnosis and, often, the treatment of patients with gastrointestinal bleeding, with sensitivity and specificity approaching 98% and 100%, respectively. Nevertheless, implementation of endoscopic procedures in the emergency setting usually poses a variety of challenges, such as variable availability of the service and an insufficient time window to perform adequate bowel preparation in the most serious cases. Mucosal visualization is poor owing to the presence of intraluminal blood clots and other intestinal contents, and the distal portion of the duodenum and the small bowel are not routinely accessed (14). Because of its ability to be used to wash and aspirate the gastric contents, esophagogastroduodenoscopy is clearly the first-line tool for diagnosis and treatment of upper gastrointestinal tract bleeding. On the contrary, urgent colonoscopy remains challenging for assessment of acute lower gastrointestinal tract bleeding because this procedure can be used to identify the source of bleeding in only 13% of cases in some series (15). A specific cause cannot be identified with endoscopy or subsequent workup in as many as 20% of patients with lower gastrointestinal tract bleeding and as many as 14% of patients with upper gastrointestinal tract bleeding (3).

Other techniques, such as scintigraphy with technetium 99m (99mTc)–labeled red blood cells or 99mTc–sulfur colloid, enteroscopy, and video capsule endoscopy, are not universally accessible in the emergency setting (16). Catheter angiography and emergency surgery are options for patients with massive life-threatening bleeding and should be used ideally as targeted therapeutic procedures (5).

The purpose of this article is to summarize the role of computed tomographic (CT) angiography in the evaluation of acute gastrointestinal bleeding. First, the clinical context in which radiologists will encounter patients with acute gastrointestinal bleeding in the emergency setting is summarized. Then the initial diagnostic evaluation is described, followed by the role of endoscopy. The rationale for incorporating multidetector CT angiography as a useful alternative in the diagnostic algorithm for these patients is explained, along with the CT imaging technique and protocol. The most common CT angiographic imaging findings are reviewed, including active bleeding (blush) and recent bleeding (clots) and their causes. Finally, imaging artifacts and potential pitfalls encountered in the setting of acute gastrointestinal bleeding are identified.

Clinical Manifestations

Gastrointestinal bleeding is not a specific disease but rather is a clinical manifestation of many diseases affecting the digestive tract. Gastrointestinal tract bleeding is classified as upper or lower, depending on whether its origin is proximal or distal to the ligament of Treitz. The locations of
upper and lower gastrointestinal tract bleeding and the main causes of bleeding in each location are shown in Figure 1.

The clinical manifestations of gastrointestinal hemorrhage depend on the location of the source, the rate of bleeding, and the effect of blood loss on the general condition of the patient. These factors dictate the priority and the order in which diagnostic tests and therapeutic procedures should be performed (17). Severe bleeding can cause hypovolemic shock, but slow and intermittent blood loss manifests most often with iron deficiency anemia or stools with positive findings on a fecal occult blood test (Hemoccult; Beckman Coulter, Brea, Calif). Direct evidence of bleeding can manifest with hematemesis (vomiting fresh blood), coffee-ground vomit (partially digested dark blood), melena (black tarry stools), or hematochezia (red blood per rectum). Patients with massive upper gastrointestinal tract bleeding may have hematochezia because of the cathartic properties of blood (1,14,18).

Overall, one in four patients with gastrointestinal bleeding will need immediate medical attention and resuscitation, and the remainder will be asymptomatic or will present with mild systemic symptoms that can be treated conservatively (5). Clinical scores can be used to estimate the risk of death or recurrent hemorrhage and the need for clinical intervention to control bleeding, and these scores can be useful for initial patient triage (19). Regardless of the amount of blood lost, approximately 75%–80% of episodes of gastrointestinal bleeding resolve spontaneously (15). In 25% of patients, hemorrhage recurs, and this recurrence increases the risk for in-hospital morbidity and mortality; this group consumes a large amount of hospital resources because these patients require a thorough clinical assessment and proper diagnostic imaging methods (5).

**Initial Diagnostic Evaluation**

Hospitalization is usually required in elderly patients and those presenting with hemodynamic instability or severe comorbidities (17). However, only 20% of the patients with acute gastrointestinal bleeding will need urgent intervention. It is therefore impractical and economically unjustified to subject all patients with acute gastrointestinal bleeding to a comprehensive emergency evaluation. Risk stratification criteria are used to assess the severity of bleeding and to determine who may potentially benefit the most from urgent resuscitation, endoscopy, and intensive clinical care (20).

The general goals of management include resuscitation, diagnosis, hemostasis, and prevention of recurrent bleeding. Most complications from acute gastrointestinal bleeding result from hypoperfusion; thus, stabilization of blood pressure and restoration of volume precede any further diagnostic measures (9). Detection and correction of a possible coagulopathy are also important (21).

Patients who show evidence of or are suspected of having an upper gastrointestinal tract source of bleeding should undergo endoscopy as the initial investigation. Endoscopy frequently facilitates definitive treatment of lesions proximal to the ligament of Treitz (18,22). If the patient is not experiencing hematemesis or if endoscopy is not immediately available, a nasogastric tube
are to confirm the source of the bleeding and to
determine whether the cause is variceal or not (22). In addition, endoscopy allows the collec-
tion of histologic specimens and, frequently, the
performance of therapeutic interventions, such as
injection therapy, thermal coagulation, and laser
therapy, in patients with active bleeding. The ben-
efits of urgent endoscopy in this setting are well
documented (23,24). The main limitations of upper
gastrointestinal tract endoscopy include poor
visualization of the distal portion of the duodenum
and an inability to study the remaining portion of
the small bowel (8,9). When upper gastrointestinal
tract endoscopy is not feasible or its findings are
inconclusive, imaging is the next option to localize
and treat the source of bleeding (22).

In patients with lower gastrointestinal tract
bleeding, colonoscopy can be used to identify
the site of bleeding in more than 70% of pa-
tients (17); however, wide variability has been
reported in this percentage, ranging from 8% to
100% (10,12,14,15,24), a range that reflects in-
herent biases in the definition of end points and
differences in equipment, timing, and prepara-
tion. Colonoscopy can be performed urgently
or electively, depending on the patient’s hemo-
dynamic status and risk stratification criteria.
For therapy, emergent colonoscopy offers no

Endoscopy

Because endoscopy is the initial diagnostic mo-
dality in patients suspected of having upper
gastrointestinal tract bleeding, the primary objec-
tives of upper gastrointestinal tract endoscopy
should be inserted to assess the rate of bleeding
and to allow gastric lavage while the patient is
awaiting endoscopy. Although bleeding from the
duodenum may manifest with a heme-negative
nasogastric aspirate (5), the combination of the
absence of blood and the presence of bile in the
aspirate makes an upper gastrointestinal tract
source unlikely, and the focus of the workup then
turns to the lower gastrointestinal tract (17).

Lower gastrointestinal tract bleeding tends to
be self-limited and less dramatic in manifesta-
tion (10). A digital rectal examination and proctoscopy
should be performed initially to exclude anorectal
sources of bleeding, such as hemorrhoids, and
to estimate the volume of blood lost (22). Lower
gastrointestinal tract bleeding typically manifests
with hematochezia, although bleeding from the
small intestine or the proximal portion of the
colon may appear as melena (1). However, an
episode of apparent lower gastrointestinal tract
bleeding may in fact originate from the upper gas-
trointestinal tract (1,17,21,22) (Fig 2).
advantage compared with radiologic intervention; therefore, the choice of one or the other approach is based on local expertise and available resources (24,25). In the emergency setting, colonoscopy is hampered by incomplete colonic cleansing and poor visualization of the mucosa in the presence of massive hemorrhage. Although urgent colonoscopy can be performed without colonic preparation (10), the available diagnostic information is limited, and expediting embolization or even surgery may be preferable to delaying definitive treatment (26). Thus, the clinical utility of urgent colonoscopy has been questioned for patients with acute lower gastrointestinal tract bleeding (15). Furthermore, the complication rate of colonoscopy is low but not negligible, ranging from 0.03% to 2.14%, with a mortality rate of 0.3% (15); these rates may be even higher when colonoscopy is performed urgently.

**Multidetector CT Angiography**

Technical improvements in multidetector CT technology, especially the higher temporal resolution that allows the ability to obtain high-resolution three-dimensional datasets with short acquisition times at different times during the administration and distribution of intravascular contrast material (multiphasic studies), have expanded the applications of CT angiography for evaluating patients with vascular diseases, including acute hemorrhage. Temporally resolved CT angiography allows the identification of active extravasation of contrast material and the accurate identification of the source of hemorrhage (22,27). Other advantages of CT angiography include its widespread availability in the emergency setting, its minimal invasiveness, and its reproducible results, which combine high sensitivity and accuracy for detecting or excluding active bleeding, as well as detecting the potential source and cause (7,9,19,28–35). CT angiography can be used to evaluate the wall of the entire gastrointestinal tract and other digestive structures that may occasionally be the source of bleeding, such as the pancreas and biliary tract (Fig 3).

**Imaging Technique**

Although the specific technical parameters used and the phase images acquired vary among institutions, most agree that three-phase examinations that include the unenhanced, arterial, and portal venous phases provide the best and most reproducible results for this clinical application in patients with acute gastrointestinal bleeding (6,7,14,19,29,32,33,36). For CT scanners with a
detector configuration of $64 \times 0.625 \text{ mm}$, the following acquisition parameters are recommended: section thickness, 1 mm, with a reconstruction interval of 0.8 mm; pitch factor, 0.828; rotation time, 0.5 second; and tube voltage, 120 kV, with automatic tube current modulation in the x-, y-, and z-axis directions. The scan should include the complete abdomen and pelvis, from the diaphragm to the inferior pubic ramus. For CT angiography performed to evaluate acute gastrointestinal bleeding, no oral contrast material is routinely administered, because positive contrast material may mask bleeding and because water or other neutral contrast material may dilute the extravasated intravenous contrast material, thereby decreasing the ability to identify the site of bleeding (28,32,33,37).

The CT angiographic examination starts with a preliminary unenhanced imaging series to depict any preexisting intraluminal hyperattenuating material, such as foreign bodies, opaque pills, hemostatic clips, suture material from previous surgery, or residual barium in diverticula, that might be misinterpreted later as active bleeding (7,33,38). A low-radiation-dose technique is recommended for this unenhanced series. Intravenous contrast material is administered through an antecubital vein with a power injector at a rate of 4 mL/sec, followed by a chaser of 50 mL of saline. The dose is adjusted for body weight and iodine concentration, with the total volume of contrast material typically varying between 100 and 125 mL of an agent high in iodine concentration (>300 mg of iodine per milliliter). The arterial phase images are usually obtained by using automated bolus triggering, starting when the attenuation coefficient in the proximal portion of the abdominal aorta reaches 150 HU. Portal venous phase images are then obtained 40–60 seconds later (ie, 70–90 seconds after the beginning of the injection of contrast material) (33,38).

### Findings of Acute Gastrointestinal Bleeding

**Active Bleeding: Blush.**—Intraluminal extravasation of contrast material is the main criterion used to define the location of the bleeding point (7,33,36) (Fig 4). Identification of this finding requires that active bleeding be present during the period of time that the injected contrast material circulates through the vascular system; CT angiography typically detects active bleeding with a rate that exceeds 0.3–0.5 mL/min, a rate that is slightly higher than the threshold assigned to catheter angiography (0.5 mL/min) and is lower than that of scintigraphy with $^{99m}$Tc-labeled red blood cells,
which can be used to detect active bleeding at a rate higher than 0.1 mL/min \( (7,22,34,36) \). Therefore, severe bleeding episodes, such as those manifesting with hemodynamic instability, increase the pretest probability of a positive result for active bleeding at CT angiography \( (28,32,33,39) \). Intermittent bleeding can cause false-negative findings at CT angiography \( (22,28,31,40) \).

The usual appearance of active bleeding is that of an intraluminal blush of contrast-enhanced blood in the arterial phase or a hyperattenuating focus of variable attenuation and morphology in the portal venous phase \( (29,33,34) \) (Fig 5). For detecting active bleeding with CT angiography, the highest sensitivity is achieved by combining findings from the arterial and portal venous phases \( (28,36) \); the changing appearance of the focus of extravasated contrast material with time (from the arterial phase to the portal venous phase) unequivocally confirms the presence of bleeding, especially when the unenhanced image shows no hyperattenuating intraluminal material.

Although the attenuation coefficient thresholds of the luminal contents have been proposed as a way to define extravasation of contrast material (starting at 90 HU) \( (31,41) \), a sequential comparison of the unenhanced images with the two-phase CT angiograms offers better performance (Figs 4–6) \( (30) \). Small foci of bleeding and subtle blushes may not reach the suggested threshold because of volume averaging \( (33,39) \). Although the source axial dataset is usually sufficient to reach a diagnosis, postprocessing of the entire acquired dataset with three-dimensional algorithms allows the radiologist to obtain tailored reformatted images, particularly multiplanar and maximum intensity projection (MIP) images. These reformatted images depict the vascular anatomy (and variants) and facilitate the identification and localization of the site of bleeding \( (32,33,38) \).
Figure 6. Rectal ulcer in a 33-year-old woman who was positive for the human immunodeficiency virus and who presented with brisk hematochezia. (a) Axial arterial phase CT angiographic image depicts a jet of extravasated contrast material (arrow) arising from the left posterior wall of the rectum, which is distended with blood and clots. (b) Axial portal venous phase CT angiographic image shows pooling of extravasated contrast material on the dependent surface of the rectum, which creates a fluid–contrast material level (arrowheads). (c) Coronal MIP reformatted image depicts bleeding from the left hemorrhoidal artery (arrow). (d) Catheter angiographic image confirms the finding of bleeding from the left hemorrhoidal artery (arrow). Therapy with embolization (not shown) was successful. (Reprinted, with permission, from reference 30.)

MIP reformatted images of the arterial phase resemble conventional angiograms and can be used to guide subsequent angiographic interventions (6,33). Identification of early-draining veins and vascular tufts is suggestive of angiodysplasia. Although extravasation of contrast material can be detected in the arterial phase, the small blush can be subtle and difficult to identify (36). Portal venous phase imaging depicts extravascular blushes with higher sensitivity than arterial phase imaging does because more time has elapsed, which allows the focus of extravasated contrast-enhanced blood to enlarge and increase in attenuation within the lumen of the bowel (36). The morphology of the extravasated contrast material varies, depending on the origin (arterial or venous) and rate of the bleeding, such that an arterial (linear) jet will be invariably present with bleeding at a high rate (Fig 6a), whereas bleeding rates of less than 0.5 mL/min are associated with a less-defined (or “cloudy”) morphology (34) (Fig 7). The extravasated contrast material may pool on the dependent surface of the bowel (Fig 6b) or may be mobilized by peristalsis into a more irregular shape (30).

In studies of experimental models, investigators have also suggested that the location of the bleeding point in the circumference of the bowel wall may create differences in the appearance of extravasated contrast material; an anterior bleeding point can be associated with a typical “jet” morphology, whereas if the bleeding point is located posteriorly, a “cloud” morphology will be more likely (34). Thus, active bleeding can adopt a variable morphology—linear and jetlike, swirled, circular or ellipsoid, pooled or cloud-shaped—or may even form a fluid–contrast material level (32,33,38) (Figs 2, 3, 6–8). With brisk hemorrhage, extravasated contrast material can fill the lumen completely, outlining bowel folds, and can appear as a hyperattenuating loop (Figs 8, 9).
Figure 7. Lower gastrointestinal tract bleeding in a 74-year-old man. Sagittal portal venous phase reformatted image shows a faint focus of contrast material extravasation (arrow) arising from the transverse colon, a finding that was not depicted in the arterial phase (not shown). Colonoscopy demonstrated findings of ischemic colitis and a bleeding ulcer.

Figure 8. Aortoduodenal fistulas in two patients. (a, b) Primary aortoduodenal fistula (no previous aortic surgery or trauma) in a 63-year-old man who presented with a severe episode of upper gastrointestinal tract bleeding. (a) Coronal unenhanced reformatted image shows hyperattenuating contents in the upper gastrointestinal tract, a finding that indicates active or recent bleeding. Note intragastric clot (arrow) and stranding of the inferior margin of the periduodenal fat (arrowheads). (b) Sagittal multiplanar reconstruction of the arterial phase dataset depicts an irregular aneurysmal aortic wall with a direct communication with the duodenal lumen (arrows). (c, d) Secondary aortoduodenal fistula in a 74-year-old woman who presented with hematemesis 7 months after she had undergone an aortobifemoral bypass graft procedure. (c) Coronal arterial phase volume-rendered reformatted image shows irregularity of the aortic wall and graft permeability, with faint opacification of the duodenal lumen (h). (d) Coronal portal venous phase volume-rendered reformatted image shows that the duodenal lumen becomes more opacified, creating a typical hyperattenuating loop (h). The duodenal folds (arrowheads) are outlined by the extravasation of intravenous contrast material into the duodenal lumen.
as that closest to the site of bleeding, in contrast to lower-attenuation unclotted blood, which is usually located farther from the source (45). Narrow window settings facilitate recognition of hyperattenuating material on CT images, and comparison with adjacent fluid-filled structures can be helpful. When differences are subtle, the attenuation can be measured directly (42).

Causes of Bleeding.—The detection and localization of active hemorrhage and the concurrent diagnosis of the specific underlying cause are the optimal results of CT angiography. However, even in the absence of active bleeding, CT angiography may be used to identify the underlying lesion and characterize it as diverticular, vascular, inflammatory, or neoplastic. The accuracy of CT angiography for detecting the cause of hemorrhage exceeds 80% (14,29). Abnormalities in the bowel wall or surrounding fat provide diagnostic clues. These clues include hyperattenuating perienteric fat (Figs 8a, 10), bowel wall thickening (Fig 10), abnormal enhancement of the bowel wall (Figs 10, 11), polypoid lesions, tumor masses (Figs 12, 13), and focal vascular dilatation or early venous drainage (features of angiodysplasia) (Fig 9).
Figure 10. Infectious colitis complicating non-Hodgkin lymphoma and causing lower gastrointestinal tract bleeding in a 56-year-old man. Oblique portal venous phase reformatted image, generated along the left colon (c), shows mural thickening and pericolonic fat stranding. No active bleeding was demonstrated with CT angiography or colonoscopy. Retroperitoneal and mesenteric lymphadenopathy was also present (not shown).

Figure 11. Massive lower gastrointestinal tract bleeding in a 17-year-old girl. (a, b) Coronal (a) and sagittal (b) arterial phase reformatted images depict an abnormal comma-shaped saccular vascular structure (arrow) located in the jejunal wall. (c) Axial portal phase image shows extravasation of contrast material (arrows). The findings at emergency surgery confirmed a jejunal arteriovenous malformation with active bleeding.
Figures 12, 13. (12) Acute lower gastrointestinal tract bleeding in a 34-year-old woman in whom CT angiography failed to show active bleeding but did show a 4-cm hypervascular partially exophytic mass originating in the wall of the jejunum; the mass was resected, and the findings at histopathologic evaluation indicated that the mass was a gastrointestinal stromal tumor (GIST). (a, b) Coronal arterial phase CT angiographic reformatted image (a) shows the hyperenhancing mass (t), which is also depicted on the coronal MIP reformatted image (b). (c) Axial arterial phase CT image shows a hyperenhancing hepatic metastasis (arrow). (13) Cecal adenocarcinoma causing lower gastrointestinal tract bleeding in a 79-year-old woman. (a) Axial portal venous phase CT angiographic image depicts a 6-cm cecal mass (t) with active extravasation of contrast material (arrows). Note the regional lymphadenopathy (arrowheads). (b) Coronal arterial phase MIP reformatted image shows the large area of extravasation originating from a branch of the ileocolic artery (arrows).
Varices cause approximately 30% of all episodes of upper gastrointestinal tract bleeding. CT angiography should be considered when endoscopy does not reveal a bleeding source and when there is a suspicion of arterial bleeding or a source in the lower gastrointestinal tract (Fig 14). Other nonvariceal causes of bleeding include duodenal and gastric ulcers, tumors, angiodysplasia, Mallory-Weiss tears, gastric erosions, and pancreatitis (7). Aortoenteric fistulas are a rare cause of catastrophic bleeding. In this entity, there is a communication between the aorta and the gastrointestinal tract, typically the distal portion of the duodenum, most often after reconstructive surgery of the abdominal aorta. In 20%–100% of cases, previous self-limited episodes of bleeding (“herald bleeds”) are reported before the episode of exsanguinating hemorrhage (46) (Fig 8). Upper gastrointestinal tract bleeding may also occur in patients who are hospitalized for other causes; stress ulcers can appear within 24 hours of admission in a patient who has suffered severe trauma or burns. Hemobilia refers to blood originating in the liver, biliary tree, or pancreas; blood passes to the duodenum through the papilla of Vater (Fig 3).

The source of lower gastrointestinal tract bleeding is colorectal in approximately 90% of cases. In the remaining 10%, the bleeding site is situated in the small bowel. Among colorectal lesions, colonic diverticula, angiodysplasia, inflammatory lesions, and malignancies are the most common causes of bleeding (7); and the accuracy of CT angiography for determining the specific cause ranges from 80% to 85% in most series (14,28,29,40,47,48). CT angiography can be used to easily diagnose bleeding from colonic diverticula, the leading cause of lower gastrointestinal tract bleeding (10) (Fig 5). Colonic angiodysplasia is the second most common cause of lower gastrointestinal tract bleeding, accounting for as many as 40% of cases in patients older than 60 years (31) (Fig 9). Investigators have reported values for the sensitivity, specificity, and positive predictive value of 70%, 100%, and 100%, respectively, for CT angiography (49). When possible, it is important to distinguish between bleeding from a diverticulum and angiodysplasia because the probability of rebleeding is as high as 85% in cases of angiodysplasia and is only 25% in cases of diverticular bleeding (33). In addition, CT angiography can be used to accurately diagnose neoplasms and colitis, which are the third and fourth most common causes of lower gastrointestinal tract bleeding, respectively (7,29,33) (Figs 10, 12, 13), and CT angiography is also helpful for the diagnosis of benign anorectal lesions (Fig 6). Postoperative bleeding can occur at an anastomotic site or a more distant location (18) (Fig 4).

**Imaging Pitfalls**

The ability to visualize active extravasation of contrast material is influenced by many factors related to the nature of the bleeding (severity, intermittence), the patient (hemodynamic status, body mass index, preexistent intestinal contents), the CT technique (examination protocol, scanner generation, iodine concentration of the contrast material used), and the experience of the radiologist (29,50). In studies for the detection of active bleeding with CT angiography, false-negative
results are most often due to intermittent or low-intensity bleeding, below the threshold of CT angiographic detection (32,34,36). Dilution of extravasated contrast material in fluid-filled dilated bowel loops is another cause of nondepiction of active bleeding with CT angiography (18,51). Inadequate bowel distention precludes detection of subtle tumors or inflammatory lesions that may be better seen at CT enterography. Mucosal enhancement of collapsed bowel loops can simulate extravasated contrast material (28,33). Errors of perception and interpretation (such as satisfaction of search), which are usually related to the inexperience of the radiologist, are other causes of false-negative results (Fig 15).

Preexisting hyperattenuating material, such as foreign bodies (including lines and tubes), metallic clips, suture material, or retained oral contrast material in the bowel lumen, may mimic acute gastrointestinal bleeding. These pitfalls can be avoided by obtaining preliminary unenhanced images (18,51). Retention of previously administered barium in colonic diverticula may be mistaken for, or may obscure, acute extravasation of contrast material. A large amount of retained oral contrast material in the digestive tract depicted on the topogram may preclude completion of the examination. Cone beam artifacts may produce areas of hyperattenuation observed at the interface between normal bowel contents and air in patients with distended loops, a finding that can also lead to false-positive results (32,51) (Fig 16). Hypervascular gastrointestinal tumors (stromal tumors, carcinoid tumors, certain metastases) may appear as hyperenhancing masses and may mimic acute gastrointestinal bleeding. Importantly, these lesions can be the cause of true hemorrhage (Fig 12).
Conclusions

CT angiography is a noninvasive, robust, widely available technique that can be easily implemented in patients with acute gastrointestinal hemorrhage. The sensitivity of CT angiography for detecting active bleeding and its cause is high. The findings of CT angiography help guide optimal treatment (directed endoscopic intervention, angiographic embolization, or surgery), as well as determine the optimal timing to implement these interventions. CT angiography is usually performed when endoscopy is not feasible or is nondiagnostic, but in most cases, CT angiography can be completed while preparing for endoscopy. Even when active hemorrhage has ceased, CT findings may assist in risk stratification and may be helpful in selecting the best option for definitive treatment, as well as its optimal timing. Nevertheless, although this approach has been successful in our hands, there is no consensus as yet with regard to the primary role of CT angiography in the evaluation of gastrointestinal bleeding. A meticulous technique is necessary, and radiologists should be aware of (a) the pertinent
imaging findings that indicate active or recent hemorrhage and (b) the most common sources of potential pitfalls. Figure 17 summarizes our proposed new algorithm for the initial evaluation of patients with acute gastrointestinal bleeding.

**References**


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