Radiology

REVIEWS AND COMMENTARY • STATEMENTS AND GUIDELINES

The Role of Imaging for GI Bleeding: ACG and SAR Consensus Recommendations

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Conflicts of interest are listed at the end of this article.

See also the editorial by Lockhart in this issue.

Radiology 2024; 301(3):e232298 • https://doi.org/10.1148/radiol.232298 • Content codes: GI CT

Gastrointestinal (GI) bleeding is the most common GI diagnosis leading to hospitalization within the United States. Prompt diagnosis and treatment of GI bleeding is critical to improving patient outcomes and reducing high health care utilization and costs. Radiologic techniques including CT angiography, catheter angiography, CT enterography, MR enterography, nuclear medicine red blood cell scan, and technetium-99m pertechnetate scintigraphy (Meckel scan) are frequently used to evaluate patients with GI bleeding and are complementary to GI endoscopy. However, multiple management guidelines exist, which differ in the recommended utilization of these radiologic examinations. This variability can lead to confusion as to how these tests should be used in the evaluation of GI bleeding. In this document, a panel of experts from the American College of Gastroenterology and Society of Abdominal Radiology provide a review of the radiologic examinations used to evaluate for GI bleeding including nomenclature, technique, performance, advantages, and limitations. A comparison of advantages and limitations relative to endoscopic examinations is also included. Finally, consensus statements and recommendations on technical parameters and utilization of radiologic techniques for GI bleeding are provided.

Supplemental material is available for this article.

This article is being published concurrently in *American Journal of Gastroenterology* and *Radiology*. The articles are identical except for minor stylistic and spelling differences in keeping with each journal's style. Citations from either journal can be used when citing this article.

A variety of radiologic imaging techniques are instrumental in the evaluation of patients with gastrointestinal (GI) bleeding and are complementary to GI endoscopy. Existing clinical practice guidelines for GI bleeding differ in the recommended utilization of radiologic examinations (1–4), and a detailed comparison between endoscopic and radiologic techniques is lacking. Owing to widespread variation in the utilization of GI testing (5) and a general lack of knowledge of advantages and limitations of each technique, we sought to derive a set of multidisciplinary consensus recommendations on the role of radiologic testing across the spectrum of GI bleeding. In this document, a panel of experts from the American College of Gastroenterology and Society of Abdominal Radiology provide a review of the radiologic examinations used to evaluate for GI bleeding including nomenclature, technique, performance, advantages, and limitations. A comparison of advantages and limitations relative to endoscopic examinations is also included. Finally, consensus statements and recommendations on technical parameters and utilization of radiologic techniques for GI bleeding are provided.

Process for Consensus

A panel of experts from the American College of Gastroenterology and Society of Abdominal Radiology was assembled to develop this document and the consensus statements. The overall process is explained in Appendix S1 and summarized in Figure 1. A four-point scale of agreement (Fig 2) was used to determine level of consensus.

The Grading of Recommendation, Assessment, Development, and Evaluations, or GRADE, system for assessing the quality of evidence was not used for these recommendations. The decision not to use the GRADE system was

Abbreviations

CA = catheter angiography, CTA = CT angiography, CTE = CT enterography, EGD = esophagogastroduodenoscopy, GI = gastrointestinal, LGIB = lower GI bleeding, RBC = red blood cell, TTP = time to positive, UGIB = upper GI bleeding

Summary

Consensus recommendations from the Society of Abdominal Radiology GI Bleeding Disease-Focused Panel and the American College of Gastroenterology will improve the understanding of specific examinations that are available for assessing gastrointestinal bleeding and how these should be used.

Key Results

- Numerous guidelines for the management of gastrointestinal (GI) bleeding, institutional variations in the nomenclature of available radiologic tests, and limited understanding of the technology can cause confusion for clinicians.
- Multiple examinations available to evaluate GI bleeding have unique advantages and limitations that help guide utilization in various clinical scenarios.
- Radiologic examinations play a major role in the diagnosis and treatment of GI bleeding and are complementary to gastroenterology examinations.

based on its prior use in published American College of Gastroenterology Clinical Practice Guidelines on the management of upper GI bleeding (UGIB) (6), lower GI bleeding (LGIB) (1,7), and small bowel bleeding (3) demonstrating low to very low quality of evidence in the support of consensus recommendations. Instead, we elected to use the expertise of a multidisciplinary panel of experts in the field of GI bleeding to develop our consensus recommendations.

Overview of GI Bleeding

GI bleeding can be characterized by the presumed location of origin. UGIB is defined as bleeding that originates from the esophagus, stomach, or duodenum. This accounts for approximately 80% of bleeding events (6). LGIB has previously been defined as bleeding that originates distal to the ligament of Treitz but more recently is defined as bleeding distal to the ileocecal valve and throughout the colon. LGIB, depending on its anatomic landmarks, accounts for approximately 15%–30% of all GI bleeding events (2,3). Finally, small bowel or midgut GI bleeding is defined as bleeding that occurs between the ligament of Treitz to the ileocecal valve and accounts for approximately 5%–10% of GI bleeding events (3,4). A more comprehensive clinical overview of GI bleeding is provided in Appendix S2.

Terminology of Cross-sectional Imaging Techniques Used in Imaging GI Bleeding

The terminology for the cross-sectional imaging techniques used to evaluate for GI bleeding can be confusing, as the terms and technical parameters used can vary by institution. In Appendix S3, we will give a general overview of the terminology used for these techniques.

Diagnostic Testing in Overt LGIB: Review of Imaging Techniques

CT Angiography

Technique.—CT imaging protocols are tailored to the specific indication (Tables 1, 2). In overt LGIB, the primary goals of

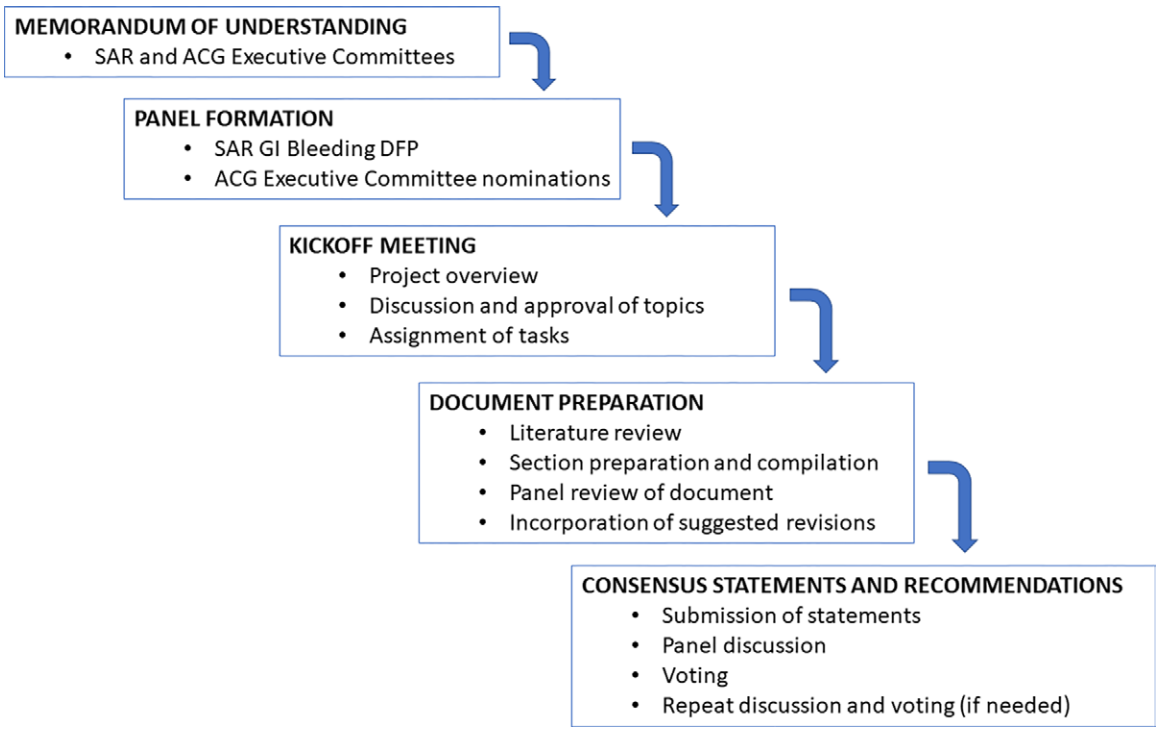

Figure 1: Diagram shows project process. ACG = American College of Gastroenterology, DFP = disease-focused panel, GI = gastrointestinal, SAR = Society of Abdominal Radiology.

Score		
1	Block	Strongly disagree; won't help implement
2	Stand-aside	Don't agree but won't block passage; may help implement
3	Accept with revisions	Will accept and help implement if suggested revisions are incorporated
4	Accept and support	Strongly agree and will help implement

Figure 2: Chart shows level of agreement.

Table 1: CT Techniques for GI Bleeding

Technical Parameter	CTA*	CTE†
Oral contrast material	None	Neutral contrast
Single-phase timing	Late arterial	Enteric or portal venous phase
Multiphase timing (>1 postcontrast phases)	Late arterial; portal venous or delayed	Late arterial phase; enteric or portal venous with or without delayed

* CT angiography (CTA) is defined as a CT examination with one of the phases acquired during the arterial phase with generation of postprocessed images to better demonstrate vascular anatomy. Most CTA examinations for gastrointestinal (GI) bleeding also obtain a second more delayed phase (multiple phases) to detect slower venous bleeds.
† CT enterography (CTE) can be performed as a single-phase examination or multiphase examination. A multiphase examination is helpful to improve detection and characterization of vascular lesions which are more common in older patients. Single-phase examinations are adequate for detecting inflammatory conditions and masses.

Table 2: Timing of Individual Phases for CT and Their Utility

Phase	Seconds After Beginning IV Contrast Material Injection	Utility
Noncontrast (or virtual noncontrast)	Not applicable	Identifies high-attenuation ingested material which can mimic bleeding
Late arterial	35	Provides arterial opacification and allows time for contrast material extravasation to begin
Enteric	50	Peak bowel wall enhancement; inflammatory conditions and some tumors (NET) may be most conspicuous on this phase
Portal venous	60–70	Provides good bowel wall enhancement and also allows better evaluation of other solid organs; allows improved detection of slow venous bleeding
Delayed	90 or more	Allows improved detection of slow venous bleeding

Note.—IV = intravenous, NET = neuroendocrine tumor.

CT are to determine the location and assess the intensity of the bleed, and a secondary goal is to identify the cause of bleeding. Confirmation of contrast material extravasation typically requires a multiphase CT technique (Fig 3) that includes acquisition of a noncontrast phase, a late arterial phase (typically 25–35 seconds after intravenous contrast bolus initiation), and a portal venous phase (60–70 seconds after bolus initiation) or late venous phase (70–90 seconds after bolus initiation) series. Most CT scanners can acquire the arterial phase through bolus tracking, which may be more suitable in patients with differing cardiac outputs, rather than timed delays. CT angiography (CTA) includes postprocessed three-dimensional images to better demonstrate the vascular anatomy, which can be helpful in guiding subsequent angiography. The noncontrast images are needed to identify high-attenuation ingested material that can mimic bleeding. In centers with access to the newer-generation multienergy CT scanners, a separate noncontrast phase may be omitted and replaced with a virtual noncontrast series (Appendix S6). Oral contrast material should be avoided because this delays scanning, and positive oral contrast can obscure bleeding. The most important finding that confirms presence of acute hemorrhage is extravasation of contrast-enhanced blood: This is defined by an accumulation of contrast material within the bowel lumen, which changes size and attenuation on subsequent phases. In 2019, the GI Bleeding Disease-Focused Panel of the Society of Abdominal Radiology published a white paper with consensus recommendations for acquisition techniques, which can be used as reference (8).

Performance data.—Several meta-analyses have found that CTA is highly sensitive (85%–90%), specific (92%), and accurate (94%–95%) for detection and localization of overt GI bleeding (9,10). CTA can also be prognostic. Extravasa-

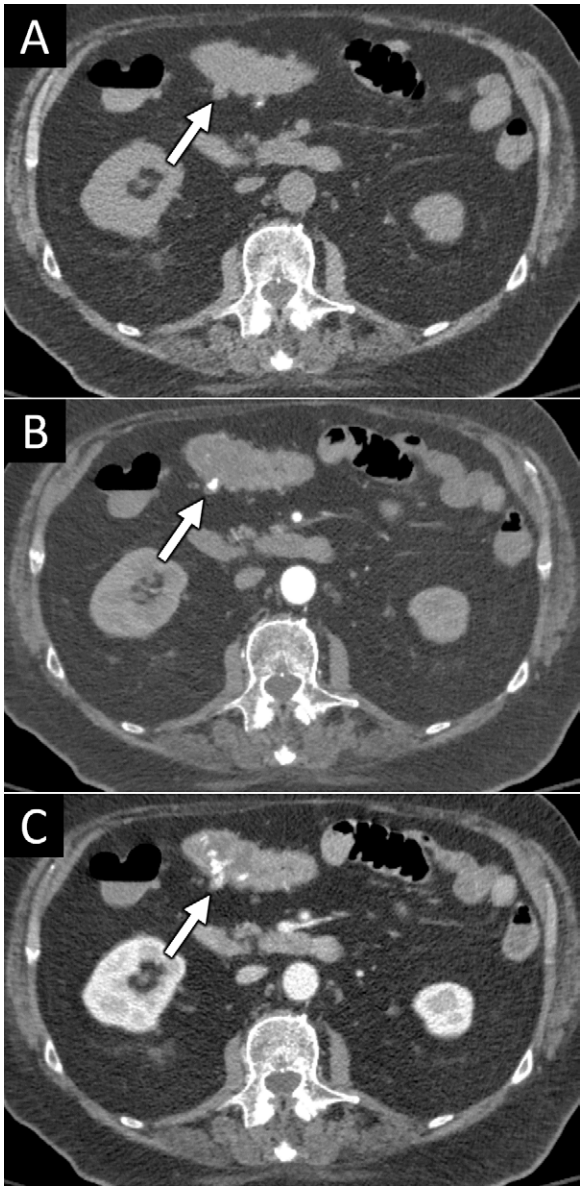

Figure 3: CT angiography (CTA) demonstration of actively bleeding colonic diverticulum in a 78-year-old man with atrial fibrillation taking warfarin with an acute onset of rectal bleeding and dropping hemoglobin level. No clear source of bleeding was identified at recent upper and lower endoscopy. **(A)** Noncontrast, **(B)** arterial phase, and **(C)** portal venous phase CT images show a diverticulum in the transverse colon (arrow in **A**), with contrast material extravasation in the diverticulum on arterial phase images (arrow in **B**) that changes in size and density in the portal venous phase (arrow in **C**) and extends further into the adjacent colon, consistent with active bleeding. Following CTA, catheter angiography was performed, which showed active bleeding from a vasa recta branch of the right colic artery (not shown). This was successfully treated with coil embolization.

tion volume can be quantified, and larger volumes are associated with higher transfusion requirements, active bleeding confirmation, and hemostatic therapy (11,12). Extravasation volumes correlate with bleeding rate, and with multidetector CT scanners, the sensitivity of bleeding detection is estimated to be 0.1 mL/min (12). This is significantly improved from historic studies reporting a sensitivity of 0.5 mL/min, which used a single detector, thicker sections, and less robust contrast bolus (13). A negative CTA examination has been shown to be associated with a decreased rate of rebleeding and need for intervention (14–16).

Advantages.—Because of its noninvasive nature, short examination time, and widespread availability, CTA is well-suited to evaluate patients with overt GI bleeding, particularly in hemodynamically unstable patients (5). In patients with overt GI bleeding, CT is used to identify intraluminal blood products or active contrast material extravasation to localize the site of hemorrhage and can also detect etiologies outside of the GI tract. CT techniques such as digital subtraction and dual-energy acquisition have improved the ability of CT to detect subtle GI tract lesions (17). CTA also provides additional information regarding the patient's vascular and enteric anatomy, which is often helpful for choosing and planning a subsequent interventional radiology, endoscopic, or surgical procedure (18).

Limitations.—CTA requires the administration of intravenous contrast material and ionizing radiation, which can be higher than standard abdominal CT because of multiple phases of image acquisition. However, techniques such as dual-energy CT and split contrast bolus acquisition can reduce radiation dose by reducing the number of phases obtained (19,20).

Nuclear Medicine

Technique.—The preferred radiopharmaceutical for LGIB imaging is technetium 99m (^{99m}Tc)–labeled red blood cells (RBCs), which have a long intravascular half-life that allows continuous imaging of the GI tract for several hours as necessary and have replaced ^{99m}Tc-sulfur colloid for evaluation of LGIB (21). The labeling methods are further described in Appendix S4.

Imaging protocol.—As ^{99m}Tc-RBCs are intravenously administered to the patient, imaging under the gamma camera begins with flow images (angiographic phase) obtained at 1–2 seconds per frame for 1 minute. Flow images can be helpful for localizing a rapid bleed, which rarely can be present at the start of imaging. Dynamic imaging obtained at 1 minute per frame for a minimum of 1 hour is generally recommended. Acquiring the dynamic images in 10- to 15-minute sequences and reviewing these images while subsequent sequences are still being acquired may decrease the time from detection of the bleed and catheter angiography (CA) (21). If no GI bleeding is detected after 1 hour of imaging, the study is usually ended. SPECT/CT may be helpful to clarify an indeterminate finding seen at planar imaging (22).

Performance data.—The sensitivity and specificity of ^{99m}Tc-RBCs have been reported to be 93% and 95%, respectively (23). Bleeds that occur early at imaging and have high intensity of uptake have the highest likelihood of being detected at subsequent CA. Time to positive (TTP), defined as the time from the start of ^{99m}Tc-labeled RBC scanning to the appearance of a bleed, can impact the diagnostic yield of CA. One study with a TTP threshold of ≤9 minutes identified 92% of the patients with positive studies. A TTP threshold of ≤9 minutes was associated with a positive CA study of six times greater compared with TTP of >9 minutes. TTP

of >9 minutes accurately predicted negative CA findings in 94% of patients. Having shorter lag time from the detection of bleed on ^{99m}Tc-RBC scans to the start of CA was also associated with higher yield of CA (24). Therefore, early interpretation of these studies is important to facilitate faster time to CA.

One study comparing CTA and ^{99m}Tc-RBC scans showed that ^{99m}Tc-RBCs scans had a lower accuracy of 55.4% compared with CTA, which had an accuracy of 96%.^{99m}Tc-RBC scans in this study were performed with standard planar imaging and did not have SPECT/CT performed (25). SPECT/CT may be helpful for distinguishing a small bowel bleed from a large bowel bleed (22). In one study, planar imaging combined with SPECT/CT showed the highest diagnostic ability for detecting the site of GI bleeding compared with planar imaging or planar imaging combined with SPECT (26). There are currently limited data on the value of SPECT/CT when planar imaging is negative because few centers perform the examination in such circumstances. More studies are needed to validate the results with SPECT/CT, including its use when planar imaging does not show evidence of GI bleeding (21).

Advantages.—The biggest advantage of ^{99m}Tc-RBC scanning is its high sensitivity because it can detect GI bleeding at a rate of as low as 0.04 mL/min in experimental animal models and 0.1 mL/min in clinical studies (21,27,28). As imaging is typically performed for at least 1 hour, intermittent bleeding can also be detected. ^{99m}Tc-RBC scanning also allows dynamic imaging for more than 1 hour, and it is possible to reimage for up to 24 hours (21). The radiation dose to the patient is lower with ^{99m}Tc-RBC scanning compared with CTA (23,29).

Limitations.—The biggest limitation of ^{99m}Tc-RBC scans is that this study can only be performed on hemodynamically stable patients. The RBC labeling preparation time and long imaging times prevents performing this study on patients who are hemodynamically unstable because of hypotension or abnormal heart rate (21). The risk-benefit ratio of obtaining a ^{99m}Tc-RBC scan, which has a long imaging time, versus correctly identifying an active LGIB site has to be weighed in borderline hemodynamically unstable patients.

RBCs also localize at sites other than active GI bleed. Physiologic activity in the ureters, penile activity, splenosis, pancreatic pseudocysts, or nonenteric bleeding/hematoma can be mistaken as sites of GI bleed (21,23,30). True GI bleeding will change in intensity and move over time, which will help differentiate GI bleeding from these normal variants and pitfalls. SPECT/CT can be performed for better characterization of indeterminate findings and help with pitfalls that can mimic GI bleeding (22).

There are patient related-factors that could potentially interfere with labeling of RBCs. Patients with low hematocrit, recent blood transfusion, and hemoglobin-related disease (sickle-cell disease or thalassemia) have lower labeling efficiency. Some medications such as heparin can also interfere with labeling (23).

Sometimes planar ^{99m}Tc-RBC scans can provide incorrect localization of the site of bleeding. Incorrect localization of bleeding has been reported in a few studies occurring in 10%–33% of cases (25,31,32). SPECT/CT can be performed to improve localization, but this could delay CA (22).

Catheter Angiography

Technique.—CA with intent to treat with embolization is most commonly performed for unstable patients with active LGIB who are not appropriate candidates for endoscopy (33). CA is rarely performed before CTA because of the high reliability, noninvasiveness, access, ability to provide a vascular roadmap, and speed of CTA. Provocative angiography with heparin and tissue plasminogen activator can be performed to diagnose and treat patients with obscure and recurrent GI bleeding if all other methods have failed to diagnose the source of bleeding (34,35).

Ideally, the patient should undergo CTA of the abdomen and pelvis to allow identification of the vessel territory before angiography. This may reduce the amount of contrast during the angiography by focusing on one of the two potential vessels (superior mesenteric artery and inferior mesenteric artery) supplying the colon. Of note, initial data did not demonstrate a decrease in contrast material administration when CTA was performed before angiography (18).

CA is usually performed through common femoral artery or left radial artery access. Selective angiograms of the superior and inferior mesenteric arteries are performed to image the site of bleeding suspected based on the prior imaging studies. Contrast material extravasation into the bowel lumen is definitive proof of active GI bleeding. When the exact site of bleeding is identified, superselective angiogram of the end vessel vasa recta supplying the area of bleeding is performed. This is followed by microcoil (36) or glue (*N*-butyl 2-cyanoacrylate) embolization (37) of the vasa recta correlating with the site bleeding. The goal of embolization is to decrease the blood flow to the bleeding site to achieve hemostasis while maintaining collateral perfusion to prevent ischemia of the bowel. Care should be taken to minimize the area embolized because collateral supply to the bowel is minimal at the level of vasa recta.

Performance data.—Technical success of embolization is above 95%; however, up to 25% of patients may present later with recurrent bleeding (37,38). Angiography with embolization is a durable treatment for patients with acute LGIB and is proving to be a definitive therapy for most patients (39,40). Glue embolization appears to have better impact on the rate of recurrent bleeding than microcoil embolization (38).

Advantages.—The major advantage of CA for LGIB is the ability to both diagnose and treat definitively at the same time with high technical success, minimal side effects, and relatively low rate of recurrent bleeding.

Limitations.—A major limitation of CA is its invasiveness. Groin arterial access in elderly atherosclerotic patients may result in injury to the vessel with resultant hematoma, dissection, or arteriovenous fistula formation. Bowel ischemia may occur in rare cases and is more commonly seen with glue embolization (41); this usually occurs without bowel necrosis and can be treated conservatively (42). A recent publication showed that severe adverse events involving embolization-induced bowel ischemia occurred in three of 56 patients (5.3%) who underwent particle embolization with or without coils versus 0 of 66

patients when coils alone were used (43). Overall, the risk of bowel ischemia after embolization is up to 10%, though most of the patients are asymptomatic (44–47). Only patients with active extravasation at the time of the angiography can be treated with targeted embolization because embolization of a wider vascular territory will result in significant bowel ischemia. As GI bleeding is frequently intermittent, this is a significant limitation of CA as both a diagnostic and therapeutic modality. In some patients, the extent of atherosclerotic disease may not allow navigation of the abdominal aorta and its branches. CA is usually performed with iodinated contrast material to diagnose bleeding. Relative (renal insufficiency) and absolute (anaphylactic shock) contraindications to iodinated contrast material should be considered before angiography. In younger patients with LGIB, consideration should be given to the significant radiation exposure associated with CA.

Gastroenterology Perspective

A discussion of advantages and limitations of radiologic testing versus colonoscopy for LGIB is provided in Appendix S5.

Consensus Recommendations for Imaging in Overt LGIB

CT Angiography

Technique.—

1. Unenhanced images (conventional or virtual noncontrast) should be acquired in all cases.
2. Images should be acquired during a late arterial phase and a portal venous or delayed phase.
3. No oral contrast material should be administered.
4. Three-dimensional CTA images can be generated to help guide subsequent conventional angiography.
5. Dual-energy CT techniques may be used if available to improve visibility of sites of contrast material extravasation.

Role/indications.—

1. CTA should be performed as the first diagnostic study in hemodynamically unstable patients.
2. CTA could be considered as the first-line study in hemodynamically stable patients where the suspicion of active bleeding is high.
3. CTA is not indicated as a first-line test in hemodynamically stable patients in whom bleeding has subsided.

Catheter Angiography

Technique.—

1. CA for LGIB can be performed through common femoral artery or radial artery access.
2. Permanent agents, such as microcoils or glue, are used to embolize vasa recta at the site of identified bleeding.
3. In the absence of active extravasation at angiography, embolization should not be performed, as the exact site of bleeding is not identified.

Role/indications.—

1. In most cases, if CTA is negative for GI bleeding, CA is not indicated.
2. In unstable patients with active extravasation at CTA, CA with embolization can be used as the primary treatment modality.
3. If the patient has recurrent intermittent LGIB and all modalities have failed to identify the source of bleeding, provocative CA can be performed to identify and treat the culprit lesion.

^{99m}Tc-RBC Scan

Technique.—

1. The in vitro RBC labeling method has the highest labeling efficiency and is the preferred method.
2. Imaging should be continued for 1 hour if no bleeding is detected.

Role/indication.—

1. In a hemodynamically stable patient with evidence of ongoing LGIB, negative evaluation with colonoscopy, and a CTA examination is negative, contraindicated, or not available, tagged-RBC scanning can be performed.

Diagnostic Testing in Suspected Small Bowel Bleeding: Review of Imaging Techniques

CT Enterography

Technique.—CT enterography (CTE) protocols are designed to optimize evaluation of the small bowel wall and require ingestion of a large volume of oral contrast material to distend the bowel. Approximately 1.5 L of fluid is ingested in divided doses over the hour preceding the examination. Neutral oral contrast agents, with attenuation values near that of water, are the preferred agents for evaluating suspected small bowel bleeding. This is because most small bowel pathologic abnormalities that cause GI bleeding hyperenhance after the administration of intravenous contrast material (inflammation, vascular lesions, and some neoplasms) and will be brighter or more conspicuous against the hypointense neutral enteric contrast (48). Intravenous contrast material is required to visualize these enhancing lesions. Scans can be acquired using a single-phase or multiphase technique (Tables 1, 2). A single phase, performed during the enteric or portal venous phase (50 or 70 seconds after starting the contrast material injection, respectively), is adequate to detect inflammation and most masses. Multiphasic examinations (Fig 4) improve the detection and characterization of vascular lesions (49). Mul-

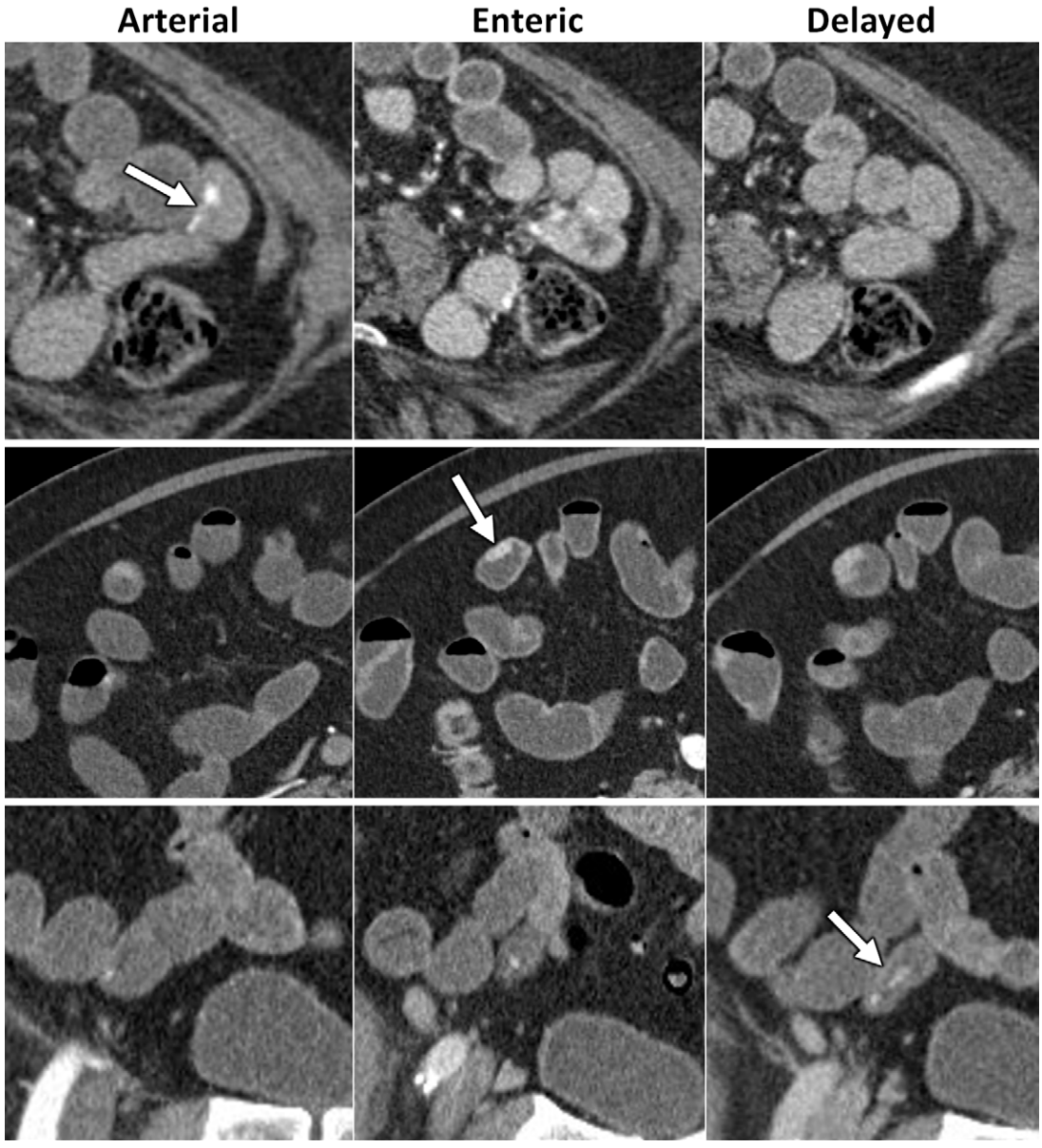

Figure 4: Multiphase CT enterography (CTE) images. Advantages of multiphasic CTE for detection and characterization of gastrointestinal bleeding etiologies. The top row shows a Dieulafoy lesion (arrow), which is most conspicuous on the arterial phase. The middle row shows a small neuroendocrine tumor (arrow) most conspicuous on the enteric phase. The bottom row shows a slowly bleeding angioectasia (arrow) most conspicuous on the delayed phase. Reproduced with permission from the American Roentgen Ray Society from Multiphase CT Enterography Evaluation of Small-Bowel Vascular Lesions, Huprich et al, *American Journal of Roetgenology*, volume 201, issue 1, 65–72 (49); © 2013 American Roentgen Ray Society.

tiphase examinations are most commonly performed with the addition of an arterial phase series to the enteric or portal venous phase, and at some institutions, a delayed phase (90 seconds after starting contrast material injection) is also added (5,49). The visualization of an abnormality on multiple phases may also increase the level of confidence in identifying the abnormality.

Performance data.—Nearly all reports on the diagnostic accuracy of CTE for evaluating suspected small bowel bleeding published in the literature contain substantial numbers of patients with overt bleeding. Therefore, specific data on CTE accuracy in patients with occult GI or suspected small bowel bleeding are scarce. In one study, which recruited patients referred for double-balloon enteroscopy for suspected small bowel bleeding, the sensitivity and specificity of CTE were 30.9% (25 of 81) and 69.4% (34 of 49), respectively, in patients with occult bleeding (52). These values were slightly lower than 39.5% (30 of 76) and 73.9% (34 of 46), respectively, in patients with overt bleeding in the same study (50). The overall (ie, not distinguishing overt and occult) sensitivity and specificity of CTE for detecting the causes of suspected small bowel bleeding reported in the literature are quite heterogeneous, with the pooled sensitiv-

ity of 72.4% (I^2 = 80.8%; range, 40%–100%) and specificity of 75.2% (I^2 = 77.7%; range, 45.5%–100%) according to a meta-analysis (51).

Several studies reported the diagnostic yields of CTE in patients with occult GI and/or suspected small bowel bleeding (ie, patients in whom CTE detected the bleeding causes divided by all patients examined with CTE) (50,52–56). Overall, the diagnostic yields were lower in patients with occult bleeding (0%–33.3%) than in patients with overt bleeding (22.4%–66.7%) (50,52–56).

Advantages.—CTE may have several advantages over endoscopic techniques (3). CTE has greater sensitivity for detecting small bowel masses, particularly those that are mural-based, and can help direct targeted, deep enteroscopy procedures when a source is identified (Figs 5, 6). Cross-sectional imaging techniques (CT and MRI) allow visualization of extraintestinal abdominopelvic structures such as malignancies that may involve bowel or changes in the mesentery, bowel wall, and bowel/mesenteric vessels as potential causes of GI bleeding even in the absence of active contrast material extravasation. In patients with occult small bowel bleeding and relative contraindications to capsule endoscopy such as radiation, prior surgery, Crohn disease, and/or small bowel stenosis, CTE maybe the first-line study to characterize the abnormality (3).

Limitations.—Limitations of CTE include the use of ionizing radiation and the need for intravenous contrast material in patients. While usually not an issue in the setting of an occult GI bleed, the neutral oral contrast agent used in CTE theoretically may dilute contrast material extravasation, making it more difficult to identify (20,48). Similar to CTA, subtle masses or vascular abnormalities may be obscured at CTE secondary to hyperintense bowel contents, radiopaque foreign bodies, and cone-beam artifacts. Incompletely distended bowel may also obscure or mimic mucosal abnormalities. If there is brisk ongoing bleeding with hemodynamic instability, CTA should be performed instead of CTE.

Meckel Scan

A Meckel scan can be performed to investigate for a Meckel diverticulum. The technique involves the intravenous administration of ^{99m}Tc pertechnetate, which accumulates in gastric mucosa often found ectopically in a Meckel diverticulum. After administration, scintigraphy is performed dynamically for a period of 30–60 minutes to identify a fixed abdominal region of ectopic gastric mucosa (57). Most symptomatic Meckel diverticula are found in children and young adults but occasionally can be seen in older individuals and can be considered when other tests are negative. There are data to suggest that the test is less sensitive in adults (63%) as compared with children (85%) (58). A Meckel diverticulum can be difficult to visualize at CTE unless there is associated inflammation or intussusception.

Gastroenterology Perspective

A discussion of advantages and limitations of radiologic testing versus capsule endoscopy and balloon-assisted endoscopy for small bowel bleeding is provided in Appendix S5.

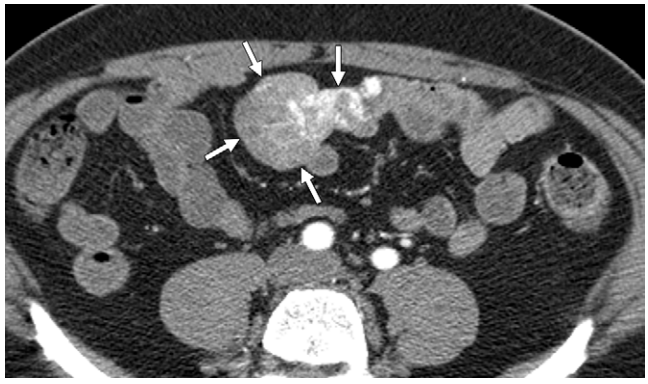

Figure 5: CT enterography (CTE) image shows a small bowel gastrointestinal (GI) stromal tumor in a 53-year-old woman with suspected small bowel bleeding and negative capsule endoscopy. Single-phase CTE shows a large exophytic vascular mass (arrows) arising from the small bowel consistent with a GI stromal tumor, which was proven at surgical resection.

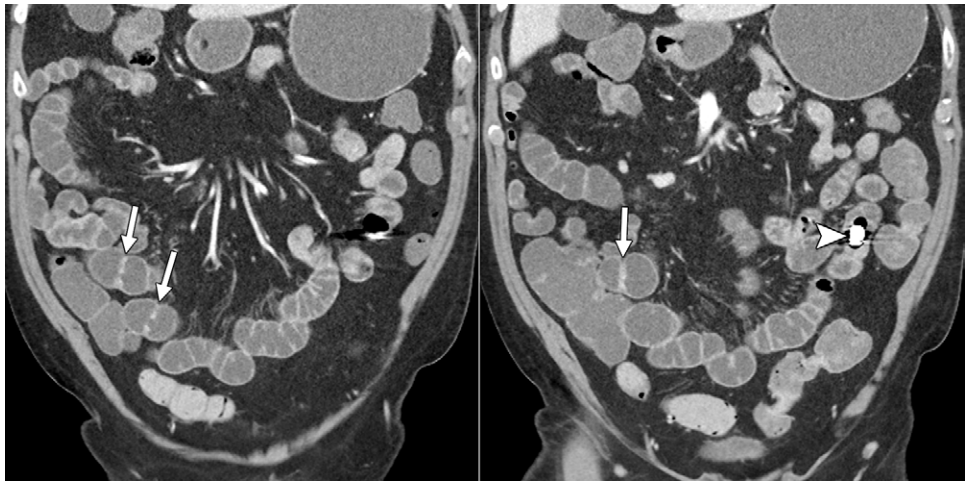

Figure 6: CT enterography (CTE) images show obstructing nonsteroidal anti-inflammatory drug diaphragms in a 50-year-old man with history of nausea, vomiting, diarrhea, and suspected gastrointestinal bleeding. Prior negative routine CT. CTE images show multiple diaphragms (arrows) in the distal small bowel, with retained capsule (arrowhead) from prior capsule endoscopy.

Consensus Recommendations for Imaging in Suspected Small Bowel Bleeding

CT Enterography

Technique.—

1. CTE should be performed using multiphase technique in patients older than 40 years of age where vascular lesions are a common cause for bleeding.
2. Multiphase CTE should include at least arterial, and enteric or portal venous phases.
3. *Multiphase CTE* is the recommended term for a CTE examination performed for suspected small bowel bleeding and acquired with multiple phases after the administration of intravenous contrast material.
4. A single phase performed during the enteric or portal venous phase is adequate to evaluate for inflammatory conditions such as Crohn disease, radiation enteritis, nonsteroidal anti-inflammatory drug enteropathy, and most malignancies.
5. Neutral enteric contrast material should be administered in divided doses beginning 1 hour before CTE.

Role/indications.—

1. CTE should be performed instead of CTA in hemodynamically stable patients presenting with ongoing suspected small bowel bleeding after negative colonoscopy and esophagogastroduodenoscopy (EGD) and capsule endoscopy (if negative or not performed).
2. If there is brisk ongoing bleeding with hemodynamic instability, CTA should be performed instead of CTE.
3. CTE should be the first-line imaging test for suspected small bowel bleeding in hemodynamically stable patients if patients are at increased risk for video capsule retention.
4. CTE should be the first-line study for suspected small bowel bleeding in hemodynamically stable patients if small bowel neoplasm is the suspected cause for small bowel bleeding.
5. CTE can be performed as the first-line diagnostic study for suspected small bowel bleeding in hemodynamically stable patients depending on clinical scenarios such as local availability and expertise.
6. CTE should be performed if there is no definitive cause for small bowel bleeding identified at capsule endoscopy and there is suspicion for ongoing bleeding.

Meckel Scan

Role/indication.—

1. A Meckel scan can be considered to identify the cause of unexplained intermittent GI bleeding in children and adolescents after negative endoscopic evaluation, including capsule endoscopy if available, and cross-sectional evaluation of the small bowel.

Diagnostic Testing in Nonvariceal UGIB: Review of Imaging Techniques

CT Angiography

The technique, advantages, and limitations of CTA are the same as those discussed for overt LGIB. Most of the published data have reported the performance of CTA in LGIB. Therefore, there is a paucity of data in those patients presenting with nonvariceal UGIB. In the rare circumstance when endoscopy identifies UGIB but cannot identify the source, CTA may be helpful localizing the bleeding site. CTA can be considered if there is no in-house emergency gastroenterology coverage or the patient is not suitable for EGD, including when postoperative anatomy limits endoscopic access (Fig 7).

Catheter Angiography

Treatment of patients presenting with symptoms of UGIB (both variceal and nonvariceal) should prioritize medical stabilization followed, in most cases, by endoscopy (59). In select cases, such as hepatic pseudoaneurysm, angiography may be the preferred first-line treatment (59,60).

If endoscopy visualizes but is unable to treat a source of bleeding, CA should be performed with the intent to embolize (61–63).

Technique.—Before CA, the patient's renal and coagulation status should be optimized (59). If the bleeding site has previously been localized, angiography should initially be targeted to the bleeding vessel (63). Next, both the celiac and superior mesenteric arteries should be interrogated to evaluate all potential bleeding sources and collateral vessels (62,63) with high volume of contrast (20 mL volume with 5 mL/sec injection rate) and long imaging time (30–40 seconds) until opacification of the portal system is seen.

In the absence of visualized contrast material extravasation, but documented extravasation at upper endoscopy or CTA, prophylactic embolization of the suspected vessel should be considered. When possible, superselective embolization should be performed in a distal to proximal fashion, which reduces the risk of "back door," rebleeding through collaterals. Currently, microcoils are the most commonly used embolic agent. Other options include gel-foam, particles, glue, and plugs (63). Placement of an endoscopic clip next to the bleeding site at the time of endoscopy may help guide embolization (Fig 7).

Outcomes.—Outcomes data for angiographic treatment of nonvariceal UGIB is limited. A technical success rate has been reported up to 95%. The clinical success rate has been reported at 67%, with a 33% rebleeding rate on the first attempt (60,63). Reported complication rates are up to 10%, including access site issues, kidney damage, nontarget embo-

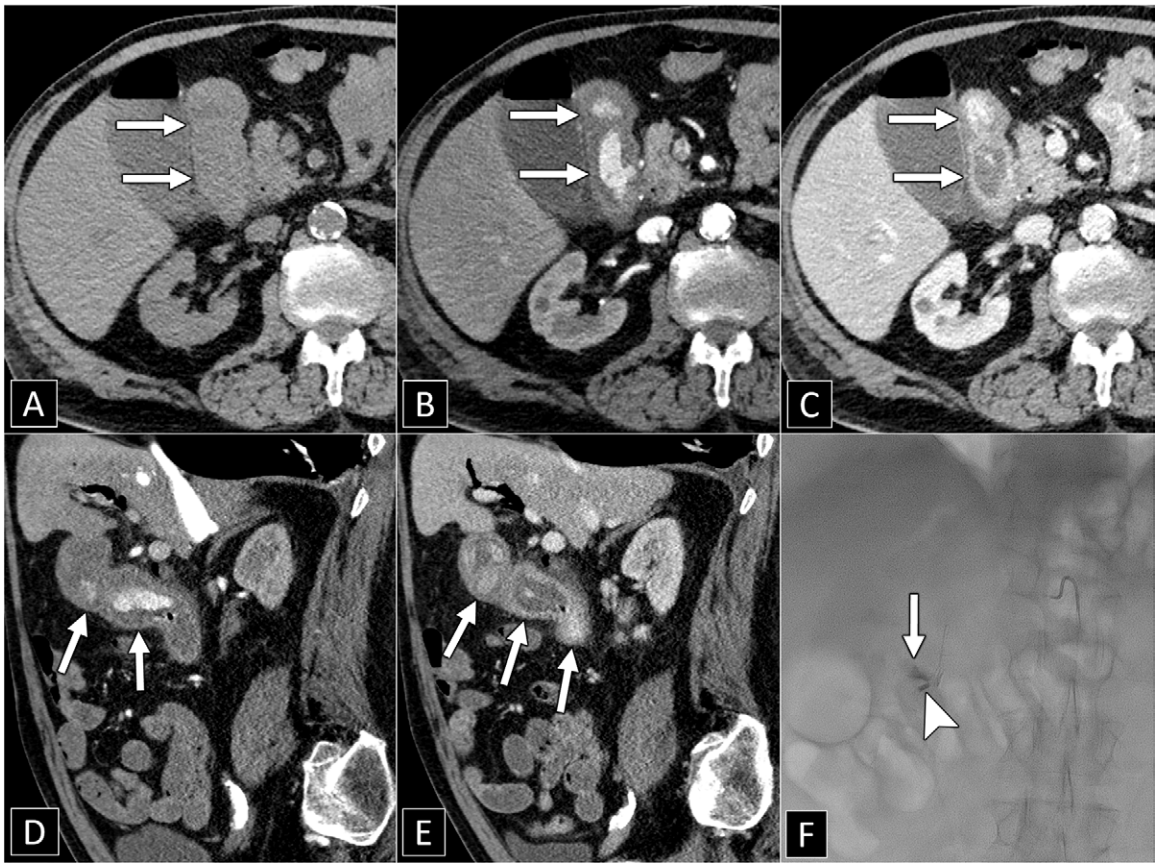

Figure 7: Actively bleeding duodenal ulcer in a 70-year-old man with a history of a large duodenal ulcer previously treated with endoscopic clipping who presented with recurrent gastrointestinal (GI) bleeding. **(A)** Noncontrast, **(B)** arterial phase axial and **(D)** sagittal, and **(C)** portal venous phase axial and **(E)** sagittal CT images show high-attenuation fluid in the duodenum on noncontrast images (arrows in **A**), representing a sentinel clot. On contrast-enhanced images, there is arterial phase contrast material extravasation in the duodenum (arrows in **B** and **D**), which changes in size and attenuation in the portal venous phase (arrows in **C** and **E**) consistent with contrast material extravasation. **(F)** Catheter angiography image shows a focus of contrast material extravasation (arrow) adjacent to a metal clip from a prior endoscopic procedure (arrowhead). The GI bleed was successfully treated with coil embolization.

lization, bowel ischemia, and bowel infarct; however, these are highly variable due to the differences in technique, embolization material, and reported complications (61,62).

Gastroenterology Perspective

A discussion on the role of CTA versus EGD for nonvariceal UGIB is provided in Appendix S5.

Consensus Recommendations for Imaging in Nonvariceal UGIB

1. CA with intent to treat is indicated when an EGD is unsuccessful in achieving initial hemostasis, or the patient experiences recurrent bleeding after a successful initial EGD and a repeat EGD is either unsuccessful or not recommended.

2. In the setting of ongoing bleeding, CTA can be considered:

   - If the patient is not thought to be suitable for EGD or if there is no in-house emergency gastroenterology coverage.

   - After negative EGD or if EGD is unable to identify the site of bleeding.

Additional Cross-sectional Imaging Techniques and Potential Future Advances

Additional cross-sectional imaging techniques, including dual-energy CT and MRI, are discussed in Appendix S6.

Special Considerations

Appendix S7 discusses an approach to imaging for GI bleeding in special considerations, including pregnancy and renal impairment.

Comparison of Recommendations With the American College of Radiology Appropriateness Criteria

The American College of Radiology has developed appropriateness criteria for nonvariceal upper gastrointestinal (GI) tract bleeding (64) and management of lower GI tract bleeding (65), which are compared with our recommendations in Appendix S8.

Author contributions: Guarantors of integrity of entire study, **N.S., D.H.B., H.V.N., V.R., A.G., J.L.F.**; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; agrees to ensure any questions related to the work are appropriately resolved, all authors; literature research, **N.S., D.M.K., M.L., J.A.L., O.R.B., M.L.W., F.F.G., H.V.N., J.A.S., S.H.P., D.C.Y., V.R., A.H., A.K., A.G., B.R.D., F.S., D.J.G., J.R.T.,**

J.L.F.; clinical studies, **N.S., D.M.K., J.A.L., O.R.B., V.R., M.A.A., F.S., J.R.T.**; statistical analysis, **D.H.B., V.R.**; and manuscript editing, all authors

Disclosures of conflicts of interest: **N.S.** No relevant relationships. **D.M.K.** Grants from Exact Sciences, Freenome, Medtronic, and Motus GI; consulting fees from Medtronic. **D.H.B.** Consulting fees from Janssen. **M.L.** Consulting fees from Olympus, Medtronic, and Ovesco; travel reimbursement from Olympus and Ovesco. **J.A.L.** President of the American College of Gastroenterology. **O.R.B.** Royalties from Thieme; payment for expert testimony; at-large board member for the Society for Advanced Body Imaging. **M.L.W.** No relevant relationships. **F.F.G.** No relevant relationships. **H.V.N.** Patent planned, issued, or pending with Thomas Jefferson University. **M.S.G.** Consulting fees from Reveal Pharmaceuticals. **J.A.S.** No relevant relationships. **S.H.P.** Member of the *Radiology* editorial board. **D.C.Y.** No relevant relationships. **V.R.** No relevant relationships. **A.H.** No relevant relationships. **A.K.** No relevant relationships. **A.G.** Speaker's fees from Philips Healthcare. **B.C.A.** No relevant relationships. **M.A.A.** Patent planned, issued, or pending with Massachusetts General Hospital. **B.R.D.** Honorarium from Siemens Healthineers. **F.S.** No relevant relationships. **D.J.G.** No relevant relationships. **J.R.T.** Grants from Bayer Healthcare and GE HealthCare; consulting fees from Intuitive Surgical; payment for lectures from CME Science. **J.L.F.** No relevant relationships.

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