American College of Radiology
ACR Appropriateness Criteria®
Imaging of Mesenteric Ischemia

Variant 1: **Suspected acute mesenteric ischemia. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
CTA abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢
CT abdomen and pelvis with IV contrast	May Be Appropriate	☢☢☢
Arteriography abdomen	May Be Appropriate (Disagreement)	☢☢☢
MRA abdomen and pelvis without and with IV contrast	May Be Appropriate (Disagreement)	O
X-ray abdomen	May Be Appropriate	☢☢
US duplex Doppler abdomen	May Be Appropriate	O
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢
MRA abdomen and pelvis without IV contrast	Usually Not Appropriate	O

Variant 2: **Suspected chronic mesenteric ischemia. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
CTA abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢
MRA abdomen and pelvis without and with IV contrast	Usually Appropriate	O
Arteriography abdomen	May Be Appropriate (Disagreement)	☢☢☢
CT abdomen and pelvis with IV contrast	May Be Appropriate	☢☢☢
MRA abdomen and pelvis without IV contrast	May Be Appropriate	O
US duplex Doppler abdomen	May Be Appropriate	O
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢
X-ray abdomen	Usually Not Appropriate	☢☢

IMAGING OF MESENTERIC ISCHEMIA

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Summary of Literature Review

Introduction/Background

Mesenteric ischemia is an uncommon disease affecting the small and large bowel resulting from a reduction of intestinal blood flow. Although the disease is responsible for fewer than 1 in 1,000 hospital admissions, the mortality rate remains high, ranging between 30% to 90% in acute settings despite advances in treatment options [1-4]. The etiology of ischemia may vary from arterial occlusion, venous thrombosis, or vasoconstriction. Higher prevalence in the elderly population and nonspecific clinical presentation leading to delayed diagnosis contributes to the high mortality rate [1]. Most cases of mesenteric ischemia are due to an acute event leading to decreased blood supply to the splanchnic vasculature. Chronic mesenteric ischemia is uncommon, accounting for <5% of cases of mesenteric ischemia, and is almost always associated with diffuse atherosclerotic disease [5].

Pathophysiology

Acute mesenteric ischemia is most commonly secondary to acute embolism to the superior mesenteric artery (SMA), which accounts for approximately 40% to 50% of all episodes. Acute mesenteric artery thrombosis is the second most common cause of acute mesenteric ischemia (20%–30%) followed by nonocclusive mesenteric ischemia (25%) and, less commonly, mesenteric and portal venous thrombosis (5%–15%). In the chronic setting, mesenteric ischemia is almost always caused by severe atherosclerotic disease, with rare causes including fibromuscular dysplasia, median arcuate ligament syndrome, dissection, and vasculitis [5-8].

Acute embolization of the SMA involves the distal aspect of the vessel, usually beyond the origin of the middle colic artery, and commonly does not have associated collateral vessels. Acute mesenteric artery thrombosis is typically associated with chronic atherosclerotic disease and, given its more insidious course, a well-developed collateral circulation is commonly present. Nonocclusive mesenteric ischemia is seen in the setting of hypoperfusion because of secondary vasoconstriction of the mesenteric arteries. In these cases, there is no evidence of vascular occlusion, and the ischemia is distributed over a wider area of the bowel in a nonconsecutive manner [9]. Mesenteric and portal venous thrombosis is the least common cause of acute mesenteric ischemia and may be idiopathic. Most common risk factors are hypercoagulable states, portal hypertension, and recent surgery [10,11]. Bowel ischemia results from impaired intestinal mucosa venous outflow, leading to visceral edema and subsequent arterial hypoperfusion.

Chronic mesenteric ischemia occurs because of occlusive or stenotic atherosclerotic disease and most commonly involves at least 2 or 3 main vessels. It is more prevalent in the elderly population and in patients with major risk factors for atherosclerosis, such as hypertension, hyperlipidemia, and smoking history [12].

Discussion of Procedures by Variant

Variant 1: Suspected acute mesenteric ischemia. Initial Imaging.

Patients with acute mesenteric ischemia present with abdominal pain out of proportion to the physical examination [2]. A high index of suspicion is necessary to achieve early diagnosis, particularly in the elderly or

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hospitalized patient population [13,14]. The main challenge is to differentiate acute mesenteric ischemia from other more common causes of acute abdominal pain, such as appendicitis, diverticulitis, peptic ulcer disease, acute pancreatitis, gastroenterocolitis, nephrolithiasis, cholelithiasis, and cholecystitis. Early in the course of disease, laboratory findings are of little value in differentiating among these causes, with the results usually demonstrating metabolic acidosis, elevated lactate and D-dimer, leukocytosis, hemoconcentration, elevated amylase levels, and/or abnormal liver enzymes [15,16]. Unfortunately, the signs, symptoms, and laboratory testing are insufficient for making the diagnosis [15].

Radiography

Radiography has historically been considered the first imaging modality in the evaluation of acute abdominal pain, but because of its low diagnostic yield and generally nonspecific findings, its role has been debated in current practice [17]. Abdominal radiography does not exclude the diagnosis of acute mesenteric ischemia as 25% of patients with this condition will have normal radiographs [18]. Radiography findings in patients with acute mesenteric ischemia are usually nonspecific, late, and associated with a high mortality rate, as they often first appear when bowel infarction has already occurred [5,18-20]. A radiograph typically shows bowel dilatation in elderly patients and a gasless abdomen in younger patients with acute mesenteric ischemia [21]. Hepatic portal venous gas is a rare but important radiographic finding associated with several pathological processes, including bowel necrosis secondary to acute mesenteric ischemia. Portal venous gas can occur alone or in association with pneumatosis intestinalis. When associated with pneumatosis intestinalis, it usually indicates the presence of advanced mesenteric ischemia [18]. In addition, given its limited role in assessing for other causes of acute abdominal pain, radiographs in mesenteric ischemia should be solely utilized to screen for bowel perforation or obstruction [17].

CTA

For the purposes of distinguishing between computed tomography (CT) and CT angiography (CTA), ACR Appropriateness Criteria topics use the definition in the ACR–NASCI–SIR–SPR Practice Parameter for the Performance and Interpretation of Body Computed Tomography Angiography (CTA) [22]:

> *"CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial or venous enhancement. The resultant volumetric dataset is interpreted using primary transverse reconstructions as well as multiplanar reformations and 3-D renderings."*

All elements are essential: 1) timing, 2) reconstructions/reformats, and 3) 3-D renderings. Standard CTs with contrast also include timing issues and recons/reformats. Only in CTA, however, is 3-D rendering a required element. This corresponds to the definitions that the CMS has applied to the Current Procedural Terminology codes.

CTA of the abdomen and pelvis is a fast, accurate, and noninvasive diagnostic tool for evaluating the bowel and assessing intestinal vasculature and should be the first-step imaging approach in patients with acute bowel ischemia [12,15,23-28]. CTA can be helpful in stratifying patients to identify those who would benefit from angiography as opposed to the ones who should undergo emergent surgery. Grading the degree of arterial stenosis with CTA has also been shown to be highly accurate compared to digital subtraction imaging (DSA) as well as other imaging modalities, including US and MRA [29]. A negative or neutral oral contrast, such as low-density barium sulfate or water, has been advocated to distend the small bowel and better evaluate the bowel wall for thickening and enhancement; however this may not be possible in the acute setting [30]. Both arterial and portal venous phases should be included as part of the protocol to assess both arterial and venous patency [25,30,31]. Three-dimensional (3-D) rendering may also assist in evaluating the vasculature and should be performed [24,32]. A noncontrast phase is typically obtained as part of the CTA and may be helpful in identifying intramural hemorrhage, atherosclerotic calcifications, and to serve as baseline for assessing wall enhancement; however, several studies have shown that obtaining the noncontrast phase may not be required for accurate acute ischemia diagnosis [25,31,33-35]. CT imaging of the abdomen and pelvis also allows accurate evaluation of the entire gastrointestinal and genitourinary tract, helping to exclude most of the other causes of acute and chronic abdominal pain, including cholelithiasis, cholecystitis, pancreatitis, appendicitis, diverticulosis with or without diverticulitis, and nephrolithiasis.

Vascular CT findings include arterial stenosis, embolism, thrombosis, arterial dissection, and mesenteric vein thrombosis. Nonvascular CT findings include bowel-wall thickening, hypoperfusion and hypoattenuation, bowel dilatation, bowel-wall hemorrhage, mesenteric fat stranding, pneumatosis intestinalis, and portal venous gas.

Quantitative methods of assessing bowel enhancement may also add value in identifying ischemic bowel [36]. CTA is also preferred in patients with renal insufficiency with GFR under 30 who have suspected acute ischemia as benefits of a fast and accurate diagnosis will generally outweigh risks associated with potential risk of contrast-induced nephropathy [37,38]. Overall, CTA is an accurate technique for acute mesenteric ischemia diagnosis, with reported sensitivity and specificity as high as 93% to 100% and potential to improve patient survival [1,12,15,25,35,39-41].

CT

CT of the abdomen and pelvis with intravenous (IV) contrast performed during the venous phase has been less well studied compared with CTA in diagnosing mesenteric ischemia. CT with IV contrast can assess nonvascular findings, major arterial lesions, and mesenteric veins; however, the lack of arterial phase may lead to suboptimal evaluation of the mesenteric arteries compared to CTA [25,42]. Schieda et al [42] showed that CT during portal venous phase identified major arterial lesions, although several diagnostic errors occurred when relying on this phase only. Arterial phase influenced care in 19% of patients compared to portal venous phase alone in one study [25]. Because CT with IV contrast is typically performed with oral contrast as well, this additional step may potentially lead to delay in image acquisition and diagnosis. Therefore, CTA is preferred over CT with IV contrast during venous phase as the initial examination when mesenteric ischemia is suspected.

There is a lack of relevant literature regarding the use of CT without IV contrast in the evaluation of acute mesenteric ischemia. Nonvascular findings, such as bowel dilation, wall thickening, mesenteric fluid, pneumatosis, and portomesenteric gas, can be identified with a noncontrast CT; however, these tend to be nonspecific or found in more advanced ischemia with a worse prognosis [40,42]. Blachar et al [43] showed that there was worse performance for CT without IV contrast compared to CT with IV contrast, although this was not statistically significant. However, in the same study, the most significant signs of ischemia, arterial filling defects, and decreased bowel wall enhancement, relied on IV contrast, emphasizing the use of contrast when possible [25,31,43]. Similarly to CT with IV contrast, oral contrast administration may delay the examination if it is routinely performed.

CT without and with IV contrast is not indicated in the evaluation of suspected acute mesenteric ischemia.

MRA

Magnetic resonance angiography (MRA) of the abdomen and pelvis with IV contrast has high sensitivity and specificity for diagnosing severe stenosis or occlusion at the origins of the celiac axis and SMA [44-47]. However, it has a limited role in diagnosing distal stenosis as well as nonocclusive mesenteric ischemia, and its use may delay therapeutic options in acute settings because it is a long examination.

MRA is tailored to depict mesenteric vasculature and less likely to show ischemic findings within the bowel itself compared to CT, such as pneumatosis and portovenous gas; it is also unlikely to provide additional information in the acute setting if portal venous phase CT has already been performed [48]. MRA without contrast can be attempted in some cases; however, evaluation of smaller vessels may be suboptimal [46].

Arteriography

Angiography has been the reference standard to aid in diagnosis and preoperative planning in acute mesenteric ischemia, with sensitivity in the range of 74% to 100% and specificity of 100% [49-56]. Early angiography has shown to be associated with increased survival in patients with mesenteric ischemia and allows for initiation of therapeutic maneuvers [12]. Whether angiography should precede surgical intervention in the presence of peritoneal signs is controversial. Some would favor immediate surgery in this setting, as signs of peritonitis usually indicate infarcted bowel. However, others advocate early angiography because of the importance of determining the etiology of bowel ischemia and providing a "roadmap" for revascularization procedures [57].

In the past decade with the advances in technology, CTA supplanted conventional angiography as the first-line imaging technique for acute mesenteric ischemia, and angiography transitioned to complementary diagnostic role with an option of endovascular treatment for revascularization candidates [57-62]. Although there is a lack of Level I evidence demonstrating clear benefits of endovascular therapy compared to open surgery in patients with acute mesenteric ischemia, the available data from systematic reviews and case series show that the endovascular approach is becoming more common and is associated with decreased mortality and need for laparotomy [57-62]. Nonetheless, acute mesenteric ischemia is a vascular surgical emergency requiring immediate surgical evaluation and angiography should not be considered in patients with significant hypovolemia or hypotension. Urgent bowel reperfusion with the goal of infarction prevention is paramount and requires early diagnosis and involvement of

vascular surgery, interventional radiology, and intensive care unit who need to work collaboratively, guiding resuscitation efforts and future treatment.

US

The efficacy of ultrasound (US) in diagnosing acute mesenteric ischemia has been evaluated in many studies. US can demonstrate proximal mesenteric vessel thrombosis via Doppler mode and can be used in detecting proximal superior mesenteric and celiac artery stenosis with high sensitivity and specificity of 85% to 90% [63,64]. US may also reveal focal superior mesenteric or portal venous thrombosis in cases of venous occlusive ischemia [65]. Unfortunately, the presence of overlying bowel gas, obesity, and vascular calcifications are challenges for an adequate sonographic evaluation. In addition, duplex US has a limited role in detecting distal arterial emboli or in diagnosing nonocclusive mesenteric ischemia. Moreover, the length of the examination and the possible pain associated with the applied pressure to the abdomen during imaging may be limiting factors in initial evaluation of patients with suspected acute mesenteric ischemia [12,63,66].

Variant 2: Suspected chronic mesenteric ischemia. Initial Imaging.

In the setting of chronic mesenteric ischemia, patients classically present with the clinical triad of postprandial abdominal pain 30 to 60 minutes after food consumption, weight loss, and food avoidance. Nausea and vomiting, postprandial diarrhea, early satiety and signs of malabsorption may also be present [12]. In an elderly patient with an underlying atherosclerosis, history of weight loss, and early satiety, chronic mesenteric ischemia should be strongly considered [28]. As with acute ischemia, clinical evaluation alone is insufficient for making the diagnosis of chronic ischemia, and imaging plays a key role for this purpose [67].

Radiography

Radiography has little to no role in the diagnosis of chronic mesenteric ischemia because these patients have not yet developed bowel necrosis, and therefore the radiograph will likely be normal or demonstrate nonspecific findings. A negative radiograph also does not exclude the diagnosis of chronic mesenteric ischemia [19,57,68].

US

US with B-mode and Doppler waveform analysis is a useful initial screening tool for chronic mesenteric ischemia. Duplex is best performed in the fasting state and early in the day to avoid bowel gas as visualizing the mesenteric vessels with duplex US can be technically challenging. Peak systolic velocity has been widely used for diagnosing stenosis, with cutoff values providing highest overall accuracy for ≥50% and ≥70% of 295 cm/s and 400 cm/s for the SMA and 240 cm/s for the celiac artery, respectively [63].

CTA

CTA of the abdomen and pelvis has been shown to provide best accuracy and inter-reader agreement for grading mesenteric vessel stenosis compared to MRA and US, with sensitivity and specificity of 95% to 100% using DSA as a reference standard [29]. Moreover, CTA is an accurate diagnosing tool for detecting median arcuate ligament syndrome as a potential cause of chronic ischemia [7]. CTA can also accurately exclude other causes of chronic abdominal pain.

CT

CT of the abdomen and pelvis with IV contrast performed during the venous phase appears to provide satisfactory evaluation of major vascular pathology, such as atherosclerotic plaques and occlusions, although this has not been well studied [69].

There is a paucity of data regarding performance of CT without IV contrast for suspected chronic mesenteric ischemia. Although able to assess the extent calcified atherosclerotic plaque affects the mesenteric vasculature, CT without IV contrast is limited in its ability to evaluate noncalcified plaque and is therefore likely to underestimate the degree of stenosis. Additionally, calcified atherosclerotic plaque in the mesenteric vasculature is a common incidental finding in the elderly population and cannot be relied upon for accurate diagnosis of chronic mesenteric ischemia [24,26,33].

CT without and with IV contrast is not indicated in the evaluation of suspected chronic mesenteric ischemia.

MRA

MRA has become increasingly accurate in depicting and grading stenosis of the mesenteric vessels, particularly for the celiac artery and SMA, with reported sensitivity and specificity in suspected chronic mesenteric ischemia up to 95% to 100% [44-47]. Although MRA performs well in grading mesenteric vessel stenosis compared to

DSA, accuracy and interobserver agreement may be lower compared to CTA [68]. Obtaining high-resolution angiograms reliably remains challenging, with the relatively lower resolution compared to CTA potentially limiting evaluation of distal branches and the inferior mesenteric artery [70]. MRA without contrast may be used in some cases; however, assessment of smaller vessels may be suboptimal [46]. MRA also offers the possibility of measuring SMA and superior mesenteric vein flow, thereby allowing a functional assessment for intestinal ischemia [70].

Arteriography

Conventional angiography has historically been considered the reference standard test for diagnosing chronic bowel ischemia, with its therapeutic role allowing physicians performing endovascular procedures at time of diagnosis ischemia [57,71,72]. In the past decade with the advances in technology, CTA became the first-line imaging technique, and angiography transitioned to complementary diagnostic role with an option of endovascular treatment for revascularization candidates [58,60,61,66,73,74]. Moreover, endovascular therapy approach has surpassed open repair because of its high efficacy and lower rate of significant complications [61]. Because of restenosis, chronic mesenteric ischemia endovascular revascularization suffers from lower rates of long-term patency [59,62,75], and angiography can be used in guiding treatment selection [33,75]. Aortic occlusive disease and long lesions measuring ≥2 cm on angiography that are close to mesenteric takeoff have been found to be associated with endovascular revascularization failure [75].

Summary of Recommendations

- CTA abdomen and pelvis with IV contrast has been shown to provide best accuracy and inter-reader agreement for grading mesenteric vessel stenosis compared to MRA and US.
- CTA abdomen and pelvis with IV contrast is the recommended initial imaging examination for patients with suspected acute mesenteric ischemia.
- CTA abdomen and pelvis with IV contrast or MRA abdomen and pelvis without and with IV contrast is recommended as the initial imaging examination in patients with suspected chronic mesenteric ischemia.

Summary of Evidence

Of the 76 references cited in the *ACR Appropriateness Criteria® Imaging of Mesenteric Ischemia* document, 22 are categorized as therapeutic references including 1 well-designed study, 5 good-quality studies, and 4 quality studies that may have design limitations. Additionally, 51 references are categorized as diagnostic references including 2 well-designed studies, 10 good-quality studies, and 5 quality studies that may have design limitations. There are 46 references that may not be useful as primary evidence. There are 3 references that are meta-analysis studies.

The 76 references cited in the *ACR Appropriateness Criteria® Imaging of Mesenteric Ischemia* document were published from 1977 to 2016.

Although there are references that report on studies with design limitations, 18 well-designed or good-quality studies provide good evidence.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document [76].

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies".		

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

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