American College of Radiology
ACR Appropriateness Criteria®

Radiologic Management of Mesenteric Ischemia

Variant: 1 Recent onset abdominal pain, no peritoneal signs, and known atrial fibrillation. CTA shows filling defect in proximal SMA consistent with embolus. No intramural or extra-luminal air. Initial therapy.

Procedure	Appropriateness Category
Systemic anticoagulation	Usually Appropriate
Angiography and aspiration embolectomy	Usually Appropriate
Transcatheter thrombolysis	Usually Appropriate
Surgical embolectomy	May Be Appropriate

Variant: 2 Recent onset abdominal pain, no peritoneal signs, and known atrial fibrillation. CTA shows calcified atherosclerotic plaque involving the aorta and its major branches, as well as proximal short-segment occlusion of the proximal SMA. No intramural or extra-luminal air. Initial therapy.

Procedure	Appropriateness Category
Angiography and endovascular intervention including possible thrombolysis, angioplasty, or stent placement	Usually Appropriate
Systemic anticoagulation	Usually Appropriate
Surgical endarterectomy or bypass	May Be Appropriate

Variant: 3 Patient with cardiac disease causing low cardiac output who developed abdominal pain but without peritoneal signs. CTA shows patent origins and proximal portions of celiac artery, SMA, and IMA, with diffuse irregular narrowing of SMA branches. Initial therapy.

Procedure	Appropriateness Category
Angiography with infusion of vasodilator	Usually Appropriate
Systemic anticoagulation	Usually Appropriate
Systemic infusion of prostaglandin E1	May Be Appropriate
Angiography with percutaneous transluminal angioplasty	Usually Not Appropriate

Variant: 4 Recent onset abdominal pain, peritoneal signs, and known atrial fibrillation. CTA shows filling defect in the proximal SMA consistent with embolus and evidence of bowel infarction. Initial therapy.

Procedure	Appropriateness Category
Surgical revascularization	Usually Appropriate
Systemic anticoagulation	Usually Appropriate
Angiography and aspiration embolectomy	May Be Appropriate
Transcatheter thrombolysis	Usually Not Appropriate

Variant: 5 Abdominal pain after meals and CTA showing widely patent origins of SMA and IMA, with compression of the celiac origin by the median arcuate ligament. Initial therapy.

Procedure	Appropriateness Category
Surgery with median arcuate ligament release	Usually Appropriate
Mesenteric angiography in lateral projection during both inspiration and expiration	Usually Appropriate
Supportive measures only	May Be Appropriate
Percutaneous transluminal angioplasty with stent placement	May Be Appropriate
Systemic anticoagulation	Usually Not Appropriate

Variant: 6 History of abdominal pain after meals for the past few months and weight loss. CTA shows aortic atherosclerotic disease and suggests SMA-origin stenosis with occlusion of celiac origin and an occluded IMA. Initial therapy.

Procedure	Appropriateness Category
Angiography with possible percutaneous transluminal angioplasty and stent placement	Usually Appropriate
Surgical bypass or endarterectomy	May Be Appropriate
Systemic anticoagulation	May Be Appropriate

Variant: 7 Previously healthy with worsening diffuse abdominal pain for 2 weeks. CTA shows occlusion of the superior mesenteric vein and its major tributaries. Bowel appears normal. Serum lactate level is normal. Initial therapy.

Procedure	Appropriateness Category
Systemic anticoagulation	Usually Appropriate
Transhepatic superior mesenteric vein catheterization and pharmacomechanical thrombolysis	Usually Appropriate
Transjugular superior mesenteric vein catheterization and pharmacomechanical thrombolysis and TIPS	May Be Appropriate
SMA angiography followed by thrombolytic infusion	May Be Appropriate
Surgical thrombectomy	Usually Not Appropriate

Panel Members

Alexander Lam, MD[a]; Yoon-Jin Kim, MD[b]; Nicholas Fidelman, MD[c]; Mikhail C.S.S. Higgins, MD, MPH[d]; Brooks D. Cash, MD[e]; Resmi Charalel, [f]; Marcelo S. Guimaraes, MD[g]; Sharon W. Kwan, MD, MS[h]; Parag J. Patel, MD[i]; Sara Plett, MD[j]; Salvatore T. Scali, MD[k]; Kevin S. Stadtlander, MD[l]; Michael Stoner, MD[m]; Ricky T. Tong, MD, PhD[n]; Baljendra S. Kapoor, MD[o].

Summary of Literature Review

Introduction/Background

Mesenteric ischemia is a serious medical condition characterized by insufficient vascular supply to the small bowel. Delays in diagnosis and intervention can lead to life-threatening bowel infarction with associated mortality rates that approach 60% [1]. In the acute setting, patients classically present with severe abdominal pain that is often out of proportion to physical examination findings. When chronic, patients commonly report long-standing postprandial pain and fear of eating, with more of an indolent clinical presentation. The causes of mesenteric ischemia can be broadly divided into mesenteric arterial occlusion, including atherosclerotic disease, anatomical causes such as median arcuate ligament (MAL) syndrome, thromboembolism, and vasospasm, mesenteric venous occlusion, and global hypoperfusion, including hypotension and shock. In

conjunction with the clinical and laboratory findings, CT of the abdomen and pelvis should be performed in the noncontrast, arterial and portal venous phases. This triple-phase study is important for identifying the underlying cause of ischemia, evaluate for possible bowel complications, and exclude other potential diagnoses of acute abdominal pain. MR angiography (MRA), with and without contrast, can also be considered. However, MRA is limited in its ability to evaluate for ischemic bowel changes, such as pneumatosis or portal venous gas, when compared with CT (see the ACR Appropriateness Criteria® topic on "Imaging of Mesenteric Ischemia" [2]). In the case that an intervention in planned, imaging is also helpful in evaluating the target vessels for revascularization, the nature and degree of stenosis/occlusion, and possible approaches to arterial access. Intervention is targeted at rapid revascularization, and the preferred modality of intervention depends on chronicity, etiology, and degree of concern for bowel infarction.

Discussion of Procedures by Variant

Variant 1: Recent onset abdominal pain, no peritoneal signs, and known atrial fibrillation. CTA shows filling defect in proximal SMA consistent with embolus. No intramural or extra-luminal air. Initial therapy.

Arterial embolism is the most common etiology of acute mesenteric ischemia. The diagnosis should be suspected in a patient with sudden, severe abdominal pain and high thromboembolic risk [3]. In most cases of arterial embolism, CT angiography (CTA) will demonstrate an occlusive filling defect in the proximal superior mesenteric artery (SMA). Although the appearance of the affected bowel can vary depending on the degree of hypoperfusion and acuity, a thickened, edematous, and dilated small bowel with variable enhancement surrounded by free fluid is typically characteristic of underlying ischemic changes [3]. In addition to volume resuscitation, empiric antibiotic therapy, and anticoagulation, rapid restoration of inline arterial flow to the affected bowel is the primary goal of treatment to avoid potentially life-threatening complications [1,4].

Variant 1: Recent onset abdominal pain, no peritoneal signs, and known atrial fibrillation. CTA shows filling defect in proximal SMA consistent with embolus. No intramural or extra-luminal air. Initial therapy.
A. Angiography and aspiration embolectomy

Although it is well understood that revascularization is paramount to decreasing mortality and morbidity, randomized prospective trials comparing open surgery with endovascular interventions are lacking [4]. In addition to aspiration embolectomy, studies evaluating efficacy and safety of endovascular interventions also typically include transcatheter thrombolysis. Contemporary literature suggests that minimally invasive interventions are initially exhausted before pursuing operative management given lower morbidity, such as lower rates of bowel resection and acute renal failure, and high technical success rates up to 94% [1,5,6]. It is important to note, however, that as many as 70% of patients may need surgical intervention for bowel resection and/or diversion with or without any intervention [7].

Regarding differences in mortality, the literature comparing endovascular and surgical approaches remain mixed. Moreover, data limited to patients with acute mesenteric ischemia from embolic etiologies receiving aspiration embolectomy are limited. Rather, most studies combine group acute mesenteric ischemia from all etiologies together and all endovascular therapies (thrombectomy and thrombolysis). One retrospective study of 8 patients who received primary aspiration embolectomy had 100% survival at 12 months; all patients were also on anticoagulation therapy,

and 1 patient received transcatheter thrombolysis before embolectomy [8]. In a retrospective review involving 93 patients, no significant difference in 30-day mortality between surgical and endovascular approaches was found [9]. Another small retrospective study including 50 patients reported a 32% 30-day mortality in patients treated with either thrombectomy or thrombolysis [6]. The same study also modeled longer survival times and estimated 18% survival at 5-years for those undergoing endovascular therapy [6]. Further subcategorization of mortality was not performed. Taken together, the results of these small studies show a wide range of mortality data that can be difficult to interpret. However, larger cohort studies generally support improved short-term mortality rates with endovascular therapy compared with surgical management. For example, in a systematic review and meta-analysis including 3,362 patients, endovascular interventions were found to have a lower 30-day mortality (odds ratio, 0.45; 95% confidence interval [CI], 0.30-0.67; *P* = .0001) compared with surgical interventions [5].

Variant 1: Recent onset abdominal pain, no peritoneal signs, and known atrial fibrillation. CTA shows filling defect in proximal SMA consistent with embolus. No intramural or extra-luminal air. Initial therapy.

B. Surgical embolectomy

Based on the literature, surgical embolectomy was previously considered the treatment option of choice before the increased use of endovascular techniques. Randomized prospective trials comparing open surgery with endovascular interventions are lacking [4]. In a retrospective cohort study involving 918 patients, 30-day mortality after surgical embolectomy was approximately 35%, with higher mortality noted in patients requiring bowel resection (*P* < .01) [10]. The literature comparing endovascular and surgical approaches remain mixed, with multiple small retrospective studies reporting a wide range of results [6,8,9]. However, larger cohort studies generally support improved short-term mortality rates with endovascular therapy compared with surgical management. For example, in a systematic review and meta-analysis including 3,362 patients, endovascular interventions were found to have a lower 30-day mortality (odds ratio, 0.45; 95% CI, 0.30-0.67; *P* = .0001) compared with surgical interventions [5].

Variant 1: Recent onset abdominal pain, no peritoneal signs, and known atrial fibrillation. CTA shows filling defect in proximal SMA consistent with embolus. No intramural or extra-luminal air. Initial therapy.

C. Systemic anticoagulation

The importance of prompt initiation of systemic anticoagulation is well established [1,4]. According to the European Society of Vascular Surgery, anticoagulation is not a surrogate for revascularization and should be started in conjunction with developing a definitive treatment plan [3]. The purpose of anticoagulation is to prevent further clot propagation and, therefore, may not be an isolated therapy for acute, occlusive mesenteric ischemia.

Variant 1: Recent onset abdominal pain, no peritoneal signs, and known atrial fibrillation. CTA shows filling defect in proximal SMA consistent with embolus. No intramural or extra-luminal air. Initial therapy.

D. Transcatheter thrombolysis

There are no randomized, prospective studies comparing aspiration embolectomy and transcatheter thrombolysis, with the decision regarding the endovascular technique of choice primarily driven by institutional preference. Although a comprehensive review suggests that transcatheter thrombolysis may be considered if aspiration embolectomy fails, a few retrospective studies have been published from institutions performing thrombolysis rather than embolectomy

without clear explanation for treatment modality [4,7,11,12]. More commonly, thrombolysis has been described as an adjunct to aspiration embolectomy [7]. One retrospective study did note that 1 patient out of 8 with worse overall clinical status preferentially underwent thrombolysis [8].

Variant 2: Recent onset abdominal pain, no peritoneal signs, and known atrial fibrillation. CTA shows calcified atherosclerotic plaque involving the aorta and its major branches, as well as proximal short-segment occlusion of the proximal SMA. No intramural or extra-luminal air. Initial therapy.

Differentiating between acute mesenteric vascular compromise caused by embolic or thrombotic phenomena can be challenging. Acute on chronic thrombosis generally refers to abrupt occlusion of a previously stenotic proximal SMA. This can be due to either in situ plaque rupture or emboli from atheromatous disease above the site of occlusion. Often concomitant calcific atherosclerosis with ostial narrowing involving the celiac and inferior mesenteric arteries (IMA) is present, further increasing the risk of bowel ischemia and infarction due to limited compensatory collateral arterial supply.

Variant 2: Recent onset abdominal pain, no peritoneal signs, and known atrial fibrillation. CTA shows calcified atherosclerotic plaque involving the aorta and its major branches, as well as proximal short-segment occlusion of the proximal SMA. No intramural or extra-luminal air. Initial therapy.

A. Angiography and endovascular intervention including possible thrombolysis, angioplasty, or stent placement

Endovascular therapy has virtually replaced open revascularization techniques in patients with acutely worsening chronic mesenteric ischemia [13]. Regarding differences in mortality, the literature comparing endovascular and surgical approaches remains mixed. Moreover, data in the literature specific to patients with acute vascular compromise from thrombotic etiologies are also limited. Contemporary literature suggests that minimally invasive interventions are initially exhausted before pursuing operative management given lower morbidity, such as lower rates of bowel resection and acute renal failure, and high rates of technical success up to 94% [1,5,6]. It is important to note, however, that approximately 70% of patients may need surgical intervention for bowel resection and/or diversion with or without intervention [7].

In the setting of acute thrombosis, primary endovascular intervention with percutaneous angioplasty and stent placement following restoration of mesenteric flow with thrombolytic therapy has been shown to have a technical success rate of up to 94% and 30-day survival of approximately 58%, an acceptable rate given the high mortality rate historically associated with the disease [6,14]. In a prospective population and registry-based cohort study in Denmark, 67 patients with acute or chronic mesenteric ischemia underwent primary endovascular repair with 5-year follow-up. The 1- and 3-year survival rates were 67% and 54%, respectively. Reintervention in this population was low, with only 1 patient requiring reintervention at 423 days, and 30 patients (45%) required bowel resection [13].

Variant 2: Recent onset abdominal pain, no peritoneal signs, and known atrial fibrillation. CTA shows calcified atherosclerotic plaque involving the aorta and its major branches, as well as proximal short-segment occlusion of the proximal SMA. No intramural or extra-luminal air. Initial therapy.

B. Surgical endarterectomy or bypass

Endovascular therapy has largely replaced open revascularization techniques as the intervention of

choice in patients with acute or chronic mesenteric ischemia [13]. In this patient population, endovascular approaches have been shown to reduce morbidity and mortality compared with surgical approaches, with no significant difference in short- and long-term survival between the 2 treatments. For example, in a retrospective database study involving 4,665 patients with acute mesenteric ischemia, mortality was lower (24.9% compared with 39.3%, $P = .01$), length of hospital stay was shorter (12.9 versus 17.1, $P = .006$), need for total parenteral nutrition was lower (13.7% compared with 24.4%, $P = .025$), and rates of bowel resection were lower (14.4% compared with 33.4%, $P < .001$) in patients undergoing endovascular repair compared with those who received open revascularization. Of note, this study did not differentiate the etiology of acute mesenteric ischemia [15].

Variant 2: Recent onset abdominal pain, no peritoneal signs, and known atrial fibrillation. CTA shows calcified atherosclerotic plaque involving the aorta and its major branches, as well as proximal short-segment occlusion of the proximal SMA. No intramural or extra-luminal air. Initial therapy.

C. Systemic anticoagulation

The importance of prompt initiation of systemic anticoagulation is well established [1,4]. According to the European Society of Vascular Surgery, anticoagulation is not a surrogate for revascularization and should be started in conjunction with developing a definitive treatment plan. The purpose of anticoagulation is to prevent further clot propagation and is not an isolated therapy for acute on chronic mesenteric ischemia due to thrombus.

Variant 3: Patient with cardiac disease causing low cardiac output who developed abdominal pain but without peritoneal signs. CTA shows patent origins and proximal portions of celiac artery, SMA, and IMA, with diffuse irregular narrowing of SMA branches. Initial therapy.

Nonocclusive mesenteric ischemia is a hypoperfusion syndrome thought to result from a combination of low cardiac output and persistent vasoconstriction typically seen in critically ill patients in shock, with severe heart failure, or with postoperative stress [4,16]. Mortality is relatively high in comparison with acute, occlusive mesenteric ischemia, ranging between 30% and 93%, at least in part due to delays in clinical diagnosis and intervention. Diagnosis on imaging can be equally challenging given the difficulty with detecting vasospasm on CTA of the mesenteric arterial branches. Pertinent negative findings, such as vessel patency and lack of underlying atherosclerotic disease, are helpful to exclude occlusive etiologies of ischemia. Additionally, CT is useful in evaluating the degree of bowel involvement, which can present as segmental and discontinuous wall thickening and hypoenhancement. Angiographic findings may include a beaded appearance of the affected mesenteric vessels, with narrowing of multiple small branches consistent with vessel spasm [3].

Variant 3: Patient with cardiac disease causing low cardiac output who developed abdominal pain but without peritoneal signs. CTA shows patent origins and proximal portions of celiac artery, SMA, and IMA, with diffuse irregular narrowing of SMA branches. Initial therapy.

A. Angiography with infusion of vasodilator

The primary treatment options described in the literature are focused on relieving mesenteric arterial vasospasm with intra-arterial therapy. However, there is a paucity of high-level evidence, mostly consisting of small case series and retrospective studies to guide intervention [4]. The largest study to date included 66 patients and compared intra-arterial papaverine with conservative therapy. In this study, patients who received papaverine therapy had significantly lower 30-day mortality at 65.7%, compared with 96.8% of those who received supportive therapy

only [17]. Additionally, the time from CT to vasodilator infusion was a significant contributor to patient survival at 1-month in a retrospective study of 21 patients [18]. In the setting of peritoneal signs, exploratory laparotomy should be considered to resect necrotic bowel, in line with recommendations from the World Society of Emergency Surgery [19].

Variant 3: Patient with cardiac disease causing low cardiac output who developed abdominal pain but without peritoneal signs. CTA shows patent origins and proximal portions of celiac artery, SMA, and IMA, with diffuse irregular narrowing of SMA branches. Initial therapy.
B. Angiography with percutaneous transluminal angioplasty

There are no data to support transluminal angioplasty as the primary treatment for patients with nonocclusive mesenteric ischemia.

Variant 3: Patient with cardiac disease causing low cardiac output who developed abdominal pain but without peritoneal signs. CTA shows patent origins and proximal portions of celiac artery, SMA, and IMA, with diffuse irregular narrowing of SMA branches. Initial therapy.
C. Systemic anticoagulation

There are no data to support systemic anticoagulation in patients with nonocclusive mesenteric ischemia as the primary treatment regimen. However, it may be reasonable to consider systemic anticoagulation in the setting of decreased cardiac output with a low flow state.

Variant 3: Patient with cardiac disease causing low cardiac output who developed abdominal pain but without peritoneal signs. CTA shows patent origins and proximal portions of celiac artery, SMA, and IMA, with diffuse irregular narrowing of SMA branches. Initial therapy.
D. Systemic infusion of prostaglandin E1

A few studies have evaluated the use of intra-arterial prostaglandin E1 therapy. The largest retrospective study to date evaluated 32 patients with nonocclusive mesenteric ischemia, 11 of whom received intra-arterial prostaglandin therapy. Although the study did not demonstrate a survival benefit in the intervention group, the authors reported a significant improvement in organ function 24 hours after initiation of therapy [20].

Variant 4: Recent onset abdominal pain, peritoneal signs, and known atrial fibrillation. CTA shows filling defect in the proximal SMA consistent with embolus and evidence of bowel infarction. Initial therapy.

In patients with evidence of bowel infarction and peritonitis secondary to mesenteric vascular compromise, reperfusion remains the primary therapeutic goal, followed closely by surgical intervention to evaluate the severity and extent of small bowel ischemia that would necessitate resection and reconstruction. As such, solely endovascular options are limited in this patient population. CT findings that should prompt immediate surgical intervention include lack of bowel wall enhancement, free intraperitoneal air, pneumatosis intestinalis, and portal venous gas [3].

Variant 4: Recent onset abdominal pain, peritoneal signs, and known atrial fibrillation. CTA shows filling defect in the proximal SMA consistent with embolus and evidence of bowel infarction. Initial therapy.
A. Angiography and aspiration embolectomy

Endovascular therapy alone has a limited role in patients exhibiting clinical or imaging signs of bowel necrosis, given the anticipated need for laparotomy and possible bowel resection. However, in the setting of clinical instability necessitating emergent intervention, intraoperative SMA angiography with endovascular revascularization can be used as an adjunctive diagnostic and therapeutic procedure. It is imperative that adjunctive interventions be performed in a hybrid procedural suite with minimal delay in

definitive surgical management.

Variant 4: Recent onset abdominal pain, peritoneal signs, and known atrial fibrillation. CTA shows filling defect in the proximal SMA consistent with embolus and evidence of bowel infarction. Initial therapy.
B. Surgical revascularization

To limit the degree of intestinal injury, prompt surgical intervention is necessary in patients with signs of peritonitis [4]. At the time of surgery, revascularization, either through endovascular techniques or surgical conduits, can be performed to manage the underlying cause of ischemia. A recent multicenter study has reported feasibility with open, retrograde SMA stenting in 25 patients with acute mesenteric ischemia. The authors report a 30-day operative mortality rate of 25%, an overall 1-year survival rate of 65%, and a 1-year primary patency rate of 92% [21].

Variant 4: Recent onset abdominal pain, peritoneal signs, and known atrial fibrillation. CTA shows filling defect in the proximal SMA consistent with embolus and evidence of bowel infarction. Initial therapy.
C. Systemic anticoagulation

The importance of prompt initiation of systemic anticoagulation is well established [1,4]. According to the European Society of Vascular Surgery, anticoagulation is not a surrogate for revascularization and should be started in conjunction with developing a definitive treatment plan. The purpose of anticoagulation is to prevent further clot propagation and is not a therapy for acute mesenteric ischemia due to thrombus.

Variant 4: Recent onset abdominal pain, peritoneal signs, and known atrial fibrillation. CTA shows filling defect in the proximal SMA consistent with embolus and evidence of bowel infarction. Initial therapy.
D. Transcatheter thrombolysis

Endovascular therapy alone has a limited role in a patient with clinical or imaging signs of bowel infarction. Adjunctive thrombolysis can be used in certain circumstances in which residual clot remains in the arterial bed following embolectomy, particularly after careful consideration of the peri- and postoperative risks of hemorrhage.

Variant 5: Abdominal pain after meals and CTA showing widely patent origins of SMA and IMA, with compression of the celiac origin by the median arcuate ligament. Initial therapy.

The MAL is a fibrous arch that connects the right and left diaphragmatic crura. External compression of the proximal celiac artery by the MAL is present in approximately 20% of the population [22]. Although the link between abdominal pain and MAL compression can be debated, the proposed pathophysiology is thought secondary to compromise of the celiac axis and irritation of the celiac plexus leading to abdominal pain and bowel ischemia. Diagnosis is typically made with a combination of clinical findings, such as abdominal pain, nausea, and vomiting that worsens meals, as well as imaging findings, including a proximal narrowing of the celiac artery in a "J-shaped" configuration.

Variant 5: Abdominal pain after meals and CTA showing widely patent origins of SMA and IMA, with compression of the celiac origin by the median arcuate ligament. Initial therapy.
A. Mesenteric angiography in lateral projection during both inspiration and expiration

Diagnostic catheter angiography may be performed to aid in diagnosis with lateral views of the origin of the celiac artery showing dynamic worsening of the stenosis on expiration. Angiography may also identify mesenteric collateralization, which may help with patient selection. One

retrospective study showed that patients with collateralization on angiography were less likely to benefit from surgical release of the MAL than those without angiographic collateralization [23].

Variant 5: Abdominal pain after meals and CTA showing widely patent origins of SMA and IMA, with compression of the celiac origin by the median arcuate ligament. Initial therapy. B. Percutaneous transluminal angioplasty with stent placement

Given the persistence of underlying extrinsic compression and chronic changes to the vessel wall from repeated stress, the literature commonly suggests that endovascular intervention alone without surgical release of the MAL may not be as effective as an intervention accompanied by surgical release [24-27]. Endovascular placement of a stent within the celiac artery after surgical release of the ligament may be performed if there is residual stenosis of the celiac artery of >30% [22]. There are no comparative studies evaluating outcomes in patients who do and do not receive additional stenting with residual stenosis. However, a multidisciplinary approach advocating stenting or surgical bypass as needed following surgical release suggests high rates of symptomatic relief of 75% and freedom from reintervention of 64% at 6 months [28].

Variant 5: Abdominal pain after meals and CTA showing widely patent origins of SMA and IMA, with compression of the celiac origin by the median arcuate ligament. Initial therapy. C. Supportive measures only

Nonoperative approaches to MAL syndrome include counseling, analgesia, and dietary modifications. There are no prospective studies comparing surgical and nonsurgical treatment methods, and even descriptive reports are limited. In a retrospective study of 67 patients, 24 were managed nonoperatively with a mix of approaches [29]. A third of these patients reported improvement in symptoms compared with 93% of patients who received operative management. Statistical significance was not determined because this was not the purpose of this study.

Variant 5: Abdominal pain after meals and CTA showing widely patent origins of SMA and IMA, with compression of the celiac origin by the median arcuate ligament. Initial therapy. D. Surgery with median arcuate ligament release

The literature indicates that surgical release of the MAL is beneficial and has been associated with symptomatic relief in 84.6% of patients in a small study of 39 patients [22,30]. Subsequent reconstruction of the celiac artery, with either endovascular stent placement or surgical bypass creation, may be necessary to provide complete symptomatic relief, restore normal hemodynamics, and prevent the development of splanchnic artery aneurysms in the setting of recurrent symptoms or persistent celiac stenosis. Such an approach was noted to result in complete resolution of symptoms in 75% of patients at 6 months [28]. A study evaluating long-term outcomes in 44 patients who received operative management for MAL syndrome reported persistent resolution of clinical symptoms in 76% of patients who underwent some form of revascularization, such as primary reanastomosis or interposition grafting, in addition to decompression, compared with 53% of patients who received decompression alone [31]. However, whether or not to reconstruct the celiac artery remains debatable. A retrospective study was performed of 31 patients who underwent surgical release of the MAL, 14 of whom also underwent vascular reconstruction. No significant difference in symptom relief (P = .72) or reintervention rates (P = 0.26) between the 2 groups was found at 5-year follow-up [32].

Variant 5: Abdominal pain after meals and CTA showing widely patent origins of SMA and IMA, with compression of the celiac origin by the median arcuate ligament. Initial therapy. E. Systemic anticoagulation

Limited data is available to recommend systemic anticoagulation in patients with MAL compression with no evidence of thrombosis.

Variant 6: History of abdominal pain after meals for the past few months and weight loss. CTA shows aortic atherosclerotic disease and suggests SMA-origin stenosis with occlusion of celiac origin and an occluded IMA. Initial therapy.

Chronic mesenteric ischemia most commonly occurs in the setting of severe, occlusive atherosclerotic disease involving the celiac axis and mesenteric arteries. Patients typically report insidious onset of postprandial pain, fear of eating, and weight loss. Severe ostial narrowing or occlusion of at least 2, if not 3, of the mesenteric arteries is the most characteristic finding on imaging. With the rich vascular supply to the bowel, patients often do not present with symptoms until severe vascular compromise is present. Although CT findings can often overlap with those of acute ischemia, the presence of extensive arterial collaterals, pre-existing atherosclerotic disease, and long-standing symptoms are compatible with chronic mesenteric ischemia [3].

Variant 6: History of abdominal pain after meals for the past few months and weight loss. CTA shows aortic atherosclerotic disease and suggests SMA-origin stenosis with occlusion of celiac origin and an occluded IMA. Initial therapy.
A. Angiography with possible percutaneous transluminal angioplasty and stent placement

Revascularization should be offered in all symptomatic patients. Endovascular therapy is associated with high technical success, ranging between 85% to 100% in the setting of stent placement [33]. Specific techniques that have been shown to increase success of endovascular revascularization include the prioritization of treatment of the SMA and the use of covered balloon-expandable stents [34-36]. Although there are more long-term data supporting open surgical treatment with bypass and endarterectomy, endovascular therapies are now favored over open surgical intervention in most patients because of lower perioperative risks [37,38]. In a large propensity-matched cohort study, in-hospital complications were lower in patients receiving endovascular therapy compared with those receiving surgical therapy (P = .006) [38]. Similarly, in a meta-analysis of 100 observational studies including 18,726 patients, surgical approaches had a higher risk of in-hospital complications (relative risk, 2.2; 95% CI, 1.8-2.6) [39]. However, endovascular therapy has been associated with increased rates of peripheral vascular complications, restenosis, recurrent symptoms, and reinterventions, with access site complications being the most common [33,40].

The 30-day mortality of patients receiving either treatment approach has been shown to be similar [39,40]. However, overall survival at 5 years was higher in patients undergoing open repair (P = .0001), even in high-risk patients (P < .04), in a retrospective study of 229 patients [40]. In a prospective population and registry-based cohort study with 5-year follow-up in Denmark, 178 patients underwent endovascular repair first with symptomatic chronic mesenteric ischemia. The 1- and 3-year survival estimates were 85% and 74%, respectively [13]. Evaluation of survival following surgical management was not performed.

Variant 6: History of abdominal pain after meals for the past few months and weight loss. CTA shows aortic atherosclerotic disease and suggests SMA-origin stenosis with occlusion of celiac origin and an occluded IMA. Initial therapy.
B. Surgical bypass or endarterectomy

Although there are more long-term data supporting open surgical treatment with bypass and endarterectomy, endovascular therapies are now favored over open surgical intervention in most patients because of lower perioperative risks and complications [37,38]. For example, in Denmark,

only 14 patients in a recent 5-year period have had open revascularization (for acute and chronic indications), and the majority were performed for failure of endovascular treatment [13]. In a propensity-matched cohort study, inpatient complications were significantly less with endovascular interventions ($P < .006$) and shorter hospital admissions ($P < .001$) compared with open surgical revascularization [38]. Because of the established safety and efficacy associated with minimally invasive interventions in relation to surgical management, endovascular revascularization is favored as the initial treatment for patients with chronic mesenteric ischemia in practice guidelines set by the Society for Vascular Surgery based on a meta-analysis of 100 observational studies [37].

Variant 6: History of abdominal pain after meals for the past few months and weight loss. CTA shows aortic atherosclerotic disease and suggests SMA-origin stenosis with occlusion of celiac origin and an occluded IMA. Initial therapy.

C. Systemic anticoagulation

There are no data to support systemic anticoagulation in patients with chronic mesenteric ischemia before revascularization [37].

Variant 7: Previously healthy with worsening diffuse abdominal pain for 2 weeks. CTA shows occlusion of the superior mesenteric vein and its major tributaries. Bowel appears normal. Serum lactate level is normal. Initial therapy.

Mesenteric vein thrombosis is the least common cause of acute mesenteric ischemia and can result from an underlying prothrombotic condition, local vessel wall injury, or venous stasis [4]. Mesenteric venous obstruction initially leads to congestion and bowel distention, with eventual arterial compromise and ischemia. Although it is nonspecific, patients are more likely to present with subacute, rather than acute, abdominal pain. In the acute phase, contrast-enhanced CT or MRI venography may demonstrate expansile filling defects with peripheral enhancement of the obstructed mesenteric-portal veins. Mesenteric venous engorgement, fat-stranding, and edema may also be seen. Although nonspecific, hyperenhancement of the serosal and mucosal surfaces of the bowel resulting in a targetoid appearance can also be seen in the setting of infarction [3].

Variant 7: Previously healthy with worsening diffuse abdominal pain for 2 weeks. CTA shows occlusion of the superior mesenteric vein and its major tributaries. Bowel appears normal. Serum lactate level is normal. Initial therapy.

A. SMA angiography followed by thrombolytic infusion

Initiation of systemic anticoagulation is the mainstay of treatment for mesenteric venous occlusion. In patients who demonstrate failure with anticoagulation, indirect thrombolytic infusion into the mesenteric veins via a SMA infusion can be considered as adjunctive therapy. A recent study evaluating the role of adjuvant catheter directed thrombolysis via the SMA in 32 patients with acute superior mesenteric vein thrombosis who underwent surgical thrombectomy found significantly higher rates of complete thrombus removal (80% versus 29%), lower rates of repeat laparotomy and bowel resection (71% versus 20%), and significantly higher survival at 1 year (93% versus 53%), at the cost of higher rates of massive abdominal hemorrhage (20% versus 12%) [41]. A study of 46 patients with superior mesenteric vein thrombosis who underwent either direct or indirect thrombolysis suggests lower rates of thrombus removal and clinical improvement with indirect thrombolysis compared with direct thrombolysis [42].

Variant 7: Previously healthy with worsening diffuse abdominal pain for 2 weeks. CTA shows occlusion of the superior mesenteric vein and its major tributaries. Bowel appears normal. Serum lactate level is normal. Initial therapy.

B. Surgical thrombectomy

No large prospective trials evaluating surgical thrombectomy in the setting of mesenteric venous occlusion are present. Surgical thrombectomy is technically challenging and can be considered in patients meeting criteria for laparotomy, such as those with evidence of hemodynamic instability, peritonitis, and/or bowel infarction where surgical resection of necrotic bowel and primary anastomosis is anticipated [4]. A hybrid approach to surgical and endovascular management has also been described with thrombolytic infusion via an intraoperatively placed infusion catheter within the middle colic vein during surgery [43]. This approach may facilitate venous recanalization and limit the extent of bowel infarction while bowel viability is assessed.

Variant 7: Previously healthy with worsening diffuse abdominal pain for 2 weeks. CTA shows occlusion of the superior mesenteric vein and its major tributaries. Bowel appears normal. Serum lactate level is normal. Initial therapy.

C. Systemic anticoagulation

There are no randomized controlled trials to guide therapy for mesenteric vein occlusion. Moreover, there are only case reports and small patient series comparing the various endovascular therapies. Medical therapy with anticoagulation alone is considered the standard of care for most patients and leads to >80% recanalization rates [4]. However, a recanalization rate of 38% at 1 year was reported in a multicenter study of 102 patients with portal venous thrombosis treated with anticoagulation. For patients with splenic or mesenteric venous thrombosis, the recanalization rate was higher at 61% [44]. Despite treatment, 40% of patients were noted to develop cavernous transformation of the portal vein at the conclusion of follow-up.

Variant 7: Previously healthy with worsening diffuse abdominal pain for 2 weeks. CTA shows occlusion of the superior mesenteric vein and its major tributaries. Bowel appears normal. Serum lactate level is normal. Initial therapy.

D. Transhepatic superior mesenteric vein catheterization and pharmacomechanical thrombolysis

Patients with high-risk features such as extensive clot burden and ascites, or demonstrating signs of treatment failure, may be considered for catheter-directed thrombolytic therapy with or without mechanical thrombolysis via transhepatic or transjugular access [4,45,46]. A study of 20 patients with symptomatic, subacute portal and/or mesenteric venous thrombosis was notable for symptomatic resolution in 85% of patients. In this study, 60% of patients had major complications, including bleeding, septic shock, and gastrointestinal hemorrhage [47]. A transjugular route allows for the creation of a transjugular intrahepatic portosystemic shunt (TIPS) to augment antegrade mesenteric-portal flow, promote clearance of portal thrombosis, and preserve patency, particularly in patients with cirrhosis [4,48].

Variant 7: Previously healthy with worsening diffuse abdominal pain for 2 weeks. CTA shows occlusion of the superior mesenteric vein and its major tributaries. Bowel appears normal. Serum lactate level is normal. Initial therapy.

E. Transjugular superior mesenteric vein catheterization and pharmacomechanical thrombolysis and TIPS

Guidance in the literature surrounding when to place a TIPS versus when to perform catheter directed thrombolysis alone is lacking. However, in patients with acute portal vein thrombus, TIPS in combination with thrombolysis has been shown to be 70% effective in achieving complete clot resolution with associated resolution of patient symptoms [45]. TIPS alone may be considered if intraprocedural venogram demonstrates robust anterograde portomesenteric flow [45].

Summary of Highlights

- **Variant 1:** Systemic anticoagulation, angiography and aspiration embolectomy, and transcatheter thrombolysis are usually appropriate as an initial therapy for a patient with recent onset abdominal pain, no peritoneal signs, and known atrial fibrillation. The patient's CTA shows filling defect in proximal SMA consistent with embolus and no intramural or extraluminal air. These procedures are complementary (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).
- **Variant 2:** Angiography and endovascular intervention (including possible thrombolysis, angioplasty, or stent placement) and systemic anticoagulation are usually appropriate as an initial therapy for a patient with recent onset abdominal pain, no peritoneal signs, and known atrial fibrillation. The patient's CTA shows calcified atherosclerotic plaque involving the aorta and its major branches, as well as proximal short-segment occlusion of the proximal SMA and no intramural or extraluminal air. These procedures are complementary (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).
- **Variant 3:** Angiography with infusion of vasodilator is usually appropriate as an initial therapy for a patient with cardiac disease and low cardiac output who developed abdominal pain but without peritoneal signs. CTA shows diffuse irregular narrowing of multiple distal SMA branches with otherwise preserved patency of the celiac axis, SMA, and IMA origins. Although there are limited data to support systemic anticoagulation as the primary treatment regimen, it may be reasonable to consider as adjunctive therapy in the setting of decreased cardiac output with a low flow state. These procedures are complementary (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).
- **Variant 4:** Surgical revascularization is usually appropriate as an initial therapy for a patient with recent onset abdominal pain, peritoneal signs, and known atrial fibrillation. CTA shows a filling defect in the proximal SMA consistent with embolus and evidence of bowel infarction. Although systemic anticoagulation is usually appropriate as adjunctive therapy to decrease further propagation of clot, anticoagulation should not be administered without a definitive plan for surgery and revascularization. These procedures are complementary (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).
- **Variant 5:** Diagnostic mesenteric angiography (in lateral projection during inspiration and expiration) and MAL release are usually appropriate as an initial therapy for a patient with abdominal pain after meals and CTA showing compression of the celiac axis by the MAL and otherwise patent SMA and IMA origins. These procedures are complementary (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).
- **Variant 6:** Angiography with possible percutaneous transluminal angioplasty and stent placement is usually appropriate as an initial therapy for a patient with a history of abdominal pain after meals for several months with associated weight loss. The patient's CTA shows aortic atherosclerotic disease and stenosis of the SMA origin with occlusion of celiac origin and an occluded IMA secondary to mural plaque.
- **Variant 7:** Systemic anticoagulation and transhepatic superior mesenteric vein catheterization with pharmacomechanical thrombolysis are usually appropriate as an initial

therapy for a previously healthy patient with worsening diffuse abdominal pain for 2 weeks. The patient's CTA shows occlusion of the superior mesenteric vein and its major tributaries. Bowel appears normal. Serum lactate level is normal. These procedures are complementary (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents, please go to the ACR website at https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria.

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.

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Disclaimer

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or

treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

[a]University of California San Francisco, San Francisco, California. [b]Research author, University of California San Francisco, San Francisco, California. [c]Panel Chair, University of California San Francisco, San Francisco, California. [d]Panel Vice-Chair, Boston University School of Medicine, Boston, Massachusetts. [e]University of Texas Health Science Center at Houston and McGovern Medical School, Houston, Texas; American Gastroenterological Association. [f g]Medical University of South Carolina, Charleston, South Carolina. [h]University of Utah Health, Salt Lake City, Utah. [i]Froedtert & The Medical College of Wisconsin, Milwaukee, Wisconsin. [j]Southwest Medical Imaging, Scottsdale, Arizona. [k]University of Florida, Gainesville, Florida; Society for Vascular Surgery. [l]Cleveland Clinic Florida, Weston, Florida. [m]University of Rochester Medical Center, Rochester, New York; Society for Vascular Surgery. [n]Main Line Health, Bryn Mawr, Pennsylvania. [o]Specialty Chair, Cleveland Clinic, Cleveland, Ohio.