Acute and Chronic Mesenteric Ischemia
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Although advances in diagnostic imaging, surgical technique, asepsis, and antibiotics have improved outcomes in most surgical diseases over the last several decades, mesenteric ischemia remains a highly morbid condition. Fortunately it remains a rare occurrence, accounting for less than 1 in every 1000 hospital admissions [1]. Likewise, mortality rates remain elevated at 30% to 90%, depending on the etiology [2–6], and may in fact be even higher if deaths in patients who have undiagnosed mesenteric ischemia are considered. In one review, only one third of patients who had acute mesenteric ischemia were correctly diagnosed before surgical exploration or death [5]. Another review of autopsy cases in Sweden suggested true mortality rates may exceed 90% for mesenteric ischemia, and in only 33% was the diagnosis even considered before death [7]. Despite its relative infrequency, the high morbidity and mortality rates thus underscore the need for surgeons to be acutely aware of the presentation and management of this disease process.

Mesenteric ischemia occurs when visceral tissues receive inadequate blood flow. This may be a consequence of an arterial embolus or thrombosis, venous thrombosis limiting arterial inflow, or even extrinsic compression of mesenteric vessels. Smooth muscle tone within the mesenteric vessels is heavily autoregulated, increasing splanchnic blood flow after a large meal from 10% of cardiac output at rest to up to 35% [8]. When demand exceeds the capacity of the mesenteric circulation because of intrinsic or extrinsic lesions, the bowel becomes ischemic, with the mucosa being most vulnerable to inadequate blood flow.

The diagnosis of mesenteric ischemia is often one of exclusion, made after eliminating more common possibilities. Patients most often present with abdominal pain, unfortunately a vague complaint common to scores of other diagnoses. Other associated symptoms, such as nausea, vomiting,
diarrhea, and bloating may also be present in various combinations \[5,9,10\], although their presence is likewise nonspecific. The differential diagnosis in patients presenting with these symptoms thus remains broad and includes ulcer disease, bowel obstruction, complications of cholelithiasis, pancreatitis, inflammatory bowel disease, appendicitis, diverticulitis, or simply gastrointestinal disease. Elevated anion gap, elevated lactate levels, and leukocytosis may be found on laboratory analysis. Elevated lactate levels, a reflection of ongoing anaerobic metabolism, is suggestive of an ischemic process. Like most other laboratory studies that may be measured in the evaluation of a patient who has abdominal pain, however, it is not specific for mesenteric ischemia \[11\]. Additional information can then be garnered from primary diagnostic imaging modalities, including computed tomographic angiography (CTA), duplex ultrasonography, and magnetic resonance angiography (MRA). Although suspicion of bowel infarction mandates urgent surgical therapy directed at potential resection of nonviable bowel, the underlying etiology of mesenteric ischemia may be managed by open and endovascular techniques.

This article briefly reviews the various etiologies, presentation, and diagnosis of different types of mesenteric ischemia. Operative management techniques and the applicability of percutaneous endovascular intervention are discussed. Finally, the authors explore emerging technologies that have the potential to further improve diagnosis and treatment of this frequently lethal disease process.

**Types of mesenteric ischemia**

*Embolic*

Embolism to the visceral vessels is the most common cause of mesenteric ischemia, responsible for approximately 30% to 50% of cases \[3,12\]. Risk factors for visceral emboli include atrial fibrillation, myocardial infarction with subsequent impaired wall motion, and structural heart defects (ie, right-to-left shunts). The acute nature of embolic disease results in rapid progression of symptoms, because collateral blood supply is limited with acute occlusion. The acuity of the presentation in combination with frequent delays in diagnosis contributes to a high mortality rate, which averages 70% for visceral emboli in a review of several published reports \[2\]. The superior mesenteric artery (SMA) is more commonly involved than the celiac axis (CA) or inferior mesenteric artery (IMA) because of its less acute angle of takeoff from the aorta. Emboli typically lodge distal to the takeoff of the middle colic artery, sparing the duodenum and the transverse colon—a characteristic that can often help differentiate it from thrombosis that typically occurs more proximally \[11,13\]. The typical patient who has visceral ischemia from an embolic source reports the sudden onset of severe pain. Physical examination is often notable for the lack of guarding or peritoneal signs, so-called “pain out of proportion” to examination. Peritoneal findings may
occur late, following embolic occurrences, after the development of infarcted bowel, and typically portend worse outcomes. Despite the classic description, only one third of patients who have embolic disease present with the triad of abdominal pain, bloody stools, and fever associated with acute mesenteric ischemia [12]. Clearly mesenteric ischemia must be considered early, especially in patients who have risk factors for atherosclerotic disease, and should be worked up aggressively in those presenting with abdominal pain and other associated symptoms that do not rapidly conform to another diagnosis.

Thrombotic

Thrombosis of arterial mesenteric inflow accounts for only 15% to 30% of cases of mesenteric ischemia. It is the most morbid of the various types, however, with an accompanying 90% mortality in a review of several studies [2]. This high mortality rate has been postulated to be a consequence of proximal thromboses affecting a greater percentage of the overall bowel. One study attempting to correlate the length of bowel with the site of thrombosis or embolus in the SMA (proximal versus distal), however, found no association between the site of occlusion and length of nonviable bowel [13]. With regard to presenting symptoms, most patients suffering from acute mesenteric arterial thrombosis have a history of chronic mesenteric ischemia (CMI) [3,14], with symptoms of weight loss, abdominal pain, and food fear predating the acute episode of mesenteric ischemia.

Venous thrombosis accounts for a minority of cases but is associated with a mortality rate between 20% and 50% [15,16]. Although many cases are associated with cirrhosis or portal hypertension, other etiologies include malignancy, pancreatitis, oral contraceptive use, inheritable hypercoagulable states to include factor V Leiden, protein C deficiency, or prothrombin 20,210 mutation, and a history of recent surgery [4,12,16,17]. In fact, approximately half of patients presenting with venous thrombosis have had a deep venous thrombosis or pulmonary embolus in the past [16]. Presentations vary from acute to chronic, depending on the rapidity with which the clot develops. Pain is more prominent in acute thrombosis, and bowel infarction is more likely in this group. Those patients who have chronic thrombosis rarely have pain, and development of esophageal or gastric varices is far more likely than bowel infarction [4]. Most important, mesenteric venous thrombosis should be considered and ruled out early in patients who have a history of a venous thrombosis or other hypercoagulable states who present with abdominal pain.

Nonocclusive ischemia

In the absence of arterial or venous occlusion, mesenteric ischemia may still occur in low-flow states. As atherosclerosis remains a systemic disease,
those patients manifesting disease elsewhere often have plaque involving the SMA, IMA, and CA. In fact, autopsy studies suggest the prevalence of atherosclerotic involvement of these vessels is between 30% and 50% [18]. Clearly most of these patients are asymptomatic, because retrospective autopsy studies evaluating the cause of death suggest the incidence of mesenteric ischemia is less than 0.01% in the general population [19,20]. Other contributing factors to nonocclusive mesenteric ischemia include the use of vasopressors, digitalis, and cocaine, which have been documented to exacerbate ischemia in the setting of pre-existing lesions [3].

Patients who have CMI typically present with postprandial abdominal pain and associated weight loss, consistent with a supply-demand mismatch process. Women are more commonly affected than men, with the stereotypical patient suffering from mesenteric ischemia being a cachectic woman in her sixth to seventh decade of life. Physical examination may reveal an epigastric bruit in 48% to 63% of patients [18,21], indicative of turbulent flow through an area of vascular narrowing. A history of smoking, peripheral vascular disease, and hypertension is also frequently present [14,22]. In addition, patients may demonstrate evidence of gallbladder dysmotility, gastroparesis, or gastric ulcers as a reflection of disease in the CA [14].

Finally, although CMI is most commonly caused by atherosclerotic disease, extrinsic compression of the CA can lead to mesenteric ischemia. Most commonly this results from impingement of the diaphragm on the CA, although the surrounding nerve plexus may also contribute to compression [23]. This syndrome, more commonly occurring in females, is known as the median arcuate ligament syndrome, also referred to as celiac compression syndrome [18,24]. This diagnosis should be considered in young patients who have unexplained abdominal pain and normal upper endoscopy, normal liver, pancreatic, and gastric laboratory studies, and particularly in those patients who have an abdominal bruit (from partially obstructed flow in the CA) [23].

**Diagnosis**

*Angiography*

Angiography was traditionally the gold standard for the diagnosis of mesenteric ischemia. The development of multidetector row computed tomography (CT), however, has permitted detailed analysis of vascular flow that was never before possible, thereby relegating angiography to more of a confirmatory role [25]. Furthermore, angiography remains an invasive technique that requires the availability of an endovascular specialist, a luxury not consistently available emergently at most medical centers. These weaknesses aside, angiography is the lone diagnostic modality that offers the potential therapeutic options for mesenteric ischemia (see section on treatment).
Typically aortography is performed with anterior and lateral views. Lateral films provide optimal visualization for detecting proximal disease, permitting analysis of the takeoff of the CA, the SMA, and the IMA [18]. Anterior views, however, are essential to diagnose ischemia caused by poor perfusion in the distal mesenteric vessels [11]. When nonocclusive ischemia is suggested by angiography, intra-arterial infusion of vasodilators such as papaverine or prostaglandin E1 may also be used to augment blood flow if a test dose suggests the limitations in flow are reversible by augmenting arterial flow [26]. Mesenteric venous thrombosis may be suggested by a slowing in arterial inflow and filling defects in mesenteric veins or absent flow in veins with reliance on collateral routes of drainage [26]. Digital subtraction angiography can be helpful in improving resolution of the images and in reducing the contrast load necessary to permit adequate evaluation [18]. Finally, angiography may be the best diagnostic modality to confirm the diagnosis of median arcuate ligament syndrome, in which dynamic compression of the CA is demonstrated with a combination of inspiratory and expiratory images (Fig. 1) [27].

**Ultrasound**

Advances in resolution of commercially available ultrasound devices have permitted the identification of mesenteric vessels transabdominally. Doppler waveform analysis has further permitted the detailed...
characterization of blood flow necessary for identification of stenotic or occluded mesenteric vessels. Duplex ultrasonography, combining B-mode ultrasonography with Doppler waveform analysis, has thus led to the emergence of ultrasound as a diagnostic option in mesenteric ischemia. The examiner not only receives an anatomic view of the vessel, but also flow detail corroborating the findings.

Established criteria for the diagnosis of mesenteric stenosis focus on the peak systolic velocity (PSV) and end diastolic velocity (EDV) as measured by duplex ultrasonography. Zwolak and colleagues [28] found an EDV greater than 45 cm/s to be 100% sensitive for detecting greater than 50% stenosis of the SMA, with retrograde common hepatic flow being the most sensitive indicator of stenosis of the CA. Other studies argue that the PSV offers greater sensitivity than EDV in diagnosing stenosis of the SMA or CA, with respective velocities greater than 275 cm/s and 200 cm/s indicating greater than 70% stenosis in these vessels [29,30]. Duplex evaluation following a meal (similar to exercise when evaluating cardiac flow) provided no increase in sensitivity in one study evaluating SMA stenoses; therefore, it is not commonly performed [31].

Although ultrasound diagnosis of mesenteric ischemia remains promising, the technique has several shortcomings. First, the IMA is often difficult to visualize with duplex ultrasonography; nonetheless, mesenteric ischemia is rare in the presence of normal flow in the CA and SMA [14]. Ultrasonography requires the availability of a skilled registered vascular technologist or physician capable of producing reliable images. Next, ultrasound evaluation may be limited by patient body habitus (obesity in particular makes evaluation more challenging), previous intra-abdominal surgeries, patient compliance, and the presence of bowel gas [30]. Evaluation following abstinence from oral intake for 8 hours is often recommended for an optimal study [30]. Yet this is rarely the situation encountered in practice, especially in the emergent setting. Ultrasound may therefore remain more suitable for evaluation of CMI until there are further enhancements in technology and technique for this diagnostic modality.

Computed tomography

CT evaluation for mesenteric ischemia remains an attractive choice, because the examination is rapid, noninvasive, and widely available in most hospitals. Early evaluations of mesenteric ischemia by CT, however, showed a disappointing sensitivity of only 64% [32]. Subsequently the development of multidetector row CT has greatly improved the images obtained with this technique. In one recent prospective study involving 62 patients undergoing biphasic multidetector row CT (involving arterial and portal phase evaluations), mesenteric ischemia was identified as a possible diagnosis in all 26 who were ultimately determined to have mesenteric ischemia [33]. Of note, only eight of these patients had arterial abnormalities noted on the CT
angiogram, demonstrating the importance of associated bowel findings in making the diagnosis [33]. Although the diagnosis made by CT altered treatment in only 5 patients (19% of those with mesenteric ischemia), this prospective study confirmed the ability of CT to accurately diagnose acute mesenteric ischemia, contradicting earlier reports that questioned its usefulness [33].

Although findings of vessel occlusion or significant narrowing may be seen on CT angiogram, associated changes in the bowel wall more often offer clues to the diagnosis. By providing the ability to evaluate the bowel wall, a diagnosis of mesenteric ischemia can be aided by findings such as wall thickening, mucosal enhancement, intramural air, or dilatation, in addition to ominous signs such as portal venous gas (Fig. 2) [25,33–35]. In isolation, the sensitivity of these findings varies widely. Kirkpatrick and colleagues [33], however, suggest that the presence of portal venous gas, pneumatosis, or a combination of bowel wall thickening with venous thrombosis, solid organ infarction, or focal lack of enhancement of bowel wall seen on CTA as criteria for the diagnosis of mesenteric ischemia results in sensitivity of 96% and specificity of 94%.

Fig. 2. These selected images are from a CT scan of a patient who had acute mesenteric ischemia secondary to a nearly occluded SMA from an embolic source (arrow, A) and resultant small bowel thickening in the ischemic ileum (B). At laparotomy, the distal ileum was found to be ischemic (C) and was resected; an SMA thrombectomy (D) and patch angioplasty was performed.
Magnetic resonance imaging

Several reports have established the usefulness of MRI in making the diagnosis of CMI. One study demonstrated significant postprandial reduction in the amount of blood flow in the SMA in healthy volunteers as compared with patients who had documented SMA stenosis [36]. Burkart and colleagues [37] documented a similar reduction in superior mesenteric and portal venous flow in patients who had CMI when compared with healthy volunteers. Finally, Lauenstein and associates [38] demonstrated decreased bowel wall enhancement following contrast administration in patients who had symptoms of mesenteric ischemia and stenosis documented angiographically. The time required to perform MRI examinations and the possible need for bowel stimulation with a meal limit the usefulness of MRI in the diagnosis of acute mesenteric ischemia, making it more appropriate for evaluating the chronic state. Even so, CTA is likely a better examination than MRI for the diagnosis of CMI because of its capacity for higher resolution in combination with faster scans [39].

Management of mesenteric ischemia

Patients who have suspected mesenteric ischemia must receive adequate fluid resuscitation, because capillary leak in the setting of visceral ischemia may lead to significant fluid shifts. To avoid exacerbating visceral ischemia, a preference should be given to β-adrenergic agonists such as dopamine when vasopressors are required [3]. In addition, empiric, broad-spectrum antibiotics such as imipenem [3] are recommended, because ischemia leads to more frequent translocation of bacteria through the intestinal wall [11]. Anticoagulation, most commonly in the form of an unfractionated heparin drip to permit rapid titration should surgery be required, is recommended to prevent further propagation of thrombus [3,10,40]. Surgical therapy is indicated for all patients who have evidence of bowel ischemia, regardless of the underlying etiology. Arterial disease has been addressed with various techniques, with a standard open approach and the emergence of endovascular repair.

Mesenteric venous thrombosis (MVT) in the absence of peritoneal findings suggestive of bowel necrosis may be managed nonoperatively. Unfortunately a significant percentage of patients require surgery, with most of these patients needing bowel resection. In a review of 72 patients who had MVT by Rhee and colleagues [16], 64% of patients required surgical exploration, of whom 85% required resection of infarcted bowel. Systemic anticoagulation remains the mainstay of nonoperative therapy, and early use of heparin has been associated with improved survival [15]. Heparin is commonly reinstituted postoperatively when safe; long-term anticoagulation is strongly recommended for those who have ischemia caused by embolic events or MVT to prevent reoccurrence [3,6]. Some investigators report the use of vasodilators such as papaverine as an adjunct [4,12]. Surgical thrombectomy
[41], thrombolysis [42,43], and percutaneous transhepatic thrombectomy [44] have also been described in isolated reports as treatments for mesenteric thrombosis. All patients should undergo a work-up for hypercoagulable states, which, as mentioned, are common contributors to the development of mesenteric venous thrombosis.

**Surgical therapy**

In the setting of arterial insufficiency, whether in the acute or chronic form, mesenteric bypass is commonly performed. Bypass may be performed in an antegrade fashion, with inflow from the supracaeliac aorta (more commonly free of atherosclerotic disease), or retrograde from the iliac vessels. Some investigators suggest that the former is more anatomically favorable, because retrograde grafts may be more prone to kinking [12,22,45]. At exploration, unless bowel is frankly necrotic, revascularization should be performed before bowel resection. Once revascularized, the bowel can be re-examined to determine if restoration of blood flow has reversed the ischemic process. Similarly, views differ on the choice of bypass grafts. Although reversed saphenous vein grafts are more appropriate in the setting of gross contamination from infarcted bowel [46], prosthetic grafts may in fact be more durable for mesenteric artery bypass. Although no randomized trials exist regarding the use of prosthetic versus endogenous grafts, most modern series indicate a preference for the use of prosthetic grafts in this setting [3,14,22,47–50]. Synthetic grafts also offer the benefit of facilitating simultaneous revascularization of the CA and SMA through a single aortotomy with the use of bifurcated grafts.

**Technique**

In performing antegrade bypass, a transabdominal approach can be used, gaining access to the aorta by dividing the triangular ligament over the left lobe of the liver and dividing the diaphragmatic crus (Fig. 3). Unless the SMA disease is proximal, a retropancreatic window is created for the aorto-SMA graft before anticoagulation. Proximal and distal control of the aorta are gained before administration of heparin, cross-clamping, and performance of an aortotomy. A bifurcated graft (most commonly made of polytetrafluoroethylene, or PTFE) is then sewn end-to-side to the aorta, after which aortic flow is restored. Alternatively a side-biting clamp may be used to avoid distal (in particular renal) ischemia. The graft is then sewn end-to-side to the common hepatic artery. The second limb may be passed behind the pancreas for distal SMA disease or anterior to the pancreas to the SMA for proximal disease, and anastomosed end-to-end or end-to-side to the SMA (Fig. 4) [14,46].

Alternatively retrograde bypass may be performed using the iliac arteries for inflow (Fig. 5). This technique may be appropriate in patients who have had a previous antegrade bypass or in patients whose distal thoracic aorta is
not appropriate for inflow to an antegrade bypass [14]. For the surgeon unfamiliar with this anatomy and less experienced performing this procedure, the retrograde technique also offers the advantage of being less technically complicated [45].

Short of mesenteric arterial bypass, other options for mesenteric ischemia include thrombectomy and embolectomy. Cunningham and colleagues
obtained comparable results to mesenteric bypass using a trap-door, transaortic endarterectomy technique, facilitating revascularization of the CA and the SMA through a single aortotomy. In this technique, creation of the trap-door involves cutting three sides of a rectangle that surrounds the CA and the SMA (with one of the long sides being left intact). In a single study reviewing transaortic and local endarterectomy, local endarterectomy was associated with a higher rate of failure, and practice has shifted accordingly [52]. Fogarty catheter embolectomy remains an option if pre-operative imaging definitively suggests embolic disease. Because thrombosis at the site of arteriotomy may occur in up to 17% of patients postoperatively [13], consideration should be given to closure with patch angioplasty.

Fig. 4. When performing an antegrade bypass, a bifurcated graft is anastomosed end-to-side to the common hepatic artery, with the second limb passing either anterior or posterior to the common hepatic artery and then following a retropancreatic course. (From Kazmers A. Operative management of chronic mesentric ischemia. Ann Vase Surg 1998;12:305; with permission.)
Results

Results following mesenteric bypass graft are largely favorable. Jimenez and colleagues [49] had 94% 5-year primary-assisted patency rates among 47 patients undergoing aortomesenteric bypass. Similarly, McMillan and colleagues [53] documented 89% patency at 6 years in a total of 38 bypass grafts as followed by serial duplex scanning or arteriography. Notably, most patients in these two studies underwent revascularization of the CA and the SMA [49,53]. Although not proven by randomized studies, it seems likely that revascularization of both vessels provides for redundancy in the event that one repair subsequently fails. For this reason, revascularization of both vessels is encouraged if flow through both is impaired. Other studies,
although not necessarily following objective measures of graft patency rates, document symptom-free survival rates (whether patients who are still alive remain free of symptoms) ranging from 57% to 86% at 5 years [21,22,51,52]. Owing to the overall rarity of mesenteric ischemia (or lack of difference between the two techniques), no studies were able to document differences in patency rates between antegrade and retrograde bypass. Although few studies report results of bypass for acute and chronic mesenteric ischemia, patency results following intervention for both disease forms are similar [52,53].

Assessment of bowel viability

Determination of bowel viability is a critical component of surgical therapy for mesenteric ischemia. Although the need for bowel resection is paradoxically associated with higher survival rates (likely because patients who have widely necrotic bowel and poor prognoses undergo no resection) [9], it remains critical to determine which bowel is salvageable to avoid the morbidity and mortality associated with extensive resections. Several different methods have been used to determine bowel viability intraoperatively. Clinical assessment by evaluating the color and motility of the bowel remains one of the most important tools of the surgeon in evaluating intestinal viability. Other techniques, including antimesenteric Doppler interrogation, and observation of perfusion following administration of intravenous fluorescein dye are also commonly used. None of these techniques, however, have proven to be thoroughly reliable in predicting future intestinal viability. One limited study evaluating these three techniques found the sensitivity for each to be less than 60% [54].

Because of the inability to accurately predict which segments of bowel remain viable, a second-look operation 24 to 48 hours after the initial procedure has been historically recommended [6,54]. In support of this opinion, one review of 43 patients undergoing open mesenteric revascularization noted that 11 of the 23 patients undergoing a second-look operation required bowel resection [9]. Realizing the morbidity associated with a negative laparotomy, exploratory laparoscopy has been suggested. One group evaluated 23 patients who had laparoscopy at 24 hours after the initial surgery, avoiding repeat laparotomy in 20 patients (87%) [55]. Increased technical skill, however, is required for thorough evaluation of what is commonly edematous, friable, dilated bowel, to avoid increasing morbidity and mortality through inadvertent perforation or overlooking of critical disease. In addition, as the rationale for a second exploration is not documented in most retrospective reviews, others suggest that only selective re-exploration should be performed. Kaminsky and colleagues [56] suggest that the yield of re-exploration is low (only 17% of patients in their review benefited from a second-look procedure), and that judgment of the surgeon based on findings at the initial surgery should guide decisions regarding a second-look. Whatever method of evaluation is eventually used, the surgeon
needs to balance overzealous resection and potential for development of short bowel syndrome with the risk of leaving behind potentially ischemic bowel.

**Endovascular therapy**

The use of endovascular therapy for mesenteric ischemia is predominantly limited to treatment of the chronic form of the disease. The first report of endovascular therapy for mesenteric vascular disease documented relief of symptoms of CMI following angioplasty of the SMA [57]. Although one study documenting outcome following percutaneous transluminal angioplasty (PTA) of mesenteric vessels versus PTA with stenting found no difference in outcome [58], the overall trend has been toward increased use of PTA with stenting in endovascular therapy for CMI. Some investigators suggest this tendency results from extrapolation of data regarding endovascular treatment of renal artery stenosis, in which PTA and stenting remain more durable than PTA alone [27,59].

Several small series have been published documenting outcome following endovascular therapy following PTA with stenting of mesenteric vessels, primarily for CMI (Table 1). For each of the studies, technical success was defined as residual stenosis of less than 30%, and relief of symptoms was considered clinical success. Long-term patency of the mesenteric vessels varied in assessment; some studies relied on duplex ultrasound, others on angiography, and still others on presence of symptoms alone. Proponents of endovascular therapy over open surgical intervention cite the low morbidity and mortality rates and shorter hospital stay. Although initial technical success rates following percutaneous intervention are high, however (88%–100%), patency rates at 1 year decreased to 70% to 80% [27,58–60].

Few studies have attempted to directly compare percutaneous intervention with surgery for mesenteric ischemia. In one review of 28 patients undergoing percutaneous intervention compared with a total of 85 patients treated with various surgical procedures (mesenteric artery bypass, endarterectomy, or patch angioplasty), the morbidity and mortality between the two groups did not differ, although recurrence of symptoms was higher in the group treated percutaneously [61]. Of note, the morbidity and mortality rates for PTA and stenting in this study, 17.9% and 10.7%, respectively, were much higher than previously summarized [61]. In addition, there was a significant difference between the average number of vessels revascularized in the PTA/stenting group as compared with the surgery group (1.1 versus 1.5, respectively, P < .01) [61]. In this limited study comparing endovascular therapy with open surgical therapy, surgery therefore seemed to offer more durable results with comparable peri-procedure morbidity and mortality. Unfortunately the higher complication rates with PTA call into question their experience with the procedure and may have affected the results of the comparison.
Table 1
Outcomes following endovascular therapy for chronic mesenteric ischemia

<table>
<thead>
<tr>
<th>Author</th>
<th>No. of patients</th>
<th>No. of interventions</th>
<th>Technical success</th>
<th>Clinical success</th>
<th>Morbidity (%)</th>
<th>Mortality (%)</th>
<th>Patency rates</th>
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<tr>
<td>Shih [58]</td>
<td>33</td>
<td>47</td>
<td>87%</td>
<td>88%</td>
<td>13</td>
<td>3.4</td>
<td>83</td>
</tr>
<tr>
<td>Sharafuddin [27]</td>
<td>25</td>
<td>28</td>
<td>96%</td>
<td>88%</td>
<td>12</td>
<td>4</td>
<td>83, 92, 15</td>
</tr>
<tr>
<td>AbuRahama [62]</td>
<td>22</td>
<td>24</td>
<td>96%</td>
<td>95%</td>
<td>0</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Landis [60]</td>
<td>29</td>
<td>63</td>
<td>97%</td>
<td>90%</td>
<td>13.7</td>
<td>6</td>
<td>70.1, 87.9, 12</td>
</tr>
<tr>
<td>Silva [59]</td>
<td>59</td>
<td>61</td>
<td>96%</td>
<td>88%</td>
<td>3.4</td>
<td>1.7</td>
<td>71, 100, 14</td>
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In a second smaller study, nine patients who underwent mesenteric bypass grafting were compared with eight patients who underwent angioplasty alone. There was no difference in mortality, because one patient died in each group [47]. Technical success, however, defined as residual stenosis less than 30%, was achieved in only 30% of the angioplasty procedures compared with 100% in the surgical group [47]. Long-term pain relief occurred in 88% of the operative bypass group at 34.5 months, as compared with 67% in the angioplasty group at just 9 months [47]. In this small study, operative repair again seems to be more durable than endovascular therapy for mesenteric ischemia.

Although these two studies directly comparing surgery to percutaneous intervention for mesenteric ischemia failed to find a difference between morbidity and mortality rates, comparison of the individual series as reported in this review suggests that morbidity and mortality and length of hospital stay are greater for patients undergoing surgical intervention. The long-term patency rates following surgical bypass, however, remain higher than those after angioplasty, with and without stenting. One particular area of weakness of percutaneous intervention is among patients who have median arcuate ligament syndrome. Several investigators note a failure of PTA and stenting among patients in which compression of the CA by the diaphragm contributes to ischemic symptoms [6,47,62]. Surgical therapy with release of the median arcuate ligament should be the primary treatment of choice in these cases.

Thrombolytic therapy

Thrombolytic therapy as an adjunct to endovascular techniques has been explored to a limited degree for acute mesenteric ischemia. As with other endovascular techniques, peritoneal examination findings suggestive of bowel infarction remain a contraindication to thrombolytic therapy and mandate surgical exploration. Other contraindications are recent surgery, trauma, cerebrovascular or gastrointestinal bleed, and uncontrolled hypertension. Highlighting a need for more data, a recent systematic review of mesenteric arterial thrombolysis found the largest series describing this technique to consist of just 10 patients [1]. In this study, Simo and colleagues used urokinase by way of catheter-directed thrombolysis in a small cohort with SMA embolism [60]. Clinical success was achieved in seven patients, one of whom later required laparotomy after abdominal pain worsened, but there was no mortality secondary to bowel ischemia [60]. All patients in whom thrombolysis was successful had resolution of abdominal pain within 1 hour of starting therapy [60]. The authors agree with the conclusion by Schoots and colleagues [1] that preliminary results suggest this technique may hold promise, but further investigation regarding safety and durability of the technique is warranted before including thrombolysis as a valid therapeutic option in mesenteric ischemia.
Emerging diagnostic technology

As bowel mucosa is the intestinal layer most vulnerable to ischemia, measurement of mucosal oxygen tension has been proposed as one means of diagnosing mesenteric ischemia earlier and more accurately. Friedland and colleagues [63] describe an oximetric device using white-light reflectance spectrophotometry used during endoscopy to measure mucosal hemoglobin saturation in the colon. Preliminary data gathered in animals revealed an oxygen saturation of 72%, which decreased more than 40% following ligation of the arterial supply of the left colon and hypoxic ventilation [63]. Further human studies demonstrated the normal level of mucosal oxygen saturations range between 60% and 70% [64]. Analysis of three patients who had CMI revealed saturations between 16% and 30%, which increased to between 51% and 60% following revascularization by mesenteric arterial angioplasty and stenting [64]. The particular role endoscopy with mucosal oximetry measurement plays remains unknown. Likely, it may prove to be an effective means of evaluating for CMI, in cases in which arteriolar disease may not be readily evident on traditional angiography or CT angiography. This technique may also gain applicability to acute mesenteric ischemia, however, with planned development of a handheld probe that could permit intraoperative measurement of mucosal perfusion [64]. Although this would currently require an enterotomy, it could be used to assess the surrounding bowel when ischemia necessitates resection of one portion of bowel.

Similarly, other investigations have included oximetric measurements of SMV flow using MRI. This technique takes advantage of the paramagnetic properties of deoxygenated hemoglobin in contrast to oxygenated hemoglobin. Li and colleagues [65] describe measurement of oxygen saturation of blood flowing through the SMV before and after ingestion of a meal. SMV oxygen saturation in patients who do not have mesenteric ischemia (as determined by angiography and a lack of symptoms) increased an average of 4.6% following a meal, whereas saturation decreased 8.8% postprandially in those patients who had clinical and radiographic evidence of mesenteric ischemia [65]. Given the time required to perform magnetic resonance oximetry, to including the need for postprandial studies, applicability of this technique remains limited to evaluation of patients who have CMI.

Summary

Mesenteric ischemia in chronic and acute forms carries a high morbidity and mortality rate, each increased by frequent delays in diagnosis [66]. Although laboratory studies have low specificity for diagnosing mesenteric ischemia, CT angiography and traditional angiography remain sensitive diagnostic imaging techniques. Once diagnosed, prompt surgical therapy and anticoagulation remain cornerstones of therapy. Although prosthetic grafts in an antegrade or retrograde fashion provide the most durable means
of repair, endovascular stenting and angioplasty have high early success rates and may be preferable for patients who have prohibitive risk factors for open surgery and who do not have evidence of infarcted bowel. In cases in which bowel viability is questionable, multiple options including second-look operations are available and should be used, despite the relative lack of data showing improved outcomes. Emerging diagnostic technologies may permit earlier diagnosis, allowing urgent treatment for mesenteric ischemia and potentially reducing the high mortality rates currently seen with this condition.

References


