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Chronic mesenteric ischemia

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Chronic mesenteric ischemia is an unusual but important cause of abdominal pain. Although this condition accounts for only 5% of all intestinal ischemic events, it can have significant clinical consequences. Among its many causes, atherosclerotic occlusion or severe stenosis is the most common. This disorder has an indolent course that results in extensive collateral vascular formation. Thus, symptoms occur when at least two of the three main splanchnic vessels are affected. Intestinal angina, weight loss, and sitophobia are common clinical features. Diagnosis can often be made by noninvasive methods such as computerised axial tomographic angiography, magnetic resonance angiography, and duplex ultrasonography as well as by invasive catheter angiography. Therapy of chronic mesenteric ischemia depends on the extent and location of vascular disease. Alternatives to traditional surgical bypass are becoming more common including embolectomy, thrombolysis, and percutaneous angioplasty with vascular stenting. Early intervention is vital as the natural course of this illness can be debilitating. Furthermore, this has potential to develop into life-threatening acute mesenteric ischemia with subsequent bowel infarction and death. Long-term studies have shown that the risk of developing symptoms from asymptomatic but significant mesenteric vascular disease is 86% with overall 40% mortality rate. The recognition and management of this unusual but important cause of abdominal pain is discussed in detail in this review.

Key words: mesenteric arteries; chronic mesenteric ischemia; mesenteric venous thrombosis; intestinal angina; splanchnic; angioplasty; vascular bypass.

Chronic abdominal pain can result from a variety of gastrointestinal and systemic disorders. Among the many causes, one of the most difficult to recognise is chronic ischemia of the splanchnic vascular system. Patients with this disorder often present with subtle or nonspecific complaints and physical findings may not be remarkable. The awareness of this entity by the clinician is vital to its recognition and subsequent medical management. Left unrecognised, chronic mesenteric ischemia has the potential to worsen and even develop into acute intestinal ischemia with bowel infarction.

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This review will outline the salient clinical features, diagnostic testing, and medical or surgical management of this unusual cause of abdominal pain.

SPLANCHNIC MESENTERIC ANATOMY

In order to understand the pathophysiology of chronic mesenteric ischemia, it is necessary to review the anatomy of the splanchnic circulation. Three main arteries arise from the abdominal aorta and include the celiac (CA), superior mesenteric (SMA) and inferior mesenteric (IMA) arteries. The foregut is supplied by the CA, which divides into three branches: the splenic artery, common hepatic artery, and left gastric artery. The midgut receives arterial supply from the SMA, which arises from the aorta very close to the CA at approximately 1 cm caudally. Branches include the middle, right and ileocolic arteries as well as jejunal and ileal arteries and arterioles. Thus the SMA and its branches are responsible for blood supply to the vast majority of the jejunum, ileum, and the ascending, transverse and splenic flexure portions of the colon. The IMA arises 3–5 cm above the aortic bifurcation and divides into ascending and descending branches. Branches include the left colic, marginal and sigmoid arteries to supply the region from the splenic flexure until the superior portion of the rectum. There can be numerous anatomical variations in the CA and SMA and their branches and may have implications in mesenteric ischemia.

Venous drainage of the splanchnic system mainly involves the portal circulation. Tributaries to the portal vein include the splenic vein (SV), inferior mesenteric vein (IMV), superior mesenteric vein (SMV), left gastric vein, right gastric vein, and cystic veins. The superior rectal, sigmoid, and left colic veins drain into the IMV. The IMV subsequently drains directly into the SV along with the pancreatic, gastroepiploic and short gastric veins. The SMV and SV join together and form the portal vein confluence adjacent to the pancreatic head. The portal vein continues onward to drain blood into the sinusoids of the liver.

ETIOLOGY

Among all intestinal ischemic events, CMI is fairly uncommon accounting for only 5% of all cases.[1] The causes of chronic mesenteric ischemia include a variety of conditions (Table 1). The most common source is atherosclerotic occlusion or severe stenosis of the vessels accounting for more than 90% of instances.[2] Well-known risk factors for atherosclerosis are also applicable to CMI such as hyperlipidemia, diabetes, and smoking. These conditions are more common in men than in women below age 65 years. However, despite these risk factors, the majority of those afflicted with CMI are elderly women. Additionally, constriction of celiac artery blood flow by diaphragmatic compression resulting in CMI is also more predominant in women.[3] Among intestinal ischemic events, those involving the CA and SMA are more common than the IMA. Embolic disease of the SMA accounts for 50% of all acute intestinal ischemic events while an additional 10% of cases consist of progression of thrombotic disease within the same vessel.[1] The prevalence of asymptomatic mesenteric arterial stenosis in patients with peripheral vascular disease and renal artery stenosis has been examined. In one study, 27% of these individuals had greater than 50% stenosis in either the celiac or superior mesenteric artery and 3.4% had significant occlusion of both vessels.[4]

Table 1. Etiology of chronic mesenteric ischemia.

Atherosclerosis and atheroma
Diabetes, hyperlipidemia, smoking
Celiac artery compression syndrome
Fibrovascular dysplasia
Takayasu's arteritis
Thromboangiitis obliterans
Radiation-induced vascular injury
Mesenteric venous thrombosis
Heritable disorders of coagulation
Pancreatitis
Inflammatory bowel disease
Cirrhosis
Portal hypertension
Paraneoplastic disorders
Postoperative states
Trauma

Furthermore, another study depicts in a group of patients with clinically significant peripheral vascular disease, the frequency of concomitant splanchnic stenosis was highest in the celiac trunk (16.1%), followed by renal artery (13%), celiac trunk with renal artery (8.6%) and celiac trunk with superior mesenteric artery (5.3%).[5]

The development of atheroma usually occurs at the proximal segments of visceral arteries with stenosis resulting from the fatty infiltration within vessel walls. Diffuse atherosclerosis is seen in fewer patients, particularly those with advanced diabetes or end-stage renal disease. These individuals may develop symptoms with only mild vascular narrowing because of the inability to develop adequate collateral vessels.[6] Despite the finding of stenosis greater than 50% in approximately 18% of patients older than 65 years, most of these individuals do not exhibit symptoms.[7] However, many nonatheromatous conditions are also implicated. These include Takayasu arteritis, dysplastic lesions, thromboangiitis obliterans, and radiation-induced vascular injury.[8]

Although rare, occlusion of the mesenteric venous system should also be considered as a cause of CMI. Primary or secondary thrombosis of the SMV accounts for the majority of these cases. Of all intestinal ischemic events, 5–15% is accounted by mesenteric venous thrombosis. Primary thrombosis of the SMV is often due to hereditary or acquired disorders of hypercoagulation such as deficiencies of protein C, protein S, antithrombin III, and factor V Leiden.[9] Secondary thrombosis of the SMV may result from a variety of inflammatory or malignant conditions. These can include trauma, pancreatitis, inflammatory bowel disease, postoperative states, paraneoplastic disorders, cirrhosis and portal hypertension.[10]

PATHOPHYSIOLOGY

A gradual reduction of blood flow to the intestines occurs in chronic mesenteric ischemia. Blood flow can vary from 25% during fasting to 35% in the postprandial phase. Therefore, symptoms of ischemia develop when the demand increases such as after eating. Any one of the three main mesenteric arterial branches may be occluded.

However, during chronic occlusive disease, an extensive collateral vascularisation develops between the three main arteries. Therefore, in most instances, occlusion of at least two of the three major vessels is necessary to produce symptoms.[11]

CLINICAL FEATURES

Also known as intestinal angina, chronic mesenteric ischemia occurs most commonly in the postprandial period (Table 2). Recurrent symptoms may progress into sitophobia with subsequent weight loss. Classically, abdominal pain occurs 15–60 minutes following ingestion of a meal and may last from 1–4 hours. Weight loss can average 20–30 pounds and is primarily the result of reduced food intake to avoid intestinal angina.[12] Chronic dull abdominal pain develops as the occlusion progresses. Additionally, CMI involving the celiac arterial distribution may result in disorders such as gastroparesis, gastric ulceration, and gallbladder dyskinesia.[13] Physical examination is usually unremarkable except for pain that is out of proportion to the exam. Sometimes, an epigastric bruit may be audible. Basic laboratory tests of blood chemistry and hematology are also usually unremarkable.

While mesenteric venous thrombosis can be an acute event, chronic symptoms may also occur. Abdominal pain is seen in 84% of individuals of whom approximately two-thirds report a history of chronic vague discomfort[14] Subacute or chronic venous thrombosis is often detected incidentally when imaging tests are performed for chronic abdominal pain or weight loss. Chronic venous disease is often not recognised until other complications develop such as variceal bleeding from portal hypertension, weight loss, and vague postprandial abdominal pain or distension.[15]

The natural course of asymptomatic but significant mesenteric vascular disease has been studied. One small study followed individuals with greater that 50% occlusion of all three major vessels for a period ranging from 1 to 6 years. Development of symptoms occurred in approximately 86% with an overall mortality of 40%.[16]

DIAGNOSTIC TESTS

The diagnosis of CMI has traditionally been accomplished by invasive catheter arteriography. This is an invasive procedure that involves accessing arterial blood flow

Table 2. Clinical features of chronic mesenteric ischemia.

Symptoms
Post-prandial intestinal angina
Fear of eating (sitophobia)
Weight loss
Nausea and vomiting
Findings
Abdominal tenderness out of proportion to exam
Epigastric bruit
Gastric ulceration
Gastroparesis
Gallbladder dyskinesia

peripherally and advancing a catheter into the vessel. Injection of contrast can be examined fluoroscopically to detect vascular disease. However, in recent years, many non-invasive diagnostic modalities have become available.

Conventional interventional angiography

Angiography has been the traditional method for diagnosis of CMI as well as the technique to which all other diagnostic modalities are compared. Being an invasive test, catheter arteriography of the mesenteric vessels is usually performed only after other more common disorders of chronic abdominal pain have been excluded. Selective arterial catheterisation of the branches of the large vessels is possible. However, contraindications to arteriography include hypotension or hypovolemia because of potentially increasing vasoconstriction and reducing specificity of findings. Contrast-induced nephrotoxicity should be considered.[17,18] The overall rate of major complications from mesenteric angiography is 1.9–2.9% and may include external iliac artery dissection or deep venous thrombosis.[19]

Duplex ultrasonography

Ultrasound evaluation of the mesenteric arteries has been used for almost the past two decades. Its noninvasive features and portability even to the bedside make it an attractive diagnostic method. The size and anatomic position make the SMA accessible to ultrasonographic measurements.[20] However, the CA may be difficult to visualise in 20% of cases and the IMA is rarely imaged by transabdominal ultrasound due to its anatomic location.[21] Overall, duplex ultrasound has approximately 90% accuracy in identifying significant proximal SMA stenosis and 80% accuracy for celiac trunk lesions.[22] While lesions may be identified, intestinal ischemia cannot be diagnosed by ultrasound as it is a clinical diagnosis. If screening ultrasonography detects vascular stenosis or occlusion, prompt interventional angiography is usually indicated.

Stenotic and occlusive lesions are identified by turbulence and velocity of blood flow in the proximal portion of the arteries. Peak systolic velocity of greater than 200 cm/s and an end-diastolic velocity exceeding 55 cm/s have been shown to have high correlation with CA stenosis.[2] Lesions of the proximal SMA are highly likely when the peak systolic velocity is greater than 275 cm/s. However, end-diastolic velocity greater than 45 cm/s is more specific.[23] In spite of this, intra- and interobserver variability may be high in the estimation of Doppler flow. The effect on ultrasonography of respirations, body habitus, food ingestion, bowel gas, and anatomic variations is not clear. Food ingestion results in splanchnic vasorelaxation as depicted by a 10-fold increase in diastolic velocity of the SMA. Exercise increases splanchnic resistance with a subsequent reduction of 25% in mesenteric blood flow. The influence of these variables with potential limitations on duplex ultrasonography needs further investigation.[24]

Computerised tomography angiography

Computerised tomography angiography (CTA) has evolved into a highly sensitive and specific tool to identify significant splanchnic vascular stenosis. This minimally invasive method is enhanced by the availability of multiple detector-row imaging with three-dimensional image reconstruction as a single study. CTA during the early arterial phase of vascular enhancement can readily diagnose significant atherosclerotic lesions of all the three major mesenteric arteries and many of their main branches.[25]

The multidetector-row CTA has many advantages over the classic helical CT images. In addition to three-dimensional images, faster scanning time is possible. Thinner collimation of 0.5–1.0 mm thickness provides much better visualisation of small vessels and branches. The quality of CTA using this technology known as volume rendering is highly comparable to conventional angiography but with less cost and morbidity. In suspected intestinal angina, a negative multidetector-row CTA study of the mesenteric vessels makes the diagnosis of chronic mesenteric ischemia virtually unlikely.[26,27] Recently, it has been shown that using multiple radiographic criteria, CTA has a sensitivity of 96% and specificity of 94% for diagnosis of acute mesenteric ischemia.[28]

Magnetic resonance angiography

Magnetic resonance angiography (MRA) has become in recent years a valuable tool for diagnosing CMI, particularly since its cost and image acquisition times have substantially decreased. Breath-hold times are usually 20 seconds but can be as little as 6 seconds. Coronal three-dimension MRA images have been shown by several studies to provide high-resolution mesenteric angiograms of greater than 90% of SMA, 75–90% of CA, 81–88% of portal veins, and 25% of IMA vessels.[29,30] In one study of 125 patients, contrast-enhanced MRA had 100% sensitivity for stenosis of the CA and SMA when compared to conventional angiography. However, small peripheral arterial branches were less well visualised.[30,31] In another study, gadolinium-enhanced MRA was compared to both catheter angiography and surgery with findings of severe stenosis ($>$75%) or occlusion of either the CA or SMA. Overall sensitivity and specificity was 100 and 95% respectively.[32] Unlike duplex ultrasonography, the detection of proximal CA and SMA stenosis by contrast-enhanced MRA has highly accurate reproducibility of results and excellent interobserver agreement.[33]

As depicted above, CTA and MRA have evolved to provide high quality angiograms that rival conventional angiography (Table 2). It is therefore recommended that invasive angiography be used only when catheter-based therapy of stenotic or occlusive lesions is planned. Such therapy is described later. However, the efficacy of noninvasive diagnostic modalities is limited in IMA occlusion compared to CA or SMA. This may be an additional role for catheter arteriography (Table 3).

THERAPEUTIC OPTIONS

Medical management

In most cases, the treatment of chronic mesenteric ischemia is not considered urgent. Nevertheless, definitive therapy is usually preferred to minimise the potential for serious clinical consequences such as acute bowel infarction. Significant vascular stenosis or occlusion usually requires operative or endovascular therapy. In the setting of chronic mesenteric venous thrombosis, however, medical therapy may have a role. Disorders of coagulation often exist in this setting. Therefore, medical therapy with warfarin, antiplatelet, or antispasmodic agents has been shown to significantly reduce mortality and recurrence of acute venous thrombotic events.[34] In those individuals who

Table 3. Diagnostic testing in chronic mesenteric ischemia.

	Duplex ultra-sound	CT angiography	MR angiography	Arteriography
Invasive	No	No	No	Yes
Sensitivity				
Celiac	80%	95–100%	95–100%	100%
Superior mesenteric	90%	95–100%	95–100%	100%
Inferior mesenteric	N/A	N/A	25%	100%
Interobserver variability	Moderate	Minimal	Minimal	Minimal
Complications	None	Contrast allergy Nephrotoxicity reduced by non-ionic contrast material	Threatening for claustrophobic patients	Contrast allergy Contrast nephro-toxicity Vascular bleeding Pseu-doaneurysms
Cost	+	++	++	+++

have had an acute episode of mesenteric venous thrombosis and have no contraindications to anticoagulation, life-long therapy with warfarin is indicated.[35]

Evidence for medical treatment of mesenteric arterial occlusion is sparse. In one study of 82 consecutive patients with SMA embolism, 23% had atypical symptoms or absence of abdominal pain despite diagnosis by angiography. These patients were treated conservatively as there were no life-threatening signs and the site of embolism was peripheral. Of this small group, 88% survived with medical management alone. Therefore, treatment should be guided by both clinical and radiographic factors.[36] Despite these findings, most experts advocate definitive therapy of mesenteric vascular occlusive disease to avoid potentially serious clinical sequelae.

Surgical management

Mesenteric arterial revascularisation has been the traditional therapy for CMI for many decades. The operative approach is different from that used in acute intestinal ischemic events. As mentioned earlier, CMI occurs when chronic occlusion or stenosis of at least two of the three main arteries is present. The natural history of CMI dictates its therapy. High-grade arterial stenosis can be progressive with consequences of malnutrition and unpredictable conversion into acute intestinal infarction. In one study, long-term follow-up of patients with significant three-vessel disease revealed that 86% progressed from asymptomatic to symptoms of abdominal pain and malnutrition with some developing visceral infarction and even death. Acute intestinal ischemia may be the first presentation of CMI in 15–50% of cases.[37] Therefore, definitive therapy is warranted.

The surgical options are mostly included in one of two categories, endarterectomy or vascular bypass. Transaortic endarterectomy has been used to achieve primary mesenteric revascularisation in single or multiple vessels in both acute and chronic mesenteric ischemia. In a prospective study of 14 patients with CMI, initial success rate for trap-door endarterectomy was 93%. Overall patency at 1 and 3 years was 85 ± 10.0 and $77 \pm 11.7\%$, respectively.[38] However, other studies have suggested that direct endarterectomy and vascular reimplantation have high failure rates with recurrent thrombosis and symptoms.[39,40] Despite this, there are technical advantages to endarterectomy. Many patients have concomitant renal artery stenosis with atherosclerotic mesenteric vascular disease. When clinically significant osteal lesions are located at both the renal artery and splanchnic vessels, transaortic endarterectomy can be effectively used to treat both conditions with minimal mortality.[41]

Surgical bypass is comprised of two types. Antegrade reconstruction results in arterial inflow arising from the thoracic or supraceliac aorta. Retrograde reconstruction contains inflow from the infrarenal aorta or the common iliac artery creating an ileomesenteric or ileosplenic bypass graft.[42,43] Single or multivessel reconstruction with outflow into the CA, SMA or rarely the IMA is achieved. Isolated IMA revascularisation has been used for CMI in selected cases in which it is not possible to revascularise from either the CA or SMA. In a study of 11 patients, failure of SMA and CA repairs resulted in IMA revascularisation including bypass grafting, transaortic endarterectomy, reimplantation, and patch angioplasty. Patent IMA repairs were detected at a median of 6 years follow-up in nine patients.[44] Controversy exists whether single or multiple vessels should be bypassed and whether prosthetic or autogenous reconstructions are more viable.

Autogenous vascular reconstruction has been achieved using the saphenous vein (SV) or superficial femoral vein (SFV) although traditional prosthetic grafts have been considered by some authorities to have more long-term durability.[45] In the setting of bowel gangrene or abdominal sepsis, native vessel grafting is a necessity to avoid contamination and loss of the graft.[43,45] In a recent study during a 7-year period, autogenous bypasses were performed in 43 patients. SV was used in 23 bypasses and SFV bypass was created in 26 patients. The overall 30-day mortality was 15%. Shorter segments of SFV were required than SV segments. However, between the two graft vessels, there was no considerable difference in clinical outcome. The authors thus concluded that when autogenous vascular conduits are desired, SFV is as acceptable as SV for graft creation.[46] Nevertheless, the small sample size of this study necessitates further analysis in larger trials to confirm these findings.

The long-term outcome of surgical bypass can be measured by various means. Relief from symptoms, graft patency rates, and overall survival are among some of the indices examined by many authorities. Graft patency rates alone may not be an appropriate measure of surgical success as it has been shown to correlate with symptom recurrence in only one-third of individuals. However, graft patency is often used as an objective measure, most commonly by duplex scanning.[47] The clinical outcome of the patient should also be correlated to this objective measure when determining success of surgical bypass.

In one study of 24 patients, 21 had atherosclerosis as the cause of CMI. Antegrade reconstruction from the supraceliac aorta to the SMA was performed in 17 patients. The remaining seven patients had retrograde bypass arising from either the infrarenal aorta or a prosthetic graft. Overall, 5-year graft patency was 78% and 5-year survival according to life-table analysis was 71%. Antegrade bypass was shown to be preferable to retrograde connections with better long-term symptom-free survival and acceptable operative morbidity.[48]

Endovascular therapy

In the last two decades, minimally invasive therapy has become a more acceptable approach for stenotic or occlusive lesions in the mesenteric vessels. Interest in this method arose from the potential for decreased morbidity and mortality in comparison to surgical bypass. While surgical bypass has been a time-honored method with excellent results, many studies suggest variability in outcomes with perioperative complications occurring in the range of 19–54% and mortality ranging from 0 to 17%.[49–51] However, reported series for percutaneous transluminal angioplasty (PTA) and stenting have contained small numbers of patients making the morbidity and mortality rates unclear.

The ideal patient for endovascular therapy has short segments of stenosis (less than 10 cm) secondary to atherosclerosis that are located near the ostia of the SMA or CA. While ostial lesions have been shown in some studies to have a 95% initial success rate for PTA, nonostial occlusions have an average technical success rate of 78%.[52,53]

In one study, 23 consecutive patients with CMI were evaluated by angiography. All but one (fibrodysplasia) had atherosclerotic stenoses. PTA was performed with a residual stenosis of 30%. Immediate technical success was 90%. At a mean follow-up of 27 months, overall clinical success was 88%. Two patients required repeat angioplasty at 24 and 36 months and two patients had minor complications suggesting both safety and efficacy for PTA.[54] In a more recent report of stent placement, 25 consecutive patients underwent 28 procedures for 26 stenosed or occluded vessels including the SMA and CA. In all but one (96%), technical success was achieved with PTA and stenting. Three patients developed major complications such as contrast-induced nephrotoxicity and pseudoaneurysm development. Clinical benefit at 11 months was 91% and stent patency at 6 months was 92%. One patient required repeat stent placement in the SMA. This study suggests that PTA with stenting for both CA and SMA lesions has a favorable outcome at least in the short-term.[55]

Endovascular therapy has also been reported to be successful in the treatment of chronic mesenteric venous thrombosis. This is a rare clinical entity as described above. Three patients who had chronic abdominal pain due to mesenteric venous thrombosis underwent angiography. In one patient, thrombolysis with urokinase infusion for 36 hours was performed followed by long-term oral anticoagulation. In two patients, percutaneous mechanical thrombectomy was performed after identifying an occlusive thrombus in the superior mesenteric vein. This new technique uses a high-pressure saline jet to clear the venous clot. In a similar method, a second device was used that contained a nitinol fragmentation basket with a rotator unit resulting in pulverisation of the clot into particles less than 3 mm in size.[56] While all three patients had favorable short-term outcomes, the routine use of these devices is not recommended until long-term safety and efficacy studies are available.

As minimally invasive techniques appear attractive, outcomes studies comparing PTA and stenting to open surgical bypass are needed. One study of PTA and stenting compared their results to a previously published series of surgical management for CMI. In a 3.5-year period, 28 patients underwent therapy for 32 vessels with either PTA alone or combined with stenting. This group was compared to a series of 85 patients with similar clinical profiles who underwent either bypass grafting, transaortic endarterectomy, or surgical patch angioplasty by open method. The authors found no difference in the two main groups for complications or mortality rates. However, at 3 years of follow-up recurrent symptoms of CMI were more common in the group receiving PTA with or without stent compared to the surgically managed group (34 vs. 13%, $p=0.001$). Despite this outcome, there were no objective findings to demonstrate that the higher rate of symptoms was due to recurrent stenosis.[49] Therefore, conclusions from this comparison need further validation.

CONCLUSIONS

In the evaluation of abdominal pain, CMI still remains a rare but important cause. As imaging technology continues to evolve, its recognition is becoming more common. However, early detection relies on clinical suspicion and a combination of medical history, physical examination, and diagnostic testing. Conventional angiography is rivaled by highly accurate noninvasive imaging modalities such as CTA and MRA. Traditionally, patients with CMI have undergone surgical bypass or embolectomy with fairly good outcomes. However, minimally invasive endovascular therapies have emerged as a viable alternative for single or short segment vascular disease. While initial studies are promising, long-term studies comparing these techniques to surgical management with regard to vessel patency, morbidity and mortality are awaited. Nevertheless, the recognition and management of CMI as an unusual but important cause of chronic abdominal pain needs to be expedient to avoid complications of the illness and its potential to progress into acute intestinal infarction.

Practice points

- chronic mesenteric ischemia is a rare condition accounting for less than 5% of all intestinal ischemic events
- more than 90% of cases are due to atherosclerotic occlusion or severe stenosis
- classic symptoms include post-prandial abdominal pain, sitophobia, and mild to moderate weight loss
- at least two of the three main splanchnic arteries must be significantly compromised to result in chronic mesenteric ischemia
- duplex ultrasonography is noninvasive and expedient but may miss up to 20% of vascular lesions in the celiac trunk
- CTA and MRA are equally excellent non-invasive modalities with highly accurate diagnosis of vascular disease in the CA and SMA and rivals conventional catheter angiography
- surgical vascular bypass is the traditional definitive therapy for CMI with overall five-year graft patency of 78%
- endovascular therapy is most optimal in short segments of atherosclerotic disease at the ostia of the SMA and CA. PTA and stenting in short-term followup has a clinical benefit and stent patency in more than 90% of cases
- conventional catheter angiography should be reserved for diagnosis of CMI only when other modalities have been non-diagnostic or if intervention such as PTA is planned

Research agenda

- the influence of certain physical and physiologic variables as well as intra-and inter-observer variability needs to be assessed in the use of duplex ultrasonography for the diagnosis of CMI
- the non-invasive detection of IMA lesions by duplex ultrasonography, CTA and MRA needs to be examined and improved in comparison to standard catheter angiography
- larger studies with long-term outcomes need to be performed to assess the benefit of PTA and stent placement in CMI
- more information is necessary to predict the long-term clinical outcomes of CMI to tailor therapy

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