Chapter 16
Technique of Open Mesenteric Catheter Embolectomy

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The arterial perfusion of the gastrointestinal tract is provided by the celiac, superior mesenteric, and the inferior mesenteric arteries. The celiac artery (CA) supplies arterial blood flow to the foregut, the spleen, and the hepatobiliary system. The superior mesenteric artery (SMA) supplies the jejunum, ileum, and ascending and transverse colon. The inferior mesenteric artery (IMA) supplies the hindgut from the transverse colon to the rectum. Robust collaterals between each vessel (superior and inferior pancreaticoduodenal arteries and arch of Riolan respectively) allow for stenosis and occlusion of one or even two of these main arteries without sequelae in the setting of chronic mesenteric ischemia (CMI), where the mesenteric vasculature has had the time to adapt to the reduced blood flow in the usual antegrade manner (Fig. 16.1). However, sudden occlusion of one of the mesenteric arteries without prior development of the collateral network leads to profound ischemia of the bowel. Acute mesenteric ischemia (AMI) is a surgical emergency with a well-documented high in-hospital mortality between 59 and 93 % [1]. The pathophysiology of the situation leading to compromise of the mesenteric circulation and development of AMI can be arterial embolism, arterial thrombosis, nonocclusive mesenteric ischemia (NOMI), and mesenteric venous thrombosis. The focus of this chapter will be the management of AMI secondary to arterial embolism.

Arterial embolism has been reported as the most common mechanism accounting for 40–50 % of cases of AMI; it accounted for >50 % of cases treated at our institution over the last two decades [2, 3]. The acute takeoff of the SMA from the aorta

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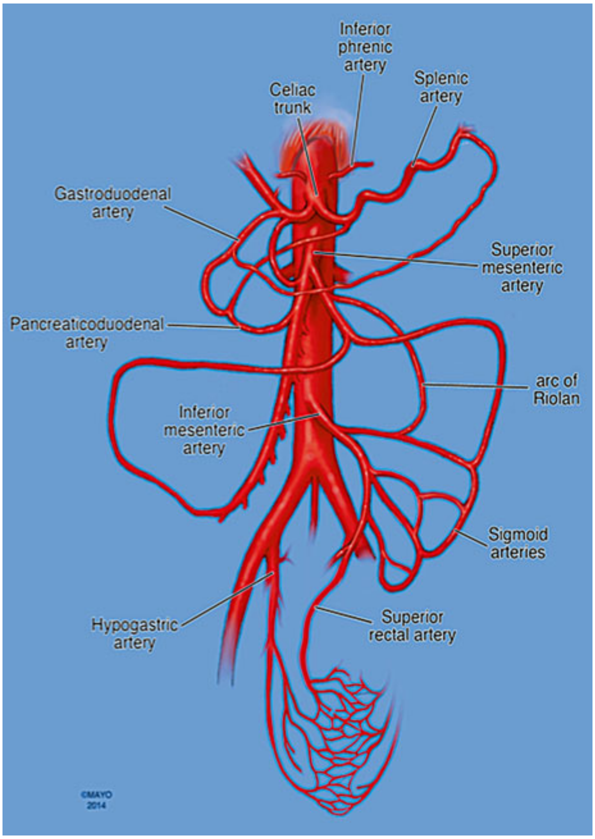

Fig. 16.1 Anatomy of the mesenteric vessels with rich collateral network (By permission of Mayo Foundation for Medical Education and Research. All rights reserved)

makes it the most vulnerable vessel to embolization, most frequently an embolus arising upstream in the arterial circulation, typically the heart or the thoracic aorta. The majority of emboli originate from thrombi in the left atrium in the setting of atrial fibrillation, in the left ventricle secondary to hypokinesis/aneurysm following myocardial infarction or upon cardiac valvular lesions/synthetic valves. The typical patient may have an acute change in his/her cardiac status including an episode of atrial tachyarrhythmia, congestive heart failure, myocardial infarction, ventricular aneurysm, or failure to maintain a therapeutic anticoagulation status with a known chronic tachyarrhythmia [4, 5]. Aortic thromboembolism is a less frequent source of AMI, arising from thrombus atop ulcerative atherosclerotic plaques. It may occur spontaneously; however, the commonest predisposing factor is an endovascular procedure in the aorta (arteriography, intra-aortic balloon placement). It can also occur during open procedures with placement of a high aortic clamp on a diseased, shaggy aorta [6–11].

Diagnosis of Mesenteric Embolism

Patient Population

The hallmark of clinical presentation of a patient with AMI is abrupt onset, severe, nonlocalized “abdominal pain out of proportion to physical signs.” Identifying important clues and risk factors in the clinical history can often help make a timely diagnosis. These include: atrial fibrillation (AF), recent myocardial infarction, congestive heart failure, and prior embolic events. Not infrequently anticoagulation is interrupted in an elderly patient with chronic AF for an invasive procedure or due to fall risk [12]. In addition, a history of symptoms suggestive of chronic mesenteric ischemia (postprandial pain, weight loss, “food fear”), previous venous thromboembolic events, hypercoagulable states, and vasopressor therapy can point to a different etiology of the AMI.

Preoperative Testing

There is no laboratory study that confirms the presence of mesenteric ischemia. Furthermore, laboratory findings are often nonspecific and unaltered in the early stages, and delaying diagnostic imaging till results of laboratory tests are available in a suspected patient significantly decreases survival [13]. In the later stages, there is evidence of hemoconcentration from sequestration of fluid in the bowel wall including leukocytosis and elevated serum lactate and amylase. By the time these occur, there has usually already been compromise of bowel viability. Experimentally in a rat model, it has been suggested that the D-dimer level after two hours from insult may correlate with the presence of AMI [14]. Further, plasma and urine levels of intestinal fatty acid-binding protein (FABP) have been linked to bowel infarction and have been suggested as tools in the early diagnosis of AMI [15–17].

Preoperative Imaging

Computed tomography angiography (CTA) with intravenous contrast is now widely available and has replaced mesenteric arteriography as the definitive diagnostic tool in contemporary practice [18, 19]. It is a fast, effective, and noninvasive way to rule out commoner causes of acute abdomen, confirm the diagnosis of AMI, and potentially identify the etiology [20]. In addition, CTA differentiates between *acute mesenteric thrombosis* when an ostial occlusion of a calcified SMA is usually seen and *acute arterial embolism* when a more distal SMA occlusion of a noncalcified SMA is demonstrated. Typically emboli lodge at a branch point in the vascular tree, usually 1–2 cm distal to the origin of the vessel, most often at the takeoff of the middle colic artery branch, which results in the typical sparing of the proximal

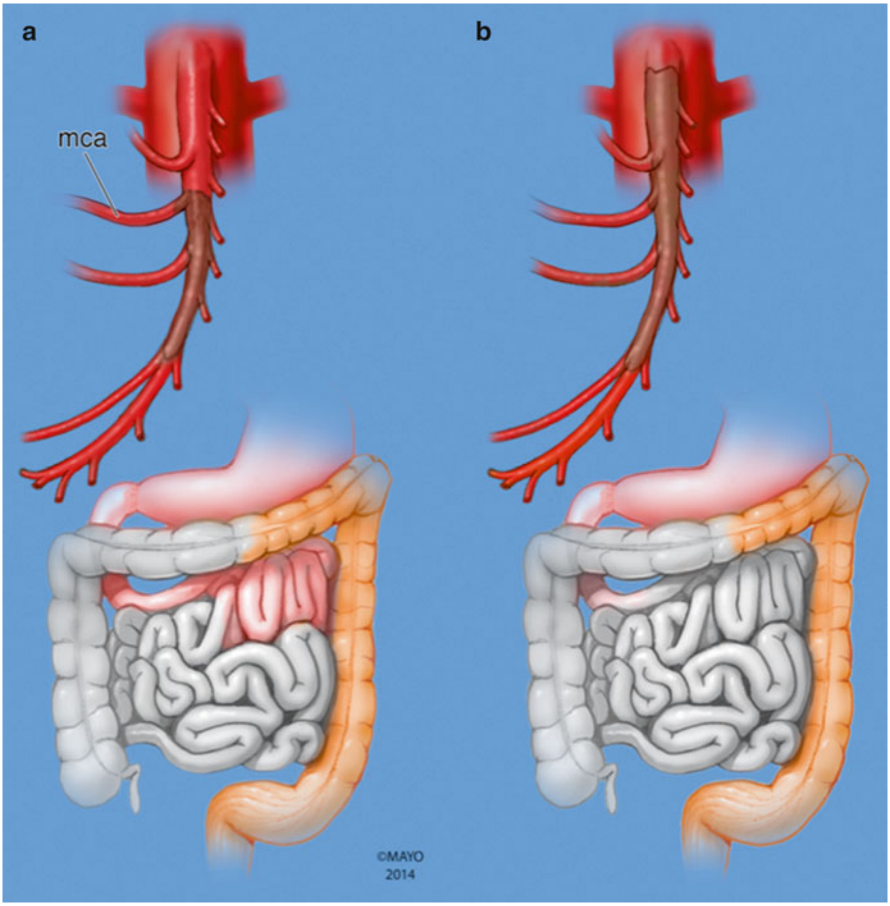

Fig. 16.2 Diagrammatic representation of typical location of embolic (**a**) and thrombotic (**b**) occlusion of the SMA with corresponding pattern of extent of bowel ischemia. (**a**) Embolic occlusion of the SMA at the branching point of the middle colic artery (*mca*). (**b**) In situ thrombosis of the SMA starting at the ostium (By permission of Mayo Foundation for Medical Education and Research. All rights reserved)

jejunum and distal transverse colon (Fig. 16.2). No one CTA finding is diagnostic of AMI; however, a combination of pneumatosis intestinalis, superior mesenteric artery occlusion, portomesenteric venous gas, or portomesenteric venous thrombosis together yields a positive predictive value of 100 % and a negative predictive value of 96 %, respectively. CTA is considered today the gold standard in diagnosis of AMI and should be the one and only imaging study ordered [19, 21].

The role of *mesenteric arteriography*, long held as the "diagnostic gold standard" has evolved to therapeutic indications mostly in the treatment of in situ mesenteric arterial thrombosis with angioplasty with or without stenting [2, 22]. Additional applications include injection of intra-arterial vasodilators, thrombolysis, and aspiration thrombectomy [23, 24].

Fig. 16.3 Plain abdominal radiograph with evidence of portal venous gas and pneumatosis intestinalis (*arrow*)

Additional noninvasive imaging modalities traditionally useful in the elective setting do not have a significant role to play in the diagnosis of AMI, where time is of the essence. *Plain abdominal radiography* is usually nondiagnostic; it only demonstrates signs of mesenteric ischemia when the process is very advanced, such as pneumatosis intestinalis and portal venous gas (Fig. 16.3) that herald a very poor prognosis in this setting [25].

Duplex ultrasonography is a very useful screening tool to identify stenosis of the mesenteric vessels in the elective setting [26, 27]. However, it is virtually useless in the acute setting due to poor visualization of the mesenteric vessels as a result of bowel gas from distention combined with significant patient discomfort. Similarly, *magnetic resonance angiography (MRA)* is theoretically appealing because of lack of the potential nephrotoxicity and allergic reaction associated with intravenous iodinated contrast for CTA; however, it is too uncomfortable and time consuming for a patient with significant abdominal pain to provide meaningful visualization of the mesenteric vasculature [28].

Preoperative Considerations

Prompt operative intervention is necessary for the treatment of acute mesenteric ischemia. Ideally, however, resuscitative efforts should be started as soon as the diagnosis is suspected and continued in the operating room. The initial management is threefold, including optimization of oxygen delivery with supplemental oxygen, intubation and mechanical ventilation, and transfusion of red blood cells to achieve a hematocrit of 30 %. Secondly, preservation of intestinal blood flow in the form of dynamic goal-directed fluid resuscitation, systemic heparinization titrated to a partial thromboplastin time of 60–80s and the use of selective vasoactive and inotropic agents to improve cardiac output. Lastly, initiation of treatment of sepsis by administering broad-spectrum antibiotics to treat bacterial translocation [29]. Further, at the time of induction of anesthesia, the patient should undergo adjunctive invasive monitoring including arterial line, central venous line, and Foley catheter placement [4].

Surgical Treatment

Once a diagnosis of AMI has been made, occlusion of the SMA has been confirmed, and the etiology of this occlusion determined, urgent bowel evaluation needs to be undertaken. All patients with suspicion of threatened bowel require prompt abdominal exploration. With the advent of minimally invasive techniques, one might suggest laparoscopy as an option. However, this has been only successfully demonstrated in a porcine model [30]. Sauerland et al. in 2006 clearly delineated that laparoscopy in the setting of an acute abdomen resulting from AMI offers very limited therapeutic benefit. Further, a limited view of the entire abdomen does not guarantee adequate recognition of ischemia [31]. Prior to midline laparotomy, the surgeon should be prepared for multiple modes of treatment of SMA occlusion, including: SMA thromboembolectomy, bypass, or retrograde stenting depending upon the final assessment. The patient should be prepped for possible great saphenous vein harvest (GSV) for an interposition graft/patch angioplasty. During laparotomy, the entire small and large bowel should be evaluated for signs of ischemia, by direct observation and peristalsis, assessment of pulses in the bowel mesentery by Doppler, and/or the use of fluorescein and ultraviolet light (Fig. 16.4) [32]. The latter technique has been reported to have a sensitivity of 96 % and a specificity of 95 % in the recognition of small bowel compromise [33]. It is recommended that revascularization be achieved prior to any bowel resection unless perforation causes significant spillage of enteric contents. Further, any necessitated small bowel resection should be limited to only necrotic segments. All segments with ischemic changes and equivocal viability should be preserved because once revascularization is achieved, these “questionable” bowel segments may recover. In the rare event that the entire small bowel demonstrates necrotic changes as a result of profound ischemia, neither further exploration nor revascularization should be undertaken as complete necrosis of the small bowel is not compatible with meaningful life. The abdomen should be closed and comfort care measures instituted.

Fig. 16.4 Evaluation of small bowel during abdominal exploration. (**a**) Direct visualization and exploration facilitates the assessment of viability of the small bowel; note the sparing of the proximal jejunum. (**b**) Same patient as in (a). Assessment of the small bowel using fluorescein and ultraviolet light (Wood's lamp)

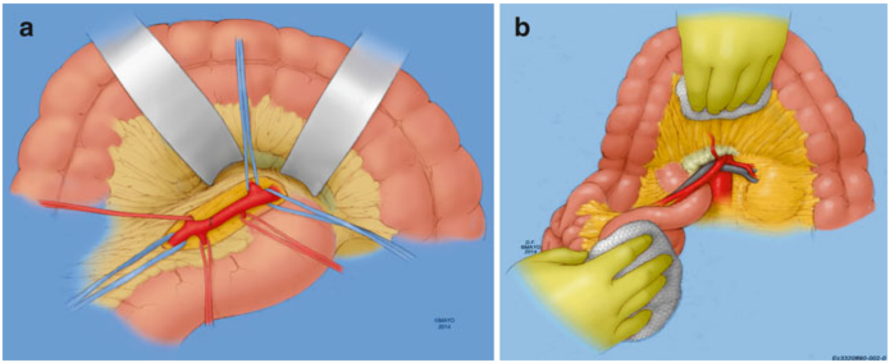

Fig. 16.5 Exposure of the superior mesenteric artery. (**a**) Anterior exposure of superior mesenteric artery. (**b**) Lateral exposure of superior mesenteric artery (By permission of Mayo Foundation for Medical Education and Research. All rights reserved)

Embolectomy of the Superior Mesenteric Artery

Once the bowel has been appropriately addressed, SMA revascularization is undertaken. The SMA can be exposed from an anterior and/or a lateral approach, both being equally effective. The *anterior approach* (Fig. 16.5a) ideally suited for embolectomy is performed through the base of the transverse mesocolon at the root of the mesentery without mobilization of the ligament of Treitz. To expose the main trunk of the SMA, the transverse colon is retracted cephalad and the small bowel caudad, which will allow for palpation of the vessel at the root of the mesentery, along the inferior margin of the pancreas especially if pulsatile or calcified. The peritoneum overlying it is next incised at the base of the transverse mesocolon, and careful dissection is carried down to the artery. It can often be difficult to expose due to the lack of pulsatility and significant mesenteric edema. It lies to the left of the superior mesenteric vein, and multiple small venous tributaries crossing the SMA may require ligation and division to facilitate exposure. The middle colic artery can also serve as a landmark to identify the SMA. It can be identified easily in the transverse mesocolon and traced proximally to its origin from the superior mesenteric artery. Careful dissection is necessary to not damage lymphatics, autonomic nerve fibers, the pancreas superiorly, and the delicate proximal jejunal branches coming off the SMA. If more proximal exposure of this vessel is necessary, this can be judiciously performed by carefully retracting the inferior pancreatic border cephalad. The *lateral approach* (Fig. 16.5b) to the SMA involves taking down the ligament of Treitz and mobilizing the entire small bowel to the right side of the abdomen. This provides access to an adequate length of the main trunk of the artery for direct revascularization without easy access for embolectomy of the distal branches. It is ideally suited for revascularization of the SMA with antegrade bypass from the supraceliac aorta or retrograde bypass from the infrarenal aorta or either iliac artery to treat in situ thrombosis.

Once the SMA and its branches have been isolated, therapeutic heparinization is confirmed, and proximal and distal control of this vessel is obtained. A transverse arteriotomy is performed in the infra-pancreatic segment of the artery. Rarely a longitudinal arteriotomy and closure with a patch are necessary, only if the artery is very small in caliber or diseased/stenotic. Following arteriotomy, the thrombus is extracted with 3–4 mm Fogarty balloons. Thromboembolectomy is performed by passage of the balloon catheter proximally as well as distally down the main trunk and into the branches if necessary, with special care not to force the catheter or overdistend the balloon and disrupt the delicate branches. Rupture of these branches that are relatively unsupported in the mesentery can result in an impressive hematoma, potentially further compromising bowel blood supply. This process is repeated until a clean pass of the balloon catheter is achieved (Fig. 16.6). After all thrombus has been removed, appropriate forward and backward bleeding followed by careful flushing with heparinized saline (10 units of heparin per mL) is performed. The arteriotomy is then closed primarily with interrupted 6–0 Prolene sutures, or with a GSV/bovine pericardium patch, and flow is restored (Fig. 16.7). At this point, reassessment of the bowel is recommended using a handheld Doppler, checking signals along the mesenteric and anti-mesenteric border of the bowel. Once SMA revascularization has been achieved and confirmed, obviously necrotic areas of bowel are resected but bowel continuity is not restored at this stage. Again, all equivocally viable bowel is preserved for reassessment at a later stage, and temporary abdominal closure is performed.

Embolectomy of the Celiac Artery

The CA and its branches are exposed through the lesser sac by opening the gastrohepatic ligament and exposing the area over the aorta just inferior to segments 2 and 3 of the liver (Fig. 16.8). Exposure and embolectomy of the CA is rarely required

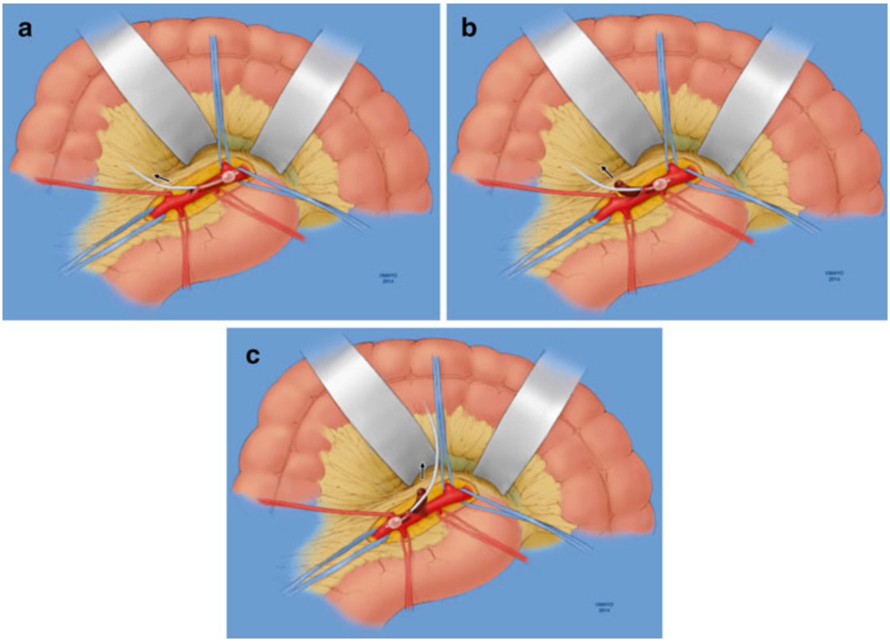

Fig. 16.6 (a–c) Balloon catheter embolectomy of the SMA, proximal and distal (By permission of Mayo Foundation for Medical Education and Research. All rights reserved)

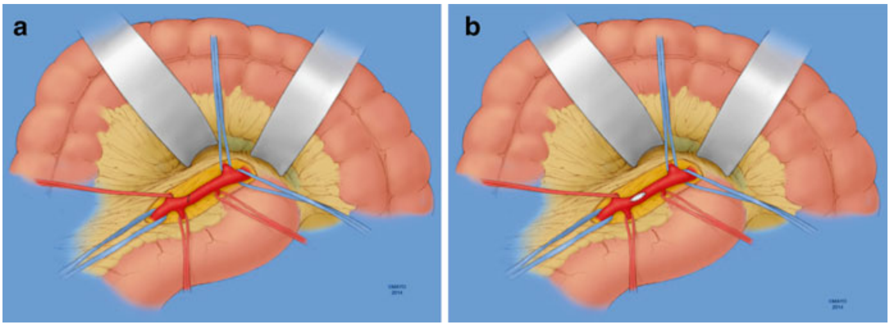

Fig. 16.7 (a and b) Arteriotomy closure, either primary or using a patch (By permission of Mayo Foundation for Medical Education and Research. All rights reserved)

and has only been reported in the literature as case reports [34]. Luther and colleagues described a case of AMI in whom they noted persistently ischemic liver and stomach following initial embolectomy of the SMA and successful revascularization of the small bowel. The CA was exposed and significant thrombus was noted to be present in all three branches of the artery. Flow to the liver and stomach was reestablished by thrombectomy of the hepatic and left gastric arteries, with only partial thrombectomy of the splenic artery.

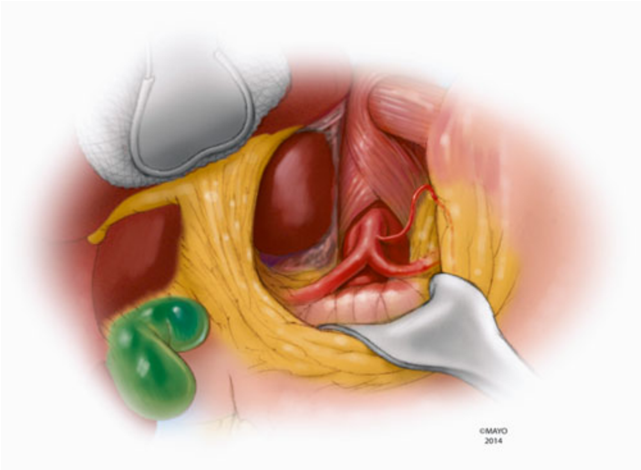

Fig. 16.8 Diagrammatic representation of celiac artery exposure (By permission of Mayo Foundation for Medical Education and Research. All rights reserved)

Embolectomy of the Inferior Mesenteric Artery

The inferior mesenteric artery is located along the anterolateral area of the infrarenal aorta at the base of the left colon mesentery (Fig. 16.9). No data is available in the literature about the utility of an embolectomy of the inferior mesenteric artery for treatment of AMI. Usually the collateral network with the branches of the internal iliac and the superior mesenteric arteries is robust enough to sustain acute occlusion of this vessel. In addition, the small caliber of this artery makes thrombo-embolectomy very challenging.

Role of Second Look Laparotomy

The benefits of a temporary abdominal closure in an acute situation were initially validated in the trauma literature and subsequently extended for use in the setting of vascular catastrophes [35–37]. These benefits include ability to reassess the small bowel with or without resection after allowing time for hemodynamic resuscitation subsequent to the revascularization. The expeditious "closure" of the abdominal cavity allows for further resuscitation and support of the patient in the intensive care unit with the plan to reanastomose segments of bowel on a different day, as well as the ability to reassess bowel anastomoses in tenuous tissues prior to final abdominal closure. In our experience, the use of this technique has increased in the most recent decade (2000–2010) from 48 to 80 % with concomitant decrease in overall mortality from 27 to 17 % from the previous decade (1990–1999) [2].

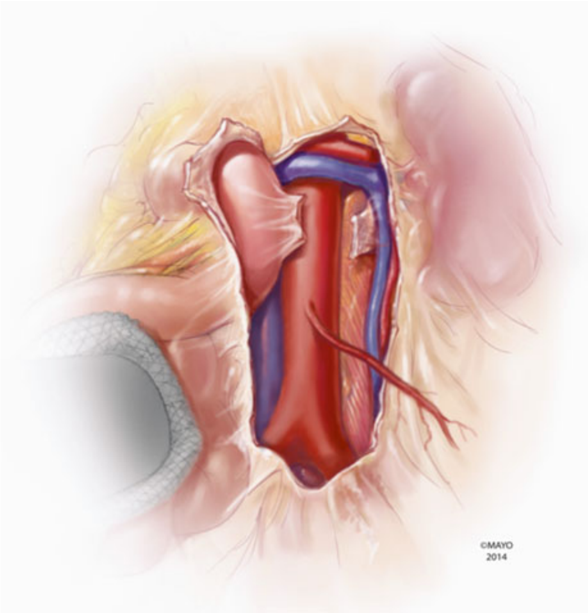

Fig. 16.9 Typical location of inferior mesenteric artery (By permission of Mayo Foundation for Medical Education and Research. All rights reserved)

Other Surgical Options

Recently, alternative treatment of SMA embolus has been described by using percutaneous mechanic-chemical thrombectomy (AngioJet®) and thrombolysis. Ballehaninna and colleagues demonstrated that this noninvasive technique was effective and successful in the treatment of an embolic event in the setting of atrial fibrillation [38]. Initial removal of the thrombus by mechanical thrombectomy (Angiojet®) was complimented with subsequent thrombolysis to treat residual thrombus identified by a filling defect on the angiogram. Complete clearance of this was confirmed on angiogram 24 h later with wide patency of the SMA and no residual stenosis. The obvious advantages of this minimally invasive technique include a lack of a general anesthetic and laparotomy. However, the latter may be a drawback as well in patients with more advanced ischemia as a lack of early bowel assessment could negatively impact outcome. It may be reasonable to defer evaluation of the bowel in patients with more subacute presentation in the setting of AMI secondary to mesenteric thrombosis, however, is almost mandatory in patients with SMA embolism due to the high likelihood of bowel compromise in the absence of preformed collaterals. The technique may be applicable in the setting of SMA embolism in very selective patients with early ischemia and significant medical comorbidities precluding laparotomy.

Surgical Outcomes: Short and Long Term

Overall, morbidity and mortality in the setting of AMI remain high (30–65 %) [39]. Although advances in endovascular techniques have offered a wide variety of potential intervention options that could help improve these high rates of negative outcomes, both morbidity and mortality remain similar between the open and endovascular era. In a retrospective review of our experience with surgically treated AMI secondary to arterial embolism and thrombosis over the last two decades [2, 3], a trend towards improved mortality from 27 to 17 % and morbidity from 73 to 63 % was observed. All patients with SMA embolism underwent laparotomy and thrombectomy in both decades with endovascular intervention being performed only for SMA thrombosis. The one factor that changed between the decades compared was the number of second-look operations (from 48 to 80 %), which aided in the diagnosis of additional 28 % of patients with necrotic bowel requiring further resection. On univariate analysis, factors predicting early mortality were SVS clinical score, serum creatinine, residing in a nursing home, and congestive heart failure. In contrast, having chronic mesenteric ischemia was protective against mortality. Our contemporary results compare favorably with other reports of large tertiary care centers. Three recent series of open revascularization for AMI from large volume centers reported mortality rates of 31–62 % [40–42]. A common theme among these reports, as well as ours, is that advanced age and visceral ischemia are predictors of poor outcome, especially in the older, sicker patients with SMA embolism who continue to be a challenge. The Cleveland Clinic reported their experience with treatment of AMI [43]. Although they adopted an endovascular first approach to patients with SMA thrombosis with significantly lower mortality (36 %) compared to open interventions (50 %), no such benefit was demonstrated in patients with SMA embolism who were mostly treated with laparotomy and thromboembolectomy. Similarly, Schermerhorn and colleagues reported on results of treatment for acute and chronic mesenteric ischemia from the Nationwide Inpatient Sample. The incidence of open surgery in the setting of acute ischemia remained unchanged over a decade (1995–2006) with the number endovascular interventions performed for mesenteric thrombosis gradually increasing. This rise was, however, very modest compared to the explosion in endovascular intervention in the setting of chronic mesenteric ischemia over the same period. The incidence of embolectomy in the setting of open surgery was 49 %, and mortality in these patients was also the highest at 49 %, proportional to the higher incidence of bowel resection (37 %) [44].

AMI with an embolic etiology continues to be a challenging problem. The patients presenting with this problem continue to get older with significant cardiac comorbidities. Regardless, a high index of suspicion, prompt diagnosis, and appropriate expeditious treatment with early assessment of bowel viability regardless of revascularization modality selected remain the keys to improving outcomes of this grave problem. The importance of liberal use of second-look laparotomy cannot be overemphasized.

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