A Review on Aorta Mesenteric Bypass in Surgical Management of Mesenteric Ischemia: Indications, Techniques and Outcomes

Danilo COCO\textsuperscript{a}, Silvana LEANZA\textsuperscript{b}

\textsuperscript{a}Department of General Surgery, Ospedali Riuniti Marche Nord, Pesaro, Italy
\textsuperscript{b}Department of General Surgery, Carlo Urbani Hospital, Jesi, Ancona, Italy

\textbf{ABSTRACT}

Mesenteric ischemia (MI) is a rare medical condition which involves insufficient blood supply, inflammatory injury and eventually bowel wall necrosis with high mortality rates. Acute mesenteric ischemia (AMI) and chronic mesenteric ischemia (CMI) are the two major types of mesenteric ischemia. Therapeutic approach of MI includes medical as well as surgical treatment. This review article aims to delineate the abreast knowledge on indications, management through mesenteric bypass surgical technique, and clinical outcomes. Clinical presentation of AMI and CMI varies substantially, depending on the etiology underlying it. The most common symptom of AMI is abdominal pain that is disproportionate to the outcomes of physical exams; whereas CMI normally induces postprandial abdominal pain, commonly epigastric or periumbilical, nausea and weight loss. Recent awareness of AMI management revealed that exploratory laparotomy surgical procedure with careful evaluation of bowel viability played a pivotal role in restoring intestinal oxygenation and avoiding serious complications such as peritonitis and perforation of the gangrene bowels. The management of CMI is mainly surgical, with Aorta/Iliac-SMA bypass and Aorta-Splenic bypass being the currently available options. Due to the high thrombosis levels, only patients whose surgical risk outweighs possible benefits are required for medical care as a single treatment. Furthermore, this review also postulates that aorto mesenteric revascularization procedures for chronic mesenteric ischemia are feasible, but involve careful selection of patients, and they should only be performed by vascular surgeons with extensive experience in laparoscopic vascular surgery at referral centers.

\textbf{Keywords}: mesenteric ischemia, AMI, CMI, Aorta/Iliac-SMA bypass, Aorta-Splenic bypass, surgery, surgeons.
INTRODUCTION

Mesenteric ischemia (MI) is a rare medical condition affecting 0.1% of all hospital admissions, with high mortality rates ranging from 24% to 94% (1). It includes insufficient blood supply, inflammatory injury and finally, bowel wall necrosis. The disease can be divided into acute mesenteric ischemia (AMI) and chronic mesenteric ischemia (CMI). Further subdividing AMI into four categories (2); consequently, AMI can result from arterial embolism, arterial thrombosis, mesenteric venous thrombosis (MVT) and non-occlusive causes (NOMI) such as hypo-perfusion from low cardiac output or mesenteric arterial vasoconstrictions (3). Bowel damage is proportional to the reduction in mesenteric blood flow, which may vary from minimum lesions due to reversible ischemia to transmural injury, accompanied by necrosis which perforation (4).

In more than 95% of cases, CMI is associated with diffusing atherosclerotic disease, with all major mesenteric arteries having stenosis or occlusion. Certain causes include dysplasia from the fibromuscular, vasculitis, arteritis from takayasu, malignancy and radiation. This disorder is often only diagnosed at an advanced stage, due to either a lack of clear signs or its often quiet appearance (5). Persistent, intermittent, non-localized or periumbilic abdominal pain remains the most common symptom (6-8). In CMI patients, postprandial pain, nausea, and weight loss occur (4). Though laboratory studies or plain abdominal films are not indicative, computed tomography (CT) imaging and CT angiography contribute to differential diagnosis and management of AMI. Angiography is also the main criterion for CMI, with high value even in mesenteric duplex ultrasoundography (US) and magnetic resonance angiography (MRA) (9-11).

Mesenteric ischemia therapeutic approach consists of both medical and surgical treatment. The most common drugs are papaverine, heparin, warfarin, and thrombolytic (12). Surgical procedures consist of restoring the blood flow with arteriectomy, endarterectomy, or antegrade bypass, while necrotic bowel resection is always applied (13).

There is no consensus on the best method of mesenteric surgical reconstruction for CMI treatment. Controversy remains about the best operative technique and the bypass conduit type selection (14). The type of operation depends on the limit and location of the aortic disease, the surgical risk to the patient, the need for other vascular procedures, and the vascular surgeon’s choice and experience. It is also contentious to need to repair only one or two arteries (superior mesenteric artery [SMA] and celiac artery). Multivessel bypass reduces the risk of symptomatic relapse and offers some protection against intestinal infarction in the event of occlusion of a single graft (15).

Mesenteric bypass is a long-time established effective method for treating symptomatic CMI, with excellent primary patency and long-term survival. Although long-term survival is comparable for endovascular therapy and surgical therapy, long-term patency with surgery appears to be superior, with additional interventions required in substantially fewer cases (16-18). Nonetheless, endovascular therapy is therefore more common in most centers than surgical therapy. Factors such as patient preference, reduced significant morbidity, and quicker recovery have motivated most preferences of surgical reconstruction to support endovascular therapy (15, 18). In many patients, mesenteric bypass is performed following failed angioplasty and stent placement.

With this scenario, the present review article aims to delineate the abreast information about signs of mesenteric ischemia, and management by mesenteric bypass surgical procedure, and clinical results to provide an update on existing concepts of surgical management of the disease.

Causes and clinical presentation of mesenteric ischemia

In terms of clinical presentation, AMI and CMI varies substantially, depending on the etiology underlying it (19). The most common symptom of AMI is abdominal pain that is disproportionate to the outcomes of physical exams. Since ischemia is the pathological process, the pain is initially visceral, diffused, non-localized and can be mild to extreme, persistent, often colicky and often unresponsive to opioid analgesics. Some common symptoms include nausea and vomiting, although there may also be diarrhea that leads to constipation. Examination findings are limited and non-specific early in the course of the disease,
including minimal abdominal tenderness. If embolic disease is due to ischemia, the pain is extreme and sudden, as occlusion is easily mounted and collateral circulation totally absent (13, 20). On the other hand, since the artery is normally already partially blocked and a collateral supply has been created, AMI due to arterial thrombosis has a much more progressive development of ischemia and infarction, and less serious presentation (21). Signs of peritonitis and septicemia are confronted as the ischemia progresses transmurally (22). Necrosis of the Bowel, septic shock and death are common complications in AMI (Table 1).

<table>
<thead>
<tr>
<th>Category</th>
<th>Causing factors</th>
<th>Clinical presentations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occlusive mesenteric</td>
<td>Arterial embolus (50%)</td>
<td>Abdominal pain (95%)</td>
</tr>
<tr>
<td></td>
<td>Cardiac disease</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Atrial fibrillation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recent myocardial infarction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Congestive cardiac failure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Infective endocarditis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thromboembolism from aorta</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Digitalis therapy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mesenteric arterial thrombosis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-existing atherosclerosis lesion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aortic dissection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mesenteric venous thrombosis (5-)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Antithrombin III deficiency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prothrombotic states</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Factor V Leiden</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protein S deficiency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pregnancy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protein C deficiency</td>
<td>Low gastrointestinal bleeding</td>
</tr>
<tr>
<td></td>
<td>Antiphospholipid antibodies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Essential thrombocythemia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oral contraceptive use</td>
<td>Abdominal distention</td>
</tr>
<tr>
<td></td>
<td>Hyperhomocysteinemia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Neoplasms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pancreatitis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Paroxysmal nocturnal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sepsis</td>
<td>Fever</td>
</tr>
<tr>
<td></td>
<td>Peritonitis and intraabdominal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inflammatory bowel disease</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cirrhosis and portal hypertension</td>
<td>Tachycardia</td>
</tr>
<tr>
<td></td>
<td>Diverticulitis, postoperative state</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Abdominal operations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chronic renal failure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hemodynamic instability</td>
<td>Tachypnoea</td>
</tr>
<tr>
<td>NOMI (20-30%)</td>
<td>Hypovolemia, sepsis, shock</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Use of vasopressors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Critically ill patients, renal insufficiency</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1.** Causing factors and clinical presentation of acute mesenteric ischemia (23)
Chronic mesenteric ischemia usually causes abdominal postprandial pain, generally epigastric or periumbilic, nausea and weight loss. Examination findings include symptoms of malnutrition, clinically excessive discomfort and abdominal bruit (5, 24). Symptomatic CMI is an indication for either open or endovascular revascularization, as patients with untreated symptomatic CMI carry a five-year mortality rate that approaches 100% (25, 26).

**Indications for surgery**
- Signs of peritonitis on physical exam
- Massive lower GI hemorrhage
- Ongoing signs of abdominal pain, fever, or sepsis
- Symptoms that have persisted for more than 14 to 21 days
- Chronic malabsorption leading to protein-losing colopathy
- Colonoscopic evidence of segmental colitis with frank ulceration
- Presence of an ischemic stricture and abdominal symptoms

**Management options of mesenteric ischemia**

Despite medical management of AMI, recent awareness has created multidisciplinary management of AMI surgery. The initial aim is to restore intestinal oxygenation and reduce or avoid serious complications such as peritonitis and perforation of the gangrenous bowel. Thus, AMI surgical diagnosis with symptoms of peritonitis primarily includes exploratory laparotomy with careful evaluation of the viability of the bowel (6, 27). It strongly suggests resection of the infarcted intestine. In addition, under Wood Lamp Illumination, intraoperative Doppler US and IV fluorescein infusion and bowel inspection may discern poorly perfused bowel. Necrotic bowel resection plays a crucial role in resuscitation of patients when an attempt at anastomosis remains contentious. A second look operation, along with clinical review and diagnostic imaging is strongly recommended. Intense screening of intestinal revascularization is also carried out (28, 29).

More precisely, an attempt at reperfusion remains vitally necessary in case of embolic AMI (6). Using a balloon-tipped Fogarty catheter for removing the clot, the surgical team will assess the position of the blockage by palpation and proceed to transverse arteriotomy proximal to the occlusion. Embolectomy can be achieved most quickly by exposing the SMA at the transverse mesocolon base. Arteriotomy can be mainly sealed or patched with veins. An alternative approach is bypassing a venous or arterial grafting technique (27, 30, 31). Revascularization is attempted either with antegrade or retrograde aortomesenteric bypass, or with trans-aortic endarterectomy in the event of thrombotic occlusion with absence of gangrenous bowel. In case of spontaneous dissection of SMA, successful percutaneous stent placement has been stated before the onset of intestinal infarction (32-34).

After repair of aortic aneurism, a significant incidence of AMI has been also recorded. Upon endovascular abdominal aortic reconstruction, the prevalence of clinically visible bowel ischemia is comparable with open surgical approach. Nonetheless, a higher incidence of small bowel ischemia has been observed in patients with endovascular repair and is associated with exceptionally high mortality. In most cases, the direct pathologic evidence and patterns of segmental, skipped, or patchy ischemia suggest that microembolization plays a central role (35, 36).

The management of CMI is chiefly surgical. Because of the high thrombosis levels, only patients whose surgical risk outweighs possible benefits are required for medical care as a single treatment. Furthermore, cautious care such as intestinal rest, avoidance of smoking and administration of vasodilator medicines do not enhance the progression of the disease (49). Medicinal drugs used in CMI include heparin and warfarin to avoid an acute thrombotic/embolic occurrence, intra-arterial papaverine as a vasodilator before surgery to minimize the risk of arterial spasm, and nitrate therapy to provide short-term relief. Given the long malnutrition time, parenteral feeding is required (5, 24).

There are two alternative treatment modalities in patients with CMI: open revascularization (OR) and endovascular revascularization (ER) (37-39). The latter tends to have lower rates of postoperative mortality and morbidity, and shorter length of intensive care unit and hospital stay. Hence, due to its minimally invasive nature, ER has been recommended for high risk surgical candidates or those with low life expectancy (39-41). In ER, a short stump of the patent artery is needed to gain access to the wire. Excessive manipulation of the
endovascular system can cause arterial dissection, perforation or embolization. Furthermore, highly calcified or long lesions and mesenteric arteries of small-diameter are often associated with an increased risk of distal embolization and restenosis. However, OR provides symptomatic relief early as well as long-term and substantially lower restenosis levels compared with ER. Thus, most patients should be treated with conventional reconstruction particularly if ER has been tried unsuccessfully beforehand. In summary, although ER had recently gained traction as an alternative therapeutic method, OR is still largely being proposed (39, 42, 43).

Surgical treatment involves transaortic celiac or SMA endarterectomy, antegrade bypass of the
supraceliac aorta and retrograde bypass of the infrarenal aorta or common iliac arteries. Bypasses can be achieved with vein or prosthetic material. In highly calcified, thrombotic, occlusive, or dissected lesions, primary stenting is preferred. Little is known about the effect of distal embolization on stent placement. In the presence of a large thrombus burden, an embolic protection device may be considered. However, there is insufficient evidence to prove its efficacy for CMI during ER (37, 38, 42).

**Techniques**

In patients with CMI, Kazmi *et al.* (44) documented the operating techniques and findings of an early encounter with laparoscopic revascularisation. All operations were carried out under general anesthesia. After intubation, all patients received intravenous antibiotic prophylaxis (Cefalotin 2 g), which was repeated every three hours until four doses in total. The patient was positioned supined on a table with the split-legs, and the surgeon stood between the legs. A surgical nurse stood on the surgeon’s left side, and an assistant stood on each patient’s side. Pneumoperitoneum was accomplished by insufflating carbon dioxide (CO2) by means of a trocar put under direct peritoneum visualisation. During surgery, a pneumoperitoneum pressure of 12 mm Hg has been maintained. Trocars were positioned, if necessary, in anatomical positions suitable for healthy peritoneal or omental adhesiolysis (Figure 1A). The small intestine pushed slowly into the right side of the abdominal cavity. One or two 10 mm fan retractors (Covidien Endo Retract II Ethicon) were used when required to keep the intestine detached from the surgical field. Abdominal aorta and iliac arteries were approached by opening the peritoneum directly to the surrounding. The infrarenal aorta was dissected free for a duration appropriate for the application of aortic clamps and for the construction of an end-to-side anastomosis (Figure 1B) (44).

**Aorto/iliac-SMA bypass**

In the area just below the combination of superior and inferior mesenteric veins, SMA had been approached. Treitz ligament was split and duodenum mobilized to free dissect the length of SMA required. Ring-enforced extended polytetrafluoroethylene (ePTFE) 8 mm (Gore-Tex Stretch Vascular Graft) was spatulated at one end and inserted via a 12 mm trocar into the abdominal cavity. To achieve anticoagulation, intravenous heparin was administered, and the SMA was clamped distally either with a long vessel loop or with a small laparoscopic bulldog artery clamp. In the case of calcified SMA, a laparoscopic aortic clamp can be used for proximal SMA cross-clamping, which has also helped in keeping the greater omentum and transverse colon, detached from the operation field. Thrombendarterectomy was conducted using a longitudinal arteriotomy. In case of an occluded stent, a partial stent resection (distal portion of the stent) was performed. An end-to-side anastomosis was performed with two hemi-circular 6–0 polypropylene sutures, each approximately 12–15 cm long and with a beforehand tied Teflon pledges to their ends (Figure 1C); 12 SMA and backflow artery clamps were temporarily removed (44).

**Aorto-splenic bypass**

Kazmi *et al.* reported that, in two cases, the splenic artery was used as the site of distal anastomosis. Figure 2A–D illustrates the position of the trocar and the different phases of the aorto-splenic bypass. The left liver lobe was elevated using the Nathanson liver retractor (Cook Medical). The hepatogastric ligament was excised across the cranial edge of the pancreas to enter the splenic artery. The artery was dissected in length appropriate for cross-clamping, and an end-to-side anastomosis was constructed. A laparoscopic iliac clamp (Carl Storz, Germany) was cautiously passed anterior to the left renal vein along the right side of the aorta and advanced toward the omental bursa, cranially behind the pancreas. Care has been taken to keep the clamp parallel with the aorta; with this clamp, a spatulated 8 mm ring enforced ePTFE graft was grasped and cautiously tunnelled from the omental bursa, dorsal to the pancreas, towards the infrarenal aorta.

The splenic artery was clamped with the laparoscopic aortic clamps or small laparoscopic artery clamps after systemic heparinization. Longitudinal arteriotomy was performed, and 6–0 polypropylene sutures were constructed with an end-to-side anastomosis. The graft was flushed with heparinized NaCl and cross clamped with a
laparoscopic aortic clamp until the anastomosis with the aorta was constructed in an end-to-side fashion (Figure 2D). Nathanson liver retractor was removed, and the proximal portion of the graft was covered by the smaller omentum and the left liver lobe. The retroperitoneum had been used to cover all SMA grafts (44).

**Clinical outcomes**

The results of the retrograde and antegrade mesenteric bypass, as stated in guidelines, have comparable patency (45). Even though one can transect SMA distal to the occlusion and construct an end-to-end anastomosis, all anastomoses were to
the SMA in an end-to-side fashion. In their research, Kazmi et al. indicated that the atherosclerotic plaque stretched over the entire length of Fullen’s zone 1 and 2 and combined the source of the lower pancreaticoduodenal artery and middle colic artery. The end-to-side anastomosis was more suitable to preserve these critical branches (44).

Furthermore, Kazmi et al. experienced free dissection without any technical difficulties of the splenic artery. Lifting the left liver lobe with the Nathanson liver retractor provided excellent access to the hepatogastric ligament and celiac artery tributaries (44). Nevertheless, Bakoyiannis et al. used a flexible laparoscopic tunneler, placing the graft anterior to the pancreas (46). Kazmi et al. designed carefully with the aid of CTA and could successfully place the graft in two patients in the retroperitoneum along the aorta (44).

Kazmi et al. (44) shared their experience of laparoscopic aortic clamps, although bulky, that can be used on the SMA and splenic arteries. Nevertheless, Bulldog clamps with laparoscopic arteries were more fitting and offered functional anastomosis working space. Alternatively, long (30 cm) vascular loops were used for clamping the mesenteric arteries by trocars among two occlusions of early grafting and one stenosis of the graft which resulted in early redo operation. In all three cases, ring enforced ePTFE was directly clamped with the laparoscopic aortic clamp instead of reclamping SMA or splenic artery after flushing the graft with heparinised NaCl. Thrombendarterectomy of the mesenteric artery and the graft’s cross-clamping period during proximal anastomosis may also have led to the growth of thrombosis in the graft. Although the greater omentum could be used to cover the graft to avoid contact with the intestine, the graft was successfully covered with the retroperitoneum in all patients in this study. Moreover, none of the subjects have developed any graft infections so far (44).

Kazmi et al. advised some technical improvement due to thrombosis of the graft and stenosis of the grafting. In-vitro, a 6 mm ePTFE graft, was end-to-side anastomosed with the central graft (8 mm) near to the distal (mesenteric) anastomosis site (Figure 3). During the process, this side canal allowed a secure and efficient route to flushing the main graft. If necessary, this side canal can be used for main graft thrombectomy. Through this side graft, one can also perform angiography of completion and if necessary, also stenting of mesenteric arteries. After completion of the bypass, Hem-o-loc polymer clips and a large metal clip were applied near the anastomosis intergraft, and the rest of the 6 mm ePTFE graft was excised and discarded (44). Furthermore, cross-clamping of the graft could be avoided from these modifications after the distal anastomosis is complete (47).

In patients with severe peritoneal adhesions due to earlier abdominal operations, Kazmers et al. reported one case of conversion due to venous bleeding, and another with left ureter injury (47). It has been estimated that 10 to 37% of patients under elective abdominal surgery would need repeated abdominal surgery (48). In patients with previous multiple abdominal surgeries, the risk of these complications is high even with open surgery (48, 49). Use of preoperative assessment tools such as the Hostile Abdomen Index risk stratification can help select the right patients for laparoscopic procedures (50).

Mocian et al. described a retrograde aortomesenteric bypass with a Gore-Tex 5 mm diameter prosthesis in a 39-year-old female patient who had been diagnosed with partial upper mesenteric artery stenosis via abdominal computed tomography angiography, and had a history of total nephrectomy, chronic kidney failure, and hypertension. Her postoperative evolution was favourable, with no short- and long-term follow up complications. Based on the clinical findings following retrograde aorto-mesenteric bypass with a

![FIGURE 3. A 6 mm expanded polytetrafluoroethylene graft, end-to-side anastomosed to an 8 mm ring enforced expanded polytetrafluoroethylene graft with graduated length markings and spatulated end. Courtesy: Kazmi et al, 2020 (44)
5 mm diameter Gore-Tex prosthesis, Mocian et al suggested that, in circumstances where the endo-
vascular approach fails or has no indication, such as multiple lesions starting from the origin of the upper mesenteric artery, open surgery should be the indication in chronic mesenteric ischemia (51).

Early experience in the treatment of chronic mesenteric ischemia with laparoscopic revascularization suffered from complications related to the procedure. This is despite long experience with laparoscopic aortic surgery by the operating team (52-54). However, previous experience assisted in anastomosis construction. During the initial experienced with laparoscopic aortic surgery, even a long operating period was observed. Nevertheless, in later experience the operation period for these procedures is not significantly longer (52-54). In summary, the benefits of a minimally invasive procedure such as mesenteric revascularization can only be accomplished by improved patient selection, diligent free dissection technique, avoidance of graft cross-clamping, and mandatory use of ultrasound during surgery or an angiography completion in future research. Only vascular surgeons with expertise in aortic surgery will conduct these advanced laparoscopic procedures in referral centers.

CONCLUSIONS

This review articles outlined that aorto mesenteric revascularization procedures are feasible for chronic mesenteric ischemia but require careful selection of patients. Only vascular surgeons with prior experience in laparoscopic vascular surgery can carry out these procedures in referral centers.

Conflicts of interest: none declared.

Financial support: none declared.

REFERENCES


