Surgical management of peritonitis secondary to acute superior mesenteric artery occlusion.

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High-quality computed tomography (CT) is now possible and is used in many centers to diagnose acute intestinal ischemia (AI). A CT scan should be immediately ordered for all patients with a clinical suspicion of acute mesenteric ischemia. CT angiography is an accurate diagnostic method and can be used to confirm the diagnosis in a short time. A combination of IV contrast enhancement and imaging in the arterial and/or portal phase is recommended. With the development of new hybrid operating rooms in vascular centers, combined with modern diagnostic techniques, it is possible to perform complete medical and surgical revascularization in a single setting. In patients with peritonitis secondary to an acute SMA occlusion, immediate surgical intervention with explorative laparotomy is necessary and bowel resection is performed, followed by a planned second look laparotomy. This approach is the current frontline surgical strategy for improving outcomes in patients with peritonitis due to acute SMA occlusion. The current hybrid operating room is very important in completing the medical and surgical revascularization in a single setting.
INTRODUCTION

Recovery following bowel resection for bowel necrosis and peritonitis secondary to mesenteric vessel occlusion was first reported in 1895\(^\text{[1]}\). Development of peritonitis, followed by exploratory laparotomy remained the main pathway to diagnose mesenteric vessel occlusion, and successful therapy was based on pure luck, whether the extent of intestinal infarction was limited and resectable, or not. One century later, the evolution of high-resolution computed tomography (CT) scanners around the clock have had a great impact on early diagnosis of mesenteric vessel occlusion\(^\text{[2]}\), and has been the prerequisite to be able to perform mesenteric revascularization in time to decrease bowel morbidity and increase survival. In current practice, collaboration between the surgeon and vascular surgeon is of great importance. The patient needs to be transported to a vascular center with available hybrid operating room facilities with a high quality, fixed angiographic system, or mobile C arm, where laparotomy and open and endovascular therapy are possible. When applicable, the principles of damage control surgery should follow mesenteric revascularization\(^\text{[3]}\). This review article aims to outline treatment options and to guide the surgeons prior to or at laparotomy when managing patients with peritonitis secondary to acute superior mesenteric artery (SMA) occlusion.

FREQUENCY OF ACUTE MESENTERIC ISCHEMIA AMONG PATIENTS WITH ACUTE ABDOMEN

The majority, two-thirds, of patients with acute mesenteric ischemia suffers from acute SMA occlusion whereas non-occlusive mesenteric ischemia and mesenteric venous thrombosis is less common\(^\text{[4]}\). The frequency of acute mesenteric ischemia depends on the patient series studied\(^\text{[5-15]}\) (Table 1). The frequency was reported to be 17.7% among patients undergoing emergency laparotomy\(^\text{[5]}\) and as high as 31% among non-trauma patients managed with damage-control surgery\(^\text{[16]}\).

DIAGNOSIS

Maintaining a high index of suspicion and awareness among physicians evaluating patients who are suffering from acute mesenteric ischemia is not enough to improve outcomes. The typical clinical triad of severe abdominal pain but minimal findings at examination (pain out of proportion), bowel emptying, and presence of a source of embolus in elderly patients with acute embolic SMA occlusion is not a consistent finding. Even though patients with acute thrombotic SMA occlusion often have known cardiovascular disease and a history of undiagnosed attacks of abdominal angina, clinicians find it very hard to diagnose this condition prior to progression towards peritonitis\(^\text{[17]}\). Unfortunately, there is no plasma marker that is accurate enough as an early diagnostic aid\(^\text{[17]}\). However, the evolution of available high-resolution CT scanners with rapid reconstructions in the sagittal, coronal and transversal planes has made early diagnosis possible, and increased the proportion of patients that may be considered for mesenteric revascularization\(^\text{[2]}\). Embolic occlusion appears often as an oval-shaped clot surrounded by contrast in a non-calcified arterial segment located in the middle and distal part of the main stem of the SMA, whereas thrombotic occlusion usually appears as a clot superimposed on a heavily calcified occlusive lesion at the ostium of the SMA.

EVALUATION OF THE EXTENT AND SEVERITY OF MESENTERIC ISCHEMIA

The patients need, if possible, to be transported to a vascular center with an available hybrid operating room. Explorative laparotomy through a midline incision is performed in patients with peritonitis, unless palliative care has been decided, to assess the extent and severity of intestinal ischemia, where color of the intestines, dilatation and peristaltic motion of the bowels, visible pulsations in the mesenteric arcade arteries, and bleeding from cut surfaces are most important in the assessment. The SMA supplies the whole small bowel and the right colon to the mid transverse colon, and the ischemic lesions at laparotomy are usually extensive. Of note, the ischemic lesions occur first in the mucosa and may be extensive, and in a few cases, no signs of ischemia may be visible on the serosa side at early laparotomy. Without treatment, development of a variable length of full bowel wall gangrene will occur. In elderly patients with complete transmural infarction of the small bowel up to the mid transverse colon, palliative care is indicated. In case of bowel perforation, the affected intestinal segment is rapidly resected with staples.

ACUTE REvascularization of the SMA

Revascularization is preferably performed prior to bowel surgery. If an explorative diagnostic laparotomy is performed as the first diagnostic step, on table SMA angiography should then be performed. Any previous CT of the abdomen should be scrutinized immediately. If no vascular surgeon is available, resection of obvious bowel necrosis should be performed, the abdomen closed, and the patient transported to a vascular centre. From the national Swedish registry of vascular procedures, SWEDVASC, there has been a steady increase in acute SMA revascularizations for intestinal ischemia since 2004\(^\text{[18]}\), and in 2009, endovascular surgery had surpassed open vascular surgery with 29 endovascular vs 24 open vascular revascularizations.

OPEN SMA EMBOLECTOMY

Most patients with embolic SMA occlusion will have a main stem embolus and an extensive intestinal ischemia\(^\text{[19]}\).
Open SMA embolectomy is a good treatment option\textsuperscript{[19]}.
After laparotomy, exposure of the SMA, transverse arteriogram, insertion of Fogarty catheter nr 3 downstream and 4 upstream, and balloon embolectomy, is performed. The result should be monitored at least by an ultrasonic transit time flow meter, but angiography of the SMA with antero-posterior and lateral views after femoral artery puncture and catheterization of the origin of the SMA gives better information about the status of the whole vascular tree, and identifies stenosis and dissection at the closure site, residual peripheral embolus in arterial branches not cleared, and venous return to the portal vein. The minority of patients with a peripheral embolic SMA occlusion\textsuperscript{[19]} in one or multiple branches and a limited bowel segment of ischemia may be treated primarily with short bowel resection and primary bowel anastomosis without attempting intestinal revascularization.

### HYBRID OR ENDOVASCULAR THERAPEUTIC OPTIONS IN ACUTE THROMBOTIC OCCLUSIONS

Most patients with acute thrombotic SMA occlusion due to thrombosis superimposed on an underlying local occlusive atherosclerotic lesion in the proximal SMA, have extensive intestinal ischemia, which requires revascularization for longer survival\textsuperscript{[18]}. Hybrid (combining open vascular and endovascular surgery) or endovascular approach in acute thrombotic occlusions of the SMA seems advantageous compared with classical open vascular procedures. Endovascular therapy in thrombotic occlusions implies less surgical trauma in these often elderly fragile patients and requires less intensive care resources than the technically more challenging open vascular reconstructions in the emergency setting. It has been learned from experience that there is rarely any indication for revascularization of both the SMA and the celiac trunk, and that SMA revascularization clearly is more important.

### ACCESS TO THE SMA

The SMA can be reached \textit{via} the femoral and brachial arterial routes, and after local exposure of the SMA intra-abdominally after laparotomy. Brachial artery access may be preferable in case of a very sharp downward angle between the aorta and the SMA, or if an extensive calcified occlusive lesion in the ostium of the SMA has to be passed with wires, catheters and introducers, to avoid dissection of the SMA. Brachial artery access is preferred when there are occlusive lesions in the aorta below the SMA and/or in the iliac arteries.

### RETROGRADE RECANALIZATION AND STENTING OF THE SMA

Laparotomy and exposure of the SMA is performed for retrograde SMA recanalization and stenting\textsuperscript{[20,21]}. This approach offers the ability to inspect the abdominal contents, to have distal control of the SMA, and to avoid bypass surgery in the setting of a necrotic bowel and necessary bowel resections with subsequent risk of infection of the vascular prosthesis.

The SMA is exposed at the junction of the mesocolon and the small bowel mesentery. A puncture is made in the main trunk of the vessel with a micro puncture needle and the occlusion is often easily recanalized with a 0.018 mm guidewire into the aorta. The SMA is clamped distally to avoid distal embolization if a fresh thrombus at the occlusion site is suspected. The proximal SMA lesion is then crossed with a stiff, bared 4 Fr catheter, exchanged for a 260 cm long 0.035-inch hydrophilic guidewire. The wire is snared in the aorta using a snare passed through the brachial or femoral artery and then brought out creating through-and-through access. A small transverse arteriogram is then performed at the level of the puncture and an over-the-wire Fogarty balloon is passed into the aorta if thrombectomy seems necessary. Thrombectomy is performed over the wire and the SMA inflow evaluated. If thrombectomy is not necessary, no arteriotomy is performed. Occasionally, predilatation with a 3 mm balloon of the hard and occlusive lesion is needed. With slight traction on the wire, a 6-7 Fr introducer, Flexor or Destination, is then placed antegrade in the SMA over the through-and-through wire. A balloon-expandable stent at the calcified ostium is often placed across the lesion, sometimes followed by a distal self-expandable stent extension into the SMA. A balloon-expandable 7-8 mm diameter large stent is chosen as this has better properties than a self-expandable stent.
be performed in a usual manner with standard devices without exposing the operators to an increased dose of radiation.

ANTEGRADE RECANALIZATION AND STENTING OF THE SMA

After laparotomy, antegrade recanalization and stenting of the SMA can be performed, perhaps in a “hostile abdomen” with extensive intra-abdominal adhesions after several prior operations or after radiotherapy. If femoral artery access fails, an attempt can be made to cross the occlusive ostial SMA lesion from brachial artery access in maintaining a larger stent lumen diameter after stent deployment. However, unfavorable artery angulation and risk of arterial dissection may appear at the distal stent end and the stented arterial segment may therefore be extended with a self-expandable stent into the middle SMA. Results after stenting are controlled by angiography as well as pressure measurements (Figure 1A-F). If there is a residual pressure gradient across the stent (> 12 mmHg), additional percutaneous transluminal angioplasty and/or stenting is performed. The access hole after withdrawal of the through-and-through guidewire in the SMA is treated by manual compression. Antegrade stenting is better than retrograde stenting, since the procedure can be performed in a usual manner with standard devices without exposing the operators to an increased dose of radiation.

ANTEGRADE RECANALIZATION AND STENTING OF THE SMA

Figure 1  Hybrid approach in a patient with computed tomography verified acute thrombotic occlusion. A: Laparotomy shows extensive small bowel ischemia with appearance of cyanosis, poor peristalsis and slight dilatation of small bowel loops. The superior mesenteric artery (SMA) was exposed followed by retrograde puncture of the SMA, passage of a guidewire across the occlusive lesion, which was first dilated with a 2 mm balloon, followed by passage of a 4 Fr Cobra slip catheter downstream from the infra-renal aorta; B-E: After retrograde puncture in the right common femoral artery, a long introducer and a snare (B) were brought up to catch the guidewire (C) introduced from the SMA, to establish through-and-through access (D) by bringing the guidewire out of the introducer that was inserted in the groin. The introducer was then advanced into the proximal SMA, followed by antegrade stenting with a short balloon expandable stent, then a longer self-expandable stent extension was introduced (E); F: Rapid recovery of normal color of the small bowel loops and peristalsis was noted before closing the abdomen. The patient had an uneventful recovery.
using a 4 Fr Headhunter catheter. When a stable 0.035 inch guidewire has been placed in the ileocolic artery, an introducer is advanced past the atherosclerotic lesion. Removal of the fresh thrombotic clot may be performed by aspiration, prior to antegrade stenting. One of the most feared complications after antegrade recanalization is a long dissection of the SMA without being able to create a re-entry with the guidewire into the true lumen of the distal SMA. The end result may be worsened ischemia of the intestines, leading to no other option than to perform extensive bowel resection and to leave the patient with short bowel syndrome[21].

OUTCOMES AFTER OPEN AND ENDOVASCULAR REVASCULARIZATION FOR ACUTE SMA OCCLUSION

There are four retrospective studies[18,22-24] reporting outcomes after open vascular and endovascular surgery for acute SMA occlusion (Table 2). Comparison between open and endovascular surgery is dubious due to the existence of many potential confounders, especially disease severity and symptom duration. In comparison with studies reporting on outcomes after emergency bowel surgery only for acute SMA occlusion, bowel morbidity and short-term mortality is clearly reduced after intestinal revascularization. There seems to be lower bowel morbidity and lower mortality after endovascular therapy for acute thrombotic occlusion compared with open vascular surgery[18,22,23]. One important aspect of the endovascular or hybrid approach compared with open vascular surgery, which may influence outcome, is that angiographic monitoring is part of the procedure after endovascular surgery[10], whereas there is room for much improvement in the percentage and quality of monitoring after open vascular surgery.

MEDICAL TREATMENT AFTER ACUTE SMA OCCLUSION

During the critical postoperative period, all patients undergoing revascularization of the SMA and/or bowel resection, are immediately treated with low molecular weight heparin, and a full dose is given to those with embolic occlusion. Patients surviving acute mesenteric vessel occlusion need to be carefully medicated when discharged. In case of thrombotic occlusion, patients need to be medicated against atherosclerosis with an antiplatelet aggregation inhibitor and statins[16]. In the case of embolic occlusion, life-long therapy with a vitamin K antagonist or low molecular weight heparin is indicated. Importantly, most patients with embolic SMA occlusion have synchronous embolism in other vascular territories[40] and need to be protected from new embolic events.

RADIOLOGICAL FOLLOW-UP AFTER STENTING OF THE SMA

Patients with stenting of the SMA need to be followed by either duplex or CT angiography at regular intervals due to the risk of restenosis, need for re-intervention, and the serious consequence of stent occlusion[40]. The small group of patients experiencing acute thrombotic stent occlusion at follow-up was reported to have a mortality rate of 50%[16]. It is suggested that the first imaging can be performed 3 mo postoperatively, followed by imaging examination every 6-12 mo.

DAMAGE CONTROL SURGERY

At laparotomy, necessary bowel resections and organ removal due to obvious transmural and gallbladder necrosis, respectively, are performed, preferably after revascularization of the SMA, according to the principles of damage control surgery[25-27]. The bowel resections are performed with staples, leaving the creation of anastomoses or stomas until the second or third look laparotomy. The abdominal wall can be left unsutured in patients scheduled for planned re-laparotomies. In such cases, a skin only closure or temporary abdominal closure with a VAC dressing may be applied when there is severe visceral swelling and risk of intra-abdominal hypertension or abdominal compartment syndrome.

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