REVIEW ARTICLE

# Intestinal ischemia: current treatment concepts

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**Abstract**

*Purpose* Mesenteric ischemia is a condition well-known among physicians treating patients with abdominal symptoms. Even so, mortality rates have not decreased significantly over the last decades. The purpose of this article is to review current treatment concepts of acute and chronic mesenteric ischemia.

*Results* Early diagnosis is one of the most important features that determine a patient's prognosis. Conventional angiography and multidetector computed tomography are therefore appropriate to quickly diagnose mesenteric ischemia, the latter being commonly more available. Once a patient presents with signs of peritonitis, instant laparotomy is indicated, and infarcted bowel segments need to be resected, followed by a second-look operation if necessary. If bowel necrosis is clinically not suspected, different approaches should be applied according to source and nature of mesenteric ischemia. Besides established surgical treatment concepts, more and more interventional procedures are developed and evaluated. However, superiority of these new techniques could only be shown for selected patient groups so far. In chronic mesenteric ischemia, interventional approaches seem to be an attractive alternative in patients who are in a condition too bad to undergo surgery. Patients with colonic ischemia are treated best in a conservative manner and by resolving the underlying cause, if identified.

*Conclusion* Patients with acute mesenteric ischemia are still at highest risk for a fatal course of disease. New diagnostic and therapeutic developments have not been tested in larger studies yet, neither has any of these methods led to an increased survival in studies published so far. Taken together, mesenteric ischemia requires high awareness, earliest possible diagnosis, and treatment by an experienced interdisciplinary team of gastroenterologists, radiologists, and surgeons.

**Keywords** Intestinal hypoxia · Acute mesenteric ischemia · Chronic mesenteric ischemia · Colonic ischemia

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## Introduction

Intestinal ischemia is a common and yet highly complex clinical problem in the daily routine of surgeons, gastroenterologists, and radiologists. This review article summarizes and discusses the subtle progress in diagnosis and treatment of mesenteric ischemia over the last decades, trying to identify tools that may help in treating these patients. Since the implementation of diagnostic angiography more than 30 years ago and of multidetector-row helical CT more than 10 years ago, there has been no really new breakthrough development that significantly improved timely diagnosis or therapy of bowel infarction. This dissatisfying fact is further underscored by high complication rates and poor overall survival of patients with acute mesenteric ischemia, regardless of the therapeutic approach applied. Thus, patients with acute

mesenteric ischemia (AMI) still face a mortality rate as high as 60% on average, despite complex treatment strategies [1].

There is a variety of underlying reasons for AMI, including arterial emboli, arterial or venous thrombosis, and non-obstructive causes. Although the pathophysiological conditions are considerably different (as further discussed in another review article in this issue), they all finally lead to hypoxemia and intestinal hypoxia—which can cause irreversible bowel damage and life-threatening complications. Early diagnosis and treatment determine the overall outcome, hence, an increased awareness among physicians of patients clinically suspicious for mesenteric ischemia, as well as timely diagnostic workup and therapy, is key to save a patient's life [2].

It is important to distinguish between the different clinical scenarios of acute or chronic mesenteric ischemia (and the specific case of colonic ischemia); therefore, these entities will be discussed separately, and emphasis will be put on current treatment strategies.

## Etiology of acute mesenteric ischemia

The intestinal blood supply is mainly secured by three large vascular systems arising from the aorta: the celiac axis, the superior mesenteric artery (SMA), and the inferior mesenteric artery. The peripheral vascular networks that derive from these three branches are interconnected via multiple collaterals to ensure appropriate intestinal perfusion, even in case of problems in one of the main vessels. Examples for these interconnections are the pancreaticoduodenal arteries, the arc of Riolan, and the artery of Drummond; an additional connection between the splanchnic and the systemic circulation is provided through the rectal vessels. However, the mucosa (and to a less extent the muscularis) of the small and large intestine are highly vulnerable to even a short discontinuation of the arterial blood supply. Gastric ischemia, on the other hand, is rarely observed because of a highly redundant network of intramural collateral vessels.

Arterial emboli are most commonly localized in the SMA due to the wide angle of its origin from and its parallel course to the aorta. Larger emboli usually get trapped within the first 3–8 cm distal to the SMA origin (which usually leaves the proximal jejunum well perfused). In contrast to a true SMA embolus, acute mesenteric arterial thrombosis generally occurs at the first branching site of the SMA [3]. Although distinguishing between SMA embolus and mesenteric arterial thrombosis can be clinically difficult (and may only be achieved by the patient's history), it can be of therapeutical relevance when considering a mesenteric bypass as discussed below. It is considered that acute thrombosis can be the consequence of pre-existing stenosis

of the mesenteric arteries in patients with chronic mesenteric ischemia (CMI, also known as "abdominal angina").

In contrast to mesenteric ischemia caused by arterial occlusion, systemic coagulation disorders are the most common cause of mesenteric venous thrombosis, which affects the superior mesenteric vein in the great majority of cases [4]. Thrombosis can also occur as a result of malignancy or "inflammation", especially under conditions of stress due to trauma or major (e.g., cardiac) surgery [5].

## Clinical diagnosis of acute mesenteric ischemia

Timely diagnosis is one of the key features that governs the overall outcome of patients with mesenteric ischemia. However, the absence of specific symptoms on clinical examination makes an appropriate assessment more difficult [6]. Thus, consistent diagnostic flow charts for the immediate and stepwise diagnostic workup play a pivotal role for the detection of bowel ischemia before irreversible damage occurs. Apart from all important clinical and interventional investigations that are discussed below, the "awareness" of the gastrointestinal surgeon for a "dead-gut problem" is the key factor that decides how successful further treatment attempts will be [7].

The patient's history should be carefully taken to explore risk factors associated with AMI. Frequently, patients with AMI are elderly and often suffer from cardiovascular diseases like ischemic heart disease, cardiac insufficiency, atrial fibrillation, hypertension, or peripheral vascular disease [8]. Other important risk factors are CMI and previous cardiac or vascular surgery [9].

### Signs, symptoms, and laboratory findings

Severe abdominal pain in the absence of accordant physical findings is a classical symptom of patients that should carefully be examined for mesenteric ischemia. Importantly, AMI is more common in the elderly, and old age is an adverse prognostic factor [9]. Abdominal pain caused by AMI is classically accompanied by other non-specific symptoms like diarrhea, vomiting, loss of bowel sounds, or fever. In at least half of patients, a Guajak test is positive [10, 11], whereby frank blood per rectum is usually a late sign of AMI. Laboratory studies are often not helpful in a real-life situation, although they can be used to substantiate suspected mesenteric ischemia in some cases. Normal values, however, do not rule out mesenteric ischemia. Findings that support mesenteric ischemia include metabolic (lactate-based) acidosis, leukocytosis, and elevated levels of amylase or seromuscular markers [12]. Procalcitonin was recently identified as another possible, but again non-specific, marker of intestinal ischemia and necrosis

[13]. In mesenteric venous thrombosis, elevated D-dimers can support the clinical suspicion of a coagulation disorder [4].

## Conventional angiography and CT/CT angiography

Mesenteric angiography is the most accurate imaging method to assess the mesenteric circulation (comparable to an angiogram of the coronary arteries in the case of myocardial infarction). There is increasing evidence that the routine use of mesenteric angiography has led to clinical benefit and even decreased mortality when promptly applied [14]. Angiography combines an imaging method with high sensitivity for diagnosing occlusive and also non-occlusive mesenteric ischemia, with the additional possibility of a therapeutic intervention. Drawbacks of this method are its invasive nature, alongside with exposure to radiation and nephrotoxicity from contrast agents in a patient that might already be in a septic state. The standardized use of angiography in patients with suspected mesenteric ischemia without peritoneal signs is supported by a number of studies, which show a decreased mortality along with high rates of sensitivity and specificity (as reviewed in [15])

Nowadays, contrast-enhanced biphasic multidetector-row helical CT of the abdomen is carried out as primary imaging modality in many medical centers. This technique enables imaging of the entire abdomen with high temporal and spatial resolution in the arterial as well as portal venous phase. Aschoff et al. reported a sensitivity of 93% and a specificity of 100% of CT angiography for the diagnosis of acute mesenteric ischemia by analyzing both vascular occlusions and the consequences of tissue damage (such as intestinal pneumatosis, bowel wall thickening, portomesenteric venous gas, or solid organ infarction) [16]. Beyond the high sensitivity and specificity, multidetector CT comprises several advantages: it is a rapid and non-invasive technique and is available 24 h a day in most acute-care medical centers. Due to its high sensitivity, specificity, availability, and non-invasiveness, multidetector CT is a suitable modality for the diagnosis of acute mesenteric ischemia and is very helpful to triage patients to subsequent conventional angiography, surgery, or clinical surveillance. For example, in patients with peritoneal signs, multidetector CT might depict signs of bowel wall perforation, a setting in which conventional angiography is usually skipped, and an emergency laparotomy is carried out.

Besides that, "non-invasive CT angiography" using multislice scanners may even be better than "conventional angiography" to detect selective severe mucosal ischemia or small peripheral segments (that may be "missed" in an angiography). Thus, biphasic multidetector CT (with an arterial as well as a venous phase) and conventional angiography are equally acceptable imaging methods. As discussed above, biphasic multidetector CT of the abdomen has become an appealing alternative to conventional angiography in the last decade: apart from the vascular status, CT imaging also allows for the evaluation of organs that are possibly affected.

In summary, biphasic multidetector CT of the abdomen can be recommended as the routine screening method for patients with AMI. Conventional angiography should be performed in patients necessitating a vascular intervention, or in those still having an unclear diagnosis.

## Ultrasound

In patients with contraindications to iodinated contrast medium, contrast-enhanced ultrasound or doppler ultrasound can be considered as an option to diagnose acute mesenteric ischemia. Although sonography is usually immediately available in most centers, the quality of this method is negatively affected by gas-filled bowel and investigator's experience. Moreover, emboli distal from the main vessels cannot be diagnosed [17, 18].

## Diagnosis by surgery

Most authors suggest performing "immediate" laparotomy in patients who present with suspected mesenteric ischemia and signs of peritonitis. These patients are at high risk for irreversible bowel infarction with subsequent abdominal sepsis, and thus, any non-surgical diagnostic test might only delay the appropriate treatment. Most of these patients are in the late stage of the disease process anyway, and their faint chances of recovery can only come from an immediate surgical intervention [11]. In this respect, laparoscopy plays a minor role in diagnosis (and treatment) of acute mesenteric ischemia, as only superficial anatomy can be assessed [1]. However, systematic exploration of the small bowel segments may increase the sensitivity of this method and spare a large wound (median laparotomy). Combining laparoscopy with an intraoperative colonoscopy could be helpful in patients with suspected colonic ischemia and may help to identify a mucosal ischemia that is not detectable from the bowel outside only.

## Practical approach

Once a patient presents with symptoms suggesting mesenteric ischemia, rapid diagnostic and therapeutical steps are mandatory to prevent catastrophic consequences. Therefore, many clinicians rightfully advocate aggressive "surgical diagnosis" by exploratory laparotomy for every case of suspected mesenteric ischemia. When peritoneal signs are present, an exploratory laparotomy should usually be per-

formed to investigate possible bowel infarction and to perform bowel resections if necessary. In patients at highest risk for peri-operative complications, an interventional approach can be considered when immediately performed and as long as no signs of peritonitis or bowel necrosis are evident [19].

If irreversible bowel infarction is unlikely and no clear peritoneal signs are present, immediate radiographic imaging (biphasic multidetector CT of the abdomen or conventional mesenteric angiography) has to be performed. A plain abdominal x-ray is generally without specific informative value, but is helpful in excluding other causes of acute abdominal pain. In our tertiary referral center, we routinely judge the urgency of the situation and tend to try a diagnostic approach first. A rapid CT scan of the abdomen is always a good option and takes only a few minutes. A patient with suspected mesenteric ischemia should never wait for an angiography. In the absence of signs of bowel necrosis, however, primary revascularization of the occluded vessels by endovascular techniques (if performed in a reasonable time frame) may shorten the ischemia time, and necrotic segments can then be resected during surgery, if necessary.

### Treatment of acute mesenteric ischemia

Primary management

Once a patient presents with abdominal pain and a history suggesting AMI, diagnostic steps should be initiated immediately to substantiate or exclude the diagnosis of potentially life-threatening acute mesenteric ischemia. In parallel, the patient should be fully "resuscitated" to treat the beginning systemic inflammatory response that is always present [14]. This includes the discontinuation of vasoconstrictive agents if possible (diuretics, digoxin, and catecholamines), the correction of metabolic acidosis, and hemodynamic support. The use of antibiotics is not evidence-based, but is routinely considered to minimize septic problems arising from bacterial translocation or bowel perforation [20]. Different therapeutical steps are then initiated that resemble the clinical suspicion, depending on the underlying cause.

Mesenteric arterial embolism

An instant surgical approach is the standard of care in patients with mesenteric arterial embolism, especially when signs of peritonitis exist. If possible at all, embolectomy should be performed as soon as possible to re-establish sufficient blood flow to the intestine and, by that, reduce the extent of ischemia–reperfusion damage and the risk for definitive bowel infarction [21]. A translocation of the SMA onto the infrarenal aorta can be considered when

there is no sufficient pulse after embolectomy; alternatively, a bypass between the aorta or iliacal vessels and the mesenteric artery can be applied [3]. Necrotic segments of the intestines should be resected in a limited way, and bowel (in which sufficient reperfusion is unclear) can be re-evaluated by a second-look operation 24–48 h later [22].

It is known that an interrupted blood flow in a segment of the embolized artery can lead to vasoconstriction in other segments of the artery even after the embolus has been removed. The risk of reflectory vasoconstriction is increasing with time until the embolus is dissolved. Several authors therefore suggest initiating an intra-arterial vaso-dilative therapy in general, although studies regarding the effectiveness of vasodilatators in AMI are conflicting [23]. Recent studies suggest primary percutaneous revascularization as an alternative to immediate surgery, especially in patients who are not eligible for an operation due to comorbidities. In a study by Heiss et al., the investigators applied a combination of aspiration and thrombolysis in patients with acute embolic SMA occlusion in whom signs of bowel wall perforation were excluded, and surgery was primarily contraindicated or not available (Fig. 1). Complete technical success was achieved in ten out of 15 patients, and overall mortality was 33%. In six patients, supplemental laparotomy was carried out because sufficient revascularization of the entire bowel was not achieved, or abdominal symptoms persisted, became worse, or recurred [24]. Though this and other studies show that primary percutaneous revascularization is feasible with promising mortality rates, this is not yet a routine treatment [25–27]. To note, angiography is incapable to diagnose or exclude bowel infarction, and the attempt of primary percutaneous revascularization might go along with loss of valuable time. Further studies are warranted to determine the role of primary percutaneous revascularization.

As a conclusion, laparotomy and embolectomy are still the gold standard for the treatment of mesenteric arterial embolism. However, in patients not eligible for immediate surgery, angiographic revascularization techniques may be used alternatively, especially in patients in whom diagnosis of AMI is achieved quickly. In addition, some studies reported successful pharmacological treatment of patients with minor emboli using thrombolytic agents, papaverin or anticoagulants [28]. In general, after surgery, it should be evaluated whether patients need further pharmacological treatment to prevent recurrent embolic events (e.g., anti-coagulative drugs) [29].

Mesenteric arterial thrombosis

Arteriosclerosis, as a precursor for arterial thrombosis, is a process that develops over time, thus enabling collaterals to develop. This fact can complicate the interpretation of
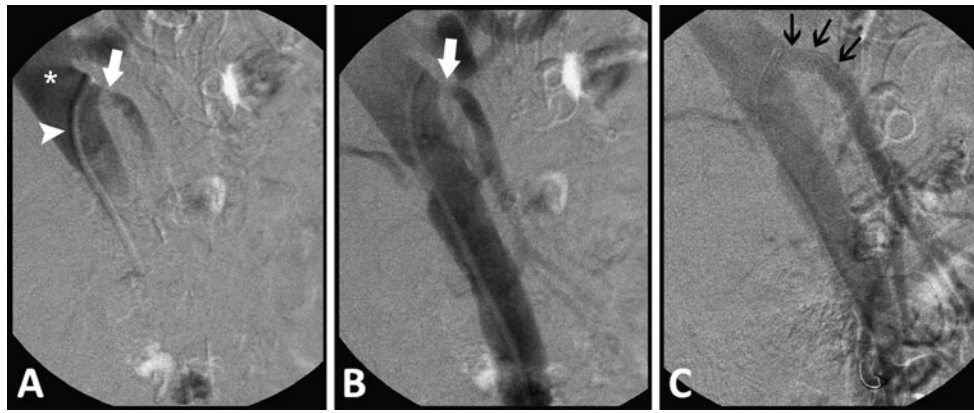
**Fig. 1** A 59-year-old man with diabetes mellitus, status post kidney transplantation and postprandial abdominal pain, intermittent nausea, vomiting, and diarrhea since 1 week, and persistent abdominal pain since 8 h. Mesenteric ischemia was assumed, and digital subtraction angiography depicted a high-grade ostial stenosis of the superior mesenteric artery (*arrow* in **a** and **b**; *asterisk* aorta; *arrowhead* sheath within the aorta). After percutaneous stenting, regular perfusion of the superior mesenteric artery was achieved (**c**; *arrows* delineate the stent within the superior mesenteric artery). After revascularization, the patient's symptoms resolved, and he was free of symptoms during a follow-up of 8 months

angiographic studies, as a fully compensated, rather long-standing arterial thrombosis can accidently be considered as the cause for acute abdominal symptoms, although a different reason may exist.

In general, patients with symptomatic mesenteric arterial thrombosis should be referred for surgical treatment. There are several methods to restore sufficient blood flow, depending on the extent of arteriosclerosis and potential intestinal damage. In some patients, transposition procedures, such as transposition of the SMA into the infra-renal aorta, may be adequate. Other patients require bypass operations, in which artificial or autologous grafts serve to create a shunt between the iliac arteries or the aorta and the mesenteric vascular network [3]. Notwithstanding the chosen technique, the principal goal is to restore intestinal perfusion as quickly as possible.

Apart from a surgical approach, some studies report that endovascular stenting in patients without peritoneal signs can lead to satisfying results [30]. In some patients, primary stenting to restore the blood supply of ischemic bowel segments followed by laparotomy has been reported to be beneficial [25]. In another case report, retrograde stenting of the mesenteric artery during laparotomy was successful [31]. Larger studies are necessary to further evaluate the role of interventional methods in the treatment of mesenteric arterial thrombosis.

Mesenteric venous thrombosis

When mesenteric venous thrombosis is diagnosed (most likely through a contrast-enhanced CT scan [32]), patients should be started on heparin to achieve intensive anticoagulation, independent of clinical symptoms. A programmed re-evaluation in short time intervals is the treatment of choice when angiography suggests appropriate vascularization [33]. Surgical thrombectomy can be performed if the thrombus is limited to the SMA or the portal vein, but is not effective in case of diffuse thrombosis. Alternatively, percutaneous endovascular intervention with direct thrombolysis of the superior mesenteric vein/portal vein or indirect thrombolysis by infusion of thrombolytic agents into the SMA has shown to be effective [34]. Controversy exists about the implementation of a routine second-look laparotomy: edematous changes due to venous congestion make the evaluation of affected bowel difficult, which is why several authors recommend a routine re-laparotomy after 24 h [35].

During angiography, intra-arterial papaverin administration is advised to prevent arterial spasm and reduce ischemia reflectory to venous thrombosis. Vitamin K antagonists or other anticoagulative drugs can be indicated to prevent recurrence in the longer term. Less established, but still notable, is the use of thrombolytic drugs, which has shown to be effective in some small studies [36–38].

Non-occlusive mesenteric ischemia

Diagnosis and treatment of non-occlusive mesenteric ischemia (NOMI) is usually achieved by angiography, as intra-arterial infusion of papaverine still represents the standard treatment [15, 39]. If signs of peritonitis arise, laparotomy has to be performed to evaluate the intestine and to resect necrotic bowel segments, but intra-arterial papaverine infusions peri-operatively should still be applied. Prostaglandins [40], tolazoline, and glycerol trinitrate [41] are alternative drugs with described efficiency when injected intra-arterially.

One study by Ward et al. showed that liberal indication for second-look operations combined with delayed intestinal anastomosis led to an improved outcome in patients with suspected surgical abdominal problems. In the same study, intra-arterial application of papaverine alone was successful in five out of seven patients without peritoneal signs [42]. In a more recent study by Mitsuyoshi and colleagues, patients suspicious for NOMI (as per clinical and CT findings) were successfully treated with continuous intravenous application of prostaglandin $E_1$ for 5 days. In eight out of nine patients, symptoms resolved. [43]. Moreover, the authors also suggest to perform multislice computed tomography instead of conventional angiography to detect NOMI as early as possible, especially because NOMI often occurs in patients too unstable to undergo angiography. This promising, alternative approach has been tested by other clinicians as well [44].

Finally, a diagnostic workup should be enforced to determine the underlying etiology of splanchnic vasoconstriction, and a causative treatment should be initiated if possible. Frequent conditions associated with NOMI are heart diseases, dehydration, or recent surgery [42]. Additional use of heparin might be effective to reduce the risk of thrombi in the affected vessels.

Second-look operation

Resection of necrotic bowel is still the mainstay of surgical treatment for AMI. A study by Park and colleagues identified bowel resection (at first- or second-look procedure) as an independent factor associated with increased survival (relative risk=0.5) [9]. As a principal rule, bowel resections during the primary operation should be rather limited to avoid short bowel syndrome by sparing bowel parts with the potential to regenerate. However, scheduled second-look operations should be applied liberally 24–48 h later to re-evaluate (and resect, if necessary) irreversibly necrotic parts of the bowel. In patients with recurrent signs of peritonitis after a first surgical intervention, a second-look operation is also mandatory [3].

**Chronic mesenteric ischemia**

CMI is a condition very much different from acute ischemia, and does not have to be considered as an emergency in most cases. Nonetheless, chronic intestinal ischemia can be a precursor of acute mesenteric thrombosis, therefore representing an important differential diagnosis. Clinically, predominant signs are progressive postprandial pain, connected with fear of eating and weight loss [15].

CMI is difficult to diagnose: Although most patients are shown to have at least two occluded splanchnic vessels, this finding can also be observed in subjects without symptoms of CMI. Hence, the combination of typical symptoms, depiction of stenotic or occluded splanchnic vessels (e.g., based on mesenteric angiography, CT angiography, MRI, or ultrasound), and the exclusion of other causes make the diagnosis of CMI likely [45].

Symptomatic patients are recommended to undergo treatment, as CMI usually is a progressive disease based on arteriosclerosis, eventually resulting in fatal malnutrition and AMI [5]. Both interventional and surgical treatment strategies exist. Studies indicate that the surgical reconstruction of intestinal arteries is superior to endovascular stenting techniques in terms of long-term results. In a study conducted by Brown et al., patients undergoing mesenteric stenting had an increased risk for re-stenosis (hazard ratio (HR)=7.3) and recurrent symptoms (HR=3.7) [46]. On the other hand, interventional revascularization tends to be associated with less complications than the surgical approach, hence, some groups started to use endovascular treatment as first-line therapy with low morbidity and high technical success rate [47–49].

Commonly, the celiac as well as the superior mesenteric artery is affected by CMI, which means that reconstruction of both is desirable to achieve a lasting asymptomatic state. The bypass can be either antegrade or retrograde, using either prosthetic vessels for longer duration or autologous grafts when an increased risk for infection exists [45]. Currently, establishment of an aorto-celiac plus an aorto-mesenteric bypass is the favored method in CMI patients. As a general rule, any bypass should be in a straight position and as short as possible [50]. The number of reconstructed vessels or the use of either antegrade or retrograde bypasses did not affect the rate of recurrence in a study by Park et al. Local or transaortic mesenteric endarteryectomy is suitable, especially if the peritoneal cavity is contaminated [51].

As a conclusion, patients capable to undergo laparotomy should be referred for surgical revascularization. Alternatively, percutaneous transluminal mesenteric angioplasty with stenting seems to be a justified method especially in a high-risk population [52, 53], particularly due to its low morbidity and high technical success rate. Furthermore, repeated endovascular techniques or surgical revascularization can still be applied once attempted angioplasty has failed in order to produce a long-lasting patency.

**Colonic ischemia/ischemic colitis**

Of all forms of intestinal ischemia, colonic ischemia (CI) has the highest incidence. Commonly, CI can be seen after

major cardiovascular surgery (e.g., cardiopulmonary bypass surgery or aortic surgery) or in the context of systemic disorders like coagulopathies, rheumatic diseases, infections, mechanical intraabdominal issues, or of iatrogenic origin (drugs and hemodialysis). Most of the time, however, a precise origin cannot be clarified [11].

Classically, patients complain about mild abdominal pain, with a moderately tender focus on the left side, followed by an episode of hematochezia. Diagnosis is based on the clinical findings as well as known comorbidities, and findings in repetitive colonoscopic studies. Common observations are a pale mucosa with petechial bleeding or signs of submucosal hemorrhagic bleedings. Furthermore, an infectious origin should be excluded by stool cultures on bacteria and parasites. Radiological imaging can be helpful if differential diagnoses imply acute mesenteric ischemia, but endoscopy is the best method to diagnose colonic ischemia [54].

In most patients, CI is of transient nature, and symptoms usually resolve within 48 h. Patients should be admitted to hospital for conservative therapy, including bowel rest and therapy of underlying conditions which might cause or aggravate CI (like withdrawal of vasoconstrictive drugs) [55]. The use of antibiotics, although widely suggested, is not supported by evidence. Surgical treatment is required in patients developing colonic infarction or mucosal necrosis in order to resect the respective segments. Depending on the localization and the presence of peritonitis, limited resections with primary anastomosis or transient stoma are indicated. Development of fulminant ischemic colitis represents an emergency indication for surgery, frequently requiring subtotal colectomy. Furthermore, patients not recovering from symptoms should be operated in a curative intent, as segmental colectomy can prevent dangerous complications like perforation [15].

## Conclusion

Mesenteric ischemia is a medical entity known for decades, therefore, with a well-described pathophysiology and a broad spectrum of diagnostic and therapeutic options tested. Although technical advances have clearly been made, an improvement in survival has not been achieved yet. Recent treatment modalities, such as interventional angiography, show no clear superior effects as compared to treatment strategies established for years, although they may be of advantage in a number of cases. Besides that, prospective studies are needed to provide evidence for any of the existing treatment regimes.

Our approach to a patient with suspected acute mesenteric ischemia is based on the data available (Fig. 2). Timely diagnosis and therapy are the key factors affecting mortality, which is why a high degree of awareness among physicians and the decision for efficient diagnostic tools are crucial. A patient with signs of peritonitis should immediately undergo laparotomy. Otherwise, patients should be referred to a biphasic CT of the abdomen or "conventional" angiography, where conventional angiography offers the option of percutanous revascularization. Depending on these results, surgical or interventional reperfusion has to be achieved if possible, with resection of irreversibly damaged bowel. Afterwards, patients have to be monitored and re-evaluated carefully.

In spite of all efforts, mortality of patients with AMI remains high. To date, a prompt diagnosis is the best way

Fig. 2 Diagnostic approach to a patient with suspected acute mesenteric ischemia
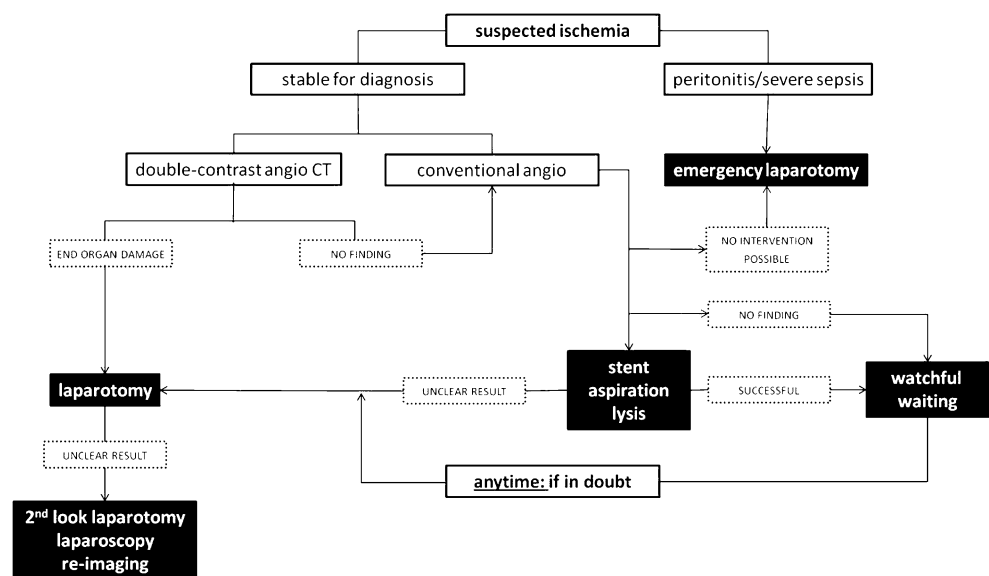
physicians can provide to improve the outcome of patients suffering from acute mesenteric ischemia.

**Conflicts of interest**   None.

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