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SCIENTIFIC REVIEW

Open and Endovascular Management of Acute Mesenteric Ischaemia: A Systematic Review

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Abstract

Background Acute mesenteric ischaemia (AMI) is a life-threatening surgical emergency resulting from thromboembolic occlusion of the mesenteric vasculature. Traditional management of AMI has been open revascularisation with or without bowel resection—a procedure which carries considerable morbidity and mortality in an already unwell, compromised patient. Endovascular and more minimally invasive management approaches to AMI have been reported. Proponents of endovascular management suggest this approach may be associated with reduced morbidity and mortality compared with open surgery.

Objectives To assess the impact of endovascular approach for AMI on mortality and need for subsequent laparotomy and/or bowel resection.

Data Sources The search bodies PubMed and Medline were interrogated.

Eligibility Criteria, Participants and Interventions All studies in English with greater than 10 patients examining outcomes for patients undergoing endovascular intervention for acute mesenteric ischaemia were included. All patients over 18 years presenting with a diagnosis of acute mesenteric ischaemia secondary to an arterial thromboembolic source were included. Studies examining endovascular intervention alone or endovascular and open intervention were selected.

Results The 30-day mortality for endovascular approach from all 13 studies was 16–42%. Of the 7 comparative studies including results of open revascularisation, the 30-day mortality for patient treated with an endovascular approach was 15–39% versus 33–50% for open revascularisation. Laparotomy rates post-initial endovascular intervention ranged from 13 to 73%. Bowel resection post-endovascular therapy ranged from 14 to 40% among studies. Concerning 7 comparative studies for open versus endovascular revascularisation, the rate of bowel resection in the endovascular group ranged 14–28% and 33–63% in the open cohort. Endovascular intervention also demonstrated lower median length (s) of bowel resected.

Limitations Heterogeneity of studies and patient populations studied including selection bias.

Conclusions and implications of findings Endovascular management may be associated with reduced mortality and need for/length of bowel resection compared with the traditional open approach, but there remains a paucity of robust data to support this. The available literature illustrates that a subgroup of patients without haemodynamic compromise and more insidious onset may garner benefit from endovascular intervention.

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Introduction

Acute mesenteric ischaemia (AMI) is a life-threatening condition resulting from an abrupt decrease in blood flow to the intestine, accounting for 0.1% of overall hospital admissions and 1% of individuals presenting with an acute abdomen [1, 2]. AMI typically results from vessel occlusion secondary to athrombotic or an embolic source [3]. Early diagnosis and prompt treatment are imperative to limit the sequelae of acute intestinal ischaemia including necrosis, perforation, sepsis and multi-organ failure [4–6]. The aetiology of AMI can be viewed broadly as occlusive and non-occlusive. Occlusive disease results from mechanical occlusion of vasculature, most commonly secondary to a thrombus or embolus. Embolic occlusion is thought to account for 40–50% of cases of occlusive AMI, the majority originating from a cardiac source, e.g. atrial fibrillation [7]. Direct formation of thrombus may be causative in 25% of cases [8]. This typically occurs in patients with pre-existing atherosclerotic disease within the mesenteric vasculature. In <5% of cases, AMI may be seen in the presence of aortic dissection [7]. Venous occlusion, i.e. superior mesenteric vein (SMV) thrombosis, is also seen in less than 5% of all AMI cases [3, 9, 10]. Clinical factors associated with a hypercoagulable state have been implicated in its causality including portal hypertension, exogenous oestrogen use, abdominal inflammatory disease, malignancy, trauma and prior surgery [11, 12]. Approximately 20–30% of cases of AMI are caused by non-occlusive mesenteric ischaemia (NOMI). This represents intestinal hypoperfusion rather than a mechanical occlusion of the vasculature. NOMI typically results from a prolonged state of hypotension and is associated with the use of vasopressors. Treatment typically encompasses correction of the underlying cause with or without the use of vasodilators such as papaverine [13].

Despite treatment advances and newer techniques, the mortality of AMI remains unequivocally high at 60–90% [8–10]. The ultimate goal of therapeutic endeavour is to restore vascular perfusion and minimise bowel resection. Traditional surgical intervention for thromboembolic AMI has comprised an emergency laparotomy with or without a revascularisation procedure and/or bowel resection. Open revascularisation interventions may include embolectomy via arteriotomy and balloon retrieval catheter or arterial bypass [14, 15]. This operative approach has been associated with significant morbidity and mortality, however [4, 16], likely pertaining to both the underlying disease process and procedural factors.

In recent years, endovascular revascularisation procedures for thromboembolic AMI have gained popularity. Methods encompass catheterisation of the mesenteric vasculature via the femoral or brachial artery and management of the offending occlusion using a combination of techniques including mechanical or aspirational thrombectomy, angioplasty, stenting and thrombolysis [10, 17]. Some studies to date have suggested that endovascular revascularisation, when selected appropriately, may be associated with more favourable outcomes compared with traditional open approach [9, 18–20].

The authors present a systematic review of current literature addressing endovascular management of acute mesenteric ischaemia. The population of interest was adult patients presenting with acute mesenteric ischaemia diagnosed by either radiological imaging or intra-operatively. Studies in which patients underwent intervention via endovascular means alone or studies comparing endovascular to open intervention were included. The results of endovascular intervention are presented compared with those of open intervention, where applicable. Specific outcome measurements were the 30-day mortality associated with endovascular approach and the rate of post-procedural bowel resection. Additionally, in the event of bowel resection, we interrogated the relationship between approach and overall length of bowel removed.

Methods

This review was conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards. Data from individual studies and pooled results are expressed as percentages with median values and inter-quartile ranges given for pooled results. IBM SPSS® version 25 and Microsoft Excel® were used for calculation. Evidence was graded according to the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) framework.

Search strategy

A systematic search in PubMed and Embase was performed to identify all relevant studies, i.e. articles reporting endovascular management of acute mesenteric ischaemia. This was performed in April 2019 and was limited to papers published with the last 20 years. The terms “acute mesenteric ischaemia AND endovascular”, “acute mesenteric ischaemia AND interventional radiology”, “open AND endovascular AND acute mesenteric ischaemia” were searched.

All abstracts were screened, and relevant studies were selected where agreed upon by two reviewers (BM and DW). Where necessary, the full text was sought to assess relevance. Grading of evidence was agreed upon by both reviewers. Due to the observational nature of all studies

without randomisation and notable selection bias, the grade of evidence was deemed low quality.

Eligibility criteria

Included for review were all studies published in the English language with greater than 10 patients reporting outcomes for endovascular management of AMI secondary to thrombotic and embolic occlusion published within the last 20 years. Comparative studies between endovascular and open approaches were included. Patients with mesenteric venous occlusion or non-occlusive mesenteric ischaemia were excluded from this review. Case reports and case series with less than 10 patients were excluded along with all studies relating to chronic mesenteric ischaemia. Where studies reported outcomes from both chronic and acute mesenteric ischaemia groups, only the AMI outcomes were included. Details of the 13 included studies are summarised in Table 1.

Results

A total of 13 studies were deemed suitable for inclusion with a total of 16,832 patients: 6 studies reported outcomes for AMI managed with endovascular approach alone and 7 were comparative studies; 12 studies were retrospective reviews with 1 prospective cohort study examining outcomes for endovascular management of AMI. In total, 6871 patients underwent endovascular revascularisation. The mean age of patients in all 13 studies ranged from 62 to 79; 49% of patients were male. A summary of all included studies is outlined in Table 1.

A total of 10 studies reported laparotomy rates post-initial endovascular intervention with a range of 13–73%; 10 studies also reported subsequent bowel resection following initial endovascular therapy. This ranged from 14 to 40% among studies, and length of bowel resected was 52–93 cm. Considering the 7 retrospective comparative studies for open versus endovascular revascularisation

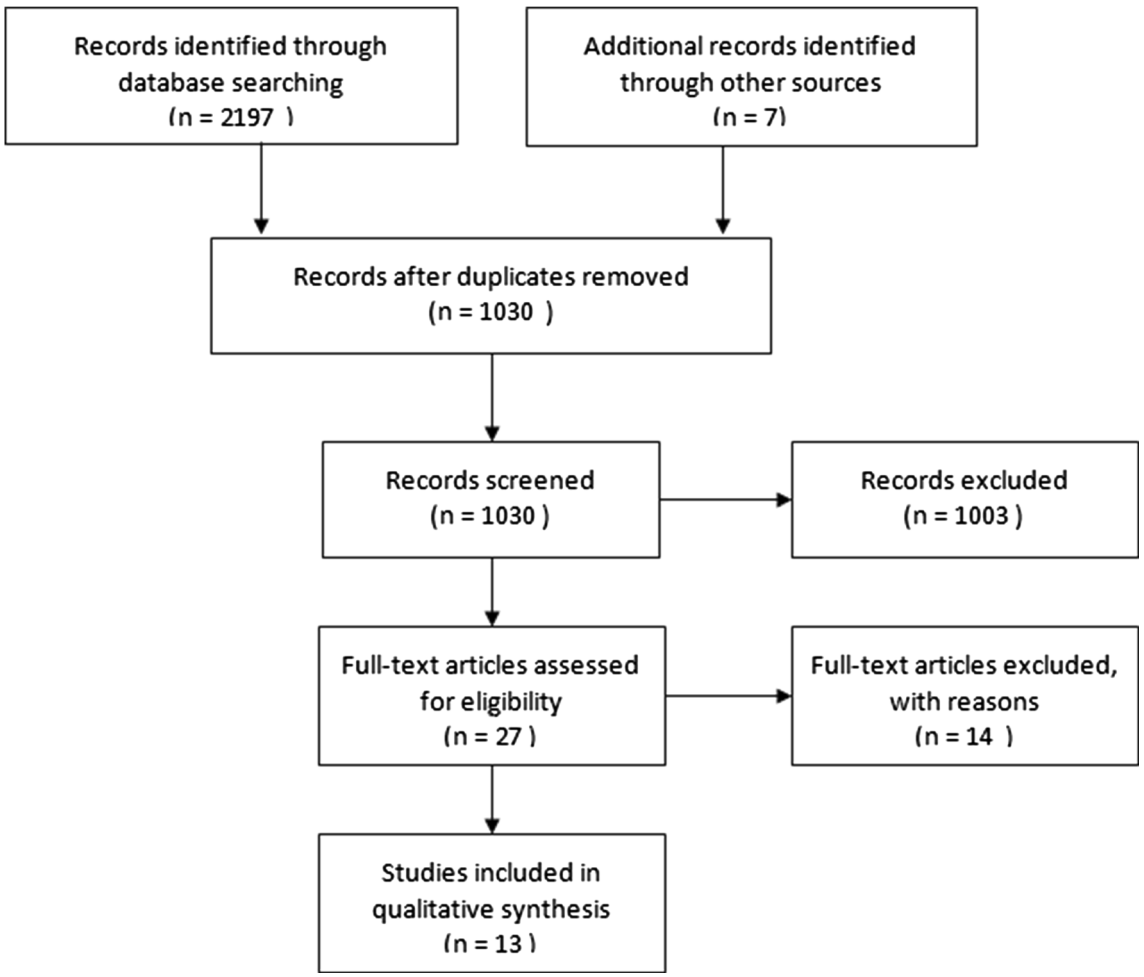

Table 1 Table of included studies

Study	No. of patients	Age (mean)	Gender (%m)	Study design	Approach % (no. of patients)	Endovascular intervention (s)	Laparotomy post-Endo. % (no. of patients)	Bowel resection % or mean length in cm	30-day mortality % (no. of patients)
Schermerhorn et al. [21]	5237	72	75	Retrospective review	Endo 35.5% (1857) Open 64.5% (3380)	PTA Stent	–	Lengths NA Endo—28.1% (1466) Open—47.8% (3771)	Endo—15.6% (816) Open—36.6% (1916)
Block et al. [20]	163	76	45	Retrospective review	Endo 26% (42) Open 74% (121)	AT CDT Stent	55% (23/42)	Lengths NA Endo—19% (8) Open—63% (72)	Endo -21% (10) Open—42% (51)
Hawkins et al. [22]	8	62	50	Retrospective review	Endo	Stent	12.5% (1/8)	0 Resections	0% (0)
Arthurs et al. [9]	70	64	50	Retrospective comparative Study	Endo—81% (56) Open—19% (14)	MT CDT PTA Stent	69% (38/56)	Numbers NA Endo—52 cm Open—160 cm	Endo—39% (22) Open—50% (7)
Ryer et al. [23]	93	68	38	Retrospective comparative Study	Endo—12% (11) Open 88% (82)	MT CDT PTA Stent	63% (7/11)	Lengths NA Endo—28% (26) Open—34 (37%)	Endo—16% (14) Open—39% (36)
Jia et al. [17]	21	71[a]	71	Retrospective review	Endo	AT CDA Stent	23% (5/21)	Numbers NA 93 cm	9.5% (2)
Beaulieu et al. [18]	679	70.5	52.9	Retrospective comparative Study	Endo—24% (165) Open 76% (514)	–	–	Lengths NA Endo—14.4% (24) Open—33.4% (172)	Endo—24.9% (125) Open—39.3% (587)
Puippe et al. [24]	13	74.5	31	Retrospective review	Endo	CDT AT	38.5% (5/13)	Lengths NA 30.8% (4)	30.8% (4)
Kärkkäinen et al. [25]	50	79	42	Retrospective Review	Endo	AT PTA CDT Stenting	30% (13/43)	Lengths NA 26%	32% (16/50)
Raupach et al. [26]	37	76[a]	49	Retrospective Review	Endo	AT CDT Stenting	73% (27/37)	40.5%	27%
Bulut et al. [27]	50	64	35	Prospective cohort	Endo	Stenting PTA	62% (31/50)	56% (28)	42% (21)

Table 1 continued

Study	No. of patients	Age (mean)	Gender (%m)	Study design	Approach % (no. of patients)	Endovascular intervention (s)	Laparotomy post-Endo. % (no. of patients)	Bowel resection % or mean length in cm	30-day mortality % (no. of patients)
Zhang et al. [19]	30	61.9	63.3	Retrospective comparative Study	Endo—60% (18) Open 40% (12)	AT PTA CDT	33% (6/18)	Numbers NA (Endo—88 cm Open—253 cm)	Endo—16.7% (3) Open—33.3% (4)
Erben et al. [28]	10,381	69	37	Retrospective comparative Study	Endo—43% (4543) Open—57% (5839)	–	–	–	Endo—12.3% (553) Open—33% (1931)

PTA percutaneous transluminal angioplasty, *CDT* catheter-directed thrombolysis, *MT* mechanical thrombectomy, *AT* aspirational thrombectomy

[a]Median

alone, the rates of bowel resection in the endovascular group ranged 14–28% and 33–63% in the open cohort; 2 comparative studies reported length of bowel resected. The length of bowel resected in the endovascular cohorts was 52 and 88 cm [9, 19] versus 160 cm and 253 cm in the open cohorts, respectively.

The 30-day mortality for endovascular approach from all 13 studies was 16–42%. Of the 7 comparative studies including results of open revascularisation, the 30-day mortality for patient treated with an endovascular approach was 15–39% versus 33–50% for open revascularisation.

Discussion

Acute mesenteric ischaemia remains an acute surgical emergency with overall poor prognosis. While historically, the treatment has been laparotomy with revascularisation ± resection, endovascular techniques are growing in popularity. The endovascular approach is attractive as it avoids a laparotomy in an acutely unwell patient with likely considerable physiological compromise. The most pertinent disadvantage is that the viability of bowel cannot be inspected at the time of the procedure which may delay resection of irredeemably necrotic intestine. Means of addressing this include a hybrid operating theatre with immediate access to CT imaging, interventional radiology and laparoscopy to facilitate synchronous bowel inspection ± resection [23].

Due to the relatively low incidence and emergency presentation of acute mesenteric ischaemia, there are no prospective data comparing open with endovascular techniques. Thus far, all comparative studies are retrospective with no randomisation of patients. These studies are therefore inherently subject to selection bias as healthier, more robust patients may have been chosen to undergo endovascular repair while a deteriorating, unwell patient may have proceeded directly to laparotomy. Supporting this, Arthurs et al. [9] found that patients who underwent open surgery trended towards a higher serum lactate measurement than the endovascular group. This was also reported by Beaulieu [18] and Kärkkäinen [25] where the groups undergoing open intervention had significantly higher rates of lactic acidosis. Furthermore, 5 studies acknowledge obvious selection bias explicitly, outlining that only patients *without* signs of peritonitis were selected for endovascular management as the initial intervention due to the risk of delayed resection of ischaemic bowel [9, 17, 19, 25, 27]. While this detracts from the grade of evidence, randomising patients with peritonitis to an index endovascular intervention is arguably unethical and therefore unsuitable for randomised controlled trial methodology in the current era. The selection rationale for the

chosen intervention (i.e. endovascular or open) is otherwise not commented upon in several studies and was at the discretion of the on-call emergency team. Available personnel and timing of presentation may also have impacted heavily. It is possible that the remaining studies employed a similar decision-making strategy which could provide an explanation in part for the more favourable outcomes, but this is merely extrapolation.

The avoidance of laparotomy is a notable advantage of endovascular therapy. It may limit secondary injury following the primary ischaemic event and confer other immediate benefits such as avoidance of general anaesthetic. The requirement for laparotomy post-endovascular intervention in our included studies ranged markedly between studies from 13 to 69%. Laparotomy was performed when patients demonstrated signs of further ischaemic insult or peritonism. No studies identified any significant predictors for re-operative intervention. Block et al. [20] demonstrated that a "second-look" operation for both open and endovascular surgeries including post-operative laparotomy was not independently associated with increased mortality. No studies reported specific mortality for patients undergoing laparotomy post-initial endovascular surgery, however, and so it is unclear if this confers a worse outcome compared with open.

Endovascular surgery may result in reduced rates and lengths of bowel resection compared to open revascularisation. This may arise as a consequence of faster time to reperfusion with endovascular intervention—Arthurs et al. [9] demonstrated shorter procedure times in the endovascular group; however, this was not statistically significant. In an animal model, work from Grootjans et al. [29] demonstrated than the intestinal epithelial lining began to disintegrate after more than 45 min of small bowel ischaemia with further destruction of villus tips and apoptosis of enterocytes during reperfusion. Further reasons may include avoidance of thermoregulatory and vasoconstrictive effects of laparotomy and general anaesthesia on splanchnic blood flow [30].

Improved rates of bowel resection may also pertain to the underlying aetiology for the ischaemic insult; 7 studies reported aetiology of AMI as either embolic or thrombotic [9, 18–20, 23, 25, 27]. Of these, 6 comprised more patients with causative thrombosis (range 55–72%) [9, 18, 20, 23, 25, 27]. Patients with thrombotic occlusions often develop collateral blood supply due to long-standing atherosclerotic disease, and so this may lend rationale to why this group had an overall shorter length of bowel resection. Challenging this, however, Zhang et al.'s [19] endovascular cohort comprised 83% AMI secondary to emboli. This group also had statistically significantly less bowel resected than the open cohort.

Along with a lower rate of bowel resection, Block et al. [20] demonstrated significantly fewer cases of subsequent short bowel syndrome (55% vs 27%, $p = 0.09$) in the endovascular group. Potentially supporting this, Beaulieu et al. [27] indentified that endovascular repair was not independently associated with ongoing total parenteral nutrition (TPN) support in the analysed cohort. While this does not conclusively support a higher rate of short gut syndrome in the open group, it may represent a potential reason for ongoing TPN reliance. Although not quantified in any included studies, the avoidance of ongoing parenteral nutrition would likely have major implications in terms of cost, morbidity and quality of life.

With regard to 30-day mortality, endovascular intervention may yield improved outcomes. Exact reasons for this remain unclear. As previously mentioned, there is obvious selection bias in the included studies where less acutely unwell patients without evidence of peritonitis were selected for endovascular intervention. The avoidance of index laparotomy is a notable benefit and may influence outcomes and limit secondary injury. Despite the fact that a number of patients will proceed to laparotomy within a number of days of initial procedure, they may be further optimised at this point having been resuscitated appropriately in a high dependency or intensive care setting. Furthermore, as endovascular intervention may be performed under local anaesthetic, avoidance of general anaesthetic may be an influential factor.

Kärkkäinen et al. [25] found that symptoms >3 days and premonitory symptoms were associated with survival. Once again, this infers that this cohort has long-standing atherosclerotic disease with a likely "acute on chronic" picture. Zhang [19] additionally observed more technical success and decreased mortality in patients presenting within 12 h of onset of pain compared to those with a longer history, and Arthurs [9] found that patients with endovascular treatment of thrombotic lesions had decreased overall mortality compared to those with embolic lesions. These patients may have presented in a more insidious fashion with some degree of physiological compensation due to their long-standing disease and thus may have been selected for endovascular repair. This presentation, i.e. premonitory symptoms with haemodynamic stability and no peritoneal signs, may potentially represent a good indicator of endovascular success, but further data are needed to explore this.

Considering this, one difficulty in appraising and comparing published data is distinguishing acute mesenteric ischaemia from chronic mesenteric ischaemia. Clear definitions for either entity are lacking, and furthermore, a high percentage of patients presenting with acute symptoms will have background chronic atherosclerotic disease. Evincing this, up to half of patients presenting with AMI have a

personal history of postprandial pain and other symptoms of CMI [31]. Whether this has any clinical implications is uncertain, but the presentation of "acute on chronic" patients may often be less acute due to the formation of collaterals as compared with the more sudden onset embolic disease. It is likely that the exclusion of patients with background symptoms of chronic mesenteric ischaemia would affect these results; however, arguably this is an unrealistic picture. The dichotomisation into acute and chronic is likely mis-representative of what is a more complex clinical entity and cohort of patients.

Further questions requiring clarification include long-term outcome of patients in terms of patency and need for re-intervention. Data from studies comparing endovascular and open management of chronic mesenteric ischaemia suggest decreased primary patency, earlier need for re-intervention and higher recurrence of symptoms in the endovascular groups, but this lies outside the scope of this review [32–34].

Conclusions

Endovascular approach for AMI may be associated with decreased 30-day mortality and avoidance of laparotomy with bowel resection. The absence of prospective randomised data prohibits meaningful conclusions to be drawn from currently available studies with regard to whether open or endovascular management is more appropriate in the acute setting. They may, however, illustrate a potential avenue to identify a subgroup of patients who may be suitable for and benefit from endovascular management as an index procedure. It remains appropriate that a patient with signs of peritonitis or haemodynamic compromise should proceed straight to laparotomy ± revascularisation. Endovascular intervention may be considered, however, in patients with more insidious onset or who are less acutely unwell at presentation. Intensive post-procedure monitoring with continual re-evaluation of clinical status is essential, as is a low threshold to proceed to laparotomy in the case of deterioration.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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