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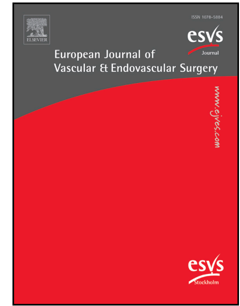

Endovascular First Approach for Embolic Acute Mesenteric Ischaemia: a 15 Year Single Centre Retrospective Study

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Running title odd: Endovascular Treatment for Embolic Acute Mesenteric Ischaemia

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Endovascular First Approach for Embolic Acute Mesenteric Ischaemia: a 15 Year Single Centre Retrospective Study

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WHAT THIS PAPER ADDS

In this single centre, retrospective study, 63 consecutive patients with embolic acute mesenteric ischaemia were treated during a 15 year study period. An endovascular first approach was used, and 48 patients underwent endovascular revascularisation, the majority of whom were aged ≥ 80 years. More than half survived past 30 days, 35% underwent laparotomy, and 21% required bowel resection. The technical success rate of the endovascular procedure was 98%, and 15% had endovascular procedure related complications. A tabular review of current literature on the treatment of embolic acute mesenteric ischaemia is included in the article.

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Objective: To evaluate outcomes of endovascular treatment as the first line approach for acute mesenteric ischaemia (AMI) caused by embolic occlusion of the mesenteric arteries.

Methods: This retrospective, single centre study included consecutive patients with occlusive AMI between 2009 and 2024. Patients with acute embolic occlusion of the mesenteric artery were included, whereas patients with thrombotic AMI were excluded. The diagnosis was confirmed by computed tomography, intra-operative findings, or autopsy. Main outcomes included rates of technical success, endovascular procedure related complications, 30 day mortality, laparotomy, and bowel resection.

Results: Of 63 patients with embolic AMI (mean age 79 ± 12 years), 15 were treated without attempted revascularisation, of whom three survived. Forty eight patients (76%, mean age 79 ± 11 years) underwent endovascular revascularisation as the first line treatment, with technical success in 47 (98%). Mechanical aspiration was performed in 45 patients, with additional balloon angioplasty in four, stenting in nine, thrombolysis in three, and stent retriever thrombectomy in three. Plain stent placement without aspiration was performed in three patients. Laparotomy was performed in 15 patients (35%) undergoing endovascular treatment; six had clinical signs of peritonitis (13%) and nine (21%) required bowel resection. Seven patients (15%) had endovascular procedure related complications (superior mesenteric artery dissection in five, access site bleeding in one, and access site pseudoaneurysm in another patient). Of the 48 patients treated with endovascular revascularisation, 21 (44%) died within 30 days. Factors prominently associated with early death after endovascular revascularisation in univariable analysis were older age (p = .001), clinical signs of peritonitis (p = .003), decreased bowel wall enhancement (p = .004), increased lactate level (p = .006), low bicarbonate level (p = .008), and low base excess (p = .009).

Conclusions: An endovascular first approach was suitable for most patients, with a good technical success rate and acceptable mortality rate considering the high mean age of the non-selected patients with AMI. One third underwent laparotomy after endovascular treatment, whereas all patients would have required laparotomy if treated with open embolectomy.

Keywords: Acute mesenteric ischemia, Embolectomy, Embolic, Embolism, Endovascular, Superior mesenteric artery

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INTRODUCTION

The 2017 European Society for Vascular Surgery (ESVS) guidelines and the 2022 World Society of Emergency Surgery advocate endovascular stenting as the first line treatment modality in acute mesenteric ischaemia (AMI) caused by atherothrombotic occlusion of the mesenteric arteries.[1,2] However, due to insufficient evidence, both guidelines have refrained from recommending the preferred revascularisation method in embolic AMI. The latest 2025 update of the ESVS guidelines takes a careful position in favour of the endovascular approach without distinction between embolic and thrombotic AMI.[3]

There are no systematic reviews that specifically address the treatment of embolic AMI, and many published cohorts pool the treatment outcomes of embolic and thrombotic AMI together, even though the treatment approach is technically very different between the two.[4] The endovascular treatment of thrombotic AMI with stenting can be a straightforward procedure, whereas the open approach requires major surgery involving laparotomy and surgical bypass. In case of embolic AMI, however, the endovascular treatment may be technically more demanding than in thrombotic AMI. Open embolectomy may be considered as a faster option to revascularise the intestines, and the vitality of the bowel can be assessed at the same laparotomy. Nevertheless, some studies that do report outcomes specifically for embolic AMI show promisingly low early mortality and bowel resection rates for the endovascular approach (Table 1).[5–15] Selection bias is likely, as many of the studies do not report patients who were treated without revascularisation.

For the past 15 years, in the current institution, the primary treatment strategy has been endovascular revascularisation (EVR) for both embolic and thrombotic AMI.[16] The aim of this study was to report outcomes of EVR as the first line treatment strategy for embolic AMI in an elderly population with all consecutive patients included regardless of their physical condition and whether they were revascularised or not.

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MATERIALS AND METHODS

Study design and patients

This was a single centre, retrospective study performed in an academic teaching hospital that provides tertiary care for a population of approximately 850 000 inhabitants in Eastern Finland. All consecutive patients diagnosed with embolic AMI during the study period from January 2009 to May 2024 were included. This study was a continuation of the 2009 – 2013 series published in 2015.[9] Patients diagnosed with thrombotic AMI, venous mesenteric ischaemia, or non-occlusive mesenteric ischaemia were excluded. Patients were searched from the electronic medical records, operative database, and radiology database using International Classification of Diseases 10 diagnosis codes K55.X and Nordic Classification of Surgical Procedures codes for visceral artery procedures. The study had an organisational permit, and obtaining formal informed consent from participants was not required. This study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for reporting observational studies.

Definition of embolic acute mesenteric ischaemia

A multidisciplinary team including a vascular and gastrointestinal surgeon and interventional radiologist evaluated the clinical data, imaging, operative reports, and pathology reports. Mesenteric artery embolism was defined as an oval shaped clot in the superior mesenteric artery (SMA) or coeliac artery on contrast enhanced computed tomography (CT) scan without an underlying calcified stenosis. Patients with major atherosclerotic plaque in the mesenteric arteries (suggesting thrombotic aetiology) were excluded. In cases with uncertainty between embolic and thrombotic aetiology, a very acute onset of symptoms, atrial fibrillation without adequate anticoagulation and synchronous embolic findings were indications of embolic aetiology. In case of a distal embolism in the marginal branches of the SMA, invisible on CT scan, the diagnosis was confirmed by an appropriate clinical presentation described above and segmental bowel necrosis on laparotomy, with findings of thromboembolic material in the small arteries of the mesentery in the pathology report. Clinical signs of peritonitis were defined as a distended abdominal wall with pain and guarding on palpation and clinical diagnosis or suspicion of peritonitis mentioned in the medical notes.

Computed tomography analysis

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All study patients underwent contrast enhanced CT with field of view from above the diaphragm to below the symphysis. A venous phase scan was obtained from all patients with acute abdomen, and in cases where mesenteric ischaemia was suspected before imaging, an arterial phase scan was also obtained; slice thickness varied from 1 – 5 mm. Multiplanar reconstructions in three planes were used for retrospective analysis of imaging. Mesenteric vasculature and bowel characteristics were evaluated by an interventional radiologist. The location of the SMA occlusion was defined as proximal, middle, or distal, based on a recently proposed anatomical segmentation.[17]

Treatment strategy of embolic acute mesenteric ischaemia and procedural details

EVR was favoured as the primary revascularisation method in all patients with AMI that were considered suitable for revascularisation based on their clinical status. Laparotomy was performed if bowel necrosis was suspected or when the symptoms did not subside after successful EVR. Patients with distal marginal SMA branch embolism, unsuitable for endovascular mechanical revascularisation, were treated with segmental bowel resection alone. Patients who were deemed too sick and/or came in too late to be rescued were treated with palliative care.

The main modality for EVR in embolic AMI was mechanical aspiration embolectomy; this was performed via femoral or brachial access (Fig. 1). When steerable sheaths (TourGuide, Medtronic, Minneapolis, MN, USA, and Destino, Oscor, Palm Harbor, FL, USA) became commercially available, femoral access was preferred. A 6 – 8F introducer sheath was inserted and an angled guiding catheter (Judkins right, Judkins left, Bentson, and Simmons) or up to 8.5F steerable sheath was used to gain stable access to the ostium of the SMA. A 0.035” hydrophilic guidewire (Terumo, Tokyo, Japan) was inserted into the SMA main branch, and an aspiration catheter (5 – 8F) was advanced into contact with the embolus. The guidewire was removed, either a manual 20 or 50 mL syringe or an electric pump (Penumbra System, Alameda, CA, USA, or Stryker Medela AXS Universal Aspiration Set, Portage, MI, USA) was used to achieve continuous suction, and the embolus was retrieved. In cases of extensive thrombus, crossing the occlusion with the guidewire was waived to avoid dislodgement of the thrombus, and large bore (8F) aspiration catheters were used. If the thrombus was more distally located or otherwise in a challenging position, a 0.014” guidewire was inserted into the target vessel and left in place to

guide the aspiration catheter to the correct location. For proximal occlusions, multipurpose guiding catheters or dedicated peripheral aspiration catheters were used for the aspiration. For selected cases of distal emboli, neurovascular aspiration catheters, gentle balloon maceration, and, occasionally, stent retrievers were used, for example, to reach a major side branch occlusion (Fig. 2). Successful recanalisation was considered as restored flow in the main stem and main branches of the SMA. Small peripheral emboli were accepted.

In case of flow limiting residual stenosis or unsuccessful primary aspiration, balloon angioplasty was performed. The same access technique was used as described earlier. The lesion was usually crossed with a 0.014” or 0.035” wire and suitable sized balloons were used. If needed, stenting was performed using balloon expandable stents (Palmaz Blue, Cordis, Miami Lakes, FL, USA; Express SD, Boston Scientific Corporation, Marlborough, MA, USA; RACER, Medtronic, Minneapolis, MN, USA) or self expanding stents (SMART, Cordis; E-Luminexx, Becton, Dickinson and Company, Franklin Lakes, NJ, USA). Flow limiting dissection was treated with primary stenting.

Additional local thrombolysis was performed in selected cases due to incomplete thrombus aspiration or major distal embolisation. Urokinase was infused from an end hole catheter; 5000 U/mL solution was prepared and 100 000 – 500 000 units were administered as a slow peri-operative infusion. Eptifibatide (Integrilin, GlaxoSmithKline Limited, Dublin, Ireland) infusion was used in a few cases according to the manufacturer’s instructions. Systematic thrombolysis was not used.

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Outcome definitions

The primary outcomes of interest were technical success, endovascular procedure related complications, 30 day mortality, and the need for laparotomy and bowel resection. Technical success was defined as a completely patent target vessel or a minor residual embolus located distal from the ileocolic artery. In detail, main branches of the SMA (inferior pancreaticoduodenal artery, right and middle colic artery, and ileocolic artery) were required to either be fully patent or have minimal residual non-flow limiting emboli. Emboli in small jejunal or ileal branches were interpreted as minor and did not constitute technical failure if the patent branches provided collateral flow to the marginal artery without angiographic defects of the bowel perfusion. EVR related complications included access site complications or dissection of

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the target artery causing flow impairment. A dissection that was successfully treated with stenting was not considered a technical failure.

Statistical analysis

A secondary aim of the study was to assess possible risk factors for 30 day mortality after EVR in embolic AMI in a univariable analysis. The Kaplan–Meier method was used to illustrate five year survival. Multivariable analysis was waived due to the low number of patients and events. All statistical analysis was performed using IBM SPSS Statistics 29.0 software (IBM, Armonk, NY, USA). Categorical variables were evaluated using χ^2 or the Fisher's exact test. Continuous variables were analysed using the Mann–Whitney *U* test. The statistical significance threshold was set at *p* values less than .05.

RESULTS

Characteristics and clinical presentation of patients with embolic acute mesenteric ischaemia

During the 15 year study period, 63 consecutive patients were diagnosed with embolic AMI. The mean age of all 63 patients was 79 ± 12 years and 41 (65%) were female. Thirty five patients (56%) were aged ≥ 80 years. Atrial fibrillation was the most prevalent comorbidity in 40 (63%) patients, and 34 (54%) had atrial fibrillation without adequate anticoagulation at presentation (Table 2). Acute abdominal pain was the most common symptom in 58 (92%) patients and bowel emptying (defined as diarrhoea or vomiting) the second most common in 31 (49%) patients (Table 3). The duration of symptoms was less than 24 hours before the hospitalisation in 45 (71%) patients with embolic AMI. The distribution of the embolic clot and the intestinal findings on CT scan are presented in Table 4. As the most common CT findings, the middle part of the SMA was occluded in 42 (67%) patients and decreased bowel wall enhancement was noted in 46 (73%) patients. At presentation, 25 (40%) patients had normal white blood cell (WBC) counts, and 18 (29%) patients had normal C reactive protein (CRP) levels; five patients (8%) had both WBC count and CRP level as normal. In contrast, 24 (38%) patients had CRP level > 100 mg/L. The lactate level was increased in 26 (41%) patients (Table 5).

Outcomes of patients treated without revascularisation

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Fifteen (14%) of the 63 patients were treated without attempted EVR; three of the 15 survived (Fig. 3). Of the 15 patients, eight received only palliative care due to their poor overall condition at presentation; none survived. Seven patients underwent laparotomy with (n = 5) or without (n = 2) bowel resection. In more detail, two patients underwent laparotomy without bowel resection; in one patient, the bowel was vital despite the SMA embolus and resection or revascularisation was not needed, and the patient survived; in the other non-surviving patient, most of the bowel was necrotic and considered unsalvageable. Five patients had bowel resection without revascularisation. Of these, two patients had distal emboli and a segmental small bowel resection alone was sufficient treatment; both survived. One patient underwent emergent laparotomy and bowel resection, before the diagnostic CT was obtained, due to septic peritonitis; after the discovery of SMA embolism, palliative care was chosen because a concomitant large metastatic mediastinal tumour was found. Another non-surviving patient underwent bowel resection alone owing to the poor overall condition caused by a delay in the diagnosis. One elderly patient with CT verified SMA embolism underwent laparotomy first owing to peritonitis; open embolectomy was attempted, but this resulted in dissection of the SMA, and major bowel resection was required, which the patient did not survive.

Outcomes after endovascular treatment

Forty eight (76%) of the 63 patients were treated with EVR (Fig. 3). The mean age of the 48 patients treated with EVR (or attempted EVR) was 79 ± 11 years, and 28 (58%) were aged ≥ 80 years; 33 (69%) were female. Three were treated with stent placement alone (two balloon expandable and one self expanding stent) and 45 underwent aspiration embolectomy as the primary approach, with the adjunctive endovascular procedures performed when necessary. These adjuncts included balloon angioplasty in four patients, stenting in nine (seven self expanding stents and two balloon expandable stents), thrombolysis in three, and stent retriever thrombectomy in three. The revascularisation was considered technically successful in 47 (98%) patients. One patient had a persistent occlusion in the middle part of the SMA after mechanical aspiration and underwent unsuccessful adjunctive thrombolysis; the unresolved occlusion of the SMA was determined as dissection and the case was considered as a technical failure. Seven (15%) patients had EVR related complications, all of which occurred before 2014; these were access site related in two cases, including a femoral pseudoaneurysm in one and access site

bleeding in the other. Five patients had an iatrogenic SMA dissection: four of them were successfully treated by immediate stenting (all self expanding stents); the one patient with technical failure underwent bowel resection and had no further attempt at revascularisation. Four of the five SMA dissections occurred when using a non-steerable sheet sheath from the femoral artery access. All except one patient survived despite EVR related complications. The one who died had SMA dissection combined with bleeding from the SMA that was treated with stenting.

Of the 48 patients treated with EVR, 21 (44%) died within 30 days. All in hospital deaths occurred within 30 days. Of the 48 patients treated with EVR, 19 (40%) underwent laparotomy and 11 (23%) needed bowel resection. Of the 19 patients who underwent laparotomy in addition to EVR, seven (37%) died, whereas 14 (48%) of the 29 patients who underwent EVR without laparotomy died within 30 days (p = .43). Of 28 patients who underwent EVR and were aged ≥ 80 years, 17 (61%) died within 30 days. Of all 63 patients diagnosed with embolic AMI, 33 (52%) died within 30 days, 26 (41%) underwent laparotomy, and 16 (25%) had bowel resection. There was no temporal difference in 30 day mortality between the first and the second half of the study period: 15 of 32 (47%) and 16 of 31 (52%) patients died, respectively (p = .80).

Factors affecting survival in patients treated with endovascular revascularisation

Age was statistically significantly associated with early death (Table 2). The mean age of those who survived AMI after EVR was 74 ± 11 years, compared with 86 ± 6 years among those who did not survive past 30 days (p = .001). Clinical signs of peritonitis and sepsis were present in six patients (13%) who underwent EVR, all of whom died within 30 days, whereas none of the survivors had these signs at presentation (p = .003, Table 3). Regarding CT findings, 36 (75%) of the EVR patients had decreased bowel wall enhancement; 16 (59%) of the EVR survivors had decreased bowel wall enhancement compared with 20 (95%) of the non-survivors, which demonstrated an association with early death (p = .004, Table 4). Regarding laboratory findings at the time of diagnosis, increased lactate levels, low bicarbonate level and bicarbonate to lactate ratio, and low base excess (metabolic acidosis) were associated with early death (Table 5). Five year survival data are presented in Supplementary Figure S1.

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DISCUSSION

Main outcomes of endovascular revascularisation in embolic acute mesenteric ischaemia

In this cohort of consecutive patients with embolic AMI, EVR was attempted as the first line treatment in every three of four patients, with a high technical success rate. Even though the 44% mortality rate was higher compared with those in many of the previous publications (Table 1), it was considered acceptable because more than half of the patients were aged ≥ 80 years and 20% were aged ≥ 90 years. Old age was associated with early death; approximately 60% of patients aged ≥ 80 years died within 30 days. The mean age of the patients undergoing EVR in this study was one of the highest compared with those in previous studies. Moreover, the revascularisation rate remains unclear in many previous studies presenting outcomes of revascularisation in AMI, which makes it unclear how patients to be treated with EVR were selected.[18]

Of those patients who underwent EVR in this study, 40% required laparotomy. This number would have been 100% if they were treated with open embolectomy. With EVR, it is believed that a significant number of patients can be spared from a physically straining open surgery. This can be especially beneficial for elderly patients with embolic AMI. However, another reason for the low laparotomy rate was that some of the elderly patients were considered too sick to undergo laparotomy. Thus, it was decided that EVR could be attempted but laparotomy was waived. In case of irreversible bowel ischaemia despite EVR, these patients would then be treated with palliative care. Moreover, the bowel resection rate after EVR in this study was 25%. In contrast, the bowel resection rate was 30% and 80% in the two studies with patients treated with open revascularisation (Table 1). The low laparotomy and bowel resection rates in the present study may not be directly associated with better survival compared with the studies with open revascularisation. Although EVR offers a less traumatic approach that could potentially lower the risk of early death compared with that associated with open revascularisation, EVR may also be considered suitable for patients unfit for open surgery; this could potentially increase mortality as older and sicker patients are being treated. A very aggressive approach to attempt EVR in all patients with embolic AMI could increase the revascularisation rate but poses a risk of overtreating elderly patients who may be beyond rescue and may not benefit from this procedure.

Observations in patient demographics, comorbidities, and diagnostic findings

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Approximately two thirds of the patients with embolic AMI were females. It has been suggested that the predominance of female sex in embolic AMI is because females live longer and most patients with embolic AMI are elderly.[19] Female sex was not a predictive factor for early death in the present study. Approximately two thirds of the patients with embolic AMI had atrial fibrillation at presentation, most of them without adequate anticoagulation. The ESVS guidelines recommend that every patient with atrial fibrillation and acute abdominal pain should be suspected of having embolic AMI.[3]

Based on this study, decreased bowel wall enhancement, increased lactate level, and metabolic acidosis are associated with early death. These should be taken as warning signs to consider early laparotomy to check bowel viability. No correlation was found between other laboratory parameters and mortality. Nearly 30% of patients had normal CRP levels, and there were a few patients with both normal CRP and normal WBC count. Thus, normal inflammatory markers do not rule out the possibility of embolic AMI in its early stage. D dimer was not screened in patients with acute abdominal pain. The recent evidence contradicts the value of biomarkers in the diagnosis of AMI.[20] However, D dimer has not been extensively and exclusively investigated in patients with embolic AMI. At least in theory, D dimer level should be increased in acute embolism of the SMA and could have some diagnostic value in patients with atrial fibrillation and acute abdominal pain.

Technical and logistic considerations in endovascular treatment of embolic acute mesenteric ischaemia

During the 15 years covered by the study, the endovascular technique for treatment of acute arterial occlusions has evolved. In the beginning of the period, mesenteric emboli were mainly aspirated with standard guiding catheters, which are designed for vascular access rather than aspiration and tend to collapse when suction is applied. The tip of these catheters can damage the vessel wall during heavy manipulation of the catheter. Dedicated aspiration catheters designed for stroke thrombectomy are much safer and more effective in mesenteric arteries.[21] Steerable sheaths have made the intervention from femoral artery access more robust and faster, so brachial artery access is seldom needed. Stent retrievers facilitate thrombus extraction when plain aspiration is not enough. However, current retrievers are designed for intracranial vessels, and therefore, they are a bit small for the proximal SMA. Still, further technical improvements

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are warranted because distal embolisation during endovascular embolectomy can worsen the clinical outcome. In stroke thrombectomies, the use of balloon guiding catheters and proximal occlusion during aspiration improves both technical and clinical success, and that technique could also be used in visceral arteries.[21]

The advancement of endovascular tools with the introduction of steerable sheaths led to a decrease in EVR related complications. All EVR related complications in this study happened during the first five years of the 15 year study period. Most SMA dissections occurred when non-steerable sheaths were used to navigate the acute angle of the SMA from femoral artery access. Brachial access may be considered if the patient has a very steep SMA angle. Although not very typical in embolic AMI, an atherosclerotic plaque at the ostium of SMA makes the tunica media more vulnerable, and the interventional radiologist or vascular surgeon must be extra careful to avoid dissection. Ideally, the embolus should be treated with a 6F aspiration catheter from femoral access over a steerable sheath. Four of five dissections in the present study occurred using non-steerable sheath when more aggressive guidewire support was needed to pass the aspiration catheter over the angle of the SMA. In case of a large SMA thrombus, a steerable sheath of up to 8.5F may be needed. Despite the challenges of EVR in embolic AMI, the technical success rate was high and most EVR procedure related complications were managed without major consequences. The ESVS guidelines recommend completion imaging after open mesenteric revascularisation to confirm patent SMA and sufficient bowel perfusion.[3] One advantage of the endovascular approach is that completion angiography is part of the procedure, whereas the surgeon may be tempted to forgo on table completion imaging after open embolectomy because it requires some additional manoeuvres.

An endovascular first approach may result in treatment delays due to logistical constraints and prolonged delay can lead to fatal consequences. Therefore, the decision on the treatment strategy should be made considering the local resources and expertise. EVR in embolic AMI can be technically demanding and, ideally, a multidisciplinary team comprising a gastroenterological surgeon, interventional radiologist, and vascular surgeon should make the treatment decision. In the current institution, a 24/7 cerebral stroke team consisting of interventional radiologists and nurses can treat mesenteric embolism during on call hours. The endovascular technique evolved over time. During the early years of the study period, manual

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aspiration was mainly applied. Later, a continuous aspiration pump was frequently used because it may facilitate more versatile manual catheter manipulation for the operator. Although a hybrid room has been available since 2015, most cases were still performed in an angiography suite because of the interventional radiologists’ preference.

Limitations and strengths

Several patients with embolic AMI (n = 18) treated between 2009 and 2013 have been part of a study cohort that has previously been reported.[9] However, in that study, the results were pooled together with thrombotic AMI. For this study, all of these patients’ records and imaging were revisited for more detailed scrutiny. The limitations of this study were its retrospective design and relatively small patient population. However, this study focused on embolic AMI and is supposedly currently the largest series of patients treated with EVR for mesenteric artery embolism. It was decided to not make any comparison between the EVR group and non-EVR group because the patients were inherently different. Given that there was no comparative arm in this study, any comparison of outcomes between the EVR group and non-EVR group was avoided because the patients were inherently different at baseline. The low rate of peritonitis in this study may have been biased due to difficulty in determining clinical signs of peritonitis in a retrospective study that relies on the accuracy of the medical notes. Only the risk factors for early death after attempted EVR underwent statistical analysis. The number of events was small for many study variables, and therefore, multivariable analysis to adjust for confounding variables was waived. This study was conducted at a single centre with rapid availability and high expertise in technically demanding endovascular services around the clock. Therefore, the study results may not be generalised in hospitals with no such resources, and in this case, surgical embolectomy may offer the patients a better chance of survival than hospital transfer.

The tabular review in Table 1 is a non-systematic literature review and should be cautiously interpreted. The open and endovascular groups are not comparable as there are no randomised studies. The prevalence of peritonitis as a measure of disease severity was rarely reported in the included studies. Therefore, the pooled outcomes are only indicative and may be heavily biased.

Conclusion

The endovascular first approach was suitable for most patients, with a good technical success rate and acceptable mortality rate considering the high mean age of non-selected patients with AMI. One third of patients undergoing endovascular treatment required laparotomy, whereas all patients would require laparotomy for open embolectomy. Embolic AMI should be considered as a potential cause for acute abdominal pain in elderly patients with atrial fibrillation, even if the laboratory values are normal.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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APPENDIX A. SUPPLEMENTARY DATA

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Figure 1. Endovascular aspiration embolectomy from brachial artery access. Superior mesenteric artery was catheterised using a 5F Judkins right 4 catheter and a hydrophilic 0.035" guidewire (Terumo, Tokyo, Japan) and a straight 6F 90 cm introducer sheath (Flexor, Cook, Bloomington, IL, USA) was advanced coaxially into the main branch of the vessel. **A** Initial angiography shows typical round shaped embolic occlusion in the ileocolic artery. **B** Manual aspiration was performed using a 50 mL syringe and a 6F Bentson catheter, and completion angiography shows successful embolectomy, no distal emboli, and some residual spasticity in the vessel because of mechanical manipulation.

Figure 2. Endovascular embolectomy using a steerable 8.5F Destino twist sheath (Oscor, Palm Harbor, FL, USA) from a femoral approach. **A, B** Aspiration with 8F MP XF guiding catheter (Cordis, Miami Lakes, FL, USA) opened the main ileal branch but a major side branch remained occluded. **C** Coaxial approach with 8F MP XF guiding catheter (Cordis, Miami Lakes, FL, USA), React 68 aspiration catheter (Medtronic, Minneapolis, MN, USA), NeuroSlider 21 microcatheter (Acandis, Pforzheim, Germany), and Synchro Select Support guidewire (Stryker, Portage, WI, USA) were used to gain access to the side branch; a stent retriever (EmboTrap 5/33 mm, Cerenovus, Irvine, CA, USA) was opened over the embolus after crossing the lesion with a microcatheter, aspiration catheter was advanced into contact with the embolus; and the electric pump aspiration activated. The stent retriever was partly pulled into the aspiration catheter and then both the aspiration catheter and the stent retriever were removed as a single unit. Digital subtraction angiography showed successful revascularisation. **D** Completion angiography shows no distal emboli and some spasticity in the treated major side branch, which resolved in a few minutes.

Figure 3. The treatment pathways and 30 day/in hospital survival of 63 patients diagnosed with embolic acute mesenteric ischaemia.

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Table 1. Non-systematic tabular review of publications reporting bowel resection and 30 day mortality rates after open revascularisation (OPEN) or endovascular revascularisation (ENDO) for embolic acute mesenteric ischaemia (AMI).

Author	Patients with embolic AMI	Mean age – y	Bowel resection – %	30 d mortality – %
Björnsson *et al.*[6]	34 ENDO	78	24	26
Jia *et al.*[7]	21 ENDO	71	24	10
Raupach *et al.*[8]	37 ENDO	76	41	27
Kärkkäinen *et al.*[9]	18 ENDO	81	28	39
El-Laboudy *et al.*[10]	11 ENDO	54	18	24
Shi *et al.*[12]	41 ENDO	74	12	27
Thurner *et al.*[14]	15 ENDO	66	60	40
Qiu *et al.*[15]	28 ENDO 66 OPEN	74	18 80	21 36
Li *et al.*[5]	21 ENDO 37 OPEN	69	65 30	19 43
Pooled outcomes	226 ENDO 103 OPEN	n/a	30 62	26 39

Case series with fewer than ten patients were excluded. ENDO = endovascular revascularisation; OPEN = open revascularisation.

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Table 2. Patient characteristics and comorbidities of 63 patients with embolic acute mesenteric ischaemia (AMI).

	All patients (*n* = 63)	**EVR (*n* = 48)**	**EVR survivors (*n* = 27)**	**EVR non-survivors (*n* = 21)**	***p* value**
Sex, female	41 (65)	33 (69)	17 (63)	16 (76)	.33
Age – y	79 ± 12	79 ± 11	74 ± 11	86 ± 6	.001
Age ≥80 y	35 (56)	28 (58)	11 (41)	17 (81)	.005
Age ≥90 y	14 (22)	10 (21)	4 (15)	6 (29)	.24
Age (range)	82 (45–97)	82 (45–95)	77 (45–94)	87 (72–95)	
Atrial fibrillation	40 (63)	31 (65)	14 (52)	17 (81)	.17
Atrial fibrillation without adequate anticoagulation (no medication or INR <2.0)	34 (54)	26 (54)	12 (44)	14 (57)	.27
Previous myocardial infarction	9 (14)	8 (17)	5 (19)	3 (14)	.70
Congestive heart failure	6 (10)	4 (8)	3 (11)	1 (5)	.43
Coronary artery disease	31 (49)	26 (54)	15 (56)	11 (52)	.83
Mechanical aortic or mitral valve implant	1 (2)	1 (2)	1 (4)	0 (0)	.37
History of arterial embolism	3 (5)	2 (4)	1 (4)	1 (5)	.86
History of deep venous thrombosis or pulmonary embolism	2 (3)	2 (4)	1 (4)	1 (5)	.86
History of a malignancy	11 (17)	10 (21)	7 (26)	3 (14)	.33
Active malignant cancer	4 (6)	2 (4)	0 (0)	2 (10)	.10
Stroke or TIA	18 (29)	12 (25)	6 (22)	6 (29)	.61
Hypertension on medication	36 (57)	27 (56)	10 (37)	17 (81)	.002
Dyslipidaemia	25 (40)	20 (42)	9 (33)	11 (52)	.18

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History of lower limb ischaemia	9 (14)	7 (15)	2 (7)	5 (24)	.11
Diabetes	17 (27)	11 (23)	5 (19)	6 (29)	.41
Recent major surgery unrelated to mesenteric ischaemia	3 (5)	2 (4)	1 (4)	1 (5)	.86
COPD	4 (6)	2 (4)	2 (7)	0 (0)	.20
Smoking	10 (16)	7 (15)	3 (11)	4 (19)	.74
Chronic kidney disease	2 (3)	1 (2)	0 (0)	1 (4)	.25
Memory disorder	9 (14)	5 (10)	2 (7)	3 (14)	.44
Dialysis	0 (0)	0 (0)	0 (0)	0 (0)	ns
Living at nursing home or other similar institution	7 (11)	4 (8)	2 (7)	2 (10)	.79

Data are presented as *n* (%), mean ± standard deviation, or median (range). Patients who underwent EVR (*n* = 48) were stratified by 30 day survival status; *p* values represent comparison between survivors and non-survivors after attempted EVR. COPD = chronic obstructive pulmonary disease; EVR = endovascular revascularisation; INR = international normalised ratio; TIA = transient ischaemic attack.

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Table 3. Symptoms and other acute conditions in 63 patients with embolic acute mesenteric ischaemia (AMI).

	All patients (*n* = 63)	EVR (*n* = 48)	EVR survivors (*n* = 27)	EVR non-survivors (*n* = 21)	*p* value
Symptom duration before hospitalisation					
≤24 h	45 (71)	34 (71)	17 (63)	17 (81)	.17
1–3 d	8 (13)	6 (13)	3 (11)	3 (14)	.74
>3 d	6 (10)	6 (13)	6 (22)	0 (0)	.021
Acute abdominal pain	58 (92)	44 (92)	24 (89)	20 (95)	.43
History of postprandial abdominal pain	1 (2)	1 (2)	1 (4)	0 (0)	.37
Diarrhoea	18 (29)	15 (31)	8 (30)	7 (33)	.78
Vomiting	26 (41)	21 (44)	11 (41)	10 (48)	.63
Bowel emptying (diarrhoea or vomiting)	31 (49)	25 (52)	13 (48)	12 (57)	.73
Gastrointestinal bleeding	7 (11)	6 (13)	4 (15)	2 (10)	.58
Peritonitis/sepsis	11 (17)	6 (13)	0 (0)	6 (29)	.003
Unstable haemodynamic	4 (6)	2 (4)	0 (0)	2 (10)	.10
Acute myocardial infarction	3 (5)	3 (6)	0 (0)	3 (14)	.043

Data are presented as *n* (%). Patients who underwent EVR (*n* = 48) were stratified by 30 day survival status; *p* values represent comparison between survivors and non-survivors after attempted EVR. EVR = endovascular revascularisation.

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Table 4. Vascular and intestinal computed tomography findings in 63 patients with embolic acute mesenteric ischaemia (AMI).

	All patients (n = 63)	**EVR (n = 48)**	**EVR survivors (n = 27)**	**EVR non-survivors (n = 21)**	***p* value**
Proximal SMA embolism*	12 (19)	11 (23)	8 (30)	3 (14)	.21
Middle SMA embolism	42 (67)	34 (71)	16 (59)	18 (86)	.045
Distal SMA embolism	5 (8)	2 (4)	2 (7)	0	.20
SMA distal branch embolism†	2 (3)	0	0	0	na
CA embolism	1 (2)	1 (2)	1 (4)	0	.99
Decreased bowel wall enhancement	46 (73)	36 (75)	16 (59)	20 (95)	.004
Bowel wall thickening	15 (24)	13 (27)	9 (33)	4 (19)	.27
Bowel paralysis/dilatation	11 (17)	6 (13)	2 (9)	4 (19)	.23
Bowel wall pneumatosis	5 (8)	4 (8)	2 (7)	2 (10)	.80

Data are presented as n (%). Patients who underwent EVR (n = 48) were stratified by 30 day survival status; p values represent comparison between survivors and non-survivors after attempted EVR. CA = coeliac artery; EVR = endovascular revascularisation; SMA = superior mesenteric artery.

* One patient with SMA embolism had no computed tomography but was diagnosed during autopsy.

† Not visible on computed tomography but diagnosed based on laparotomy, pathology examination, and clinical findings.

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Table 5. Laboratory findings at the time of the diagnosis before endovascular revascularisation (EVR) in 63 patients with embolic acute mesenteric ischaemia (AMI).

	All patients (*n* = 63)	**EVR (*n* = 48)**	**EVR survivors (*n* = 27)**	**EVR non-survivors (*n* = 21)**	***p* value**
Haemoglobin – g/L	135 ± 23.9	138 ± 23.1	137 ± 27.1	139 ± 17.9	.77
Low haemoglobin (F: <120 g/L, M: <130 g/L)	20 (31)	12 (24)	8 (30)	4 (19)	.40
WBC count – 10^9/L	14.5 ± 6.3	14.4 ± 5.3	13.6 ± 5.5	15.3 ± 4.9	.19
WBC count ≥11 g/L	38 (59)	31 (63)	16 (59)	15 (71)	.48
WBC count <11 g/L	25 (40)	17 (35)	10 (37)	6 (29)	.48
CRP – mg/L	118 ± 145	96 ± 116	86 ± 103	109 ± 133	.69
CRP >100 mg/L	24 (38)	16 (33)	10 (37)	6 (29)	.63
CRP ≥10 mg/L	42 (66)	31 (63)	17 (63)	14 (67)	.55
CRP <10 mg/L	18 (29)	14 (29)	9 (33)	5 (24)	.55
CRP <10 mg/L and WBC count <11 g/L	5 (8)	3 (6)	2 (7)	1 (5)	.71
INR	1.6 ± 0.7	1.6 ± 0.7	1.6 ± 0.7	1.5 ± 0.7	.77
INR <2	33 (52)	25 (51)	13 (48)	12 (57)	.94
Krea – µmol/L	95 ± 37	94 ± 34	92 ± 35	96 ± 34	.60
GFR – mL/min*	65 ± 26	64 ± 26	68 ± 27	60 ± 25	.25
GFR <30	4 (6)	3 (6)	0 (0)	3 (14)	.011
Arterial blood gas analysis†					
Lactate – mmol/L	3.3 ± 2.0	3.3 ± 2.2	2.1 ± 1.6	4.2 ± 2.2	.003
Lactate >2.2 mmol/L	26 (41)	16 (33)	3 (11)	113 (62)	.006
BE – mmol/L	−2.6 ± 4.5	−3.0 ± 4.4	−0.7 ± 4.5	−4.5 ± 3.7	.009
BE < −2.5 mmol/L	21 (33)	18 (37)	3 (11)	15 (71)	.002
HCO_3 – mmol/L	21.8 ± 4.8	21.2 ± 5.0	24.2 ± 3.4	19.3 ± 5.4	.008
HCO_3 to lactate ratio	10.6 ± 8.4	11.0 ± 9.2	17.9 ± 9.4	6.4 ± 5.4	.008

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Data are presented as *n* (%) or mean ± standard deviation. Patients who underwent EVR (*n* = 48) were stratified by 30 day survival status; *p* values represent comparison between survivors and non-survivors after attempted EVR. BE = base excess; CRP = C reactive protein; EVR = endovascular revascularisation; F = female; GFR = glomerular filtration rate; INR = international normalised ratio; M = male; WBC = white blood cell.

* CKD-EPI creatinine equation was used to calculate GFR.

† Arterial blood gas test was obtained from 42 patients.

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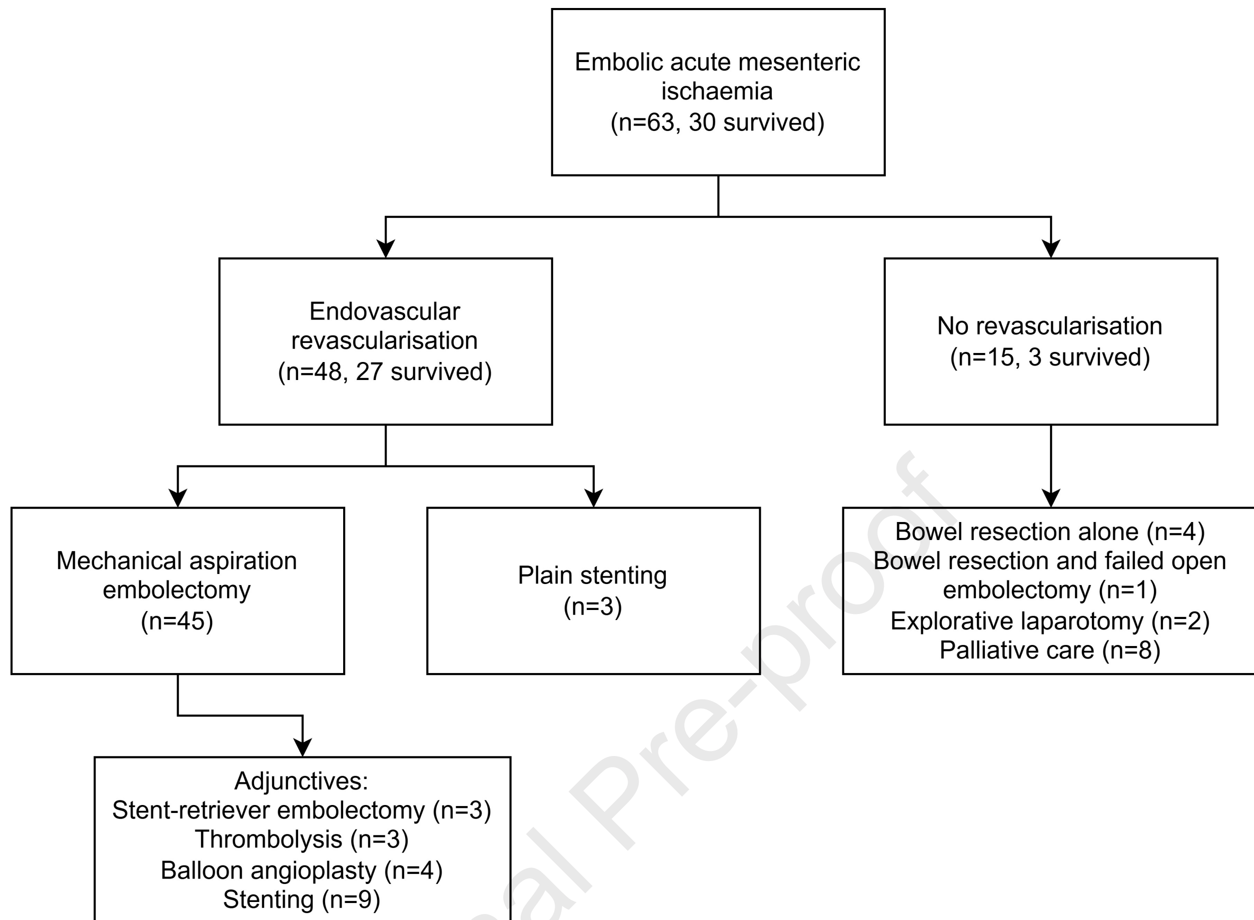

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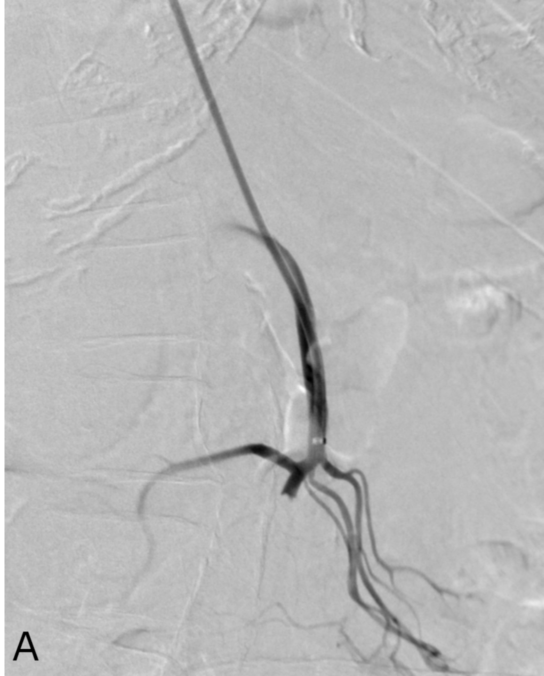

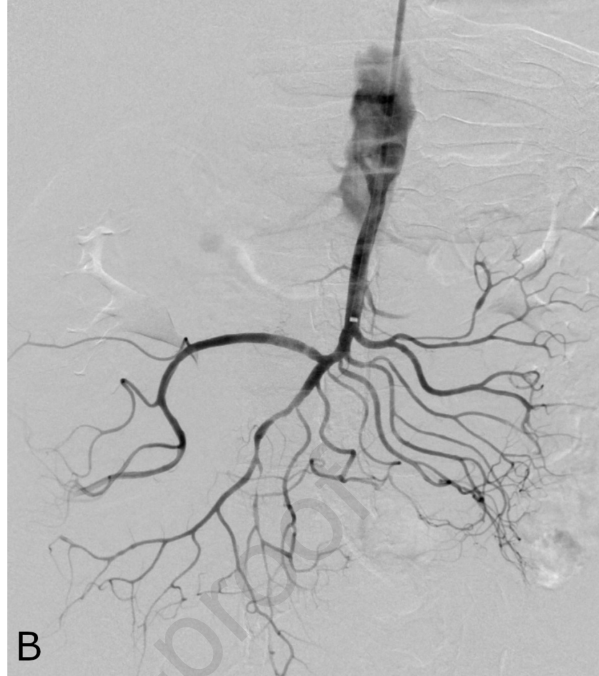

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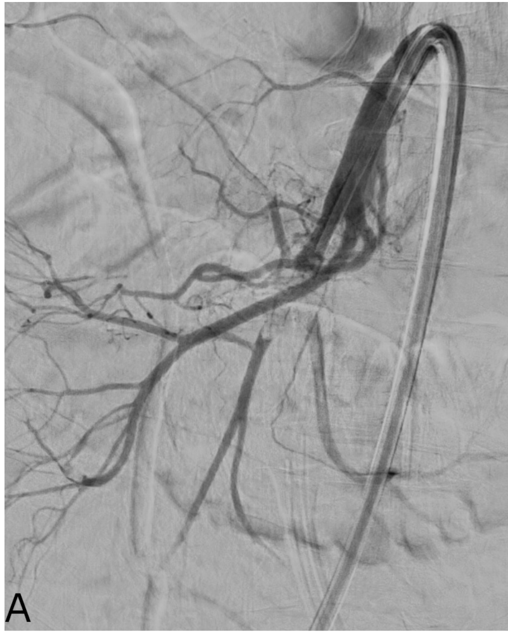

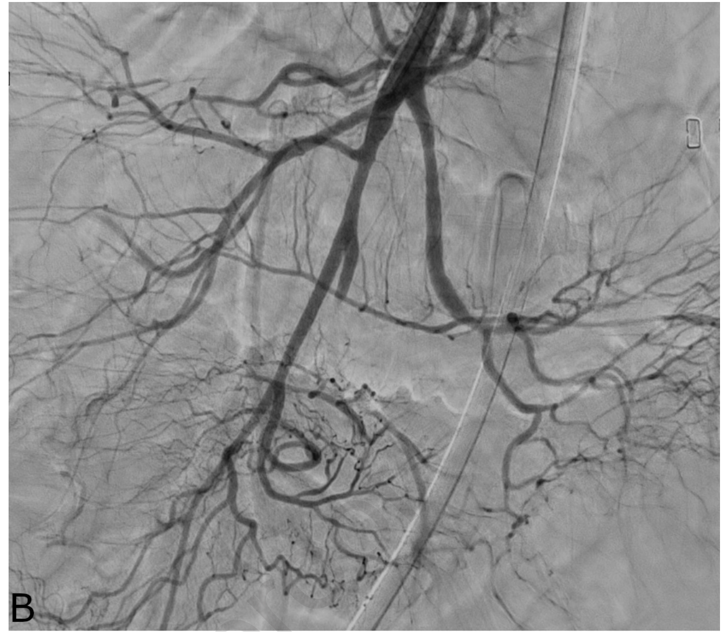

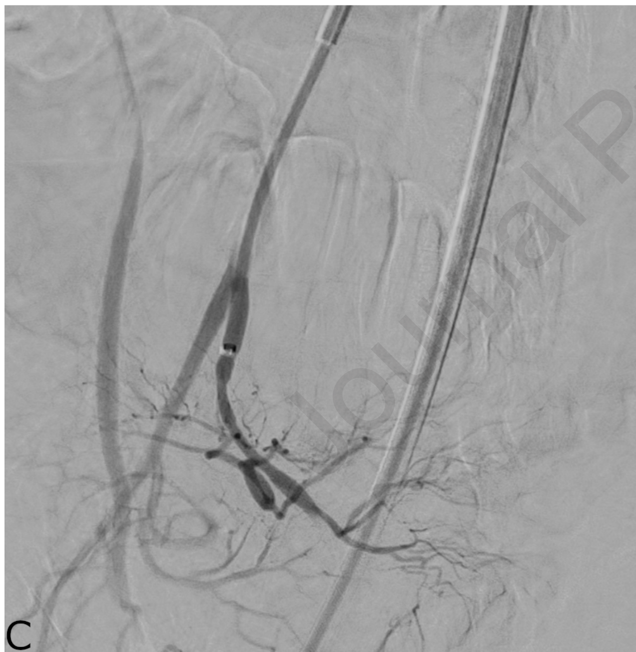

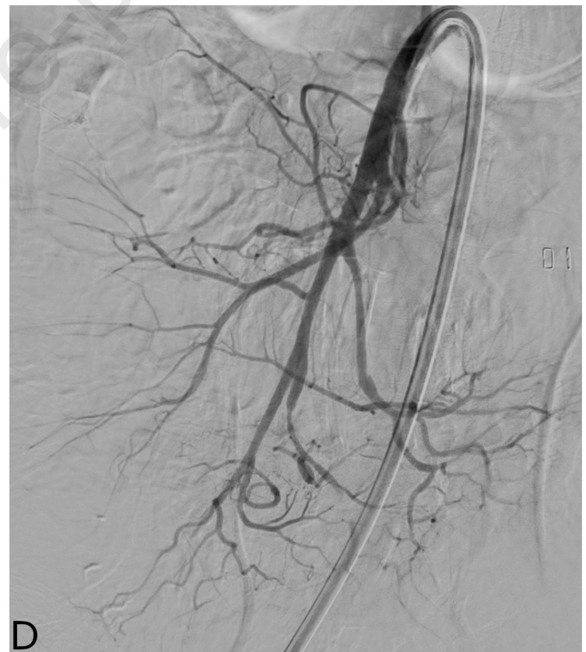

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