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# Surgical and Interventional Visceral Revascularization for the Treatment of Chronic Mesenteric Ischemia—When to Prefer Which?

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**Abstract**

*Background:* The purpose of the present study was to compare surgical and endovascular revascularization for chronic mesenteric ischemia (CMI).

*Methods:* Forty-nine patients underwent surgical (SG) or endovascular (EG) treatment. Relief of symptoms was considered the primary endpoint; patency, morbidity, and mortality were secondary endpoints. For statistical analysis, significance was assumed if $P$ values $\leq$ *0.05.*

*Results:* Twenty-six patients (53%) underwent surgical revascularization; 23 patients (47%), endovascular repair. Mean follow-up was 25 ± 21 months (SG) versus 10 ± 10 (EG) months ($P = 0.07$). Except for body mass indices (SG 18.9 ± 2.7 versus EG 23.6 ± 4.8; $P = 0.001$), preoperative data were comparable. Freedom from symptoms was 100% (SG) versus 90% (EG) after intervention ($P = 0.194$), and 89% (SG) versus 75% (EG) at the end of follow-up. Reocclusion or re-stenosis occurred in 8% (SG) versus 25% (EG) (log-rank test: $P = 0.003$), and mesenteric ischemia developed in 0% (SG) versus 9% (EG) ($P = 0.04$). Reintervention for CMI was required in 0% (SG) versus 13% (EG) ($P = 0.01$). Surgical patients experienced more early complications (42% versus EG 4%; $P = 0.02$) and longer hospital stays (11.6 ± 10.9 days versus EG 1.3 ± 0.5 days; $P < 0.001$). Overall mortality at the end of follow-up was 31% (SG) versus 4% (EG) (log-rank test: $P = 0.08$), including all patients with combined open mesenteric and aortic reconstruction ($P = 0.001$).

*Conclusions:* Surgical treatment has superior long-term patency and requires fewer reinterventions, but it is also more invasive with greater morbidity and mortality compared to endovascular treatment. Endovascular techniques may be preferable in patients with significant co-morbidities, concomitant aortic disease, or indeterminate symptoms.

The pathophysiologic mechanism underlying chronic mesenteric ischemia (CMI) is failure to achieve normal postprandial hyperemic arterial flow to the viscera. Hypoxia occurs as a result of this mismatch of intestinal oxygen demand and supply from the diseased vasculature.[1]

Atherosclerosis is the most common cause of CMI, while fibromuscular dysplasia, polyarteritis nodosa, and Takayasu's arteritis are less frequent findings. Autopsy studies revealed a prevalence of mesenteric atherosclerotic disease of 6%–10%,[2] while symptomatic visceral artery occlusive disease is much rarer. Less than 0.5% of all

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peripheral vascular reconstructions involve the mesenteric arteries.[3,4] Abundant mesenteric blood supply and rather slow progression of the atherosclerosis often allows collateral circulation pathways to develop. Consequently, symptomatic visceral ischemia rarely occurs unless at least two of the three major splanchnic arteries (celiac artery, superior mesenteric artery, and inferior mesenteric artery) are either occluded or highly stenotic.[5,6]

Open surgical mesenteric revascularization has technical success rates close to 100%, and 5-year patency ranges between 76% and 94%.[7,8] However, postoperative complication rates reach 33%–57%, and early mortality rates are high (5.1%–13%).[7–11] The ability to simultaneously identify and treat a culprit lesion, together with low procedural complication rates (5%–12%),[12–14] have largely increased the popularity of percutaneous treatment over the last decade. Technical success has been reported in the range of 90%–100%, and clinical alleviation of symptoms is achieved in 77%–88% of patients.[12–15] However, compared to open mesenteric artery repair, angioplasty and stenting have a higher incidence of re-stenosis or occlusion over a mid-term follow-up (up to 29%–48%).[7,10,14–16] As for endovascular treatment in other vascular beds, this is also reflected by the reported high rates of secondary procedures (up to 53%) after interventional mesenteric revascularization.[16,17] This study was conducted to review our experience with surgical and endovascular management of CMI and to better delineate which patients might benefit from one form of therapy over the other.

## PATIENTS AND METHODS

We conducted a retrospective analysis of all consecutive patients undergoing treatment for chronic mesenteric ischemia by surgical revascularization (surgical group: SG) or endovascular treatment (endovascular group: EG) at our institution between February 1994 and December 2003. Early in our experience, all patients underwent surgical revascularization, and endovascular treatment was started in 2000. To augment the interventional group, a consecutive cohort of patients undergoing interventional treatment at our institution for symptoms of chronic mesenteric ischemia between January 2004 and October 2005 was included and added to the interventional arm. Diagnostic work-up and inclusion criteria to undergo endovascular treatment in this group was identical as for the other patient collective. Patient demographic and hospitalization data, details of treatment, and postoperative follow-up were derived from an electronic database and supplemented with review of the patients' paper charts. Clinical follow-up was obtained through return office visits and, if the patient was alive but had not been clinically evaluated within a six-month period prior to the analysis, a follow-up telephone call was placed. This study was approved by a Mayo Clinic Institutional Review Board, which, due to the retrospective nature of this investigation, waived the need for informed consent.

### Diagnosis and Treatment Methods

Patients with acute mesenteric ischemia were excluded from this analysis. Upon a patient's initial presentation, the clinical work-up included a detailed evaluation of symptoms of chronic mesenteric ischemia, including epigastric discomfort, postprandial abdominal pain, weight loss, malnutrition (defined by body mass index [BMI] and percentage of ideal body weight[18]), nausea/vomiting, constipation or diarrhea, and abdominal imaging. Imaging studies included ultrasound with mesenteric vessel occlusion being defined as a clearly visualized vessel with absence of color-flow or Doppler flow signals. Superior mesenteric artery (SMA) stenosis greater than 70% was diagnosed when the peak systolic velocity exceeded 275 cm/s with poststenotic turbulence. Celiac artery stenosis of 70%–99% was diagnosed when the mapped peak systolic velocity exceeded 200 cm/s with poststenotic turbulence.[19] Confirmatory imaging was performed in all patients, using contrast-enhanced computed tomography (CT) angiography with 3 mm collimation and multiple 3-dimensional reconstructions; aortography with selective injection of the celiac artery (CA), the SMA, or the inferior mesenteric artery (IMA); or gadolinium-enhanced magnetic resonance angiography imaging (MRI) (if the patient was allergic to radio-opaque contrast, or had an elevated (>1.5 mg/dl) serum creatinine level). The ultrasound study was compared with the confirming imaging study, with relief of symptoms and patency of the reconstructed vessels (as evident from the last available imaging study) being considered primary endpoints. Perioperative and late morbidity and mortality, total length of stay, and need for reintervention were also evaluated. Major complications of the procedure included persisting abdominal pain or any condition resulting in intensive care unit (ICU) admission, reintubation, reintervention, prolonged length of stay (> 14 days), or in-hospital death.

All patients with open revascularization were scheduled for cross-sectional imaging of their mesenteric vasculature 1 month after the procedure, with follow-up visits at 6 months and yearly or biannually thereafter, including clinical follow-up and ultrasound and/or CT imaging as needed. Patients with endovascular visceral arterial reconstruction were followed for the first postoperative year by clinical and ultrasound evaluation at 6 and 12 months, and annually thereafter.

## Statistical Analysis

Numeric data were expressed as mean ± standard deviation (SD) or total number (%). Statistical analyses were performed with the Statistical Package for Social Sciences for Windows, version 12.0 (SPSS, Chicago, IL). Categoric variables were compared at baseline and postprocedure with either the $\chi^2$ of Fisher's exact test. The one-sample Kolmogorov-Smirnov test was used to test of normal distribution in numeric variables, and either *t*-tests or the Mann Whitney-*U* test was used for intergroup comparison, as appropriate. Kaplan-Meier estimator and log-rank tests were used to calculate cumulative patient survival and patency rates. For all tests, statistical significance was assumed when $p \leq 0.05$.

# RESULTS

Of the 49 patients included in this cohort, 26 (53%; 25 women) underwent open surgical mesenteric revascularization (SG), and 23 (47%; 15 women) had endovascular treatment (EG). Patients undergoing surgical treatment had a lower body mass index (18.9 ± 2.73 versus 23.61 ± 4.81; *P* = 0.001), and a lesser percentage of ideal body weight (89.7 ± 13.4 versus 109.5 ± 22.4; *P* = 0.02) compared to endovascular patients. Demographic data and preoperative risk factors were otherwise comparable between the two groups (Table 1).

**Table 1.**
Preprocedural demographic data and co-morbidities for two groups of patients, one undergoing surgery (SG) and one receiving endovascular treatment (EG)

| Risk factor | SG n = 26 | EG n = 12 | *P* Value |
|---|---|---|---|
| Age (years) | 65.36 ± 10.77 | 70.83 ± 10.29 | 0.077 |
| Preoperative weight (kg) | 49.1 ± 8.64 | 65.86 ± 15.12 | 0.012 |
| Hypertension | 15 (58%) | 9 (39%) | 0.156 |
| Diabetes mellitus | 32 (8%) | 2 (9%) | 0.634 |
| Coronary artery disease | 7 (27%) | 6 (26%) | 0.603 |
| Prior CABG | 1 (4%) | 1 (4%) | 0.724 |
| Pulmonary disease | 5 (19%) | 4 (17%) | 0.424 |
| Renal disease[a] | 3 (12%) | 2 (9%) | 0.560 |

SG: surgical group; EG: endovascular group; CABG: coronary artery bypass grafting.
[a]Serum creatinine ≥ 1.5 mg/dl.

**Table 2.**
Symptoms related to chronic mesenteric ischemia

| | SG n (%) | EG n (%) |
|---|---|---|
| Preoperative weight loss | 26 (100) | 16 (70) |
| Weight < 90% of ideal body weight | 13 (50) | 4 (17) |
| Abdominal pain | 22 (85) | 16 (70) |
| Postprandial pain | 18 (69) | 15 (65) |
| Food fear | 7 (27) | 1 (4) |
| Constipation | 8 (61) | 1 (4) |
| Diarrhea | 10 (39) | 7 (30) |
| Nausea/vomiting | 14 (54) | 5 (22) |
| Combined weight loss/postprandial pain | 26 (100) | 15 (65) |

## Preoperative Symptoms and Radiographic Data

Forty-one of the 49 patients (83.7%) reported preoperative abdominal discomfort (Table 2). The most common symptom in both groups was unintentional weight loss. Concomitant diagnoses in the SG included aortoiliac occlusive disease (12%), status abdominal radiation therapy post-lymphoma (4%), ulcerative colitis (4%), lupus vasculitis (4%), and Sjögren syndrome (4%). In the EG, two patients (9%) with abdominal aortic aneurysm disease had asymptomatic high-grade stenosis of the SMA (1) and the CA and SMA (1), respectively, and they underwent mesenteric revascularization prior to endoluminal aortic aneurysm repair. Two EG patients (9%) presented with lower GI bleeding. Visceral artery involvement as demonstrated by preoperative imaging studies is shown in Table 3.

## Treatment Modalities

In the surgical group, antegrade revascularization from the supraceliac aorta was performed in 19 (73%) patients, and retrograde grafts and transaortic visceral vessel endarterectomy (one with patch angioplasty) were performed in 3 (12%) and 4 (15%) patients, respectively. In the interventional group, one patient (4%) underwent angioplasty alone; all other patients received additional stents (96%).

A total of 77 vessels were treated. The number of vessels treated per patient was higher in the surgical group (SG 1.68 ± 0.53 versus EG 1.26 ± 0.45; *P* = 0.001). Single-vessel revascularization was performed in 23% (SG) versus 74% (EG) of patients, double-vessel reconstruction in

**Table 3.**
Splanchnic vessel involvement

| | SG n (%) | EG n (%) |
|---|---|---|
| 1-vessel disease | 0 (0) | 5 (22) |
| 2-vessel disease | 8 (31) | 8 (35) |
| 3-vessel disease | 18 (69) | 10 (43) |
| CA | 24 (92) | 14 (61) |
| SMA | 26 (100) | 19 (83) |
| IMA | 20 (77) | 7 (30) |

CA: celiac artery; SMA: superior mesenteric artery; IMA: inferior mesenteric artery.

73% (SG) versus 26% (EG), and triple-vessel reconstruction in 4% (SG) versus 0% (EG). The most common target vessel in both groups was the SMA (SG 89% versus EG 65%; $P = 0.05$). The celiac artery was treated in 48% of EG patients and in 12% of SG patients ($P = 0.06$), who were more likely to undergo common hepatic artery revascularization (SG 57.7% versus EG 4%; $P = 0.0001$). The IMA was treated in 12% (SG) versus 8% (EG; $P = 0.54$). More occluded vessels were treated in the surgical group (SG 72% versus EG 17%).

## Early Treatment Outcome

Amelioration of abdominal pain was achieved in all patients (100%) in the SG patients, compared to 19/21 (two asymptomatic patients excluded; 90%) in the EG patients (clinical failure rate SG 0% versus EG 10%; $P = 0.194$). Complete relief of preoperative symptoms was reported by 100% in the SG and 14/19 (79%) in the EG ($P = 0.03$).

Overall 30-day mortality was 6% (SG 2: 8% versus EG 0: 0%; $P = 0.52$). Two deaths occurred within the first month, one after iatrogenic laceration of the internal mammary artery during central-line placement (postoperative day 2), another after a major stroke (day 17). A third surgical patient died on postoperative day 36 after a prolonged hospital stay (8% in hospital mortality; SG 13% versus EG 0%; $P = 0.36$).

The overall 30-day complication rate was 29%, with one early complication (4%) in the interventional group (versus SG 42%; $P = 0.02$). Complications are listed in Table 4. One colonic perforation occurred in a patient with ulcerative colitis on postoperative day 8 following surgical revascularization of the CA and SMA. Preoperative malnutrition (less than 90% of ideal body weight) was not associated with higher postoperative morbidity ($P = 0.40$). Mean length of hospital stay was significantly longer in the surgical group (SG 11.61 ± 10.89 versus EG 1.32 ± 0.47 days; $P < 0.001$).

**Table 4.**
30-Day complications following mesenteric artery revascularization

| | Total n (%) | SG n (%) | EG n (%) | *P* Value |
|---|---|---|---|---|
| 30-day mortality | 2 (4) | 2 (8%) | 0 (0) | 0.276 |
| Respiratory complication[a] | 7 (14) | 7 (27) | 0 (0) | 0.008 |
| Neurological complication[b] | 1 (2) | 1 (4) | 0 (0) | 0.531 |
| Cardiac complication | 2 (4) | 2 (8) | 0 (0) | 0.276 |
| Hepatic complication[c] | 1 (2) | 1 (4) | 0 (0) | 0.531 |
| Pulmonary embolism | 0 (0) | 0 (0) | 0 (0) | NA |
| Deep venous thrombosis | 0 (0) | 0 (0) | 0 (0) | NA |
| Gastrointestinal bleeding | 1 (2) | 0 (0) | 1 (4) | NA |

[a]Respiratory distress requiring intubation (5 pts); pneumonia (1 pt); and difficult weaning which required prolonged intubation (1 pt).
[b]Major stroke.
[c]Transient liver enzyme elevation after hepatic artery revascularization.

## Late Follow-up

Follow-up time was 24.7 ± 21.1 months in the SG and 10.1 ± 10.4 months in the EG ($P = 0.07$). During this time, symptomatic mesenteric ischemia (severe postprandial abdominal pain) developed in 2 (4%) patients (SG 0% versus EG 9%; $P = 0.04$).

Objective follow-up data for visceral artery patency as by radiologic evaluation were available in 23 SG patients (89%) and 6 EG patients (26%). Occlusion or stenosis was documented in 2 (8%) SG patients and 3 (25%) EG patients during follow-up (log-rank test: $P = 0.003$).

One patient (4%) in the endovascular group and 8 patients (31%) in the surgical group died (log-rank test: $P = 0.08$), including all patients with concomitant aortic reconstruction (versus 0% in EG; $P = 0.001$).

All surviving patients were questioned for evidence of recurrent symptoms. Complete freedom from postprandial pain after a regular diet was reported by 83%. Eleven percent of the surgical patients and 17% of the interventional patients ($P = 0.28$) reported intermittent mild to moderate (visual analog pain score 3–5) postprandial pain. Diarrhea was reported by 28% of the SG patients and 9% of the EG patients ($P = 0.39$).

Seven secondary procedures (SG 2 versus EG 5), 71% endovascular and 29% surgical, were necessary during follow-up. In the surgical group, one patient with simultaneous visceral and aortobifemoral reconstruction underwent removal of an infected Y-graft 3 years after operation; another underwent reoperation for colonic perforation. All five reinterventions in the EG group were required within the first year: One patient received two interventions for reocclusion of the SMA and eventually was converted to open bypass grafting. A second patient received a replacement stent for persisting symptoms (with favorable result), and a third was treated for asymptomatic high-grade re-stenosis 351 days after the initial procedure. A fourth patient with two-vessel atherosclerosis (of the celiac artery and the inferior mesenteric artery) reported diminished but persistent postprandial pain after stent implantation into the celiac artery. Six weeks later, the inferior mesenteric artery was also stented, and the postprandial symptoms completely resolved. Patients undergoing endovascular revascularization had a higher risk of requiring reintervention for symptoms of mesenteric ischemia (SG 0% versus EG 13%; log-rank test: $P = 0.01$).

Postprocedural weight gain was reported in 64% of the SG patients and 33% of the EG patients, and weight stabilization was maintained in 0% (SG) and 33% (EG), respectively. At time of last follow-up, body weight was comparable in the two groups (SG 58.48 ± 7.27 and EG 67.78 ± 17.30; $P = 0.12$), and body mass index had normalized in both groups (SG 22.78 ± 2.21 and EG 23.45 ± 3.6; $P = 0.54$).

## DISCUSSION

Occlusive disease of the visceral arteries, although often asymptomatic, is found in up to 27% of patients undergoing arteriography prior to peripheral vascular surgery.[20] Symptomatic chronic mesenteric ischemia (CMI) often presents as postprandial abdominal pain starting 15–60 min after food intake ("intestinal angina"), and various other symptoms, including diarrhea, constipation, steatorrhea, nausea, vomiting, atrophic gastritis, and ischemic colitis may also be present.[1] Typically, patients suffering these symptoms decrease their food intake and can develop actual fear of food ( = sitophobia). The ischemic functional impairment of the viscera together with food restriction often results in profound weight loss and malnutrition. Compared to aortic occlusive disease, CMI is more common in women and usually develops at a younger age (female:male ratio 3:1, age between 40 to 70 (mean 59) years).[1] The reason for this female preponderance is unknown, but it is possibly related to narrower arteries in women.

The aim of visceral revascularization in CMI is alleviation of the abdominal symptoms, improvement of the patient's nutritional status, and prevention of progression to intestinal infarction. After the first successful revascularization by Shaw and Maynard in 1958,[21] surgery has been the standard treatment for CMI,[22] but endovascular treatment modalities have already become the treatment of first choice for CMI in some centers.[23] However, the decision for either method should be made with regard to the specific advantages and weaknesses of the two types of revascularization.

The popularity of the endovascular approach is based in large part on the less invasive type of intervention in these often fragile patients, together with a high technical success rate. Consequently, postinterventional morbidity and mortality are lower than after open repair.[7–11] In our study, this was evident in the setting of concomitant mesenteric and aortic aneurysm disease. In the surgical group, all patients with simultaneous visceral and aortic reconstruction died during follow-up, whereas there were no complications after two-stage endovascular repair in patients with mesenteric artery stenosis and abdominal aortic aneurysm disease. Elevated mortality after concomitant mesenteric and aortic reconstructions has been reported by others.[4,24]

In addition, if recurrent stenosis occurs following percutaneous intervention, this does not usually preclude the possibility that an open surgical revascularization could be performed. Thus, the primary technical success rates (80%–90%) are lower than those for open surgery (close to 100%),[7,8,13–15] and long-term primary patency rates between only 52% and 80%[13] reported in endovascular series are accepted for often being "worth a try," saving the patient from a surgical procedure. Only possible bowel necrosis, external compression syndrome (tumor or ligamentous compression of the celiac artery by the median arcuate ligament), or presence of diffuse or extensive disease with major side branch involvement are presently widely acknowledged contraindications for percutaneous treatment.[24]

In our series, patency rates fall within the reported range, with a 75% patency/freedom from re-stenosis rate over a mean follow-up of 14 months. However, in accordance to the data reported in the literature, the re-stenosis rate was significantly higher than in our surgical cohort, as was the need for secondary interventions for recurrent symptoms. In their study of 14 patients undergoing mesenteric stenting for chronic mesenteric ischemia, Brown and co-workers reported 93% of patients as symptom-free after a mean follow-up of 13 months; however, over half of their patients (53%) had required at least one reintervention during the same time period. This underlines the possibility that mesenteric stenting is currently an applicable but not always durable treatment option.

In efforts to limit the extent of the operation, the optimal number of vessels to revascularize has been debated.

Proponents of "complete" revascularization maintain that it may result in decreased symptomatic recurrence even if reocclusion of one of the grafts occurs.[25,26] Foley *et al.* however, demonstrated comparable durability with a primary assisted 9-year patency rate of 79% in a series of 49 patients undergoing SMA reconstruction alone, and they concluded that multiple bypass grafts to other splanchnic vessels are unnecessary when adequate SMA reconstruction has been accomplished.[27] In the present series, supraceliac antegrade double-vessel revascularization was the preferred surgical approach, resulting in significantly more vessels treated in the SG patients than in the EG patients. Although the preferred primary target vessel in both groups was the SMA, the CA was primarily treated more commonly in the endovascular group, and the surgical group with celiac artery stenosis/occlusion typically underwent bypass to the common hepatic artery.

The in-hospital data and the length of stay showed the expected differences in favor of endoluminal treatment compared to major abdominal surgery. Early postoperative complications all occurred in the surgical group, and there were no early complications in the interventional group. Complication rates in both groups compare favorably to numbers reported in the literature;[7,10,13] however, they underline the invasiveness of surgical procedures in often malnourished and fragile patients. We found a significantly lower complication rate in interventionally treated patients than in those who underwent open surgery, with a 10% clinical failure rate in the latter group. More patients in the surgical group presented with weight loss (100% versus 70%) and body weight less than 90% of the ideal body weight (50% versus 17%). These findings more than likely can be explained by the hesitancy to assign a patient with radiographic visceral artery disease but abdominal symptoms not clearly attributable to CMI to extensive surgical reconstruction. In addition, that early in our series, we treated all patients with CMI predominantly with a surgical approach, regardless of nutritional status. The significantly lower prevalence of hyperlipidemia in surgical patients also seems related to the poorer nutritional status of patients in this group.[28] Preoperative malnutrition is a known risk factor for postoperative complications[4,29] after mesenteric revascularization. Therefore we have recently used percutaneous techniques in several patients who, owing to malnutrition or other reasons, were considered at high risk for complications after open surgery. One profoundly malnourished patient with severe obstructive pulmonary disease underwent serial interventions, all of which failed after a short time. Nevertheless, the patient was able to improve her nutritional status and to gain strength between interventions, and later underwent uncomplicated surgical repair.

In conclusion, we think that surgical revascularization remains the preferred treatment for CMI in most patients, owing to superior long-term patency and minimal need for secondary procedures. However, endovascular treatment demonstrates comparable technical success rates with lower mortality rates, especially in severely malnourished patients or patients with concomitant aortic occlusive disease. Especially in these patients, endovascular treatment appears safer than open surgery, and, while hindered by a higher re-stenosis rate requiring secondary interventions, it may be the preferred first-line approach. In addition, percutaneous revascularization seems be the treatment of choice for CMI patients undergoing endovascular aortic aneurysm repair with significant superior mesenteric artery stenosis, or for patients with vague abdominal symptoms and significant visceral vessel disease.

Despite lower long-term patency rates in critically ill patients, endovascular treatment often effectively relieves the symptoms and improves the co-morbidites associated with CMI, and still leaves the possibility of later surgical revascularization, if needed.

In an era when both options are readily available, careful individual patient selection and selective, unbiased use of all surgical and interventional techniques seems paramount to achieve optimal durability in conjunction with low periprocedural complication rates.

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