Endovascular and open surgery for acute occlusion of the superior mesenteric artery

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Background: **Acute thromboembolic occlusion of the superior mesenteric artery (SMA) is associated with high mortality. Recent advances in diagnostics and surgical techniques may affect outcome.**

Methods: **Through the Swedish Vascular Registry (Swedvasc), 121 open and 42 endovascular revascularizations of the SMA at 28 hospitals during 1999 to 2006 were identified. Patient medical records were retrieved, and survival was analyzed with multivariate Cox-regression analysis.**

Results: **The number of revascularizations of the SMA increased over time with 41 operations in 2006, compared to 10 in 1999. Endovascular approach increased sixfold by 2006 as compared to 1999. The endovascular group had thrombotic occlusion ($P < .001$) and history of abdominal angina ($P = .042$) more often, the open group had atrial fibrillation more frequently ($P = .031$). All the patients in the endovascular group, but only 34% after open surgery, underwent completion control of the vascular reconstruction ($P < .001$). Bowel resection ($P < .001$) and short bowel syndrome (SBS; $P = .009$) occurred more frequently in the open group. SBS (hazard ratio [HR], 2.6; 95% confidence interval [CI], 1.3-5.0) and age (HR, 1.03/year; 95% CI, 1.00-1.06) were independently associated with increased long-term mortality. Thirty-day and 1-year mortality rates were 42% vs 28% ($P = .03$) and 58% vs 39% ($P = .02$), for open and endovascular surgery, respectively. Long-term survival after endovascular treatment was better than after open surgery (log-rank, $P = .02$).**

Conclusion: **The results after endovascular and open surgical revascularization of acute SMA occlusion were favorable, in particular among the endovascularly treated patients. Group differences need to be confirmed in a randomized trial. (J Vasc Surg 2010;52:959-66.)**

Acute thromboembolic occlusion of the superior mesenteric artery (SMA) is associated with poor prognosis.[1-6] With the advancement of radiologic imaging, early detection is feasible, which may result in a more planned technique for achieving intestinal revascularization.[7,8] Hence, it is likely that more patients may be treated in present times, and that the development of endovascular options offers a possibility to improve clinical outcome.[9-15] However, prospective studies are difficult to carry out, due to the low incidence and emergency presentation of these patients. In a previous study, data from the Swedish vascular registry (Swedvasc) from 1987 to 1998 was analyzed to study the outcome in patients undergoing intestinal revascularization, almost exclusively by open surgical technique.[16] A renewed search from 1999 to 2006 in Swedvasc was performed to assess the influence of radiologic imaging and endovascular treatment in a large patient cohort. The purpose of the present study was to analyze time-trends and patient-related and management-related factors for outcome after open and endovascular intestinal revascularization for acute SMA occlusion.

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PATIENTS AND METHODS

Swedvasc was started in 1987 and is a nationwide registry for open and endovascular vascular surgery with high reported validity.[17-20] We identified 174 revascularizations performed on the indication of acute intestinal ischemia during the period from 1999 to 2006. Vascular procedures are registered regardless whether they are open or endovascular. They are entered in accordance with "intention-to-treat," ie, both successful and failed interventions are registered. Patients are usually registered during the hospitalization period for the surgery or endovascular intervention, preferably immediately after the operation or at discharge/death. Variables in Swedvasc are registered prospectively, patient and procedural data at operation and clinical outcome after 1 month and 1 year. Registry data was supplemented by retrospective analysis of patient medical records from 28 surgical departments. Long-term mortality data was obtained by cross-matching with the national population registry in September 2009 using the personal identity codes. Patients with symptoms of previous chronic mesenteric ischemia were included if they presented with an acute onset of intestinal ischemia. Eleven patients were excluded due to misclassification. The remaining 163 procedures and 161 patients were included in this study.

Hypertension was defined as blood pressure >140/90 mm Hg or medication for hypertension. Ischemic heart disease (IHD) was defined as angina pectoris or previous myocardial infarction. Cerebrovascular disease (CVD) was defined as previous stroke or transient ischemic attack. Renal insufficiency was defined as a creatinine level >150

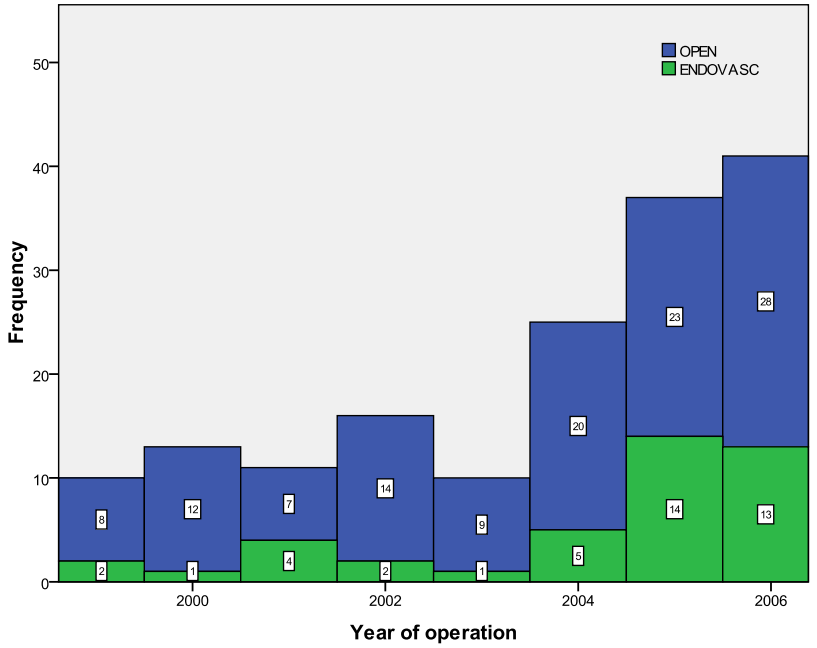

Fig 1. Incidence of open and endovascular revascularizations for acute superior mesenteric artery occlusion in Sweden from 1999 to 2006.

μmol/L.[21] The onset of abdominal pain was divided into sudden (instantaneous, within minutes), acute (within 1 hour), or insidious (more than 1 hour). The clinical triad of acute embolic occlusion of the SMA was defined as: pain out of proportion to abdominal signs, possible source of embolus (such as atrial fibrillation), and bowel emptying (diarrhea and/or vomiting). Chronic mesenteric ischemia was defined as postprandial abdominal pain with weight loss and/or chronic diarrhea. Patient's delay was defined as the time delay from onset of symptoms to hospital admission, and doctor's delay was defined as the time from hospital admission to start of the operation. Total delay was patient's + doctor's delay. Short bowel syndrome (SBS) was defined as need of parenteral nutrition or antidiarrheic medication at discharge. The distinction between open and endovascular surgery was based on the primary vascular reconstruction. As a consequence, patients undergoing laparotomy with exposure of the SMA and retrograde open mesenteric stenting[12-15] of the SMA through an open abdomen were considered part of the endovascular group.

A second-look operation was defined as a planned control of bowel viability after endovascular or open surgery. If a laparotomy was performed as an immediate procedure in conjunction with an endovascular revascularization, it was not considered a second-look, but as a part of the primary procedure. If, however, a laparotomy was performed later after an endovascular procedure at a defined time-interval, it was considered a "second-look" procedure despite the fact that it was indeed the first laparotomy performed. A reoperation was defined as being performed for deterioration or unexpected surgical complications. Completion control refers to any method used to objectively assess the patency of the vascular reconstruction at the end of open or endovascular surgery.

STATISTICAL ANALYSIS

All statistical analysis was performed by SPSS Statistics v. 17.0 (SAS Institute Inc, Cary, NC). Analysis was made according to intention-to-treat. Continuous variables were expressed as median and interquartile range (IQR) and analyzed using Mann-Whitney *U* test. Discrete variables were analyzed with Pearson χ^2 test, Fisher's exact test, or Kendall's Tau-b test, as appropriate. Variables associated with 30-day and 1-year survival ($P < .1$) were entered into a multivariate logistic regression analysis, and significant associations were expressed in terms of odds ratio (OR) with 95% confidence interval (CI). Variables associated with long-term survival were tested in a Cox regression analysis, and expressed in terms of hazard ratio (HR) with 95% CI. Cumulative survival was analyzed using the Kaplan-Meier method and life table analysis. Log-rank test was used in the overall comparison of survival curves for open and endovascular surgery. The *P* values $< .05$ were considered significant.

RESULTS

Time trends. The number of revascularizations increased steadily to 41 interventions in 2006 as compared to 10 interventions in 1999. Endovascular approach increased during the last 3 years of the study, with a sixfold increase in the frequency of endovascular interventions by 2006 as compared to 1999 (Fig 1).

Patient characteristics. Median age was 76 years (IQR 65-82), 90 women, and 71 men. The frequency of hypertension was 42% (68 of 157), IHD 45% (72 of 159), atrial fibrillation 52% (81 of 155), CVD 22% (36 of 161), diabetes mellitus 13% (20 of 159), and previous vascular surgery 24% (39 of 161). Medication with acetyl salicylic acid and vitamin K antagonists was documented in 56% (75 of 134) and 10% (13 of 129), respectively.

Symptoms and signs. Symptoms and signs were analyzed by retrospective analysis of patient medical records, explaining why there are missing data regarding some variables. All 161 patients presented with abdominal pain. The onset of symptoms was sudden in 33% (50 of 153), acute in 44% (67 of 153), and insidious in 23% (36 of 153). Insidious onset was associated with patient ($P < .001$), doctor ($P < .001$), and total delay ($P < .001$). Vomiting, diarrhea, and hematochezia were present in 51% (76 of 148), 53% (76 of 144), and 16% (23 of 147), respectively. The clinical triad at presentation was denoted in 32% (45 of 139) and generalized peritonitis at presentation was present in 5% (7 of 139). The median time from onset of symptoms to treatment was 24 hours (IQR 10-72).

Laboratory data at admission. Median C-reactive protein (CRP) was 30 mg/L (IQR 5-136; n = 88), white blood cell (WBC) count 14.6×10^9/L (IQR 11.5-20.5; n = 102), hemoglobin 140 g/L (126-151; n = 98), and creatinine 97 μmol/L (IQR 79-128; n = 94). D-dimer was tested in 35 patients and was elevated in all. The median D-dimer value was 2.6 mg/L (IQR 0.9-4.3). Four patients had a prothrombin complex value of ≥2.0 international normalized ratio. A total of 25% of the patients (22 of 88) had a CRP value of ≤5 mg/L and 9 patients (9%) had a WBC count of $\leq 8.0 \times 10^9$/L.

Diagnosis. Documentation of the diagnostic method was retrieved in 153 patients (95%). Diagnosis was confirmed after computed tomography with intravenous contrast (CTiv) with findings of occlusion of the SMA (n = 76) or findings of ischemic intestinal lesions (n = 4). Diagnosis was confirmed after explorative laparotomy (n = 50), angiography (n = 13), duplex ultrasound scan (n = 3), and magnetic resonance tomography with intravenous contrast (n = 1). Re-evaluation of CTiv diagnosed another 6 patients.

CTiv showed occlusion of the SMA at first evaluation in 75% (76 of 101) of the examined patients. A total of 18% of the patients (18 of 101) that underwent a CTiv displayed synchronous visceral emboli. An isolated embolus was dislodged into the spleen, kidney, and liver in 5, 6, and 1 patient, respectively, whereas multiple visceral emboli were detected on CT exams in 6 patients. CT scan with or without intravenous contrast showed intestinal findings compatible with ischemia in 34% (37 of 110). Suspicion of intestinal ischemia in the referral letter was associated with a diagnostic CT in 92% (48 of 52), whereas unawareness of intestinal ischemia was associated with a low rate of positive CT scans 37% (15 of 41; $P < .001$).

Treatment according to disease etiology. The following procedures for embolic occlusion (n = 99) were performed: open SMA embolectomy (n = 85), local SMA thrombolysis (n = 9), and endovascular aspiration SMA embolectomy from the groin (n = 3). Two failed SMA embolectomies resulted in aorto-SMA bypass operations with synthetic (n = 1) and vein graft (n = 1), respectively.

The following procedures for thrombotic occlusion (n = 54) were performed: antegrade stenting of the SMA (n = 18), thrombendarterectomy (n = 10), aorto-SMA bypass with synthetic (n = 11) or vein graft (n = 4), retrograde open mesenteric stenting (n = 4), local SMA thrombolysis (n = 4), thrombendarterectomy with a balloon catheter (n = 2), and reimplantation of the SMA into the aorta (n = 1).

Revascularization due to acute SMA dissection was performed in 5 patients with the following procedures: aorto-SMA bypass with synthetic graft (n = 2), stenting (n = 1), fenestration (n = 1), and embolectomy (n = 1). One patient had an acute thrombotic occlusion of a previously inserted stent within the SMA for chronic mesenteric ischemia, which was treated with recanalization and stenting. In 4 patients, the pathophysiology could not be determined. They were treated with bypass (n = 1) and embolectomy (n = 3).

Open and endovascular surgery. The group treated with open surgery had a higher frequency of atrial fibrillation ($P = .031$) and a trend toward a higher frequency of CVD ($P = .053$). The group treated with endovascular surgery had a higher frequency of history of abdominal angina ($P = .042$) and a trend for a higher frequency of previous vascular surgery ($P = .09$; Table I). Patients treated by open surgery had a higher rate of embolic vs thrombotic occlusion ($P < .001$), a higher frequency of small bowel resection ($P < .001$), colonic resection ($P = .022$), second-look operation ($P < .001$), and SBS ($P = .009$), compared to the endovascular group (Table II). All patients in the endovascular group underwent completion angiographic control, whereas 34% of the patients in the open surgery group underwent completion control with Doppler scan (n = 38) or blood flow measurement with ultrasonic transit-time flow meter (n = 3; $P < .001$). No revascularization was followed by intraoperative Duplex scan examination. Successful revascularization at primary intervention was denoted in 86% (96 of 111) in the open group and 79% (33 of 42) in the endovascular group, respectively ($P = .23$).

Of the nine failed endovascular revascularizations, there were five thrombolysis, three antegrade stenting, and one aspiration embolectomy. Four endovascular revascularizations were converted to open surgery; two antegrade stenting procedures and two thrombolysis. The remaining five were treated with additional thrombolysis. Of the 15 failed open revascularizations, there were 10 embolectomies, three bypasses with autologous vein, and two thrombectomies. The failed revascularizations had a 30-day mortality of 56% (5 of 9) in the endovascular group and 87% (13 of 15) in the open group, respectively ($P = .09$).

Short-bowel syndrome. The frequency of SBS at discharge was higher in the openly treated group vs the

Table I. Clinical and laboratory data in patients undergoing open vs endovascular surgery for acute SMA occlusion

	Open (n = 121)	*Endovascular (n = 42)*	P *value*
Gender (M/F)	55/66	18/24	.77
Age (IQR)	76 (66-81)	77 (59-82)	.50
Comorbidities	N (%)	N (%)	
IHD	51/118 (43)	21/41 (51)	.67
Atrial fibrillation	67/117 (57)	15/40 (38)	.031
History of abdominal angina	13/104 (12)	11/42 (26)	.042
Diabetes mellitus	15/121 (12)	5/42 (12)	.48
Smoking	25/121 (21)	10/42 (24)	.39
CVD	32/121 (26)	5/42 (12)	.053
Previous vascular surgery	24/121 (20)	15/42 (36)	.09
Symptoms			
Onset of symptoms			.61
Sudden	36/114 (32)	14/39 (36)	
Acute	55/114 (48)	12/39 (31)	
Insidious	23/114 (20)	13/39 (33)	
Vomiting	59/111 (53)	17/37 (46)	.59
Diarrhea	57/109 (52)	19/37 (51)	.93
Hematochezia	19/110 (17)	4/37 (11)	.57
Delay in hours	Median (IQR)	Median (IQR)	
Patient delay (n = 130)	6 (2-16)	8 (3-36)	.13
Doctor delay (n = 118)	12 (6-24)	24 (6-72)	.16
Total delay (n = 107)	24 (10-50)	36 (11-132)	.12
Laboratory tests			
CRP (mg/L; n = 102)	19 (5-133)	46 (14-148)	.29
WBC ($\times 10^9$/L; n = 88)	14.9 (11.5-21.0)	14.0 (11.1-18.2)	.76
Hb (g/L; n = 94)	143 (126-152)	134 (122-149)	.33
Creatinine (μmol/L; n = 98)	101 (78-131)	92 (79-120)	.49

CRP, C-reactive protein; *CVD,* cerebrovascular disease; *F,* female; *Hb,* hemoglobin; *IHD,* ischemic heart disease; *IQR,* interquartile range; *M,* male; *SMA,* superior mesenteric artery; *WBC,* white blood cell count.

Table II. Management-related factors, morbidity, and mortality in patients undergoing open vs endovascular surgery for acute SMA occlusion

	Open (n = 121)	*Endovascular (n = 42)*	P *value*
Embolus:thrombus	87:28	12:26	<.001
Management	N (%)	N (%)	
Diagnostic CT	55/113 (49)	25/40 (62)	.13
Laparotomy	121/121 (100)	23/42 (55)	<.001
Completion control	41/116 (35)	42/42 (100)	<.001
Small bowel resection	67/114 (59)	8/42 (19)	<.001
Colonic resection	34/114 (30)	5/42 (12)	.022
Any bowel resection	72/115 (63)	8/42 (19)	<.001
Second-look operation	76/113 (67)	12/39 (31)	<.001
Morbidity			
Reoperation	29/114 (25)	11/39 (28)	.73
Postoperative infection	17/99 (17)	5/32 (16)	.61
Short bowel syndrome	36/65 (55)	8/30 (27)	.009
Mortality			
30-day	51/121 (42)	10/42 (24)	.034
1-year	71/121 (59)	16/42 (38)	.021

CT, Computed tomography; *SMA,* superior mesenteric artery.

endovascular group ($P = .009$; Table II). SBS was associated with the length of small bowel ($P < .001$) or colonic resection ($P = .004$). Five of 6 patients with stomas could be discharged. Four patients required intravenous nutrition at discharge due to SBS. Within 1 year, 1 patient died and 2 had their parenteral nutrition support discontinued. One patient was still dependent on intravenous nutrition after 1 year.

Short-term mortality. The 30-day mortality for patients with acute thrombotic and embolic occlusion was 40% (21 of 53) and 37% (36 of 98), respectively ($P = .73$). Patient's delay ($P = .67$), doctor's delay ($P = .7$), and total delay ($P = .79$) were not associated with 30-day mortality, neither was second-look operation ($P = .96$). Age ($P = .004$), hematochezia ($P = .008$), and insidious onset of abdominal pain ($P = .012$) were associated with an in-

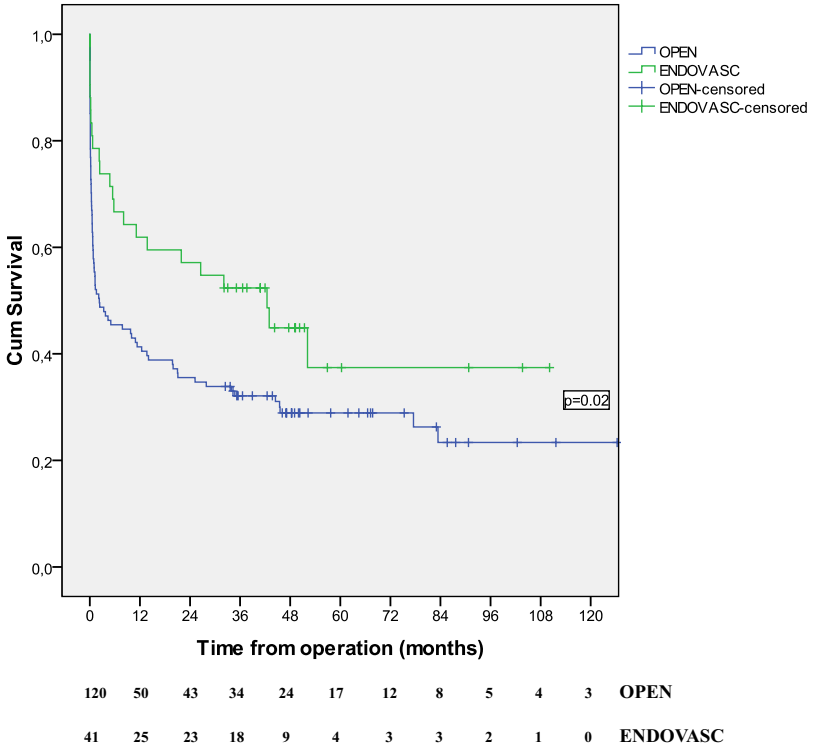

Fig 2. Kaplan-Meier analysis of long-term survival in acute superior mesenteric artery occlusion comparing open and endovascular surgery (log-rank test; $P = .020$). Life tables show patients at risk for open and endovascular surgery at each respective time point.

creased 30-day mortality rate. There was a trend that the length of colonic resection was associated with an increased 30-day mortality ($P = .097$). Successful intestinal revascularization at primary intervention ($P < .001$), endovascular surgery ($P = .034$), and correct diagnosis after CTiv ($P = .027$) were associated with a decreased 30-day mortality rate. When entering these seven variables into a multivariate regression model, age (OR, 1.05/year; 95% CI, 1.01-1.09; $P = .012$), hematochezia (OR, 4.8; 95% CI, 1.4-16.2; $P = .012$), resected length of colon (OR, 1.02/cm; 95% CI, 1.01-1.04; $P = .004$), and insidious onset (OR, 7.1; 95% CI, 2.4-21.2.3; $P < .001$) remained as independent factors associated with 30-day mortality, whereas diagnostic CT (OR, 2.9; 95% CI, 1.1-7.4; $P = .024$), successful intestinal revascularization at primary intervention (OR, 26.5; 95% CI, 5.9-119.1; $P < .001$), and endovascular surgery (OR, 3.7; 95% CI, 1.2-11.6; $P = .025$) remained as independent factors associated with improved 30-day survival. In the absence of SBS, the 30-day mortality rate after endovascular surgery was 5% (1 of 22) compared to 0% (0 of 29) after open surgery ($P = .43$).

One-year mortality. The 1-year mortality for patients with acute thrombotic occlusion was 51% (27 of 53), compared to those with embolic occlusion 54% (53 of 98; $P = .71$). The following variables were associated with an increased 1-year mortality rate: age ($P = .012$), insidious onset ($P = .019$), and SBS ($P < .001$). There were trends that the length of small bowel resection ($P = .061$) and the length of colonic resection ($P = .083$) were associated with increased 1-year mortality rates. Successful intestinal revascularization at primary intervention ($P = .014$) and endovascular surgery ($P = .021$) were associated with an increased 1-year survival rate. When entering these seven variables into a multivariate regression model, only SBS (OR, 6.4; 95% CI, 1.6-24.7; $P = .007$) remained as an independent factor associated with increased 1-year mortality rate. In the absence of SBS, the 1-year mortality rate after endovascular surgery was 9% (2 of 22) compared to 10% (3 of 29) after open surgery ($P = .88$).

Long-term survival. Long-term survival after endovascular treatment for acute SMA occlusion was better than after open surgery ($P = .02$; Fig 2). When the five factors associated with outcome 1 year after operation in the univariate analysis ($P < .05$) were entered in a Cox regression analysis, SBS (HR, 2.6; 95% CI, 1.3-5.0; $P = .005$) and age (HR, 1.03/year; 95% CI, 1.00-1.06; $P = .039$) remained as independent factors associated with decreased long-term survival.

DISCUSSION

There has been an increase in the number of revascularizations performed in Sweden for acute SMA occlusion during the last 2 decades,[16] especially from 2004 and

onward (Fig 1). This increase may be associated with the acquisition of high-resolution multi-slice CT scanners and an increased research activity with several publications in this field of surgery. The dissemination of D-dimer as an exclusion test for acute mesenteric ischemia among patients with acute bowel symptoms[22,23] may also have had an effect. Although an elevated D-dimer lacks specificity for acute mesenteric ischemia (many serious medical conditions with activation of coagulation and fibrinolysis have elevated D-dimer levels), this study verifies that it does serve as an exclusion test. None of the 35 tested patients had a normal D-dimer.

This study indicated that the delay from onset of symptoms to revascularization was not significantly correlated with survival. This is probably explained by patient selection. Patients with severe symptoms are more easily diagnosed, but also suffer from a more severe intestinal ischemia. Time delay to intervention is important,[24] but the study results imply that revascularization may still be considered as a treatment option in cases with a significant delay to surgery. This finding has been reported previously,[16] and could be explained by the rich collateral mesenteric blood flow in some patients. Patients with a verified acute SMA occlusion at a nonvascular center could benefit from transport to an emergency vascular service with the possibility of both open and endovascular surgery. Such a strategy might offer a higher chance of proper intervention and survival.[25] Insidious onset was, on the other hand, both associated with a longer delay to intervention and a higher mortality rate, which could reflect a lower diagnostic activity.

CTiv is readily available in virtually every modern surgical department and was the most frequent preoperative diagnostic method in this study. A previous study showed a trend toward a higher rate of correct diagnosis by CT if the referral letter included a suspicion of intestinal ischemia and/or SMA occlusion.[26] In this study, clinical suspicion in the referral letter resulted in a higher proportion of correct diagnosis by CTiv, and correct diagnosis after CTiv was associated with an improved early survival rate. This is an important observation; the clinician should guide the radiologist by expressing his or her suspicion.

The endovascular group had a more favorable outcome compared to those treated with open surgery, both in the short-term and long-term. There were no significant differences between the two groups regarding age or gender. The endovascular group had a higher frequency of thrombotic occlusion and abdominal angina, whereas the group treated with open surgery had a higher frequency of embolic occlusion, atrial fibrillation, and synchronous embolism. There was a trend toward a higher frequency of previous vascular surgery in the endovascular group and previous CVD in the group treated with open surgery. Previous studies have reported that both thrombotic occlusion[2,16] and previous vascular surgery[16] are factors associated with adverse outcome. The impact of disease severity in patients receiving endovascular as opposed to open surgery could only be addressed in a randomized trial. But such a trial is unlikely to ever be performed, due to the low frequency of SMA revascularization in most centers.

Completion control by angiography was more often performed in the endovascular group, which may have implications on outcome. Doppler scan measurement was used in a large proportion of patients in the open group and this method should be considered inaccurate, whereas blood flow measurement with ultrasonic transit-time flow meter is more accurate, but inferior to angiography.[27] No patient in the open group underwent angiography as completion control. It must be emphasized that angiography is superior for controlling the result after vascular intervention and provides accurate imaging and flow dynamics of the mesenteric vascular tree. Any insufficient revascularization can be visualized and small peripheral emboli can be detected. The information at completion control could be considered to have prognostic implications. It seems advisable to validate the revascularization with angiography whenever possible. Blood flow measurement of the main stem of the SMA should preferably be performed in the abdomen before and after open surgery revascularization. In previous discussions on the advantages and shortcomings of open and endovascular therapy, the advantages of open surgery including completion control and inspection of the bowel have been evaluated. The results of this study imply that the better completion control of the vascular reconstruction, being an integrated part of endovascular therapy, may be equally important.

Second-look operation was more frequent in the open group compared to the endovascular group but was not associated with increased survival. This finding may be a result of selection bias. Patients with the most favorable prognosis, not experiencing any bowel symptoms after revascularization, are not likely to undergo a second-look procedure. This, however, is also the case for those with poor prognosis who are not considered candidates for further operative treatment due to advanced age or multiple comorbidities. The same conclusion was made in the previous investigation studying acute SMA occlusion in Sweden from 1987 to 1998.[16]

In the multivariate Cox-regression analysis, only age and SBS remained as independent factors associated with long-term mortality. SBS has documented implications for survival[28] and seems to be a strong negative factor for long-term outcome in this group of patients. SBS was significantly associated with the length of intestinal resection, as expected.

The limitations of the study are attributed to the retrospective analysis of the patient files, although patients were entered prospectively in Swedvasc. It should be remembered that this study includes only patients undergoing revascularization. Patients receiving bowel resection only, or no active treatment, are thus not included. Previous validations of Swedvasc, based on the fact that every Swedish citizen has a personal identity code used in all health care registries, have shown that more than 90% of procedures that are core surgery are registered.[17] Revascularization of the SMA is considered core surgery.

It remains unclear if disease severity may have accounted for differences in outcome between the endovascular and open group: comparing the extent of bowel ischemia based on

retrospective data is impossible, and would have been difficult even in a prospective study. Most patients in the endovascular group did not undergo laparotomy for assessment of the bowel. If this is a result of less severe disease on presentation, or a better outcome of treatment, remains speculative. Disease severity in terms of CRP values at admission or time delay to intervention did not differ between the groups. Previous studies have reported that patients with thrombotic occlusion have more extensive bowel gangrene than those with an embolic occlusion[2,16,29] and the endovascularly treated group had a higher proportion of thrombotic occlusion than the open group.

Hypothetically, endovascular therapy offers many advantages over open surgery, in particular when only endovascular therapy without subsequent laparotomy for evaluation of the intestines is performed. It gives immediate and complete visualization of the vascular tree before and after intervention and the patient can be treated without the inherent risks of general anesthesia. With the endovascular technique, the surgical trauma can be minimized and thus reduce infection, inflammatory response, postoperative paralysis, opioid medication, and immobilization. All of the above could affect the clinical outcome in this group of often elderly patients with multiple comorbidities.

In conclusion, the results after endovascular and open surgical revascularization of acute SMA occlusion were favorable, in particular among the endovascularly treated patients. Group differences need to be confirmed in a randomized trial.

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AUTHOR CONTRIBUTIONS

Conception and design: TB, SA, MB
Analysis and interpretation: TB, SA, MB
Data collection: TB, MB
Writing the article: TB, SA, MB
Critical revision of the article: TB; SA, MB
Final approval of the article: TB, SA, MB
Statistical analysis: TB, SA
Obtained funding: TB
Overall responsibility: TB

REFERENCES

1. Park WM, Gloviczki P, Cherry KJ Jr, Hallett JW Jr, Bower TC, Panneton JM, et al. Contemporary management of acute mesenteric ischemia: factors associated with survival. J Vasc Surg 2002;35:445-52.
2. Schoots IG, Koffeman GI, Legemate DA, Levi M, van Gulik TM. Systematic review of survival after acute mesenteric ischaemia according to disease aetiology. Br J Surg 2004;91:17-27.
3. Oldenburg WA, Lau LL, Rodenberg TJ, Edmonds HJ, Burger CD. Acute mesenteric ischemia: a clinical review. Arch Intern Med 2004; 164:1054-62.
4. Kassahun WT, Schulz T, Richter O, Hauss J. Unchanged high mortality rates from acute occlusive intestinal ischemia: six year review. Langenbecks Arch Surg 2008;393:163-71.
5. Acosta-Merida MA, Marchena-Gomez J, Hemmersbach-Miller M, Roque-Castellano C, Hernandez-Romero JM. Identification of risk factors for perioperative mortality in acute mesenteric ischemia. World J Surg 2006;30:1579-85.
6. Wyers MC. Acute mesenteric ischemia: diagnostic approach and surgical treatment. Semin Vasc Surg 2010;23:9-20.
7. Hellinger JC. Evaluating mesenteric ischemia with multidetector-row CT angiography. Tech Vasc Interv Radiol 2004;7:160-6.
8. Furukawa A, Kanasaki S, Kono N, Wakamiya M, Tanaka T, Takahashi M, et al. CT diagnosis of acute mesenteric ischemia from various causes. AJR Am J Roentgenol 2009;192:408-16.
9. Zerbib P, Lebuffe G, Sergent-Baudson G, Chamatan A, Massouille D, Lions C, et al. Endovascular versus open revascularization for chronic mesenteric ischemia: a comparative study. Langenbecks Arch Surg 2008;393:865-70.
10. Razavi M, Chung HH. Endovascular management of chronic mesenteric ischemia. Tech Vasc Interv Radiol 2004;7:155-9.
11. Schoots IG, Levi MM, Reekers JA, Lameris JS, van Gulik TM. Thrombolytic therapy for acute superior mesenteric artery occlusion. J Vasc Interv Radiol 2005;16:317-29.
12. Milner R, Woo EY, Carpenter JP. Superior mesenteric artery angioplasty and stenting via a retrograde approach in a patient with bowel ischemia–a case report. Vasc Endovascular Surg 2004;38:89-91.
13. Wyers MC, Powell RJ, Nolan BW, Cronenwett JL. Retrograde mesenteric stenting during laparotomy for acute occlusive mesenteric ischemia. J Vasc Surg 2007;45:269-75.
14. Sonesson B, Hinchliffe RJ, Dias NV, Resch TA, Malina M, Ivancev K. Hybrid recanalization of superior mesenteric artery occlusion in acute mesenteric ischemia. J Endovasc Ther 2008;15:129-32.
15. Acosta S, Sonesson B, Resch T. Endovascular therapeutic approaches for acute superior mesenteric artery occlusion. Cardiovasc Intervent Radiol 2009;32:896-905.
16. Björck M, Acosta S, Lindberg F, Troëng T, Bergqvist D. Revascularization of the superior mesenteric artery after acute thromboembolic occlusion. Br J Surg 2002;89:923-7.
17. Troëng T, Malmstedt J, Björck M. External validation of the Swedvasc registry: a first-time individual cross-matching with the unique personal identity number. Eur J Vasc Endovasc Surg 2008;36:705-12.
18. Ravn H, Bergqvist D, Björck M; Swedish Vascular Registry. Nationwide study of the outcome of popliteal artery aneurysms treated surgically. Br J Surg 2007;94:970-7.
19. Kragsterman B, Pärsson H, Lindbäck J, Bergqvist D, Björck M; Swedish Vascular Registry (Swedvasc). Outcomes of carotid endarterectomy for asymptomatic stenosis in Sweden are improving: results from a population-based registry. J Vasc Surg 2006;44:79-85.
20. Björck M, Bergqvist D, Eliasson K, Jansson I, Karlström L, Kragsterman B, et al. Twenty years with the Swedvasc Registry. Eur J Vasc Endovasc Surg 2008;35:129-30.
21. Kini AS, Sarkar K, Rafael OC, Jakkula M, Kaplish D, Lee P, et al. Serum creatinine ratio: a novel predictor of mortality after percutaneous coro-

nary intervention in patients with normal and abnormal renal function. Catheter Cardiovasc Interv 2009;74:49-55.
22. Acosta S, Nilsson TK, Björck M. Preliminary study of D-dimer as a possible marker of acute bowel ischaemia. Br J Surg 2001;88:385-8.
23. Acosta S, Nilsson TK, Björck M. D-dimer testing in patients with suspected acute thromboembolic occlusion of the superior mesenteric artery. Br J Surg 2004;91:991-4.
24. Kougias P, Lau D, El Sayed HF, Zhou W, Huynh TT, Lin PH. Determinants of mortality and treatment outcome following surgical interventions for acute mesenteric ischemia. J Vasc Surg 2007;46:467-74.
25. Hafez H, Owen LW, Lorimer CF, Bajwa A. Advantage of a one-stop referral and management service for ruptured abdominal aortic aneurysms. Br J Surg 2009;96:1416-21.
26. Wadman M, Block T, Ekberg O, Syk I, Elmståhl S, Acosta S. Impact of MDCT with intravenous contrast on the survival in patients with acute superior mesenteric artery occlusion. Emerg Radiol 2010;17:171-8.
27. Desai ND, Miwa S, Kodama D, Koyama T, Cohen G, Pelletier MP, et al. A randomized comparison of intraoperative indocyanine green angiography and transit-time flow measurement to detect technical errors in coronary bypass grafts. J Thorac Cardiovasc Surg 2006;132:585-94.
28. Schalamon J, Mayr JM, Höllwarth ME. Mortality and economics in short bowel syndrome. Best Pract Res Clin Gastroenterol 2003;17:931-42.
29. Acosta S, Ogren M, Sternby NH, Bergqvist D, Björck M. Clinical implications for the management of acute thromboembolic occlusion of the superior mesenteric artery: autopsy findings in 213 patients. Ann Surg 2005;241:516-22.

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