Contemporary management of acute mesenteric ischemia: Factors associated with survival

Woosup M. Park, MD,[a] Peter Gloviczki, MD,[a] Kenneth J. Cherry, Jr, MD,[a] John W. Hallett, Jr, MD,[a] Thomas C. Bower, MD,[a] Jean M. Panneton, MD,[a] Cathy Schleck, BS,[b] Duane Ilstrup, MS,[b] William S. Harmsen, MS,[b] and **Audra A. Noel, MD,[a]** *Rochester, Minn*

Purpose: **Acute mesenteric ischemia (AMI) is a morbid condition with a difficult diagnosis and a high rate of complications, which is associated with a high mortality rate. For the evaluation of the results of current management and the examination of factors associated with survival, we reviewed our experience.**

Methods: **The clinical data of all the patients who underwent operation for AMI between January 1, 1990, and December 31, 1999, were retrospectively reviewed, clinical outcome was recorded, and factors associated with survival rate were analyzed.**

Results: **Fifty-eight patients (22 men and 36 women; mean age, 67 years; age range, 35 to 96 years) underwent study. The cause of AMI was embolism in 16 patients (28%), thrombosis in 37 patients (64%), and nonocclusive mesenteric ischemia (NMI) in five patients (8.6%). Abdominal pain was the most frequent presenting symptom (95%). Twenty-five patients (43%) had previous symptoms of chronic mesenteric ischemia. All the patients underwent abdominal exploration, preceded with arteriography in 47 (81%) and with endovascular treatment in eight. Open mesenteric revascularization was performed in 43 patients (bypass grafting, n = 22; thromboembolectomy, n = 19; patch angioplasty, n = 11; endarterectomy, n = 5; reimplantation, n = 2). Thirty-one patients (53%) needed bowel resection at the first operation. Twenty-three patients underwent second-look procedures, 11 patients underwent bowel resections (repeat resection, n = 9), and three patients underwent exploration only. The 30-day mortality rate was 32%. The rate was 31% in patients with embolism, 32% in patients with thrombosis, and 80% in patients with NMI. Multiorgan failure (n = 18 patients) was the most frequent cause of death. The cumulative survival rates at 90 days, at 1 year, and at 3 years were 59%, 43%, and 32%, respectively, which was lower than the rate of a Midwestern white control population ($P < .001$). Six of the 16 late deaths (38%) occurred because of complications of mesenteric ischemia. Age less than 60 years ($P < .003$) and bowel resection ($P = .03$) were associated with improved survival rates.**

Conclusion: **The contemporary management of AMI with revascularization with open surgical techniques, resection of nonviable bowel, and liberal use of second-look procedures results in the early survival of two thirds of the patients with embolism and thrombosis. Older patients, those who did not undergo bowel resection, and those with NMI have the highest mortality rates. The long-term survival rate remains dismal. Timely revascularization in patients who are symptomatic with chronic mesenteric ischemia should be considered to decrease the high mortality rate of AMI. (J Vasc Surg 2002;35:445-52.)**

Acute mesenteric ischemia (AMI) is an uncommon condition. It can occur as a result of acute arterial thrombosis, usually as a complication of underlying atherosclerosis, or, less frequently, because of arteritis, fibromuscular dysplasia, dissection, trauma, or mesenteric aneurysm rupture.[1,2] In mesenteric embolism, the embolus originates from the left ventricle, from the left atrium, or, less frequently, from the thoracic or upper abdominal aorta.[3-6] Nonocclusive mesenteric ischemia (NMI) develops as a result of hypoperfusion caused by a low cardiac output or mesenteric arterial spasm.[7-9] Ischemic colitis is a separate clinical entity that usually develops as the result of thrombosis or low flow in the inferior mesenteric artery or hypogastric circulation.[10] Finally, AMI may also develop because of acute mesenteric venous thrombosis.[11]

AMI affects predominantly the circulation to the midgut. Impairments of the arterial circulation because of thrombosis, embolism, or nonocclusive ischemia are morbid conditions and have a difficult diagnosis. The overall mortality rate in reported series averaged 69% (Table I).[2,5,6,12-32] For the evaluation of the results of contemporary management and for the examination of factors associated with survival, we reviewed our experience.

PATIENTS AND METHODS

The clinic records of all the patients who underwent surgical treatment for AMI because of embolism, thrombosis, and NMI between January 1, 1990, and December 31, 1999, were retrospectively reviewed. The demographic information, comorbid medical conditions, history and physical examination findings, laboratory test results and records of the radiologic examinations (arteriography,

From the Division of Vascular Surgery[a] and the Section of Biostatistics, Mayo Clinic.[b]

Competition of interest: nil.

Presented at the Twenty-ninth Annual Meeting of The Society for Clinical Vascular Surgery, Boca Raton, Fla, Apr 4–8, 2001.

Additional material for this article may be found online at www.mosby.com/jvs.

Reprint requests: Peter Gloviczki, MD, Mayo Clinic, 200 First St SW, Rochester, MN 55905 (e-mail: gloviczki.peter@mayo.edu).

0741-5214/2002/$35.00 + 0 **24/6/120373**

doi:10.1067/mva.2002.120373

Table I. Published series of acute mesenteric ischemia

First author	*Publication year*	*No. of patients*	*Mortality rate*
Foley	2000	21	24%
Mamode	1999	57	81%
Newman	1998	98	60%
Urayama	1998	34	35%
Klempnauer	1997	90	66%
Voltolini	1996	47	72%
Konturek	1996	28	96%
Ward	1995	34	45%
Deehan	1995	43	70%
Levy	1990	62	40%
Batellier	1990	65	51%
Bapat	1990	20	40%
Finucane	1989	32	69%
Sitges-Serra	1988	83	71%
Wilson	1987	102	92%
Lazaro	1986	23	27%
Andersson	1984	60	82%
Sachs	1982	30	77%
Krausz	1978	40	78%
Kairaluoma	1977	44	70%
Boley	1977	30	46%
Smith	1976	23	91%
Singh	1975	32	81%
Ottinger	1967	136	92%
Total		1234	69%

computed tomography [CT], duplex scanning), and endovascular procedures were abstracted. The data from operative records, postoperative complications, mortality, and hospital stay were recorded. The results of any follow-up imaging study were noted, and the patency of the revascularization or the earliest date of symptom recurrence or mesenteric vascular disease recurrence were also recorded. The long-term follow-up information was obtained from the clinical records and from telephone interviews. The factors associated with survival were analyzed. Cause of death was determined from clinic records, autopsy findings, and death certificates. This study was approved by the Institutional Review Board of the Mayo Foundation.

For statistical analysis, the associations between perioperative mortality rate and risk factors were assessed univariately with two-sample t test, Wilcoxon rank sum test, and χ^2 test or Fisher exact test. The survival rate was estimated with the Kaplan-Meier method. Comparisons of survival curves were made with the log-rank test. A multivariate Cox proportional hazards model was constructed with factors found to be significantly associated with survival rate on univariate analysis results. All the tests were two-tailed. The test results were considered significant at a P value of less than .05.

RESULTS

Demographic data and risk factors. From January 1, 1990, to December 31, 1999, 58 patients underwent surgical intervention for AMI at the Mayo Clinic in Rochester, Minn. There were 36 women and 22 men (mean age, 67 years; range, 35 to 96 years). The cause of AMI was embolism in 16 patients (28%), thrombosis in 37 patients (64%), and NMI in five patients (9%). The patients with embolism, in comparison with the patients with thrombosis, were older (74 versus 63 years; P = .0027) and had a higher percentage of atrial fibrillation (50% versus 11%; P = .002; Table II). Only two of the eight patients in the embolism group with atrial fibrillation were undergoing long-term anticoagulation therapy at presentation. Atherosclerosis was highly prevalent, and 64% of the patients had disease in two or more of the vascular distributions (Table II).

The thrombosis group had a higher incidence rate of chronic mesenteric ischemia symptoms than did the embolism group (65% versus 6%; P = .001; Table II). The mean duration of symptoms before the acute presentation was 8.2 months (median, 5.5 months). Fifteen patients (26%) had AMI within 6 weeks after a cardiac (n = 4 patients) or vascular operation (aortic, n = 3 patients; mesenteric, n = 3 patients; peripheral vascular procedures, n = 2 patients). Prior mesenteric reconstruction was performed in eight patients.

Clinical presentation. Fifty-five patients (95%) were seen with acute abdominal pain for a median of 24 hours duration and were available for preoperative evaluation (Appendix A, online only). Three patients were seen with shock with worsening acidosis and were taken immediately to the operating room for exploration. Nausea was the second most frequent symptom (44%), followed by vomiting and diarrhea (35% each). Sixteen percent of the patients had blood per rectum. The mean leukocyte count was elevated at 20.3×10^9/mL; the count was abnormal in 98% of the tested patients and was more than 20×10^9/mL in 50%. Lactate level was elevated in 91% of all the tested patients and was more than 3 mmol/L in 61% (Appendix B, online only).

Diagnostic evaluation. Aortography and selective mesenteric arteriography, if possible, were performed in 49 patients (84%), and results confirmed mesenteric arterial occlusive disease in all the cases (Appendix C, online only). A distinction between embolism and thrombosis could not always be made before surgery. Embolism was identified in 11 of the 13 studies (77%) and thrombosis in 33 of the 34 studies (97%). Arteriographic results confirmed occlusion of a previously placed graft in eight of eight studies (100%). Arteriography was used in the identification of NMI in two of five patients.

CT scanning was performed in 18 patients, and results confirmed superior mesenteric artery occlusion in 14 patients (78%; Appendix C, online only). Findings suggestive of bowel ischemia, including pneumatosis intestinalis, bowel wall thickening, ileus, and bowel dilatation, were seen in 11 patients (61%). Overall, 16 of the 18 CT scans (89%) had positive results that confirmed either arterial occlusion or bowel changes compatible with AMI. Duplex scan evaluation was performed in three patients, and results confirmed mesenteric vessel occlusion in two.

Endovascular treatment. Eight patients underwent initial endovascular treatment. Six patients underwent

Table II. Patient demographics, group characteristics, and medical conditions

Condition	*EMB*	*THR*	*NMI*	*Total*	*95% CI*
No. of patients	16 (28%)	37 (63%)	5 (9%)	58	
Age (mean; years)	74	63	69	67	
No. of female patients	10	22	4	36 (62%)	52% - 78%
No. of male patients	6	15	1	22 (38%)	26% - 52%
Hypertension	14 (88%)	26 (70%)	5 (100%)	45 (78%)	65% - 87%
Tobacco	8 (50%)	28 (76%)	5 (100%)	41 (71%)	57% - 82%
Family history of cardiovascular disease	8 (50%)	28 (76%)	4 (80%)	40 (69%)	55% - 80%
Peripheral vascular disease	11 (69%)	21 (57%)	4 (80%)	36 (62%)	48% - 74%
Coronary artery disease	9 (56%)	16 (43%)	4 (80%)	29 (50%)	37% - 63%
Chronic mesenteric ischemia symptoms	1 (6%)	24 (65%)	0 (0%)	25 (43%)	30% - 57%
Recent surgery	3 (19%)	10(27%)	3 (60%)	16 (28%)	15% - 39%
Diabetes	4 (25%)	12 (32%)	1 (20%)	17 (29%)	18% - 43%
Congestive heart failure	8 (50%)	7 (19%)	2 (40%)	17 (29%)	18% - 43%
Renal insufficiency	7 (44%)	9 (24%)	2 (40%)	18 (31%)	20% - 45%
Prior myocardial infarction	4 (25%)	7 (19%)	3 (60%)	14 (24%)	14% - 37%
Cerebrovascular disease	4 (25%)	9 (24%)	1 (20%)	14 (24%)	14% - 37%
Chronic obstructive pulmonary disease	4 (25%)	8 (22%)	2 (40%)	14 (24%)	14% - 37%
Digoxin use	7 (44%)	6 (16%)	1 (20%)	14 (24%)	14% - 37%
Hypercholesterolemia	4 (25%)	6 (16%)	2 (40%)	12 (21%)	11% - 33%
Atrial fibrillation	8 (50%)	4 (11%)	0 (0%)	12 (21%)	11% - 33%

EMB, Embolism; *THR*, thrombosis; *NMI*, nonocclusive mesenteric ischemia; *CI*, confidence interval.

transcatheter vasodilator therapy, one patient underwent percutaneous balloon angioplasty, and catheter-directed thrombolysis was attempted in another patient. This last patient subsequently needed laparotomy, embolectomy with patch angioplasty, and bowel resection. Second-look procedure showed healthy bowel. Among the six patients who underwent transcatheter vasodilator therapy, all underwent subsequent laparotomy, five needed surgical revascularization, and four had bowel resection. Six of these eight patients died within 30 days.

Surgical treatment. All 58 patients underwent surgical exploration (Table III). Mesenteric revascularization was performed in 43 patients (bypass grafting, n = 22; thromboembolectomy, n = 19; patch angioplasty, n = 11; endarterectomy, n = 5; reimplantation, n = 2). Twenty-three patients (40%) underwent second-look procedures. Bypass grafting was performed in 22 patients with thrombosis with polyester grafts in 17 patients (straight, n = 7; bifurcated, n = 10) and vein in five patients (straight, n = 4; bifurcated pantaloon graft, n = 1). The supraceliac aorta was used in 15 patients (celiac artery alone, n = 1; mesenteric alone, n = 5; celiac/hepatic and mesenteric, n = 9), and the infrarenal aorta was used in seven patients (all mesenteric).

Thirty-one patients underwent bowel resection during the first procedure. Of the 23 second-look procedures, 11 patients had bowel resections (further resection, n = 9; resection at second-look only, n = 2). Thirty-three patients underwent bowel resections at first-look or second-look laparotomy, and 16 of these patients had ostomies.

Morbidity rate. Major complications were frequent and occurred in 46 patients (79%; Appendix D, online only). Patients had a mean of 4.1 complications. Respiratory failure (36%) and multiorgan failure (31%) were the most frequent complications. Fifteen patients had suspected or known recurrent bowel infarction in the early postoperative period. Although seven patients underwent emergency bowel resection, eight additional patients received only supportive care for suspected or known recurrent bowel ischemia and a nonsalvageable condition. Only three of these 15 survived, and all the survivors underwent bowel resection. Reocclusion of the mesenteric arteries was documented in four patients and resulted in death in two patients. Three additional patients had embolism elsewhere: two to the lower limbs and one with diffuse mesenteric and systemic atheroembolism. There were seven myocardial infarctions, and 13 cardiac arrests. Eleven patients became ventilator-dependent. There was renal failure in nine patients (one patient needed dialysis), hepatic failure in nine patients, and two strokes. Gastrointestinal hemorrhage occurred in 12 patients.

Early mortality rate. The 30-day mortality rate was 32% (95% confidence interval [CI], 15% to 46%). The rate was 31% (95% CI, 4% to 51%) in patients with embolism, 32% (95% CI, 15% to 46%) in patients with thrombosis, and 80% (95% CI, 0 to 96%) in patients with NMI (embolism versus thrombosis, P value was not significant; embolism or thrombosis versus NMI, $P < .001$). Twenty-four patients died within 90 days (41%; 95% CI, 27% to 53%), and 23 patients died while still in the hospital. The causes of early death included multiorgan failure in 18 patients, mesenteric ischemia as the result of rethrombosis in two patients, myocardial infarction in two patients, chronic obstructive pulmonary disease in one patient, and unknown cause in one patient. Mesenteric ischemia contributed to multisystem organ failure in 12 of 18 patients (67%; Table IV). The patients who died were older (mean age, 72 versus 63 years; $P = .03$). Age greater than or equal to 60 years resulted in a 54% mortality rate as com-

Table III. Procedures

	EMB	*THR*	*NMI*	*Total*
Thromboembolectomy	12 (75%)	7 (19%)	0	19
Patch angioplasty	6 (38%)	5 (14%)	0	11
Endarterectomy	0	5 (14%)	0	5
Reimplantation of SMA into aorta	0	2 (5%)	0	2
Bypass graft	0	22 (59%)	0	22
Vein	0	5 (23%)	0	5
Polyester	0	17 (77%)	0	17
Antegrade	0	15 (68%)	0	15
Retrograde	0	7 (32%)	0	7
Single	0	12 (55%)	0	12
Double	0	10 (45%)	0	10
Resection				
Of small bowel	5 (31%)	13 (35%)	2 (40%)	20
Of large bowel	0	2 (5%)	0	2
Of small and large bowel	5 (31%)	3 (8%)	1 (20%)	9
Second-look procedure	9 (56%)	12 (36%)	2 (40%)	23
Resection of bowel (any)	5 (31%)	6 (16%)	0	11
Resection of small bowel	3 (30%)	6 (40%)	0	9
Resection of large bowel	1 (10%)	0	0	1
Resection of small and large bowel	1 (10%)	0	0	1

EMB, Embolism; *THR*, thrombosis; *NMI*, nonocclusive mesenteric ischemia; *SMA*, superior mesenteric artery.

Table IV. Causes of early and late mortality

Mortality	*No. of deaths*
At ≤90 days	
Multiorgan failure/sepsis	18 (75%)
Mesenteric thrombosis	2 (8%)
Myocardial infarction	2 (8%)
Coronary obstructive pulmonary disease	1 (4%)
Unknown	1 (4%)
Total	24
At >90 days	
Cardiac	4 (25%)
Short bowel syndrome	3 (19%)
Mesenteric ischemia	2 (13%)
Cancer	2 (13%)
Unknown	2 (13%)
Pulmonary embolus	1 (6%)
Chronic obstructive pulmonary disease	1 (6%)
TPN line sepsis	1 (6%)
Total	16

pared with a rate of 12% for those patients who were younger than 60 years (P = .003). Age greater than or equal to 70 years was related to a 39% mortality rate as compared with a 26% rate for patients who were younger than 70 years (P = .01). Gender, revascularization, chronic mesenteric ischemia symptoms, and cardiovascular risk factors were not associated with early death. Having AMI as a complication of another surgery performed within 43 days was associated with increased mortality rate at 90 days (66% versus 36%; P = .03).

Late results. The mean follow-up period was 529 days (range, 0 to 2877 days) and was complete. Recurrent symptoms occurred in 10 patients and included abdominal pain in six, diarrhea in five, and nausea and vomiting in two. Five patients had short bowel syndrome, and all were on long-term total parenteral nutrition (TPN). At last follow-up examination, 10 patients had weight gain (mean, 20 lbs), 12 had unchanged weights, and seven had weight loss (mean, 17 lbs). Follow-up imaging studies were obtained for 11 of 16 patients with prosthetic grafts (duplex scan, n = 5; arteriography, n = 3; CT scan, 2; magnetic resonance angiography, n = 1). Patency was demonstrated in nine grafts to a mean of 1.4 years. Two graft occlusions occurred at 21 and 136 days, and both were associated with recurrent mesenteric ischemia. One patient underwent surgical thrombectomy of the occluded bypass graft, and the other patient underwent percutaneous angioplasty. Both patients had symptom resolution. One patient died 1.5 years later of TPN line sepsis, and the other, also 1.5 years later, died of a cardiac arrhythmia. Two additional patients had superior mesenteric artery occlusive disease develop. Both refused reoperation, and both died at 131 and 176 days after symptom recurrence (Table IV).

The overall survival rate (Fig 1) was 59% (95% CI, 47% to 73%) at 90 days, 43% (95% CI, 32% to 58%) at 1 year, and 32% (95% CI, 21% to 48%) at 3 years, which was significantly less than the rate for a white Midwestern control population (P < .001). The median survival time for all patients was 238 days. Survival analysis results by groups (Fig 2) showed significantly worse survival rate in the NMI group as compared with the rates in the embolism or thrombosis groups (P < .001). Six of 16 late deaths (38%) were attributable to mesenteric ischemia (Table V).

Factors associated with survival rate. Univariate analysis results for factors associated with improved survival rate are listed in Table V. The significant factors include age less than 60 years, bowel resection at first-look or second-look procedure, and no recent major cardiovascular surgery. Approaching significance was bowel resec-

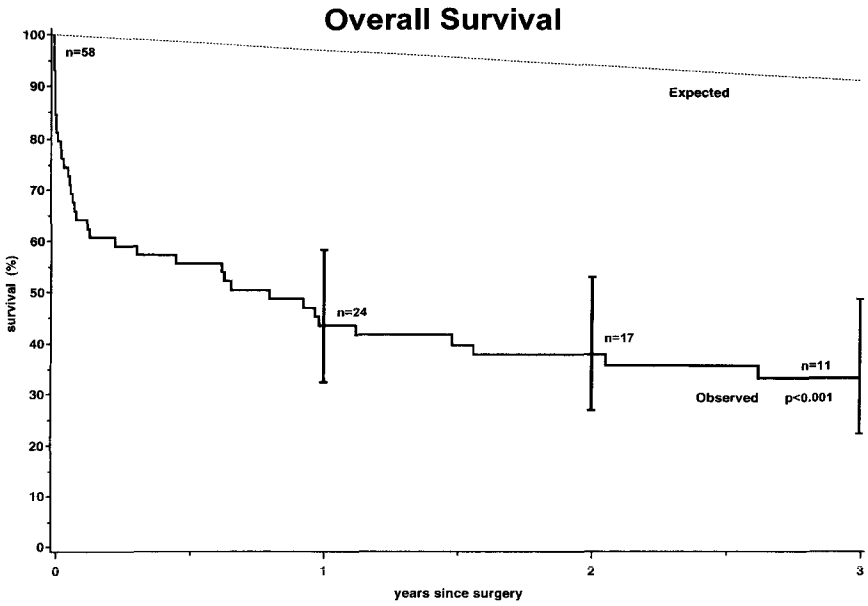

Fig 1. Overall survival rate (n = 58 patents).

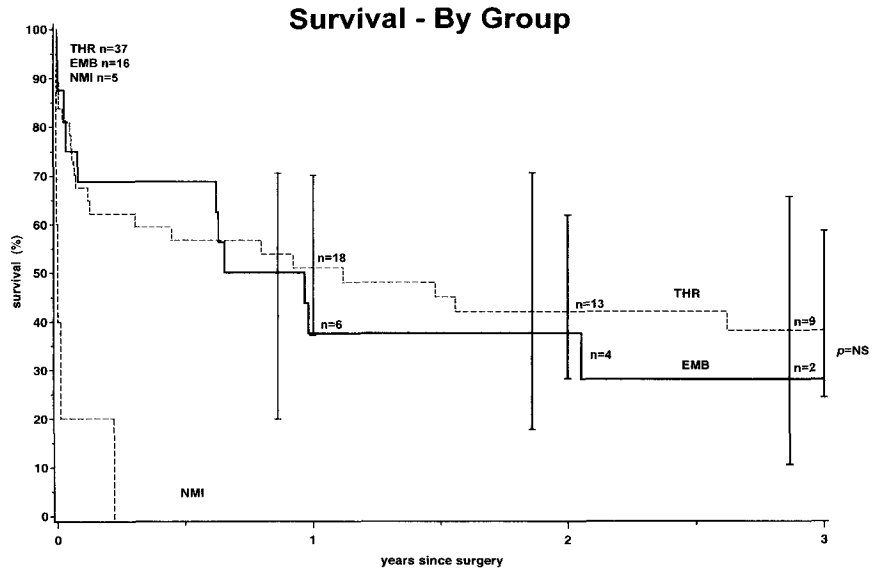

Fig 2. Survival rates by cause.

tion at first operation ($P = .056$), performance of arteriography ($P = .074$), and time to presentation greater than or equal to 24 hours ($P = .085$). When the association of time greater than 24 hours and bowel resection at first operation was analyzed, the results showed improved survival rate ($P = .03$). Survival rate was not significantly different whether the bypass graft was antegrade (n = 15 patients) or retrograde (n = 7 patients) or single (n = 12 patients) or double (n = 10 patients; P value not significant for all). No statistically significant association with improved survival rate was found with chronic mesenteric ischemia symptoms, second-look procedures, cardiac risk factors, and comorbid medical conditions.

Variables found to be univariately associated with survival rate (age >60 years, recent surgery, bowel resection at first or second procedure) were entered into a multivariate analysis, and each was found to be independently associated with survival rate (Table VI). Age older than 60 years increased mortality rate with a relative risk ratio of 3.0 (95% CI, 1.3 to 6.9; $P = .009$). Recent surgery increased

Table V. Factors associated with survival rate with univariate analysis

Variable	*Survival rate (95% CI)*			P *value*
	At 30 days	*At 1 year*	*At 3 years*	
Age less than 60 years				
Yes	88% (74% - 100%)	77% (58% - 100%)	55% (33% - 88%)	.0027
No	54% (40% - 71%)	29% (18% - 47%)	23% (13% - 41%)	
Bowel resection at first-look or second-look procedure				
Yes	68% (54% - 85%)	53% (39% - 73%)	46% (30% - 67%)	.03
No	58% (43% - 82%)	28% (14% - 54%)	12% (4% - 40%)	
Recent major cardiovascular procedure				
Yes	43% (23% - 79%)	21% (8% - 58%)	21% (8% - 58%)	.03
No	69% (56% - 85%)	50% (37% - 68%)	36% (23% - 55%)	
Bowel resection at first operation				
Yes	66% (51% - 84%)	53% (41% - 76%)	46% (29% - 67%)	.056
No	62% (45% - 83%)	29% (16% - 54%)	13% (4% - 42%)	
Arteriography				
Yes	68% (56% - 83%)	47% (34% - 63%)	36% (23% - 54%)	.074
No	46% (24% - 87%)	27% (10% - 72%)	18% (4% - 64%)	
Time to presentation ≥24 h				
Yes	68% (54% - 85%)	50% (36% - 70%)	40% (26% - 61%)	.085
No	56% (37% - 87%)	31% (15% - 65%)	12% (22% - 62%)	

CI, Confidence interval.

Table VI. Variables independently associated with worsened survival rate with multivariate analysis

Variable	*Relative risk ratio (95% CI)*	P *value*
Age >60 years	3.0 (1.3 - 6.9)	.0093
Bowel resection at first-look or second-look procedure	0.5 (0.2 - 0.9)	.0182
Previous surgery	2.4 (1.2 - 4.9)	.0229

P values determined with χ^2 test.
CI, Confidence interval.

the relative risk of mortality rate 2.4 times (95% CI, 1.2 to 4.9). Bowel resection at first-look or second-look procedure decreased mortality rate with a relative risk ratio of 0.5 (95% CI, 0.2 to 0.9).

DISCUSSION

AMI remains a morbid condition with poor short-term and long-term survival rates. Although no population-based data have been published, the incidence rate of this lethal condition is increasing. In 1967 in an autopsy series, Ottinger and Austen[32] reported a rate of 8.8 cases of AMI per 10,000 hospital admission. Almost 30 years later, Stoney and Cunningham[33] observed an incidence rate of 1 in 1000 hospital admissions. As the mean age of the population increases and the proportion of older patients in our hospitals grows, AMI will predictably be more common. Unfortunately, as reported in other series as well, mortality rate in older patients is significantly greater and carries a relative risk of mortality rate of 3.0 for those more than the age of 60 years.

Early recognition of AMI is crucial because irreversible bowel necrosis develops in many patients by the time of abdominal exploration. Fifty-seven percent of our patients needed bowel resection at the time of the first operation, and no resection was performed because of an unsalvageable situation with excessive bowel necrosis in an additional 5%. A high index of clinical suspicion is needed, and our data concur with the classic teaching of pain out of proportion to physical findings. Pain was present in 95% of our patients, but signs of frank peritonitis were frequently late or absent. Abdominal distension and motility problems, such as nausea, vomiting, or constipation, were more frequent. Laboratory abnormalities were present in 98% of our patients, particularly leukocytosis and high lactate levels. Unfortunately, none of these findings is specific for AMI. CT scanning and contrast arteriography continue to play a major role in the diagnosis of AMI.[34-38] CT scanning has been reported to be sensitive in the diagnosis of mesenteric occlusion,[39,40] and our findings are in agreement. CT scan results confirmed mesenteric arterial occlusion or suggested ischemic bowel in 89% of the patients studied. This imaging method also allows the identification of nonvascular causes of acute abdominal pain. CT scan with three-dimensional reconstruction is an increasingly useful technique, which may allow identification of vascular anatomy and pathology with good enough detail for diagnosis and operative planning.

Contrast arteriography plays an important role in early diagnosis and is helpful in planning and initiating treatment.[29,38] We found that arteriographic results confirmed mesenteric vascular disease in 100% of the cases and correctly identified thrombosis or embolism in 94%. Endovascular interventions or catheter-directed vasodilator therapy can be started immediately after arteriography.

The role of endovascular therapy in AMI continues to be limited and somewhat controversial. Boley and others[29]

used arteriography and subsequent catheter-based interventions or transcatheter vasodilator therapy as the initial or sole therapy of AMI. In NMI, catheter-directed vasodilator infusion without peritonitis continues to be the treatment of choice and is the accepted treatment. Mortality rate in NMI continues to be excessive. Gallego and colleagues[41] and McBride and Gaines[42] have used catheter-directed thrombolysis with good results in the treatment of acute mesenteric embolism. Successful use of percutaneous angioplasty for AMI was reported by van Deinse and colleagues.[43]

Undoubtedly, the number of endovascular interventions, angioplasty, and stenting for both acute and chronic mesenteric occlusive disease will increase in the future. In AMI, potential advantages include the chance to replace or decrease the need for open surgical reconstructions of the occluded arteries, performed not infrequently with prosthetic grafts in a potentially or de facto infected field. Our experience with catheter-based reconstructions in AMI is limited, and only two patients had such treatment in this series, with good results in one.

The goal of surgical care in AMI is the removal of nonsalvageable bowel, the minimization and prevention of further bowel infarction, and the preservation of small intestinal length. The surgical procedure involves assessment of bowel viability, determination or confirmation of the underlying cause, revascularization, and resection of infarcted bowel. Second-look procedures allow for the reassessment of bowel viability and further bowel resection as needed. Exploratory laparotomy (open or laparoscopic) remains the gold standard for the determination of bowel viability, and an operation is the only way to remove dead bowel. Bowel viability is assessed with physical examination (inspection, palpation), hand-held Doppler scan examination,[44] and intravenous injection of fluorescein.[10] Absent, perivascular, or patchy fluorescein patterns are considered positive for impaired perfusion. Because some of these perfusion problems are reversible, the sensitivity and predictive value of positive test results at first operation do not negate the value of a second-look procedure.[45]

The most useful surgical revascularization technique in embolism remains the balloon catheter thromboembolectomy, with or without patch angioplasty of the superior mesenteric artery. Patients with chronic proximal occlusion or stenosis undergo revascularization with an aortomesenteric or, less frequently, iliomesenteric bypass graft. Good results have been reported for both multivessel[46] and single-vessel reconstruction[12] in both the acute and chronic settings. Equally good results were obtained in this study when revascularization was performed from a supraceliac aortic origin or from a retrograde position, regardless of whether it was performed to one or two vessels. In AMI, most surgeons in our group favor single-vessel reconstruction now to the superior mesenteric artery, performed frequently in a retrograde fashion that is simpler to perform in the acute setting. In patients with bowel perforation, a saphenous vein or rifampin-soaked polyester graft is our choice for conduit.

Resection of the infarcted bowel is performed after revascularization. In our series, 48% of the patients needed an ostomy. Patients with bowel of questionable viability undergo a second-look procedure, usually within 24 hours. The decision to reoperate is made during the first operation and is independent of the clinical status of the patient during the two procedures. The utility of second-look procedures was shown in other studies and in ours as well. Of our patients who underwent second-look procedures, 48% needed bowel resection.

Resection of bowel in either first-look or second-look procedures was associated with improved survival rate on univariate and multivariate analysis results and was associated with a risk reduction of 0.5. Resectability may represent a selection process of patients who had clearly demarcated necrotic and conversely remaining viable bowel, and the unresected group included both the nonsalvageable cases (n = 3 patients) and patients whose conditions subsequently deteriorated (n = 8 patients) but did not undergo operation (ie, resectability may be a marker for improved survival rate). There may also be a causal relationship between bowel resection and improved survival rate, but this cannot be determined from these retrospective data.

Major postoperative complications remain excessive, and both early and late mortality rates continue to be high. Multiorgan failure is the most lethal complication, and it is the result of a combination of bowel ischemia, sepsis, and generalized atherosclerosis because many patients are elderly with several cardiovascular risk factors. Recurrent and persistent mesenteric ischemia remains a major threat to these patients and contributes significantly to the early and late mortality rates. Successful revascularization, therefore, remains imperative and likely contributes to the reduction of mortality rate to the 30% range in the embolism or thrombosis group from the 60% to 70% range reported earlier in several studies. Age less than 60 years and removal of the dead bowel were factors in our multivariate analysis that predicted improved survival rate.

Prevention of AMI may be an effective way to reduce the high mortality rate of this lethal disease. In some patients with underlying mesenteric atherosclerosis, AMI could clearly be prevented with recognition and timely, elective revascularization for symptoms of chronic mesenteric occlusive disease, with much lower morbidity and mortality rates.[12,46,47] Almost half of the patients in our series had prior symptoms of chronic mesenteric ischemia. Our data also support treatment of atrial fibrillation with anticoagulation therapy. Seventy-five percent of the patients with mesenteric embolism were not undergoing anticoagulation therapy with heparin or warfarin sodium at the time of the ischemic event.

In conclusion, contemporary management of AMI should include a high index of clinical suspicion, rapid preoperative evaluation, revascularization with open surgical techniques, resection of nonviable bowel, the liberal use of second-look procedures, sophisticated postoperative care

for the prevention of multiorgan failure, and the recognition of recurrent mesenteric ischemia. Although overall clinical outcome is still poor, such management will result in the early survival of two thirds of the patients with embolism and thrombosis. Older patients, those who did not undergo bowel resection, and those with NMI have the highest mortality rates. Long-term survival rate remains dismal because of the underlying cardiovascular disease and recurrent mesenteric ischemia and shows how much needs to be done to prevent and treat this lethal disease. Timely revascularization of symptomatic patients with chronic mesenteric occlusive disease could be one effective way to decrease the incidence and subsequent high mortality rates of AMI.

REFERENCES

1. Ottinger LW. The surgical management of acute occlusion of the superior mesenteric artery. Ann Surg 1978;188:721-31.
2. Wilson C, Gupta R, Gilmour DG, et al. Acute superior mesenteric ischaemia. Br J Surg 1987;74:279-81.
3. Boley SJ, Feinstein FR, Sammartano R, et al. New concepts in the management of emboli of the superior mesenteric artery. Surg Gynecol Obstet 1981;153:561-9.
4. Hertzer NR, Beven EG, Humphriesw AW. Acute intestinal ischemia. Am Surg 1978;44:744-9.
5. Batellier J, Kieny R. Superior mesenteric artery embolism: eighty-two cases. Ann Vasc Surg 1990;4:112-6.
6. Lazaro T, Sierra L, Gesto R, et al. Embolization of the mesenteric arteries: surgical treatment in twenty-three consecutive cases. Ann Vasc Surg 1986;1:311-5.
7. Benjamin E, Oropello JM, Iberti TJ. Acute mesenteric ischemia: pathophysiology, diagnosis, and treatment. Dis Mon 1993;39:131-210.
8. Bradbury AW, Brittenden J, McBride K, et al. Mesenteric ischaemia: a multidisciplinary approach. Br J Surg 1995;82:1446-59.
9. Bruch HP, Broll R, Wunsch P, et al. Non-occlusive ischemia enteropathy: diagnosis, therapy and prognosis. Chirurg 1989;60:419-25.
10. Bergman RT, Gloviczki P, Welch TJ, et al. The role of intravenous fluorescein in the detection of colon ischemia during aortic reconstruction. Ann Vasc Surg 1992;6:74-9.
11. Rhee RY, Gloviczki P, Mendonca CT, et al. Mesenteric venous thrombosis: still a lethal disease in the 1990's. J Vasc Surg 1994;20:688-97.
12. Foley MI, Moneta GL, Abou-Zamzam AM, et al. Revascularization of the superior mesenteric artery alone for treatment of intestinal ischemia. J Vasc Surg 2000;32:37-47.
13. Mamode N, Pickford I, Leiberman P. Failure to improve outcome in acute mesenteric ischaemia: seven year review. Eur J Surg 1999;165: 203-8.
14. Newman TS, Maguson TH, Ahrendt SA, et al. The changing face of mesenteric infarction. Am Surg 1998;64:611-6.
15. Urayama H, Ojtake H, Kawakama T, et al. Acute mesenteric vascular occlusion: analysis of 39 patients. Eur J Surg 1998;164:195-200.
16. Kempnauer J, Grothues F, Bektas H, et al. Long-term results after surgery for acute mesenteric ischemia. Surgery 1997;121:239-43.
17. Voltolini F, Pricolo R, Naldini G, et al. Acute mesenteric ischemia. Analysis of 47 cases. Minerva Chir 1996;51:285-92.
18. Konturek A, Cichon S, Gucwa J, et al. Acute intestinal ischemia in material of the III Clinic of General Surgery, Collegium Medicum at the Jagellonian University. Przegl Lek 1996;53:719-21.
19. Ward D, Vernava AM, Kaminski DL, et al. Improved outcome by identification of high-risk non-occlusive mesenteric ischemia, aggressive reexploration, and delayed anastomosis. Am J Surg 1995;170:577-81.
20. Deehan DJ, Heys SD, Brittenden J, et al. Mesenteric ischaemia: prognostic factors and influence of delay upon outcome. J Royal Coll Surg Edinburgh 1995;40:112-5.
21. Levy PJ, Krausz MM, Manny J. Acute mesenteric ischemia: improved results—a retrospective analysis of ninety-two patients. Surgery 1990;107:372-80.
22. Bapat RD, Aiyer PM, Relekar RG, et al. Ischemic bowel disease. Indian J Gastroenterol 1990;9:19-22.
23. Finucane PM, Arunachalam T, O'Dowd J, et al. Acute mesenteric infarction in elderly patients. J Am Geriatr Soc 1989;37:355-8.
24. Sitges-Serra A, Mas X, Roqueta F, et al. Mesenteric infarction: an analysis of 83 patients with prognostic studies in 44 cases undergoing massive small-bowel resection. Br J Surg 1988;75:544-8.
25. Andersson R, Parsson H, Isaksson B, et al. Acute intestinal ischemia: a 14 year retrospective investigation. Acta Chir Scand 1984;150:217-21.
26. Sachs SM, Morton JH, Schwartz SI. Acute mesenteric ischemia. Surgery 1982;92:646-53.
27. Krausz MM, Manny J. Acute superior mesenteric arterial occlusion: a plea for early diagnosis. Surgery 1977;82:856-66.
28. Kairaluoma MI, Karkola P, Heikkinen D, et al. Mesenteric infarction. Am J Surg 1977;133:188-93.
29. Boley SJ, Sprayregan S, Siegelman SS, et al. Initial results from an aggressive roentgenological and surgical approach to acute mesenteric ischemia. Surgery 1977;82:848-55.
30. Smith S, Patterson LT. Acute mesenteric infarction. Am J Surg 1976;42:562-7.
31. Singh RP, Shah RC, Lee ST. Acute mesenteric vascular occlusion: a review of thirty-two patients. Surgery 1975;78:613-7.
32. Ottinger L, Austen WB. A study of 136 patients with mesenteric infarction. Surg Gynecol Obstet 1967;124:251-61.
33. Stoney RJ, Cunningham CG. Acute mesenteric ischemia. Surgery 1993;114:489-90.
34. Hibbard JS, Swenson PC, Levin AG. Roentgenology of experimental mesenteric vascular occlusion. Arch Surg 1933;26:20.
35. Danse EM, Van Beers BE, Goffette P, et al. Acute intestinal ischemia due to occlusion of the superior mesenteric artery: detection with Doppler sonography. J Ultrasound Med 1996;15:323-6.
36. Klein HM, Lensing R, Klosterhalfen B, et al. Diagnostic imaging of mesenteric infarction. Radiology 1995;197:79-82.
37. Bottger T, Jonas J, Weber W, et al. Sensitivity of preoperative diagnosis in mesenteric vascular occlusion. Bildgebung 1991;58:192-8.
38. Clark RA, Gallant TE. Acute mesenteric ischemia: angiographic spectrum. Am J Roengenol 1984;142:555-62.
39. Fock CM, Kullnig P, Ranner G, et al. Mesenteric arterial embolism: the value of emergency CT in diagnostic procedure. Eur J Radiol 1994;18:12-4.
40. Czerny M, Trubel W, Claeys L, et al. Acute mesenteric ischemia. Zentralbl Chir 1997;122:538-44.
41. Gallego AM, Ramirez P, Rodriguez JM, et al. Role of urokinase in the superior mesenteric artery embolism. Surgery 1996;120:111-3.
42. McBride KD, Gaines PA. Thrombolysis of a partially occluding superior mesenteric artery thromboembolus by streptokinase. Cardiovasc Intervent Radiol 1994;17:164-6.
43. van Deinse WH, Zawacki JK, Phillips D. Treatment of acute mesenteric ischemia by percutaneous transluminal angioplasty. Gastroenterolgy 1986;91:475-8.
44. Hobson RW, Wright CB, Rich NM, et al. Assessment of colonic ischemia during aortic surgery by Doppler ultrasound. J Surg Res 1976;20:231-5.
45. Ballard JL, Stone WM, Hallett JW, et al. A critical analysis of adjuvant techniques used to assess bowel viability in acute mesenteric ischemia. Am Surg 1993;59:309-11.
46. McAfee MK, Cherry KJ Jr, Naessens JM, et al. Influence of complete revascularization on chronic mesenteric ischemia. Am J Surg 1992; 164:220-4.
47. McMillan WD, McCarthy WJ, Bresticker MR, et al. Mesenteric artery bypass: objective patency determination. J Vasc Surg 1995;21:729-41.

Submitted Apr 11, 2001; accepted Aug 30, 2001.

Additional material for this article may be found online at www.mosby.com/jvs.