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COULD RISK FACTORS BE BETTER PREDICTORS OF EARLY ACUTE MESENTERIC ISCHEMIA THAN LABORATORY AND IMAGING STUDIES? RETROSPECTIVE STUDY AND ALGORITHM FOR THE EARLY INTERVENTION

Mogu li faktori rizika biti bolji prediktori rane akutne mezenterijalne ishemije od laboratorijskih i slikovnih pretraga? Retrospektivna studija i algoritam za ranu intervenciju

Zlatko Fiolić, Goran Augustin, Željko Jelinčić, Petar Matošević

Abstract

Objectives. The aim is to delineate relevant risk factors and construct an algorithm for earlier performance of selective mesenteric angiography, thus lowering mortality rates of acute mesenteric ischemia.

Methods. During a 5-year period 31 patients were examined. Thirteen risk factors were analysed and compared to standard diagnostic procedures.

Results. Only one patient did not have arterial hypertension. The second most common risk factor is atrial fibrillation with the incidence rate of 64.5%. The largest group of patients (38.7%) had two risk factors and there were 6.5% patients with six risk factors and 87.2% of all patients had two or more risk factors. In 67.7% of the patients we only performed emergency laparotomy due to inoperable state. Hospital mortality was 74.2%.

Conclusions. Combination of age over 70, hypertension and two or more risk factors associated with elevated D-dimers, in a patient with severe abdominal pain and minimal clinical findings with nonspecific laboratory findings and plain abdominal radiographs, could be an indication for early selective mesenteric angiography.

Keywords

acute mesenteric ischemia, risk factors, selective mesenteric angiography, algorithm

Sažetak

Ciljevi. Cilj je naznačiti relevantne faktore rizika i izraditi algoritam za ranije slučajeve selektivne mezenterijalne angiografije te na taj način smanjiti stopu smrtnosti akutne mezenterijalne ishemije.

Metode. Tijekom petogodišnjeg razdoblja pregledan je 31 pacijent. Analizirano je 13 faktora rizika koji su uspoređeni sa standardnim dijagnostičkim postupcima.

Rezultati. Samo jedan pacijent nije imao arterijsku hipertenziju. Drugi najčešći faktor rizika je atrijalna fibrilacija s učestalošću od 64,5%. Najveća skupina pacijenata (38,7%) imala je dva faktora rizika, 6,5% pacijenata imalo je šest faktora rizika, a 87,2% svih pacijenata imalo je dva ili više faktora rizika. U 67,7% pacijenata izveli smo samo hitnu laparotomiju zbog neoperabilnog stanja. Bolnička smrtnost bila je 74,2%.

Zaključci. Kombinacija dobi iznad 70, hipertenzije i dva ili više faktora rizika povezanih s povišenim D-dimerima, kod pacijenta sa znatnom abdominalnom boli i minimalnim kliničkim zaključcima s nespecifičnim laboratorijskim zaključcima i uobičajenim abdominalnim radiografima mogu biti indikacija za ranu selektivnu mezenterijalnu angiografiju.

Ključne riječi

akutna mezenterijalna ishemija, faktori rizika, selektivna mezenterijalna angiografija, algoritam

Introduction

Acute mesenteric ischemia (AMI) is a potentially fatal vascular emergency with the overall mortality rate of 60% to 80% [1–3]. Although AMI accounts for only about 1–2% of gastrointestinal diseases, the incidence has been increasing considerably [1, 4, 5]. Early clinical presentation is nonspecific in most cases and is characterized by an initial discrepancy between severe abdominal pain and minimal clinical findings. There is

Department of Surgery, University Hospital Centre Zagreb, Zagreb, Croatia

Correspondence: Goran Augustin, MD, PhD, Department of Surgery, Kišpatićeva 12, 10 000 Zagreb, Croatia, e-mail: augustin.goran@gmail.com

no confirmatory laboratory test for *early AMI* and even leukocytosis may not be present. Abdominal X-rays are normal in 25% of patients or nonspecific and cannot confirm the diagnosis [6–8]. Duplex Doppler ultrasound has a limited role in patients with distended bowel loops [8, 9]. Computed tomography, not very useful in diagnosing acute embolic events, is the study of choice only in patients with mesenteric vein thrombosis [10, 11]. In the absence of a clinical indication for emergency laparotomy, biplanar mesenteric angiography remains the examination of choice in suspected AMI [12].

The problem is that the latter diagnostic modality is invasive, time-consuming and must be performed by a highly educated team which means that indications for emergency mesenteric angiography are strict. Therefore the aforementioned observations leave only the risk factors as parameters that could direct the clinician, who has a patient with severe abdominal pain, to the diagnosis of AMI.

The aim of this study is to delineate potentially relevant risk factors and construct an algorithm which could lead to earlier performance of selective mesenteric angiography with low incidence of negative results. Earlier performance of angiography could lead to diagnosis of AMI early in the disease process when the disease is potentially curable. The final result could be lowering the mortality rates of AMI.

Patients and methods

During a 5-year period (2001–2005), we retrospectively examined 31 patients with intraoperative verification of AMI at the University Hospital Centre Zagreb. No intraoperative diagnostic test has yet been described that is superior to the clinical judgement of experienced surgeons in determining intestinal viability [13]. The study included patients who came to the surgical or internal medicine emergency department from their home. The analysed parameters were age, sex, duration of symptoms, examination to treatment time (diagnostic period), peritoneal irriation (acute abdomen), leukocyte count, hematocrit, C-reactive protein, plain abdominal radiographs, abdominal sonography, abdominal computed tomography (CT), second-look operation and risk factors for AMI. The risk factors included hypertension (≥ 140/90 mmHg), atrial fibrillation, digitalis use, previous abdominal operation, previous pulmonary embolism, renal insufficiency, previous myocardial infarction, previous deep venous thrombosis, valvular/structural cardiac disease, previous stroke, intraabdominal neoplasm and portal hypertension (Table 1). The last row in Table 1 (bold letters) represents average values or percentage of patients with specific signs or risk factors. Table 2 contains a percentage of patients with specific risk factors and a percentage of patients with the combination of these risk factors. All currently identified risk factors for AMI are listed in Table 3.

Results

Female to male ratio was 1.2:1 (17 women and 14 men). The average age was 77 years, but 29 out of 31 patients (93.5%) were 68 years old or older. The average age of female population was 82.2 and of male population 71.6 years. The average duration of abdominal pain was 4.6 days (range 5 hours to 10 days). Almost all the patients had diarrhea (bloody diarrhea was not noted in most patients probably due to the inadequate clinical examination or insufficient medical documentation) or were vomiting. The average examination to treatment time (diagnostic period) was 12.2 hours (range 4–36 hours). Peritoneal irritation (acute abdomen) was found in 25 patients (81%). The average leukocyte count was 17.2 (range 5.0–31.0) and C-reactive protein 125 (range 13–384). Plain abdominal radiographs showed distended loops of small and large intestine with aero-liquid levels in 30 patients (96.8%) and only one of normal finding. Abdominal sonography was done in 27 patients (87.1%) and revealed only distended loops of small intestine without the possibility of accurate delineation of other structures. Abdominal CT or CT angiography was not done in these patients.

None of the patients had intraabdominal neoplasm or portal hypertension (therefore these risk factors are not presented in Table 1). Only one patient did not have arterial hypertension (incidence of hypertension was 96.8%), but had two other risk factors (previous abdominal operation and renal insufficiency). Second most common risk factor was atrial fibrillation with the incidence rate of 64.5%. The occurrence of other risk factors is presented in Table 2 in their decreasing incidence. Table 2 also contains cumulative incidence of risk factors. The largest group of patients (38.7%) had two risk factors and there were patients (6.5%) with even six risk factors. It is important to note that patients with two or more risk factors made the total of 87.2% of patients with AMI. It has to be noted that arterial hypertension was excluded from risk factors group because it is a widespread sign in general population and almost all the patients (96.8%) had hypertension.

Only exploratory laparotomy, without the possibility of performing resectional procedures due to the inoperable state, was made in 21 patients (67.7%). Thrombendarterectomy with a patch on the superior mesenteric artery was done on one patient and the other nine patients (29.0%) had resections of necrotic small or large bowel. Second-look operation was performed on only six patients (19.4%). Hospital mortality was 74.2% (23 patients; 13 women and 10 men).

Discussion

Despite the advances of diagnostic and therapeutic modalities, AMI is still a vascular emergency with high mortality ranging from 60 to 80% [1–3]. High mortality rate of 74.2% was present in our study as well. This is attributed to the diagnosis of *advanced AMI*, which, in fact, is not a diagnosis of AMI but of acute abdomen and therefore is the indication for emergency laparotomy. In our study, 81% of patients presented with acute abdomen or developed acute abdomen during the diagnostic period. Another element indicating that diagnosis was made too late is that only exploratory laparotomy, without the possibility of performing resectional procedures, embolectomies or thrombectomies due to the inoperable state, was performed on 67.7% of patients. Second-look operation was performed in six patients (19.4%) and three (50%) of these patients died. This, unfortunately, presents a low percentage of second-look operations. Low percentage of these operations is also an indicator that patients presented with an advanced disease without even the possibility of second-look operations. The mortality rate in this group was 50%, which is significantly lower than 74.2% in the overall group. This only confirms that emergency laparotomy is mandatory in acute abdomen and objectively we cannot state that second-look operation by itself is therapeutic, rather that these patients had a potentially curable disease at the time of initial operation.

Survival rates are significantly higher once AMI is diagnosed and treated in early stages (≤ 24 h), especially using mesenteric angiography and splanchnic vasodilators [2]. Selective catheter angiography is the gold standard for the diagnosis of *early AMI*. Sensitivities range between 90 and 100% and specificity is almost 100% [2]. High sensitivity and therapeutic potential of early angiography significantly lowered the mortality rate with a reported range of 18–53% [2]. Therefore it is imperative to make a diagnosis of *early AMI* to lower the mortality rate as well as the number of abdominal explorations which are the risk factors for morbidity and mortality in patients with significant comorbid diseases. It is apparent that clinical examination, laboratory findings, plain abdominal radiographs or abdominal sonography could not establish the diagnosis of AMI in early stages when the process is potentially curable. The levels of plasma D-dimers were shown to have increased in instances of deep venous thrombosis, pulmonary embolism, ischemic cardiac diseases, vasculitides with disseminated intravascular coagulation, trauma and surgical interventions [14]. It must be stressed that coagulation and fibrinolysis activity are increased in the elderly without evident diseases, especially in those with atherosclerotic disease and long-term immobilization [15]. Acute intraabdominal conditions such as severe acute pancreatitis are complicated with disseminated intravascular coagulation with subsequent elevation of D-dimers [16]. Even patients with intraabdominal malignancies have elevated levels of D-dimers [17, 18]. A study performed by Acosta et al. compared two groups (bowel ischemia with thromboembolic incident of superior mesenteric artery and bowel ischemia with causes other than thromboembolic incident of superior mesenteric artery) with a small number of patients and concluded that patients with thromboembolic incidents have significantly higher levels of D-dimers [19]. This study has some shortcomings. The compared groups included patients with acute abdomen which is a sign of advanced disease. Second, the control group had patients with mechanical obstruction, but not caused with malignancy which causes elevation of D-dimer levels. Furthermore, D-dimer values are lowered by therapeutic doses of warfarin and heparin [20, 21]. Atrial fibrillation is another specific problem. Patients with at least one risk factor for embolism (which includes hypertension and age over 75) had elevated levels of D-dimer compared with patients without any risk factors and with control subjects [22]. Therefore, elevated D-dimers are present in patients with atrial fibrillation without abdominal or other pathology. All these observations made D-dimers not specific for acute mesenteric ischemia as isolated predictor of *early AMI*. In our study 96.8% of patients had aero-liquid levels on plain abdominal radiographs, but it must be remembered that 81% of patients presented with acute abdomen. Therefore, plain abdominal radiographs are diagnostic only in the advanced disease. Ankle brachial index (ABI) less than 0.90 has been used as a sensitive and specific diagnostic tool for peripheral arterial disease with a 5% false-negative rate due to calcification of lower-extremity arteries. The presence of a low ABI was predictive of 3- to 4-fold increase of total and cardiovascular mortality [23–26]. These studies lack the direct correlation between ABI and AMI which could only be assumed by the fact that atherosclerosis is a generalized disease. Prospective studies are necessary to define the correlation between ABI and AMI in patients with severe abdominal pain. Duplex Doppler ultrasound results have been disappointing. The wide range of normal superior mesenteric artery flows (300–600 cc/min) limits its diagnostic value in the acute setting, where no baseline study for comparison is generally available [27]. CT findings suggestive of intestinal ischemia include atherosclerotic disease of intestinal arteries and thrombosis of proximal intestinal arteries, as well as intestinal distention, intestinal wall thickening, intraabdominal fluid and intestinal perforation. These findings may also be present in patients without intestinal ischemia. Findings suggestive of intestinal ischemia include pneumatosis intestinalis and portal venous air, both of which are late findings. Because CT scanning for evaluation of abdominal pain requires administration of intravenous iodinated contrast material, which may affect later arteriography, this test is not the best initial examination for suspected AMI [28]. A study performed by Taourel et al. is the most comprehensive evaluation of the usefulness of CT in the diagnosis of AMI with sensitivity of 64% and specificity of 92% [29]. Abdominal CT has a limited role and is the study of choice only in patients with superior mesenteric vein thrombosis with sensitivity exceeding 90% [10, 11]. Unfortunately the subset of these patients is the smallest (5–10%) [30]. These conclusions are confirmed in practice guidelines published by the American Gastrointestinal Association [2].

It is well established that angiography is the gold standard for the diagnosis and in some cases treatment of AMI, but the main problem, how to, objectively, make an early suspicion of AMI, remains unsolved. Even ACC/AHA 2005 practice guidelines for the management of patients with peripheral arterial disease only state the following: *patients with acute abdominal pain out of proportion to physical findings and who have a history of cardiovascular disease should be suspected of having acute intestinal ischemia (Level of Evidence: B)* [28]. Since the publication of guidelines of the American Gastrointestinal Association in 2000, CT diagnosis of AMI was significantly improved by using multiple detector row computed tomography angiography (MDCTA) with a sensitivity of 96% and specificity of 94% [31]. Another diagnostic modality is 3D contrast-enhanced magnetic resonance (MR) angiography. MR angiography is not indicated in patients with acute symptoms of mesenteric ischemia because this modality does not yet offer sufficient resolution to demonstrate nonocclusive low-flow states or distal emboli [32]. CT seems to be more appropriate because it can simultaneously demonstrate the level of occlusion (arterial or venous) and its ischemic consequences on the bowel [29]. Unfortunately vasospastic ischemia (NOMI) still remains a diagnostic dilemma even with mesenteric MDCTA. A disadvantage of MDCTA is that it depicts the vessels at a single point in time, and the temporal changes in vascular filling that are seen on catheter angiographic images cannot be appreciated. A patient may demonstrate poor opacification of distal SMA branches at CT for a number of reasons, including generalized slow blood flow (as seen, for example, in cardiac disease) or diffuse spasm related to nonocclusive ischemia. Since NOMI follows severe microvascular vasoconstriction, angiography is the only diagnostic modality which reliably establishes an early diagnosis. It is a very important observation because NOMI represents 20% of causes of AMI.

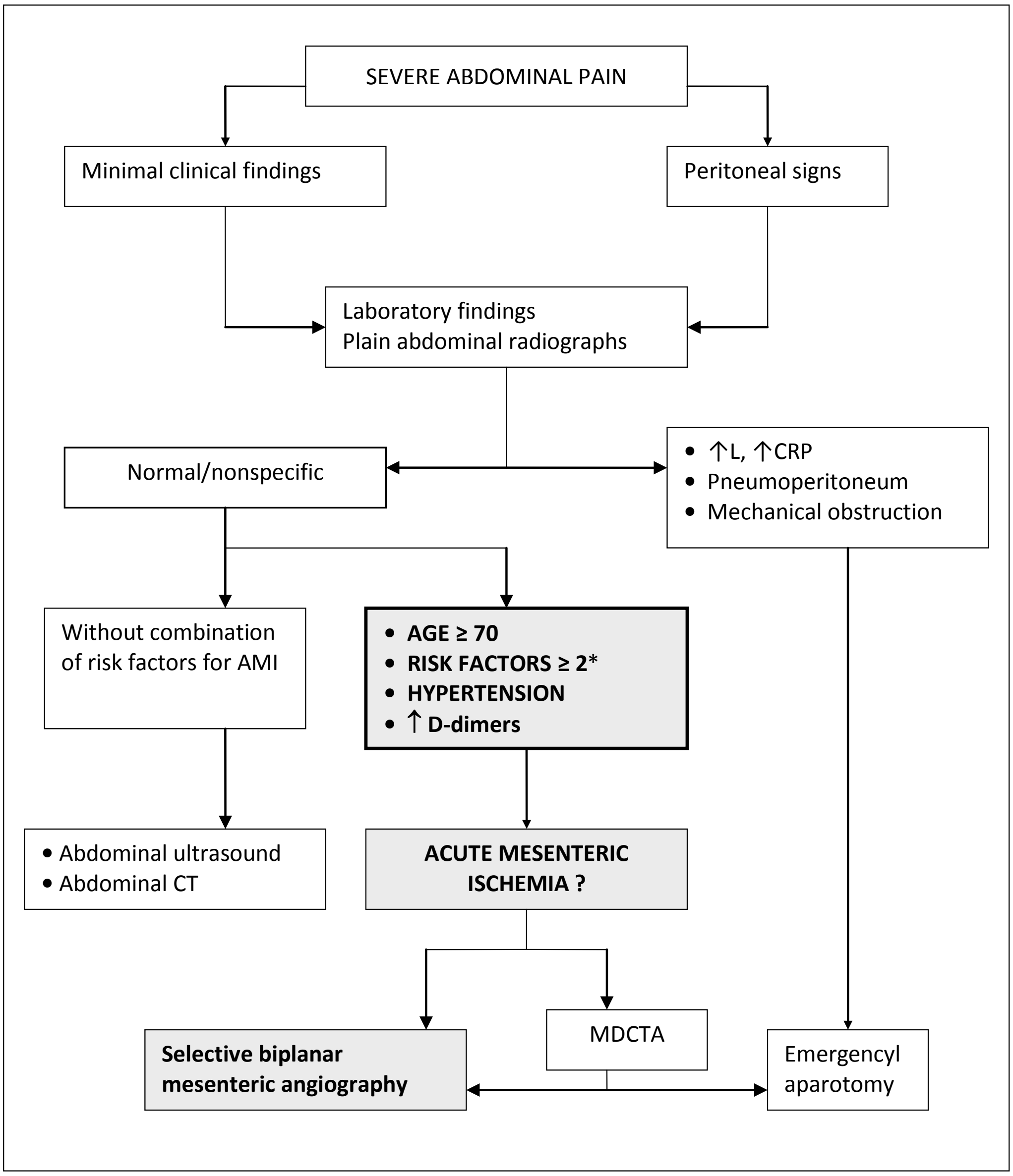
Despite all these advances in noninvasive diagnostic procedures, angiography is still the gold standard because it is reserved for NOMI and equivocal cases and is also used in conjunction with transcatheter therapeutic techniques (PTA/stent placement, thrombolysis and papaverin infusion). Disadvantages of traditional angiography are its limited availability and potential renal toxicity.

Since all clinical, laboratory and imaging diagnostic modalities are not sufficiently helpful, we analysed the known risk factors for AMI. One of the contributing factors of AMI is advanced age. The average age in our study was 77 years (average female age was 10 years higher than average male age; 82 compared to 72 years of age). It is important to take into consideration that 93.5% of patients were 68 years old or older, thus making the age over 70 the first predictor of *early AMI*. Almost all the patients (96.8%) had hypertension and there was only one patient without any other risk factor except hypertension (Table 1). We made hypertension the second predictor of *early AMI*, but it must be present with two other predictors to justify clinical suspicion of *early AMI*.

The main topic of this retrospective study were risk factors for AMI. Unfortunately the patients' medical records showed no subcategorization of AMI. All these categories have slightly different risk factors, so we included all of them in this group of our patients. It is difficult to analyse the impact of a single risk factor on *early AMI*. Obviously, previous abdominal operations or renal insufficiency could not be compared to previous atrial fibrillation, deep vein thrombosis or pulmonary embolism. Also, until prospective, randomized, multicentric studies are made, it is impossible to compare the impact of specific combinations of risk factors on *early AMI*, but our results point out that two or more risk factors were present in 87.2% of patients, thus making the combination of two or more risk factors the third predictor of *early AMI*. Another three patients (9.7%) had a single risk factor present and only one patient was without risk factors. This patient had hypertension and was only 61 years old. Unfortunately analysis of possible etiology including hypercoagulable states was not made on this patient/cadaver. Based on these data, an algorithm for detection of *early AMI* was constructed (Figure 1). This is not the complete algorithm for the diagnosis and treatment of AMI but a part of algorithm which is missing in all algorithms found in literature. A detailed algorithm for AMI from the time of performing selective mesenteric angiography to definite treatment is excellently described in the review by Oldenburg et al. [12].Using this algorithm the number of selective mesenteric angiographies would increase and the number of negative results would be present, but it is necessary to evaluate this algorithm prospectively for conclusions. The problem is that the number of patients with AMI in hospitals is relatively small and prospective studies should be multicentric to obtain statistically significant results and conclusions.

Despite this algorithm with four predictors, there are some shortcomings and limitations. All patients came to the emergency department from home. The patients who had aortoiliac (AMI incidence of 2.8%) or cardiac surgical operations were excluded because of specific pathophysiologic and pathologic conditions [33]. It is well known that AMI should be suspected early in these patients, especially if they are elderly or on intraaortic balloon counterpulsation and having abdominal pain without laboratory or imaging confirmation of other acute abdominal conditions. Also, an identifiable coagulopathy was not searched for in our group of patients. It would be valuable to have these specific coagulation tests and possible deficiencies of coagulation factors, especially in patients with a small number of risk factors and age under 70. Also, re-establishment of flow to infarcted bowel may cause a sudden systemic release of endotoxins, which may be associated with the sudden onset of disseminated intravascular coagulation, adult respiratory distress syndrome and sudden cardiovascular collapse. Therefore, in the presence of infarcted bowel or markedly elevated lactic acid levels, initial angiographic treatment should be weighed against surgical options in which control of the venous outflow (and the endotoxins) from the infarcted bowel segment can be achieved. Another problem exists. The average examination to treatment time (diagnostic period) in our study (and our emergency department) was 12.2 hours (range 4–36 h). If this algorithm is correct then this diagnostic period could be significantly shortened and a part of patients with *early AMI* able to be treated angiographically or surgically. More importantly, a significantly longer period of disease progression is from the onset of abdominal pain to clinical examination in the surgical unit. In our study the average duration of symptoms was 4.6 days (range 5 hours to 10 days with the remark that only two patients

Figure 1.



had symptoms lasting less than 24 hours). This period from when the patient is at home or examined by general physician to being sent to hospital or sequentially examined by the same physician, could be shortened knowing this combination of risk factors for AMI. The importance of this possible algorithm is even more evident when the following facts are known: in one prospective study of acute thromboembolism of the superior mesenteric artery 20 out of 24 patients were evaluated by a total of 48 doctors at their first consultation, of whom 23 were surgical specialists. Sixteen of these patients had to wait a median of 33 h (range 8±188 h) for diagnostic laparotomy and four patients were diagnosed post-mortem [34].

Algorithm for establishing clinical predicament and early diagnosis of acute mesenteric ischemia. L – leukocyte count, CRP – C-reactive protein, AMI – acute mesenteric ischemia, MDCTA – multiple detector row computed tomography angiography.

* See Table 3 for details.

Table 1. Clinical, laboratory parameters and risk factors.

Age	Sex	Duration	Diag. period	Perit. irrit.	WBC	Hct	CRP	H	AF	MI	VD	Abd. op.	DVT	PE	RI	Digitalis	Stroke	Second look
99	F	12 h	8 h		12.9	0.50	20	1				C				1		
79	M	10 d	9 h	1	13.1	0.32	225					PVU			1			
85	F	2 d	30 h	1	20.4	0.31	16	1	1									
81	F	10 d	10 h	1	19.5	0.35	50	1	1							1		
89	F	8 d	15 h	1	16.5	0.40	30	1	1								1	
87	F	24 h	9 h	1	19.5	0.40	25	1	1	1	1					1		
80	M	30 h	30 h	1	5.0	0.38	280	1	1					1	1	1	1	
78	F	3 d	36 h	1	27.9	0.38	384	1	1							1		
83	M	24 h	11 h	1	27.5	0.38	211	1	1	1			1					
78	F	36 h	10 h	1	12.5	0.38	143	1	1			C, S				1		
61	M	3 d	36 h	1	30.5	0.35	101	1		1		C	1		1		1	
61	M	3 d	10 h		9.5	0.45	13	1										
42	M	10 d	15 h	1	31.0	0.40	58	1						1				1
78	F	3 d	15 h	1	15.0	0.49	290	1	1							1		
71	F	1 d	6 h	1	20.0	0.36	158	1						1			1	
72	M	8 d	8 h	1	18.6	0.45	89	1					1					
71	M	6 d	10 h	1	17.9	0.35	60	1	1						1	1		1
90	F	8 d	5 h	1	16.7	0.40	222	1	1			C	1					
98	F	10 d	6 h	1	6.5	0.30	189	1		1		A		1	1	1	1	
68	M	10 d	8 h	1	13.3	0.35	170	1		1				1				
70	M	10 d	4 h		15.5	0.40	90	1		1		C			1			
77	F	3 d	8 h	1	31.0	0.35	90	1	1			C						
81	F	5 d	8 h	1	6.5	0.40	70	1	1				1	1			1	
86	M	5 h	20 h		28.6	0.35	35	1	1		1	A						1
82	F	5 d	10 h	1	16.4	0.51	150	1	1			C		1		1		
79	F	10 d	10 h		18.8	0.35	56	1	1					1		1		1
69	F	3 d	6 h	1	5.9	0.33	36	1	1			A	1		1	1	1	1
73	M	1 d	6 h		6.3	0.35	89	1	1	1								1
70	M	3 d	8 h	1	18.3	0.38	130	1						1	1			
76	F	1 d	6 h	1	16.3	0.40	228	1	1	1			1		1		1	
86	M	1 d	6 h	1	15.4	0.30	160	1	1			G						
77	M 45.2%	4.6 d	12.2 h	81%	17.1	0.38	125	96.8%	64.5%	25.8%	6.5%	32.2%	22.6%	29.0%	29.0%	38.7%	25.8%	19.4%

Abbreviations: WBC, white blood count; Hct, hematocrit, CRP, C-reactive protein; H, hypertension (> 140/90 mm Hg); AF, atrial fibrillation; MI, myocardial infarction; VD, ventricular/structural cardiac defect; DVT, deep vein thrombosis; PE, pulmonary embolism; RI, renal insufficiency; C, cholecystectomy; A, appendectomy; G, gynecologic operation; S, splenectomy; PVU, perforated ventricular ulcer; Average values are in the last row and bold type.

Table 2. Risk factors with their occurance rate and combination of risk factors with incidence and cumulative incidence of ≥ 2 risk factors.

Risk factors	Incidence		Combination	Incidence
Arterial hypertension	96.8%	(30/31)	2 risk factors	38.7% (12/31)
Atrial fibrillation Digitalis	64.5%	(20/31)	3 risk factors	19.4% (6/31)
Abdominal operation	38.7%	(12/31)	4 risk factors	12.9% (4/31)
Pulmonary embolism Renal insufficiency	32.2%	(10/31)	5 risk factors	9.7% (3/31)
	29.0%	(9/31)	6 risk factors	6.5% (2/31)
Myocardial infarction Stroke	29.0%	(9/31)		
Deep venous thrombosis	25.8%	(8/31)	**≥ 2 risk factors**	**87.2%**
Valvular/structural Cardiac disease	25.8%	(8/31)		
	22.6%	(7/31)		
	6.5%	(2/31)		

Table 3. Risk factors distribution according to underlying cause of acute mesenteric ischemia.*

Cause	Arterial embolism	Arterial thrombosis	Nonocclusive	Venous thrombosis
Incidence, %	40–50	25	20	10
Risk factors	Dysrhythmia Myocardial infarction Rheumatic valve disease Endocarditis Cardiomyopathies Ventricular aneurysms Previous embolic events Recent angiography Renal insufficiency Stroke	Atherosclerosis Prolonged hypotension Estrogen Hypercoagulability Stroke	Hypovolemia Hypotension Lw cardiac output status α-adrenergic agonists Digoxin β-blocking agents Cardiopulmonary bypass Renal insufficiency Hemodialysis Critcally ill Cocaine use Stroke	Right-sided heart failure Previous deep vein thrombosis or pulmonary embolism Portal hypertension Intraabdominal malignancy Hepatitis Pancreatitis Recent abdominal surgery or infection Splenectomy Estrogen Polycythemia Sickle cell disease Vasculitides Hypercoagulability Nephrotic syndrome Blunt abdominal trauma

** Some risk factors are present in more than one etiology of AMI making the precise diagnosis of the underlying cause of acute mesenteric ischemia difficult.*

References

1. Schneider TA, Longo WE, Ure T, Vernava AM III. Mesenteric ischemia: acute arterial syndromes. Dis Colon Rectum 1994;37: 1163–1174.
2. Brandt LJ, Boley SJ. AGA technical review on intestinal ischemia. Gastroenterology 2000;118: 954–968.
3. Lock G. Acute intestinal ischaemia. Best Pract Res Clin Gastroenterol 2001;15: 83–98.
4. Corder AP, Taylor I. Acute mesenteric ischaemia. Postgrad Med J 1993;69: 1–3.
5. Bjorck M, Troeng T, Berqvist D. Risk factors for intestinal ischemia after aortoiliac surgery: a combined cohort and case control study of 2824 operations. Eur J Vasc Surg 1997;13: 531–539.
6. Smerud MJ, Johnson CD, Stephens DH. Diagnosis of bowel infarction: a comparison of plain films and CT scans in 23 cases. Am J Radiol 1990;154: 99–103.
7. Lund EC, Han SY, Holley HC, Berland LL. Intestinal ischemia: comparison of plain radiographic and computed tomographic findings. Radiographics 1988;8: 1083–1108.

8. *Wolf EL, Sprayregen S, Bakal CW. Radiology in intestinal ischemia: plain film, contrast, and other imaging studies. Surg Clin North Am 1992;72: 107–124.*
9. *Kaleya RN, Boley SJ. Acute mesenteric ischemia. Crit Care Clin 1995;11: 479–512.*
10. *Harward TR, Green D, Bergan JJ, Rizzo RJ, Yao JS. Mesenteric venous thrombosis. J Vasc Surg 1989;9: 328–333.*
11. *Vogelzang RL, Gore RM, Anschuetz SL, Blei AT. Thrombosis of the splanchnic veins: CT diagnosis. Am J Roentgenol 1988;150: 93–96.*
12. *Oldenburg WA, Lau LL, Rodenburg TJ, Edmonds HJ, Burger CD. Acute mesenteric ischemia: a clinical review. Arch Intern Med 2004;164: 1054–1062.*
13. *Bulkley GB, Zuidema GD, Hamilton SR, O'Mara CS, Klacsmann PG, Horn SD. Intraoperative determination of small intestinal viability following ischemic injury: a prospective, controlled trial of two adjuvant methods (Doppler and fluorescein) compared with standard clinical judgment. Ann Surg 1981;193: 628–637.*
14. *Saito T, Tsuchiya M, Shikata C, et al. Microscopic polyangiitis associated with marked systemic bleeding tendency caused by disseminated intravascular coagulation. Intern Med 2003;42: 850–855.*
15. *Kario K, Matsuo T, Kobayashi H. Which factors affect high D-dimer levels in the elderly? Thromb Res 1991;62: 501–508.*
16. *Maeda K, Hirota M, Ichihara A, et al. Applicability of disseminated intravascular coagulation parameters in the assessment of the severity of acute pancreatitis. Pancreas 2006;32: 87–92.*
17. *Di Micco P, Romano M, Miglio A, et al. Alteration of haemostasis in non-metastatic gastric cancer. Dig Liver Dis 2001;33: 546–550.*
18. *Oya M, Akiyama Y, Okuyama T, Ishikawa H. High preoperative plasma D-dimer level is associated with advanced tumor stage and short survival after curative resection in patients with colorectal cancer. Jpn J Clin Oncol 2001;31: 388–394.*
19. *Acosta S, Nilsson TK, Bjorck M. Preliminary study of D-dimer as a possible marker of acute bowel ischaemia. Br J Surg 2001;88: 385–388.*
20. *Li-Saw-Hee FL, Blann AD, Lip GY. Effects of fixed low-dose warfarin, aspirin-warfarin combination therapy, and dose-adjusted warfarin on thrombogenesis in chronic atrial fibrillation. Stroke 2000;31: 828–833.*
21. *Couturand F, Kearon C, Bates SM, Ginsberg JS. Decrease in sensitivity of D-dimer for acute venous thromboembolism after starting anticoagulant therapy. Blood Coagul Fibrinolysis 2002;13: 241–246.*
22. *Inoue H, Nozawa T, Okumura K, et al. Prothrombotic activity is increased in patients with nonvalvular atrial fibrillation and risk factors for embolism. Chest 2004;126: 687–692.*
23. *Newman AB, Siscovick DS, Manolio TA, et al. Ankle-arm index as a marker of atherosclerosis in the Cardiovascular Health Study. Cardiovascular Heart Study (CHS) Collaborative Research Group. Circulation 1993;88: 837–845.*
24. *Newman AB, Sutton-Tyrrell K, Vogt MT, Kuller LH. Morbidity and mortality in hypertensive adults with a low ankle/arm blood pressure index. JAMA 1993;270: 487–489.*
25. *McKenna M, Wolfson S, Kuller L. The ratio of ankle and arm arterial pressure as an independent predictor of mortality. Atherosclerosis 1991;87: 119–128.*
26. *Sikkink CJ, Van Asten WN, Van't Hof MA, et al. Decreased ankle/brachial indices in relation to morbidity and mortality in patients with peripheral arterial disease. Vasc Med 1997;2: 169–173.*
27. *Qamar MI, Read AE, Skidmore R, et al. Transcutaneous Doppler ultrasound measurement of superior mesenteric artery blood flow in man. Gut 1986;27: 100–105.*
28. *Hirsch AT, Haskal ZJ, Hertzer NR, et al. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease. Circulation 2006;113: e463–e654.*
29. *Taourel PG, Deneuville M, Pradel JA, et al. Acute mesenteric ischemia: diagnosis with contrast-enhanced CT. Radiology 1996;199: 632–636.*
30. *Stoney RJ, Cunningham CG. Acute mesenteric ischemia. Surgery 1993;114: 489–490.*
31. *Kirkpatrick ID, Kroeker MA, Greenberg HM. Biphasic CT with mesenteric CT angiography in the evaluation of acute mesenteric ischemia: initial experience. Radiology 2003;229: 91–98.*
32. *Gilfeather M, Holland GA, Siegelman ES, et al. Gadolinium-enhanced ultrafast three-dimensional spoiled gradient-echo MR imaging of the abdominal aorta and visceral and iliac vessels. Radiographics 1997;17: 423–432.*
33. *Bjorck M, Bergqvist D, Troeng T. Incidence and clinical presentation of bowel ischaemia after aortoiliac surgery – 2930 operations from a population-based registry in Sweden. Eur J Vasc Endovasc Surg 1996;12: 139–144.*
34. *Acosta S, Bjorck M. Acute thrombo-embolic occlusion of the superior mesenteric artery: a prospective study in a well defined population. Eur J Vasc Endovasc Surg 2003;26: 179–183.*