ORIGINAL PAPER

The Surgical Management of Acute Mesenteric Ischemia - a Retrospective Study in a 2nd Grade Emergency Hospital

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Abstract

Introduction: Acute mesenteric ischemia represents one of the most severe pathological entity that needs rapid diagnosis and initiation of treatment in order to reduce the mortality rate and the long-term morbidity. **Material and method:** A monocentric, retrospective study that included 68 patients with acute mesenteric ischemia with or without bowel infarction has been undertaken within the General Surgery Department of the "Sfântul Pantelimon" Clinical Emergency Hospital from Bucharest, Romania, between January 2014 and January 2019, a 2nd grade hospital, according to the provisions of the Order of the Ministry of Public Health no. 1764 of 22 December 2006 on the approval of criteria for the classification of local, county and regional emergency hospitals in terms of competences, material and human resources and their capacity to provide emergency medical care and medical care for patients in critical condition, published in the Federal Law Gazette of Romania, Part I, no. 63 of 26 January 2007.

Results and conclusions: Acute mesenteric ischemia is associated with poor outcomes, high morbidity and mortality rates, making the early diagnosis and treatment initiation imperative in order to prevent severe complications, such as transmural bowel infarction, and, thus, potentially decreasing the morbidity and mortality rates.

Keywords: acute mesenteric ischemia, bowel infarction, surgery, treatment.

Rezumat

Introducere: Ischemia acută mezenterică reprezintă una dintre cele mai grave entități patologice ce necesită diagnostic rapid și tratament în regim de urgență în scopul reducerii morbidității și mortalității. **Material și metodă:** Un studiu monocentric, retrospectiv, ce a inclus datele a 68 de pacienți cu ischemie acută mezenterică cu sau fără infarct intestinal, a fost realizat în perioada Ianuarie 2014-Ianuarie 2019, în cadrul Departamentului de Chirurgie Generală a Spitalului Clinic de Urgență „Sf. Pantelimon” din București, România, un spital de nivel 2 conform Ordinului Ministerului Sănătății Nr. 1764 din 22 Decembrie 2006, publicat în Monitorul Oficial al României, Partea I, Nr. 63 din 26 Ianuarie 2007, în ceea ce privește capacitatea de a furniza îngrijire medicală în urgență pentru pacienții critici. **Rezultate și concluzii:** Ischemia acută mezenterică prezintă prognostic infaust, rate ridicate ale morbidității și mortalității, elemente ce susțin importanța stabilirii precoce a diagnosticului și a strategiei terapeutice în scopul prevenirii complicațiilor severe, de tipul infarctului intestinal transmural, și, astfel, diminuând ratele morbidității și mortalității.

Cuvinte cheie: ischemie acută mezenterică, infarct intestinal, chirurgie, tratament.

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INTRODUCTION

Acute mesenteric ischemia represents one of the most severe pathological entity that needs rapid diagnosis and initiation of treatment in order to prevent mortality and reduce long-term morbidity. Recent studies often use the expression “Time is bowel”, taking into account the high morbidity and mortality rates of the disease and the need for emergent management¹.

The annual reported incidence of the disease is 0.09-0.2%, representing approximately 1% of the total acute abdomen hospitalizations. The mortality rate associated with acute mesenteric ischemia within the first 24 hours has been estimated between 60-80%, taking into consideration the high probability of cases of missed diagnosis².

Four entities have been identified in the etiology of the acute mesenteric ischemia: the arterial embolism, the arterial thrombosis, the venous thrombosis and the non-occlusive mesenteric ischemia, with no history or physical examination findings that can definitively lead to the early clinical diagnosis of the medical condition. Frequently encountered symptoms and signs in the early phases of the disease are represented by severe pain, gut emptying and minimal tenderness on examination. Peritoneal signs may occur after the transmural infarction of the bowel. The presence of the risk factors, such as severe comorbidities, peripheral vascular disease, coronary artery disease, heart arrhythmia, end-stage renal disease, dialysis, and hypercoagulable states, may be of help in the process of diagnosis. Computed tomography angiography represents the best imaging technique for the diagnosis of the acute mesenteric ischemia, while laboratory tests do not have sufficient sensitivity and specificity rates for ruling out or in the disease. The optimal treatment algorithm includes surgery, interventional radiology, intra-venous antibiotics, hydric and electrolytic rebalancing and anticoagulation.

Judging by the fact that the general population around the world is growing older, its incidence is continually increasing. Unfortunately acute mesenteric ischemia is associated with a wide variety of nonspecific symptoms and signs that overlap with other pathologies, thus representing a great challenge even for the quick and highly experienced clinicians and surgeons, thus associating high morbidity and mortality rates. The aim of the present study is to evaluate the incidence, the morbidity and mortality rates and the therapeutic options for patients with acute mesenteric ischemia with or without transmural bowel infarction in the context of a 2nd grade clinical hospital, also pre-

sending the novel therapeutic options recommended by recently published international guidelines.

MATERIAL AND METHOD

Anonymous data taken from the InfoWord Data Base of the General Surgery Department of the “Sfântul Pantelimon” Emergency Hospital from Bucharest, Romania, were used in order to elaborate the present study. The ICD-10 diagnostic codes (International Code of Disease - 10th Edition: K55.0 – bowel infarction, K55.1- vascular disorders of the intestine, I74 – arterial embolism and thrombosis, I82 – other venous embolism and thrombosis 3) and the ROv1DRG Surgical Codes (J045 – small bowel resection with anastomosis or with stoma formation, J062- colectomy with anastomosis or stoma formation, J12101- exploratory laparotomy 4) were used in order to search for the patients, thus providing information on the etiology and the surgical intervention. The results were useful in identifying the patients with acute mesenteric ischemia with or without transmural bowel infarction that have been admitted in the General Surgery Department of „Sf. Pantelimon” Emergency Hospital from Bucharest, Romania, between January 2014 and January 2019, their evolution being followed-up for approximately 5 months. According to the provisions of the Order of the Ministry of Public Health no. 1764 of 22 December 2006 on the approval of criteria for the classification of local, county and regional emergency hospitals in terms of competences, material and human resources and their capacity to provide emergency medical care and medical care for patients in critical condition, published in the Federal Law Gazette of Romania, Part I, no. 63 of 26 January 2007, the „Sf. Pantelimon” Emergency Hospital from Bucharest has been estimated as being part of the 2nd grade category⁵.

Using the variables resulted from the analysis of the database, the mean age, the anatomical site of the ischemia or necrosis, the type and the time of the surgical intervention, the risk of intra- and postoperative complications and the duration of hospitalization were estimated the statistical algorithm being created using Microsoft Office Excel Software 2013. The long-term evolution has been estimated by strictly monitoring the readmissions within the General Surgery Department.

Taking into consideration the data resulted and comparing it to the total admissions in the General Surgery Department in the study interval, the incidence and the general mortality rate could be estimated.

The right of individual confidentiality has been respected for every patient included in the study. The informed consent of each patient, for any diagnostic maneuver or therapeutic procedure, has been, previously, obtained. The study protocol respects the ethical guidelines of the Declaration of Ethics adopted by the 18th WMA General Assembly, Helsinki, Finland, June 1964, and amended by WMA General Council of Fortaleza, Brazil, 2013 at the 64th edition (64th WMA General Assembly, Fortaleza, Brazil, October 2013).

RESULTS

Between January 2014 and January 2019, there were 30425 patients undergoing major surgical interventions, admitted in the General Surgery Department of the „Sf. Pantelimon” Emergency Clinical Hospital from Bucharest, with 68 cases of acute mesenteric ischemia with or without total transmural bowel infarction that were included in the study population.

The demographic characteristics of the study group (mean age, mean body mass index (BMI), female: male ratio (F: M) and mean ASA score (American Society of Anesthesiology) are shown in Table 1.

Table 1. The demographic characteristics of the study group

The demographic characteristics	Value
Mean age	76 ± 4.2 years
BMI	25.3 kg/m ²
F:M	22: 19
ASA score	
ASA II (%)	19 (27.94%)
ASA III (%)	31 (45.58%)
ASA IV (%)	18 (26.47%)

All patients included in the study had, at the time of admission, diffuse abdominal pain of increased intensity, signs of peritoneal irritation being present in 42.64% of cases (29 patients) during the physical examination.

The pathological variables observed in the study population, such as the type of histological lesion (ischemia/ infarction), the site of anatomical changes, concomitant lesions, and comorbidities, are shown in Table 12. Thus, 6 patients (8.82%) had ischemia, for the rest of the cases (91.17%) the lesions evolving to the stage of transmural intestinal necrosis (Figures 1, 2).

The concomitant lesions, such as the obstructing sigmoid adenocarcinoma were observed in one case, the perforation and the peritonitis being objectified in 29 of the patients included in the study. From the personal pathological history, cardiac arrhythmias (of the type of atrial fibrillation) or coronaropathies under chronic treatment with oral anticoagulants, have been identified as risk factors for acute mesenteric ischemia, in most cases (67 patients from the total study group).

From the analysis of the data presented in Figure 3 it can be deduced that most ischemic or necrosis lesions are extensive.

The 6 patients with acute mesenteric ischemia without transmural intestinal necrosis benefited from upper mesenteric artery embolectomy with a Fogarty catheter, in two cases (with 1 recorded death), and from exploratory laparotomy, associating anticoagulant or hydroelectric re-balancing therapy, with or without surgical reintervention with segmental enterectomy for the lesions that evolved to transmural necrosis (at 24 hours or at 14 days), in 4 cases (3 deaths recorded in this group) (Table 3).

Table 2. The pathological variables of the study population

Pathological variables	Number of patients (%)	
Type of the lesion	Ischemia	6 (8.82%)
	Infarction	62 (91.17%)
The anatomical site of the lesion	Small bowel	24 (35.29%)
	Large bowel	9 (13.23%)
	Omentum	1 (1.47%)
	Extended/ total	34 (50%)
Concomitant lesions/ Complications	Perforation	3 (4.41%)
	Peritonitis	26 (38.23%)
	Obstructing sigmoidian adenocarcinom	1 (1.47%)
Commorbidities	Cardiac arrhythmias	39 (57.35%)
	Vasculopathies (Takayasu Disease)	1 (1.47%)
	Coronaropathies	27 (39.7%)
	Coagulopathies	1 (1.47%)

Figure 1. The intraoperative (laparoscopic) macroscopic aspect of the extended infarction of the terminal ileum (image from the author's collection).

Figure 2. The intraoperative macroscopic aspect of the extended small bowel infarction (image from the author's collection).

The 62 patients from the study that had transmural intestinal necrosis underwent a certain type of surgical intervention, according to the extension of the lesion; in this respect, there have been registered 13 cases of segmental/ extended enterectomy, 10 cases of right hemicolectomy with ileotransverse anastomosis, 2 cases of right hemicolectomy with terminal ileostomy, 1 patient with enteroraphy with upstream jejunostomy, Hartman intervention in 3 cases, total omentectomy in one patient, total colectomy with terminal ileostomy for 30 patients. The types of surgical interventions recorded in the study population are shown in Table 3.

1 case benefited from „damage-control” surgery (open abdomen using Bogota Bag technique after exploratory laparotomy – Figure 4) and 3 patients from the study population underwent surgical re-intervention in order to reassess intestinal viability with or without recalibrating the enterectomy.

Thus, 59 deaths were recorded in the studied group, the calculated mortality rate being 86.76%.

The 9 surviving patients presented, during the course of the postoperative evolution, the following postoperative complications: surgical short bowel syndrome with malabsorption and protein-caloric malnutrition, postoperative wound infection, fixed evisceration and incisional hernia (Table 4).

DISCUSSION

Acute mesenteric ischemia can be defined as abrupt interruption of vascularization at the level of an intestinal segment, resulting in ischemia, cell injury, intestinal

Table 3. The types of surgical interventions in the study population

Type of lesion	Type of surgical intervention	Number of patients	Deaths
Ischemia	Embolectomy of the superior mesenteric artery using the Fogarty catheter	2	1
	Exploratory laparotomy+ conservative treatment	2	1
	Exploratory laparotomy+ reintervention with segmental/ extended enterectomy	2	1
Necrosis	Segmental/ extended enterectomy	13	13
	Enteroraphy with jejunostomy	1	1
	Right hemicolectomy with anastomosis/ ileostomy	12	8
	Hartman intervention	3	3
	Total omentectomy	1	0
	Segmental colectomy	1	0
	Total colectomy with ileostomy	1	1
	Exploratory laparotomy	30	30
Total		68	59

Figure 3. The distribution of the patients judging by the site of the ischemic or necrotic lesion.

necrosis and, in the absence of correct and rapid treatment, death. Acute mesenteric ischemia may be non-occlusive or occlusive, with primary etiology such as mesenteric artery embolism (50%), mesenteric arterial thrombosis (15-25%) or mesenteric venous thrombosis (5-15%)^{7,8}.

The incidence is low (between 0.09 and 0.2% of total admissions in emergency units), representing a rare cause of severe abdominal pain, the data resulting from the statistical analysis of the present study being similar to those reported by the international specialized literature⁹.

Early diagnosis and rapid treatment initiation are the key elements for reducing the high mortality rates by 50-80%, according to recent studies¹⁰.

At present, there is no standardized guide for evaluation and treatment of patients with high suspicion of acute mesenteric ischemia, the valid data being based mainly on institutional reviews, case studies and personal recommendations. The purpose of the present study is to evaluate the incidence, the evolution, the morbidity and mortality rates for acute mesenteric ischemia, whether or not associated with transmural intestinal infarction, within a level 2 hospital unit, reporting the data to the international literature, through a review of the literature, mentioning the recommendations of recently published diagnostic-therapeutic guidelines.

The superior mesenteric artery represents the main arterial source for the small bowel, being supplemented by collaterals from the celiac artery system, by the upper and lower pancreatic-duodenal arteries, and by the inferior mesenteric artery. The venous return from the intestinal territory is done through the portal vein.

Table 4. The postoperative complications in the group of the surviving patients

Postoperative complications	Number of patients
Short bowel syndrome	2
Postoperative wound infection	1
Fixed evisceration	2
Incisional hernia	3

Splanchnic circulation receives about 15-35% of the cardiac output, but the extraction of oxygen at the intestinal level is relatively small, so that a reduction of arterial vascularization of more than 50% is required for the occurrence of ischemic lesions. Experimental studies have shown that mesenteric ischemia occurs only at an average patient blood pressure of <44 mmHg, the small intestine having the ability to compensate for 12 hours a 75% reduction of the mesenteric flow^{11,12}.

Mesenteric artery embolism

About 50% of all mesenteric ischemia cases are caused by acute mesenteric artery embolism. The origin of embolism may be represented by the left atrium, in the context of cardiac arrhythmias (atrial fibrillation), myocardial dysfunction in the left ventricle, complicated cardiac valves with endocarditis or aortic atherosclerosis. Most emboli are implanted 3-10 cm distal to the origin of the superior mesenteric artery, usually sparing the proximal jejunum and colon. Over 20% of the cases of embolism of the superior mesenteric artery associate the embolism of the arterial bed at the level of the spleen or kidneys⁸.

Figure 4. Bogota Bag technique using a pre-sterilized, soft, 2L intravenous bag. (Image from [6]).

Mesenteric artery thrombosis

Superior mesenteric artery thrombosis is involved in approximately 25% of mesenteric ischemia cases, usually associating preexisting chronic atherosclerotic disorders with consecutive arterial stenosis. Most patients in this group have chronic abdominal pain in the recent history, especially after meal ingestion, weight loss, and „fear of eating.” Thrombosis occurs at the origin of distal arteries, progressive stenosis of the superior mesenteric artery through thrombosis resulting in stenosis, over time, of the collateral circulation. Vasculitis, mesenteric dissection, and mycotic aneurysms are other possible causes of superior mesenteric artery thrombosis. Involvement of the ileocolic artery causes necrosis of the terminal ileum and proximal colon¹³.

Non-occlusive mesenteric ischemia

Non-occlusive mesenteric ischemia occurs in 20% of cases, usually being a consequence of superior mesenteric artery vasoconstriction associated with reduced splanchnic blood flow, frequently causing ischemia and necrosis of the proximal colon by affecting ileocolic artery. Patients with non-occlusive mesenteric ischemia are critical patients with severe heart failure, possibly aggravated by sepsis. Hypovolemia and the use of vasoconstrictive agents may exacerbate non-occlusive mesenteric ischemia¹³.

Mesenteric venous thrombosis

Mesenteric venous thrombosis represents approximately 10% of the causes of mesenteric infarction. The thrombosis may be secondary to a combination of the

Virchoff triad (venous stasis, hypercoagulability, vascular inflammation), but in 20% of cases it is idiopathic. Hypercoagulability may be congenital (Leiden factor V, prothrombin mutations, C or antithrombin protein deficiency, antiphospholipid syndrome) or acquired (neoplasms, haematological disorders, oral contraceptives). High blood pressure, pancreatitis, inflammatory bowel disease, sepsis and trauma can alter the vascular flow, intestinal edema and increased vascular resistance secondary to venous thrombosis determining reduced arterial flow with intestinal ischemia¹³.

Early diagnosis, based on a high level of clinical suspicion, is the essential element to ensure the favorable evolution of the patients.

Severe abdominal pain, with disproportionate intensity to the clinical examination data, represents the classic scenario in acute mesenteric ischemia. The presence of signs of peritoneal irritation leads to the diagnosis of irreversible ischemia with parietal necrosis of the intestine and peritonitis. A recent study on acute mesenteric ischemia has shown that 95% of patients had abdominal pain, 44% nausea, 35% vomiting, 35% diarrhea and 16% rectal bleeding, for one third of the cases the triad of abdominal pain- fever- positive Fecal Occult Blood Test being present¹⁴.

A variability of the clinical picture was observed depending on the cause of the mesenteric ischemia. Thus, patients with arterial thrombosis usually report chronic postprandial abdominal pain and progressive weight loss, with or without mesenteric revascularization procedures in the personal surgical history, for patients with non-occlusive mesenteric ischemia the pain being diffuse and episodic, the patients with thrombosis of the mesenteric vein presenting nausea, vomiting, diarrhea and abdominal cramps. About 50% of patients with embolism of the superior mesenteric artery have a personal history of atrial fibrillation.

Conventional radiological techniques have limited diagnostic value in mesenteric ischemia, being able to show signs of intestinal perforation.

There are no specific and sensitive laboratory data for establishing or excluding the diagnosis of ischemia or intestinal necrosis, the high levels of L-lactate or D-dimers having only an indicative value. Over 90% of patients with mesenteric ischemia have leukocytosis.

Emergency computerized angiography is indicated for all patients with suspected acute mesenteric ischemia, representing the diagnostic method of choice, the main disadvantage being the need of experienced personnel in carrying out the investigation and interpre-

ting the results, which is why it was not possible to perform the angiography for the patients included in the present study. Renal insufficiency does not contraindicate the angiography, given the benefits that outweigh the risks (sensitivity of 93%, specificity of 100%, positive and negative predictive value of 100% and 94%, respectively)¹⁵.

After establishing the diagnosis of acute mesenteric ischemia, it is imperative to initiate the hydroelectrolytic rebalancing treatment with crystalloid solutions and blood transfusion (to prevent cardiovascular collapse during anesthetic induction) and to mount the nasogastric tube for decompression. Vasopressors are to be avoided, being indicated only in the case of volume overload and installation of abdominal compartment syndrome. Dobutamine, Dopamine in low doses and Milrinone used to improve cardiac function have not shown beneficial results on mesenteric flow.

Broad spectrum antibiotics should be given immediately and, in the absence of contraindications, patients should undergo intravenous anticoagulant treatment with unfractionated heparin (mesenteric ischemia causes loss of mucosal barrier, facilitating bacterial translocation and increased risk of septic complications).

Emergency exploratory laparotomy is indicated for all patients with signs of peritoneal irritation. The goal of the surgical treatment in mesenteric ischemia is to restore the vascular supply to the ischemic intestinal tract, to resect non-viable regions and to preserve viable intestinal segments. Intestinal viability is the main determining factor for the evolution of patients. Intraoperative non-recognition of the non-viable bowel segment leads to multiple organ failure and death. Thus, emergency laparotomy allows rapid assessment of the intestinal viability. Intraoperative Doppler ultrasound allows the evaluation of the signals in the distal branches of the superior mesenteric artery.

Techniques used to restore arterial circulation are represented by embolectomy with or without primary or patch angioplasty (in case of superior mesenteric artery embolism), bypass procedures (in superior mesenteric artery thrombosis). Endovascular revascularization procedures may be beneficial in cases of partial arterial obstruction. Non-occlusive mesenteric ischemia and venous thrombosis do not benefit from revascularization procedures.

„Damage-control” surgery is an effective method for patients with severe sepsis or those who need surgery to re-evaluate the intestinal viability. Different types of abdominal closure techniques have been described,

the principle of all these methods being to ensure constant traction of the fascia to facilitate the closure of the abdominal wall. Scheduled surgical reintervention is an essential aspect in the management of patients with acute mesenteric ischemia, having the potential to prevent extended bowel resection.

The extended entero-mesenteric infarction in the small intestine with / without the large intestine can, also, be approached from a philosophical perspective by the surgeon: the resection of the entire small intestine leads to short bowel syndrome and its severe pathophysiological consequences, a situation to be avoided, preferably, in elderly patients or in those with multiple comorbidities, that could not tolerate the long-term parenteral nutrition. A detailed discussion with the patient and his / her family, during the preoperative period, is necessary in order to bring awareness of the high postoperative morbidity and to establish, through a detailed agreement, an optimal therapeutic management plan.

CONCLUSIONS

- Acute mesenteric ischemia represents a surgical emergency with an average incidence of 0.2% and a high mortality rate (80%).
- Abdominal pain with sudden onset and high intensity (in the absence of a relevant clinical examination), acidosis and multiple organ failure leads to the diagnosis of acute mesenteric ischemia and indicates computerized angiography evaluation, with or without 3D reconstruction.
- Clinical data can guide to the etiology of the acute mesenteric ischemia: arterial embolism, arterial thrombosis, non-occlusive mesenteric ischemia, venous thrombosis.
- Classical radiological techniques and laboratory data have limited diagnostic value.
- In parallel with the hydro- electrolytic resuscitation and after angiographic evaluation, it is necessary to determine the intestinal viability, the vascular flow and the level of intestinal resection.
- Broad spectrum antibiotics and anticoagulant treatment should be initiated immediately after the diagnosis is established.
- The exploratory laparotomy is of absolute indication in emergency surgery, in the presence of signs of peritoneal irritation.
- Damage-control surgery has an adjuvant role for patients requiring re-evaluation of the intesti-

nal viability or for those with refractory sepsis. Scheduled surgical reintervention is a frequent part of the therapeutic algorithm for mesenteric ischemia.

- In the case of extended intestinal necrosis with indication of extended/ total enterectomy, careful evaluation of the benefit-risk ratio is an essential element in establishing the optimal therapeutic algorithm.

Compliance with ethics requirements: The authors declare no conflict of interest regarding this article. The authors declare that all the procedures and experiments of this study respect the ethical standards in the Helsinki Declaration of 1975, as revised in 2008(5), as well as the national law. Informed consent was obtained from all the patients included in the study.

References

1. Meyers SI. Acute embolic and thrombotic mesenteric ischemia. In: Stanley J, Vieth F, Wakefield T, editors. *Current Therapy in Vascular and Endovascular Surgery*. 5th ed. Philadelphia: Elsevier; 2014. p. 718–20.
2. Sise MJ. Acute mesenteric ischemia. *Surg Clin North Am* 2014; 94(1):165–181.
3. <https://www.icd10data.com/ICD10CM/Codes>
4. https://www.hosptm.ro/files/drg/rodrgrv1/Lista_tabelara_a_procedurilor_RODRGv1.pdf
5. Ordinul ministrului sănătății publice nr. 1764 din 22 decembrie 2006: <http://www.sant.ro/informatii-utile/legislatie/legislatie-invigoare/2006/Ordin%20MSP%20nr.%201764%20din%2022%20decembrie%202006.pdf/view>
6. Feliciano D.V., Borraez Gaona O.A. (2018) Origin of the Bogota Bag and Its Application. In: Duchesne J., Inaba K., Khan M. (eds) *Damage Control in Trauma Care*. Springer, Cham
7. Acosta S. Mesenteric ischemia. *Curr Opin Crit Care*. 2015;21:171–178. doi: 10.1097/MCC.000000000000189. [PubMed] [CrossRef] [Google Scholar].
8. Clair DG, Beach JM. Mesenteric Ischemia. *N Engl J Med*. 2016;374:959–968. doi: 10.1056/NEJMra1503884. [PubMed] [CrossRef] [Google Scholar]
9. Duran M, Pohl E, Grabitz K, Schelzig H, Sagban TA, Simon F. The importance of open emergency surgery in the treatment of acute mesenteric ischemia. *World J Emerg Surg*. 2015;26:10–45. [PMC free article] [PubMed] [Google Scholar]
10. Beaulieu RJ, Arnaoutakis KD, Abularrage CJ, Efron DT, Schneider E, Black JH. Comparison of open and endovascular treatment of acute mesenteric ischemia. *J Vasc Surg*. 2014;59:159–164. doi: 10.1016/j.jvs.2013.06.084. [PubMed] [CrossRef] [Google Scholar]
11. Haglund U, Bergqvist D. Intestinal ischemia—the basics. *Langenbeck's Arch Surg*. 1999;384:233–238. doi: 10.1007/s004230050197. [PubMed] [CrossRef] [Google Scholar].
12. van Petersen AS, Kolkman JJ, Meerwaldt R, Huisman AB, van der Palen J, Zeebregts CJ, Geelkerken RH. Mesenteric stenosis, collaterals, and compensatory blood flow. *J Vasc Surg*. 2014;60:111–119. doi: 10.1016/j.jvs.2014.01.063. [PubMed] [CrossRef] [Google Scholar]
13. Kärkkäinen JM, Acosta S. Acute mesenteric ischemia (part I) -incidence, etiologies, and how to improve early diagnosis. *Best Pract Res Clin Gastroenterol*. 2017;31:15–25. doi: 10.1016/j.bpg.2016.10.018. [PubMed] [CrossRef] [Google Scholar]
14. Park WM, Gloviczki P, Cherry KJ, Jr, Hallett JW, Jr, Bower TC, Panneton JM, Schleck C, Ilstrup D, Harmsen WS, Noel AA. Contemporary management of acute mesenteric ischemia: Factors associated with survival. *J Vasc Surg*. 2002;35:445–452. doi: 10.1067/mva.2002.120373. [PubMed] [CrossRef] [Google Scholar]
15. Hagspiel KD, Flors L, Hanley M, Norton PT. Computed tomography angiography and magnetic resonance angiography imaging of the mesenteric vasculature. *Tech Vasc Interv Radiol*. 2015;18:2–13. doi: 10.1053/j.tvir.2014.12.002. [PubMed] [CrossRef] [Google Scholar]