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Acute Mesenteric Infarction: The Chameleon of Acute Abdomen Evaluating the Quality of the Diagnostic Parameters in Acute Mesenteric Ischemia

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Keywords

Acute abdomen · Mesenteric infarction · Mesenteric ischemia · Diagnostic parameter

Abstract

Introduction/Objective: Acute mesenteric ischemia (AMI) is difficult to diagnose. Since the established parameters have low sensitivity and specificity, the aim of this study is to analyze the diagnostic quality of the established parameters of AMI. ***Methods:*** All patients that underwent emergency surgery due to suspected diagnosis of mesenteric ischemia at the University Medical Center Hamburg-Eppendorf between 2008 and 2014 were evaluated. Overall, 275 patients were enrolled and pre-, intra- and postoperative data were evaluated. ***Results:*** In 200 patients, a mesenteric ischemia was confirmed intraoperatively, and 75 patients had no ischemia. Comparing these groups, the rate of patients with pH < 7.2 (25 vs. 12%; $p = 0.021$) and elevated mean CRP level (175 ± 117 mg/L vs. 139 ± 104 mg/L; $p = 0.019$) was significantly higher in ischemic patients. There was no significant difference in the level of preoperative lactate. Concerning abdominal CT scan, a sensitivity and specificity of 61 and 68%, respectively, was found. ***Conclusion:*** New diagnostic parameters are needed. So far, explorative laparotomy is the only reliable diagnostic method to detect mesenteric infarction.

Introduction

Acute mesenteric ischemia (AMI) is a life-threatening surgical emergency, which is difficult to diagnose [1–3]. With an incidence of 0.09–0.2%, it is a rare disease [4]. AMI can grossly be classified into superior mesenteric arterial occlusion (by embolus or thrombosis), superior mesenteric venous thrombosis, and nonocclusive mesenteric ischemia (NOMI) [1, 5, 6].

The survival rate of AMI has not improved in the last 60 years [7]. Prognosis is still poor and the in-hospital mortality is high, ranging from 60 to 90% [8–10]. The poor survival rate of these patients is mainly attributed to the following factors: (1) the inability of early diagnosis; (2) the progression of mesenteric infarction after the op-

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eration; (3) the different findings in preoperative diagnosis of nonocclusive ischemia and occlusive forms; and (4) the existing comorbidities like vascular disease, commonly associated with elderly patients [8, 11].

The clinical presentation of patients with AMI varies. Most commonly, patients present with acute abdominal pain (90%). Forty-seven percent of the patients suffer from vomiting or unspecific symptoms like fever, nausea, diarrhea, and anorexia or may also present with a variety of signs [12]. Approximately 1% of patients with acute abdominal pain have an AMI [13, 14]. Arterial occlusions are associated to cardiac arrhythmias, myocardial infarction, coronary heart disease, and previous emboli [13]. Other predisposing conditions include sepsis, hypotension due to cardiac heart failure, need of norepinephrine, or recent major cardiac or abdominal surgery [10, 13, 15].

Contrast-enhanced computed tomography (CT) and CT angiography are the methods of choice in diagnosing an occlusive arterial or venous mesenteric ischemia [16, 17]. The diagnostic quality of abdominal ultrasound in patients with ischemia is poor [9].

There are no established serum parameters with appropriate sensitivity or specificity for diagnosis of mesenteric ischemia [4, 13, 18]. Although up to 90% of patients with mesenteric ischemia have elevated serum lactate, conversely, patients with acute abdominal pain without mesenteric ischemia often reveal elevated lactate levels too. Accordingly, additional parameters are required to increase diagnostic accuracy [19]. Currently, due to the remaining uncertainty, explorative laparotomy is the gold standard [4, 20]. Therefore, many patients in whom suspected mesenteric ischemia is not confirmed intraoperatively undergo unnecessary exploratory laparotomy [13].

The aim of this study was to evaluate the quality of established parameters in the diagnostic procedure for AMI in terms of sensitivity and specificity in order to identify those patients who need to be treated surgically and, vice versa, patients who can be treated conservatively.

Material and Methods

Study Design and Patients

The institutional review board of the hospital approved the study. All patients that underwent emergency surgery due to acute abdomen at the Department of Surgery, University Medical Center Hamburg-Eppendorf between 2008 and 2014 were retrospectively evaluated based on the prospective database. Overall, 275 patients were operated due to the suspicion of AMI and were enrolled in this study. Medical history, medication, comorbidities, diagnostic results of blood testing, and CT abdomen were recorded and correlated with intraoperative findings. In the nonischemic patient population, the intraoperative findings were analyzed on prognostic factors for survival and outcome. The patients with intraoperative-confirmed mesenteric ischemia (ischemic patients) were compared to those without evidence of ischemia (nonischemic patients).

Intraoperative Approach

The operation was performed by a senior surgeon as standard. The indication for resection was made in gangrenous infarction. The ischemic section of the intestine is tubularly resected, and marginally perfused areas are left, which can potentially recover.

If the cause of the ischemia was a strangulation/torsion of the intestine that could be remedied or if there was a vascular occlusion that could be revascularized, the first step was to wait and see if there was a recovery after detorquing or embolectomy. We routinely perform a 2nd-look operation after 24 h.

Clinicopathological Data

Data including the patient's sex, age, date of operation, medical history, medication, comorbidities, and preoperative laboratory findings were acquired from the clinical records and from our prospective database. The abdominal CT scans were re-examined by a radiologist. Data concerning the patient's length of stay on intensive care unit, intraoperative findings, outcome, and complication were recorded.

Statistical Analysis

Statistical analysis was performed with SPSS® for Windows® Version 22.0 (SPSS Inc., Chicago, IL, USA). Data are presented as mean ± standard deviation. The continuous data for the different groups were compared using the Student's *t* test. For all noncontinuous variables, cross tables were generated, followed by calculation of the *p* value by using the χ^2 test/Fisher's exact test. A 2-tailed p value <0.05 was considered statistically significant.

Results

Characteristics of the Patients

Overall, 275 patients that underwent surgery with the suspected diagnosis of mesenteric ischemia were included. 144 patients (52%) were men, and 131 patients (48%) women. At the time of surgery, the mean age of the patients was 67.8 ± 15.1 years. Comparing the patients with confirmed ischemia with those in which mesenteric infarction was not found (nonischemic patients), the patients with ischemia were older (69.7 ± 13.1 vs. 65.7 ± 17.1; $p = 0.042$). No significant difference could be found concerning the patient's sex.

Comorbidities and Medication

Comparing the comorbidities of the ischemic patients to those of the nonischemic patients, there were no significant differences of atrial fibrillation, diabetes melli-

Table 1. Blood gas analysis and CT scan findings

	Suspected for MI		Mesenteric infarction		*p* value	Sensitivity, %	Specificity, %
N	75		200				
pH							
<7.2	9	12%	50	25%	0.021	75	12
>7.2	66	88%	150	75%			
Lactate							
<3	30	40%	76	38%	0.782	62	40
>3	45	60%	124	62%			
Findings of ACT							
Paralytic ileus	15	2%	57	29%	0.49	39	42
Portal gas	4	5%	31	16%	0.079	30	95
Intramural gas	17	23%	53	27%	1	35	63
Swollen intestine	27	36%	115	58%	0.014	71	35
Ascites	30	40%	75	38%	0.131	79	38
Vascular occlusion	3	4%	37	19%	0.006	50	91

CT, computed tomography.

tus, and arteriosclerosis. 90/275 (32%) of the patients suffered from low cardiac output syndrome (LCOS) after myocardial infarction and cardiac surgery. In 83 of these 90 patients (92%), ischemia has been confirmed ($p <$ 0.001).

The impact of medications was analyzed. Thirty-seven patients (32 with AMI and 5 without) received oral anticoagulation. The INR was 1.94 ± 1.16 and 1.89 ± 0.37, respectively ($p = 0.944$).

The level of INR was comparable in both groups. Evaluating the effect of subtherapeutic application of warfarin, no impact on mortality was detected (47 vs. 54%; $p =$ 0.446). The sensitivity and specificity were found to be 44 and 63%, respectively. Preoperatively 35/200 (18%) of AMI patients and 45/75 (60%) of non-AMI patients were on heparin ($p < 0.001$). No significant differences concerning clopidogrel (12 vs. 8%, $p = 0.347$) and aspirin (42 vs. 29%; $p = 0.07$) were detected.

Findings of Abdominal CT Scan

Overall, 196 patients (71%) underwent an abdominal CT scan (contrast-enhanced CT scan with angiographic phase). Analyzing the abdominal CT scan, 37 (19%) ischemic patients had a vascular occlusion of the SMA or their branches versus 3 (4%) nonischemic patients ($p = 0.006$) as a specific sign of mesenteric infarction (Table 1). Interestingly, no significant differences were found concerning the presence of portal gas, intramural air, intestinal paralysis, and ascites. Even though it is a nonspecific finding, the rate of edema of the bowel wall was significantly higher in ischemic patients compared to nonischemic patients (58 vs. 36%; $p = 0.014$). Analyzing the specific signs of AMI (portal gas, intramural air, and vascular occlusion), the sensitivity and specificity were found to be 61 and 68% respectively.

Of the 79 patients who were operated on without prior CT examination, the findings of an AMI were confirmed intraoperatively in 51 (65%) patients, 9 (11%) patients had ascites, and 1 (1%) patient had a morphologically abnormal gall bladder. In contrast, 18 of the 79 (23%) patients had no intraoperative correlate.

Impact of Diagnostic Factors for Mesenteric Ischemia

Preoperative mean values of lactate were analyzed. No significant differences were detected in ischemic patients compared to nonischemic patients (6.0 ± 5.3 vs. 5.4 ± 5.2; $p = 0.407$). Additionally, the rate of patients with increased lactate (>3 mmol/L) was equally distributed upon in both groups ($p = 0.782$). The specificity and sensitivity of lactate (>3 mmol/L) in patients suspected to have a mesenteric infarction was found to be 62 and 40% respectively. Analysis of the preoperative 12- and 24-h course of the lactate value revealed no significant differences comparing ischemic patients to nonischemic patients.

The rate of patients with pH < 7.2 was significantly higher in ischemic patients compared to nonischemic patients (25 vs. 12%; $p = 0.021$), while no significant differences in mean pH (7.29 ± 0.2 vs. 7.32 ± 0.1; $p = 0.107$) were detected. The sensitivity and specificity were found to be 75 and 12% respectively.

Table 2. Laboratory findings

	Suspected for MI mean ± SD	Mesenteric infarction mean ± SD	*p* value
Lactate	5.4±5.2	6.0±5.3	0.407
pH	7.32±0.12	7.29±0.15	0.107
Hemoglobin	10.4±2.4	10.7±2.5	0.482
Leukocytes	18.0±12.7	16.8±10.9	0.456
Thrombocytes	193±140	191±142	0.945
Bilirubin	2.5±8.3	1.5±2.5	0.132
Cr	2.1±1.4	2.1±1.7	0.996
ASAT	256±500	930±2,868	0.044
CK	470±1,673	1,068±3,245	0.129
CRP	139±104	175±117	0.019
PCT	12.6±19.9	18.9±36.0	0.289
INR	1.44±0.62	1.43±0.72	0.955
PTT	50±25	55±28	0.151

The mean CRP was significantly higher in ischemic patients compared to nonischemic patients (175 ± 117 vs. 139 ± 104 mg/L; $p = 0.019$). Furthermore, the mean GOT (ASAT) was significantly higher in ischemic patients (930 ± 2,868 U/L vs. 256 ± 500 U/L; $p = 0.044$). No significant differences were found regarding preoperative mean leukocytes, hemoglobin, thrombocytes, PCT, bilirubin, Cr, creatine kinase, INR, and partial thromboplastin time (Table 2).

The preoperative norepinephrine administration rate (41 ± 52 vs. 22 ± 24 μg/mL; $p = 0.046$) and the norepinephrine administration rate 24 h preoperatively (20 ± 24 vs. 9 ± 10 μg/mL; $p = 0.013$) were significantly higher in ischemic patients compared to nonischemic patients. An increase of the preoperative norepinephrine of >10 μg/mL within 24 h was detected in 66 and 42% of the patients respectively ($p = 0.029$).

The mortality rate was significantly higher in ischemic patients compared to nonischemic patients (70 vs. 48%; $p = 0.001$). Within the ischemic group, the mortality related to the etiology of ischemia for the occlusion of the SMA is 57% (21/37) and for the NOMI, 73% (119/163).

Characteristics and Prognostic Factors in Nonischemic Patients

As the sensitivity of the diagnostic methods for the detection of AMI is low, the patients are laparotomized as a last resort to rule out intestinal ischemia. In order to characterize the patient group, in which an AMI was suspected but ultimately not confirmed intraoperatively, a subgroup analysis was carried out with the aim of avoiding unnecessary laparotomies in the future by knowing the underlying pathologies. Therefore, these patients without intraoperative findings of AMI were analyzed. In 75 patients, mesenteric infarction was excluded intraoperatively (♂38 vs. ♀37), the patient's mean age was 66 ± 17 years. The patient's sex and age had no significant impact on survival.

Analyzing the comorbidities, a higher mortality rate was found in patients with diabetes (10 vs. 33%; $p = 0.023$) and arteriosclerosis (41 vs. 69%; $p = 0.02$). The presence of pathologic results in CT scan (e.g., portal gas and intramural air) had no impact on survival. No association between medication and mortality could be detected.

In nonischemic patients, the mean preoperative lactate was significantly lower for surviving patients compared to non-surviving patients (3.9 ± 3.8 mmol/L vs. 7.1 ± 6.0 mmol/L; $p = 0.008$). Correspondingly, the mean pH value was significantly higher in surviving patients (7.35 ± 0.9 vs. 7.29 ± 0.14; $p = 0.007$). Additionally, the mean CRP level was lower in surviving patients (113 ± 93 mg/L vs. 167 ± 108 mg/L; $p = 0.024$). Significant differences were also found for PCT (6.1 ± 13.4 μg/L, vs. 17.9 ± 22.8 μg/L; $p = 0.038$) and for the Cr (1.8 ± 1.5 mg/dL vs. 2.5 ± 1.1 mg/dL; $p = 0.019$).

Thrombocytes were significantly higher in patients that survived compared to those who died (229 ± 136 × 10^9/L vs. 153 ± 136 × 10^9/L; $p = 0.018$). No significant differences were detected for hemoglobin, leukocytes, bilirubin, GOT, and CK (Table 3).

Evaluating the effect of subtherapeutic application of warfarin, no impact on mortality was detected (47 vs. 54%; $p = 0.446$). The sensitivity and specificity were found to be 44 and 63%, respectively.

In 42 (56%) of the patients with intraoperatively unconfirmed mesenteric ischemia, another nonischemic intestinal pathology was detected. Nineteen (45%) patients had inflammatory changes in the intestine; 13 (31%) an intestinal paralysis, mostly of unknown origin; 7 (17%) had ascites; and 3 (7%) of the patients had an acute cholecystitis.

Overall, 36/75 (48%) patients died in the hospital. Of these patients, 25 (69%) died due to sepsis and 11 patients (31%) due to cardiac reasons. The intraoperative findings had no impact on the mortality rate.

Evaluation of Patients with AMI and Non-Transmural Intestinal Necrosis

Previously, non-transmural intestinal necrosis (non-TIN) mesenteric ischemia has been described. Patients in whom AMI could be excluded intraoperatively were evaluated in this regard.

Table 3. Nonischemic patients: findings at the time of AMI diagnosis

	Survival (*n* = 39)		Exitus letalis (*n* = 36)		*p* value
Preoperative	16	41%	28	78%	0.002
Pre-op lactate	3.9±3.8		7.1±6.0		0.008
Pre-op pH	7.36±0.91		7.29±0.14		0.007
Hemoglobin preOP	10.8±2.7		10.6±1.82		0.206
Leukocytes preOP	18.8±12.3		17.1±13.2		0.579
Thrombocytes	229±136		153±136		0.018
Bilirubin	1.1±1.1		4.0±11.9		0.126
Cr	1.78±1.5		2.52±1.14		0.019
GOT	154±440		368±543		0.064
CK	143±174		812±2,377		0.089
CRP	113±93		167±108		0.024
PCT	6.1±13.4		17.9±22.8		0.038

AMI, acute mesenteric ischemia.

Table 4. Multivariate analysis: parameter associated with mesenteric ischemia

	p value	RR	95% CI
pH < 7.2	0.031	4,063	1.137–14.525
Status post cardiac surgery	<0.001	31,946	6.486–157.339
CT vascular obstruction	0.043	3,716	0.895–15.432
CT bowl edema	0.151	1,989	0.777–5.090
Acetylsalicylic acid	0.930	0.930	0.333–2.598
Warfarin	0.691	1,329	0.327–5.413
Heparin	<0.001	0.047	0.015–0.150
Pre-op ICU	0.311	1,605	0.643–4.002

Taking into account that all patients without intraoperative AMI but CT findings of pathogomonic ischemic signs had a non-TIN-AMI sensitivity of 71% and specificity of 69% of the CT scan which were detected ($p = 0.525$). When comparing the non-TIN-AMI patients with those who had no evidence of ischemia on CT but a pathological correlate intraoperatively, no significant difference was detected ($p = 0.568$). For the other prognostic factors, no relevant clinical differences were detected comparing these groups.

Multivariate Analysis

In the multivariate analysis, a low pH < 7.2, status post cardiac surgery, and the detection of vascular occlusion in the CT scan were confirmed as independent prognostic factors for the presence of AMI (Table 4).

Discussion

The diagnosis of AMI remains challenging, especially against the background of a high mortality of approximately 70% [2, 4, 8–10, 21–23]. Interestingly, the mortality rate of patients in which an intestinal ischemia was excluded intraoperatively is still 48%. Thus, the mortality rate of this patient collective is higher than in patients who are treated surgically for acute abdomen or ileus. But looking at these data in detail, 56% of the patients had other intraoperative pathological findings that were not detected preoperatively, such as ascites or bowel paralysis. This could well correspond to secondary phenomena of a non-TIN AMI. To date, there are no data available that would have subjected these patients to further diagnostics. To our knowledge, no other study exists that analyzes the outcome of these patients. One reason for the high mortality rate of these patients is likely the large proportion of multimorbid patients with cardiovascular disease. Additionally, mesenteric ischemia is often suspected when the clinical condition of intensive care patients worsens with an increase of lactate and catecholamines.

In this study population, the mean age was 68 years and the gender distribution was balanced. This is in accordance with published data [2, 21–23]. Previously, a higher mortality rate was described for older patients with ischemia, while in this study no significant differences were detected for age.

Impact of Medical History and Medication

Arteriosclerosis is a well-known risk factor for the development of mesenteric ischemia [24]. The rate of arteriosclerosis was comparable in the ischemic and nonischemic group. Only in nonischemic patients, arteriosclerosis was found to be a relevant risk factor for mortality.

As reported by Schuetz et al. [6], AMI is a rare but severe complication after cardiac surgery. Correspondingly, the status post major cardiac surgery was found to be an important risk factor for intestinal ischemia (42 vs. 9%). Diabetes mellitus and cardiac arrhythmias, especially atrial fibrillation, are well known risk factors for mesenteric ischemia [2, 25, 26] although our study was not able to confirm the association between these risk factors and AMI.

The patients that were on ASS or warfarin on a regular basis were more likely to have mesenteric ischemia, while patients with therapeutic heparinization were less likely to suffer from mesenteric ischemia. Cardiovascular risk factors for embolism include a status post myocardial infarction and arrhythmia. Since these patients regularly take ASS or warfarin, the association described above is more likely due to the underlying disease.

One possible reason for the increased norepinephrine administration rate in ischemic patients is the vasoconstrictive effect on arterioles which increases the risk of impaired circulation of the intestine, especially if norepinephrine is required for a longer period of time. The fact that the nonischemic patients that died also had a higher preoperative dosage of norepinephrine preoperatively is in accordance to clinical experience.

Impact of Laboratory Testing

So far, no laboratory findings are sufficient for diagnosis of AMI [4, 12, 13]. Elevated serum lactate is often used as a diagnostic parameter [17]. The analysis of elevated lactate levels (>3 mmol/L) showed no association to mesenteric infarction neither in the 2 groups separately nor in the entire group.

Regarding the lactate course, the increase of lactate within 24 h preoperatively was comparable between ischemic and nonischemic patients. However, lactate is an unspecific marker of inadequate tissue oxygenation, for example, favored by pneumonia, renal insufficiency, or liver cirrhosis and therefore represents an imprecise parameter in the diagnosis of mesenteric ischemia. Thus, numerous patients on ICU develop increased lactate levels. In general, however, it is the synopsis of the clinical findings, the laboratory parameters, and imaging that ultimately leads to the indication for surgery, which is then carried out as an emergency procedure.

Other pathological laboratory findings in mesenteric infarction are metabolic acidosis and leukocytosis [6, 27]. In accordance to these data, the present study demonstrates that patients with mesenteric ischemia more commonly presented with metabolic acidosis (pH < 7.2). There are many causes of metabolic acidosis like acute respiratory insufficiency (usually with respiratory acidosis) or a septic disease. Not surprisingly, nonischemic patients with metabolic acidosis also have a higher mortality rate in this analysis.

In contrast to earlier publications, leukocytosis had no impact on survival. It is known that AMI causes an inflammatory reaction and can therefore be associated with an increase of CRP and PCT. Kassahun et al. [23] and Reissfelder et al. [26] reported about CRP increases in patients with AMI, while other authors postulated that CRP is not suitable for the early diagnosis [28]. PCT has also proved to be an inappropriate parameter for the diagnosis of AMI in several studies [21, 29].

In the present study, a strongly elevated mean CRP and elevated PCT were detected, but equally in TIN- and non-TIN-AMI patients. In the group of nonischemic patients, an increase in these serum markers was associated with high mortality.

In this study, slightly higher values of ASAT (GOT) were detected in the ischemic patient population. This is in line with data from Kawaguchi et al. [30] and Mitsuyoshi et al. [31] who reported on ASAT elevation in AMI patients. Additionally, Delaney et al. [32] reported on ASAT elevation in patients with NOMI.

When analyzing the mortality of the nonischemic patients, coagulation disorders were associated with a higher mortality. Again, an association with pre-existing cardiovascular disease requiring anticoagulant medication or septic disease with consecutive coagulation disorders should be considered.

Impact of Abdominal CT Scan

Abdominal CT scan is the gold standard in evaluating acute abdomen and mesenteric ischemia. Different pathologic signs are described such as portal gas, vessel occlusion, ascites, swollen intestine, or bowel dilation. These signs must be evaluated in the clinical context [17, 33]. Direct signs are an embolus or thrombosis of the SMA, while dilated intestines, paralytic ileus, edema of the bowel wall, or portal gas are indirect signs.

196 of the 275 patients (71%) with suspected AMI underwent a CT scan. In the other 79 patients, clear clinical findings or a pathological finding in X-ray or ultrasound led to emergency surgery. The rate of patients that underwent CT scan is comparable to the published data of Kassahun et al. [23] whereof 72% underwent preoperative imaging. More than 90% of the CT scans revealed a pathological finding.

Vascular occlusions were more frequent in the ischemic patient group but were found in <20% of patients. The most common although unspecific signs were swollen intestine and ascites. The analysis of the specific signs such as portal gas, intramural air or vascular occlusion revealed a sensitivity of 61% and a specificity of 68% with respect to the diagnosis "mesenteric ischemia." The low sensitivity and specificity of CT findings underlines the difficulties in diagnosing AMI.

The guidelines of the American Gastroenterological Association and the German Association of Vascular Surgery recommend an angiography of the SMA as it offers the chance of a nonoperative intervention and of improving survival [34, 35]. As angiography is an invasive procedure which is not available 24 h in all hospitals, it has been increasingly replaced by abdominal CT scanning (CT angiography) [8, 36].

Therefore, abdominal CT scan with biphasic contrast enhancement is the gold standard in patients with acute abdomen. This imaging can be used to assess the entire abdominal area. In literature, the sensitivity of this method for acute abdomen is described to be 90–100% with a specificity of 100% [16, 37].

New Diagnostic Concepts

The intestinal fatty acid binding protein (I-FABP) is a new parameter to diagnose AMI [38–40]. It is early to detect in serum and urine after mucosa defect. Matsumoto et al. [39] describe a better diagnostic use for I-FABP in AMI patients compared to leukocytes, lactate, CRP, and CK. Shi et al. [40] noted a higher I-FABP concentration in mesenteric ischemia patients compared to acute abdomen patients without mesenteric ischemia.

In 25% of the patients with elevated I-FABP concentration, no ischemia was detected intraoperatively. There is no valid data in the literature on the rate of false-positive patients in the diagnosis of AMI, but this rate seems acceptable for a clinical situation in which early surgical intervention is the only chance for the patient.

Alpha-GST appears to have a cytoprotective role against oxidative injury. An elevated alpha-GST had a 72 percent sensitivity and 77 percent specificity for diagnosing AMI but could not distinguish between ischemia with and without infarction [41]. Overall accuracy was 74 percent. The negative predictive value of alpha-GST was 90 percent when combined with serum lactate and 100 percent when combined with the white blood cell count.

A cobalt-albumin binding assay was assessed in 26 patients who were scheduled for laparotomy for clinical features consistent with AMI and/or bowel obstruction [42]. Postoperatively, 12 patients were diagnosed with AMI, all of whom had significantly higher cobalt-albumin binding assay levels than those who did not have AMI. The sensitivity and specificity were 100 and 86 percent, respectively.

Impact and Limitations of This Study

The challenge in AMI is identifying patients with AMI in a group of critically ill patients and deciding whether surgery with the appropriate risks is indicated. The indication becomes complex in many cases due to the multimorbidity of these patients, for example, decompensated liver cirrhosis, hepatorenal syndrome, pneumonia, or sepsis, presenting in such a poor general condition, in which pathological findings in the abdominal CT or in the laboratory examination make a clear differentiation from mesenteric ischemia considerably more difficult. In these critically ill patients, the risk of anesthesia and exploratory laparotomy must be weighed against the fatal consequences of missed or delayed diagnosis of mesenteric ischemia. Factors that should encourage surgeons to perform laparotomy are, in addition to the clinical findings, evidence of vascular occlusion on CT and the risk factors LCOS, high norephinephrine administration, and a low pH value. From our point of view, special attention should also be paid to the CT findings of an edema of the intestinal wall.

To our knowledge, this study is the largest series analyzing the quality of diagnostic concepts of mesenteric ischemia in a suitable clinical setting. Additionally, the patients who had no mesenteric ischemia confirmed intraoperatively were analyzed in detail. This group of patients has not been subjected to any more detailed analysis so far.

Limitations

However, this study has limitations: the analysis is retrospective and observational and the included patients are a selected population. Nonetheless, all patients were diagnosed by an experienced consulting surgeon, who finally indicated the operation. Thus, these patients represent the challenging clinical collective of those patients with suspected mesenteric ischemia.

Conclusion

Diagnosing an AMI continues to be challenging. Even modern contrast-enhanced computed tomography (angio-CT) often only provides indirect signs of ischemia and must be interpreted in connection with other clinical and laboratory parameters. Relevant risk factors such as the LCOS after heart attack or cardiac surgery as well as high norepinephrine doses could be confirmed with this study. In addition, the evidence of an occlusion of a mesenteric vessel and, in this study, the intestinal wall edema is significantly associated with an AMI. In contrast, the lactate value in the serum has proven to be unreliable although there is an association with a pH value <7.2.

Taking into consideration that the mortality of these patients is high, new diagnostic algorithms and parameters are needed. So far, explorative laparoscopy and possibly laparotomy is the only reliable procedure to detect or exclude a mesenteric infarction.

Statement of Ethics

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by our institutional review board. This University Medical Center Hamburg Institutional Review Board belongs to University Medical Center Hamburg. According to law, no informed consent of the patients or statement by the Federal Ethics Committee is needed as the study is noninterventional and retrospective (§12HmbKHG – city law of Hamburg). This article does not contain any studies with animals performed by any of the authors.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Rainer Grotelueschen: interpretation of data and drafting of the manuscript. Verena Miller: acquisition of data, analysis and interpretation of data, and revision of the manuscript. Lena M. Heidelmann: assistance in drafting of the manuscript, interpretation of data, and revision of the manuscript. Nathaniel Melling: assistance in drafting and revision of the manuscript and interpretation of data. Tarik Ghadban: critical revision of the manuscript for important changes and revision of the manuscript. Katharina Grupp: acquisition of data, analysis and interpretation of data, and revision of the manuscript. Matthias Reeh: assistance in drafting of the manuscript interpretation of data and revision of the manuscript. Maria-Noemi Welte: assistance in drafting of the manuscript, interpretation of data, and revision of the manuscript. Faik G. Uzunoglu: acquisition of data, analysis and statistical analysis, and revision of the manuscript. Jakob R. Izbicki: study concept and design, revision of the manuscript, and study supervision. Kai A. Bachmann: study concept and design, revision of the manuscript, and study supervision.

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