One-stage versus two-stage procedure for the surgical management of patients with acute mesenteric ischemia

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Background
Damage control surgery (planned second look) is preferred by many surgeons in the management of patients with acute mesenteric ischemia (AMI) with established bowel necrosis. However, some surgeons prefer to perform primary anastomosis during the first operation, making the second look only when indicated. Herein, we compare the perioperative outcomes of the previous two approaches in AMI patients.
Patients and methods
In this prospective, randomized study, AMI was diagnosed in 74 patients who were divided into group A (one-stage approach) and group B (two-stage approach).
Results
The one-stage approach spent more operative time compared with the first step of the other approach (110 vs. 70 min, respectively). The planned second look had an average of 75 min, and intestinal resection was done in 35.14% of cases due to advancing ischemia. The incidence of leakage was higher in the one-stage group (32.43%) compared with the other (5.4%), leading to a high reoperation rate in the former. ICU stay was longer with the damage control approach. Nonetheless, no difference was detected regarding the hospitalization period. The one-stage approach was associated with a higher 30-day mortality rate (29.73 vs. 8.11% in the other group). Risk factors for mortality included shock at presentation, prolonged operative time, and postoperative leakage.
Conclusion
The application of the damage control approach in patients with AMI is of great benefit as it is associated with low leakage rates, less need for reoperation, and less incidence of 30-day mortality compared with the one-stage approach.

Keywords:
acute mesenteric ischemia, damage control surgery, one stage

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Introduction

Acute mesenteric ischemia (AMI) is acute occlusion of the arterial or venous systems or a drop in the systemic perfusion pressure, leading to insufficient blood supply to the mesentery and the bowel compared with metabolic demands [1]. This condition is encountered in elderly people [2] and often requires emergency bowel resection [3].

AMI may be occlusive or nonocclusive. The former is classified into three types: arterial embolism, arterial thrombosis, and venous thrombosis [4,5]. Although it is not frequently encountered in clinical practice (0.2% of emergency department admissions) [6], previous studies reported high mortality rates associated with that pathology (65%) [7,8].

AMI is extensively discussed in the literature. Nonetheless, its diagnosis and management are still challenging. Such patients are often subjected to delayed diagnosis because of the wide and nonspecific range of presentations, which makes rapid diagnosis more difficult [9,10].

Although the human gut can withstand a 75% reduction in blood flow for 12 h, complete occlusion could yield irreversible damage and necrosis only within 6 h [1]. That will require aggressive surgical intervention for resection of the necrotic or gangrenous bowel [11].

Damage control strategy has been accepted in patients with abdominal trauma decades ago [12], and it is considered an excellent valid option for AMI according to the recommendations of 'The World Society of Emergency Surgery' [6,13]. The planned second look provides some advantages for such critical

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patients as it allows reassessment of bowel viability after stabilization of the patient's condition after primary source control in the primary procedure [14].

Nonetheless, some surgeons still prefer to perform source control with primary anastomosis in one session, especially when the patient has a stable condition, controlled medical comorbidities, and there is good demarcation line between the ischemic and the healthy bowel sufficient to make a satisfactory anastomosis [15].

The current literature is poor with randomized trials comparing the outcomes of one-stage (exploration, resection, with primary anastomosis) versus two-stage (damage control surgery) approaches in the management of patients with AMI. The present study is conducted to elucidate the approach associated with better outcomes in such highly morbid cases. The terms 'damage control surgery' and 'two-stage approach' will be used interchangeably in the current paper.

Patients and methods

This is a prospective, randomized trial that included patients diagnosed with AMI, whatever their age, who presented to the Emergency Department of Mansoura University Hospitals and underwent surgical exploration during the period between November 2021 and October 2023 (2-year duration). We did not start patient enrollment until we gained scientific approval from our university's Institutional Review Board (IRB code: R.21.11.1512). The diagnosis of AMI was dependent on clinical assessment (abdominal pain not relevant to clinical examination findings in the presence of risk factors like heart or liver disease) [6] and radiological imaging (lack of wall enhancement on enhanced images, mesenteric stranding, bowel dilatation, and wall pneumatosis) [16], which was confirmed on subsequent abdominal exploration [17].

All patients with suspected AMI were adequately assessed on presentation to the emergency department, and that included detailed history taking (focusing on abdominal pain, its duration, and the presence of risk factors like cardiac or liver disease), clinical examination (focusing on BMI, patient look, vital signs, and abdominal examination), and laboratory evaluation (focusing on inflammatory markers like leukocyte count and C-reactive protein in addition to arterial blood gas analysis and electrolyte assessment). All patients were radiologically evaluated through abdominal ultrasound with duplex assessment of the portal and mesenteric vasculature. The diagnosis was additionally confirmed by triphasic pelviabdominal computed tomography (CT). An arterial etiology was suspected when thinning of the intestinal wall was detected, while a venous etiology was suspected when there was wall thickening with intraperitoneal free fluid [16].

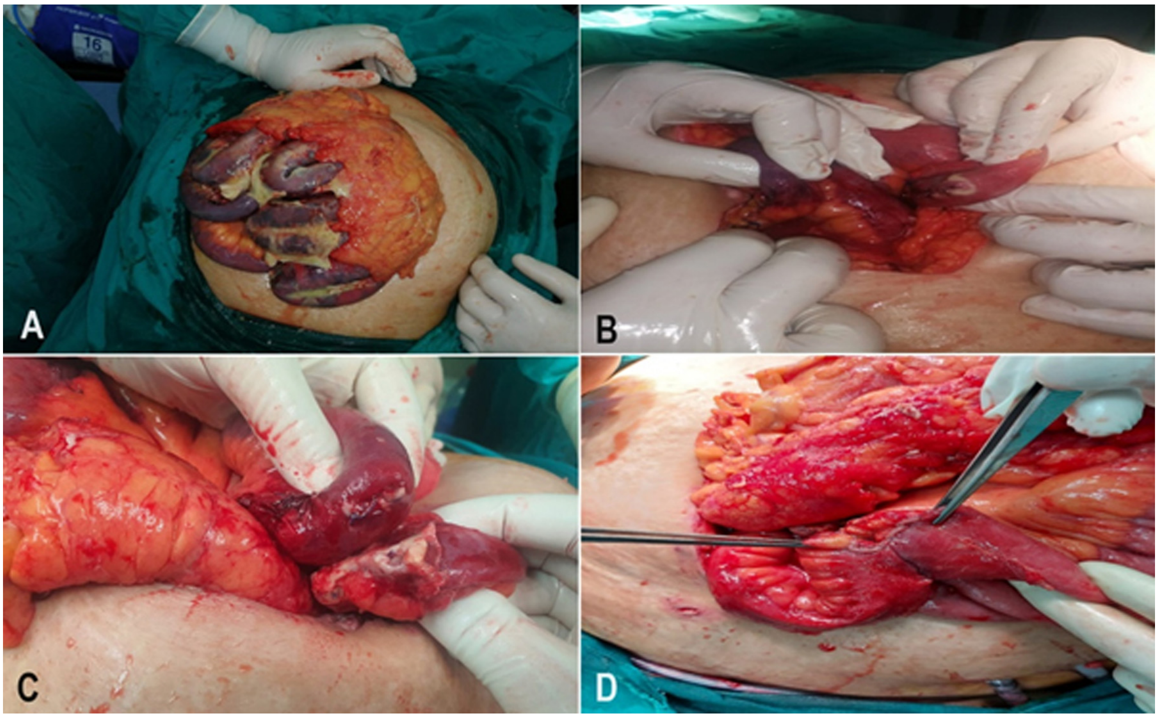
Patients with early intestinal ischemia amenable to angiographic intervention, massive intestinal necrosis (extensive ischemia not amenable to surgical intervention) [17], or colonic affection were excluded from the study. In all, 74 patients met our enrollment criteria (Fig. 1). The patients or their relatives (in cases who presented with shock) were informed about the nature and the aim of the study, with the potential advantages and disadvantages of each approach. Their approval to participate in the study was documented by written consent.

All patients were initially admitted to the ICU, and a therapeutic dose of low molecular weight heparin (1.5 mg/kg/day) [18] was started for all patients, and it was continued during the perioperative period with the same dose. Using the 'sealed envelope method,' our patients were assigned into two groups (Fig. 1): group A (n=37) included patients who had the one-stage approach, and group B (n=37) included patients who had the two-approach strategy (damage control approach).

In group A, abdominal exploration was performed through a midline incision. Resection of the gangrenous bowel with its related mesentery was done, followed by the creation of an entero-enteric anastomosis (handsewn or stapled according to surgeon preference). Good wash and hemostasis were done, and a drain was inserted into the pelvis, followed by abdominal wall closure. The patient was transferred to the ICU after the operation. No revascularization procedures were done in both groups.

In group B, the same steps were done for the gangrenous bowel. However, no anastomosis was created. The two bowel ends were closed by continuous Vicryl 3/0 sutures, and a nasogastric tube was passed through the pylorus down to the duodenum for bowel decompression. Only the skin of the abdominal wall was closed, and the patient was transferred to the ICU to correct his general condition for 48 h. Then, a second look was done through the same incision (Fig. 2). Bowel viability was reassessed, and any necrotic segments were

Figure 1



Flowchart of the study cases and groups.

resected, followed by the creation of anastomosis, as mentioned before. The abdominal wall was closed after placing a surgical drain in the pelvis, and the patient was transferred again to the ICU after a second look.

The patients were closely monitored in the ICU and repeated clinical, laboratory, and radiological assessments were conducted. The patients were discharged from the ICU to the internal ward once recommended by the attending ICU physician. The incidence of postoperative morbidity and 30-day mortality was recorded in both groups. The need for additional reoperation was also recorded in both groups. Patients were discharged from the hospital when they were able to have full oral intake and free from complications. Low molecular weight heparin was gradually shifted to oral warfarin therapy with strict monitoring of the international normalized ratio to be kept between 2 and 3.

Study outcomes

The incidence of postoperative leakage was our main outcome. It was defined as a defect in the anastomotic site resulting in a communication between the intra- and extra-luminal compartments diagnosed clinically (intestinal content discharge through the drain or the wound) or radiologically (contrast leakage on gastrografin follow-through) [19]. Other outcomes included operative time, the need for reoperation, the duration of ICU and hospital stay, the incidence of other complications, 30-day mortality, and its predictors.

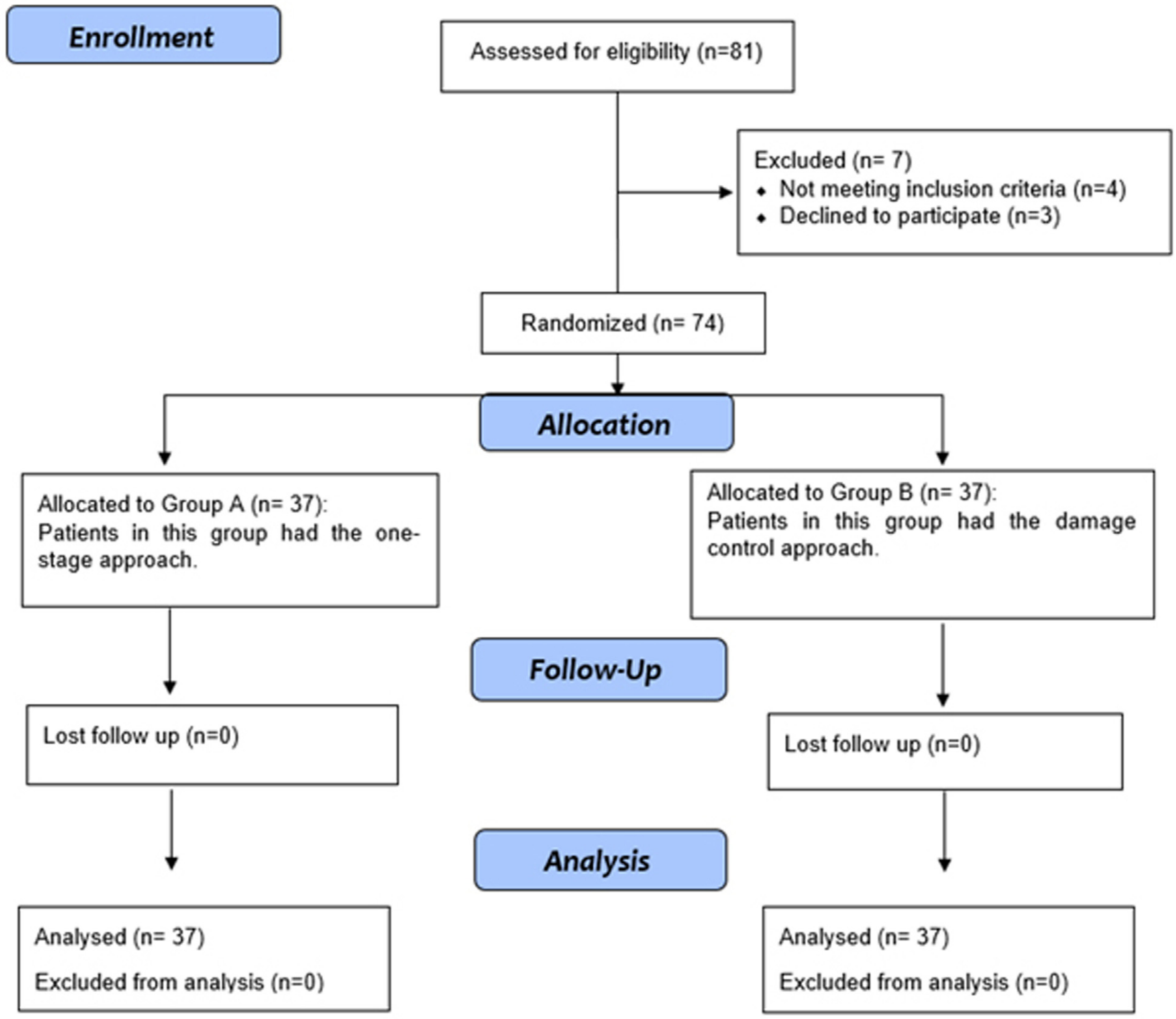
Sample size calculation

Our proper sample size was estimated through the 'Power Analysis and Sample Size software' for Windows (version 15.0.5), considering the incidence of anastomotic leakage as our primary outcome. To detect a large effect size (0.7), we needed to enroll 33 patients in each group to achieve an 80% study power and 0.05 significance level. That number was increased to 37 patients in each group to avoid possible nonresponse rates.

Statistical analysis

We used SPSS software (version 26, IBM Corp, Armonk, NY, USA) for Windows to tabulate, organize, and analyze the collected data. We used the χ^2 test to compare categorical variables between the two groups, which were presented as numbers and frequencies. In addition, Students t test was used to compare nonskewed numerical variables (means and SDs) between the same groups. Furthermore, the Mann–Whitney test was used to compare skewed data (medians and ranges). Regression analysis was also performed to elucidate predictors of mortality

Figure 2



(a) A 62-year-old female patient presented with AMI. On exploration, there was a gangrenous small bowel about 2.5 m in length starting 1 m from the duodenojejunal flexure. (b) After resection of the gangrenous bowel. The two bowel ends were closed by continuous Vicryl 3/0 sutures. (c) No advancing ischemia on the second look. No additional resection was needed. (d) Restoration of intestinal continuity using a GIA stapler. AMI, acute mesenteric ischemia.

after the surgical intervention. Any *P* value of less than 0.05 was considered statistically significant.

Results

Patients in group A had a mean age of 58.57 years compared with 58.51 years in group B. Men were more prevalent than women in both groups as they formed 72.97 and 81.08% of cases in the same groups, respectively. The prevalence of smoking and systemic comorbidities (diabetes, hypertension, and heart failure) was comparable between the two groups. As regards the risk factors for AMI, cardiac disease (atrial fibrillation) was the most common one, followed by liver cirrhosis, while previous splenectomy accounted for the minority of cases. Table 1 illustrates the previous data.

Abdominal pain was reported in all cases in our study. Other presentations included distension, fever, melena, and shock. The duration between symptom onset and surgical intervention ranged between 2 and 7 days (median=4 days in both groups) (Table 2).

Table 3 shows preoperative laboratory and radiological data in both groups. One could notice the rise in inflammatory markers like leukocyte count and C-reactive protein and a tendency toward metabolic acidosis on arterial blood gas analysis.

Table 1 Basic demographic data

	Group A (*N*=37)	Group B (*N*=37)	*P* value
Age (years)	58.57±6.06	58.51±5.39	0.968
Sex [*n* (%)]			
Male	27 (72.97)	30 (81.08)	0.407
Female	10 (27.03)	7 (18.92)	
BMI (kg/m^2)	28.72±3.71	28.88±4.54	0.873
Smoking [*n* (%)]	16 (43.24)	19 (51.35)	0.485
Risk factors for AMI [*n* (%)]			
Cardiac disease (AF)	19 (51.35)	17 (45.95)	0.801
Liver cirrhosis	13 (35.14)	13 (35.14)	
Postsplenectomy	5 (13.51)	7 (18.92)	
Other medical comorbidities [*n* (%)]			
Diabetes mellitus	11 (29.73)	12 (32.43)	0.802
Hypertension	15 (40.54)	14 (37.84)	0.812
Heart failure	3 (8.11)	2 (5.41)	0.643

AF, atrial fibrillation; AMI, acute mesenteric ischemia.

Table 2 Patient presentation and duration of complaints in both groups

	Group A (*N*=37) [*n* (%)]	Group B (*N*=37) [*n* (%)]	*P* value
Presentation			
Abdominal pain	37 (100)	37 (100)	–
Abdominal distension	25 (67.57)	27 (72.97)	0.611
Fever	17 (45.95)	14 (37.84)	0.480
Melena	8 (21.62)	8 (21.62)	1
Shock	6 (16.22)	5 (13.51)	0.744
Duration between symptom onset and intervention (day)	4 (2–7)	4 (2–7)	0.651

CT findings included a thickened bowel wall in venous obstruction (cirrhosis and postsplenectomy cases), while a thin wall was noted in arterial embolism (patients with atrial fibrillation). Other findings included absent or diminished wall enhancement, wall pneumatosis, and mesenteric stranding. Free peritoneal fluid was more encountered in patients with venous obstruction. No significant difference was noted between the two groups regarding the previous parameters.

The one-stage approach led to a significantly prolonged operative time compared with the first stage of the damage control strategy (110 vs. 70 min,

Table 3 Preoperative laboratory and computed tomography radiological findings in both groups

	Group A (*N*=37)	Group B (*N*=37)	*P* value
Laboratory findings			
Leukocyte count (×10^3/mm^3)	18.06±3.58	18.34±2.84	0.704
CRP (mg/l)	97 (40–294)	86 (42–295)	0.333
Albumin (gm/dl)	3.18±0.52	3.16±0.51	0.822
Creatinine (mg/dl)	1.28±0.20	1.29±0.18	0.951
pH	7.31±0.05	7.31±0.04	0.657
HCO_3 (mEq/l)	19.14±2.96	19±2.93	0.844
Na (mEq/l)	140±3.01	139.84±2.52	0.802
K (mEq/l)	4.22±0.54	4.21±0.62	0.936
CT findings [*n* (%)]			
Thickened bowel wall	18 (48.65)	20 (54.05)	0.642
Thin bowel wall	19 (51.35)	17 (45.95)	0.642
Absent wall enhancement	30 (81.08)	31 (83.78)	0.760
Wall pneumatosis	22 (59.46)	25 (67.57)	0.469
Mesenteric stranding	33 (89.19)	31 (83.78)	0.496
Free peritoneal fluid	23 (62.16)	27 (72.97)	0.321

CRP, C-reactive protein; CT, computed tomography.

respectively - $P<0.001$). The length of the resected bowel segment ranged between 80 and 250 cm in both groups. In addition, intraoperative blood loss had a median value of 200 ml in both groups (Table 4).

In the planned second laparotomy in group B, positive findings were noted in 13 (35.14%) cases in the form of advancing bowel ischemia, and resection was done in all of these cases. The duration of the second look procedure ranged between 60 and 90 min (median=75 min) (Table 5).

The duration of ICU stay was statistically longer in group B (P=0.049). However, the duration of hospitalization was statistically comparable between the two groups (P=0.115). Group A was associated with a significant increase in the incidence of leakage (32.43 vs. 5.4% in group B), and all of these cases required reexploration and stoma creation. The incidence of other complications, including wound infection, pulmonary infection, and pulmonary embolism, did not reach statistical differences when the two groups were compared (P>0.05).

Nonetheless, the incidence of 30-day mortality was higher in group A (29.73 vs. 8.11% - P=0.018) (Table 6). The main cause of mortality was leakage, subsequent sepsis, and organ dysfunction (five cases in group A and one case in group B). Other causes of mortality included liver cell failure (four cases in group A and one case in group B) and hepatorenal syndrome (one case in each group). The remaining case in group A died of a stroke.

Table 4 Operative data

	Group A (*N*=37)	Group B (*N*=37)	*P* value
Operative time (min)	110 (90–120)	70 (60–75)	<0.001**
Blood loss (ml)	200 (100–300)	200 (100–300)	0.978
Resected segment length (cm)	160 (80–250)	150 (80–250)	0.886

**highly significant *p* value less than 0.00.

Table 5 Operative data in the second look in group B

Variables	Data (*N*=37)
Operative time (min)	75 (60–90)
Need for additional bowel resection [*n* (%)]	13 (35.14)

Table 6 Postoperative data

	Group A (*N*=37)	Group B (*N*=37)	*P* value
ICU stay (day)	4 (3–6)	4 (4–6)	0.049*
Hospital stay (day)	10 (9–13)	11 (9–13)	0.115
Leakage [*n* (%)]	12 (32.43)	2 (5.4)	0.003**
Reoperation [*n* (%)]	12 (32.43)	2 (5.4)	0.003**
Wound infection [*n* (%)]	10 (27.03)	8 (21.62)	0.588
Pulmonary infection [*n* (%)]	3 (8.11)	4 (10.81)	0.691
Pulmonary embolism [*n* (%)]	1 (2.7)	0	0.314
Mortality [*n* (%)]	11 (29.73)	3 (8.11)	0.018**

*significant *p* value less than 0.05. **highly significant *p* value less than 0.00.

Table 7 Regression analysis to detect risk factors for mortality

		Multivariate analysis		
Variables	Univariate analysis	OR	95% CI for OR	*P* value
Age	0.874			
Male sex	0.582			
BMI	0.818			
Diabetes mellitus	0.678			
Hypertension	0.755			
Heart failure	0.949			
Abdominal pain	0.999			
Abdominal distension	0.916			
Fever	0.935			
Melena	0.464			
Shock	0.001*	2.415	1.849–2.923	0.005*
Operative time	0.**027***	1.641	1.012–1.942	0.042*
Blood loss	0.901			
Resected segment length	0.409			
Leakage	0.016*	1.823	1.207–2.013	0.046*
Wound infection	0.276			
Pulmonary infection	0.999			
Pulmonary embolism	0.986			

CI, confidence interval; OR, odds ratio. *significant *p* value less than 0.05.

Regression analysis showed that shock at presentation, prolonged operative time, and postoperative leakage were independent predictors of mortality in the study population (Table 7).

Discussion

Our study was conducted to compare the one-stage approach with the damage control one in the management of AMI cases. According to our research in the literature, we found no previous randomized studies handling the same previous comparison, which is a great advantage in favor of our research. In addition, most preoperative variables expressed a P value more than 0.05, indicating no significant differences. This not only denotes proper randomization but also decreases bias risk.

We should also highlight that all of our patients underwent CT with contrast to confirm the diagnosis, even if they had elevated serum creatinine. This is in accordance with the World Society of Emergency Surgery guidelines, which recommend the same action as kidney injury induced by mesenteric ischemia, and its consequences of sepsis and shock are more detrimental than contrast-induced injury [6,13].

Considering the operative time, there was a significant prolongation associated with the one-stage approach compared with the first stage of the other group. Of course, omitting anastomosis creation and closure of the abdominal wall should save some time in explaining the previous difference. One should also remember that there was a second look in group B in all cases, which also spent considerable operative time. Nonetheless, that second look was performed under different circumstances as the patient's general condition was improved during the 48-h interval, with correction of their electrolyte abnormalities, pH, and serum albumin.

That is one of the concepts of the damage control approach, which is to save some operative time during the initial exploration, as prolonged anesthesia and operative time in such critically ill patients could be challenging. Other pros that motivate the surgeon to prefer the damage control approach are: (a) the absence of a definite tool to assess bowel vascularity, (b) bowel ischemia could extend beyond the acute event, and (c) the introduction of supportive measures to improve the general condition during the interval period [14,15,20]. In addition, the bowel in these patients is swollen and oedematous, which increases the risk of anastomotic leakage [13], which will be discussed later.

Our second look laparotomy in group B yielded positive findings (ischemia) in 35.14% of cases that required additional bowel resection. That lies within the range reported in the literature regarding the need for resection in the second laparotomy (8–50%) [3,14–16,21].

We noticed a higher incidence of anastomotic leakage in the one-stage group, and all of these cases were found to have gross ischemia in one or both ends on the second laparotomy. The incidence of leakage in the previous group was 32.43% compared with 5.4% in group B. That should highlight the advantage of the second-look laparotomy as the detection of subsequent ischemia will prevent the incidence of leakage, which would carry higher morbidity and mortality risk in such patients with impending organ dysfunction.

Our findings agree with Brillantino and colleagues, who reported that the risk of the same dreadful adverse event decreased significantly when the damage control approach was done (5.3 vs. 23.4% in the one-stage approach – P=0.03). Consequently, there was a lower stoma rate with the former approach (2.6 vs. 19.1% in the one-stage approach – P=0.03) [16]. In the same context, Hau *et al.* [22] found that a planned second look was associated with a lower leakage rate compared with an on-demand second look in patients with intra-abdominal infections.

The incidence of wound infection was 27.03 and 21.62% in our two groups, respectively, and that is close to the findings of Yıldırım *et al.* [23], who reported an incidence of 21.74% for the same adverse event.

We noted a significant increase in ICU stay in the damage control group, and that could be explained by the additional 48-h interval spent by these cases in the ICU while omitted by the other group. However, the hospitalization period did not differ between the two groups. In contrast to our findings, in another previous study, the damage control approach was associated with a longer hospitalization period (median=13.5; range, 9–21) compared with the one-stage procedure (median=12.5; range, 7–19) [16]. Differences in the incidence of complications and center protocols could explain the previous heterogenicity.

We noted a significant reduction in mortality rate when the damage control approach was used. That could be secondary to the decreased morbidity rate with that approach. Our incidence of mortality is in accordance with the reported range in the literature, which is also high for that fatal pathology (50–80%) [1,24–27].

Although some authors in the literature reported a high mortality rate after such procedures in AMI patients, other authors reported a low mortality rate. The incidence of mortality in our series was 29.73 and 8.11% in group A and group B, respectively. Other authors even reported lower mortality rates compared with us like those of Brillantino *et al.* [16], who reported a 2.3% overall postoperative mortality rate. It is expected to encounter different mortality rates between different centers depending on the status of the patient, presentation, time interval between presentation and surgical intervention, surgical expertise, postoperative care, and postoperative complications.

We could explain the relatively low mortality rate in group B (second look group) by the following explanations; beginning with our exclusion criteria, as we excluded cases with extensive mesenteric ischemia with massive intestinal necrosis or those with colonic affection from the study. Also, the advantages of the damage control strategy; as in our series on the second look operation, there was advancing bowel ischemia in 13 (35.14%) cases that needed additional bowel resection; as a result, we achieved a noticeable and statistically significant decrease in the incidence of leakage compared with the one-stage approach (5.4 vs. 32.43%). Being a strong predictor of mortality and as the incidence of leakage was lower in the damage control group, it is expected to encounter lower mortality rates. Moreover, we are a tertiary surgical center with high experience in emergency and critical care cases, which could explain the lower mortality rate.

Our findings revealed that presentation with shock was a strong predictor for postoperative mortality. That could be explained by the hemodynamic instability and organ dysfunction associated with shock [28]. Other studies agreed with our findings regarding the relationship between shock presentation and postoperative mortality (P=0.004) [17].

Prolonged operative time was a significant predictor for mortality in our study sample. Although no previous studies reported similar findings in AMI patients, we could explain our findings by the increased exposure to anesthesia and surgical stress response. It may also denote the complexity of the surgical procedure. Exposure to the previous factors certainly increases mortality risk in such critically ill patients.

We also noted that the development of postoperative leakage was a significant risk factor for mortality. The association between leakage and poor survival has been documented after various gastrointestinal resection procedures [29,30]. Leakage results in peritonitis, sepsis, and organ dysfunction, which explains its association with mortality [31].

Despite the unique surgical topic handled by our study, it has some limitations. Collecting our patients from a single center and lack of long-term follow-up are the main drawbacks. More studies should be done to address these limitations.

Conclusion

The application of the damage control approach in patients with AMI is of great benefit over the one-stage approach. The former is associated with low leakage rates, less need for reoperation, and less incidence of 30-day mortality. That approach should be used for AMI patients to improve their perioperative outcomes.

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Conflicts of interest

There are no conflicts of interest.

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