Original Article

Evaluation of damage-control surgery in cases of acute mesenteric ischemia for salvaging small bowel length

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ABSTRACT

Background: In the context of acute mesenteric ischemia (AMI), the extent of bowel resection poses a surgical complexity due to the potential exacerbation of mesenteric ischemia postsurgery. Consequently, employing damage-control surgery (DCS) alongside a subsequent second-look operation presents an opportunity to effectively address the critical state of the patient and evaluate bowel viability after resuscitative measures.

Objectives: Evaluate the role of DCS in salvaging small bowel segments that were doubtful during the primary operation after resection of the necrotic bowel. Assess the role of DCS in overall morbidity and mortality.

Patients and Methods: A prospective cohort study conducted at Ain-Shams University Hospitals. A total of 29 patients were admitted to our department with the diagnosis of AMI and underwent DCS. Twenty-two patients were hemodynamically unstable intraoperatively, and seven patients were stable. They were evaluated regarding saving bowel length from resection and overall morbidity and mortality.

Results: A total of 29 patients underwent DCS for diffuse mesenteric ischemia with ill-defined margins for gangrenous bowel; all patients passed without stump blowout, and further resection of previously query ischemic segments done in 22 (75.9%) patients, saving bowel length from resection reaching up to 18 cm. Three (10.3%) patients had anastomotic leakage that has been managed conservatively; one of them had an enterocutaneous fistula that resolved over 6 weeks.

Conclusion: The DCS strategy (abbreviated laparotomy) offers significant advantages and demonstrates commendable outcomes among patients with AMI with diffuse and indistinct margins. This approach notably contributes to preserving bowel length and reducing the overall morbidity and mortality rates in affected patients.

Key Words: Damage-control surgery, mesenteric ischemia, salvaging bowel length.

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INTRODUCTION

Acute mesenteric ischemia (AMI) encompasses a range of conditions marked by inadequate blood supply within the mesenteric vasculature, leading to ischemia and subsequent bowel necrosis. Despite its infrequent incidence, AMI constitutes a potentially fatal health concern[1]. Given its elevated mortality rate and diagnostic challenges, AMI represents a substantial legal liability. Mitigating this risk involves maintaining a heightened clinical suspicion, prompt utilization of diagnostic imaging techniques, and timely engagement of surgical consultation and intervention[2].

AMI manifests in nonocclusive or occlusive forms, primarily attributed to mesenteric arterial embolism (50%), mesenteric arterial thrombosis (15–25%), or mesenteric venous thrombosis (5–15%)[3]. Treatment approaches hinge upon the etiology of intestinal ischemia, the patient's hemodynamic stability, and the surgical proficiency of the attending surgeon. Nonocclusive AMI typically receives medical management, while occlusive instances necessitate surgical intervention. Irrespective of the underlying cause, cases of mesenteric ischemia presenting with peritonitis or suspected intestinal infarction mandate immediate surgical intervention aimed at excising ischemic or necrotic intestinal segments[4].

After the initial resuscitative measures, a midline exploratory laparotomy is indicated, involving a comprehensive assessment of all intestinal segments and the excision of visibly necrotic portions[5]. The preferred surgical approach for critically ill AMI patients, considering physiological and technical considerations, is the damage-control surgery (DCS) method, also known as abbreviated laparotomy. Early consideration of employing the DCS approach, contingent upon the response to resuscitation and ongoing physiological parameters, correlates with enhanced mortality outcomes in these cases[6].

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Aim

The aim is to evaluate the role of DCS in salvaging small bowel segments that were doubtful during the primary operation after resection of the necrotic bowel and to assess the role of DCS in overall morbidity and mortality.

PATIENTS AND METHODS:

This prospective cohort study aims to assess the efficacy of DCS in salvaging potentially viable small bowel segments following the resection of clearly necrotic bowel sections. Additionally, it seeks to investigate the impact of DCS on the overall morbidity and mortality rates associated with this condition.

The study was conducted from November 2021 to May 2023, involving 47 patients admitted to our department diagnosed with AMI and subsequently operated upon. Among these patients, 15 individuals underwent either primary anastomosis or stoma formation based on intraoperative considerations determined by the surgeon's discretion and the patient's overall condition. These cases were excluded from the study. Furthermore, three patients died in the ICU before the scheduled second-look operation and were also excluded from the study.

In the cohort of 29 patients who were subjected to DCS, 22 exhibited intraoperative hemodynamic instability, while seven maintained stability. The DCS procedure involved the closure of both bowel ends without the execution of an anastomosis, or stoma. Subsequent to the surgery, these patients were transferred back to the ICU for appropriate resuscitation. They were later returned to the operating room for a second look and the restoration of bowel continuity. Hemodynamic instability was characterized by the presence of at least one physiological parameter, such as systemic hypertension, hypotension, tachycardia, or bradycardia, either individually or in combination[7].

The determination to execute DCS in patients was contingent on the intraoperative identification of at least one of the following conditions: an arterial systolic blood pressure less than 70 mmHg, hypothermia with a body temperature below 35°C, a serum pH value less than 7.25, or the presence of diffuse mesenteric ischemia (either arterial or venous) characterized by indistinct proximal and distal boundaries of a healthy, viable bowel.

This study was conducted at Ain-Shams University Hospitals. The approval of the Ethical Committee and written informed consent from all participants were obtained.

Inpatient postoperative recovery time ranged from 7 days to a maximum of 9 days. All patients were discharged with a set of instructions and a follow-up schedule. Our patients were all followed up for 6 months for both early and late complications for early intervention and proper management.

Patient selection was achieved through several inclusion and exclusion criteria.

Inclusion criteria

(1) Diffuse mesenteric ischemia (arterial or venous) with ill-defined proximal and distal margins of healthy, viable bowel.

(2) Both patients were included as either hemodynamically stable or unstable.

Exclusion criteria

(1) Well-demarcated mesenteric ischemia with well-defined proximal and distal margins.

(2) Massive bowel gangrene involving the whole bowel length from the dudenojejunal junction to the ileocecal junction.

(3) Patients who died in the ICU before going to the second-look operation.

Surgical technique

Following preoperative resuscitation in the ICU for unstable patients, all patients underwent surgery via a xiphi-pubic incision. A formal exploration was conducted, and the clearly gangrenous segment was excised. The length of the query segment, characterized as dusky, congested, and edematous without evident gangrene even after 5 min of hot fomentation, was measured. This segment was left closed intra-abdominally for assessment during a second-look operation postresuscitation. Both ends of the bowel were closed blindly, with only a temporary abdominal wall closure skin closure. The patient was then returned to the ICU for appropriate resuscitation and was fully anticoagulated with a heparin infusion. A second examination was performed 48–72 h later, contingent on the patient's response to resuscitation and the potential need for further resection of the small bowel. Subsequently, gastrointestinal continuity was reestablished through a hand-sewn anastomosis.

RESULTS:

In our study, we included 29 patients who underwent midline exploration for AMI and subsequently received DCS without the restoration of bowel continuity, followed by second-look laparotomy. This was out of a total of 47 patients who were operated on. We excluded 10 (21.2%) patients who had undergone bowel resection and re-anastomosis in the same setting, five (10.6%) patients who had a bowel resection and stoma formation, and three (6.3%) patients who unfortunately passed away in the ICU following the primary operation.

As regards the demographic data of the included cases shown in (Table 1), 17 (58.6%) patients were females, whereas 12 (41.4%) patients were males, with a mean age of 52.03±8.66.

Table 1: Patient demographic data

	AMI patients (*N*=29)
Age (years)	
Mean±SD	52.03±8.66
Range	35–72
Sex	[*n* (%)]
Male	12 (41.4)
Female	17 (58.6)
Comorbidities	[*n* (%)]
Diabetes mellitus	15 (51.7)
Hypertension	10 (34.5)
Coronary stents	7 (24.1)
Atrial fibrillation	8 (27.6)
Others	
Recent COVID	3 (10.3)
CKD	1 (3.4)
Previous DVT	1 (3.4)
Mitral valve replacement	1 (3.4)
Previous stroke	1 (3.4)
Antiphospholipid $	1 (3.4)

AMI, acute mesenteric ischemia.

The majority of the patients in the study had associated comorbidities. The most prevalent comorbidities were cardiovascular disorders, which included atrial fibrillation, myocardial infarction, and coronary stents, and valvular disease. Diabetes mellitus and hypertension were also commonly associated comorbidities. These findings are illustrated in (Fig. 1).

In terms of the preoperative hemodynamic assessment, 22 (75.9%) patients were classified as hemodynamically unstable. This instability manifested as hypotension, necessitating the use of inotropes to support blood pressure, tachycardia, oliguria, or even anuria and metabolic acidosis, as detailed in (Table 2). Conversely, seven (24.1%) patients were deemed hemodynamically stable.

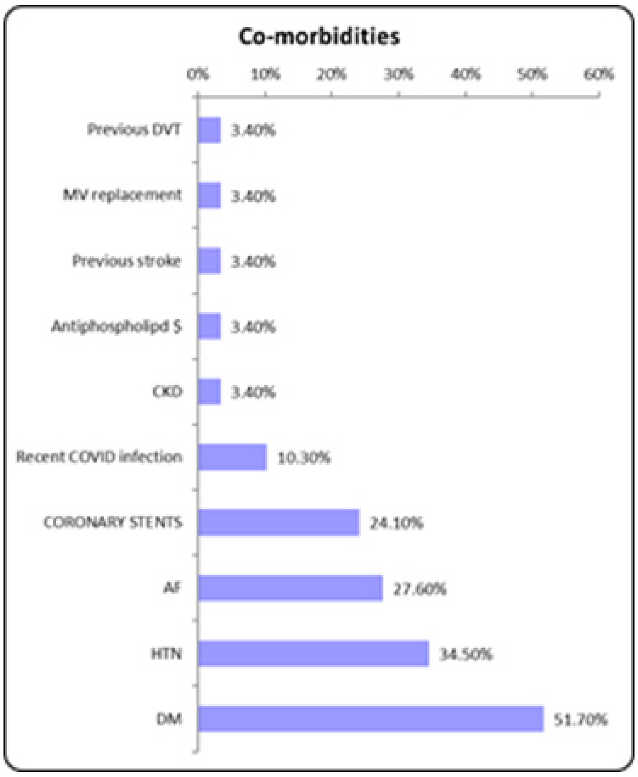

Fig. 1: Percentage of comorbidities of the studied patients.

Table 2: Preoperative hemodynamics

Preoperative hemodynamics (on admission)	Total *N*=29 [*n* (%)]
Hemodynamic stability	
Stable	7 (24.1)
Unstable	22 (75.9)
Systolic blood pressure	
Mean±SD	93.1±16.85
Range	74–128
Diastolic blood pressure	
Mean±SD	54.93±10.97
Range	40–82
Heart rate	
Mean±SD	117±13.19
Range	88–149
Urine output	
No	4 (13.8)
Yes	25 (86.2)
Urine output (ml/h)	
Mean±SD	47.6±21.85
Range	30–100
Arterial blood gases (pH)	
Mean±SD	7.29±0.06
Range	7.15–7.4

For the purpose of the study, as shown in (Table 3), the ischemic bowel segment was intraoperatively categorized based on its location into three distinct regions: region 1, the proximal jejunum, extended from the duodenojejunal junction to 60 cm into the jejunum; region 2 commenced 60 cm distal to the duodenojejunal junction and extended to 100 cm proximal to the ileocecal junction; and region 3 encompassed the distal 100 cm of the ileum up to the ileocecal junction.

The most frequently affected region was region 1, with 13 (44.8%) patients, while region 3 was the least affected, with seven (24.1%) patients; of these, two (6.9%) patients exhibited ischemia extending to the ileocecal junction (Fig. 2).

The overtly gangrenous segment was excised, and the length of the query segment, characterized as dusky, congested, and edematous without evident gangrene even after 5 min of hot fomentation, was measured and found to range from 8 to 26 cm. Both ends of the bowel were left closed intra-abdominally for assessment during a second-look operation following appropriate resuscitation in the ICU.

Table 3: Intraoperative findings in the first operation regarding the ischemic bowel segment

Intraoperative findings of small intestine	*N*=29 [*n* (%)]
Length of query segment (cm)	
Mean±SD	14.93±4.94
Range	8–26
Reaching ileocecal junction	
Yes	2 (6.9)
No	27 (93.1)
Region of ischemic bowel segment	
Region 1	
Proximal jejunum, 0–60 cm jejunum	13 (44.8)
Region 2	
Distal jejunum, 60 cm from dudenojejunal junction, till distal ileum, 100 cm away from the ileocecal junction	9 (31)
Region 3	
Distal 100 cm of ileum	7 (24.1)

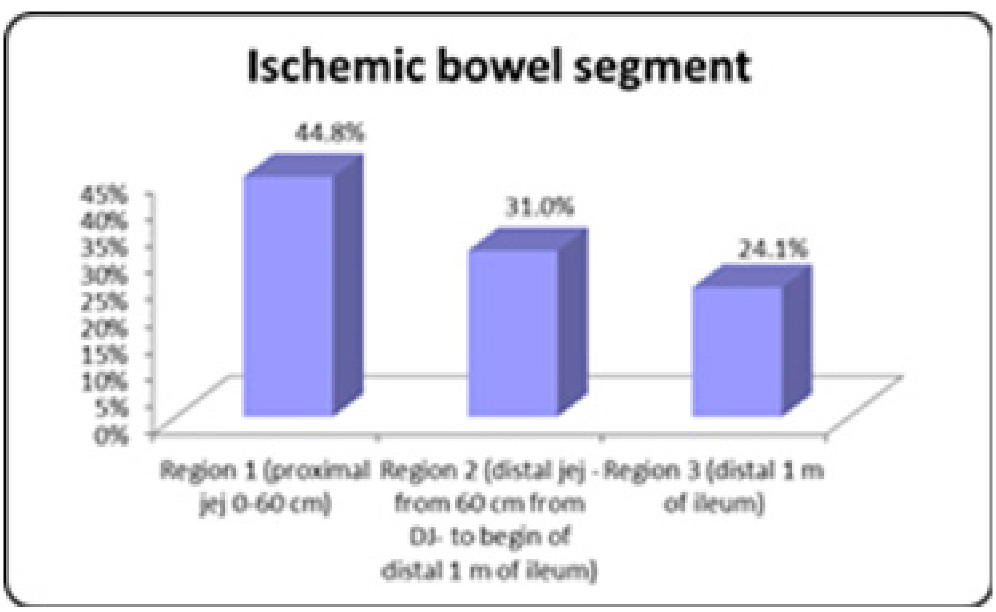

Fig. 2: Regions of the ischemic bowel segment in AMI patients. AMI, acute mesenteric ischemia.

As indicated in (Table 4), intraoperative hemodynamic parameters were documented. It was observed that patients who were initially unstable began to respond to resuscitation and damage control measures, which included the resection of the overtly gangrenous bowel segment. A total of 17 (58.6%) patients were administered inotropes to bolster blood pressure and sustain organ function. Furthermore, 21 (72.4%) patients required an intraoperative blood transfusion, receiving between 2 and 4 U of packed red blood cells. The duration of the surgical procedure, measured from the initial skin incision to the final skin closure, varied between 33 and 47 min. This expedited surgical timeline facilitated a reduced duration under anesthesia, early transfer to the ICU, starting anticoagulation, proper resuscitation, and monitoring.

Table 4: Intraoperative hemodynamics' blood transfusion, use of inotropes, and duration of the surgical procedure

Intraoperative hemodynamics	AMI patients (*N*=29)	
SBP (mmHg)	Mean±SD	98.41±14.38
	Range	80–125
DBP (mmHg)	Mean±SD	61.24±9.64
	Range	45–85
Heart rate (beat/min)	Mean±SD	112.86±15.91
	Range	78–129
Urine output (ml/h)	Mean±SD	55.52±18.82
	Range	30–100
Duration of the surgical procedure (min)	Mean±SD	40.83±3.76
	Range	33–47
Use of inotropes [*n* (%)]	Yes	17 (58.6)
	No	12 (41.4)
Need for blood transfusion [*n* (%)]	Yes	21 (72.4)
	No	8 (27.6)

AMI, acute mesenteric ischemia.

During the ICU interval, there was a significant improvement in hemodynamic parameters, as seen in (Table 5). The systolic blood pressure ranged from 96 to 132 mmHg, the diastolic blood pressure varied between 55 and 84 mmHg, and the heart rate fluctuated between 75 and 112 beat/min. Additionally, urine output was satisfactory, ranging from 50 to 100 ml/h. Within the first 24 h of their ICU stay, 19 (65.5%) patients were extubated. The number of patients requiring inotropic support decreased from 17 (58.6%) during the intraoperative period to eight (27.6%) during their stay in the ICU.

Table 5: Hemodynamics during the ICU interval after primary damage-control surgery

ICU interval hemodynamics'	AMI patients (*N*=29)	
SBP (mmHg)		
Mean±SD	110.45±9.06	
Range		96–132
DBP (mmHg)		
Mean±SD	68.86±6.67	
Range		55–84
Heart rate (beat/min)		
Mean±SD	97.72±9.42	
Range		75–112
Urine output (ml/h)		
Mean±SD	70.69±25.06	
Range		50–100

Extubation in the first 24 h [*n* (%)]	
Yes	19 (65.5)
No	10 (34.5)
Still on inotropes to support BP [*n* (%)]	
Yes	8 (27.6)
No	21 (72.4)

AMI, acute mesenteric ischemia.

As demonstrated in (Table 6), in the second-look operation, upon examination, it was found that none of the patients experienced stump blowout. Further resection was performed on the previously query ischemic segment, which had progressed to overt gangrene, in 26 (89.7%) patients. The length of the resected segment reached up to 10 cm, compared to the 8–26 cm range observed in the initial operation. Consequently, up to 18 cm of small bowel length was salvaged, which otherwise could have been unnecessarily resected.

Table 6: Second-look operation findings

Second-look operation findings	*N*=29 [*n* (%)]
Stump blow out	
Yes	0
No	29 (100)
Need for further resection of the previously query ischemic segment	
Yes	26 (89.7)
No	3 (10.3)
Length of resected segment in the second look (cm)	
Median (IQR)	7 (4–8)
Range	0–10
Length of the salvaged segment after the second look (cm)	
Mean±SD	8.93±4.23
Range	2–18

Outlined in (Table 7) that after the second operation, patients were closely monitored revealing that their vital signs remained stable, and bowel function recovery was observed within 2–4 days postoperatively. The duration of the hospital stay varied between 7 and 9 days.

Table 7: Postoperative follow-up

Recovery of bowel function after the second operation	
Mean±SD	2.69±0.71
Range	2–4
Hospital stay (days)	
Mean±SD	7.31±2.12
Range	7–9

Upon discharge, patients were provided with a follow-up schedule to monitor for any delayed complications, such as dehydration, electrolyte imbalance, and impaired kidney functions. Kidney function tests were scheduled twice weekly for the initial 2 weeks postdischarge.

In (Table 8) results revealed that during the follow-up period, morbidity evaluation revealed six cases of surgical site infection that were managed with daily dressing and progressed without incident, except for two instances of wound dehiscence. Three cases exhibited anastomotic leakage, which was delayed until the 12th to 14th postoperative day and was managed conservatively. Among these, one patient developed an enterocutaneous fistula, which resolved spontaneously over a span of 6 weeks. One case involved a pelvic abscess, which was drained using an ultrasound-guided catheter. Additionally, eight cases presented with an electrolyte imbalance, specifically hypokalemia and hypomagnesemia, all of which were resolved with electrolyte replacement and the initiation of oral feeding.

Importantly, no mortality was reported following the second operation during the follow-up period.

Table 8: Postoperative complications

Postoperative complications	*N*=29 [*n* (%)]
Wound infection	
No	23 (79.3)
Yes	6 (20.7)
Wound dehiscence	
No	27 (93.1)
Yes	2 (6.9)
Electrolyte disturbance	
No	21 (72.4)
Yes	8 (27.6)
Thromboembolic complications (deep venous thrombosis)	
No	29 (100.0)
Yes	0
Anastomotic leakage	
No	26 (89.7)
Yes	3 (10.3)
Enterocutaneous fistula	
No	28 (96.6)
Yes	1 (3.4)
Pelvic abscess	
No	28 (96.6)
Yes	1 (3.4)

DISCUSSION

In the present study, we conducted a prospective analysis of data from 29 patients who underwent DCS for acute bowel ischemia, followed by a second-look operation. The aim was to evaluate the outcomes of the DCS strategy.

Our findings, in agreement with Kaminsky *et al*.[8] and Edwards *et al*.[9], revealed that females were the predominant sex, with an average age of □52 years. Furthermore, Weber *et al*.[10] noted that advanced age is not a contraindication to DCS, as favorable results have been documented in elderly patients. Additionally, metabolic diseases such as diabetes mellitus and cardiovascular disorders (e.g. hypertension and coronary stents) were the most frequently associated comorbidities.

Two patients in our study had a recent coronavirus disease 2019 infection, which could be the cause of the mesenteric ischemia, Although the supportive evidence has not yet confirmed. This aligns with the findings of Lodigiani *et al*.[11], who reported that AMI has been observed in patients with a coronavirus infection, likely due to large and small vessel thrombosis associated with hypercoagulability and inactivity of fibrinolysis.

Gupta and Tomar[12] suggested that the DCS approach is the preferred technique for unstable patients. In our study, 22 patients were hemodynamically unstable and underwent DCS to manage and reverse hemodynamic instability and counteract the lethal triad of hypothermia, acidosis, and coagulopathy. The remaining seven patients were hemodynamically stable; however, they had diffuse bowel ischemia with ill-defined margins of gangrene, so DCS was applied in an attempt to preserve bowel length. This is consistent with Bala *et al*.[5], who recommended that in cases of uncertainty regarding bowel viability, the stapled-off bowel ends should be left in discontinuity and re-inspected after a period of continued ICU resuscitation to reestablish physiological balance.

For the purposes of the study, we classified the small bowel affected by mesenteric ischemia into three regions intraoperatively, and the overtly gangrenous segment was resected. Region 1 was affected in 44.8% of patients, so applying DCS prevented them from high-output stoma and its complications. Only two patients had the affected segment reach the ileocecal junction, which was preserved and improved in the second operation, thereby increasing the intestinal transit time with a competent ileocecal valve and reducing the risk of short bowel syndrome (SBS) and electrolyte imbalance. This correlates with Merida *et al*.'s[13] results, which showed that the inclusion of the right colon in resection was a negative prognostic factor.

In the current study, the query segment, defined as being dusky, congested, edematous, and not overtly gangrenous even after hot foments for 5 min, was measured and left closed intra-abdominally for assessment after resuscitation in the second operation. This approach aligns with the findings of Bala *et al*.[5]. Additionally, Acosta[14] and Wyers[15] reported that the viability of the remaining bowel should be determined after the patient has been adequately resuscitated and any resection or revascularization performed.

The duration of the surgical procedure, measured from skin incision to skin closure, ranged from 33 to 47 min. This allowed for less time under anesthesia, early transfer to the ICU, initiation of anticoagulation, proper resuscitation, and monitoring. This is slightly less than the median operative time of about 55 min for damage control patients reported by Girard *et al*.[16]. Furthermore, Hamed *et al*.[17] reported that patients who underwent diverting stoma experienced an increased mean operative time (94 min) when compared with those in the damage control group (52 min), a difference that was statistically significant ($P<0.001$). This discrepancy can be attributed to the time consumed for stoma creation and definitive closure of the abdominal fascia, while in the damage control group, temporary abdominal skin closure was performed.

Luther *et al*.[18] stated that anticoagulation initiated following diagnosis was associated with a better outcome in arterial AMI. Our study confirmed this, as patients in the ICU interval continued to receive proper resuscitation, monitoring, anticoagulation with heparin infusion monitored with activated partial thromboplastin time, and sepsis treatment through proper antibiotics according to ICU protocol. This led to notable improvements in hemodynamics and extubation during the ICU stay, which was performed in 19 (65.5%) patients. This is also supported by the results of Rhodes *et al*.[19], who stated that due to the potential bacterial translocation from the injured gut, broad-spectrum antibacterial treatment according to current guidelines should be continued after surgery based upon the degree of contamination and culture results.

After 48–72 h of resuscitation in the ICU, a second-look operation was performed, showing that none of the patients had stump blow out. Further resection of the query ischemic segment (that became overtly gangrenous) was performed in 26 (89.7%) of patients, salvaging small bowel length reaching up to 18 cm. Although the salvaged bowel length could be too small to be considered, this may help to avoid SBS, as Luther *et al*.[18] reported that if additional resection of more bowel segments is required, one should consider the critical lengths of the remaining bowel. If these limits are not met, the patient develops SBS, which necessitates constant parenteral nutrition or even a bowel transplant. Therefore, when deciding to exceed these resection limits, one should consider the patient's age and comorbidities.

Critical lengths of the remaining bowel to avoid SBS.

100 cm for a permanent jejunostomy (loss of colon).

65 cm for a jejunocolic anastomosis (preservation of colon).

35 cm for a jejunoileal anastomosis with preservation of the ileocecal region.

Haltmeier *et al*.[20] suggested that the elevated incidence of surgical site infections in the DCS group, compared to the conventional surgery group, could be attributed to the distinct characteristics of the patients, such as associated comorbidities and hemodynamic parameters upon presentation. Consistent with this, our postoperative morbidity assessment revealed surgical site-related complications, as surgical site infection was identified in six (20.7%) patients who had multiple metabolic and cardiac comorbidities.

Wound dehiscence was observed in two (6.9%) patients, a finding that aligns with the results of Haltmeier *et al*.[20], which demonstrated a significant weighted proportion of abdominal wall hernias of 16.6% in patients undergoing DCS. However, as reported in Basta *et al*.[21], emergency laparotomy itself is a recognized risk factor for incisional hernias.

Electrolyte imbalance, in the form of hypokalemia, was detected in eight (27.6%) patients and was corrected with intravenous potassium administration and close monitoring. Two instances of anastomotic leakage were effectively managed conservatively, with one of them resulting in an enterocutaneous fistula that spontaneously closed over a period of 6 weeks. Another case involved a pelvic abscess, which was drained using an ultrasound-guided pigtail catheter and treated with antibiotics based on culture and sensitivity results.

Girard *et al*.[16] reported a median ICU stay of 4 days and a total hospital stay of 15 days in a study evaluating the efficacy of damage-control strategies in AMI. In our study, the total hospital stay ranged from 7 to 9 days, with 2–3 days of ICU admission and 5–6 days following the second operation. The extended length of stay in the DCS may be due to the necessity for relook laparotomies.

In a meta-analysis, Haltmeier *et al*.[20] concluded that the observed mortality was significantly lower than the expected mortality rate in the DCS group, suggesting a benefit of the DCS approach. In our study, three mortality cases were observed postoperatively during the ICU interval due to multiple comorbidities, severe hemodynamic instability, and delayed presentation. This is supported by Kougias *et al*.'s[22] findings, which showed that mortality dramatically increases when symptoms have been present for more than 24 h in AMI. No mortality was recorded after the second-look operation during our follow-up period.

Limitations

Despite the promising outcomes related to DCS, our study has several limitations. This study only describes data from a single surgical unit with a small number of patients (n=29). To address these limitations, we are continuously recruiting patients to increase the sample size and ensure long-term follow-up. In the future, a multicentric study will be required to avoid investigator bias.

CONCLUSION

The DCS strategy has emerged as a pivotal approach in the management of patients with AMI with diffuse and ill-defined margins using less operative time, facilitates the salvaging of small bowel length, also proved the safe closure of both bowel ends blindly without stump blowing out. Moreover, DCS circumvents intestinal stoma complications, improving the postoperative quality of life. Importantly, DCS also mitigates the risk of anastomotic leakage if primary anastomosis is performed over a questionable ischemic bowel segment.

CONFLICT OF INTEREST

There are no conflicts of interest.

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