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Original Article

Rate of stoma formation following damage-control surgery for severe intra-abdominal sepsis: a single-centre consecutive case series

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Preliminary results were presented at the World Congress of Surgery 2017 (poster), the Congress of the European Society of Coloproctology 2017 (poster) and the Swiss Surgical Congress 2017 (oral presentation).

Abstract

Background: Severe intra-abdominal sepsis (IAS) is associated with high mortality and stoma rates. A two-stage approach with initial damage-control surgery (DCS) and subsequent reconstruction might decrease stoma and mortality rates but requires standardization.

Methods: A standardized two-stage damage-control algorithm for IAS was implemented in April 2016 and applied systematically.

Results: Some 203 consecutive patients (median age 70 years, 62 per cent ASA score greater than 3) had DCS for severe IAS. Median operation time was 82 minutes, 60 per cent performed during night-time. Median intraoperative noradrenaline doses were 20 (i.q.r. 26) μg/min and blood gas analysis (ABG) was abnormal (metabolic acidosis) in 90 per cent of patients. The second-stage operation allowed definitive surgery in 76 per cent of patients, 24 per cent had up to four re-DCSs until definitive surgery. The in-hospital mortality rate was 26 per cent. At hospital discharge, 65 per cent of patients were stoma free. Risk factors for in-hospital death were noradrenaline (odds ratio 4.25 (95 per cent c.i. 1.72 to 12.83)), abnormal ABG (pH: odds ratio 2.72 (1.24 to 6.65); lactate: odds ratio 6.77 (3.20 to 15.78)), male gender (odds ratio 2.40 (1.24 to 4.85)), ASA score greater than 3 (odds ratio 5.75 (2.58 to 14.68)), mesenteric ischaemia (odds ratio 3.27 (1.71 to 6.46)) and type of resection (odds ratio 2.95 (1.24 to 8.21)). Risk factors for stoma at discharge were ASA score greater than 3 (odds ratio 2.76 (95 per cent c.i. 1.38 to 5.73)), type of resection (odds ratio 30.91 (6.29 to 559.3)) and longer operation time (odds ratio 2.441 (1.22 to 5.06)).

Conclusion: Initial DCS followed by secondary reconstruction of bowel continuity for IAS within 48 hours in a tertiary teaching hospital was feasible and safe, following a clear algorithm.

Introduction

Treatment of intra-abdominal sepsis (IAS) is technically challenging and associated with high mortality rates (28 per cent in severe sepsis and 68 per cent in septic shock). There are high rates of stoma formation (72–75 per cent in patients operated at primary intention) with long-term stoma reversal in only about half of patients[1–8]. Primary anastomosis, as opposed to non-restorative Hartmann's procedure, was shown to have fewer surgical-site infections and lower reoperation and stoma rates[9], but is not always feasible in patients with severe IAS at the primary operation. Management of patients with severe IAS should not only aim for aggressive early resuscitation and source control, but also have the goal of a high rate of anastomosis in appropriate patients. A damage-control approach with two surgical stages might achieve this objective.

The principle of damage-control surgery (DCS) was first embraced in therapeutic packing of hepatic injuries in the early 20th century[10–12]. The concept re-emerged in the late 1970s and early 1980s[13,14] for patients with major hepatic injury as an 'unorthodox technique to abruptly terminate laparotomy after source control'[15]. The aim was to prevent early deaths due to uncontrolled haemorrhage exacerbated by the lethal triad of progressive coagulopathy, hypothermia and acidosis. In 1993, the term 'damage control', which originates from US naval usage, 'the ability to sustain, control, and repair combat damage and allow warship to return to offensive action', was adopted in trauma surgery to describe a two-stage DCS approach in exsanguinating penetrating abdominal injury[16].

In the 21st century, DCS has become of interest in non-trauma patients. Critically ill patients with IAS due to mesenteric ischaemia or perforation may benefit from DCS, as single laparotomy cannot always control this kind of infection effectively[17]. However, there is a risk of overtreatment with DCS, as not all IAS patients require planned re-laparotomy but can be managed by re-laparotomy if clinically required[18]. Pioneer groups proposed and successfully tested DCS for IAS[19–25], suggesting both low

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mortality and stoma rates at discharge[5,21,26–29]. A recent randomized controlled trial including 21 patients with diverticular perforation Hinchey III–IV highlighted the lower stoma rate of DCS compared with that of the traditional one-stage approach with ostomy formation[30]. Despite DCS being recommended by the World Society of Emergency Surgery Guidelines for critically ill patients with sepsis or septic shock[31,32], there is a need to define and refine the management of this non-traumatic emergency

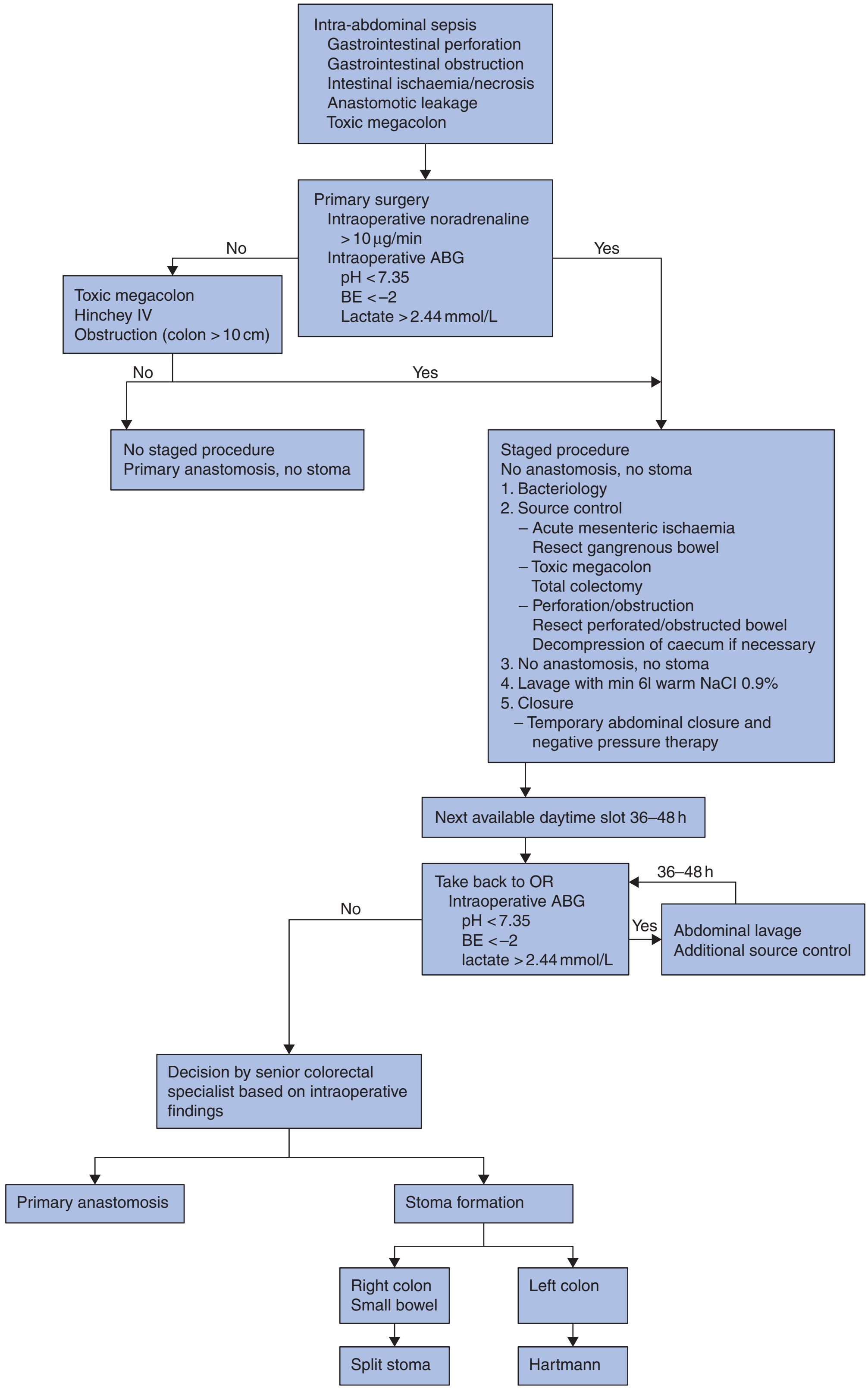

Fig. 1 Treatment algorithm

Standardized treatment approach for critically ill patients with abdominal sepsis. ABG, arterial blood gas analysis; BE, base excess; OR, operating room.

group[33,34]. Haemodynamic and physiological disturbances, like acidosis, are risk factors for adverse outcome in severely injured patients undergoing DCS[35–38]. These parameters might also be of paramount importance in the indication for DCS in septic patients.

The aims of the present study were to assess feasibility, safety and outcomes in a consecutive cohort of patients treated by a new and original, standardized two-stage algorithm following clearly defined decisional criteria in a tertiary teaching hospital. The hypothesis was that damage control, already used in the management of trauma patients, can be applied safely and efficiently in patients with IAS.

Methods

This study included consecutive patients operated for IAS after implementation of a standardized two-stage strategy (22 April 2016 to 31 March 2020) at the University Hospital Lausanne, Switzerland. This hospital is a tertiary centre with a catchment area with 850 000 inhabitants. The algorithm (*Fig. 1*) was introduced systematically for all patients with severe IAS, and the local ethical committee granted permission for the study (CECV # 2018–00137). STROBE criteria[39] for cohort studies were followed.

Standardized two-stage damage-control pathway

DCS was defined as resection of affected bowel, washout and abdominal vacuum therapy followed by stabilization of the patient in the ICU or intermediate-care unit and planned second-look laparotomy with the goal of re-establishing bowel continuity if appropriate.

Second-look laparotomy was planned according to the patient's clinical condition at 36–48 hours after the initial surgery and ideally during daytime with the presence of a senior colorectal surgeon. At second-look laparotomy, the senior colorectal surgeon made the decision to re-establish bowel continuity by anastomosis or to form a terminal stoma. If a patient remained unstable, a second damage-control operation was performed at that stage.

Selection and inclusion criteria

The designed institutional pathway displayed inclusion criteria and decisional criteria for surgical strategy (*Fig. 1*). Inclusion criteria were based on haemodynamic instability (noradrenaline requirement) and physiological disturbance (pathological ABG) after resection of the diseased bowel and washout of the abdominal cavity. Doses of noradrenaline greater than 10 μg/min, as well as pH less than 7.35, base excess less than –2, or lactate greater than 2.44 mmol/l were considered indications for DCS. Furthermore, in the absence of the above-mentioned criteria, the presence of toxic megacolon, severe faecal peritoneal contamination of the entire abdominal cavity, and dilatation of the colon greater than 10 cm were considered unsuitable for primary anastomosis and thus inclusion criteria for DCS. Second-look laparotomy with intended reconstruction was planned according to the patient's general condition 36–48 hours after initial surgery as described.

Data collection

Demographic and surgical information and data on death and presence or absence of stoma at hospital discharge were documented prospectively in an institutional database. Data collection was performed by two authors, and differences and sources of bias were discussed with the supervising authors.

Table 1 Variables for overall study population

Variables	Study population ($n = 203$)
Noradrenaline (μg/min)*	20 (26)
pH*	7.302 (0.144)
Base excess*	−6.5 (8.4)
Lactate (mmol/l)*	2.55 (2.46)
Gender	
Female	88
Male	115
Immunosuppression	28 (14)
Age (years)*	70 (20)
BMI (kg/m^2)*	26.2 (7.2)
ASA score >3	126 (62)
Diagnosis	
Mesenteric ischaemia	95 (47)
Intestinal perforation	61 (30)
Anastomotic leakage	25 (12)
Intestinal obstruction	13 (6)
Bleeding	8 (4)
Toxic megacolon	1 (0)
Type of resection	
Small bowel	46 (23)
Large bowel	123 (61)
Small and large bowel	14 (7)
Anastomosis only	20 (10)
Operation time (min)*	82 (49)
Daytime (operation start 7.00–17.00 hours)	81 (40)
Operation request to skin incision (min)*	98 (68)
Number of re-damage control†	
None	156 (77)
One	35 (17)
Two	10 (5)
Three	1 (0)
Four	1 (0)

Values in parentheses are percentages unless indicated otherwise; *values are median (i.q.r.). †Re-damage control represents the number of intermediate operations for abdominal lavage prior to definitive surgery with anastomosis or stoma formation and fascial closure.

Table 2 Type of discontinuity resection during damage-control surgery

Type of resection	Number ($n = 203$)
Small bowel resection	46 (23)
Ileocaecal resection, right/extended right resection	37 (18)
Rectosigmoid resection	33 (16)
Total colectomy	27 (13)
Left/extended left colectomy	22 (11)
Resection of insufficient anastomosis	20 (10)
Multiple small and large bowel resections	14 (7)
Transverse colic resection	4 (2)

Values in parentheses are percentages.

Statistics and analysis

Descriptive statistics for continuous variables were reported as mean(s.d.) if parametric or as median (i.q.r.) if non-parametric; categorical variables were reported as frequency (per cent). Primary outcomes 'death' and 'stoma at hospital discharge' were defined as death within hospital stay (even if over 30 days) and patient discharged from hospital to home or rehabilitation facility with a stoma (protective stoma or terminal stoma). Simple logistic regression was performed to find risk factors for death and stoma at hospital discharge, odds ratio and 95 per cent confidence intervals were reported. All statistical tests were

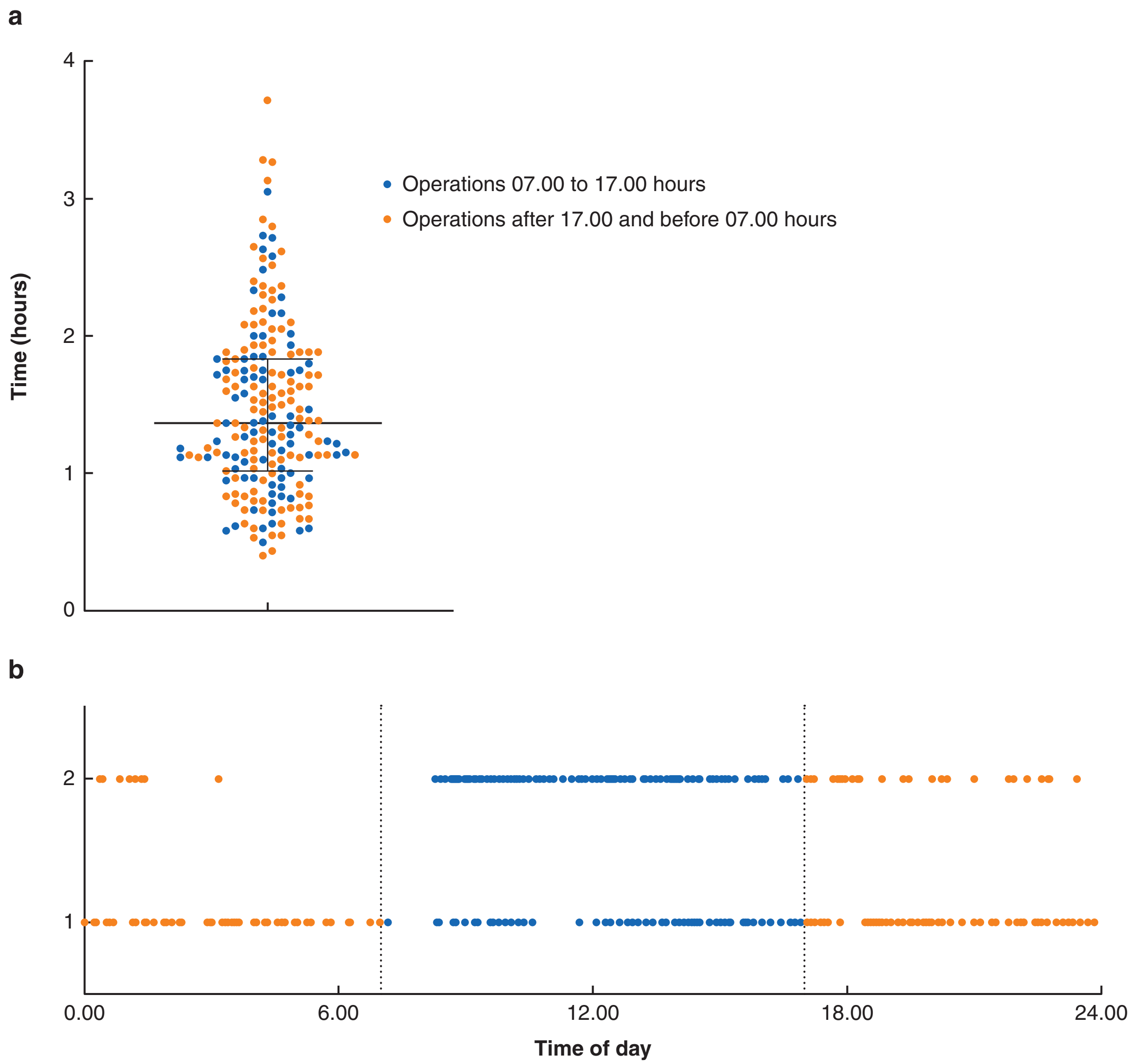

Fig. 2 Duration and time of day of operation

a Operating duration of damage-control surgery is represented in scatter plot where each dot represents one patient, line represents median and error bars represent interquartile range. **b** Graph of time of day displaying starting hour of operation at first-look operation (1) and definitive surgery (2) with anastomosis or stoma formation.

two-sided, and a level of $P < 0.050$ indicated statistical significance. Data analyses were performed using GraphPad Prism 8 for Windows 64-bit, version 8.3.0 (538), (GraphPad Software, San Diego, California, USA, www.graphpad.com).

Results

Overall, 203 patients underwent DCS for IAS. Pre- and intraoperative findings are detailed in *Table 1*. Bowel resections included small bowel in 46 patients (23 per cent), large bowel in 123 patients (61 per cent), both small and large bowel in 14 patients (7 per cent), and insufficient anastomosis in 20 patients (10 per cent) (*Table 2*). Median operation time for DCS was 82 (i.q.r.49) minutes with 81 operations (60 per cent) performed during night-time (*Fig. 2*). Median intraoperative noradrenaline doses were 20 (i.q.r. 26) µg/min) and ABG at time of skin incision was abnormal in 90 per cent of patients, showing pathological pH in 141 patients (69 per cent), base excess (less than –2) in 161 patients (79 per cent) and lactate (greater than 2.44 mmol/l) in 104 patients (51 per cent) (*Fig. 3*).

Planned second-stage operation took place after a median of 45 (i.q.r. 22) hours. Patients had up to five DCS operations, allowing definitive surgery in 184 of 203 patients (91 per cent), 120 of whom (65 per cent) had anastomosis without protective stoma (*Fig. 4*). Definitive surgery was performed during daytime in 149 of 184 patients (81 per cent) (*Fig. 2*) and during night-time in 35 patients (19 per cent): 26 patients (14 per cent) before midnight and nine (5 per cent) after midnight.

In-hospital death occurred in 53 of 203 patients (26 per cent), including 19 deaths before definitive surgery and 34 deaths after definitive surgery (14 patients with anastomosis, 18 patients with stoma and 2 patients with anastomosis and stoma), with a median time to death of 11 (range 0–82) days. Eight patients with initially unprotected anastomosis required reoperation and underwent secondary stoma formation (6 terminal stomas and 2 protective stomas). At hospital discharge, 98 of 150 patients (65 per cent) had no stoma, 33 (22 per cent) had terminal colostomy, 11 (7 per cent) had terminal ileostomy, six (4 per cent) had an anastomosis with protective ileostomy and two patients (1 per cent) had a split ileostomy.

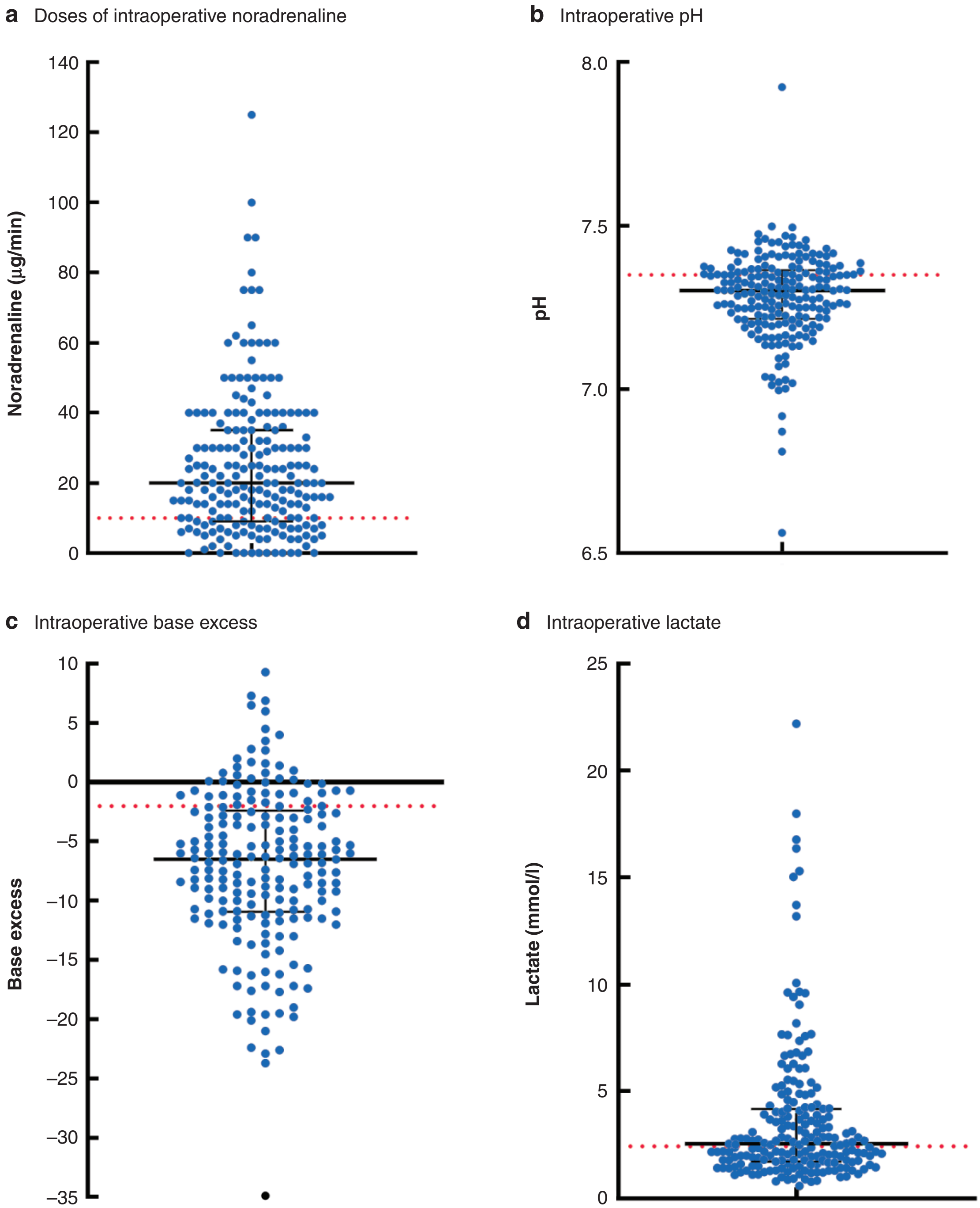

Fig. 3 Physiological variables

a Maximum doses of intraoperative noradrenaline. **b** pH; **c** base excess; and **d** lactate measured in intraoperative arterial blood gas analysis. Each dot represents one patient, line represents median and error bars represent interquartile range. Red dotted line highlights threshold for staged procedure.

Significant risk factors for in-hospital death and hospital discharge with a stoma are listed in *Tables 3* and *4*.

Discussion

Objectives in the management of patients with severe IAS include early resuscitation, urgent source control and low stoma rate at discharge in appropriate patients. A non-restorative approach is the traditional strategy for patients with haemodynamic instability or deranged physiology. A DCS approach can significantly increase primary anastomosis rate, but indications, timing and techniques of this approach need to be refined. The present paper proposes clear decisional criteria for DCS in IAS.

This two-stage damage-control approach was feasible with an acceptable in-hospital mortality rate of 26 per cent, considering the high-risk patient population. Out of the 74 per cent of patients that were discharged from hospital, 65 per cent did not require a stoma.

Despite many advances in the management of IAS, intensive care and adherence to current recommendations for the management of IAS[1,40–42], the mortality rate of patients with severe IAS remains high. In a randomized trial of patients with

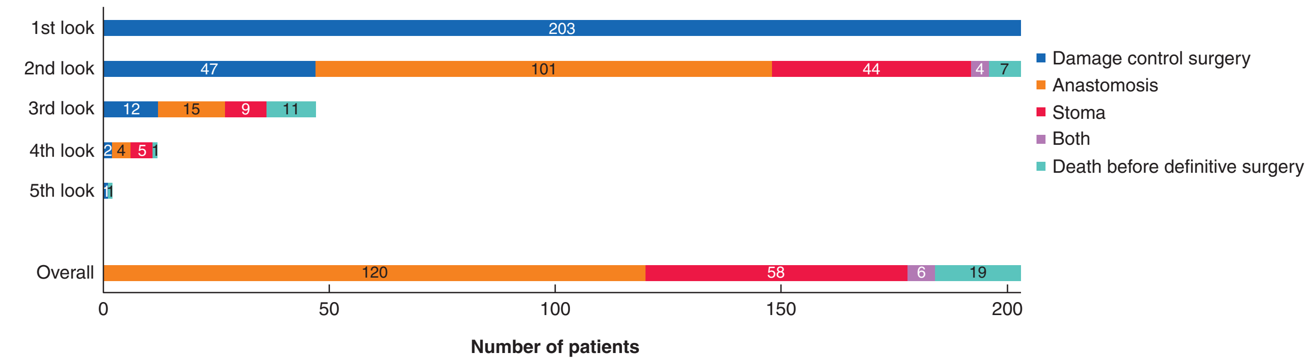

Fig. 4 Course of treatment along treatment algorithm

Table 3 Independent risk factors for death

Independent variables	Death (*n* = 53)	Odds ratio†
Noradrenaline (μg/min)	28 (33)*	**4.25 (1.72, 12.83)**
pH	7.224 (0.187)*	**2.72 (1.24, 6.65)**
Base excess	−9.6 (12.905)*	1.61 (0.70, 4.22)
Lactate (mmol/l)	4.1 (4.0)*	**6.77 (3.20, 15.78)**
Gender (female, male)	15, 38	**2.40 (1.24, 4.85)**
Immunosuppression	11 (21)	2.05 (0.87, 4.68)
Age (years)	73 (19)*	1.61 (0.86, 3.06)
BMI (kg/m^2)	26 (7)*	0.99 (0.47, 2.02)
ASA score >3	46 (87)	**5.75 (2.58, 14.68)**
Diagnosis		**3.27 (1.71, 6.46)**
Mesenteric ischaemia	36 (68)	
Intestinal perforation	9 (17)	
Anastomotic leakage	5 (9)	
Intestinal obstruction	2 (4)	
Bleeding	1 (2)	
Toxic megacolon	0 (0)	
Type of resection		**2.95 (1.24, 8.21)**
Small bowel	6 (11)	
Large bowel	37 (70)	
Small and large bowel	5 (9)	
Anastomosis only	5 (9)	
Operation time (min)	76 (52.5)*	0.67 (0.35, 1.25)
Daytime (operation start 7.00–17.00 hours)	24 (45)	0.74 (0.39, 1.40)
Operation request to skin incision (min)	92 (89)*	0.63 (0.31, 1.30)
Number of re-damage control‡		1.77 (0.78, 3.87)
None	33 (62)	
One	16 (30)	
Two	2 (4)	
Three	1 (2)	
Four	1 (2)	

Values in parentheses are percentages unless indicated otherwise; Odds ratios in bold are statistically significant. *values are median (i.q.r.), †values in parentheses are 95 per cent confidence intervals. ‡Re-damage control represents the number of intermediate operations for abdominal lavage prior to definitive surgery with anastomosis/stoma formation and fascial closure.

severe sepsis and septic shock, implementation of protocol-based early goal-directed therapy or protocol-based standard therapy did not decrease 90-day and 1-year mortality rates compared with standard care[43]. In several studies, inadequate initial source control was suspected to be a significant risk factor for death[41,42]. However, an analysis of the National Surgical Quality Improvement Program (NSQIP) database did not find clear survival benefit for rapid source-control laparotomy compared with primary closure in patients with septic shock[44]. In this study a mortality rate of 26 per cent was observed in a frail population with ASA score 45 in 62 per cent of patients, severe sepsis and haemodynamic instability.

Noradrenaline dose, pathologically low pH, elevated lactate, male gender and high ASA score were risk factors for death. A multicentre trial including 290 patients with septic shock demonstrated that mean vasopressor dose, physiological disturbance and coagulopathy were associated with death[45]. In patients after DCS for severe trauma with exsanguination, predictive factors for death (69 per cent) were pH 7.2 or lower, hypothermia, blood and fluid replacement and blood loss[38]. Low pH and hypothermia were considered risk factors for death in critically injured patients with a mean pH of 7.09[15]. Patients with trauma-induced uncontrollable haemorrhage, with pH 7.18 or lower, hypothermia, coagulopathy and transfusion of more than 10 units, had a mortality rate of 100 per cent[35]. Coagulopathy is a risk factor for death in non-traumatic patients with sepsis, the mortality rate increasing progressively from 25.4 per cent without sepsis-associated coagulopathy to 56.1 per cent in severe sepsis-associated coagulopathy[46].

Death of septic patients depends on the severity of sepsis. The WISS Study validated the sepsis-severity score and confirmed that this score was an independent predictive factor of death for sepsis patients[2]. A prospective study with 51 patients with perforated diverticulitis identified ASA score, initial organ failure and cardiac co-morbidity as risk factors for death (9.8 per cent)[21]. The CIAOW study, a worldwide multicentre observational study including 1898 patients with intra-abdominal infection (appendicitis in one third of patients), found an overall mortality rate of 10.5 per cent with independent variables predictive of death being age, the presence of small bowel perforation, a delayed initial intervention (a delay exceeding 24 hours), ICU admission and patient immunosuppression[47]; results for Europe were similar[48].

Time from admission to DCS was shown to be a critical determinant of survival in patients with gastrointestinal perforation and associated septic shock[49]. The target time for favourable outcome was within 6 hours from admission. In a retrospective analysis, delayed source control in patients with DCS for IAS of over 6 hours was related to increased mortality rates, which increased with every 6-hour delay before surgery[50]. In the present study, median time between booking theatre and skin incision was short (98 (i.q.r. 68) minutes), never exceeded 6 hours and was not related to increased mortality rate. Operation time (median 82 (i.q.r. 49) minutes), operating in daytime and number of re-DCSs were not risk factors for death.

Stoma rates in patients with one-stage surgery for IAS are high; for example, in perforated diverticulitis, rates were 72 per cent in a Spanish multicentre retrospective study[4], and 75 per cent in a US NSQIP review[3]. Stoma reversal was performed in only about 50 per cent of patients and was associated with high complication

Table 4 Independent risk factors for stoma at discharge

Independent variables	No stoma at discharge ($n = 98$)	Stoma at discharge ($n = 52$)	Odds ratio†
Noradrenaline (μg/min)	15.5 (18.5)*	23 (27)*	2.07 (0.97, 4.69)
pH	7.326 (0.149)*	7.306 (0.101)*	1.81 (0.87, 3.95)
Base excess	−6 (8.8)*	−6.1 (6.4)*	1.60 (0.68, 4.14)
Lactate (mmol/l)	2.1 (1.6)*	2.2 (2.6)*	1.36 (0.68, 2.70)
Gender (female, male)	48, 50	25, 27	1.04 (0.53, 2.04)
Immunosuppression	13 (13)	4 (8)	0.55 (0.15, 1.64)
Age (years)	69 (21)*	69 (15)*	0.86 (0.44, 1.69)
BMI (kg/m^2)	26 (7)*	28 (7)*	1.89 (0.88, 4.06)
ASA score >3	44 (45)	36 (69)	**2.76 (1.38, 5.73)**
Diagnosis	43 (44)	16 (31)	0.57 (0.22, 1.15)
Mesenteric ischaemia	34 (35)	18 (35)	
Intestinal perforation	8 (8)	12 (23)	
Anastomotic leakage	8 (8)	3 (6)	
Intestinal obstruction	5 (5)	2 (4)	
Bleeding	0 (0)	1 (2)	
Toxic megacolon			
Type of resection			**30.91 (6.29, 559.29)**
Small bowel	39 (40)	1 (2)	
Large bowel	47 (48)	39 (75)	
Small and large bowel	6 (6)	3 (6)	
Anastomosis only	6 (6)	9 (17)	
Operation time (min)	77 (47.5)*	98 (49.3)*	**2.44 (1.22, 5.06)**
Daytime (operation start 7.00–17.00 hours)	37 (38)	20 (38)	0.97 (0.49, 1.96)
Operation request to skin incision (min)	104 (76)*	95 (59)*	0.53 (0.24, 1.16)
Number of re-damage control‡			1.56 (0.61, 3.87)
None	83 (85)	40 (77)	
One	11 (11)	8 (15)	
Two	4 (4)	4 (8)	
Three	0 (0)	0 (0)	
Four	0 (0)	0 (0)	

Values in parentheses are percentages unless indicated otherwise; *values are median (i.q.r.), †values in parentheses are 95 per cent confidence intervals. ‡Re-damage control represents the number of intermediate operations for abdominal lavage prior to definitive surgery with anastomosis/stoma formation and fascial closure.

rates and costs as well as reduced quality of life[6–8,51]. A systematic review and meta-analysis demonstrated the advantages of a primary anastomosis as opposed to a non-restorative resection for acute diverticulitis (fewer surgical-site infections and lower reoperation and ostomy non-reversal rates), with no difference in mortality rate[9]. A surgical approach allowing higher anastomosis rates is desirable. With DCS in IAS, anastomosis was possible in 60–70 per cent, as shown in the present study with 68 per cent of patients having an anastomosis at discharge (including 3 per cent with protective stoma and considering a mortality rate of 26 per cent). This has been described in previous studies with anastomosis rates between 62 and 83 per cent of patients in perforated diverticulitis and additional protective ileostomy in 7–29 per cent (anastomotic leak rate 5–10 per cent)[5,26,28,52,53].

A comparative study with DCS and control group (one-stage procedure) displayed a significantly lower stoma rate in the DCS group of 47 *versus* 83 per cent[27]. In the present study, risk factors for stoma at discharge were ASA score, type of resection and longer operating time. Metabolic acidosis was surprisingly not a risk factor for stoma at discharge but was associated with death.

The present study has some limitations. The population was heterogeneous with various causes of IAS, which reflects the nature of acute surgical admissions to a large tertiary teaching hospital. All consecutive patients were included without exclusion. Indication for DCS was based on clinical judgment following the therapeutic algorithm and its decisional criteria. Patients were included due to defined measurable parameters such as noradrenaline dose, pathological ABG at a defined time point after resection of diseased bowel and washout of the abdominal cavity, and in the presence of faecal contamination of the entire abdominal cavity. Therefore, some patients might have had severe systemic inflammatory response syndrome without strictly defined sepsis at the time of initial surgery. Nevertheless, patients were only included for DCS if they presented with disseminated intestinal liquid in the intra-abdominal cavity due to bowel perforation or mesenteric ischaemia with necrotic bowel. On this basis these patients were classified as having IAS and included in the study. Implementing DCS for all patients with IAS could risk overutilization of this approach. In the authors' centre many of the initial emergency operations were performed during nighttime and by junior consultants or fellows. This may not reflect the surgical practice in other international centres. However, DCS allows for stabilization of patients in an intensive-care setting and a second operation during daytime, when more experienced surgeons and anaesthetists are present.

This new algorithm allowed stoma-free discharge from hospital in a high number of patients, even in severe IAS. DCS is the new standard in the authors' centre, and future large international cohort studies are needed to validate this approach for these high-risk patients.

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