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ORIGINAL SCIENTIFIC REPORT

Damage Control Surgery for Non-traumatic Abdominal Emergencies

Edouard Girard[1,2,5] · Julio Abba[1] · Bastien Boussat[2,3] · Bertrand Trilling[1,2] · Adrian Mancini[1] · Pierre Bouzat[4] · Christian Létoublon[1] · Mircea Chirica[1] · Catherine Arvieux[1]

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Abstract

Background Damage control surgery (DCS) was a major paradigm change in the management of critically ill trauma patients and has gradually expanded in the general surgery arena, but data in this setting are still scarce. The study aim was to evaluate outcomes of DCS in patients with general surgery emergencies.

Methods Between 2005 and 2015, 164 patients (104 men, age 66) underwent DCS for non-traumatic abdominal emergencies. The decision to perform DCS was triggered by the presence of at least one trauma DCS criterion: hypotension (<70 mmHg), hypothermia (<35 °C), acidosis (pH < 7.25), coagulopathy (INR ≥ 1.7) and massive (>5 RBC) transfusion. Statistical tests were performed to identify risk factors for operative mortality. Observed outcomes were compared to those predicted by commonly employed scores (APACHE II, POSSUM, P-POSSUM, SAPS II).

Results DCS was performed for acute mesenteric ischemia ($n = 68$), peritonitis ($n = 44$), pancreatitis ($n = 28$), bleeding ($n = 14$) and other ($n = 10$). Abdominal compartment syndrome was associated in 52 patients (32%). Seventy-four (45%) patients died and 150 patients (91%) experienced complications. On multivariate analysis, age ($p = 0.018$) and INR ≥ 1.7 ($p = 0.001$) were independent predictors of mortality. Mortality was 24% (13/55), 48% (22/46) and 62% (39/63) in patients with one, two and ≥3 DCS criteria, respectively. Comparison of observed and score-predicted mortality suggested DCS use resulted in significant survival benefit of the whole cohort and of patients with pancreatitis and postoperative peritonitis.

Conclusions DCS can be lifesaving in critically ill patients with general surgery emergencies. Patients with peritonitis and acute pancreatitis are those who benefit most of the DCS approach.

✉ Edouard Girard
egirard1@chu-grenoble.fr

[1] Digestive and Emergency Surgery Department, Grenoble-Alpes University Hospital, Grenoble, France

[2] TIMC Research Unit, CNRS, Grenoble-Alpes University, Grenoble, France

[3] Quality of Care Unit, Grenoble-Alpes University Hospital, Grenoble, France

[4] Anesthesiology and Intensive Care Medicine, Grenoble-Alpes University Hospital, Grenoble, France

[5] Service de Chirurgie Digestive et Générale, Hôpital Michallon, Centre Hospitalier Universitaire Grenoble-Alpes, Boulevard de la Chantourne, 38700 Grenoble, La Tronche, France

Introduction

Damage control surgery (DCS) is a well-established practice in the management of critically ill patients with traumatic injuries to the abdomen [1–3]. The DCS strategy includes abbreviated source-control laparotomy followed by transfer in the intensive care unit (ICU) for physiology resuscitation and delayed take-back to the operative room for definitive surgical management [4, 5]. The physiological rationale behind adoption of DCS is the interruption of the vicious circle of acidosis–hypothermia–coagulopathy which is often present in trauma patients and leads gradually to patient exhaustion and death [6].

Introduction of DCS was a major paradigm change in trauma management and has led to significant improvements in the survival of critically injured patients. DCS is currently the standard approach in most high volume trauma units across the world [7]. As general surgery patients with severe intraperitoneal sepsis or bleeding are just as susceptible to the detrimental effects of acidosis, hypothermia and coagulopathy, acute-care and emergency general surgeons have gradually applied the principles of DCS to severely ill surgical patients in the non-trauma setting [8]. An increasing number of recent publications [9–23] have reported promising results of DCS in acute mesenteric ischemia (AMI), hollow viscus perforation peritonitis, postoperative peritonitis, acute pancreatitis, necrotizing enterocolitis, hemorrhage, abdominal compartment syndrome (ACS), etc. Most papers report heterogeneous series with small number of patients with a large range of conditions, sometimes including patients managed with open abdomen and delayed laparotomy in the absence of DCS criteria. The combination of all these factors renders difficulty in the analysis and the interpretation of results. Evaluation of DCS in large prospective cohorts by categorizing patients on their physiological derangement (hemorrhage, sepsis) and clinical diagnosis (perforation, mesenteric ischemia, etc.) is paramount to improve selection criteria and outcomes.

At the Grenoble-Alpes University Hospital, DCS for trauma has been introduced in 2001 and DCS principles were progressively applied to non-trauma abdominal emergencies starting 2004. The aim of the study was to report our experience with 164 patients who underwent DCS for non-trauma abdominal emergencies across a 10-year period. Their outcomes were compared to different predictive scores (APACHE II [24], POSSUM [25], P-POSSUM [26] and SAPS II [27] in order to evaluate the usefulness of the DCS approach.

Materials and methods

Patients

Data from patients who underwent surgery for non-trauma abdominal emergencies in the Digestive and Emergency Surgery Department of the Centre Hospitalier Universitaire Grenoble-Alpes, France, were entered in a prospective database. The files of all consecutive patients who underwent DCS for non-trauma abdominal emergencies between January 2005 and December 2015 were reviewed retrospectively and made the subject of the present study. Patients under age of 18, patients who underwent DCS for trauma and patients who underwent emergency surgical procedures without DCS were excluded. The study was approved by the ethics committee of the Centre Hospitalier Universitaire Grenoble-Alpes.

Indications of DCS

DCS was performed for a wide range of non-trauma abdominal emergencies including abdominal sepsis (peritonitis, mesenteric ischemia, pancreatitis), hemorrhage and ACS (defined as intra-abdominal pressure (IAP) >20 mmHg associated with the occurrence of at least one organ dysfunction/failure [28]). The decision to perform DCS in patients with non-trauma abdominal emergencies relied on the presence of at least one of the following DCS criteria for trauma: arterial systolic blood pressure bellow 70 mmHg, hypothermia <35 °C, serum pH <7.25, international normalized ratio (INR) ≥1.7 and transfusion exceeding five packed red blood cells (RBCs). DCS was preceded by intensive preoperative damage control resuscitation [29, 30]. Briefly, this consisted of rapid sequence induction and orotracheal intubation, fluid and vasoconstrictor administration by large venous access, broad spectrum antibiotherapy and blood transfusion. Measures aiming to correct physiologic parameters such as pH, core temperature and systolic pressure were initiated during this phase. The damage control resuscitation was continued for a maximum of 3-h period without delaying surgery. Surgery was undertaken through a xipho-pubic midline laparotomy allowing thorough exploration of the whole abdomen. The main aim was to obtain a rapid control of bleeding, septic contamination and/or of abdominal hypertension. Bleeding from large vessels was suture controlled and packing was liberally employed for diffuse bleeding. Sepsis was controlled by a combination of maneuvers including peritoneal lavage, limited resection of diseased bowel segments leaving behind blind ending stumps and external diversion of digestive and/or biliary contents (duodenum, postoperative frozen bowel) by

intubation of digestive perforations with flexible drains. Direct closure of perforation sites by single sutures was undertaken in dramatic situations. Extensive tissue dissection and organ mobilization was avoided to prevent propagation of inflammation to the retroperitoneum. The type of abdominal closure (skin closure only vs. open abdomen) relied on intraoperative findings, but closure of the abdominal aponeurosis was avoided to preserve it for further repair. Open abdomen (OA) using a vacuum suction device (VAC) was performed if skin closure only (SCO) was impossible or in the presence of massive abdominal contamination and/or of ACS. If OA was required, the bowel was protected with omentum and perforated nylon sheets before application of the intra-abdominal part of the VAC system. Four capillary drains were placed along the parietal peritoneum above the protective layer to enhance suction, and the abdomen was closed by sub-cutaneous placement of the black polyurethane foam (V.A.C®, GranuFoam, KCI, Austria) and of an adhesive film as described by the manufacturer. Negative pressure was adjusted to 100–125 mmHg. Patients were admitted to the intensive care unit for ventilation, rewarming, inotropic support, coagulopathy correction and dialysis as required. Definitive surgery was scheduled 36–72 h after the source-control laparotomy; the delay in reoperation was correlated to the evolution of clinical and biological parameters.

Statistical analysis

Postoperative mortality and morbidity were defined as death or complications, respectively, within 90 days after source-control laparotomy. Complications were graded according to the Dindo–Clavien classification [31]. Variables recorded in the present study allowed estimation of several most commonly employed severity of disease classification systems including the APACHE II [24], POSSUM [25], P-POSSUM [26] and SAPS II [27] scores. Observed patient outcomes were compared with score-specific predicted mortality and morbidity rates.

Baseline characteristics are reported as median and interquartile ranges (IQR; i.e., 25th and 75th percentiles) for continuous variables and number and percentage for categorical variables. We compared continuous variables using the Mann–Whitney test, and categorical variables using the Chi-square test, or Fisher exact test where appropriate. We performed multivariable analysis to identify the factors that were independently associated with operative mortality among baseline characteristics, biological data and DCS criteria. Variables associated with p value <0.20 in univariate analysis were selected for the multivariate regression model. The linearity relationship between continuous variables and the logit of operative mortality was assessed by the use of fractional polynomial models. The Kaplan–Meier estimate was used to create survival curves according most usual DCS indications. Predicted and observed mortality and morbidity were compared using the two-proportion z test. Two-sided p values <0.05 were considered significant. All statistical analyses were performed using Stata Special Edition version 14 (Stata Corporation, College Station, TX, USA).

Results

Patients

Across the study period, 1925 patients underwent surgery for non-traumatic abdominal emergencies; 164 (8.5%) of them underwent DCS and were the subject of the study. There were 104 (63%) men and median age was 66 years [54; 75]. Abdominal sepsis was the indication for the index laparotomy leading to DCS in 150 patients (91%) with a diagnosis of AMI ($n = 68$; 41%), peritonitis by hollow viscus perforation ($n = 21$; 13%), postoperative peritonitis ($n = 23$; 14%), acute pancreatitis ($n = 28$; 17%) and other ($n = 10$; 6%). DCS was undertaken for intra-abdominal bleeding in 14 patients (9%). An ACS was associated in 52 patients (32%); median bladder pressure in these patients was 21 mmHg [20; 22].

DCS criteria included the presence of hypotension (<70 mmHg) in 155 patients (95%), pH values <7.25 in 94 patients (57%), hypothermia (<35 °C) in 10 patients (6%), transfusion of >5 RBCs in 22 patients (13%) and INR values ≥1.7 in 74 patients (45%). Fifty-five patients (34%) met one, 46 patients (28%) met 2 and 63 patients (38%) met 3 or more DCS criteria. Patient characteristics are shown in Table 1.

Across the study period, 15 patients who met DCS criteria did not undergo DCS management; protocol violations were mostly the result of attending surgeon preferences. There were 5 (33%) men and median age in this group was 74 [68; 79] years. Indication for index laparotomy leading to DCS was abdominal sepsis in 12 patients (AMI: $n = 4$, hollow viscus perforation: $n = 3$, postoperative peritonitis: $n = 3$ and other: $n = 2$) and bleeding in 3 patients. Median SAPS II, APACHE II and POSSUM scores in these patients were 55, 21 and 54, respectively. The small cohort size did not allow further statistical comparison with DCS patients.

Perioperative course

Details of intraoperative management and postoperative course for the whole patient cohort and the most usual DCS indications are depicted in Table 2. Median operative duration was 55 min [30; 60]. Organ resection was

Table 1 Characteristics of 164 patients who underwent damage control surgery (DCS) for non-traumatic abdominal emergencies

	DCS ($n = 164$) Median [IQR] or n (%)
Age (years)	66 [54; 75]
Gender (male)	104 (63%)
Indication	
Abdominal sepsis	150 (91%)
Acute mesenteric ischemia	68 (41%)
Hollow viscus perforation	21 (13%)
Postoperative peritonitis	23 (14%)
Acute pancreatitis	28 (17%)
Other*	10 (6%)
Bleeding	14 (9%)
Abdominal compartment syndrome	52 (32%)
DCS criteria	
SBP $\leq$ 70 mmHg	155 (95%)
Transfusion $\geq$ 5RPC	22 (13%)
INR $\geq$ 1.7	74 (45%)
pH < 7.25	94 (57%)
Hypothermia < 35 °C	10 (6%)
Number of DCS criteria	
1	55 (34%)
2	46 (28%)
3 or more	63 (38%)
Biological data	
Leukocytes (G/l)	15 [8; 22]
Hemoglobin (g/dl)	99 [82; 120]
Creatinine (µmol/l)	138 [89; 204]
pH	7.23 [7.10; 7.31]
INR	1.7 [1.3; 2.2]

DCS damage control surgery, *IQR* interquartile range, *SBP* systolic blood pressure, *RPC* red packed cells

* Included patients with: toxic megacolon ($n = 4$), major bowel distension ($n = 5$) and infected peritoneal dialysis ($n = 1$)

performed during the DCS operation in 103 patients (63%) including the colon (right: $n = 32$, transverse: $n = 12$, left: $n = 22$, total colon: $n = 17$; rectum: $n = 3$), the small bowel ($n = 50$), the gallbladder ($n = 10$), the stomach ($n = 3$) and the spleen ($n = 2$). OA management was undertaken in 71 patients (43%) and SCO in 93 patients (57%).

Thirty-five patients (21%) died shortly after DCS and the 129 survivors (79%) returned to the operative room for definitive surgery. Median delay in reoperation was 2 days [2; 3], and patients underwent a median of 1 [1; 3] reoperation/per patient. At the time of reoperation, 31 patients underwent further digestive resection including the colon (right: $n = 9$, transverse: $n = 4$, left: $n = 6$, total colon: $n = 3$; rectum: $n = 3$), the small bowel ($n = 24$), the gallbladder ($n = 11$), the spleen ($n = 2$) and the esophagus-stomach ($n = 1$).

Sixty patients (37%) died within 30 days and 74 (45%) patients died within 90 days of DCS. The median delay between DCS and operative mortality was 6 days [1; 26]. On univariate analysis, advanced age ($p = 0.019$), serum potassium levels ($p = 0.038$), pH < 7.25 ($p = 0.026$) and INR $\geq$ 1.7 ($p < 0.0001$) were predictive of operative mortality. On multivariate analysis, age (10-year increase adjusted-OR 1.336; CI 1.051–1.699, $p = 0.018$) and INR $\geq$ 1.7 (adjusted-OR 3.672; CI 1.759–7.667, $p = 0.001$) were independent predictors of operative mortality (Table 3). The same factors were predictive of 30 days mortality and of death prior to reoperation (data not shown). Postoperative complications were recorded in 150 patients (91%). Operative mortality was 24% (13/55), 48% (22/46) and 62% (39/63) in patients who met one, two and $\geq$3 DCS criteria, respectively.

Median ICU and hospital stay were 13 days [2; 24] and 26 days [4; 54], respectively.

Primary fascia closure was performed prior to discharge in 71 (43%) patients (30 OA and 41 SCO) a median of 3 days [2; 5] after DCS. Eventually, 27 patients did seek medical advice for incisional hernia and 13 of them underwent surgical repair. Sixty-five patients underwent ostomy construction. Of them, 46 patients had a stoma on discharge which remained definitive in 27.

Long term outcomes

Eventually, 90 (55%) patients survived DCS. Median follow-up for patients who survived DCS was 23 months [5; 47]. At 1 year, 24 patients were lost to follow-up. Fourteen more patients died during the first ($n = 9$), the second ($n = 3$) and the third ($n = 2$) year. Kaplan–Meier survival curves of most usual DCS indications are shown in Fig. 1.

Observed versus predicted outcomes

At 30-day observed mortality was significantly lower than the mortality predicted by the most usually employed physiologic scores for both the whole cohort and specific DCS indications (Table 4). Although various scores remained consistent in showing a benefit in observed versus predicted 90-day mortality for the whole group, only patients with acute pancreatitis and postoperative peritonitis seemed to really benefit of the DCS approach in terms of operative mortality (Table 5).

Observed morbidity was lower than the POSSUM score-predicted morbidity for the whole cohort and most specifically in patients with bleeding and peritonitis (postoperative and by hollow viscus perforation) (Table 6).

Table 2 Perioperative characteristics and outcomes of patients who underwent damage control surgery for non-traumatic abdominal emergencies

	Overall ($n = 164$) Median [IQR] or n (%)	AMI ($n = 68$)	Hollow viscus perforation ($n = 21$)	PO peritonitis ($n = 23$)	Pancreatitis ($n = 28$)	Bleeding ($n = 14$)	Other* ($n = 10$)
ACS	52 (32%)	11 (16%)	1 (5%)	4 (17%)	22 (79%)	5 (36%)	9 (90%)
Operative time (min)	60 [30; 60]	60 [40; 78]	60 [40; 60]	45 [20; 50]	60 [45; 60]	40 [30; 125]	20 [20; 30]
Perforated bowel	27 (16%)	4 (6%)	21 (100%)	0	2 (7%)	0	0
Digestive resection	103 (63%)	64 (96%)	19 (90%)	8 (25%)	7 (25%)	3 (27%)	3 (30%)
Digestive re-resection	31 (20%)	17 (27%)	5 (25%)	3 (13%)	2 (8%)	4 (29%)	0
Organ resected							
Small bowel	50 (30%)	31 (46%)	8 (38%)	7 (30%)	2 (7%)	1 (7%)	1 (10%)
Colon	72 (44%)	47 (63%)	14 (67%)	2 (9%)	4 (14%)	2 (14%)	3 (30%)
Right	32	24	5	2	1	0	0
Left	22	12	6	1	3	0	0
Total	17	11	2	0	0	2	2
Rectum	3	3	0	0	0	0	0
Gallbladder	10	4	1	0	5	0	0
Spleen	2	0	1	0	1	0	0
Stomach	3	1	1	0	1	0	0
Closure							
Open abdomen	71 (43%)	14 (21%)	6 (29%)	16 (70%)	25 (89%)	5 (36%)	5 (50%)
Skin closure only	93 (57%)	54 (79%)	15 (71%)	7 (30%)	3 (11%)	9 (64%)	5 (50%)
ICU stay (days)	13 [2; 24]	4 [1; 16]	13 [4; 18]	16 [7; 24]	40 [19; 63]	9 [1; 18]	10 [4; 16]
Hospital stay (days)	26 [4; 54]	15 [1; 34]	23 [13; 40]	46 [25; 68]	79 [41; 123]	21 [1; 33]	10 [5; 41]
Number reoperation	1 [1; 3]	1 [0; 2]	1 [1; 3]	1 [1; 3]	5 [2; 6]	1 [1; 2]	1 [0; 1]
Delay in reoperation (days)	2 [2; 3]	2 [2; 2]	2 [2; 3]	2 [2; 3]	3 [3; 4]	2 [1; 4]	4 [3; 4]
90-day morbidity	150 (91%)	64 (94%)	19 (90%)	17 (74%)	27 (96%)	13 (93%)	10 (100%)
C–D grade 1–2	15 (10%)	5 (8%)	1 (5%)	4 (24%)	3 (11%)	1 (8%)	1 (10%)
C–D grade 3–4	61 (41%)	19 (30%)	6 (32%)	9 (53%)	20 (74%)	4 (31%)	3 (30%)
30-day mortality	60 (37%)	34 (50%)	9 (43%)	3 (13%)	4 (14%)	6 (43%)	4 (40%)
90-day mortality	74 (45%)	40 (59%)	12 (57%)	4 (17%)	4 (14%)	8 (57%)	6 (60%)
Definitive stomy	26	13	3	4	3	1	2
APACHE II score	21 ± 8	23 ± 8	21 ± 9	17 ± 7	20 ± 8	22 ± 8	19 ± 6
SAPS II score	59 ± 21	62 ± 21	60 ± 24	52 ± 22	57 ± 21	61 ± 21	55 ± 15
POSSUM score	57 ± 10	59 ± 11	58 ± 9	53 ± 10	54 ± 8	60 ± 13	56 ± 10

Data are shown for the whole patient cohort ($n = 164$) and for most common causes leading to DCS

AMI acute mesenteric ischemia, *IQR* interquartile range, *PO* postoperative, *ACS* abdominal compartment syndrome, *ICU* intensive care unit, *C–D* Clavien–Dindo, *APACHE* acute physiology and chronic health evaluation, *SAPS* simplified acute physiologic score, *POSSUM* physiological and operative severity score for the enumeration of mortality and morbidity

* Included patients with: toxic megacolon ($n = 4$), major bowel distension ($n = 5$) and infected peritoneal dialysis ($n = 1$)

Discussion

Since the paradigm change in trauma management by the introduction of DCS, the concept has been promulgated widely to general surgery abdominal emergencies [8]. Currently DCS is used with increased frequency in general surgery patients although the level of evidence supporting abbreviated surgery in a non-trauma setting is still low. The present study reports outcomes of a large monocentric series of patients who underwent DCS for the management of non-trauma abdominal emergencies. The damage control strategy was triggered only in patients with at least one criterion for trauma DCS; as such, patients undergoing "de principe" OA [32] and/or delayed laparotomy [33]

management were excluded which allowed evaluation of outcomes in a homogenous group of patients. The short operative time (<1 h) mirrors the abbreviated laparotomy strategy. The operative morbidity (91%) and mortality (45%) rates were high, but this could be expected in a population of critically ill patients. Mortality increased significantly with the number of DCS criteria at the time of surgery, reaching 62% in patients in whom three or more criteria were present. This looks as common sense as patients with a more severe initial condition can be expected to have high risk of death. However, this finding also suggests that akin to trauma, DCS interruption of the lethal triad may avoid intraoperative multiplication of negative high risk criteria and thus benefit critically ill patients with general surgery emergencies.

As mechanisms of shock differ in trauma (mostly hemorrhagic) and emergency general surgery (mostly septic), it has been postulated that acute physiology indicators which help guide intraoperative decisions might also be different [23]. Criteria for application of DCS in emergency general surgery still need to be defined; advanced age [9; 23], acidosis (pH < 7.25) [23], elevated lactates (≥3) [23], male gender [23] and multiple (≥3) comorbidities [21, 23] have been associated with adverse outcomes and might be used to improve patient selection. In the present study, of the DCS criteria only the presence of acidosis (pH < 7.25) and of coagulopathy (INR ≥ 1.7) were associated with increased mortality in the univariate analysis. Advanced age and severe coagulopathy were the only independent predictors of mortality in the multivariate model.

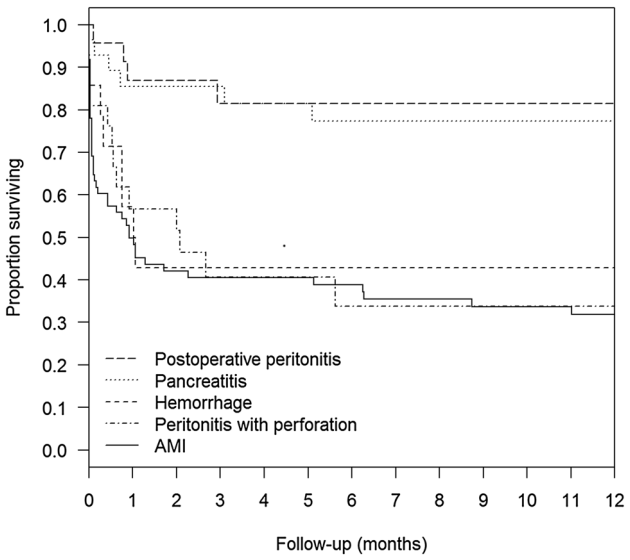

Fig. 1 Kaplan Meier survival at one year in patients who underwent damage control surgery for acute mesenteric ischemia (AMI) ($n = 68$), postoperative peritonitis ($n = 23$), acute pancreatitis ($n = 28$) intra-abdominal bleeding ($n = 14$) and peritonitis by hollow viscus perforation ($n = 21$)

An increasing number of reports have attempted to validate the DCS approach in the non-trauma setting by comparing outcomes with those of non-randomized concurrent patients or with those predicted by various

Table 3 Risk factors for operative mortality (90 days) in patients who underwent damage control surgery (DCS) for non-traumatic abdominal emergencies: univariate and multivariate analysis

	Operative death YES ($n = 74$)	Operative death NO ($n = 90$)	Univariate analysis p	Multivariate analysis	
				aOR [CI 95%]	p
Age (years)	69 [58; 79]	64 [52; 70]	**0.008**	**1.45* [1.12; 1.88]**	**0.004**
Gender (men)	44 (59%)	60 (67%)	0.340		
ACS	19 (26%)	33 (37%)	0.132	0.69 [0.32; 1.48]	0.343
SBP ≤ 70 mmHg	70 (95%)	85 (94%)	0.966		
Transfusion ≥ 5RPC	14 (19%)	8 (9%)	0.061	1.43 [0.51; 4.03]	0.497
INR ≥ 1.7	47 (64%)	27 (30%)	**<0.001**	**3.91 [1.83; 8.36]**	**<0.001**
pH < 7.25	49 (66%)	45 (50%)	**0.037**	0.97 [0.43; 2.15]	0.931
Hypothermia < 35 °C	6 (8%)	4 (4%)	0.349		
Natremia (mmol/l)	139 [136; 143]	139 [137; 143]	0.459		
Kalemia (mmol/l)	4.2 [3.6; 5.4]	4.0 [3.3; 4.6]	**0.038**	1.39[a] [0.99; 1.97]	0.059
Leukocytes (G/l)	16 [8; 22]	13 [9; 20]	0.323		
Hemoglobin (g/l)	100 [79; 118]	99 [84; 120]	0.441		

Statistically significant values are given in bold

aOR adjusted odds ratio, *CI* confidence interval, *ACS* abdominal compartment syndrome, *SBP* systolic blood pressure, *RPC* red packed cells

* aOR associated with a 10 years increase in age

[a] aOR associated with a 1 mmol/l increase in kalemia

Table 4 Comparison of predicted and observed 30-day mortality in patients who underwent damage control surgery (DCS) for non-traumatic abdominal emergencies

	30-day observed mortality (%)	APACHE II (%)	SAPS II (%)	POSSUM (%)	P-POSSUM (%)
AMI	50	52	*63**	*75**	*62**
HVP	43	40	57	*84**	*72**
PO peritonitis	13	*36**	*45**	*78**	*61**
Pancreatitis	14	*38**	*55**	*76**	*61**
Bleeding	43	56	59	*88**	*77**
Overall	37	*46**	*58**	*78**	*65**

Evaluation was performed for the whole cohort ($n = 164$) and for most common causes leading to DCS

APACHE acute physiology and chronic health evaluation, *SAPS* simplified acute physiologic score, *POSSUM* physiological and operative severity score for the enumeration of mortality and morbidity, *P-POSSUM* portsmouth POSSUM, *AMI* acute mesenteric ischemia, *HVP* hollow viscus perforation, *PO* postoperative

* Significant difference ($p < 0.05$). Significant differences were italicized to increase readability

Table 5 Comparison of predicted and observed 90-day mortality in patients who underwent damage control surgery (DCS) for non-traumatic abdominal emergencies

	90-day observed mortality (%)	APACHE II (%)	SAPS II (%)	POSSUM (%)	P-POSSUM (%)
AMI	59	52	63	*75**	62
HVP	57	40	57	*84**	72
PO peritonitis	17	*36**	*45**	*78**	*61**
Pancreatitis	14	*38**	*55**	*76**	*61**
Bleeding	57	56	59	*88**	77
Overall	45	46	*58**	*78**	*65**

Evaluation was performed for the whole cohort ($n = 164$) and for most common causes leading to DCS

APACHE acute physiology and chronic health evaluation, *SAPS* simplified acute physiologic score, *POSSUM* physiological and operative severity score for the enumeration of mortality and morbidity, *P-POSSUM* portsmouth POSSUM, *AMI* acute mesenteric ischemia, *HVP* hollow viscus perforation, *PO* postoperative

* Significant difference ($p < 0.05$). Significant differences were italicized to increase readability

Table 6 Comparison of observed (90 days) and POSSUM predicted morbidity in patients who underwent damage control surgery (DCS) for non-traumatic abdominal emergencies

	Observed 90-day morbidity (%)	POSSUM predicted morbidity (%)
AMI	94	96
HVP	90	*98**
PO peritonitis	74	*98**
Pancreatitis	96	97
Bleeding	93	*99**
Overall	91	*97**

Evaluation was performed for the whole cohort ($n = 164$) and for most common causes leading to DCS

POSSUM physiological and operative severity score for the enumeration of mortality and morbidity, *AMI* acute mesenteric ischemia, *HVP* hollow viscus perforation, *PO* postoperative

* Significant difference ($p < 0.05$). Significant differences were italicized to increase readability

physiological and operative scores (APACHE II, APACHE IV, POSSUM, P-POSSUM) [11–14]. The design of the present study (critically ill patients selected for DCS) prevented relevant comparison with patients undergoing standard laparotomy for abdominal emergencies during the same period. Most of the studies using predictive scores to

evaluate outcomes of DCS for general surgery emergencies have demonstrated lower observed versus score-predicted mortality rates, although statistical significance was seldom reached [14] due to small cohort sizes. One major drawback in the interpretation of these results is the known propensity of various scores to either overestimate (POSSUM) or underestimate (APACHE II) mortality. We evaluated predicted mortality by using several commonly employed scores (POSSUM, P-POSSUM, SAPS II, APACHE II) in order to obtain a more comprehensive overview of outcomes. In accordance with previous reports [11–14], most scores demonstrated a significant benefit of actual versus score-predicted 30-day mortality both for the whole cohort as for the main etiologies leading to DCS. However, at 90 days the scores were consistent in showing a survival benefit only in patients who underwent DCS for acute pancreatitis and postoperative peritonitis; this advantage was also obvious on the 12-month survival curves. This raises two important issues that warrant further discussion. First, operative outcomes after DCS for general surgery emergencies should probably be evaluated at 90 rather than at 30 days. This was recently supported by Bruns et al. [34] who showed an additional 11% mortality after hospital discharge in 96 patients managed by OA for non-trauma abdominal emergencies. The information should be taken in consideration when designing further studies on the topic. Second, the present results point out at patients with postoperative peritonitis and acute pancreatitis as having a potential survival benefit from the DCS approach. This is not unexpected as patients with postoperative peritonitis had been recently evaluated for major surgery and close postoperative follow-up allowed timely reoperation. Indications of surgery for acute pancreatitis have evolved recently [35] and a high number of patients (42%) in the present study underwent DCS for ACS-related complications; prompt decompression had important effects despite need for prolonged OA management. In contrast DCS did not seem to improve survival of patients with mesenteric ischemia, hollow viscus perforation peritonitis or non-traumatic abdominal bleeding. It is likely that the severity of the primary disease outweighs the type of treatment in these situations. In the absence of proven survival benefit, abbreviated laparotomy with delayed takeback seems, however, justified in some of these patients in view of the high digestive resection rates during the second surgical procedure.

The major study limitations are the monocentric setting and retrospective design precluding comparison with emergency general surgery patients undergoing laparotomy without DCS. As a large prospective observational study, the present work offers a comprehensive picture of indications and outcomes of DCS in a non-trauma setting and may be used as benchmark for the design and the realization of a multicentre randomized controlled trial on the topic.

In conclusion, patients with non-traumatic abdominal emergencies who underwent DCS management have high operative mortality and morbidity rates. Advanced age and the presence of severe coagulopathy on presentation have negative influence on survival. DCS is justified in critically ill EGS patients as the interruption of the hypothermia–acidosis–coagulopathy circle can improve survival by avoiding intraoperative multiplication of pejorative criteria. Further research is required to refine the indications, the timing and the techniques of damage control surgery and resuscitation in patients with non-traumatic abdominal emergencies.

Compliance with ethical standards

Conflict of interest Authors report no conflict of interest and no grant support for the research.

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