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Damage Control Laparotomy in Severe Blunt Abdominal Trauma: Assessing the Morbidity of Nonindicated Use and the Prognostic Role of Initial Serum Lactate

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Abstract

Background: Damage control laparotomy (DCL) is lifesaving in physiologically exhausted trauma patients, but potentially avoidable use may increase morbidity. We evaluated outcomes of DCL performed without prespecified damage-control criteria for patients with severe blunt abdominal trauma (BAT) and the prognostic value of admission lactate.

Methods: Adults with abdominal AIS ≥4 undergoing emergency laparotomy from 2015–2024 were retrospectively analyzed. DCL and definitive laparotomy (DEF) were compared according to prespecified physiologic/anatomic criteria. Logistic and Firth penalized regression identified predictors of complications, prolonged ICU stay, and mortality; ROC analysis compared lactate with lethal-triad variables.

Results: Seventy-nine patients were included (DCL 31; DEF 48). Among 41 patients without prespecified criteria, 10 underwent DCL. Compared with DEF, the DCL subgroup had longer hospitalization (24.5 vs 14.0 days, p=0.001) and more complications (50.0% vs 16.1%, p=0.045); DCL remained associated with complications after adjustment for abdominal AIS (OR 5.7, 95% CI 1.1–30.6; p=0.041). In the overall cohort, lactate independently predicted mortality (OR 1.20 per mmol/L, 95% CI 1.01–1.46; p=0.043), whereas DCL predicted prolonged ICU stay (OR 4.14, 95% CI 1.10–15.62; p=0.036). Lactate discrimination for mortality (AUC 0.731) exceeded the conventional lethal triad (AUC 0.614); optimal cutoff was 4.7 mmol/L.

Conclusions: DCL used without clear prespecified criteria was associated with greater morbidity and longer hospitalization for patients with severe BAT. Admission lactate may complement conventional physiologic criteria and support more selective trauma laparotomy decision-making.

Keywords: damage control surgery; damage control laparotomy; abdominal trauma; serum lactate level; lethal triad

Background

Damage control surgery (DCS) was introduced as an abbreviated operative strategy for exsanguinating abdominal trauma, prioritizing hemorrhage and contamination control until physiology is restored [1]. It is intended to interrupt the “lethal triad” of hypothermia, acidosis, and coagulopathy [2, 3]. Current guidance supports DCS in patients with hemorrhagic shock, uncontrolled bleeding, or coagulopathy, particularly with severe hypothermia or acidosis [4–6]. Use of damage control laparotomy (DCL) has broadened beyond clearly unstable patients, raising concern for potentially avoidable open-abdomen management. Utilization varies substantially among trauma centers [7–10]. DCL carries risks including failure of fascial closure, enteroatmospheric fistula, intra-abdominal infection or sepsis, and greater ventilator and resource use [11–13]. Quality-improvement studies suggest that reducing avoidable DCL can decrease morbidity without worsening survival [7, 9], however, the actual impact of DCL on non-indicated use of patients with blunt abdominal trauma (BAT) has received less attention.

On the other hand, serum lactate is a well-established early marker of tissue hypoperfusion and shock burden. Although elevated admission lactate levels and impaired lactate clearance are known to correlate with mortality in trauma patients [14, 15], their utility in guiding damage control laparotomy (DCL) and their incremental prognostic value beyond the physiological "lethal triad" remain uncertain, particularly in BAT.

At our tertiary trauma center in Asia, most admitted trauma patients involve blunt mechanisms. Although trauma surgeons at our institution perform DCL for severe BAT, the decision to employ DCL relies primarily on the operating surgeon's clinical judgment. We hypothesized that

the non-indicated use of DCL is associated with increased morbidity in patients with BAT. Accordingly, the primary objective of this study was to evaluate clinical outcomes of DCL in patients who did not meet prespecified damage control surgery (DCS) indications. The secondary objective was to identify predictors of mortality, major complications, and prolonged intensive care unit (ICU) stay following emergency trauma laparotomy, with a specific focus on admission lactate levels.

Methods

Study design and population

This was a single-center retrospective cohort study. All patients with severe blunt abdominal injury (abdominal AIS ≥ 4) who underwent emergency laparotomy at Far Eastern Memorial Hospital between January 2015 and December 2024 were screened for eligibility. The exclusion criteria were (1) age < 18 years; (2) severe associated injury (AIS ≥ 4 in any other body region); (3) transfer to our institution more than 24 hours after injury; and (4) surgery for failed nonoperative management more than 6 hours after admission. This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of Far Eastern Memorial Hospital (No. 114107-E); the requirement for individual informed consent was waived given the retrospective design. This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Patient stratification

Patients were classified according to whether at least one prespecified DCS-related criterion was documented before or during the index operation. All the criteria and thresholds were defined a priori before the outcome analyses. Physiologic criteria were assessed using the first available

value recorded from the time of arrival at the emergency department to the time of operation and included a core temperature <35°C, an International Normalized Ratio (INR) >1.5, an arterial pH <7.20, and a serum lactate concentration >5 mmol/L. Persistent hemorrhagic hypotension was defined as a sustained systolic blood pressure <90 mmHg despite initial resuscitation, accompanied by activation of a massive transfusion protocol, transfusion of ≥4 units of packed red blood cells within 1 hour, and/or continuous vasopressor support.

Intraoperative criteria included major aortic, inferior vena caval, or iliac vascular injury associated with ongoing hemorrhage, hemodynamic instability, or complex repair or ligation, and gross fecal or enteric contamination involving at least two abdominal quadrants. Patients in whom none of the prespecified criteria were documented were categorized into the no-criterion group. This operational classification was not intended to indicate that DCL was clinically inappropriate because additional nonprespecified or undocumented considerations may have influenced operative decision-making.

Patients were further classified according to the operative strategy performed: DCL, defined as an abbreviated operation for hemorrhage or contamination control with temporary abdominal closure and planned reoperation, or definitive laparotomy (DEF), defined as single-stage definitive repair. The primary analysis compared DCL and DEF among patients in the no-criterion group (n = 41; Figure 1).

Data collection and definitions

Data were extracted from the institutional trauma registry and electronic medical records. Variables included demographics; injury mechanism, regional AIS and ISS; admission systolic blood pressure, heart rate, GCS score, temperature, arterial pH, INR, and serum lactate; emergency department resuscitation volume; time to operation, operative duration, estimated

blood loss; and clinical outcomes. For physiologic and laboratory variables, the first value obtained after emergency department arrival and before incision was used.

Outcomes

For patients without prespecified DCS-related criteria, the primary outcome was any postoperative complication. For the overall cohort risk-factor analysis, the primary outcome was in-hospital mortality; secondary outcomes were major complications and ICU stay ≥7 days. Major complications included unplanned relaparotomy for bleeding, intra-abdominal abscess requiring drainage, enterocutaneous/enteroatmospheric fistula, anastomotic leak, clinically relevant bile or pancreatic leak, sepsis, acute respiratory distress syndrome, severe acute kidney injury, and multiple organ failure.

Statistical analysis

Continuous variables are presented as medians (interquartile ranges [IQRs]) and were compared using the Mann–Whitney U test. Categorical variables are presented as numbers (percentages) and were compared using Pearson's chi-square test or Fisher’s exact test, as appropriate. In the primary analysis cohort comprising patients without prespecified DCS-related criteria, the association between DCL and overall postoperative complications was evaluated using binary logistic regression, with separate adjustments for ISS and abdominal AIS.

Univariable regression identified factors associated with mortality, major complications, and ICU stay ≥7 days. Because deaths were few, mortality was analyzed with Firth penalized logistic regression, restricted to admission lactate and operative strategy to limit overfitting; adjusted ORs with 95% profile penalized-likelihood CIs are reported. Major-complication and prolonged-ICU models used conventional logistic regression with parsimonious selection of candidates

showing univariable $p<0.20$. Hosmer–Lemeshow testing assessed calibration. Lactate analyses used complete cases.

Receiver operating characteristic (ROC) analysis compared temperature, arterial pH, INR, admission lactate, the conventional lethal triad (temperature, pH, and INR), and the lethal triad plus lactate for in-hospital mortality. AUCs were compared using the DeLong test; 95% CIs were obtained from 2,000 bootstrap iterations, and the optimal lactate cutoff from the maximum Youden index.

Descriptive analyses, group comparisons, and conventional logistic regression analyses were performed using IBM SPSS Statistics for Windows, version 31.0 (IBM Corp., Armonk, NY, USA). Firth-penalized logistic regression was performed using R version 4.5.3 (R Foundation for Statistical Computing, Vienna, Austria) with the logistf package. ROC analyses, bootstrap confidence intervals (2,000 iterations), and DeLong tests for paired AUC comparisons were performed in R using the pROC package. All tests were two-sided, and a p value <0.05 was considered to indicate statistical significance.

Results

Study population

Between January 2015 and December 2024, 162 patients with severe abdominal injury (abdominal AIS ≥ 4) underwent emergency laparotomy. After the exclusion criteria were applied ($n = 83$), 79 patients were included in the final analysis (Figure 1). Of these, 38 (48.1%) met prespecified DCS criteria, and 41 (51.9%) did not. Among those meeting these criteria, 21 underwent DCL, and 17 underwent DEF. Among those not meeting the criteria, 10 underwent DCL, and 31 underwent DEF.

Overall cohort: DCL versus definitive laparotomy

In the overall cohort, patients who underwent DCL exhibited greater physiologic derangement and injury severity than those who underwent definitive laparotomy (DEF). The DCL group had a higher ISS (27.0 vs. 25.0, $p = 0.029$), lower GCS score ($p = 0.007$), lower body temperature ($p = 0.018$), lower arterial pH ($p = 0.007$), higher serum lactate level (5.9 vs. 2.3 mmol/L, $p < 0.001$), and greater ED resuscitation volume ($p = 0.015$) (Table 1). Patients who underwent DCL also had a shorter interval from admission to operation (90.0 vs. 112.5 minutes, $p = 0.030$) and greater intraoperative blood loss (5000 vs. 2000 mL, $p < 0.001$).

Compared with DEF, DCL was associated with longer mechanical ventilation ($p = 0.007$), ICU stay ($p = 0.013$), and total hospital stay (25.0 vs. 14.0 days, $p = 0.001$), as well as higher rates of postoperative complications (67.7% vs. 25.0%, $p < 0.001$) and in-hospital mortality (22.6% vs. 4.2%, $p = 0.024$) (Table 1). Notably, among patients who did not meet any prespecified DCS-related criteria, 24.4% nevertheless underwent DCL, indicating that DCL was used in a subset of patients without documented prespecified criteria for damage control management.

Patients without prespecified DCS-related criteria

Among 41 patients without prespecified criteria, 10 underwent DCL and 31 DEF. Demographic characteristics, injury severity, and measured physiology were similar, including serum lactate (2.8 vs. 2.2 mmol/L, $p = 0.167$), temperature, arterial pH, INR, systolic blood pressure, heart rate, and GCS score (Table 2). Time from admission to operation was shorter with DCL (89.5 vs. 113.0 minutes, $p = 0.015$), with no other significant baseline or operative differences. Thus, measured variables did not clearly distinguish patients selected for DCL, although unmeasured intraoperative considerations may have influenced operative choice.

Clinical outcomes in patients without prespecified DCS-related criteria

To further characterize patients without prespecified DCS-related criteria, clinical outcomes were compared between those who underwent DCL and those who underwent definitive laparotomy (DEF) (Table 3). Despite having similar baseline characteristics, patients who underwent DCL had longer total hospital stays (24.5 vs. 14.0 days, p = 0.001) and higher overall complication rates (50.0% vs. 16.1%, p = 0.045). After adjustment for abdominal AIS score, DCL remained independently associated with postoperative complications (adjusted OR 5.7, 95% CI 1.1–30.6; p = 0.041). No in-hospital deaths occurred in either group, and the rate of unplanned relaparotomy did not differ significantly. These findings suggest that among patients without prespecified DCS-related criteria, DCL was associated with increased postoperative morbidity and longer hospitalization without an observable difference in mortality or unplanned reoperation.

Predictors of mortality, major complications, and prolonged ICU stay

In the overall cohort (N = 79), nine patients (11.4%) died during hospitalization. In the univariable analysis, mortality was significantly associated with older age (OR 1.05, p = 0.022), higher Charlson comorbidity index (OR 1.50, p = 0.047), lower admission systolic blood pressure (OR 0.96, p = 0.004), lower GCS score (OR 0.82, p = 0.019), higher initial serum lactate (OR 1.27, p = 0.005), higher DCL (OR 6.71, p = 0.024), longer operative duration (p = 0.004), and greater intraoperative blood loss (p = 0.015). Blunt injury mechanism was associated with lower mortality (OR 0.18, p = 0.026) (Table 4).

Given the limited number of mortality events, multivariable analysis was performed using Firth penalized logistic regression and was restricted to the initial serum lactate concentration and operative strategy. Lactate data were available for 77 patients, including eight of the nine patients

who died. Initial serum lactate levels remained independently associated with in-hospital mortality (adjusted OR 1.20 per 1 mmol/L increase, 95% CI 1.01–1.46; p = 0.043), whereas DCL was not independently associated with mortality after adjustment for lactate (adjusted OR 2.13, 95% CI 0.34–14.85; p = 0.412). The results of the overall penalized likelihood ratio test were significant (p = 0.011). These findings suggest that initial serum lactate levels provide prognostic information for mortality beyond the operative strategy, whereas the higher crude mortality observed in the DCL group may partly reflect greater underlying physiologic derangement.

Major complications occurred in 20 patients (25.3%), and a prolonged ICU stay (≥7 days) occurred in 47 patients (59.5%); corresponding risk factor analyses are presented in Supplementary Tables S1 and S2. On univariable analysis, DCL and higher serum lactate were associated with adverse outcomes. Multivariable analysis revealed that DCL remained independently associated with a prolonged ICU stay (adjusted OR 4.14, 95% CI 1.10–15.62; p = 0.036; Hosmer–Lemeshow p = 0.806). Overall, these analyses indicate that initial serum lactate was independently associated with mortality, whereas DCL was more strongly associated with subsequent critical care utilization.

Mortality discrimination of physiologic markers

To compare the discriminative performance of physiologic markers for in-hospital mortality, ROC curves were constructed for temperature (AUC 0.646, 95% CI 0.380–0.889), arterial pH (AUC 0.577, 95% CI 0.365–0.780), INR (AUC 0.506, 95% CI 0.263–0.744), initial serum lactate concentration (AUC 0.731, 95% CI 0.461–0.952), the conventional lethal triad (temperature, pH, and INR; AUC 0.614, 95% CI 0.331–0.885), and the lethal triad plus lactate concentration (AUC 0.731, 95% CI 0.441–0.956) (Figure 2). Among the individual physiologic

parameters, the initial serum lactate concentration demonstrated the greatest discrimination. Adding the conventional lethal-triad parameters to lactate did not significantly improve discrimination (DeLong test, $\Delta AUC = 0.007$; $p = 0.871$). The optimal lactate concentration cutoff was 4.7 mmol/L according to the Youden index (0.504), yielding a sensitivity of 75.0% and a specificity of 75.4%. These findings suggest that admission lactate may serve as a simple and objective prognostic marker for mortality, with little incremental discrimination achieved by combining it with conventional lethal-triad parameters.

Discussion

This study addresses two related clinical challenges in the management of abdominal trauma: the potentially avoidable use of DCL beyond established indications and the identification of objective prognostic markers that may improve patient selection. In the overall cohort, patients who underwent DCL had greater injury severity and more pronounced physiologic derangement than those who underwent DEF, suggesting that their worse unadjusted outcomes were attributable, at least in part, to greater baseline severity than to the operative strategy alone. More importantly, among patients who did not meet any prespecified DCS-related criteria, the DCL and DEF groups showed no significant differences in measured demographic, injury-severity, or physiologic characteristics. Nevertheless, DCL was associated with a higher postoperative complication rate and longer hospitalization. Although unmeasured intraoperative factors may have contributed to operative decision-making, these findings suggest that when objective DCS-related criteria were absent, the choice of DCL may have depended substantially on individual surgeon judgment. This practice pattern is consistent with previous reports that have described considerable variability and potentially avoidable use of DCL [7, 9, 10, 16] and emphasized the need for more standardized patient-selection criteria.

The morbidity associated with open-abdomen management and staged reoperation, including enteroatmospheric fistula, failure of fascial closure, intra-abdominal infection or sepsis, and prolonged critical care requirements, is well recognized [13, 17]. In our subgroup without prespecified DCS-related criteria, postoperative complications occurred in 50.0% of patients who underwent DCL and 16.1% of those who underwent DEF, and the median hospital stay was approximately 10 days longer. DCL remained associated with postoperative complications after adjustment for abdominal AIS score (adjusted OR 5.7). Although the small sample size and wide confidence interval require cautious interpretation, these findings suggest that potentially avoidable DCL may expose selected patients to additional morbidity without an observable advantage in mortality or unplanned reoperation. They support a selective rather than liberal approach to DCL when clear physiologic or anatomic indications are absent.

Among the physiologic variables examined, admission serum lactate demonstrated the strongest association with mortality. Lactate reflects the cumulative oxygen debt generated during hemorrhagic shock: as the circulation volume and oxygen delivery decrease, inadequate tissue perfusion promotes lactate accumulation. The first lactate measurement obtained after hospital arrival may therefore integrate both the magnitude and duration of prehospital hypoperfusion and provide an early estimate of the overall physiologic burden of hemorrhage [6, 15, 18, 19]. In contrast, the pH, INR, and temperature represent related but distinct aspects of physiologic deterioration. Systemic pH is modified by buffering and respiratory compensation; INR reflects the complex interactions among tissue injury, hypoperfusion, coagulation factor consumption, fibrinolysis, and resuscitation; and hypothermia may evolve progressively through shock, environmental exposure, and the administration of unwarmed fluids or blood products [6].

Consequently, these variables may not convey equivalent prognostic information when only the initial values obtained around hospital arrival are considered.

Previous studies support the prognostic value of admission lactate levels in trauma patients. Qi et al. reported greater discrimination for 72-hour mortality with lactate than with base excess or pH in patients with severe multiple trauma [18]. Odom et al. demonstrated an independent association between increasing admission lactate levels and mortality after adjustment for age, injury severity, GCS score, heart rate, and blood pressure [15], whereas Dezman et al. found that admission lactate levels are strongly predictive of early trauma mortality [19]. A systematic review including more than 44,000 trauma patients similarly demonstrated a consistent association between elevated levels of lactate in the emergency department and mortality [20]. Our findings are in accordance with these observations. In the Firth penalized multivariable model, admission lactate remained independently associated with in-hospital mortality, whereas DCL did not after adjustment for lactate. ROC analysis also revealed greater discrimination with lactate levels than with temperature, pH, INR, or the combined conventional lethal-triad parameters, while adding the lethal-triad variables to lactate yielded little additional discrimination.

These findings may also have implications for how physiologic DCS criteria are interpreted. Lactate concentrations >5 mmol/L, a pH <7.20, an INR >1.5, and hypothermia have been proposed as markers of severe physiologic derangement [6, 21], but they may not represent equivalent degrees or identical phases of hemorrhagic shock. Lactate may increase as oxygen debt accumulates, whereas acidemia, coagulopathy, and hypothermia may increasingly reflect downstream manifestations of prolonged physiologic deterioration. Therefore, simply counting abnormal criteria may not fully capture their differential prognostic importance. The lactate

cutoff of 4.7 mmol/L identified in our cohort provided balanced sensitivity (75.0%) and specificity (75.4%) and was close to the >5 mmol/L threshold incorporated into our prespecified criteria. However, this cutoff was derived from a small single-center cohort and should not be interpreted as a stand-alone indication for DCL. Rather, our findings suggest that individual physiologic criteria may warrant different prognostic weights and that admission lactate levels could serve as an objective adjunct to hemodynamic status, acid–base disturbance, coagulation abnormalities, transfusion requirements, anatomic injury patterns, and intraoperative findings. Larger studies are needed to determine whether a weighted physiologic model can improve selection for DCL.

DCL was also independently associated with a prolonged ICU stay. This association is clinically plausible because staged abdominal management typically involves temporary abdominal closure, subsequent reexploration, delayed definitive repair, and continued critical care support. Nevertheless, the observational nature of this study precludes attributing prolonged ICU utilization directly to DCL itself, and residual confounding by injury complexity or unmeasured intraoperative factors remains possible. These findings should therefore be interpreted as an association with greater subsequent critical care utilization than as proof of a causal effect.

Several limitations should be acknowledged. First, the retrospective, single-center design limits generalizability and is susceptible to residual confounding by indication. Although the DCS-related criteria were prespecified for this analysis, no universally validated set of numerical criteria for DCS exists; consequently, classification as having no prespecified criterion does not establish that DCL was clinically inappropriate. Relevant intraoperative considerations—including bowel edema, evolving tissue viability, technical difficulty of definitive repair, and concern for abdominal compartment syndrome—may not have been consistently documented

and could have influenced operative decisions. Second, the number of in-hospital deaths was small (n = 9), and only 10 patients without prespecified DCS-related criteria underwent DCL, limiting statistical power and resulting in wide confidence intervals. Firth-penalized logistic regression was therefore used for the mortality model to reduce small-sample bias. Third, admission lactate levels were unavailable for two patients, including one who died; lactate-based analyses were consequently restricted to complete cases and may be subject to minor missing-data bias. Fourth, the lactate cutoff of 4.7 mmol/L was derived and evaluated in the same cohort and requires external validation. Finally, changes in resuscitation strategies, operative techniques, and institutional DCL practices during the 10-year study period may have introduced temporal heterogeneity.

Conclusions

DCL identifies a severely injured and physiologically compromised population by a blunt mechanism but may add morbidity and prolong hospitalization when applied outside clear DCS-related indications. Admission lactate levels independently predict mortality and may provide an objective complement to conventional lethal-triad criteria when considering DCL. These findings support more careful patient selection and more objective decision making when performing trauma laparotomy for patients with severe blunt abdominal trauma.

Abbreviations

DCS = damage control surgery; BAT = blunt abdominal trauma; DCL = damage control laparotomy; ICU = intensive care unit; INR = International Normalized Ratio; AIS = abbreviated injury scale; ISS = injury severity score; DEF = definitive laparotomy; IQR = interquartile range; OR = odds ratio; CI = confidence interval; ROC = receiver operating characteristic; AUC = area under the curve

Supplementary Information

Additional file 1: Supplementary Tables S1 and S2.

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Author contributions

Conceptualization: Chien Wu, Heng-Fu Lin; Data curation: Chien Wu, Keng-Li Lin; Formal analysis: Chien Wu; Investigation: All authors; Methodology: Chien Wu, Heng-Fu Lin; Validation: Chien Wu, Heng-Fu Lin; Visualization: Chien Wu, Keng-Li Lin; Software: Chien Wu; Project administration: Chien Wu, Yau-Ren Chang, Heng-Fu Lin; Resources: Chien Wu, Keng-Li Lin, Hu-Lin Christina Wang, Heng-Fu Lin; Writing – original draft: Chien Wu, Keng-Li Lin; Writing – review & editing: All authors; Supervision: Heng-Fu Lin. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of Far Eastern Memorial Hospital (No. 114107-E). The requirement for individual informed consent was waived by the Institutional Review Board because of the retrospective study design.

Clinical trial number

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Use of generative AI and AI-assisted technologies in manuscript preparation

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with language editing and manuscript formatting. The authors subsequently reviewed and edited the content and take full responsibility for the final manuscript.

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Figure legends

Figure 1. Study flow and patient stratification by DCS criteria and operative strategy. AIS = abbreviated injury scale; DCL = damage control laparotomy; DEF = definitive laparotomy; NOM = nonoperative management.

Figure 2. ROC curves for in-hospital mortality prediction. Receiver operating characteristic curves compare (A) temperature, (B) arterial pH, (C) INR, (D) initial serum lactate, (E) the conventional lethal triad (temperature + pH + INR), and (F) the lethal triad + lactate. Shaded areas represent 95% confidence intervals from 2000 bootstrap iterations. The orange dot in panel D denotes the optimal lactate cutoff (4.7 mmol/L; sensitivity 75.0%, specificity 75.4%). AUC = area under the curve; CI = confidence interval; INR = international normalized ratio.

Table 1. Baseline characteristics and outcomes by operative strategy in the overall cohort (N = 79)

	Overall (N = 79)	DEF (n = 48)	DCL (n = 31)	P value
Demographics				
Age	34.0 (31.2)	33.0 (29.5)	35.5 (32.8)	.793†
Male, n (%)	63 (79.7%)	40 (83.3%)	23 (74.2%)	.324‡
BMI	23.9 (4.9)	23.0 (5.7)	24.0 (6.1)	.106†
CCI	0 (2.0)	0 (2.0)	0 (1.0)	.964†
Injury characteristics				
Blunt injury, n (%)	66 (83.5%)	39 (81.3%)	27 (87.1%)	.456‡
AIS of abdomen	5.0 (1.0)	4.0 (1.0)	5.0 (1.0)	.058†
ISS	26.0 (10.0)	25.0 (15.5)	27.0 (10.0)	.029†
Physiology and resuscitation				
SBP, mm Hg	108.0 (43.0)	113.0 (32.8)	93.0 (59.0)	.122†
Heart rate, beats/min	94.0 (25.0)	94.5 (22.8)	94.0 (51.0)	.655†
GCS	15.0 (1.0)	15.0 (0.0)	15.0 (6.0)	.007†
Temperature, °C	36.0 (1.4)	36.1 (1.2)	35.6 (1.2)	.018†
Arterial pH	7.32 (0.15)	7.36 (0.09)	7.25 (0.15)	.007†
Serum lactate, mmol/L	2.9 (3.7)	2.3 (1.9)	5.9 (6.0)	<.001†
INR	1.06 (0.12)	1.06 (0.11)	1.08 (0.13)	.168†
ED resuscitation volume, mL	2300.0 (2700.0)	1800.0 (2900.0)	2650.0 (3000.0)	.015†
Operative findings				
Time from admission to operation, min	103.0 (56.0)	112.5 (69.0)	90.0 (39.0)	.030†
Operative time, min	132.0 (85.0)	130.0 (71.5)	140.0 (94.0)	.619†
Blood loss, mL	3000.0 (3350.0)	2000.0 (2000.0)	5000.0 (5000.0)	<.001†
Outcomes				
Mechanical ventilation, days	5.0 (10.3)	4.0 (6.0)	8.0 (14.0)	.007†
ICU stay, days	8.0 (11.0)	6.0 (7.8)	11.0 (11.0)	.013†
Hospital length of stay, days	17.0 (16.0)	14.0 (10.5)	25.0 (20.0)	.001†
Any postoperative complication, n (%)	33 (41.8%)	12 (25.0%)	21 (67.7%)	<.001‡
Unplanned relaparotomy, n (%)	7 (8.9%)	5 (10.4%)	2 (6.5%)	.698#
Mortality, n (%)	9 (11.4%)	2 (4.2%)	7 (22.6%)	.024#

Data are presented as median (interquartile range) or n (%).

† Mann-Whitney U test; ‡ Pearson chi-square test; # Fisher exact test.

DEF = definitive laparotomy; DCL = damage control laparotomy; BMI = body mass index; CCI = Charlson comorbidity index; AIS = abbreviated injury scale; ISS = injury severity score; SBP = systolic blood pressure; GCS = Glasgow Coma Scale; INR = international normalized ratio; ED = emergency department; ICU = intensive care unit.

Table 2. Characteristics without prespecified DCS indications by operative strategy (N = 41)

	Overall (N = 41)	DEF (n = 31)	DCL (n = 10)	P value
Demographics				
Age	30.0 (28.5)	30.0 (34.0)	31.5 (22.0)	.622†
Male, n (%)	33 (80.5%)	26 (83.9%)	7 (70.0%)	.378#
BMI	24.8 (5.1)	24.8 (5.5)	24.8 (3.4)	.211†
CCI	0 (2.0)	0 (2.0)	0 (1.3)	.709†
Injury characteristics				
Blunt injury, n (%)	37 (90.2%)	27 (87.1%)	10 (100.0%)	.556#
AIS of abdomen	4.0 (1.0)	4.0 (1.0)	4.5 (0.5)	.823†
ISS	26.0 (15.0)	25.0 (17.0)	29.0 (10.0)	.151†
Physiology and resuscitation				
SBP, mm Hg	118.0 (26.5)	116.0 (25.0)	121.0 (54.8)	.622†
Heart rate, beats/min	90.0 (22.5)	92.0 (21.0)	84.0 (35.5)	.086†
GCS	15.0 (0.0)	15.0 (0.0)	15.0 (1.0)	.520†
Temperature, °C	36.2 (1.2)	36.3 (1.0)	35.9 (1.5)	.363†
Arterial pH	7.37 (0.08)	7.38 (0.05)	7.25 (0.15)	.120†
Serum lactate, mmol/L	2.3 (1.3)	2.2 (1.3)	2.8 (1.7)	.167†
INR	1.05 (0.09)	1.06 (0.10)	1.05 (0.07)	.601†
ED resuscitation volume, mL	2050.0 (2900.0)	1300.0 (3200.0)	2400.0 (2150.0)	.093†
Operative findings				
Time from admission to operation, min	105.0 (58.5)	113.0 (64.0)	89.5 (25.5)	.015†
Operative time, min	125.0 (53.5)	130.0 (55.0)	120.0 (62.5)	.754†
Blood loss, mL	2000.0 (1750.0)	2000.0 (1600.0)	3000.0 (3250.0)	.057†

Data are presented as median (interquartile range) or n (%).

† Mann-Whitney U test; # Fisher exact test.

DEF = definitive laparotomy; DCL = damage control laparotomy; BMI = body mass index; CCI = Charlson comorbidity index; AIS = abbreviated injury scale; ISS = injury severity score; SBP = systolic blood pressure; GCS = Glasgow Coma Scale; INR = international normalized ratio; ED = emergency department.

Table 3. Outcomes without prespecified DCS indications by operative strategy (N = 41)

					ISS-adjusted model		Abdominal AIS-adjusted model	
Outcome	**Overall (N = 41)**	**DEF (n = 31)**	**DCL (n = 10)**	**Crude P value**	**aOR (95% CI)**	**P value**	**aOR (95% CI)**	**P value**
Mechanical ventilation, days	4.0 (7.0)	4.0 (7.0)	6.0 (10.0)	.102†	—	—	—	—
ICU stay, days	7.0 (8.0)	6.0 (8.0)	9.5 (8.8)	.057†	—	—	—	—
Hospital length of stay, days	17.0 (13.0)	14.0 (11.0)	24.5 (16.5)	.001†	—	—	—	—
Any postoperative complication, n (%)	10 (24.4%)	5 (16.1%)	5 (50.0%)	.045#	4.7 (0.9–23.9)	.062	5.7 (1.1–30.6)	.041
Unplanned relaparotomy, n (%)	3 (7.3%)	3 (9.7%)	0 (0.0%)	.564#	Not estimable	—	Not estimable	—
Mortality, n (%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	—	Not estimable	—	Not estimable	—

Data are presented as median (interquartile range) or n (%).

† Mann-Whitney U test; # Fisher exact test.

Adjusted odds ratios were estimated using binary logistic regression with DCL as the primary exposure. Separate models adjusted for ISS or abdominal AIS. Adjusted analyses were not estimable when outcome events were absent in one group.

DEF = definitive laparotomy; DCL = damage control laparotomy; aOR = adjusted odds ratio; CI = confidence interval; ISS = injury severity score; AIS = abbreviated injury scale; ICU = intensive care unit.

Table 4. Predictors of in-hospital mortality after emergency laparotomy for abdominal trauma (N = 79)

			Univariable		Multivariable (Firth)	
Variable	**Survived (n = 70)**	**Died (n = 9)**	**OR (95% CI)**	**P value**	**aOR (95% CI)**	**P value**
Demographics						
Age	34.0 (31.3)	56.0 (32.5)	1.05 (1.01–1.09)	.022	—	—
Male, n (%)	54 (77.1%	9 (100%)	Not estimable	.998	—	—
BMI	23.9 (4.9)	26.7 (6.8)	1.15 (0.97–1.36)	.114	—	—
CCI	0.0 (2.0)	1.0 (3.5)	1.50 (1.01–2.23)	.047	—	—
Injury characteristics						
Blunt injury, n (%)	61 (87.1%)	5 (55.6%)	0.18 (0.04–0.82)	.026	—	—
AIS of abdomen	5.0 (1.0)	5.0 (1.0)	1.78 (0.41–7.71)	.438	—	—
ISS	26.0 (10.0)	25.0 (7.0)	0.99 (0.91–1.07)	.713	—	—
Physiology and resuscitation						
SBP, mm Hg	108.0 (43.0)	70.0 (35.0)	0.96 (0.93–0.99)	.004	—	—
Heart rate, beats/min	94.0 (25.0)	100.0 (49.0)	1.00 (0.98–1.03)	.848	—	—
GCS	15.0 (1.0)	15.0 (10.5)	0.82 (0.70–0.97)	.019	—	—
Temperature (°C)	36.0 (1.4)	35.0 (1.9)	0.54 (0.28–1.03)	.060	—	—
Arterial pH	7.32 (0.15)	7.30 (0.13)	0.08 (0.00–11.1)	.312	—	—
Serum lactate, mmol/L	2.9 (3.7)	7.3 (11.8)	1.27 (1.08–1.51)	.005	1.20 (1.01–1.46)	.043
INR	1.06 (0.12)	1.06 (0.19)	0.98 (0.00–520.10)	.994	—	—
ED resuscitation volume, mL	2300.0 (2700.0)	3950.0 (2150.0)	1.00 (1.00–1.00)	.283	—	—
Operative findings						
Damage control laparotomy, n (%)	24 (34.3%)	7 (77.8%)	6.71 (1.29–34.83)	.024	2.13 (0.34–14.85)	.412
Time from admission to operation, min	103.0 (56.0)	103.0 (48.5)	0.99 (0.98–1.01)	.423	—	—
Operative time, min	132.0 (85.0)	200.0 (105.0)	1.02 (1.01–1.03)	.004	—	—
Blood loss, mL	3000.0 (3350.0)	6000.0 (5442.5)	1.00 (1.00–1.00)	.015	—	—

Data are presented as median (interquartile range) or n (%).

Univariable analyses used standard binary logistic regression. Because of the limited number of deaths, the multivariable model used Firth penalized logistic regression and was restricted to initial serum lactate and operative strategy (DCL vs DEF). Lactate data were unavailable for 2 patients; the multivariable analysis therefore used complete cases (n = 77; 8 deaths). Adjusted odds ratios and 95% confidence intervals were derived using profile penalized likelihood. Overall penalized likelihood ratio test: P = .011.

OR = odds ratio; aOR = adjusted odds ratio; CI = confidence interval; BMI = body mass index; CCI = Charlson comorbidity index; ISS = injury severity score; AIS = abbreviated injury scale; SBP = systolic blood pressure; GCS = Glasgow Coma Scale; INR = international normalized ratio; ED = emergency department; DCL = damage control laparotomy; DEF = definitive laparotomy.

Supplementary Files

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