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# The effects of reoperation on surgical outcomes following surgery for major abdominal emergencies. A retrospective cohort study

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ABSTRACT

*Background:* The objective of this study was to analyze outcomes and determine independent predictors of subsequent reoperation following emergency laparotomy (EL).

*Materials and methods:* Patients undergoing EL (n = 854) from 2012 to 2018 at our institution were retrospectively assessed. Postoperative complications, in-hospital mortality and predictive factors were assessed.

*Results:* Among the studied patients, 307 (35.9) required subsequent reoperation, and 547 (64.1%) did not. The mean number of surgeries was 2.02 ± 1.54, with a median of 2 (range 1–10). Viscus organ perforation had the highest reoperation rate (25.6%), followed by hemorrhage (16.1%), anastomotic leakage (15.4%), mesenteric ischemia (14.9%), and bowel obstruction (11.9%). The incidence of postoperative complications was higher in reoperated patients (100%) than in non-reoperated patients (58.9%). There were 305 deaths, with an overall in-hospital mortality rate of 35.7%; 175 (57%) occurred in the reoperated group, and 130 (23.8%) occurred in the non-reoperated group. In multivariate regression (N = 854), an American Society of Anesthesiologists (ASA) class of 3 or above (OR, 4.27; 95% CI, 2.54–7.18), coexisting liver cirrhosis of Child grade B or above (OR, 2.50; 95% CI, 1.46–4.29), coexisting cardiac arrhythmia (OR, 1.59; 95% CI, 1.10–2.30), and steroid use (OR, 1.95; 95% CI, 1.01–3.77) strongly predicted reoperation.

*Conclusion:* Our data showed notably high mortality due to subsequent reoperation, and there was a steady increase in mortality as the number of reoperations increased. A high ASA class, liver cirrhosis, cardiac arrhythmia and steroid use were independently associated with the risk of subsequent reoperation.

## 1. Introduction

Despite current major advances in surgery, emergency laparotomy (EL) still places patients at an increased risk for postoperative complications and mortality [1,2]. The underlying pathology is diverse, but viscus organ perforation, mesenteric ischemia, hemorrhage and bowel obstruction are thought to be the most common causes [3,4]. Abdominal reoperations due to unforeseen surgical events following EL are associated with an even higher risk of death and prolonged hospital stay than EL alone. Disproportionately high mortality rates approaching 80% have been reported [5–9]. The reasons for in-hospital mortality in these patients are multifactorial and complex. In the majority of cases, reoperations are not optional operations, and they may save countless lives. Although death is expected in these patients if they don't undergo surgery, the likelihood of reoperation survival is often unclear. It is sometimes difficult to determine which patients will benefit from reoperation and which will not.

Gaining a better understanding of why reoperations occur and how they can be prevented is essential for improving surgical outcomes as well as utilizing health care resources effectively. Data on the predictors of subsequent abdominal reoperations following EL for different surgical indications are scarce.

Therefore, the current report examines the clinical outcomes of patients undergoing major EL for different indications at a single high-volume center and compares those patients who required reoperation during the same hospitalization with those patients who did not. The objectives of the study were to specifically analyze the effects of reoperation on surgical outcomes, identify the independent risk factors associated with these effects and determine the independent predictors of reoperation. We hypothesized that the patients who required reoperation following EL for major abdominal emergencies had multifold higher mortality rates than patients who did not, and the patients who required reoperation could be distinguished by a limited number of clinical parameters that were evident at admission and during

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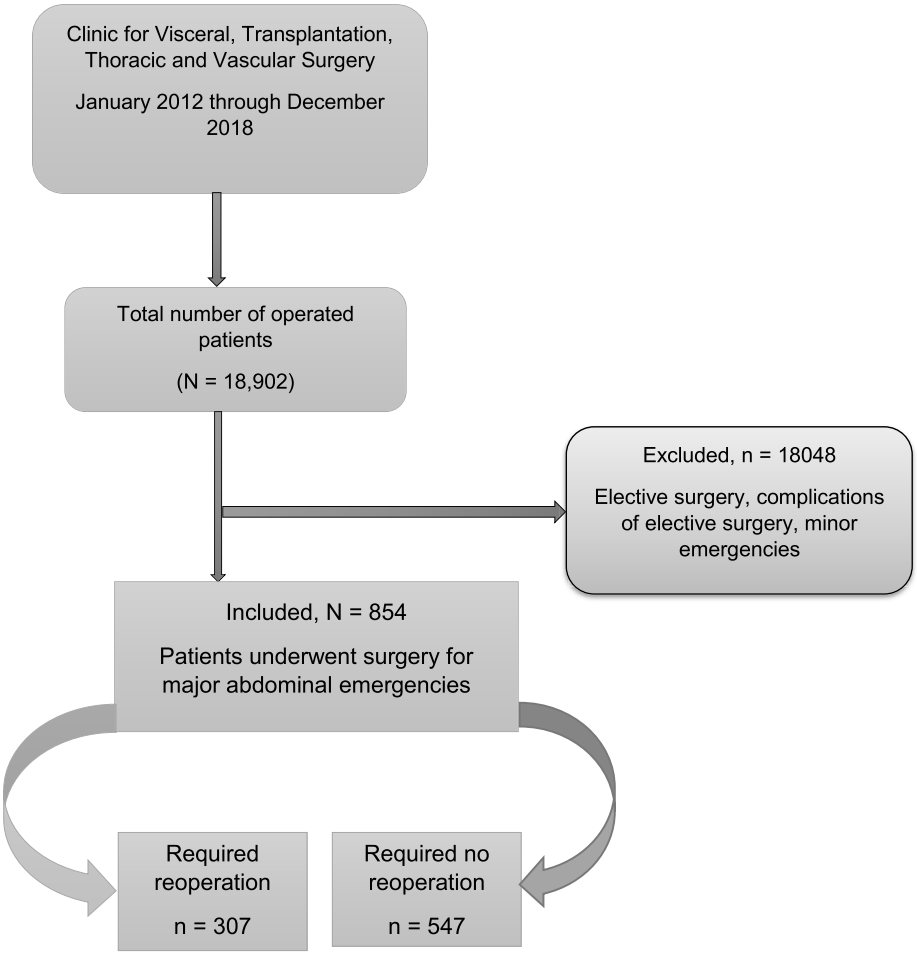


**Fig. 1.** Flow Diagram summarizing patient inclusion.

hospitalization. This information will aid in understanding the relative clinical and economic importance of emergent and unplanned abdominal reoperations.

## 2. Materials and Methods

A retrospective analysis of 1433 emergent abdominal surgical operations for major abdominal emergencies performed on 854 patients during a 7-year period (January 2012 through December 2018) was undertaken to identify factors that were associated with the risk of morbidity, mortality and surgical reintervention. Data were obtained from a database of patients treated at the department of transplantation, thoracic, visceral and vascular surgery of the University of ***. The study data was obtained from inpatient hospital stays for all patients undergoing EL or laparoscopy. Information on more than 100 variables, such as the patients' demographic information, preexisting comorbidities, and postoperative morbidity and mortality outcomes, was assessed. The patients were separated into 2 groups based on the necessity of reoperation (Fig. 1).

Of the 854 patients, 307 were identified as having undergone at least one emergency abdominal reoperation (REOP group) for various surgical indications, representing 35.9% of all the major EL cases. These patients formed the basis for this report. The outcomes of these patients were compared with the outcomes of the remaining 547 patients – those who did not require reoperation following EL (non-REOP group) – to determine whether there were any significant differences between the groups.

For the purpose of this study, we categorized all operation indications into 4 different types and all procedures into 7 different types.

EL or laparoscopy was defined as abdominal exploration that must be performed as soon as possible after admission or after the onset of related clinical symptoms in a patient aged 18 years or older and requiring unscheduled emergency surgery. Indications to operate on were identified on the basis of clinical and radiologic findings. Reoperation was defined as a formal reexploration performed during a patient's hospital stay after the initial laparotomy and applied to patients who were brought back to the operating room for confirmed or suspected complications of the initial or subsequent laparotomy.

Due to multiple early and late reexplorations, in some studied patients during initial hospitalization, access to the abdominal cavity was technically limited by extensive adhesions. We felt that to use the term relaparotomy may be inaccurate and misleading. Therefore, for the purpose of this study, we use the term reoperation throughout. This definition resulted in the dichotomous classification of reoperated patients (REOP group) and non-reoperated patients (non-REOP group). This avoids confusion about the correct term and allows us to discuss the same procedure with confidence.

Patients undergoing minor procedures, such as uncomplicated laparoscopic appendectomy, were excluded from this study, as were patients undergoing simple laparoscopic cholecystectomy because the majority of these patients were young and otherwise healthy, and the risk of complications requiring reoperation and death associated with these procedures is extremely low and has been addressed previously in other studies [10,11]. We intentionally analyzed a select group of critically ill patients. By doing so, we focused on a relatively homogenous group of patients, thus allowing an accurate statistical interpretation of data.

The American Society of Anesthesiologists (ASA) physical status

classification [12], a five-point assessment of a patient's physical status conducted by the anesthesiologist, was also collected. The severity of complications was generally assessed using the Clavien-Dindo (CD) classification system [13]. Based on CD classification, the comprehensive complication index (CCI) [14] was calculated to evaluate the true overall morbidity burden of each procedure.

Reoperation was indicated by clinical signs, such as abdominal tenderness, pathologic laboratory findings, such as leukocytosis and positive imaging; moreover, reoperation was sometimes performed without abdominal or radiologic findings in an effort to establish a surgically amenable focus in a patient with a worsening clinical condition. In some cases, reoperation was performed to reevaluate the patient for expected progression of the disease for which the primary EL had been performed, as in cases of mesenteric ischemia with enteric infarction. The operations were performed under the auspices of a teaching surgical team.

The primary outcomes of interest were the identification of predictors of in-hospital mortality, defined as death during the initial hospitalization and reoperation.

Pre- and postoperative clinical practice patterns were in compliance with the World Society of Emergency Surgery guidelines (https://www.wses.org.uk/guidelines).

Data management and statistical analyses were performed using SPSS software version 24 for Windows (IBM Corporation, USA). All the statistical tests were 2-sided. Descriptive statistics assessed the distribution of the patients, the procedures, comorbidities, morbidity and mortality by group. Univariate statistical comparisons between groups were performed using Student's t-test for continuous variables and chi-square tests for discrete variables to examine the univariate relations between risk factors and outcome variables. Multiple logistic regression was performed to assess the contribution of significant independent variables in predicting the likelihood of postoperative complications, reoperation and in-hospital mortality. These analyses were performed by entering the factors that appeared to be significant in the univariate analysis ($P \leq 0.05$) in the multivariate logistic regression analysis, with the outcome variables as dependent variables and the risk factors as independent variables to test for significant effects while adjusting for multiple factors simultaneously. The results were expressed as arithmetic means ± standard deviations, medians with interquartile ranges or frequencies with percentages. Odds ratios (ORs) and 95% confidence intervals (CIs) for the ORs as well as P values for each variable are given. A P value ≤ 0.05 was considered significant.

The local institutional review board and the University of *** Medical Faculty Ethics Committee reviewed and approved this study protocol.

The study is registered on www.researchregistry.com with the Unique Identifier Number researchregistry5119.

The paper was written to comply with STROCSS guidelines (www.strocssguidelines.com) [15].

## 3. Results

The details of patients' demographic information and preexisting comorbidities are depicted in Table 1.

The 854 patients in this study underwent a total of 1433 operations. There were 487 men and 367 women. The causes of initial EL varied, with the most common being viscus organ perforation (41.5%), bowel obstruction (23.3%), and mesenteric ischemia (17.2%). The primary indications for surgery and surgical procedures are depicted in Table 2.

Among all the studied patients, 307 patients (35.9%) required subsequent reoperation (1 reoperation, n = 159, 2 reoperations, n = 72, 3 reoperations, n = 36, more than 3 reoperations n = 40); the remaining 547 patients (64.1%) did not require reoperation. The mean number of required surgeries was 2.02 ± 1.54, with a median of 2 operations (range 1–10). Among all reoperations, a total of 56.8% of were indicated due to abdominal sepsis related to viscus organ perforation (25.4%), postoperative anastomotic leakage (16.4%) or mesenteric ischemia with enteric infarction (15.0%). The other indications for reoperation were postoperative hemorrhage (16.1%) bowel obstruction (11.9%) and miscellaneous indications (15.2%). The likelihood of reoperation did not significantly differ by type of surgery (procedure category). A substantial proportion of the patients across all the groups had one or more of the comorbidities listed in Table 1. Every evaluated comorbid condition was more prevalent in the REOP group than in the non-REOP group, but these trends were not statistically significant except for cardiac arrhythmia (P = 0.001), peripheral arterial disease (P < 0.0001), and liver cirrhosis (P < 0.0001). In the REOP group, the average number of comorbidities per patient was

**Table 1**
Preoperative patient characteristics.

| | REOP group | non-REOP group | p value |
|---|---|---|---|
| Variable | N = 307 | N = 547 | |
| Male | 188 (61.2) | 299 (54.7) | 0.068 |
| Age, years, mean ± SD | 65.72 ± 15.03 | 65.18 ± 17.55 | 0.649 |
| BMI, mean ± SD | 27.22 ± 6.67 | 26.20 ± 6.54 | 0.030 |
| Hypertension | 209 (68.4) | 351 (64.2) | 0.223 |
| Cardiac arrhythmias | 116 (37.8) | 145 (26.5) | 0.001 |
| Diabetes mellitus | 83 (27.0) | 126 (23.0) | 0.220 |
| Peripheral arterial disease | 103 (33.6) | 115 (21.0) | < 0.0001 |
| Chronic kidney disease | 60 (19.6) | 86 (15.7) | 0.148 |
| CNS | 80 (26.1) | 122 (22.3) | 0.206 |
| Coronary artery disease | 62 (20.3) | 90 (16.5) | 0.163 |
| Chronic heart failure | 61 (19.9) | 101 (18.5) | 0.600 |
| COPD | 48 (15.7) | 74 (13.5) | 0.388 |
| Liver cirrhosis | 47 (15.4) | 27 (4.9) | < 0.0001 |
| Surgery in PMH | 197 (64.2) | 347 (65.3) | 0.702 |
| Malignancy in PMH | 91 (29.6) | 148 (27.1) | 0.419 |
| AAA | 137 (44.6) | 234 (42.8) | 0.601 |
| Steroids | 25 (8.2) | 19 (3.5) | 0.003 |
| ASA* ≥ 3 | 285 (92.8) | 363 (71.3) | < 0.0001 |
| COD, mean ± SD | 5.87 ± 2.99 | 4.98 ± 3.02 | < 0.0001 |

BMI, body mass index; SD, standard deviation; COD, coexisting disease per patient; COPD, chronic obstructive pulmonary disease; CNS, indicates central nervous system disease and holds for patients with medically documented cerebral vascular accident, transient ischemic attack, or neurological deficit of central origin, PMH, past medical history; AAA, medication with oral anticoagulants and antiplatelet agents; ASA, the American society of anesthesiologists physical status classification. Numbers in bracket indicate values presented in n (%) by group unless noted otherwise. *, Percents may not total 100 due to missing data; P values represent the difference between the REOP and non-REOP group.

**Table 2**
Primary Indications for surgery and initial surgical procedures by group.

| Primary Indications | REOP group | non-REOP group |
|---|---|---|
| | N = 307 | N = 547 |
| Perforated viscus | 122 (39.7) | 232 (42.4) |
| Mesenteric ischemia | 67 (21.9) | 80 (14.6) |
| Bowel obstruction | 55 (18.0) | 144 (26.3) |
| Miscellaneous | 63 (20.6) | 91 (16.6) |
| Procedures | REOP group N = 307 | non-REOP group N = 547 |
| Bowel resection large | 42 (13.7) | 56 (10.2) |
| Bowel resection small | 37 (12.1) | 60 (11) |
| Combined resection | 54 (17.6) | 52 (9.5) |
| Closure of viscus organ | 46 (15.0) | 86 (15.7) |
| Multiorgan procedure | 74 (24.0) | 88 (16.1) |
| Extensive adhesiolysis | 36 (11.7) | 96 (17.6) |
| Miscellaneous | 18 (5.9) | 109 (19.9) |

Numbers in bracket indicate values presented in n (%); A combined bowel resection indicates a combination of small and large bowel resection.

**Table 3**
Major outcomes.

| Variable | REOP group | non-REOP group | p value |
|---|---|---|---|
| | N = 307 | N = 547 | |
| Operation at night | 246 (80.1) | 446 (81.5) | 0.615 |
| Operative time ≥ 2 h | 175 (57.0) | 214 (39.1) | < 0.0001 |
| Complications | 307 (100.0) | 322 (58.9) | < 0.0001 |
| Hemorrhage | 119 (38.9) | 84 (15.4) | < 0.0001 |
| Surgical site infection | 188 (61.1) | 126 (23.0) | < 0.0001 |
| Anastomotic leaks | 113 (36.8) | 11 (2.0) | < 0.0001 |
| Pneumonia | 141 (45.9) | 95 (17.4) | < 0.0001 |
| Thromboembolism | 131 (42.7) | 95 (17.4) | < 0.0001 |
| Liver failure | 116 (37.8) | 80 (14.6) | < 0.0001 |
| GI-Bleeding | 34 (11.1) | 25 (4.6) | 0.0003 |
| Acute renal failure | 179 (58.3) | 116 (21.2) | < 0.0001 |
| Complications PP, mean ± SD | 7.01 ± 3.62 | 3.82 ± 2.82 | < 0.0001 |
| CCI, mean ± SD | 83.44 ± 22.10 | 42.04 ± 35.53 | < 0.0001 |
| ICU | 290 (94.5) | 367 (67.1) | < 0.0001 |
| ICU-LOS, days, mean ± SD | 20.01 ± 22.01 | 6.01 ± 8.95 | < 0.0001 |
| ICU-LOS, days, median (IR) | 12 (1–139) | 3 (1–79) | |
| MV | 258 (84.0) | 228 (41.7) | < 0.0001 |
| DMV, hours, mean ± SD | 291.29 ± 354.76 | 97.69 ± 191.65 | < 0.0001 |
| DMV, hours, median (IR) | 141 (1–1865) | 24 (1–1641) | |
| In-hospital mortality | 175 (57.0) | 130 (23.8) | < 0.0001 |
| LOS, days, mean ± SD | 33.81 ± 29.33 | 14.52 ± 14.25 | < 0.0001 |
| LOS, days, median (IR) | 26 (2–200) | 10 (1–124) | |

PP, per patient; surgical site infection is defined as being contained within the skin or subcutaneous tissue (superficial), or involving the muscle and/or fascia (deep); acute renal failure was considered if it required dialysis; CCI, the comprehensive complication index; ICU, intensive care unit requirement; MV, mechanical ventilation defined as ventilation at any time during hospitalization and applies for all patients who required ventilation beyond the operation room; DMV, duration of mechanical ventilation; LOS, length of hospital stay defined as the time from the date of the initial admission to the date of discharge, transfer to external services, or death, which ever came first.

significantly higher than that in the non-REOP group (5.87 ± 2.99 vs. 4.98 ± 3.02, P < 0.0001), and an increased number of patients were classified as ASA class III or above (285 [92.8%] vs. 363 [71.3%], P < 0.0001).

Postoperative outcomes, including in-hospital mortality, which was defined as death at any time during the initial hospitalization, and several other variables are depicted in Table 3. For all the patients, the overall complication rate was 73.7%. When compared by group, according to the mean number of complications per patient and the mean CCI, subsequent reoperation was associated with the highest incidence of postoperative complications. Not surprisingly, compared to those patients without the need for repeat surgical intervention, reoperated patients required increased intensive care unit (ICU) and hospital stays and were ventilator dependent. These differences were significant at a level of P < 0.0001 (Table 3).

Among the 854 patients, there were 305 deaths, with an overall in-hospital mortality rate of 35.7%; 175 (57.0%) deaths occurred in the REOP group, and 130 (23.8%) occurred in the non-REOP group. In both groups, mesenteric ischemia was associated with the highest mortality rate, and bowel obstruction was associated with the lowest mortality rate. Overall, 253 patients (156 in the REOP group and 97 in the non-REOP group) died of abdominal sepsis with multiorgan failure, and 52 (19 in the REOP group and 33 in the non-REOP group) died of other causes.

Among the 307 patients who underwent reoperation, the incremental in-hospital mortality rates for 1, 2, 3, and more than 3 reoperations were 50.9%, 56.9%, 69.4%, and 72.2%, respectively. This implies a steady increase in mortality with an increasing number of reoperations.

Table 4 shows the odds of in-hospital mortality according to a specific risk factor, along with the P value, which was calculated with the chi-square test for linear trend by group. As depicted in this table, 12 and 16 variables were univariately associated with in-hospital mortality in the REOP and non-REOP groups, respectively.

After adjusting for potential confounding variables using a logistic regression analysis by group, liver failure (OR, 17.38; 95% CI, 5.04–59.93) and acute renal failure (OR, 4.38; 95% CI, 1.81–10.64) were still significant contributors to the risk of all cause in-hospital mortality in reoperated patients.

Liver failure (OR, 31.22; 95% CI, 5.10–191.52), acute renal failure (OR, 7.79; 95% CI, 2.44–24.80), age ≥ 70 years (OR, 5.22; 95% CI, 1.57–17.37), an initial diagnosis of mesenteric ischemia (OR, 4.29; 95% CI, 1.09–16.85), and hemorrhage requiring blood transfusion (OR, 3.44; 1.15–10.24) were identified as predictive of mortality in the non-REOP group.

Overall, in addition to high mortality, reoperated patients had increased durations of hospital stay and ventilator dependence, likely reflecting significant morbidity and a slow recovery after surgery.

In the multivariate regression including all the patients in this cohort (N = 854), an ASA class 3 or above classification (OR, 4.27; 95% CI, 2.54–7.18), coexisting Child grade B or above liver cirrhosis (OR, 2.50; 95% CI, 1.46–4.29), and coexisting cardiac arrhythmia (OR, 1.59; 95% CI, 1.10–2.30) strongly predicted reoperation, as did the use of steroids (OR, 1.95; 95% CI, 1.01–3.77).

## 4. Discussion

These data represent morbidity and in-hospital mortality rates of EL and subsequent reoperations related to different pathologies in a large single institutional patient cohort. Patients had a significantly increased risk of developing postoperative complications and death following EL, and we observed a high rate of reoperation. When patients with one or more subsequent abdominal reoperations were compared with patients without reoperation, virtually all of the evaluated comorbid conditions, complications and death continued to be more likely in reoperated patients than in non-reoperated patients.

Reoperation was accompanied by an increased prevalence of coexisting diseases. However, no coexisting diseases retained in the multivariate logistic regression were significantly associated with morbidity or in-hospital mortality in reoperated patients. In the non-REOP group, hypertension, liver cirrhosis, peripheral arterial disease and dementia predicted morbidity, but no coexisting disease predicted mortality. This implies that given the high number of evaluated coexisting diseases in our study, coexisting disease did little to alter the mortality rate. This is in general agreement with the results of previous studies. Martínez-Casas et al. [8] evaluated data from 254 patients undergoing emergency relaparotomy, and none of the evaluated coexisting diseases were retained in the multivariate model. Mik et al. [16] analyzed 121 patients who underwent relaparotomy after initial surgery for colorectal cancer and found no associations between comorbid conditions and the risk of mortality.

Postoperative mortality is usually associated with a complication, and the risk of mortality is increased with the increasing number of complications [17]. Recent study results showed that postoperative renal failure [18], pneumonia [19], thromboembolism [20], and liver failure [21] were among the most common complications associated with death.

In the analysis of postoperative complications, we found that patients who required one or more subsequent reoperations had higher rates of surgical site infection; hemorrhage requiring transfusion; anastomotic leakage; and cardiovascular, pulmonary, and hepato-renal complications than patients who did not. Acute renal failure requiring dialysis and liver failure independently predicted mortality in the REOP group. In the non-REOP group, renal failure, liver failure and hemorrhage strongly predicted mortality. This suggests that postoperative complications were strongly associated with the risk of subsequent reoperation and death. Moreover, the strongest predictors of death were

**Table 4**
Risk of in-hospital mortality associated with a specific comorbidity and postoperative complication (univariate analyses).

| Risk factor | REOP group | p value | non-REOP group | p value |
|---|---|---|---|---|
| | n = 307 | | n = 547 | |
| | OR (95% CI) | | OR (95% CI) | |
| Age ≥ 70 years | 1.07 (.68–1.69) | 0.757 | 2.13 (1.42–3.18) | 0.0002 |
| ASA ≥ 3 | 9 (2.59–31.26) | < 0.0001 | 15.64 (5.65–43.30) | < 0.0001 |
| Hypertension | 1.38 (.85–2.24) | 0.189 | 1.63 (1.06–2.50) | 0.027 |
| Chronic heart failure | 1.43 (.80–2.56) | 0.222 | 2.45 (1.55–3.90) | 0.0001 |
| Cardiac arrhythmia | 1.77 (1.11–2.84) | 0.019 | 2.32 (1.53–3.53) | < 0.0001 |
| COPD | 1.18 (.63–2.22) | 0.603 | 2.21 (1.32–3.72) | 0.002 |
| Chronic renal failure | 1.66 (.92–3.00) | 0.092 | 2.06 (1.30–3.38) | 0.004 |
| Liver cirrhosis | 5.29 (2.29–12.24) | < 0.0001 | 6.12 (2.73–13.74) | < 0.0001 |
| Peripheral arterial disease | 2.43 (1.47–4.04) | < .0.0001 | 3.75 (2.41–5.83) | < 0.0001 |
| Mesenteric ischemia¥ | 2.25 (1.25–4.05) | 0.006 | 12.79 (7.43–21.91) | < 0.0001 |
| ICU | 24 (3.14–183.45) | < 0.0001 | 97.02 (13.44–700.65) | < 0.0001 |
| PMV ≥ 48 h | 3.26 (1.84–5.76) | < 0.0001 | 1.62 (.92–2.85) | 0.092 |
| Hemorrhage | 2.90 (1.77–4.75) | < 0.0001 | 9.81 (5.87–16.39) | < 0.0001 |
| Pneumonia | 2.96 (1.84–4.76) | < 0.0001 | 8.27 (5.10–13.41) | < 0.0001 |
| Thromboembolism | 3.67 (2.07–5.49) | < 0.0001 | 18.29 (10.75–31.12) | < 0.0001 |
| Liver failure | 44.05 (17.12–113.35) | < 0.0001 | 145.32 (51.12–413.05) | < 0.0001 |
| Acute renal failure* | 23.37 (12.83–42.57) | < 0.0001 | 83.54 (43.83–159.24) | < 0.0001 |

OR, odds ration; CI, confidence interval; ¥, initial diagnosis of mesenteric ischemia; *, acute renal failure that required dialysis; ICU, intensive care unit stay; PMV, Prolonged mechanical ventilation defined as ventilation longer than 48 h at any time during hospitalization.

not surgical complications but specific medical complications, and survival partly depended on the effectiveness of the treatment used to address these complications, indicating opportunities for improvement.

Ninety-four percent (290 of 307) of the patients in the REOP group were admitted to the ICU postoperatively, among which 184 patients (63.4%) required prolonged mechanical ventilation for more than 48 h after surgery. Ninety-one percent (159 of 175) of those who died never left the ICU, despite advanced full hemodynamic and cardiorespiratory support and optimization. The possible explanation for this is that due to the high prevalence of certain comorbid conditions, reoperated patients may already be prone to severe postoperative complications that contribute to subsequent reexploration and prolonged mechanical ventilation. This is consistent with previous studies that found ventilator dependence to be a risk factor for reoperation and death [22,23].

At 57%, the in-hospital mortality rate of the REOP group was higher than that of the non-REOP group (23.8%). These results were in line with previous findings that showed comparably high mortality rates in reoperated patients [6–9,24]. This highlights the need to identify patients at high risk of reoperation.

Eighty-nine percent (156 of 175) of the mortality cases in the REOP group were associated with postoperative septic complications and multiple organ failure. These data suggest that the increased mortality risk in patients requiring subsequent reoperation is not necessarily the inevitable result of surgical reintervention but is strongly associated with the occurrence of serious postoperative complications that warrant subsequent reoperation. Furthermore, the results of the present study indicate that in-hospital mortality is unaffected by the initial diagnosis and surgical procedure among reoperated patients, suggesting that a patient's preoperative overall condition is more important than the performed procedure. Overall, avoiding unnecessary operations requires the identification of risk factors associated with poor outcomes. Thus, the most practical approach to reduce mortality due to reoperation is the prompt recognition and treatment of postoperative complications.

Given the strong association between subsequent reoperation and adverse postoperative surgical outcomes, we sought to identify predictors of reoperation in these patients. The results showed that preexisting liver cirrhosis of Child grade B or above, preexisting cardiac arrhythmia, the use of steroids, and an ASA class of 3 or above were independent predictors of subsequent reoperation even after adjusting for various patient and disease characteristics. All of these variables have been found to be important predictors of subsequent reoperation in other patient populations [23–30].

To our knowledge, these findings have not been reported with regard to abdominal reoperation following EL in a large patient cohort, and relevant data are scarce.

In the few existing studies [9,16], the number of studied patients was very small, making it difficult to draw a conclusion from the analysis. Thus, the overall information generated by those studies was inconclusive. The majority of previous studies with a sizable number of patients mainly concentrated on the strategy of reoperation (whether reoperation was on demand or planned) and not on analyzing factors that independently predicted the risk of reoperation.

Therefore, given the large number of studied patients, we believe that the identified risk factors associated with morbidity, mortality and surgical reintervention following EL in this study likely represent reliable data.

For patients undergoing elective surgery, some of the indicated predictive factors of reoperation can be modified to reduce the risk of severe complications and improve the outcome. Unfortunately, the clinical situation in patients who require emergency surgery, as those in the present study, is different because there is one patient with several problems that need to be solved immediately. The events are unforeseen and life threatening, and surgery must be performed as soon as possible after admission. Thus, there is a very limited window of opportunity to optimize preexisting conditions, such as liver cirrhosis, to reduce complications and reoperation rates.

There are noteworthy limitations to the data presented in this study.

First, our study was limited by its retrospective nature. Our data collection relied on existing documentation that was not specifically collected for the purpose of this study. We tried to account for this by reviewing each electronic data record thoroughly. Each record in the data set was specifically reviewed by the lead author (W.T.K.).

Second, our study was conducted at a single institution, which limits the generalizability of the findings. However, our institution is a high-volume center; the patients were consecutive, and the applied clinical practice patterns were similar.

Third, we controlled for available clinical confounders identified in our institutional database; however, unmeasured confounders may have influenced the results.

## 5. Conclusions

Despite advances in anesthetic agents and surgical techniques, EL continues to be associated with a high risk of mortality, as it was decades ago. Surgical outcomes worsened when subsequent abdominal reoperation was required. This is apparent from our data, which showed notably high mortality due to subsequent reoperation. The key question regarding alternatives to reoperation remains unanswered. Here, we demonstrated that liver cirrhosis, cardiac arrhythmia, use of steroids, and an ASA class of 3 or above were significantly associated with an increased risk of reoperation following EL. Our results support further efforts to develop decision tools with which to guide early intervention and institute preventive measures.

## Ethical approval

The local institutional review board and the University of Leipzig Medical Faculty Ethics Committee reviewed and approved this study protocol.

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## Trial registry number

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Hyperlink to the registration (must be publicly accessible): https://www.researchregistry.com/browse-the-registry#home/registrationdetails/5d762f0ccc93950010a3380c/

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Not commissioned, externally peer-reviewed.

## Availability of data and materials

Due to internal institutional restrictions, raw data would remain confidential and would not be shared but would be made available on reasonable request and with the permission of the institution where the data were generated.

## CRediT authorship contribution statement

**Woubet Tefera Kassahun:** Conceptualization, Funding acquisition, Formal analysis, Writing - original draft. **Matthias Mehdorn:** Funding acquisition, Formal analysis. **Tristan Cedric Wagner:** Funding acquisition, Formal analysis.

## Declaration of competing interest

No conflict of interest in relation to this study.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijsu.2019.11.024.

## References

[1] A.A. Shah, A.H. Haider, C.K. Zogg, et al., National estimates of predictors of outcomes for emergency general surgery, J. Trauma Acute Care Surg. 78 (3) (2015) 482–490.
[2] B.H.L. Tan, J. Mytton, W. Al-Khyatt, et al., A comparison of mortality following emergency laparotomy between populations from New York state and England, Ann. Surg. 266 (2) (2017) 280–286.
[3] E. Barrow, I.D. Anderson, S. Varley, et al., Current UK practice in emergency laparotomy, Ann. R. Coll. Surg. Engl. 95 (8) (2013) 599–603.
[4] L.T. Tengberg, M. Cihoric, N.B. Foss, et al., Complications after emergency laparotomy beyond the immediate postoperative period - a retrospective, observational cohort study of 1139 patients, Anaesthesia 72 (3) (2017) 309–316.
[5] T.J. Bunt, Urgent relaparotomy: the high-risk, no-choice operation, Surgery 98 (3) (1985) 555–560.
[6] R.R. Hutchins, M.P. Gunning, D.N. Lucas, T.G. Allen-Mersh, N.C. Soni, Relaparotomy for suspected intraperitoneal sepsis after abdominal surgery, World J. Surg. 28 (2) (2004) 137–141.
[7] H.R. Unalp, E. Kamer, H. Kar, A. Bal, M. Peskersoy, M. Ali Onal, Urgent abdominal re-explorations, World J. Emerg. Surg. 1 (2006) 10.
[8] I. Martínez-Casas, J.J. Sancho, E. Nve, M.J. Pons, E. Membrilla, L. Grande, Preoperative risk factors for mortality after relaparotomy: analysis of 254 patients, Langenbeck's Arch. Surg. 395 (5) (2010) 527–534.
[9] J.J. Kim, M.K. Liang, A. Subramanian, C.J. Balentine, S. Sansgiry, S.S. Awad, Predictors of relaparotomy after nontrauma emergency general surgery with initial fascial closure, Am. J. Surg. 202 (5) (2011) 549–552.
[10] C.P. Childers, J.Q. Dworsky, M. Maggard-Gibbons, M.M. Russell, The contemporary appendectomy for acute uncomplicated appendicitis in adults, Surgery 165 (3) (2019) 593–601.
[11] K.K. Jensen, N.O. Roth, P.M. Krarup, L. Bardram, Surgical management of acute cholecystitis in a nationwide Danish cohort, Langenbeck's Arch. Surg. (2019), https://doi.org/10.1007/s00423-019-01802-0.
[12] W.D. Owens, J.A. Felts, E.L. Spitznagel Jr., ASA physical status classifications: a study of consistency of ratings, Anesthesiology 49 (4) (1978) 239–243.
[13] P.A. Clavien, J. Barkun, M.L. de Oliveira, et al., The Clavien-Dindo classification of surgical complications: five-year experience, Ann. Surg. 250 (2009) 187–196.
[14] P.A. Clavien, D. Vetter, R.D. Staiger, et al., The comprehensive complication index (CCI®): added value and clinical perspectives 3 Years "down the line", Ann. Surg. 265 (2017) 1045–1050.
[15] R.A. Agha, M.R. Borrelli, M. Vella-Baldacchino, R. Thavayogan, D.P. Orgill, STROCSS Group, The STROCSS statement: strengthening the reporting of cohort studies in surgery, Int. J. Surg. 46 (2017) 198–202.
[16] M. Mik, J. Magdzinska, L. Dziki, M. Tchorzewski, R. Trzcinski, A. Dziki, Relaparotomy in colorectal cancer surgery–do any factors influence the risk of mortality? A case controlled study, Int. J. Surg. 12 (11) (2014) 1192–1197.
[17] R.E. Freundlich, M.D. Maile, J.J. Sferra, E.S. Jewell, S. Kheterpal, M. Engoren, Complications associated with mortality in the national surgical quality improvement program database, Anesth. Analg. 127 (1) (2018) 55–62.
[18] L. C Chiulli, A.H. Stephen, D.S. Heffernan, T.J. Miner, Association of medical comorbidities, surgical outcomes, and failure to rescue: an analysis of the Rhode Island hospital NSQIP database, J. Am. Coll. Surg. 221 (6) (2015) 1050–1056.
[19] R.T. Nagle, B.E. Leiby, H. Lavu, E.L. Rosato, C.J. Yeo, J. M Winter, Pneumonia is associated with a high risk of mortality after pancreaticoduodenectomy, Surgery 161 (4) (2017) 959–967.
[20] K. Keller, L. Hobohm, M. Engelhardt, Impact of atrial fibrillation on postoperative adverse outcomes of surgical patients with knee Endoprosthetic surgery, J. Arthroplast. 33 (11) (2018) 3567–3573.
[21] L. Araujo, V. Dombrovskiy, W. Kamran, et al., The effect of preoperative liver dysfunction on cardiac surgery outcomes, J. Cardiothorac. Surg. 12 (2017) 73.
[22] H. Algattas, K.T. Kimmell, G.E. Vates, Risk of reoperation for hemorrhage in patients after craniotomy, World Neurosurg. 87 (2016) 531–539.
[23] N.R. Sangal, K. Nishimori, E. Zhao, S.H. Siddiqui, S. Baredes, R. Chan Woo Park, Understanding risk factors associated with unplanned reoperation in major head and neck surgery, JAMA Otolaryngol. Head Neck Surg. 144 (11) (2018) 1044–1051.
[24] P.J. Harbrecht, R.N. Garrison, D.E. Fry, Early urgent relaparotomy, Arch. Surg. 119 (4) (1984) 369–374.
[25] R.P. ten Broek, Y. Issa, E.J. van Santbrink, et al., Burden of adhesions in abdominal and pelvic surgery: systematic review and met-analysis, B.M.J 347 (2013) f5588, https://doi.org/10.1136/bmj.f5588.
[26] L.E. Kuo, K.D. Simmons, D.N. Holena, G. Karakousis, R.R. Kelz, A risk prediction model for mortality in the moribund general surgical patient, J. Crit. Care 30 (2) (2015) 310–314.
[27] T. Crombe, J. Bot, M. Messager, V. Roger, C. Mariette, G. Piessen, Malignancy is a risk factor for postoperative infectious complications after elective colorectal resection, Int. J. Colorectal Dis. 31 (4) (2016) 885–894.
[28] M. Abou Khalil M, J. Abou-Khalil, J. Motter, et al., Immunosuppressed patients with crohn's disease are at increased risk of postoperative complications: results from the ACS-NSQIP database, J. Gastrointest. Surg. (2019), https://doi.org/10.1007/s11605-019-04186-0.
[29] L. Hickman, L. Tanner, J. Christein, S. Vickers, Non-hepatic abdominal surgery in patients with cirrhotic liver disease, J. Gastrointest. Surg. 23 (3) (2019) 634–642.
[30] G.E. Yin, A.C.T. Ha, C.L. Atzema, et al., Association of atrial fibrillation and oral anticoagulant use with perioperative outcomes after major noncardiac surgery, J. Am. Heart Assoc. 6 (2017) e006022, , https://doi.org/10.1161/J.A.H.A.117.006022.