1. Title

The correlation between actual and predicted 30-day mortality using the National Emergency Laparotomy Audit (NELA), American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP), and Surgical Outcome Risk Tool (SORT) risk prediction tools following emergency laparotomy: a multicentre, retrospective, longitudinal, observational, cohort study in northeastern Romania.

2. Authors

Gabriel-Andi Iordache[1,2,*], Sergiu Timofeiov-Tudose[1,2,*], Radu Florin Popa[1,3], Marius Emilian Hojbotă[1,4] , Daniela Jardan[1,3] , Viorel Scripcariu[1,5] , Andrei Moscalu[1,6,7,8,*]

3. Affiliations

[1] "Grigore T. Popa" University of Medicine and Pharmacy, Iași, Romania
[2] Third Department of General Surgery, "Sf. Spiridon" Emergency Clinical Hospital, Iași, Romania
[3] Department of Vascular Surgery, "Sf. Spiridon" Emergency Clinical Hospital, Iași, Romania
[4] Department of General Surgery, "Sf. Ioan cel Nou" County Emergency Hospital, Suceava, Romania
[5] First Department of General Surgery, Regional Institute of Oncology, Iași, Romania
[6] Department of General and Upper GI Surgery, Addenbrooke's Hospital, Cambridge University Hospitals NHS Foundation Trust, Cambridge, UK
[7] School of Cardiovascular and Metabolic Medicine & Sciences, Faculty of Life Sciences & Medicine, King's College London, London, UK
[8] Harvard Medical School, Boston, Massachusetts, USA
[*] - these authors have contributed equally (also know as co-first author)
[#] - corresponding author

4. Corresponding author

Correspondence to: Mr. Andrei Moscalu, Department of General and Upper GI Surgery, Addenbrooke's Hospital, Cambridge University Hospitals NHS Foundation Trust, Cambridge, UK.
Email: andrei.moscalu@nhs.net
Postal: Hills Road, Cambridge, CB2 0QQ, UK

5. Source of funding

This study was funded by the "Grigore T. Popa" University of Medicine and Pharmacy, Iași, Romania, via the first author doctoral grant. The funding body had no role in the design of the study, data collection, analysis, interpretation, or manuscript writing.

6. Category

Study Protocol - According to the STROBE Checklist

7. Previous communication

This manuscript is original and has not been presented, in whole or in part, at any scientific meeting or society conference.

8. Disclosure statement

The authors declare no conflicts of interest.

9. Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Due to ethical and legal restrictions related to patient confidentiality, individual-level data are not publicly available.

Abstract

Introduction

Emergency laparotomy carries a high risk of death, with a 30-day mortality rate of 10–15%, especially in patients over 70. Risk prediction tools such as the National Emergency Laparotomy Audit (NELA), ACS National Surgical Quality Improvement Program (ACS-NSQIP), and Surgical Outcome Risk Tool (SORT) are widely used internationally to guide perioperative care. Their implementation has improved outcomes, yet they remain underutilized in Eastern Europe. This retrospective cohort study aims to compare observed 30-day mortality with predictions generated by these tools in Romanian surgical patients.

Methods

Adult patients (≥18 years) who underwent emergency laparotomy between January 1, 2022, and December 31, 2023, across six Romanian hospitals (including two tertiary care centers) were included. Preoperative risk scores (NELA, ACS-NSQIP, and SORT) will be calculated and compared to actual 30-day postoperative mortality. Statistical analyses will be performed using GraphPad Prism version 10.4.1.

Expected Results

A pilot study on 207 patients at a tertiary center in northeastern Romania showed a 30-day mortality rate of 31.4%, with 15.5% among patients under 70 years of age and 45.6% among those aged 70 years and above, significantly higher than predicted by both NELA and ACS-NSQIP. Although the scores correlated positively, they underestimated actual mortality. SORT was not assessed. The ongoing study will include 1512 patients with similar demographics: mean age ~65, predominantly male, with high ASA scores, frailty, and comorbidities.

Expected Conclusions

Initial findings indicate that NELA and ACS-NSQIP underestimate 30-day mortality in Romanian patients undergoing emergency laparotomy. These risk tools may require local recalibration to ensure accurate prognostication in this population.

Table of contents

List of Abbreviations

ACS-NSQIP – American College Of Surgeons National Surgical Quality Improvement Program
ASA – American Society of Anaesthesiologists
ASGBI – Association of Surgeons of Great Britain and Ireland
AUC – Area Under the Curve
BGS – British Geriatrics Society
BMI – Body Mass Index
BMJ – British Medical Journal
CCI – Charlson Comorbidity Index
CFS – Clinical Frailty Scale
CGA – Comprehensive Geriatric Assessment
CNAS – Romanian National Health Insurance House
COPD – Chronic Obstructive Pulmonary Disease
CRP – C-Reactive Protein
CT – Computed Tomography
ERAS – Enhanced Recovery After Surgery
GCS – Glasgow Coma Scale
GDP – Gross Domestic Product
GDPR – General Data Protection Regulation
ICU – Intensive Care Unit
IQR – Interquartile Range
NCEPOD – National Confidential Enquiry into Patient Outcome and Death
NHS – National Health Service
NELA – National Emergency Laparotomy Audit
NOS- Newcastle–Ottawa Scale
SD – Standard Deviation
SORT – Surgical Outcome Risk Tool
STROBE – STrengthening the Reporting of OBservational studies in Epidemiology
ROC – Receiver Operating Characteristic
UK – United Kingdom
VA – Veteran's Affairs
WJES – World Journal of Emergency Surgery

Title

1. Type of Study

This will be a multicenter, retrospective, longitudinal cohort study including all patients aged over 18 years who underwent emergency laparotomy or laparoscopy over a two-year period, from 00:00 on January 1, 2022, to 23:59 on December 31, 2023. Inclusion will be based on the NELA eligibility criteria, across six hospitals, two of which are tertiary referral centers (Table 1: NELA inclusion and exclusion criteria) [1]

Introduction

2. Rationale

Context and Epidemiology

Emergency laparotomy is a major surgical procedure where the abdominal cavity is opened through a incision of the abdominal wall to provide unrestricted access to the peritoneal cavity for exploration or treatment [2].

The historical origins of emergency laparotomy date back to the 17th century, and the procedure has undergone continuous refinement ever since [3]. The current 30-day mortality following emergency laparotomy is estimated between 10% and 15%, with a significant increase in mortality after the age of 70, reaching as high as 49% at 180 days postoperatively in patients aged over 85 [4].

Despite a global downward trend in mortality rates, emergency laparotomy remains a major concern across healthcare systems worldwide. For example, in the United Kingdom (UK), the 30-day mortality rate following emergency laparotomy was 14.8% in 2013 and steadily decreased to 8.7% by 2021 [5].

A study conducted in 2022 reported an observed 30-day mortality of 9.74% in the general population and 13.96% in patients aged ≥70 years. In the same study, the NELA-predicted mortality was 9.8% overall and 14.01% in the elderly subgroup [6].

In 2024, a comparative analysis assessed the 30-day mortality predictive accuracy of NELA and ACS-NSQIP scores. The study demonstrated that the NELA score offered superior prediction accuracy, particularly in patients aged under 70 [7].

Across Europe, 30-day postoperative mortality remains substantial. In Sweden, it was reported at approximately 14.2% in 2021 [8], while Denmark recorded a rate of 16.7% in 2020 [9]. In Greece, 30-day mortality was assessed at 16.3% in a study conducted between 2019 and 2020 [10].

In the United States, the mortality rate shows a similar declining trend. For example, a 2017 study in New York found a 30-day postoperative mortality of 6.9% [11], while a single-centre study in Detroit reported a comparable figure of 6.8% [12].

Mortality prediction scores

The ability to predict postoperative mortality is critically important and facilitates multidisciplinary decision-making, resource allocation, and communication with the patient [13]. Since the introduction of the ASA (American Society of Anaesthesiologists) score in 1941,

continuous efforts have been made to develop an ideal mortality prediction tool with high accuracy—efforts that persist to this day. In order to ensure the validity and applicability of any newly developed clinical score, it must undergo rigorous evaluation and validation through large-scale, multicentre studies encompassing a variety of surgical procedures. Such research is essential to confirm the robustness and relevance of the tool in diverse clinical settings and patient populations [14].

To better understand operative risk and to anticipate postoperative mortality—especially in the context of emergency laparotomy—several clinical prediction scores have been developed and validated. Among these, three stand out due to their widespread use and international validation: the National Emergency Laparotomy Audit (NELA) score, the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP), and the Surgical Outcome Risk Tool (SORT). All three offer estimates of mortality and postoperative complication risks, thus aiding informed clinical decision-making and improving the quality of surgical care. However, the use and interpretation of these tools must be approached with caution, as they are known to present certain limitations, including the tendency to underestimate—or in some cases overestimate—the actual risk of death or postoperative complications [15-17]. In elderly populations (≥65–70 years) undergoing emergency laparotomy, approximately 20–50% present with frailty, which is associated with significantly increased risks of short-term (30–90 days) postoperative mortality, complications, and prolonged hospital and intensive care unit (ICU) stays [18].

NELA is a national audit programme implemented in the UK across 180 National Health Service (NHS) hospitals, evaluating the quality of care provided to patients undergoing emergency laparotomy. Established in 2012, the programme has been successful in reducing 30-day mortality from 11.8% in its first year to 9.2% in 2024, as well as reducing average hospital length of stay from 19.2 to 15.1 days [19]. The score has undergone internal validation in England and Wales across 186 NHS hospitals for patients undergoing emergency laparotomy between 2013 and 2015, as well as external validation [6]. It has subsequently been validated in international studies, demonstrating excellent discriminative performance, with ROC curve AUC values of 0.892 in Australia [20] and 0.85 in cohorts from New Zealand and Denmark [21]. A total of 43 566 patients were included in these validation studies, providing robust support for the predictive validity of the NELA score [22]. The most recent report—the ninth—published in October 2024 for the 2021–2023 period, includes 27 863 patients, with a cumulative total of approximately 224 921 patients enrolled in the database since 2013 [23], making it the largest global database of emergency laparotomy patients.

ACS-NSQIP is an outcome-based, nationally validated programme created to measure and improve the quality of surgical care. Initially developed within the Veterans Affairs (VA) hospital system to assess surgical performance, NSQIP was successfully piloted in 14 hospitals between 2001 and 2004. From 2005 onwards, the American College of Surgeons expanded the programme to include non-VA hospitals, becoming an independent initiative [24]. The programme has since grown rapidly and now includes approximately 700 participating hospitals in 49 of the 50 United States, as well as 150 hospitals across 18 other countries [25]. Since 2013, ACS-NSQIP has published semi-annual reports using the full dataset to objectively evaluate surgical quality and identify areas requiring improvement [25].

The SORT score was developed in the UK by the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) team, based on a sample of 19 097 patients who underwent non-cardiac surgery in 2014. This tool aims to estimate 30-day postoperative mortality using a simplified model based on six preoperative variables. During internal validation, SORT demonstrated excellent discriminative power, with an AUC of 0.91 [26]. The updated version, SORT v2, incorporates the clinician's subjective risk assessment into the algorithm, providing superior predictive accuracy compared to the original model, with reported AUC values of at least 0.92. External validations conducted across varied geographical and clinical contexts confirmed the robustness of the model, including in high-complexity surgical settings. However, a tendency to underestimate mortality, particularly in high-risk patients, remains a recognised limitation [27]. An external validation conducted in five independent hospitals in the UK included 3 305 patients undergoing major abdominal surgery. SORT maintained a high discriminative capacity (AUC = 0.899), though again a trend toward underestimation of actual mortality was noted in high-risk patients [28]. Outside the UK, SORT has been validated in Sweden, where it showed acceptable discrimination (AUC = 0.79) [29] and in Greece, where it demonstrated remarkable predictive performance with an AUC of 0.98 in a cohort of patients with complex oncological pathology [30].

NELA, ACS-NSQIP, and SORT all rely on the input of standardised clinical, demographic, and paraclinical variables to provide personalised risk estimates for postoperative death and, in the case of ACS-NSQIP, major complications, physical decline, and discharge to rehabilitation facilities [31-33].

The NELA calculator is available online at https://data.nela.org.uk/riskcalculator and is intended exclusively for patients undergoing emergency laparotomy. It incorporates variables such as patient age and sex, preoperative physiological parameters (e.g., Glasgow Coma Scale, heart rate, systolic blood pressure, white blood cell count, serum lactate, and albumin levels), ASA score, presence of malignancy or dyspnea, as well as intraoperative factors such as peritoneal contamination, urgency grade of the intervention, and operative indication. Based on these data, the calculator estimates a 30-day postoperative mortality risk [31]. An original version of the calculator is available in Appendix 1. Since 2024, a simplified version known as Parsimonious NELA Risk Calculator has been introduced, using a reduced set of variables while maintaining high predictive accuracy. This version is also accessible via the official NELA platform and is particularly useful in resource-limited clinical settings [31].

The ACS-NSQIP calculator, available at https://riskcalculator.facs.org/RiskCalculator, was developed by the American College of Surgeons and applies to a broad range of surgical procedures, including emergency operations. It is based on data collected from a large network of healthcare institutions, including over 700 hospitals in 49 US states and more than 150 international hospitals across 18 countries [25]. The prediction model uses a validated risk-adjustment algorithm incorporating variables such as sex, age, weight, height, body mass index (BMI), functional status, comorbidities, and clinically relevant risk factors. These include diabetes, hypertension, heart failure, chronic obstructive pulmonary disease (COPD), dialysis, disseminated cancer, active smoking, chronic steroid use, sepsis, and mechanical ventilation requirement. The calculator also includes the ASA score, whether the intervention is elective or emergency, and the specific surgical procedure selected from a coded list. Upon completion,

ACS-NSQIP provides not only a predicted mortality percentage, but also detailed estimates of various postoperative complications including cardiac and pulmonary events, surgical site infections, postoperative ileus, anastomotic leaks, reoperations, sepsis, and readmissions [32]. See Appendix 2 for the original format of the calculator.

The SORT calculator is used preoperatively to estimate 30-day mortality risk following non-cardiac surgery and is available at https://www.sortsurgery.com. Designed for quick and easy clinical use, it relies on a small number of relevant clinical variables to support medical decision-making and the informed consent process. The original version (SORT v1) uses six preoperative variables: age, ASA score, presence of active malignancy, urgency grade of surgery, surgical specialty, and procedure severity [26]. These are entered into an algorithm that generates an estimated 30-day mortality percentage [33]. The updated version, SORT v2, includes a seventh variable—subjective clinical risk estimation by the treating physician—enhancing the personalised assessment of surgical risk [30]. This model is clinically validated and useful for risk stratification, perioperative resource allocation, and patient communication [26, 28, 29]. See Appendix 3 for the original version of the calculator.

Pilot study

Given the multiple benefits reported in the international literature regarding the use of postoperative mortality prediction scores in emergency laparotomy, a pilot study was initiated. This retrospective, observational cohort study was conducted at a single tertiary centre in northeastern Romania. The study included all adult patients who underwent emergency laparotomy between 00:00 on 1 December 2017 and 23:59 on 30 November 2019. Patient selection was carried out in accordance with the inclusion and exclusion criteria defined by the NELA audit [34].

The primary objective of this initiative was to evaluate the accuracy of the NELA and ACS-NSQIP scores in predicting 30-day mortality in the specific context of a Romanian patient population. The study also aimed to assess the feasibility of a larger-scale study with sufficient statistical power to validate these tools within Romania. Data were collected retrospectively from patient records, hospital IT systems, and, when necessary, by confirming deaths with relatives, general practitioners, or hospital registries. For each patient, preoperative NELA and ACS-NSQIP scores were calculated using the official online calculators [34].

The pilot study observed an actual 30-day postoperative mortality rate of 31.4%, significantly above the global average of 10–15%. Both the NELA and ACS-NSQIP scores were calculated and showed a strong positive correlation with each other ($R^2 = 0.88$, $p < 0.0001$) and a significant positive correlation with actual mortality: $R^2 = 0.33$ ($p < 0.0001$) for NELA and $R^2 = 0.41$ ($p < 0.0001$) for ACS-NSQIP. Observed 30-day mortality was 15.5% among patients under 70 years of age and 45.6% among those aged 70 years and above. Within the same cohort, the NELA score estimated a mean mortality of 6.7% for patients under 70 and 27% for those aged ≥70. The ACS-NSQIP score predicted mortality rates of 8.1% and 27.9% for the two subgroups, respectively. Cumulative mortality in the cohort reached 35.6% at six months postoperatively—19.6% for patients under 70 and 59.2% for those aged ≥70. At one year, mortality rose to 38.2% (21.8% <70 years vs. 63% ≥70 years), reaching 42.3% at two years (25.6% <70 years vs. 67.1% ≥70 years). At three years, cumulative mortality was 42.8% (25.6% vs. 68.4%), at four years 44.8% (27.5% vs. 70.2%), and at five years it reached 51.2%, of which 35.2% were patients under 70 years and 74.3% were aged 70 or over. Although both predictive

scores demonstrated a strong correlation with observed 30-day mortality, the results clearly indicated that they systematically underestimated the actual mortality rate in this Romanian cohort [34].

The Ten Most Common Surgical Procedures Performed in Emergency Laparotomy

Emergency laparotomy does not represent a single, uniform procedure but rather constitutes a heterogeneous surgical category that encompasses a wide array of interventions performed in the acute setting. These procedures share the common requirement of gaining access to the entire peritoneal cavity. As such, emergency laparotomy functions as an umbrella concept that includes procedures ranging from suturing perforated ulcers and extensive bowel resections to peritoneal lavage, haemorrhage control, or the management of postoperative complications. This heterogeneity is reflected not only in the diversity of therapeutic indications but also in the varying degrees of operative complexity, individual patient prognosis, and associated perioperative risk [35]. Such variability justifies the implementation of clinically validated preoperative risk stratification tools, which support multidisciplinary decision-making, optimise perioperative care, and facilitate communication with patients and/or their families.

Following the pilot study, a descriptive analysis was conducted to identify the ten most frequently performed emergency laparotomy procedures. The Romanian medical literature lacks systematised data regarding procedure-specific postoperative mortality. Nevertheless, due to the limited number of cases per individual procedure in the pilot study, it was not feasible to apply robust statistical methods capable of yielding valid comparative assessments of mortality specific to each surgical technique.

Despite the statistical limitations posed by small sample sizes for some procedures, the analysis of the ten most common emergency laparotomy procedures remains relevant, as these operations collectively account for approximately 80% of all surgeries performed, deaths recorded, and associated complications [36].

According to the findings of the pilot study, the ten most frequently performed emergency laparotomy procedures were: suture of perforated peptic ulcer, adhesiolysis, left colectomy with stoma formation (Hartmann's procedure), exploratory laparotomy, enterectomy with anastomosis, right colectomy with anastomosis, suture of bleeding peptic ulcer, peritoneal lavage and drainage, colostomy and ileostomy. These ten procedures will form the basis of subsequent subgroup analyses in the expanded study, given their cumulative impact on surgical outcomes and their prevalence within the Romanian emergency surgical landscape.

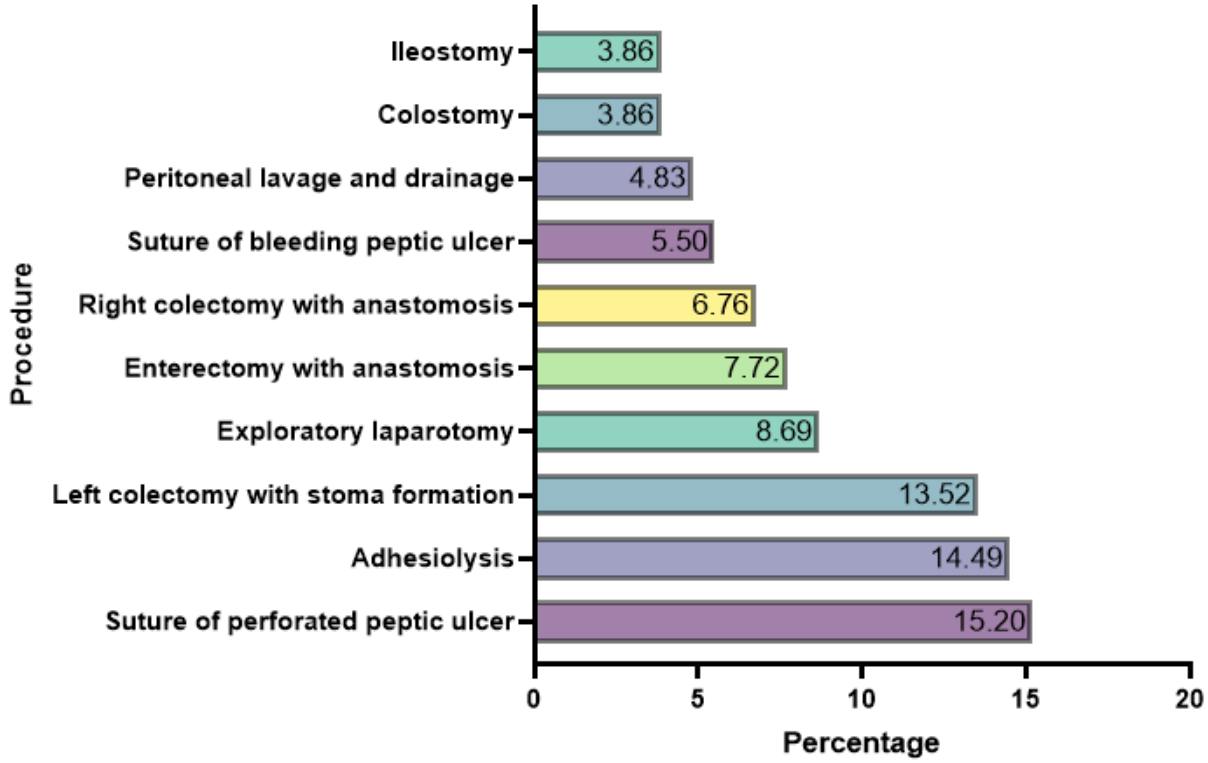


Figure a: Proportion of the top 10 surgical procedures within the study population included in the 2017–2019 pilot study in Romania

Rationale for the present study

While the pilot study represented an essential step in elucidating the actual post-interventional mortality following emergency laparotomy in Romania, it was subject to multiple limitations. A major limitation was its single-centre design, which significantly reduced its external validity. At a national level, considerable inter-hospital variability exists reflecting differences in available resources, the expertise of surgical teams, treatment protocols, and case complexity [37]. Mortality may be significantly influenced by local hospital characteristics, limiting the generalisability of findings at regional or national levels. Tertiary centres typically manage more complex pathologies than secondary or district-level hospitals [38]. Tertiary hospitals are referral centres offering the highest level of expertise, with advanced infrastructure and complex multidisciplinary teams. They are often affiliated with universities or county-level emergency networks and receive complex cases referred from other facilities. In contrast, second-level hospitals provide intermediate-level care, treating common and moderately complex conditions, while referring highly complex cases to tertiary centres. First-level hospitals operate as the basic units of the healthcare system, delivering general medical care and managing patients with low to moderate severity. These facilities transfer complex cases to higher-level institutions [39].

In addition to hospital-related factors, postoperative mortality may be significantly influenced by local socioeconomic determinants, which vary across regions. These include unequal access to adequate healthcare services [40], variable levels of patient education, and differences in general nutritional status. Romania currently allocates only 5.75% of its gross

domestic product (GDP) to healthcare, compared to the European Union average of 10.2%, a disparity that negatively affects both infrastructure and the quality of medical care [41, 42]. Structural limitations also contribute to outcome disparities like restricted access to intensive care services, limited availability of advanced imaging (e.g., CT scanning), the absence of standardised therapeutic protocols, and, importantly, the lack of integrated geriatric assessment in the management of elderly patients [43]. These cumulative factors may worsen postoperative prognosis, particularly in the context of emergency surgical interventions. [44].

Another important limitation of the pilot study was the small sample size, only 207 patients were included which did not allow for statistically robust analyses stratified by procedure type. This limitation increases the risk of type II statistical error, whereby a true difference between groups may remain undetected, particularly for variables with low incidence, such as mortality in specific age subgroups. For instance, certain procedures such as peritoneal lavage and drainage, colostomy, or ileostomy involved relatively few patients, impeding the evaluation of associated mortality. Moreover, the impact of certain variables such as advanced age (≥70 years), the number or severity of comorbidities, or preoperative status may prove difficult to assess [34].

To overcome these limitations, the present research project was designed as a multicentre study conducted across six hospitals in northeastern Romania over a two-year period, from 1 January 2022 to 31 December 2023. The study aims to include an estimated 1 512 patients, covering a catchment population of 2 462 451 inhabitants. This provides a more comprehensive and representative framework for analysing postoperative mortality following emergency laparotomy. Sample size estimation was based on extrapolation from the pilot study, in which 207 patients were enrolled over two years in a 75-bed surgical department. Applying the same ratio to the cumulative capacity of 548 surgical beds across the six participating hospitals yielded a projected enrolment of 1 512 eligible patients. This expanded dataset allows for a more robust and representative analysis capable of generating reliable conclusions applicable to clinical practice. The outcomes of this research may inform future protocols and optimise perioperative care strategies in Romania [45]. The statistical power of the study has been calculated with a significance level (α) fixed at 5%, and the risk of type II error (β) estimated as negligible. Accordingly, the results obtained will have high representativeness and will support the formulation of solid, practice-relevant conclusions [46].

3. Objectives

Primary Objective

The primary objective of this study is to determine the actual 30-day postoperative mortality following emergency laparotomy performed in six hospitals located in Northeastern Romania: "Sf. Spiridon" County Emergency Clinical Hospital in Iași, "Sf. Apostol Andrei" County Emergency Clinical Hospital in Galați, "Sf. Ioan cel Nou" County Emergency Hospital in Suceava, Bârlad Municipal Hospital, Fălticeni Municipal Hospital, and Pașcani Municipal Hospital. This observed mortality will be compared and correlated with the mortality estimates generated by three preoperative risk prediction scores: NELA, ACS-NSQIP and SORT. The analysis will be performed for the entire cohort, as well as for age-based subgroups: patients under 70 years of age and those aged 70 and above. This study represents the first national initiative, albeit retrospective, to evaluate the correlation between observed mortality and predicted mortality using validated risk

scores in the context of emergency laparotomy in Romania, thus offering an important perspective on the applicability of these models in Romanian surgical practice.

Secondary Objectives

1. To evaluate survival at 3, 6, 12, 24, and 36 months postoperatively using Kaplan-Meier survival analysis. This analysis will be conducted both for the overall cohort and separately for the two age subgroups: <70 years and ≥70 years.

2. To assess the predictive accuracy of the NELA, ACS-NSQIP, and SORT scores in estimating the risk of postoperative death. This will be achieved through analysis of sensitivity, specificity, and Receiver Operating Characteristic (ROC) curves, with calculation of the Area Under the Curve (AUC). The evaluation will be performed for the entire cohort and independently for the two age-based subgroups.

Tertiary Objectives

1. To conduct a subgroup analysis of the ten most common surgical procedures performed in the setting of emergency laparotomy, with the aim of evaluating the correlation between observed 30-day mortality and the mortality predicted by NELA, ACS-NSQIP, and SORT. This analysis will be applied both to the full cohort and to the two age-based subgroups (<70 and ≥70 years).

2. To perform a subgroup analysis of the ten most frequently performed emergency laparotomy procedures, assessing actual mortality at 1, 3, 6, 12, 24, and 36 months postoperatively. Survival will be analysed using the Kaplan-Meier method for both the entire cohort and the two age subgroups.

3. To evaluate the predictive accuracy of the NELA, ACS-NSQIP, and SORT scores in estimating postoperative mortality for each of the ten most common surgical procedures. This will include the calculation of sensitivity, specificity, and interpretation of ROC curves, along with AUC values. The analysis will be conducted for the full cohort and separately for the <70 and ≥70 age groups.

Methods

4. Study design

Key elements

The present investigation is a multicentre, retrospective, longitudinal cohort study conducted over a two-year period, from 1 January 2022 to 31 December 2023, encompassing the full calendar days from 00:00 to 23:59. The study is carried out across six hospitals located in Northeastern Romania, including two tertiary-level centres with advanced expertise and regional referral capacity.

The study population comprises patients aged 18 years or older who meet the inclusion and exclusion criteria defined by the NELA protocol, as detailed in Table 1. To ensure methodological rigour and enhance both internal and external validity, the STROBE checklist was employed as a guiding framework in the development of the study protocol. The significance threshold (α) was set at 5%, and the risk of type II error (β) was estimated to be approximately zero, reflecting a very high statistical power. The anticipated sample size is 1 512 patients.

Data will be collected retrospectively from hospital archives and electronic medical record systems. Verification of vital status and cause of death will be performed using the official platform of the Romanian National Health Insurance House (CNAS) [47] , as well as through direct contact with the patient's relatives, family physician, or hospital information systems. A next of kin is defined as the individual legally designated or recognised as having the responsibility to represent the patient in situations where the patient has lost decision-making capacity. Typically, this includes family members: spouse, parents, adult children, siblings; or other close individuals able to provide relevant medical information, be contacted in emergencies, and, in certain cases, express informed consent on behalf of the patient. According to Article 14 of Romanian Law no. 46/2003 on patients' rights, in cases where the patient cannot express their will and requires an urgent medical intervention, healthcare professionals are authorised to act on presumed consent based on the patient's previously expressed wishes [48].

All data will be collected exclusively by the principal investigator and stored in a password-protected Microsoft Excel file on a dedicated research laptop. This device will be used solely for the purposes of the study and will be secured with password protection to ensure compliance with ethical approvals and current data protection legislation.

Bias

Retrospective cohort studies are inherently susceptible to various forms of systematic error (bias), which may affect both the internal validity and the generalisability (external validity) of the conclusions drawn. In the present study, ten major potential sources of bias have been identified, for which specific prevention and control measures have been defined and implemented. Detailed information regarding these categories of bias and the corresponding management strategies is provided in Chapter 9: Bias.

5. Setting

The study will be conducted in the Northeastern region of Romania and will involve six hospitals serving a total population of 2 462 451 inhabitants. Of the six participating medical institutions, two are university-affiliated hospitals:

1. "Sf. Spiridon" County Emergency Clinical Hospital in Iași, which includes four surgical departments providing care for approximately 700 000 inhabitants of Iași County, as well as complex surgical cases referred from other counties in the historical region of Moldova. The total number of surgical beds is 250. Based on data from the pilot study which indicated that 207 eligible patients were identified for every 75 surgical beds over a two-year period, the estimated number of eligible patients from this centre is approximately 686. [49].

2. "Sf. Apostol Andrei" County Emergency Clinical Hospital in Galați, which comprises three surgical departments and serves a population of 626 000. The total number of surgical beds is 131. Based on the inclusion criteria defined by the NELA protocol and extrapolating from pilot study data, an estimated 361 patients will be eligible for inclusion from this hospital [50].

3. "Sf. Ioan cel Nou" County Emergency Hospital in Suceava, which has 76 surgical beds and serves a catchment population of 614 451. According to the same extrapolation method, approximately 202 patients from this hospital are expected to meet the inclusion criteria [51].

4. Bârlad Municipal Hospital, which serves a population of 200 000 and has a total of

42 surgical beds. Based on pilot data, approximately 104 patients will be included from this centre [52].

5. Pașcani Municipal Hospital, which serves 182 000 inhabitants and has a surgical department comprising 25 beds. It is estimated that approximately 68 patients from this hospital will be enrolled in the study [53].

6. Fălticeni Municipal Hospital, which serves a population of 140 000 and has a general surgery ward with 24 beds. Based on bed capacity and projections from the pilot study, an estimated 128 patients will be included from this institution [54].

6. Participants

The participants included in this study will be patients who presented to hospital as emergencies between 00:00 on 1 January 2022 and 23:59 on 31 December 2023, and who were diagnosed with a surgical pathology requiring emergency laparotomy, with eligibility determined according to the NELA inclusion and exclusion criteria outlined in Table 1.

	Inclusion Criteria	Exclusion Criteria
Demographics	Adults aged 18 years and older	Children under 18 years; elective (non-emergency) surgical procedures
Approach and Surgical Intent	Open, laparoscopic, or laparoscopically-assisted abdominal procedures performed in an expedited, urgent, or emergency setting, as defined by NCEPOD	Diagnostic laparotomy / laparoscopy where no therapeutic procedure is performed due to inoperable findings (e.g. peritoneal or hepatic metastases, non-viable ischaemic bowel)
Anatomy	Procedures involving the stomach, small bowel, colon, or rectum	Surgeries targeting the oesophagus, spleen, kidneys, liver, gallbladder, biliary tract, pancreas, or urinary tract
Indication	Cases involving gastrointestinal perforation, intestinal ischaemia, intra-abdominal abscess, gastrointestinal haemorrhage, or mechanical obstruction	
Appendix		All procedures where appendicitis is the primary diagnosis, regardless of severity or extent
Biliary System	Laparotomy or enterotomy for gallstone ileus	Any primary surgery of the gallbladder or biliary tract, unless incidental to a major gastrointestinal procedure
Oesophagus		Any laparotomy or laparoscopy

		undertaken for primary oesophageal pathology
Stomach	Emergency laparotomy/laparoscopy for gastric pathologies, including haemorrhage, hiatal hernia repair, and removal of foreign bodies or gastric bands. Iatrogenic gastric perforation following endoscopic procedures	
Small Intestine	Emergency procedures for bleeding duodenal ulcers, gallstone ileus, or foreign body removal	
Colon and Rectum	Emergency surgery for colorectal pathology, including iatrogenic perforations post-endoscopy	Foreign body removal from the colon or rectum (considered trauma cases)
Stomas	Emergency formation of a colostomy or ileostomy as a primary procedure via midline laparotomy	Emergency stoma formation via trephine incision or laparoscopic approach
Dehiscence	Return to theatre for major abdominal wound dehiscence (i.e. “burst abdomen”)	Minor or superficial dehiscence unless it results in bowel pathology necessitating resection
Vascular	Emergency laparotomy for bowel ischaemia not preceded by primary vascular or endovascular intervention	Laparotomies for primary vascular pathologies or complications following vascular procedures, regardless of whether bowel resection was performed
Gynaecology	Return to theatre requiring the assistance of a general surgeon following gynaecology-oncology surgery	Laparotomies for primary gynaecological pathology, including ruptured ectopic pregnancy or pelvic abscess due to pelvic inflammatory disease; returns to theatre for complications of gynaecological surgery unless involving gastrointestinal complications secondary to gynaecology-oncology procedures
Peritoneum	Washout or drainage of peritoneal abscess or haematoma	Any procedure related to pancreatitis, removal of peritoneal dialysis catheters, or washout / drainage procedures related to appendicectomy,

		cholecystectomy, or vascular / urological / gynaecological surgery
Hernias	Emergency repair of inguinal, femoral, incisional, or parastomal hernias involving adhesiolysis or bowel resection / repair	Emergency hernia repairs not involving adhesiolysis or bowel resection / repair
Adhesiolysis	Laparotomy or laparoscopy undertaken exclusively for adhesiolysis	
Trauma		Any abdominal procedure performed for blunt or penetrating trauma, including laparotomy for foreign body removal from the sigmoid or rectum
Transplant		All procedures related to organ transplantation, including reoperations
Relaparotomy	Any reoperation for complications following elective upper gastrointestinal or colorectal procedures meeting NELA criteria. Also included are returns to theatre involving general surgical assistance following gynaecology-oncology surgery or interventional radiology procedures	Returns to theatre for complications following non-gastrointestinal surgery (e.g. renal, urological, vascular, hepatic, pancreatic, oesophageal, or splenic surgery), except where complications follow gynaecology-oncology surgery or interventional radiology and require general surgical intervention

Table 1: *Inclusion and Exclusion Criteria According to NELA*

Based on preliminary estimates and the application of the eligibility criteria defined by the NELA, approximately 1 512 patients are expected to be included in the final analysis. This estimate derives from the pilot study, which evaluated patients who underwent surgery between 00:00 on 1 December 2017 and 23:59 on 30 November 2019, according to the same inclusion and exclusion criteria. In that study, 207 patients were enrolled over a two-year period in a tertiary centre with 75 surgical beds. This corresponds to an average of 0.115 eligible patients per surgical bed per month [34]. Extrapolating this rate to a combined total of 548 surgical beds over a 24-month period yields an estimated cohort of 1 512 patients. The statistical power of the current multicentre study with this sample size is estimated to be close to 1.

At "Sf. Spiridon" County Emergency Clinical Hospital in Iași, the average number of emergency admissions per general surgery on-call shift is approximately 9.75, equating to an

estimated 292.5 admissions over a 30-day period. This figure reflects the proportional utilisation of the 250 available surgical beds and aligns with the operational capacity of the institution. The estimate was calculated using the arithmetic mean of all on-call admissions recorded during 2024, based on data extracted from the hospital's electronic system. Over the course of the 24-month multicentre study period, approximately 7 020 patients are expected to be assessed at this site.

Extrapolating these data across the total capacity of the six participating hospitals—which together comprise 548 surgical beds—yields an estimated 15 387 potentially eligible patients. Applying the NELA eligibility criteria, a total of 1 512 patients, representing approximately 10% of emergency surgical admissions, will be selected for inclusion in the study.

In the previously conducted pilot study, survival and mortality were analysed at 1, 6, 12, 24, and 36 months. Given that both the demographic structure and the methodology employed in the present study are comparable to those in the pilot, it is anticipated that survival and mortality estimates for the above-mentioned time points can be calculated with a high degree of accuracy.

Following the planned analyses, the cohort of 1 512 patients will be categorised according to the ten most common surgical procedures, which collectively account for approximately 80% of all interventions (see Figure 1) [36]. These procedures will be identified using the relevant procedural codes listed on the official Romanian registry of medical coding (www.codificaremedicala.ro), as outlined in the following table (42):

Procedure	Applicable Codes
Suture of perforated peptic ulcer	J03701, J03704, J04001
Suture of bleeding peptic ulcer	J02201, J03704, J04001
Adhesiolysis	J12201, J05301, J06902, J12504, J04801, J06502, J04802, J12202
Hartmann's procedure	J06201, J06210, J07801
Exploratory laparotomy	J12101
Enterectomy with anastomosis	J04502, J04604, J05102, J12511, J12904, J13104, J05001, J05002, J04604
Right colectomy with anastomosis	J06203, J06204, J06208
Peritoneal lavage and drainage	J12303, J12504
Colostomy	J06402, J06403, J06701, J06401, J06701
Ileostomy	J04701, J04702, J05201, J05201

Table 2: Codes for the 10 most common procedures

Based on the proportions identified for each of the ten most common surgical procedures in the pilot study and assuming a similar distribution in the current research, it is possible to accurately estimate the percentage corresponding to each procedure type. Using these percentages and the total number of patients included in the study, the estimated number of patients allocated to each procedure category can be calculated. These estimates are essential for structuring subgroup statistical analyses and for comparing outcomes according to the type of surgical intervention performed.

According to data from the international literature, the ten most frequently performed emergency surgical procedures account for approximately 80% of all interventions [36]. Within the present cohort, estimated at 1 512 patients, it is anticipated that 20% of cases (n = 302) will not fall within these ten procedure categories. Consequently, a total of 1 210 patients will be included in the specific analysis, distributed according to procedure type, as illustrated in the graphical representation below.

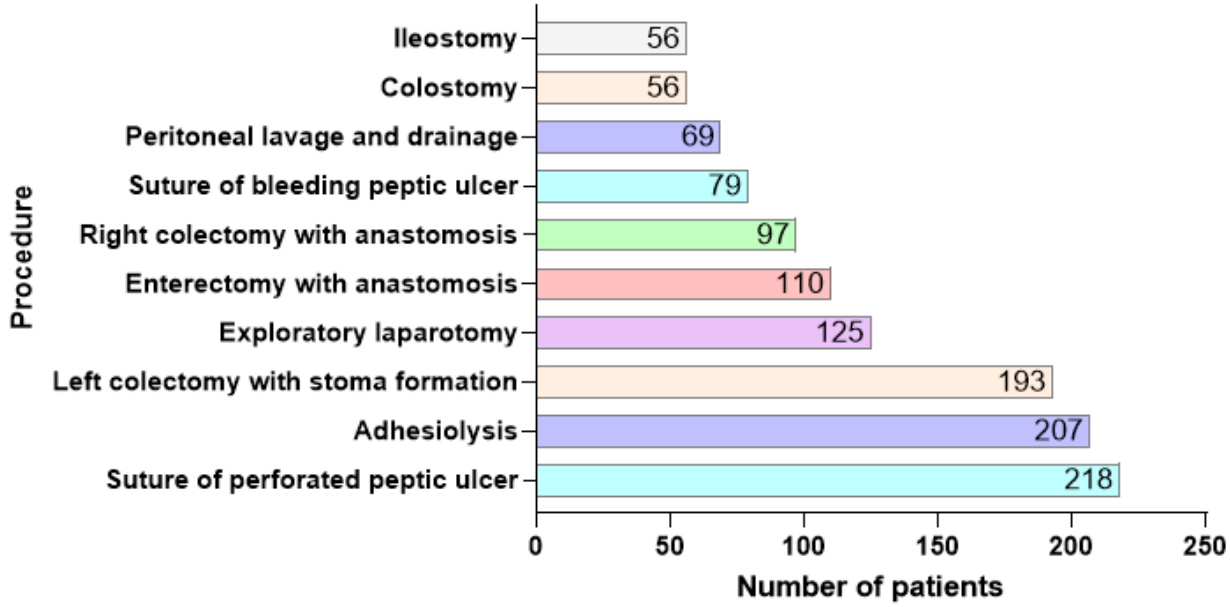


Figure b : Distribution of Patients by the Most Common Surgical Procedures

7. Collected Variables

Demographic data

For each patient, the following demographic variables will be recorded: sex, age at the time of surgery, height (in centimetres), weight (in kilograms), and BMI. Preoperative risk scores including ASA, NELA, ACS-NSQIP, SORT, the Rockwood Clinical Frailty Scale (CFS), and the Charlson Comorbidity Index (CCI) will also be documented.

Preoperative clinical data and functional scores

Information will be collected regarding functional status (independent, partially dependent, or fully dependent), ASA classification, Rockwood Frailty Score (ranging from 1 to 9), CCI, and the presence of relevant comorbidities, including hypertension, diabetes mellitus (insulin-dependent or non-insulin-dependent), COPD, disseminated malignancy, dialysis dependence, heart failure, stroke (with or without residual neurological deficit), and chronic corticosteroid use. The presence of sepsis will be recorded according to the criteria of The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3), defined as life-threatening organ dysfunction resulting from a dysregulated host response to infection occurring within the past 48 hours. Preoperative mechanical ventilation status and duration will also be noted [55].

Preoperative physiological and laboratory parameters

The following parameters will be recorded: systolic and diastolic blood pressure, heart rate, Glasgow Coma Scale (GCS) score, and laboratory values available in the patient's medical

chart, including serum albumin, white blood cell count, blood glucose, urea, and lactate levels. To monitor the inflammatory response, C-reactive protein (CRP) levels will be measured preoperatively and on postoperative days 1, 3, and 5, as outlined in Table 4.

Operative Data

For each patient, the date and time of surgery will be recorded, along with the day of the week on which the procedure occurred, the professional rank and specialty of the lead surgeon, and the urgency classification according to the NCEPOD scale (Elective, Expedited, Urgent, or Emergency) [56]. The primary surgical procedure and principal operative indication (e.g. perforation, ischaemia, obstruction, haemorrhage, postoperative complication, infection, or other relevant clinical scenarios) will be documented. Intraoperative peritoneal contamination will be graded using the NELA contamination scale, ranging from level 0 (no contamination) to level 3 (generalised peritoneal contamination) [57].

These variables will also be used to support the tertiary objective of the study, which involves subgroup characterisation of the ten most commonly performed emergency laparotomy procedures.

Preoperative risk scores

For each patient, preoperative risk scores will be calculated using the NELA, ACS-NSQIP, and SORT calculators. In the case of ACS-NSQIP, all predictive outputs will be evaluated, including estimated risk of postoperative mortality, overall risk of major complications, and probabilities of specific complications such as pneumonia, cardiovascular events, venous thromboembolism, sepsis, surgical site infections, urinary tract infections, acute kidney injury, need for reoperation, and risk of readmission. Additionally, the predicted likelihood of discharge to an institutional care facility (non-home discharge) will be analysed as a surrogate marker for postoperative functional prognosis.

These variables are essential for addressing the primary objective of the study—determining 30-day mortality following emergency laparotomy and comparing it with the predicted risk scores generated by NELA, ACS-NSQIP, and SORT. These scores will also be used to address the second secondary objective (evaluating predictive performance) and the tertiary objectives (comparing predicted and observed outcomes for the ten most frequent emergency procedures).

Postoperative outcomes and patient evolution

The following outcomes will be assessed: 30-day and 90-day mortality, and survival at 3, 6, 12, 24, and 36 months. Vital status will be verified using the official platform of the Romanian National Health Insurance House (CNAS) [47]. In the event of death, the exact date will be recorded, and where available, the primary diagnosis listed on the death certificate will be included. Length of hospital stay and ICU stay (where applicable) will also be documented. The incidence of major postoperative complications will be evaluated according to the categories defined in the ACS-NSQIP risk model, including pneumonia, cardiovascular complications, venous thromboembolism, sepsis, surgical site infections, urinary tract infections, renal failure, reoperation, and hospital readmission. All postoperative complications will be classified according to the Clavien-Dindo grading system, which provides a standardised framework for assessing severity based on the level of therapeutic intervention required.

Thirty-day mortality represents the primary endpoint for addressing the study's main objective, while medium and long-term postoperative survival analysis contributes to achieving

the first secondary objective.

Variable	Description Type
Age	Over 18 years
ASA Score	Range: 1–5
Albumin	Expressed in g/L
Heart Rate	Beats per minute
Blood Pressure	Expressed in mmHg
White Cell Count	x 10^9/L
GCS	Range: 1–15
Malignancy Severity	None / Primary tumour / Nodal metastases / Distant metastases
Dyspnoea	None / On exertion or mild COPD / Limited exertion or moderate COPD / At rest or radiographic fibrosis/consolidation
Degree of Urgency	Expedited (>18 hrs) / Urgent (6–18 hrs) / Urgent (2–6 hrs) / Immediate (<2 hrs), as per NCEPOD criteria
Peritoneal Contamination	None / Serous fluid / Localised purulent collection / Generalised stercoral or purulent peritonitis, or haemoperitoneum
Surgical Indication	As defined by NELA

Table 3: Variables analysed in the NELA score calculation

Variable	Description Type
Age	Between 18 and 112 years
Sex	Male or Female
Functional Status	Independent / Partially dependent / Fully dependent
Emergency Surgery	Yes / No
ASA Score	Range: 1–5
Chronic Steroid Use	Yes / No
Ascites within 30 Days Preoperatively	Yes / No
Sepsis within 48 Hours Preoperatively	Yes / No
Ventilator Dependence	Yes / No
Disseminated Cancer	Yes / No
Diabetes	No / Oral treatment / Insulin
Hypertension Requiring Medication	Yes / No
Congestive Heart Failure	Yes / No
Dyspnoea	No / On moderate exertion / At

	rest
Smoking in the Past Year	Yes / No
History of Severe COPD	Yes / No
Dialysis	Yes / No
Acute Renal Failure	Yes / No
Height	In centimetres
Weight	In kilograms

Table 4 : Variables analysed in the ACS-NSQIP score calculation

After entering the necessary variables into the ACS-NSQIP risk calculator, the following individual risk estimates will be generated for each patient: major complication, any postoperative complication, pneumonia, cardiac complication, surgical site infection, urinary tract infection, venous thromboembolism, acute renal failure, postoperative ileus following colectomy, anastomotic leak, need for reoperation (relaparotomy), hospital readmission, mortality, and discharge to an institutional care facility.

The generated ACS-NSQIP score incorporates all three levels of risk adjustment applied to each case: patient-level risk adjustment, procedure-specific adjustment, and shrinkage adjustment, in accordance with the standardised methodology of the ACS-NSQIP programme [32].

Variable	**Unit of Measurement**
Sex	Male / Female
Age	Years (>18 years)
Body Mass Index	Kg/m^2
Height	Cm
Weight	Kg
ASA Score	Range: 1-5
Predicted Mortality (NELA)	Percentage
Date of Laparotomy	Day – Month – Year
Day of the Week Surgery Was Performed	1–7 (Monday → Sunday)
ICU Monitoring	Yes / No
ICU Stay	Days
Grade of Lead Surgeon	Specialist / Consultant
Primary Procedure	According to procedural coding
30-Day Mortality	Yes / No
90-Day Mortality	Yes / No
Date of Death	Day – Month – Year
Surgical Ward Length of Stay	Days
Indication for Surgery	As per NELA criteria
Predicted Mortality (ACS-NSQIP)	Percentage
CRP Preoperatively	mg/dL
CRP at 24 Hours Postoperatively	mg/dL
CRP at 3 Days Postoperatively	mg/dL
CRP at 5 Days Postoperatively	mg/dL
Cause of Death	As per death certificate
Preoperative Albumin	g/dL

Heart Rate	Beats per minute
Preoperative Blood Pressure (Systolic/Diastolic)	mmHg
Preoperative Glucose	mg/dL
Preoperative Urea	mg/dL
Preoperative White Cell Count	*1000/µL
Preoperative Lactate	mmol/L
GCS	3-15
Peritoneal Contamination	0-3
Chronic Steroid Use	Yes / No
Presence of Ascites	Yes / No
Sepsis within 48h Preoperatively	Yes / No
Preoperative Ventilator Dependence	Yes / No
CCI – Score	0-40
CCI – Estimated 10-Year Survival	Percentage
Rockwood Frailty Score	1-9
SORT Score	Percentage

Table 5: Variables collected, used, and analysed in the study and their units of measurement

The calculation of the SORT score does not require additional variables beyond those already collected for the other two risk models. In addition to the specific surgical procedure, the model includes the following parameters: ASA score, urgency level according to the NCEPOD classification, type of surgical procedure (vascular, gastrointestinal, or thoracic), presence of malignancy, patient age, and the surgeon's global clinical assessment of the patient's condition [33].

Variable	**Description Type**
ASA Score	Range: 1-5
Urgency Level (NCEPOD)	Elective / Expedited / Urgent / Immediate
Vascular / Gastrointestinal / Thoracic Surgery	Yes / No
Malignancy	Yes / No
Age	<65 years / 65–79 years / >79 years
Clinician Assessment	Unknown / <1.0% / 1.0%–2.5% / 2.6%–5.0% / 5.1%–10.0% / 10.1%–50% / >50%

Table 6: Variables Analysed in the SORT Score Calculation

8. Data Collection

In the initial phase, applications for ethical approval will be submitted to the ethics committees of the six hospitals included in the study. Once all six favourable opinions have been obtained, the necessary documentation will be submitted to the Ethics Committee of "Grigore T. Popa" University of Medicine and Pharmacy in Iași, to obtain final institutional approval. Following the completion of all ethical procedures, the principal investigator will conduct successive on-site visits to each participating hospital to collect the required data, a process

scheduled between 1 July and 30 September 2025.

Data collection will involve the retrieval of patient medical records from hospital archives and from each hospital's electronic information system. The collected data will be entered into separate Excel databases for each hospital, as well as into a centralised database aggregating all cases across sites, for subsequent analysis. Both the personal computer used and the Excel files will be password-protected. Access to the data will be restricted to the principal investigator only, and all records will be securely stored for a period of seven years.

In this study, only the relatives of deceased patients will be contacted to confirm the exact date and cause of death. For this purpose, the telephone numbers recorded in medical files or in hospital information systems will be used. If such contact details are unavailable, the patient's general practitioner will be approached to facilitate communication with the family. In cases where neither contact information nor the general practitioner can be identified, the patient will be excluded from the study. All exclusions and their underlying reasons will be rigorously documented and monitored to ensure full transparency and traceability of the selection process. A study flow diagram will be presented, outlining all excluded cases and the justification for each exclusion.

All data will be collected and analysed with strict adherence to confidentiality requirements and in full compliance with applicable legal provisions on personal data protection. The research team acknowledges the obligations set out in Regulation (EU) 2016/679 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation – GDPR) [58] as well as Law No. 506/2004 concerning the processing of personal data and the protection of privacy. The principal and senior investigators undertake to use the data securely and solely for the declared purpose of the study, in accordance with the approvals granted by the ethics committees.

9. Bias

Retrospective cohort studies are susceptible to multiple sources of systematic error (bias), which may affect both the internal and external validity of the results. In the present study, ten main types of bias have been identified, for which specific preventive or mitigation strategies have been defined and implemented [59, 60].

The first source is selection bias, which occurs when the patients included in the study are not representative of the general population. To minimise this risk, the study is multicentric, involving six hospitals from different areas of Northeastern Romania, including both tertiary and municipal centres. Patient selection is conducted using standardised inclusion and exclusion criteria in accordance with the NELA protocol [1, 60]. Moreover, these six medical institutions serve a combined population of 2 462 451 inhabitants, representing approximately 12.91% of Romania's national population (estimated at 19 064 409) [61]. Regarding surgical staffing, the "Sf. Ioan cel Nou" Emergency County Hospital in Suceava has 12 general surgeons [62]; Pașcani Municipal Hospital has 5 [63]; Fălticeni Municipal Hospital employs 4 [64, 65]; "Sf. Spiridon" Hospital in Iași includes 15 surgeons in Clinic I, 12 in Clinic II, 14 in Clinic III, and 9 in Clinic IV [66] and Bârlad Municipal Hospital has 8 general surgeons [66]. Regarding the Galați County Emergency Clinical Hospital, it is structured into three general surgery departments, staffed by 4, 5, and 3 surgeons, respectively [67, 68].

A second major concern is information bias, which arises when data extracted from medical records are incomplete or inaccurate. To reduce this risk, multiple sources will be used (clinical notes, hospital information systems, ICU and operative registers), and clinical scores will be reviewed and validated prior to analysis [60, 69].

Recall bias, commonly encountered in retrospective research, refers to potentially inaccurate information provided by relatives or general practitioners. In this study, the risk is minimal since the data obtained from relatives will be limited to confirmation of the date of death, which will be cross-validated with death certificates and official records from the CNAS platform [60].

Misclassification bias may occur when patients are incorrectly assigned to categories or subgroups. To mitigate this risk, surgical interventions will be rigorously coded using the official nomenclature available at www.codificaremedicala.ro, and patient inclusion will strictly follow the criteria defined by the NELA audit [1, 70].

Confounding bias is a systematic error that occurs when a third variable is associated with both the exposure (e.g. type of intervention or risk score) and the outcome of interest (e.g. postoperative mortality), without being part of the actual causal pathway. This may distort observed relationships and lead to misleading conclusions. To address this, multivariate logistic regression models will be used, incorporating potential confounders such as age, ASA score, CCI, and frailty score. Additionally, stratified analyses will be conducted for clinically relevant subgroups (e.g. patients <70 vs ≥70 years), to assess the robustness of observed associations. The standardised selection of patients based on NELA criteria further contributes to confounding control by reducing population heterogeneity [60].

Attrition bias refers to the loss of follow-up, which can affect the accuracy of outcome estimates. In this study, vital status will primarily be confirmed via the CNAS database. Patients for whom essential information (e.g. exact cause of death) cannot be retrieved will be excluded from the analysis and appropriately reported.[71]

Survivorship bias arises when patients who die shortly after surgery are excluded. The present study includes all patients who underwent emergency laparotomy, regardless of postoperative survival duration, thereby eliminating this bias [72].

Publication bias refers to the selective reporting of statistically significant or favourable results. This study is committed to reporting all findings, regardless of statistical significance, in alignment with the principles of scientific transparency [73].

Seasonal bias may affect mortality depending on the time of year when surgery is performed. This is addressed by conducting the study over a full two-year period, thereby covering all seasons and avoiding seasonal variation [74].

Finally, inter-hospital bias may impact result validity due to differences in infrastructure, available resources, treatment protocols, and the level of surgical expertise across centres. To account for such variability, the protocol includes a comparative analysis of participating hospitals, assessing the distribution of key clinical variables and outcomes per centre. Statistical adjustment methods such as multivariate logistic regression will be applied, with hospital included as a covariate or fixed effect. Depending on data distribution, stratified analysis or mixed-effects models (multilevel modelling) may also be employed if inter-hospital variability significantly influences outcomes [37].

Comparison of observed mortality with mortality predicted by the NELA and ACS-NSQIP scores will serve as an internal validation mechanism, enabling a rigorous evaluation of the predictive performance of these models in real-world practice.

To ensure methodological rigor, the quality of this retrospective cohort study will be systematically evaluated using the Newcastle–Ottawa Scale (NOS). This validated tool is specifically designed for assessing the risk of bias in non-randomized studies and has been widely applied in epidemiological and clinical research. The NOS evaluates three major domains: Selection of study groups, including representativeness of the exposed cohort and ascertainment of exposure; Comparability of cohorts based on design or analysis; and Outcome assessment, including adequacy of follow-up and reliability of outcome determination. The NOS employs a "star system" to score items, facilitating a transparent and structured appraisal of bias risk. Its face and content validity have been confirmed by expert review, and it has been refined through multiple applications in epidemiological and clinical research [75].

10. Study size

Based on data from the pilot study, and primarily on the relationship between the number of surgical beds and the number of eligible patients, it is estimated that the study will include approximately 1 512 patients. Of these, around 302 patients (approximately 20%) are expected to be excluded from final analysis due to incomplete follow-up data following hospital discharge. Although it will be possible to confirm mortality status via the CNAS platform, the exact date and cause of death may not be available. After excluding such cases, along with patients who cannot be reached by telephone, the final analytical cohort is expected to comprise approximately 1,210 patients [34].

This study tests a one-directional hypothesis, namely that current mortality in Northeastern Romania is significantly higher than the mortality predicted by the NELA, ACS-NSQIP, and SORT risk models, an assertion supported by pilot data [34]. The null hypothesis (H0) states that observed mortality is equal to or lower than predicted, while the alternative hypothesis (H1) posits that it is significantly higher.

For statistical analysis, the significance level (α) is set at 0.05, which implies a 5% risk of incorrectly concluding that mortality in Romania is higher than the international average when no true difference exists. An alpha level of 5% reflects the probability of obtaining apparently significant results due to random chance rather than a true difference between groups [76].

The β parameter expresses the probability of failing to detect a true difference between mortality rates when such a difference objectively exists (Type II error). Statistical power is defined as $1 - \beta$ and represents the study's ability to detect a significant effect when it is present [77]. A higher statistical power implies increased sensitivity of the analysis. A sample size of 1,512 patients substantially increases the study's power and reduces the risk of Type II error, bringing it close to zero.

Based on findings from the pilot study, it is estimated that the observed mortality in the current study will be approximately 30% (denoted P1) [34]. Emergency laparotomy mortality across the European Union is estimated at 10–15%, with an average of 12.5% used here as a comparator (denoted P2) [23, 78, 79]. The next step involves calculating the effect size using Cohen's *h* for proportions [46].

The variance for Romania is P1(1−P1) = 0.21. The variance for Europe is P2(1−P2) = 0.109375. The square root of the average of these variances is approximately 0.3996, resulting in an estimated effect size of h = 0.438. Using GraphPad Prism [80] he calculated statistical power is approximately 1. This indicates that the risk of committing a Type II error is close to zero and that the study has an extremely high capacity to detect a significant difference between emergency laparotomy mortality in Romania and in Europe. To achieve a statistical power of 0.99, only 322 patients would be required. Since the current study includes approximately 1 512 patients, it confidently fulfils the criteria for a statistical power of 1.

11. Statistical Methods

Descriptive statistical analysis will be employed to characterise the study population and the distribution of clinical, demographic, and paraclinical variables included in the research. Given the mixed nature of the data—both in terms of type (quantitative and qualitative) and distribution—both parametric and non-parametric methods will be applied, depending on the results of normality tests. Most variables included in the analysis (such as risk scores, biochemical values, and preoperative vital parameters) are expected to exhibit non-Gaussian distributions, based on preliminary observations from the pilot study. For these variables, central tendency will be expressed using the median, and dispersion will be presented via the interquartile range (IQR), as well as minimum and maximum values. For variables approximating a normal distribution, the arithmetic mean and standard deviation (SD) will be calculated [81]. A distribution is considered approximately normal when the skewness coefficient lies between −1 and +1 (indicating relative symmetry around the mean) and kurtosis values are close to zero (excess kurtosis), reflecting a curve shape similar to a theoretical normal distribution [82]. Distribution assessments will be conducted using skewness and kurtosis [83], supplemented by graphical methods to identify outliers and to validate the choice of appropriate statistical tests. Outliers will be detected using the boxplot method, based on the IQR. This method defines outliers as those observations lying beyond 1.5 × IQR below the first quartile (Q1) or above the third quartile (Q3). This method is justified by its robustness and descriptive power in continuous variable analysis, particularly in retrospective observational studies, where distributions may be skewed and affected by atypical values. Identified outliers will be reported separately and will not be removed unless clinical justification or clear recording error is evident [84].

For the primary objective of the study, which consists of determining 30-day mortality following emergency laparotomy and comparing it with values predicted by the NELA, ACS-NSQIP, and SORT scores, statistical analysis will include calculating the 30-day mortality rate with corresponding 95% confidence intervals [81]. Comparisons of mortality rates between patients aged <70 and ≥70 years will be conducted using the chi-square test, given the sufficiently large sample sizes that meet the test's assumptions [85]. In cases where contingency table frequencies fall below 5 in one or more cells, Fisher's exact test will be employed to provide more accurate p-value estimation for sparse or imbalanced data [86]. The correlation between predictive scores (NELA, ACS-NSQIP, SORT) and observed 30-day mortality will be analysed using Spearman's rank correlation coefficient, as the scores are continuous variables and mortality is binary. Spearman's method is preferred in this context due to potential non-Gaussian distributions and the presence of outliers, which can significantly affect Pearson's coefficient [87]. However, should the

data conform to the normality assumption, Pearson's coefficient will also be calculated to assess potential linear relationships [88]. For ACS-NSQIP, each of the three adjustments (risk, procedure, and shrinkage) will be individually assessed using separate correlation analyses and simple linear regression models. Subsequently, a multiple logistic regression model will be applied to determine which score component provides the best predictive performance relative to observed mortality.

For the first secondary objective, regarding survival analysis at 1, 3, 6, 12, 24, and 36 months postoperatively, the Kaplan-Meier method will be used [89]. Comparisons between age groups (<70 vs. ≥70 years) will be performed using the chi-square test [81]. For the second secondary objective, the predictive accuracy of NELA, ACS-NSQIP, and SORT scores for 30-day mortality will be evaluated via ROC curve analysis, calculation of the AUC [90], and assessment of sensitivity and specificity at various thresholds. Risk thresholds for evaluating model performance will be determined using two complementary approaches. Firstly, the optimal cut-off will be identified using Youden's index (J = sensitivity + specificity – 1), to pinpoint the score value that simultaneously maximises sensitivity and specificity for predicting 30-day mortality [91]. Secondly, predefined thresholds commonly cited in the literature, such as NELA ≥ 5% or ACS-NSQIP ≥ 5%, will be examined, as they are considered indicative of high risk [32, 57, 92]. Employing these thresholds allows for comparison with international studies and provides clinically relevant interpretative benchmarks. Comparative analysis of the predictive performance of NELA, ACS-NSQIP, and SORT scores in estimating 30-day mortality will be conducted using the DeLong test, which allows comparison of two AUCs derived from the same set of cases. This test is justified by the dependent nature of the scores, which are calculated for the same cohort, and DeLong's test ensures rigorous statistical evaluation of differences between model performances [93].

For the tertiary objectives, a detailed analysis will be performed for the ten most common emergency surgical procedures. For each procedure, 30-day mortality will be determined as a proportion with corresponding 95% confidence intervals [81]. The correlation between predictive scores (NELA, ACS-NSQIP, SORT) and 30-day mortality will be assessed for each of these ten procedures using Spearman's correlation, due to non-normal distribution patterns and the likelihood of monotonic relationships between score and mortality [87]. Comparisons of scores between groups (e.g. deceased vs. survivors or between intervention types) will be performed using the independent samples t-test when data meet the normality assumption [94], otherwise, the Mann-Whitney U test will be used, as it is suitable for skewed distributions and non-parametric data [95]. Survival at 3, 6, 12, 24, and 36 months postoperatively for each of the ten most frequent surgical procedures will be assessed using the Kaplan-Meier method, which estimates survival probability over time and appropriately handles censored data [89]. Comparisons of survival between age groups (<70 vs. ≥70 years) or between intervention types will be made using the log-rank test, which tests the statistical significance of differences between Kaplan-Meier curves without assuming any specific distribution of survival times [96]. Regarding score accuracy by procedure type, ROC curves will be generated for each intervention, AUCs will be calculated, and sensitivity and specificity values will be interpreted to enable a nuanced assessment of score performance in diverse clinical scenarios [97].

A comparative analysis will also be conducted between the six participating hospitals, assessing the distribution of clinical variables and outcomes by hospital of origin. To control for the potential influence of this factor, statistical adjustment methods such as multivariate logistic

regression will be used, with hospital included as a control variable (fixed effect or covariate). If significant inter-hospital variability is observed, stratified analyses or multilevel (hierarchical) models will be employed to adequately correct for systemic differences [37].

The analysis will be complemented by graphical representations including histograms, bar charts, truncated violin plots, and box-and-whisker plots, given that most variables exhibit non-parametric distributions. These visualisations allow intuitive assessment of central tendency, dispersion, and outliers and are particularly well-suited for data that do not meet the assumption of normality [98].

All statistical analyses will be conducted using GraphPad Prism version 10.4.1 (627) [80].

Expected Results

13. Participants

As outlined in Chapter 6 – Participants, a total of 1 512 patients undergoing emergency laparotomy will be included in the study.

For the evaluation of the primary objective—to determine and compare observed 30-day mortality with the predictions generated by the NELA and ACS-NSQIP scores—the analysis will be conducted on the entire cohort, as well as on the age-defined subgroups: patients aged <70 years (n = 883) and those aged ≥70 years (n = 629). These figures are based on the pilot study, in which patients under 70 years of age accounted for 58.45% of the overall cohort [34].

For the secondary objectives, survival data at 3, 6, 12, 24, and 36 months postoperatively will be analysed. The follow-up data for patients operated on up to 31 December 2023 at 23:59 allow long-term survival analysis, specifically up to 24 months for those operated by the end of 2023, and up to 36 months for those operated by the end of 2022. This enables the cohort to be divided equally into two subgroups of 756 patients each. Additionally, for assessing the predictive accuracy of risk scores, sensitivity, specificity, and AUC will be calculated for both the full cohort and the age-based subgroups.

For the tertiary objectives, the ten most frequent emergency surgical procedures will be identified. Patients undergoing these procedures (n = 1 210) will be included in subgroup analyses. Separate analyses will also be performed for patients aged <70 and ≥70 years.

14. Descriptive data

In the previously conducted pilot study, it was observed that the majority of included patients were male, with a median age of 65 years and a mean body mass index of 26 kg/m². The median Rockwood frailty score was 4, while the median CCI was 5. The preoperative mortality risk was estimated at 5.78% using the NELA score and 5.5% using the ACS-NSQIP calculator. In contrast, the actual observed 30-day postoperative mortality was significantly higher, reaching 31.4% [34].

Given the methodological and demographic similarities between the pilot and the current study, comparable results are anticipated in terms of patient characteristics and clinical outcomes.

In line with the study's objectives, initial analyses will focus on comparing actual 30-day mortality following emergency laparotomy with risk estimates from NELA, ACS-NSQIP, and SORT. Long-term mortality at 3, 6, 12, 24, and 36 months will subsequently be examined to

evaluate the medium- and long-term predictive performance of these risk scores. Accordingly, the descriptive statistics from this study are expected to largely mirror those observed in the pilot investigation.

15. Study outcomes

The outcomes derived from this study will be interpreted in line with the predefined objectives and statistical methods outlined in the methodology section. Given the similarity in study design and population characteristics, results are expected to be broadly consistent with those from the pilot study.

The primary objective focuses on 30-day postoperative mortality across the full cohort of 1,512 patients. In the pilot, the overall 30-day mortality rate was 31.4%. This figure was further analysed by age group, revealing a mortality rate of 14.87% in patients under 70 years of age and a significantly higher rate of 44.18% in patients aged ≥70 years. These findings highlight an extremely high mortality rate in the elderly population and a rate in younger patients that aligns with the upper range of European averages [34].

For the secondary objectives, postoperative mortality will be analysed at 3, 6, 12, 24, and 36 months. While the pilot study did not include data on 3-month mortality, extrapolation suggests it will lie between 31.4% and 35.6%. Observed mortality rates in the pilot were 35.6% at 6 months, 38.25% at 12 months, 42.3% at 24 months, and 42.8% at 36 months. The estimated 30-day mortality was 5.78% using NELA and 5.5% using ACS-NSQIP, both showing strong positive correlations with observed outcomes [34].

For the tertiary objectives, analysis will focus on the ten most frequent procedures performed under emergency laparotomy. For each of these, both observed mortality at 1, 3, 6, 12, 24, and 36 months and preoperative risk estimates from the NELA and ACS-NSQIP models will be evaluated. These analyses will be stratified by age (<70 and ≥70 years) to explore variations in prognosis depending on the type of procedure and patient profile [34].

16. Primary Outcome

The principal objective of this study is to evaluate 30-day postoperative mortality. In the pilot study, the overall 30-day mortality rate was 31.4%, with significant differences observed between age subgroups: 14.87% in patients under 70 years of age and 44.18% in those aged 70 years or older [34].

These marked differences in 30-day mortality between age groups highlight both clinical challenges and opportunities to improve the care of patients undergoing emergency laparotomy. Key issues identified include the frailty commonly seen in elderly patients—often associated with multiple comorbidities—as well as the limitations of existing risk assessment tools in the emergency surgical context [99]. The absence of standardised protocols specifically adapted to geriatric populations may also contribute to suboptimal therapeutic decision-making. Moreover, limited access to intensive care resources can adversely affect postoperative outcomes in this vulnerable cohort. Conversely, these findings underscore the need to implement risk prediction tools tailored for older patients and to incorporate preoperative geriatric assessment whenever time allows [100]. The development of specific clinical protocols for elderly patients in the emergency surgical setting may further optimise intraoperative and postoperative management. Lastly, more

effective allocation of resources, including prioritised access to critical care, could substantially reduce mortality in this patient group [99].

The findings of the present study have the potential to significantly influence clinical practice by enabling the accurate identification of high-risk profiles among patients undergoing emergency laparotomy [101]. Confirming these age-based differences may support the formulation of recommendations concerning perioperative resource allocation such as prioritised access to intensive care and the involvement of multidisciplinary teams, including geriatricians, thereby reducing early mortality and enabling more individualised, risk-adjusted therapeutic strategies [102].

17. Additional Analyses

These represent supplementary analyses which, although not part of the study's primary objectives, may yield valuable insights for interpreting the results obtained. Among the variables that may be explored is the day of the week on which the surgical intervention took place, which could reveal a potential "weekend effect" [103]. Additionally, the professional grade of the operating surgeon—whether a specialty registrar, consultant, or trainee—may influence postoperative outcomes, including mortality [104]. The start time of the surgical procedure, i.e., whether performed during regular working hours or outside of them (on-call periods), may also be a relevant factor to consider [105]. Furthermore, the duration of the surgical procedure, as a possible indirect indicator of case complexity or intraoperative technical difficulties, may have a significant impact on patient outcomes, particularly mortality [106].

Discussion

18. Key Findings

The hypothesis of this study is that the preoperative risk scores NELA, ACS-NSQIP, and SORT significantly underestimate 30-day postoperative mortality in the Romanian population undergoing emergency laparotomy. Identifying high-risk procedures may guide strategic resource allocation [107, 108].

Comparing postoperative mortality by type of surgical procedure across the six participating hospitals may highlight substantial variations in surgical practices, the quality of perioperative care, and resource availability. These differences may not only reflect case mix variability but also discrepancies in technical infrastructure, or the training level of medical personnel.

A study published in BMJ Open highlighted that variations in the delivery of emergency surgical care can lead to significant differences in mortality, emphasising the need for protocol standardisation to reduce such disparities [109].

Internationally reported mortality rates following emergency laparotomy range between 8% and 15%. However, in Romania, these rates are significantly higher. While NELA and ACS-NSQIP scores have already been validated in multiple studies conducted in Western and Central Europe, validation in Eastern Europe is still pending [7, 22, 25, 110].

The results of this study may hold clinical and practical implications, such as the optimisation of perioperative management, resource planning, postoperative care allocation,

improvement of the informed consent process, and identification of system-level limitations [102].

The validation and implementation of risk scores within the Romanian healthcare system could reduce both postoperative complications and overall costs [45]. These tools enable individualised risk estimation, support decision-making, and facilitate the process of obtaining informed consent. Risk scores also aid in identifying high-risk patients and in planning appropriate surgical and postoperative strategies [111, 112].

Identified risk factors can support early intervention strategies, such as stabilisation of critical patients and thorough assessment of elderly patients—those aged over 70 years and/or with multiple or severe comorbidities.

The observed difference in mortality may be partially explained by the fact that, in countries with more developed healthcare systems, predictive risk scores perform better due to a more standardised perioperative care framework. In Romania, inter-hospital variability and limited resources may reduce the accuracy of such predictive models. Socioeconomic and contextual factors—such as delayed presentation, prolonged time to CT imaging, limited access to advanced preoperative investigations, restricted ICU availability for patients with predicted mortality over 5%, and the absence of geriatric specialists on surgical teams—may account for the elevated mortality in Romania compared to other European nations [37].

Geriatric assessment plays a pivotal role in the management of elderly patients undergoing emergency laparotomy. This multidimensional approach allows the identification and management of risk factors specific to this population, thereby improving postoperative outcomes. One study, involving 882,929 emergency surgical patients between 2007 and 2015, demonstrated a significant association between frailty and postoperative mortality [44].

To improve the care of elderly patients undergoing emergency laparotomy, the British Geriatrics Society (BGS) recommends frailty screening and comprehensive geriatric assessment (CGA). All patients aged 65 years and older should be screened using the CFS. Those with a CFS score ≥5, or aged ≥80 regardless of score, should receive a CGA led by a geriatrician within 72 hours of hospital admission or transfer from ICU. Geriatric support should be integrated throughout perioperative care, and data collection regarding cognitive and functional status and discharge destination should be standard practice for patients aged over 65 years [113]. Implementing CGA in the emergency laparotomy setting has been associated with multiple benefits, including reduced mortality, shorter hospital stays, and improved postoperative functional outcomes [113].

A study published in WJES highlighted that elderly patients who received CGA had better clinical outcomes compared to those who did not [114]. Another study, published in Annals of Surgery in 2021, found that one in five elderly patients undergoing emergency laparotomy were frail. Frailty was independently associated with higher postoperative mortality and morbidity, regardless of chronological age. The study supports the incorporation of frailty scoring in the preoperative assessment of emergency surgical patients to support clinical decision-making and guide postoperative care planning [18].

19. Limitations

1. The retrospective design of the study represents a significant methodological limitation, as it may lead to documentation errors or the absence of relevant information in patient records. It also introduces multiple forms of bias (see Chapter 9: Bias). Consequently,

the accuracy and completeness of the collected data rely heavily on the quality of previous medical documentation.

2. The sample is derived exclusively from the Northeastern region of Romania, which may limit the generalisability of the results to the national level. Although this area encompasses a population of approximately 2.5 million inhabitants, the conclusions may reflect regional specificities that are not necessarily applicable to other regions of the country, which may have different infrastructures and levels of healthcare access [37]. The proposed study involves an evaluation of the clinical practices of over 91 general surgeons.

3. The lack of frailty scoring, systematic geriatric evaluations, clearly defined preoperative stabilisation protocols, as well as variability in the time to computed tomography (CT), surgery, or administration of the first antibiotic dose—may represent a significant source of variability. Furthermore, the presence or absence of a consultant surgeon and consultant anaesthetist in the operating theatre, along with variable access to intensive care for high-risk patients (e.g., NELA score >5%), may impact inter-institutional comparability and the accuracy of the predictive scores NELA, ACS-NSQIP, and SORT [115].

4. The limited applicability of the NELA, ACS-NSQIP, and SORT scores in the Romanian context, as these models were developed and validated in healthcare systems with different resources and standardised protocols. The pilot study highlighted a clear tendency to underestimate actual mortality [34].

5. The study population is predominantly elderly, with a median age of 65 years in the pilot study, potentially resulting in a higher mortality rate than that reported in younger or more selectively operated international cohorts. This limits comparability with studies involving younger populations [116].

6. Inter-hospital differences in resource availability (e.g., CT access, ICU teams, availability for rapid interventions) and subspecialty expertise among medical staff may introduce significant variability into the results, which cannot be fully adjusted for using statistical methods [37].

7. The exclusion of patients with incomplete post-discharge data, due to an inability to contact relatives or the general practitioner, introduces a potential selection bias, as these patients may represent a distinct risk profile [117].

8. The relatively small number of patients undergoing some of the top ten procedures identified in the pilot study limits the statistical power of subgroup analyses. Therefore, robust conclusions regarding procedure-specific mortality cannot be drawn [34].

9. The absence of social and economic data (e.g., educational level, financial status, or prior access to medical care) limits the capacity to conduct a comprehensive assessment of factors influencing postoperative mortality [118].

10. The validation of predictive scores is based solely on 30-day mortality, although one of the recognised limitations in the international literature is that these scores do not accurately predict long-term outcomes (at 3, 6, 12, 24, and 36 months), which are assessed only as secondary objectives in this study [112].

20. Interpretations

Should predictive scores such as NELA, ACS-NSQIP, and SORT prove to underestimate mortality within the Romanian context, it becomes necessary to consider their methodological adaptation to local population and systemic characteristics, or the integration of additional factors into preoperative risk assessment. Numerous international studies have underscored the need for recalibration of these models to improve predictive accuracy across varying geographical and clinical contexts [21, 119, 120].

One potential improvement would involve the inclusion of additional variables reflecting the specificities of the national healthcare system and local clinical realities. These may include limited or delayed access to intensive care, which can significantly influence mortality outcomes [121]. Furthermore, the time from presentation at the Emergency Department to surgical intervention represents a critical variable in the context of surgical emergencies and should be factored into risk assessment [122]. The lack or delay of preoperative imaging investigations, particularly CT, may impact diagnostic accuracy and treatment decisions. Frailty assessment, using validated instruments such as the Rockwood score, represents another valuable component that may enhance risk stratification [123]. Socio-economic status and educational level may also influence compliance with treatment and access to adequate medical care. Incorporating such variables into predictive models could improve mortality risk estimation in the Romanian context [37].

Should inter-hospital analysis reveal significantly higher mortality rates in certain healthcare units, this may indicate systemic deficiencies in resource availability, technical infrastructure, or the uniform application of preoperative care protocols. Similar discrepancies have been observed in other healthcare systems, such as in the UK, where variations in care quality and infrastructure have been linked to differences in institutional management across NHS trusts [124].

The implementation of standardised care bundles for managing acute abdominal pain and emergency laparotomy may help reduce inter-hospital variability and optimise postoperative outcomes. In this context, the general surgeon plays a central role in coordinating the multidisciplinary team and ensuring rigorous adherence to perioperative protocols [125].

The ERAS® Society's consensus guidelines on emergency laparotomy (Part III) emphasise the importance of organisational structures in patient care, highlighting the role of multidisciplinary approaches and standardised protocols. Effective inter-specialty coordination, prompt evaluation, early surgical intervention, and structured perioperative management are recommended as key strategies to reduce inter-hospital variability and improve outcomes [126].

21. Generalisability – External Validity

Regarding external validity, the present study aims to produce results that may be extrapolated beyond the immediate setting of the six participating hospitals. As a multicentric investigation, it includes healthcare institutions of varying levels of competence and resources—two county clinical emergency hospitals and four municipal hospitals—all located in the Northeastern region of Romania. This institutional diversity offers high regional

representativeness and facilitates the evaluation of NELA, ACS-NSQIP, and SORT performance within a realistic and heterogeneous clinical context.

Collectively, the six centres serve a population of approximately 2.5 million inhabitants, strengthening the generalisability of the findings to other Romanian regions with similar demographic, epidemiological, and healthcare organisational characteristics. Moreover, the size of the cohort and the study's statistical power—approaching 1—further reinforce the robustness and clinical applicability of the conclusions.

By carefully managing the most common sources of bias and applying standardised selection and analysis criteria, the study ensures a high degree of internal validity, which inherently supports external validity. The explicit acknowledgement of limitations—such as the inability to generalise findings to elective surgery or to unrepresented regions—demonstrates a scientifically rigorous and transparent approach.

The results obtained through this research may encourage practising clinicians to reconsider their current management strategies, particularly regarding the use of mortality prediction tools in the context of emergency laparotomy.

Additional Information

22. Funding

Funding for this study is provided by the author's doctoral scholarship, amounting to 3,200 RON per month for a duration of four years, as well as by personal financial resources. There are no external funding sources from pharmaceutical companies, government agencies, or private organisations.

The funding is intended to cover the costs of essential equipment, such as a laptop (5 000 RON) and related accessories (3 000 RON), as well as licences for various software programmes, including Microsoft Office Suite (500 RON), OneDrive (included with Office), LinkedIn Learning (1 200 RON), GraphPad Prism (2 600 RON), EndNote (550 RON), BioRender (1 200 RON), Grammarly (free), and Adobe Acrobat Reader (free). Additionally, the budget must account for travel and accommodation expenses during the data collection period in various cities.

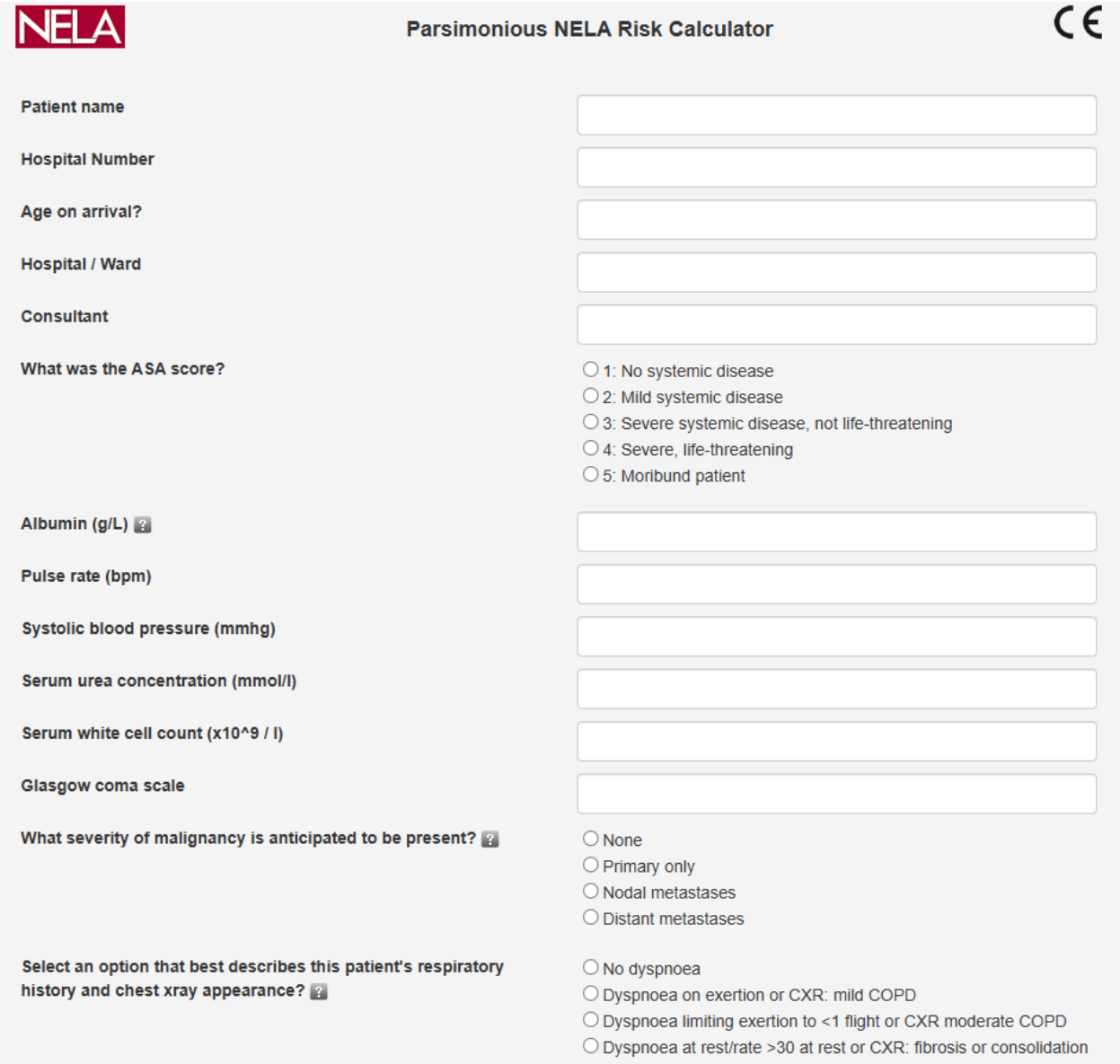
Hospital	Accommodation	Daily Allowance	Transport	Duration
Iași	-	-	-	10 days
Galați	-	100 RON/day	80 RON/day	10 days
Suceava	200 RON/day	100 RON/day	120 RON	8 days
Fălticeni	200 RON/day	100 RON/day	100 RON	6 days
Bârlad	-	100 RON/day	64 RON/day	5 days
Pașcani	-	100 RON/day	60 RON/day	4 days
Total	2 800 RON	3 300 RON	2 930 RON	43 days

Table 7: Data Collection Costs

The funding has not influenced the design of the study, the collection or analysis of the data, or the interpretation of the findings. All conclusions and interpretations are independent and based solely on the data analysed.

There are no conflicts of interest that have influenced the conduct of this study.

Appendices



NELA

Parsimonious NELA Risk Calculator

CE

Patient name

Hospital Number

Age on arrival?

Hospital / Ward

Consultant

What was the ASA score?

- ○ 1: No systemic disease
- ○ 2: Mild systemic disease
- ○ 3: Severe systemic disease, not life-threatening
- ○ 4: Severe, life-threatening
- ○ 5: Moribund patient

Albumin (g/L) ?

Pulse rate (bpm)

Systolic blood pressure (mmhg)

Serum urea concentration (mmol/l)

Serum white cell count (x10^9 / l)

Glasgow coma scale

What severity of malignancy is anticipated to be present? ?

- ○ None
- ○ Primary only
- ○ Nodal metastases
- ○ Distant metastases

Select an option that best describes this patient's respiratory history and chest xray appearance? ?

- ○ No dyspnoea
- ○ Dyspnoea on exertion or CXR: mild COPD
- ○ Dyspnoea limiting exertion to <1 flight or CXR moderate COPD
- ○ Dyspnoea at rest/rate >30 at rest or CXR: fibrosis or consolidation

Please select the *urgency* of surgical intervention

- ○ 3. Expedited (>18 hours)
- ○ 2B. Urgent (6-18 hours)
- ○ 2A. Urgent (2-6 hours)
- ○ 1.Immediate (<2 hours)

Please select a value that best describes the likely degree of peritoneal soiling

- ○ None
- ○ Serous fluid
- ○ Localised pus
- ○ Free bowel content, pus or blood

Indications for surgery

Bleeding

- ☐ Haemorrhage

Other

- ☐ Abdominal wound dehiscence
- ☐ Abdominal compartment syndrome
- ☐ Planned relook
- ☐ Other

Obstruction

- ☐ Tender Small bowel obstruction
- ☐ Non-Tender Small bowel obstruction
- ☐ Tender Large bowel obstruction
- ☐ Non-Tender Large bowel obstruction
- ☐ Gastric outlet obstruction
- ☐ Incarcerated/strangulated hernia
- ☐ Hiatus Hernia/para-oesophageal hernia
- ☐ Volvulus
- ☐ Internal hernia
- ☐ Obstructing incisional hernia
- ☐ Intussusception
- ☐ Pseudo-obstruction
- ☐ Foreign body

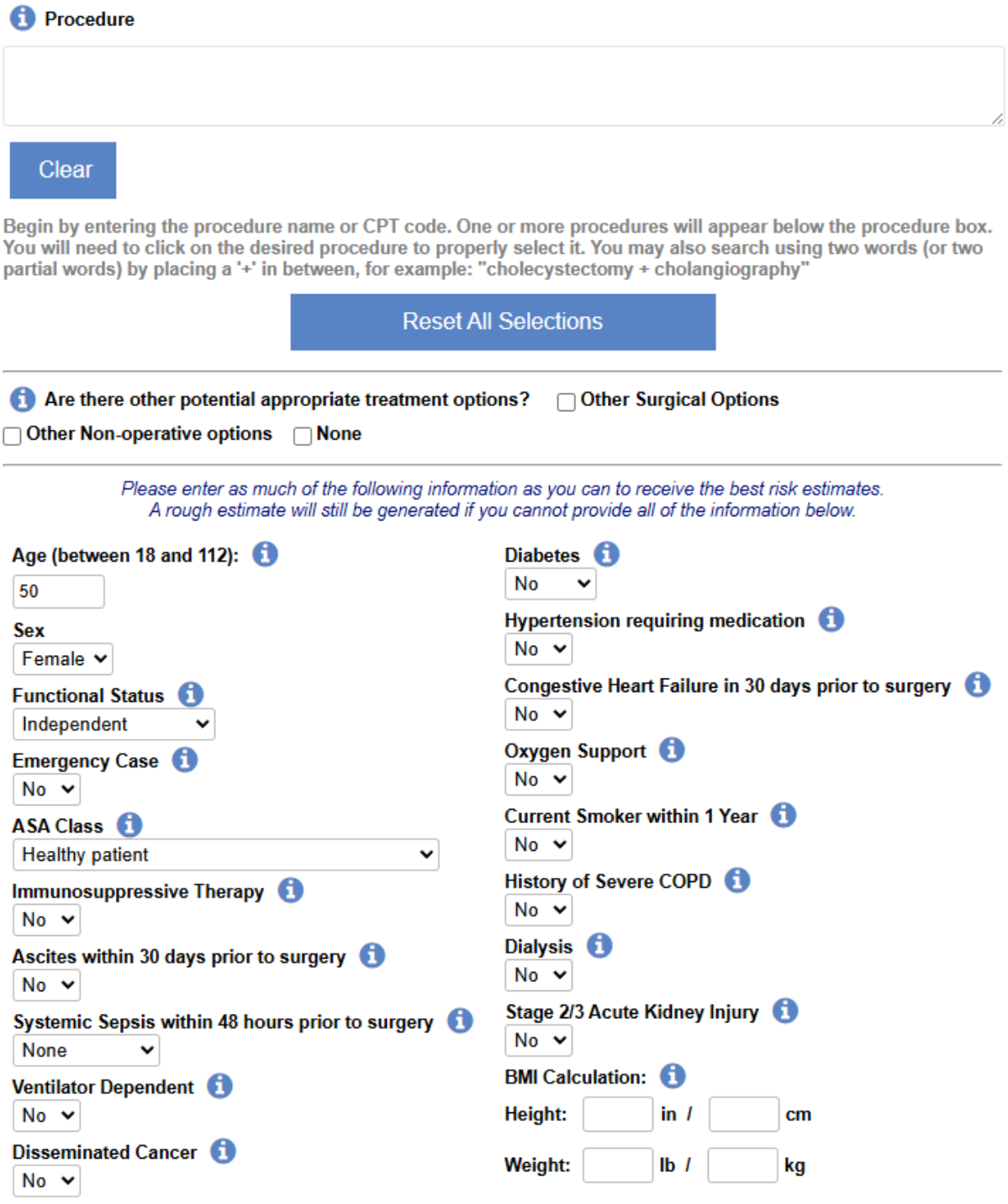
Sepsis

- ☐ Phlegmon
- ☐ Pneumoperitoneum
- ☐ Sepsis
- ☐ Iatrogenic injury
- ☐ Anastomotic leak
- ☐ Peritonitis
- ☐ GI Perforation
- ☐ Abdominal abscess
- ☐ Intestinal fistula

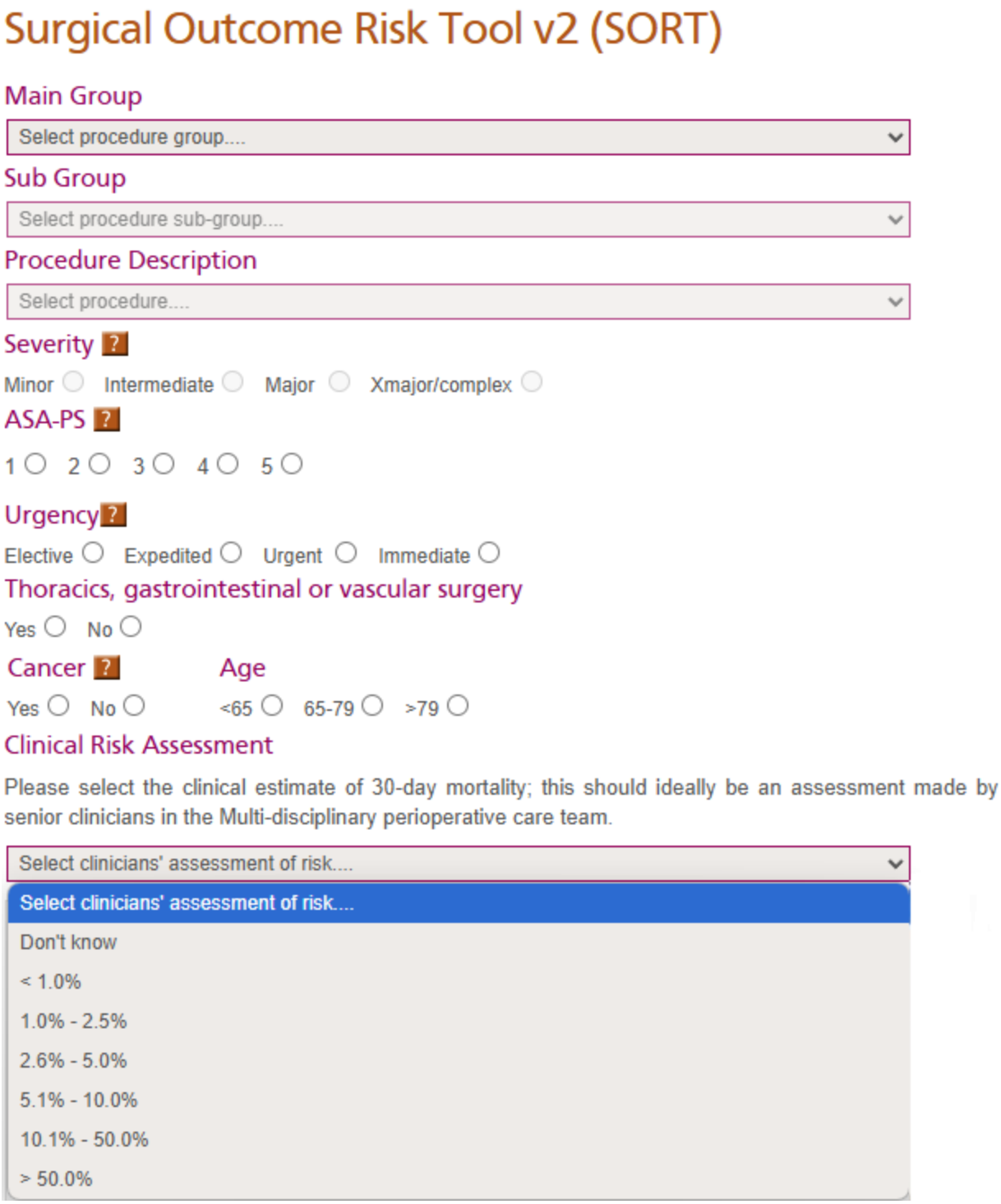
Ischaemia

- ☐ Necrosis
- ☐ Ischaemia/infarction
- ☐ Colitis
- ☐ Acidosis

Appendix 1: NELA Risk Calculator



Appendix 2: ACS-NSQIP Risk Calculator



Appendix 3: Sort Risk Calculator

References

1. NELA. Audit Inclusion & Exclusion Criteria 2023 [Available from: https://www.nela.org.uk/Criteria; Access: 30 September 2024.
2. Rajaretnam N OE, Burns B. Laparotomy Treasure Island (FL): StatPearls Publishing2023 [Available from: https://www.ncbi.nlm.nih.gov/books/NBK525961/; Access: 17 April 2025.
3. Simões J, Braga G, Bagatini M. Laparotomy: From Efficacy to Safety. Complimentary Copy. 2023:139.
4. Cooper Z, Mitchell SL, Gorges RJ, Rosenthal RA, Lipsitz SR, Kelley AS. Predictors of Mortality Up to 1 Year After Emergency Major Abdominal Surgery in Older Adults. J Am Geriatr Soc. 2015;63(12):2572-9.
5. Aggarwal G, Scott M, Peden CJ. Emergency Laparotomy. Anesthesiol Clin. 2022;40(1):199-211.
6. Moscalu A, Saravanan B, Kamal A, Sinclair M. NELA Prize The correlation between actual and predicted 30-day mortality for emergency laparotomies in adults, using National Emergency Laparotomy Audit (NELA) risk predicting tool – a multi-center, retrospective, observational, cohort study. British Journal of Surgery. 2022;109(Supplement_5).
7. Moscalu A, Mohsen F, Battili M, Timofeiov S, Sinclair M. NELA 1 - Actual and predicted 30-day mortality following emergency laparotomy using National Emergency Laparotomy Audit (NELA) and American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) risk prediction tools. British Journal of Surgery. 2024;111(Supplement_8).
8. Jansson Timan T, Hagberg G, Sernert N, Karlsson O, Prytz M. Mortality following emergency laparotomy: a Swedish cohort study. BMC Surgery. 2021;21(1):322.
9. Liljendahl MS, Gögenur I, Thygesen LC. Emergency Laparotomy in Denmark: A Nationwide Descriptive Study. World J Surg. 2020;44(9):2976-81.
10. Lasithiotakis K, Kritsotakis EI, Kokkinakis S, Petra G, Paterakis K, Karali G-A, et al. The Hellenic Emergency Laparotomy Study (HELAS): A Prospective Multicentre Study on the Outcomes of Emergency Laparotomy in Greece. World Journal of Surgery. 2023;47(1):130-9.
11. Tan BH, Mytton J, Al-Khyatt W, Aquina CT, Evison F, Fleming FJ, et al. A comparison of mortality following emergency laparotomy between populations from New York state and England. Annals of surgery. 2017;266(2):280-6.
12. Shahait AD, Dolman H, Mostafa G. Postoperative Outcomes After Emergency Laparotomy in Nontrauma Settings: A Single-Center Experience. Cureus. 2022;14(3):e23426.
13. Frederick Torlot C-YY, Jennifer R. Reilly, Michael Phillips, Dieter G. Weber, Tomas B. Corcoran, Kwok M. Ho, Andrew J. Toner. External validity of four risk scores predicting 30-day mortality after surgery. BJA Open. 2022;Volume 3.
14. Nag DS. Assessing the risk: Scoring systems for outcome prediction in emergency laparotomies. Biomedicine (Taipei). 2015;5(4):20.
15. Darbyshire AR, Kostakis I, Pucher PH, Prytherch D, Mercer SJ. P-POSSUM and the NELA Score Overpredict Mortality for Laparoscopic Emergency Bowel Surgery: An Analysis of the NELA Database. World J Surg. 2022;46(3):552-60.
16. Connell L. NELA Risk Calculator Significantly Underestimates Mortality Risk of Laparotomy for Mesenteric and Colonic Ischaemia in Older Adult Surgical Patients. Open Access Surgery. 2023;Volume 16:1-6.
17. Laane CLE, Van Lieshout EMM, Van Heeswijk RAM, De Jong AI, Verhofstad MHJ, Wijffels MME. Validity of the ACS NSQIP surgical risk calculator as a tool to predict postoperative outcomes in subacute orthopedic trauma diagnoses. Heliyon. 2024;10(4):e25796.

18. Parmar KL, Law J, Carter B, Hewitt J, Boyle JM, Casey P, et al. Frailty in Older Patients Undergoing Emergency Laparotomy: Results From the UK Observational Emergency Laparotomy and Frailty (ELF) Study. Annals of Surgery. 2021;273(4):709-18.
19. RCOA. National Emergency Laparotomy Audit (NELA): Royal College of Anasesthetists; 2024 [Available from: https://www.rcoa.ac.uk/research/research-projects/national-emergency-laparotomy-audit-nela; Access: September 2023
20. Tran ET, Ho KM. Utility of the National Emergency Laparotomy Audit prognostic model in predicting outcomes in an Australian health system. Anaesth Intensive Care. 2023;51(1):51-8.
21. Hansted AK, Storm N, Burcharth J, Diasso PDK, Ninh M, Møller MH, et al. Validation of the NELA risk prediction model in emergency abdominal surgery. Acta Anaesthesiol Scand. 2023;67(9):1194-201.
22. Eugene N, Oliver CM, Bassett MG, Poulton TE, Kuryba A, Johnston C, et al. Development and internal validation of a novel risk adjustment model for adult patients undergoing emergency laparotomy surgery: the National Emergency Laparotomy Audit risk model. Br J Anaesth. 2018;121(4):739-48.
23. NELA. All Patient Reports [Available from: https://www.nela.org.uk/All-Patient-Reports#pt; Access: 05.01.2025 2025.
24. Cohen ME, Ko CY, Bilimoria KY, Zhou L, Huffman K, Wang X, et al. Optimizing ACS NSQIP modeling for evaluation of surgical quality and risk: patient risk adjustment, procedure mix adjustment, shrinkage adjustment, and surgical focus. J Am Coll Surg. 2013;217(2):336-46.e1.
25. ACS. History: American College of Surgeons; 2024 [Available from: https://www.facs.org/quality-programs/data-and-registries/acs-nsqip/history/; Access: September 2024
26. Protopapa KL, Simpson JC, Smith NC, Moonesinghe SR. Development and validation of the Surgical Outcome Risk Tool (SORT). Br J Surg. 2014;101(13):1774-83.
27. Wong DJN, Harris S, Sahni A, Bedford JR, Cortes L, Shawyer R, et al. Developing and validating subjective and objective risk-assessment measures for predicting mortality after major surgery: An international prospective cohort study. PLOS Medicine. 2020;17(10):e1003253.
28. Oakland K, Cosentino D, Cross T, Bucknall C, Dorudi S, Walker D. External validation of the Surgical Outcome Risk Tool (SORT) in 3305 abdominal surgery patients in the independent sector in the UK. Perioperative Medicine. 2021;10(1):4.
29. Semenas E, Helleberg J, Bartha E, Kalman S, Holm M. Surgical Outcome Risk Tool (SORT) to predict 30-day postoperative mortality in a mixed surgical population in Swedish tertiary hospitals. Br J Surg. 2023;110(5):584-90.
30. Karamolegkou AP, Fergadi MP, Magouliotis DE, Samara AA, Tatsios E, Xanthopoulos A, et al. Validation of the Surgical Outcome Risk Tool (SORT) and SORT v2 for Predicting Postoperative Mortality in Patients with Pancreatic Cancer Undergoing Surgery. J Clin Med. 2023;12(6).
31. NELA. Parsimonious NELA Risk Calculator 2024 [Available from: https://data.nela.org.uk/riskcalculator/; Access: September 2024
32. ACS. ACS-NSQIP Surgical Risk Calculator 2024 [Available from: https://riskcalculator.facs.org/RiskCalculator/; Access: September 2024
33. Surgery S. Surgical Outcome Risk Tool v2 (SORT): SORT Surgery; 2025 [Available from: https://www.sortsurgery.com/; Access: 8 June 2025
34. Moscalu A, Iordache A, Sinclair M, Timofeiov S. FP7.8 - Perioperative risk prediction for Emergency Laparotomy in Adults, using the National Emergency Laparotomy Audit (NELA) and the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) risk prediction tools – an Eastern European perspective. British Journal of Surgery. 2024;111(Supplement_8).

35. Harji DP, Griffiths B, Stocken D, Pearse R, Blazeby J, Brown JM. Key interventions and outcomes in perioperative care pathways in emergency laparotomy: a systematic review. World Journal of Emergency Surgery. 2025;20(1):20.
36. McCarthy M. Seven procedures account for 80% of emergency general surgery operations, deaths, and complications, US study finds. Bmj. 2016;353:i2498.
37. Breazu A, Olariu AA, Popa S, Popa C. The Level of Resources and Quality of the Health System in the Romanian Country2023.
38. McKee M HJe. Hospitals in a Changing Europe. Buckingham; 2002.
39. Sănătății M. Ordin nr. 323 din 18 aprilie 2011 privind aprobarea metodologiei și a criteriilor minime obligatorii pentru clasificarea spitalelor în funcție de competență. Partea I. Monitorul Oficial al României2011.
40. Mazilu P. Acces limitat la sănătate: Sute de localități fără medic de familie: 03 Aprilie 2025; 2025 [Available from: https://www.antenasatelor.ro/viata-la-tara/social/acces-limitat-la-sanatate-sute-de-localitati-fara-medic-de-familie-id39603.html; Access: 25 April 2025.
41. database WHOGHE. Current health expenditure (% of GDP): World Bank Group; 2023 [Available from: https://data.worldbank.org/indicator/SH.XPD.CHEX.GD.ZS?; Access: 25 April 2025.
42. European Commission D-GfHaFS. State of Health in the EU: Synthesis Report 2023. Publications Office of the European Union. 2023.
43. Ahmed N, Mandel R, Fain MJ. Frailty: An Emerging Geriatric Syndrome. The American Journal of Medicine. 2007;120(9):748-53.
44. Castillo-Angeles M, Cooper Z, Jarman MP, Sturgeon D, Salim A, Havens JM. Association of Frailty With Morbidity and Mortality in Emergency General Surgery by Procedural Risk Level. JAMA Surgery. 2021;156(1):68-74.
45. Nimeri AA, Bautista J, Philip R. Reducing Healthcare Costs Using ACS NSQIP-Driven Quality Improvement Projects: A Success Story from Sheikh Khalifa Medical City (SKMC). World J Surg. 2019;43(2):331-8.
46. Cohen J. Statistical Power Analysis for the Behavioral Sciences. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.
47. CNAS. Casa Națională de Asigurări de Sănătate - Verificare asigurat 2024 [Available from: http://cas.cnas.ro/page/verificare-asigurat.html; Access: September 2024
48. României P. Legea drepturilor pacientului nr. 46 din 21 ianuarie 2003. Monitorul Oficial.nr. 51(29 ianuarie 2003).
49. Iași SCJdUSS. Structură organizatorie 2025 [Available from: https://spitalspiridon.ro/index.php/spital/structura; Access: 17 April 2025.
50. Galați SCJdUSAA. Secția Chirurgie Generală 2025 [Available from: https://www.spitalulurgentagalati.ro/sectii.html; Access: 17 April 2025.
51. Suceava SdUSIcN. Secția Chirurgie Generală 2025 [Available from: https://spitaluljudeteansuceava.ro/chirurgie-generala/; Access: 17 April 2025.
52. Bârlad SMdUEB. Secția Chirurgie Generală 2025 [Available from: https://www.spital-barlad.ro/servicii-medicale/; Access: 17 April 2025.
53. Pașcani SMdU. Secție Chirurgie Generală 2025 [Available from: https://smupascani.com/acasa/sectii/chirurgie/#:~:text=Sec%C5%A3ia%20de%20chirurgie%20are%2035,si%20sali%20de%20mese%20separate.; Access: 17 April 2025.
54. Fălticeni SM. Raport de activitate 2022 [Available from: http://spital-falticeni.ro/wp-content/uploads/2023/03/RAPORT-DE-ACTIVITATE-SPITAL-AN-2022.pdf; Access: 17 April 2025.
55. Singer M, Deutschman CS, Seymour CW, Shankar-Hari M, Annane D, Bauer M, et al. The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). Jama. 2016;315(8):801-10.

56. NCEPOD. The NCEPOD Classification of Intervention 2018 [Available from: https://www.ncepod.org.uk/classification.html; Access: September 2024
57. Team NP. Ninth Patient Report of the National Emergency Laparotomy Audit. London: Royal College of Anaesthetists; 2024.
58. Europene PEșCU. Regulamentul (UE) 2016/679 al Parlamentului European și al Consiliului. Jurnalul Oficial al Uniunii Europene 2016.
59. Jager KJ, Tripepi G, Chesnaye NC, Dekker FW, Zoccali C, Stel VS. Where to look for the most frequent biases? Nephrology (Carlton). 2020;25(6):435-41.
60. Ramirez-Santana M. Limitations and Biases in Cohort Studies. In: Barría RM, editor. Cohort Studies in Health Sciences. Rijeka: IntechOpen; 2018.
61. Union E. Romania – European Union Member Country Profile: European Commission; 2024 [Available from: https://european-union.europa.eu/principles-countries-history/eu-countries/romania_en?; Access: 8 June 2025.
62. Suceava SJdUSIcN. Secția Chirurgie Generală Suceava, România: Spitalul Județean Suceava; 2025 [Available from: https://spitaluljudeteansuceava.ro/chirurgie-generala/; Access: 29 June 2025.
63. Pașcani SMdU. Secția Chirurgie Pașcani, România: Spitalul Municipal de Urgență Pașcani; 2024 [Available from: https://smupascani.com/acasa/sectii/chirurgie/; Access: 29 June 2025.
64. Fălticeni SM. Cabinete Medicale – Spitalul Municipal Fălticeni Fălticeni, România: Spitalul Municipal Fălticeni; 2025 [Available from: http://spital-falticeni.ro/cabinete/; Access: 02 July 2025.
65. Fălticeni SM. Structură Personal - Spitalul Municipal Fălticeni Fălticeni, România: Spitalul Municipal Fălticeni; 2025 [Available from: http://spital-falticeni.ro/structura-personal/; Access: 02 July 2025.
66. Iași SCJdUSS. Lista completă a medicilor Iași, România: Spitalul „Sf. Spiridon" Iași; 2025 [Available from: https://www.spitalspiridon.ro/index.php/medici/ista-completa-medici-20151023?; Access: 02 July 2025.
67. Galați SCJdUSAA. Secții medicale Galați, România: Spitalul Clinic Județean de Urgență „Sf. Apostol Andrei" Galați; 2025 [Available from: https://www.spitalulurgentagalati.ro/sectii.html; Access: 02 July 2025.
68. Galați SCJdUSAA. Personal medical 2024 2024 [Available from: https://www.spitalulurgentagalati.ro/despre_noi/Personal_medical_2024.pdf; Access: 3 July 2025.
69. Althubaiti A. Information bias in health research: definition, pitfalls, and adjustment methods. J Multidiscip Healthc. 2016;9:211-7.
70. Pham A, Cummings M, Lindeman C, Drummond N, Williamson T. Recognizing misclassification bias in research and medical practice. Family Practice. 2019;36(6):804-7.
71. Bhandari P. Attrition Bias | Examples, Explanation, Prevention Scribbr2021 [Available from: https://www.scribbr.com/research-bias/attrition-bias/; Access: 29 May 2025.
72. Howe CJ, Robinson WR. Survival-related Selection Bias in Studies of Racial Health Disparities: The Importance of the Target Population and Study Design. Epidemiology. 2018;29(4):521-4.
73. Siddiqi N. Publication bias in epidemiological studies. Cent Eur J Public Health. 2011;19(2):118-20.
74. Christiansen CF, Pedersen L, Sørensen HT, Rothman KJ. Methods to assess seasonal effects in epidemiological studies of infectious diseases—exemplified by application to the occurrence of meningococcal disease. Clinical Microbiology and Infection. 2012;18(10):963-9.
75. Institute OHR. Newcastle–Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses 2021 [Available from: https://www.ohri.ca/programs/clinical_epidemiology/oxford.asp; Access: 9 September 2025.

76. Tenny S, Abdelgawad I. Statistical Significance. StatPearls. Treasure Island (FL): StatPearls Publishing

77. Huecker. JSMR. Type I and Type II Errors and Statistical Power. StatPearls Publishing. 2023.
78. Nally DM, Sorensen J, Kavanagh DO. Emergency laparotomy research methodology: A systematic review. The Surgeon. 2020;18(2):80-90.
79. Jansson Timan T, Hagberg G, Sernert N, Karlsson O, Prytz M. Mortality following emergency laparotomy: a Swedish cohort study. BMC Surg. 2021;21(1):322.
80. Software G. GraphPad Prism versiunea 10.4.1 Boston, Massachusetts USA 2025 [pentru Windows, GraphPad Software, Boston, Massachusetts USA]. Available from: www.graphpad.com; Access:
81. Mishra P, Pandey CM, Singh U, Gupta A, Sahu C, Keshri A. Descriptive statistics and normality tests for statistical data. Ann Card Anaesth. 2019;22(1):67-72.
82. Paul DGaM. IBM SPSS Statistics 23 Step by Step: A Simple Guide and Reference. 14 ed. New York: Routledge; 2016.
83. Kim HY. Statistical notes for clinical researchers: assessing normal distribution (2) using skewness and kurtosis. Restor Dent Endod. 2013;38(1):52-4.
84. Dovoedo Y, Chakraborti S. Boxplot-Based Outlier Detection for the Location-Scale Family. Communications in Statistics - Simulation and Computation. 2014;44:140917052913006.
85. McHugh ML. The chi-square test of independence. Biochem Med (Zagreb). 2013;23(2):143-9.
86. Kim H-Y. Statistical notes for clinical researchers: Chi-squared test and Fisher's exact test. Restor Dent Endod. 2017;42(2):152-5.
87. Mukaka MM. Statistics corner: A guide to appropriate use of correlation coefficient in medical research. Malawi Med J. 2012;24(3):69-71.
88. Turney S. Pearson Correlation Coefficient (r) | Guide & Examples Scribbr2022 [Available from: https://www.scribbr.com/statistics/pearson-correlation-coefficient/; Access: 02 June 2025.
89. Rich JT, Neely JG, Paniello RC, Voelker CC, Nussenbaum B, Wang EW. A practical guide to understanding Kaplan-Meier curves. Otolaryngol Head Neck Surg. 2010;143(3):331-6.
90. VAN DER SCHOUW Y, VERBEEK A, RUIJS J. ROC Curves For the Initial Assessment of New Diagnostic Tests. Family Practice. 1992;9(4):506-11.
91. Perkins NJ, Schisterman EF. The Youden Index and the optimal cut-point corrected for measurement error. Biom J. 2005;47(4):428-41.
92. Banks J, Macadam R. TU8.10 Should patients with a predicted NELA mortality of 5–10% be managed on ICU? An audit of the management of high-risk laparotomies as per NELA Guidelines. British Journal of Surgery. 2022;109.
93. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. Biometrics. 1988;44(3):837-45.
94. Mishra P, Singh U, Pandey CM, Mishra P, Pandey G. Application of student's t-test, analysis of variance, and covariance. Ann Card Anaesth. 2019;22(4):407-11.
95. Nachar N. The Mann-Whitney U: A Test for Assessing Whether Two Independent Samples Come from the Same Distribution. Tutorials in Quantitative Methods for Psychology. 2008;4.
96. Bland JM, Altman DG. The logrank test. BMJ. 2004;328(7447):1073.
97. Hajian-Tilaki K. Receiver Operating Characteristic (ROC) Curve Analysis for Medical Diagnostic Test Evaluation. Caspian J Intern Med. 2013;4(2):627-35.

98. Wilke CO. Fundamentals of Data Visualization: A Primer on Making Informative and Compelling Figures. Sebastopol, CA: O'Reilly Media; 2019.
99. Halle-Smith JM, Naumann DN, Powell SL, Naumann LK, Griffiths EA. Improving Outcomes for Elderly Patients Following Emergency Surgery: a Cutting-edge Review. Current Anesthesiology Reports. 2021;11(4):396-404.
100. Sharrock AE, McLachlan J, Chambers R, Bailey IS, Kirkby-Bott J. Emergency Abdominal Surgery in the Elderly: Can We Predict Mortality? World J Surg. 2017;41(2):402-9.
101. Cihoric M, Tengberg LT, Foss NB, Gögenur I, Tolstrup MB, Bay-Nielsen M. Functional performance and 30-day postoperative mortality after emergency laparotomy-a retrospective, multicenter, observational cohort study of 1084 patients. Perioper Med (Lond). 2020;9:13.
102. Saunders DI, Murray D, Pichel AC, Varley S, Peden CJ. Variations in mortality after emergency laparotomy: the first report of the UK Emergency Laparotomy Network. British Journal of Anaesthesia. 2012;109(3):368-75.
103. Smith SA, Yamamoto JM, Roberts DJ, Tang KL, Ronksley PE, Dixon E, et al. Weekend Surgical Care and Postoperative Mortality: A Systematic Review and Meta-Analysis of Cohort Studies. Med Care. 2018;56(2):121-9.
104. D'Souza N, Hashimoto D, Gurusamy K, Aggarwal R. Comparative Outcomes of Resident vs Attending Performed Surgery: A Systematic Review and Meta-Analysis. Journal of Surgical Education. 2016;73.
105. Cortegiani A, Ippolito M, Misseri G, Helviz Y, Ingoglia G, Bonanno G, et al. Association between night/after-hours surgery and mortality: a systematic review and meta-analysis. Br J Anaesth. 2020;124(5):623-37.
106. Meschino MT, Giles AE, Rice TJ, Saddik M, Doumouras AG, Nenshi R, et al. Operative timing is associated with increased morbidity and mortality in patients undergoing emergency general surgery: a multisite study of emergency general services in a single academic network. Can J Surg. 2020;63(4):E321-e8.
107. Schwarze ML, Barnato AE, Rathouz PJ, Zhao Q, Neuman HB, Winslow ER, et al. Development of a List of High-Risk Operations for Patients 65 Years and Older. JAMA Surgery. 2015;150(4):325-31.
108. Thumma SR, Dualeh SHA, Kunnath NJ, Bonner SN, Ibrahim AM. Outcomes for High-Risk Surgical Procedures Across High- and Low-Competition Hospital Markets. JAMA Surgery. 2023;158(10):1041-8.
109. Vanessa PH, Christopher WT, Wyatt PB, Elizabeth P, Jarrod D, Alfred FC, et al. Mortality burden from variation in provision of surgical care in emergency general surgery: a cohort study using the National Inpatient Sample. Trauma Surgery & Acute Care Open. 2024;9(1):e001288.
110. Vos EL, Russo AE, Hohmann A, Yoon SS, Coit DG, Ko CY, et al. Performance of the American College of Surgeons NSQIP Surgical Risk Calculator for Total Gastrectomy. J Am Coll Surg. 2020;231(6):650-6.
111. Bilimoria KY, Liu Y, Paruch JL, Zhou L, Kmiecik TE, Ko CY, et al. Development and evaluation of the universal ACS NSQIP surgical risk calculator: a decision aid and informed consent tool for patients and surgeons. J Am Coll Surg. 2013;217(5):833-42.e1-3.
112. Barazanchi AWH, Bhat S, Park B, Zeng I, MacFater W, Xia W, et al. Long-term accuracy of the National Emergency Laparotomy Audit risk score: Analysis of the impact of comorbidities on mortality 5 years after emergency laparotomy. J Trauma Acute Care Surg. 2025;98(4):635-41.
113. Society BG. BGS Position Statement: Older patients undergoing emergency laparotomy British Geriatrics Society2020 [updated 21 April 2020. Available from: https://www.bgs.org.uk/resources/bgs-position-statement-older-patients-undergoing-emergency-laparotomy?utm_source=chatgpt.com; Access: 25 April 2025.

114. Tian B, Stahel PF, Picetti E, Campanelli G, Di Saverio S, Moore E, et al. Assessing and managing frailty in emergency laparotomy: a WSES position paper. World J Emerg Surg. 2023;18(1):38.
115. Banks J, Macadam R. TU8.10 Should patients with a predicted NELA mortality of 5–10% be managed on ICU? An audit of the management of high-risk laparotomies as per NELA Guidelines. British Journal of Surgery. 2022;109(Supplement_5).
116. Gill TM, Vander Wyk B, Leo-Summers L, Murphy TE, Becher RD. Population-Based Estimates of 1-Year Mortality After Major Surgery Among Community-Living Older US Adults. JAMA Surgery. 2022;157(12):e225155-e.
117. Howe CJ, Cole SR, Lau B, Napravnik S, Eron JJ, Jr. Selection Bias Due to Loss to Follow Up in Cohort Studies. Epidemiology. 2016;27(1):91-7.
118. Armenia SJ, Pentakota SR, Merchant AM. Socioeconomic factors and mortality in emergency general surgery: trends over a 20-year period. J Surg Res. 2017;212:178-86.
119. Ma M, Liu Y, Gotoh M, Takahashi A, Marubashi S, Seto Y, et al. Validation study of the ACS NSQIP surgical risk calculator for two procedures in Japan. The American Journal of Surgery. 2021;222(5):877-81.
120. Ma M, Liu Y, Gotoh M, Takahashi A, Marubashi S, Seto Y, et al. Validation study of the ACS NSQIP surgical risk calculator for two procedures in Japan. The American Journal of Surgery. 2021;222.
121. Cardoso LT, Grion CM, Matsuo T, Anami EH, Kauss IA, Seko L, et al. Impact of delayed admission to intensive care units on mortality of critically ill patients: a cohort study. Crit Care. 2011;15(1):R28.
122. Silver DS, Lu L, Beiriger J, Reitz KM, Khamzina Y, Neal MD, et al. Association between timing of operative interventions and mortality in emergency general surgery. Trauma Surg Acute Care Open. 2024;9(1):e001479.
123. Joseph B, Zangbar B, Pandit V, Fain M, Mohler MJ, Kulvatunyou N, et al. Emergency General Surgery in the Elderly: Too Old or Too Frail? Journal of the American College of Surgeons. 2016;222(5):805-13.
124. Ozdemir BA, Sinha S, Karthikesalingam A, Poloniecki JD, Pearse RM, Grocott MPW, et al. Mortality of emergency general surgical patients and associations with hospital structures and processes. British Journal of Anaesthesia. 2016;116(1):54-62.
125. Kokotovic D, Jensen TK. Acute abdominal pain and emergency laparotomy: bundles of care to improve patient outcomes. British Journal of Surgery. 2023;110(12):1594-6.
126. Peden CJ, Aggarwal G, Aitken RJ, Anderson ID, Balfour A, Foss NB, et al. Enhanced Recovery After Surgery (ERAS®) Society Consensus Guidelines for Emergency Laparotomy Part 3: Organizational Aspects and General Considerations for Management of the Emergency Laparotomy Patient. World J Surg. 2023;47(8):1881-98.