Cohort Study

Succoring the challenging acute mesenteric ischemia: Feasibility of lactate dehydrogenase for evaluation of intestinal necrosis extension and mortality

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\textbf{Abstract}

\textbf{Background:} Acute mesenteric ischemia is a lethal challenging pathology for surgeons in the emergency department due to its ambiguous clinical presentation and lack of early diagnostic markers. Serum lactate is considered a relevant biomarker in terms of bowel necrosis length and mortality prediction. Nevertheless, its association has been poorly studied. Hence, we evaluated the relation between serum lactate admission levels, bowel necrosis extension, and mortality in patients with acute mesenteric ischemia.

\textbf{Methods:} A Retrospective cross-sectional study with a prospective database was conducted, including patients over 18 years old with mesenteric ischemia that required surgical management between January 2012 and December 2018. We describe the association between serum lactate admission levels with bowel necrosis length and mortality. Serum lactate admission levels can be considered as a useful prognostic tool in terms of mortality in patients with acute mesenteric ischemia.

\textbf{Results:} 74 patients presented with acute mesenteric ischemia, 44 males and 30 females. Mean age was 73.5 ± 10.7 years old. Significant association between serum lactate admission levels and mortality was found (ROC cut-off value of 3.8 mmol/l, 81.0% sensitivity and 76% specificity, LR\textsuperscript{+} 3.41 (95\%CI 1.57, 7.40), LR\textsuperscript{-} 0.25 (95\%CI 0.13-0.45))(P < 0.001). Nonetheless no statistically significant association was found between serum lactate admission levels and bowel necrosis length (p = 0.195, 95\%CI -0.046, -0.436, P > .99). As post hoc analysis, a classification and regression tree on mortality was fitted.

\textbf{Conclusions:} Early diagnosis, prognosis and management of mesenteric ischemia is vital given its high morbidity and mortality. Serum lactate admission levels can be considered as a useful prognostic tool in terms of mortality in patients with acute mesenteric ischemia.

1. Background

Acute mesenteric ischemia (AMI) is a challenging pathology for general surgeons in the emergency department due to its ambiguous clinical presentation and lack of precocious tools for diagnosis [1]. It is considered a vascular emergency secondary to a sudden interruption of small intestine blood supply, that can lead to an ominous outcome even if treated [1,2]. AMI can be classified as occlusive (OAMI) or non-occlusive (NOMI) in terms of its etiology, being OAMI associated with 60–80% of all cases [1,3–8].

Despite being a rare entity with an incidence of 0.09–0.2% of all admissions to the emergency department and 1–2% of gastrointestinal illnesses, its suspicion and diagnosis must be prompt due to its high mortality rate (32–92%) [1,4–13]. Intestinal ischemia stems from transmural necrosis of the bowel wall caused by severe hypoperfusion, which can progress to sepsis, peritonitis or extensive gangrene [1,4–6]. Initial management includes gastrointestinal decompression, fluid resuscitation, hemodynamic monitoring and support, correction of electrolyte abnormalities, pain control, anticoagulation under most circumstances, and initiation of broad-spectrum antibiotics [1,4,6,10,
Larger extension of bowel necrosis, requiring larger resections with the room [10, 13, 14]. In cases who present with peritonitis or obvious bowel perforation, graphic, or laboratory parameters, regardless of etiology [1, 4]. Even though multiple markers such as serum lactate [2, 12, 14, 16], -lactate [20–25], d-dimer [26, 27] and intestinal fatty acid-binding protein (I-FABP) [28–31] have been employed to ease AMI diagnosis, none has shown accurate and consistent results [1, 4, 5, 7]. Lack of a reliable marker for prediction of bowel necrosis extension and mortality leads to surgical procedures where inoperable massive bowel infarction is evidenced [14, 16, 24]. Serum lactate is a frequently used hypoperfusion biomarker, it is inexpensive and available in most centers, but results in most studies show heterogeneous sensitivity and specificity in AMI [2]. Given the growing demand of tools that help elucidate diagnosis, bowel compromise and mortality, we aim to describe the association between serum lactate in the emergency room, bowel necrosis extension and mortality.

2. Methods

With the Institutional Review Board’s approval, following Health Insurance Portability and Accountability Act (HIPAA) guidelines, a retrospective review of a prospectively collected database was conducted. All patients over 18 years of age that required laparotomy with a postoperative confirmed diagnosis of AMI were included between January 2012 and December 2018. Patients with no description of the serum lactate admission levels (SLAL) or extension of intestinal necrosis were excluded. The present study has been reported in line with STROCCS guidelines [32] Ethical compliance with the Helsinki Declaration, current legislation on research Res. 008430-1993 and Res. 2378-2008 (Colombia) and the International Committee of Medical Journal Editors (ICMJE) were ensured under our Ethics and Research Institutional Committee (IRB) approval.

Preoperative data included patient demographics, comorbidities, symptoms, findings in the physical examination, serum lactate admission levels, blood analysis results, CT results. Intraoperative and postoperative data included surgical findings, pathology report of intestinal necrosis and 30 days mortality. Data was reviewed by external investigators from UR-SIG, a research group alliance forged by Universidad del Rosario and Hospital Universitario Mayor de Mederi to evaluate data quality. Descriptive statistics were reported in terms of variable nature. Qualitative analysis was performed in terms of frequencies and percentages, while quantitative analysis was done in terms of mean and standard deviations of normally distributed data and medians and interquartile ranges (IQRs) for non-normally distributed data. Bivariate analysis was performed. Qualitative variables were analyzed using chi-square statistics (Fisher’s exact test when appropriate). Quantitative variables were analyzed, based on normality, with Spearman’s or Pearson’s associations correlation coefficient accordingly. Bivariate analysis between qualitative and quantitative variables was performed using Mann-Whitney test or the t-test for independent samples [32, 53]. For associations between categorical variables, odds ratios with 95% confidence intervals were provided. Diagnostic performance of SLAL for mortality was evaluated using the receiver operating characteristic curve (ROC) [32–34].

Classification and regression tree (CART) [32] implemented in the R package part was fitted to assess the predictive power of relevant sociodemographic, clinical, and laboratory variables for mortality. A multivariable logistic regression model was fitted with the highest importance value variables selected by the CART model without any mathematical transformation. Finally, the ROC curve of the decision tree was calculated. For both ROC curves, the area under de ROC curve (AUC) with its 95% confidence interval is reported [35]. Positive likelihood ratio (LR+) and negative likelihood ratio (LR-) with their 95% confidence intervals were calculated [36]. Specificity and sensitivity were reported with their 95% exact binomial confidence limits. Statistical analysis was performed using R Software 3.6.3.39.

3. Results

3.1. Descriptive statistics

From January 2012 to December 2018 a total of 74 patients underwent urgent laparotomy with a postoperative diagnosis of AMI. Mean age was 73.5 ± 10.7 years old. 44 Males and 30 females. Mean body mass index was 25 ± 2.9 kg/m2 (Table 1). 15 patients (20%) presented NOMI. All the patients presented abdominal pain, 17 (23%) had peritoneal signs and 23 (31%) gastrointestinal bleeding on physical examination. Median time from symptom’s onset to arrival to the emergency room (ER) was 24 (IQRs 61) hours. Median SLAL was 5.6 (IQRs 5) mmol/l. Median time between AMI’s diagnosis and surgical management was 5 (IQRs 5) hours. Documented bowel necrosis involved the small intestine and colon with a median length of 161.5 (IQRs 207) cm. Surgical resection was performed in 37 (50%) patients. Overall, mortality within thirty days was 72%, of which 35 occurred within the first 24 postoperative hours.

3.2. Analytic statistics of serum lactate admission levels (SLAL), bowel necrosis length, and mortality

Non-significant statistical association between SLAL and necrosis length was established (p = 0.195, 95%CI -0.046 to –0.436, P > .99) (Table 2). Median SLAL in fatal cases was 6.3 (IQRs 4.5) mmol/l and 2.9 (IQRs 1.3) mmol/l (P.001) in non fatal (Table 3). SLAL cut-value for mortality of 3.8 mmol/l was determined by ROC- analysis with a sensitivity of 81.0% (95% CI: 68–91%) and specificity of 76% (95% CI: 53–92%), LR+ 3.41 (95% CI: 1.57–7.40), LR- 0.25 (95% CI: 0.13–0.45) (Fig. 1).

3.3. Classification and regression tree (CART) and logistic regression

CART was fitted to determine the importance and cutoff value of variables on mortality (Fig. 2A), resulting variables were included in the logistic regression (Table 4). The variables with the highest importance value were SLAL with a cut-value of 3.8 mmol/l, bowel necrosis length with a cut-value of 177 cm, time of performance of surgical procedure within 3.5 h after diagnosis, and bowel resection (Fig. 2B). CART analysis showed a cut-value of 0.61 on the probability of the mortality with 91% sensitivity (95% CI: 79–97%) and 86% specificity (95% CI: 64–97%), LR+ 6.34 (95% CI: 2.22–18.14), LR- 0.11 (95% CI: 0.05–0.26) (Fig. 2C).

4. Discussion

In this retrospective cross-sectional study of patients with AMI who underwent laparotomy, non statistically significant correlation between SLAL and bowel necrosis length was documented despite reported in literature by different studies [15, 18]. Nonetheless, a statistically significant correlation between SLAL and mortality was elucidated. SLAL cut-value of 3.8 mmol/l for mortality prediction was identified with a sensitivity of 81% and specificity of 76%, LR+ 3.41 (1.57, 7.40), LR- 0.25 (0.13–0.45), which relates to results found by Leone et al. (cut–value of 3.9 mmol/l, sensitivity of 60% and a specificity of 83%) [16] and Caluwaerts et al. (cut value of 3.65 mmol/l) [17]. CART analysis showed SLAL had the highest importance value (27%) in predicting mortality and was the only significant variable in the logistic regression.
in relation with former studies that have shown serum lactate as an important independent risk factor for mortality [15,17,37].

The CART model provided five mortality profiles (Fig. 2) that may be relevant in terms of prognosis. Predictions were done using a SLAL cutoff point of 3.8 mmol/l, from there, mortality was determined by bowel necrosis length, intestinal resection and time within surgical procedure was performed. Cases with a necrosis length shorter than 177 cm had a 13% mortality, while those with longer necrosis had a mortality of 80%, in concordance with reports by Akyildiz et al. in a retrospective study of

### Table 1

| Sociodemographic Characteristics (n = 74) | No (%) |
|-----------------------------------------|--------|
| Men                                     | 44 (60) |
| Age, mean (SD), y                       | 73.5 (10.7) |
| Body Mass Index, mean (SD), kg/m2 (n = 39) | 25 (2.9) |
| Comorbidities (n = 74)                  | No (%) |
| Smoking tobacco                         | 16 (22) |
| Alcohol consumption                     | 7 (10)  |
| Hypertension                            | 50 (68) |
| Diabetes mellitus type II               | 17 (23) |
| Peripheral vascular disease             | 14 (19) |
| Chronic kidney disease                  | 12 (16) |
| Atrial fibrillation                     | 12 (16) |
| COPD                                    | 14 (19) |
| Coronary heart disease                  | 10 (14) |
| Admission Characteristics (n = 74)      | No (%) |
| Time of symptoms onset to arrival to the emergency room, median (IQ(Rs), h) | 24 (61) |
| Abdominal pain                          | 74 (100) |
| Peritoneal signs                        | 17 (23) |
| Gastrointestinal bleeding               | 23 (31) |
| Multiorgan failure                      | 54 (75) |
| SLAL, median (IQ(Rs), mmol/L)           | 5.6 (5) |
| Total WBC, median (IQ(Rs), 106/mm3      | 14555 |
| (IQR270)                                |        |
| Ph, mean (SD)                           | 7.31 (0.1) |
| Base excess, mean (SD)                  | –9.4 (6.6) |
| CPR, median (IQ(Rs), mg/L               | 71.6 (151) |
| Marshall Score                          |        |
| 2                                       | 19 (29) |
| 3                                       | 12 (18) |
| 4                                       | 9 (12)  |
| 1                                       | 7 (9)   |
| 6                                       | 5 (7)   |
| 5                                       | 5 (7)   |
| 8                                       | 4 (6)   |
| 9                                       | 3 (4)   |
| 2                                       | 2 (3)   |
| CT-Scan Findings (n = 28)               | No (%) |
| Bowel Dilatation                        | 20 (69) |
| Mesenteric arterial or venous obstruction | 17 (53) |
| Acescts                                 | 12 (43) |
| Decreased Bowl Enhancement              | 7 (25)  |
| Pneumatisitis intestinalis              | 3 (11)  |
| Pneumpropertoneum                      | 1 (3)   |
| Surgical Findings and Outcomes (n = 74) | No (%) |
| Time from diagnosis to surgery, median (IQ(Rs), h) | 5 (5) |
| Bowel Necrosis Length, median (IQ(Rs), cm) | 161.5 (207) |
| Bowel resection                         | 37 (50) |
| NOMI                                    | 15 (20) |
| Vessel Occlusion                        |        |
| Venous                                  | 11 (19) |
| Arterial                                | 48 (81) |
| Death within 30 postsurgical days       | 53 (72) |
| Post surgical death, median (IQ(Rs), d) | 1 (1) |
| Death on the first postsurgical day     | 35 (66) |
| Pathology Findings n = 37               | No (%) |
| Bowel Necrosis Length in pathology, median (IQ(Rs), cm) | 105 (101) |
| Acute inflammation                      | 32 (84) |
| Cellular necrosis in pathology          | 32 (84) |
| Transmural hemorrhage in pathology      | 30 (78) |

COPD: Chronic obstructive pulmonary disease, SLAL: Serum lactate admission levels, WBC: White blood cells, CPR: C-reactive protein, CT: Computed tomography, NOMI: non-obstructive mesenteric ischemia.

### Table 2

| Serum lactate admission levels- cross-tabulation. | Median (IQ(Rs)) | Effect measure (95%CI) | p-value* |
|--------------------------------------------------|---------------|------------------------|---------|
| Primary outcomes                                 |               |                        |         |
| Bowel necrosis length, correlation               | –             | 0.195 (-0.04-0.43)     | >.99    |
| Death within 30 postsurgical days                |               |                        |         |
| Yes                                               | 6.3 (4.5)     | –                      | .001    |
| No                                                | 2.9 (1.3)     | –                      |         |
| Secondary outcomes                               |               |                        |         |
| Men                                               | 5.9 (5.3)     | –                      | >.99    |
| Women                                             | 4.3 (4.8)     | –                      |         |
| Age, correlation                                  | –             | -0.032                 | >.99    |
| Diabetes mellitus type II                         | 6.3 (5.3)     | –                      | >.99    |
| No                                                | 5 (3.5)       | –                      |         |
| Mesenteric arterial or venous disease             |               |                        |         |
| Yes                                               | 4 (4.2)       | –                      | >.99    |
| No                                                | 6 (5.1)       | –                      |         |
| Chronic kidney disease                            |               |                        |         |
| Yes                                               | 6.6 (8)       | –                      | >.99    |
| No                                                | 5.3 (5)       | –                      |         |
| Atrial fibrillation                               |               |                        |         |
| Yes                                               | 6.6 (5.1)     | –                      | >.99    |
| No                                                | 5.2 (5.1)     | –                      |         |
| Pneumatisitis intestinalis                        |               |                        |         |
| Yes                                               | 6.5 (6)       | –                      | >.99    |
| No                                                | 5 (5)         | –                      |         |
| Coronary heart disease                            |               |                        |         |
| Yes                                               | 5.4 (5.8)     | –                      | >.99    |
| No                                                | 5.6 (5)       | –                      |         |

Secondary outcomes:

Blood necrosis length, correlation: – 0.195 (-0.04-0.43) >.99

Death within 30 postsurgical days:

Yes: 6.3 (4.5) – .001
No: 2.9 (1.3) –

Secondary outcomes:

Men: 5.9 (5.3) – >.99
Women: 4.3 (4.8) –
Age: – 0.032 >.99

Diabetes mellitus type II:

Yes: 6.3 (5.3) – >.99
No: 5 (3.5) –

Perineal signs:

Yes: 6 (3) – >.99
No: 5.1 (5.3) –

Gastrointestinal bleeding:

Yes: 6.9 (5.6) –
No: 5.2 (4.9) – >.99

Total WBC, correlation:

– 0.15 (-0.08-0.3) >.99

Ph, correlation:

– 0.05 (-0.7-0.3) <.001

Base excess, correlation:

– 0.63 <.001

CPR, correlation:

– 0.135 (-0.4-0.708) >.99

Marshall Score:

1: 5.4 (5.3) – >.99
2: 6.8 (3.8) –
3: 2.9 (5.2) –
4: 5 (3.3) –
5: 4.7 (3.8) –
6: 4.9 (2.2) –
7: 7 (1.8) –
8: 8.3 (3.8) –
9: 5 (4.1) –

CT-Scan Findings:

Bowel Dilatation, mean (SD):

Yes: 5.4 (3.6) (Reference) >.99
No: 5.9 (4.4) 0.5 (-2.7-3.8)

Mesenteric arterial or venous obstruction

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with symptoms that lasted less than 12 h compared to only 20% viability in those with symptoms that lasted longer than 24 h [41], while Park et al. showed that bowel resection constitutes an important factor associated with fatal outcomes. In our study, these continuous variables spearman correlation coefficient is reported with its 95% normality assumption held, otherwise median and IQRs are reported. For mean difference and its 95% confidence interval, estimated by t-test if normality assumption held, otherwise median and IQRs are reported.

**Table 2**

| Surgical Findings and Outcomes | Effect measure (95%CI) | p-value* |
|--------------------------------|------------------------|----------|
| Time from diagnosis to surgery, correlation | -0.274 (-0.5—0.04) | .74 |
| Bowel resection | 4.8 (4.5) | >.99 |
| NOMI | 4 (2.1) | >.99 |
| Vascular | 2.8 (0.6) | .01 |
| Postoperative death day, correlation | -0.407 (-0.6—0.1) | .095 |
| Death on the first postoperative day | 4.15 (3) | .06 |
| Pathology Findings | 7.8 (4.2) | 
| Bowel Necrosis Length in pathology, correlation | 7 (4.2) | .03 |
| Acute Inflammation | 4.75 (4) | >.99 |
| Cellular necrosis in pathology | 8.6 (7) | >.99 |
| Transmural hemorrhage in pathology | 5.9 (5.8) | >.99 |
| Yes | 4 (0.9) | >.99 |
| No | 4.5 (4.9) | >.99 |

COPD: Chronic obstructive pulmonary disease, SLAL: Serum lactate admission levels, WBC: White blood cells, CPR: c-reactive protein, CT: Computed tomography, NOMI: non-obstructive mesenteric ischemia. Effect measure correlates to mean difference and its 95% confidence interval, estimated by t-test if normality assumption held, otherwise median and IQRs are reported. For continuous variables spearman correlation coefficient is reported with its 95% confidence interval. *p-value corrected with the Bonferroni method.

104 patients with AMI, where an association (OR 5.6, p = .002) between necrosis length (>100 cm) and mortality was found [15,38,39].

Prompt diagnosis and surgical management associated with bowel resection constitutes an important factor associated with fatal outcomes in patients with mesenteric ischemia [16,40,41]. In our study, these variables are shown to be determinant factors in the CART model, resembling results reported by Kassahun et al. and Park et al. Kassahun et al. described that intestinal viability is maintained in 100% of patients with symptoms that lasted less than 12 h compared to only 20% viability in those with symptoms that lasted longer than 24 h [41], while Park et al. showed that bowel resection at first or second-look procedure decreased the mortality rate with a relative risk ratio of 0.5 (95%CI, 0.2–0.9) [11].

According to our model, an based on a high suspicion of AMI, in patients with an SLAL below 3.8 mmol/l, survival could be determined by the bowel necrosis length, while for cases with SLAL over 3.8 mmol/l, survival could be determined by a bowel resection performed within 3.5 h after diagnosis. Thus, SLAL might be a potential mortality biomarker for AMI and an objective tool for a patient’s prognosis. Stemming from this, our CART model might be a reliable tool to characterize a patient’s conditions.

**Table 3**

Mortality at 30 post-surgical days- Cross-Tabulation.

| Non-Survivors – 53 (72) n (%) | Survivors – 21 (28) n (%) | Effect measure (95%CI) | p-value* |
|-----------------------------|---------------------------|------------------------|----------|
| Men | 29 (55) | 15 (71) | 1 (Reference) | >.99 |
| Age, mean (SD) | 74 (10) | 71 (12) | 3.28 (9.1-2.5) | >.99 |
| Body Mass Index, mean (SD) | 25 (2.9) | 23 (2.4) | 3.32 (-28-21) | >.99 |

**Comorbidities**

| Smoking tobacco | Yes | 12 (23) | 4 (19) | 1 (Reference) | >.99 |
| No | 41 (77) | 17 (81) | 0.9 (0.3-3.9) | >.99 |
| Alcohol consumption | Yes | 3 (6) | 4 (19) | 1 (Reference) | >.99 |
| No | 50 (94) | 17 (81) | 0.2 (0.06-1.2) | >.99 |
| Hypertension | Yes | 37 (70) | 13 (62) | 1 (Reference) | >.99 |
| No | 16 (30) | 8 (38) | 1.4 (0.4-4.7) | >.99 |
| Diabetes mellitus type II | Yes | 12 (23) | 5 (24) | 1 (Reference) | >.99 |
| No | 41 (77) | 16 (76) | 0.7 (0.2-2.8) | >.99 |
| Peripheric vascular disease | Yes | 12 (23) | 2 (10) | 1 (Reference) | >.99 |
| No | 41 (77) | 19 (90) | 1.8 (0.5-10.1) | >.99 |
| Chronic kidney disease | Yes | 11 (21) | 1 (5) | 1 (Reference) | >.99 |
| No | 42 (79) | 20 (95) | 2.5 (0.6-21.9) | >.99 |
| Atrial fibrillation | Yes | 9 (17) | 3 (14) | 1 (Reference) | >.99 |
| No | 44 (83) | 18 (85) | 0.9 (0.2-4.3) | >.99 |
| COPD | Yes | 10 (19) | 4 (19) | 1 (Reference) | >.99 |
| No | 43 (81) | 17 (81) | 0.7 (0.2-3.2) | >.99 |
| Coronary heart disease | Yes | 5 (9) | 5 (24) | 1 (Reference) | >.99 |
| No | 48 (91) | 16 (76) | 0.2 (0.09-1.2) | >.99 |

**Admission Characteristics**

| Peritoneal signs | Yes | 11 (21) | 6 (29) | 1 (Reference) | >.99 |
| No | 42 (79) | 15 (71) | 0.5 (0.21-1.9) | >.99 |
| Gastrointestinal bleeding | Yes | 18 (34) | 5 (24) | 1 (Reference) | >.99 |
| No | 35 (66) | 16 (76) | 1.6 (0.5-5.7) | >.99 |
| Multigorgan failure | Yes | 42 (81) | 12 (60) | 1 (Reference) | >.99 |
| No | 10 (19) | 8 (40) | 2.7 (0.8-8.7) | >.99 |
| SLAL, median (IQRs) | 6.3 (4.5) | 2.9 (1.3) | .001 |
| Total WBC, median (IQRs) | 14740 (6830) | 12790 | – | >.99 |
| Ph, mean (SD) | 7.2 (0.14) | 7.4 (0.08) | 0.131 (-0.06-0.2) | >.99 |
| Base excess, median (IQRs) | –11.1 (-15.2) | –6.4 (-5.5) | – | >.99 |
| CPR, mean (SD) | 156.2 (139) | 38 (48) | –117.5 (-210-24) | >.99 |

**Marshall Score**

| 1 | 3 (6.5%) | 4 (20) | 3 (0.3-238) | >.99 |
| 2 | 11 (22.9%) | 8 (40) | 2 (0.2-114) | >.99 |
| 3 | 8 (17.3%) | 4 (20) | 1.3 (0.1-88) | >.99 |
| 4 | 5 (10.8%) | 4 (20) | 2 (0.23-142) | >.99 |
| 5 | 2 (4.3%) | 0 | 0 (0.02-97) | >.99 |
| 6 | 5 (10.8%) | 0 | 0 (0.01-40) | >.99 |
| 7 | 5 (10.8%) | 0 | 0 (0.01-40) | >.99 |
| 8 | 4 (8.6%) | 0 | 0 (0.01-40) | >.99 |
| 9 | 3 (6.5%) | 0 | 1 (Reference) | >.99 |

**CT-Scan Findings**

| Bowel Dilatation | Yes | 14 (74) | 6 (60) | 1 (Reference) | >.99 |

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length, bowel resection, and the time from diagnosis to surgery appear postoperative management and most importantly discuss prognosis with the patient and his family.

It is important to take into account that despite SLAL, bowel necrosis length, bowel resection, and the time from diagnosis to surgery appear relevant, only SLAL is a mortality marker in all cases. This difference might be explained by the fact that latter variables are not crucial for the entire population but only for patients with specific profiles shown in the CART. For instance, bowel necrosis length is relevant for patients with SLAL below 3.8 mmol/l but not for those with higher SLAL values. Hence, the CART model is a valuable statistical tool that classifies the population into subgroups and identifies crucial variables for each one, which has never been conducted before regarding AMI research.

On the other hand, our mortality rate was 72%, higher in contrast to other studies [2,11,15,16,42,43]. Differences could be explained by the median time from symptom onset to arrival to the emergency room in our population (24 (IQRs 61) hours). Upon arrival at the emergency room, all the subjects presented abdominal pain while gastrointestinal bleeding and peritonitis signs had a low incidence, which concurs with the classical clinical description of AMI and previously reported data [11,43]. Common comorbidity factors associated with this entity, like diabetes mellitus, arterial hypertension, atrial fibrillation, and peripheral vascular disease, had similar prevalence as reported in other studies [2,11,15,18,43].

In spite of the similar results of vague clinical findings and clinical diagnosis relying on a high suspicion index found in our cases and in the literature, imaging is considered a helpful tool that can be used after careful consideration of time available [1,46]. A computed tomography (CT) scan has a 93% sensitivity and 100% specificity for AMI [1]. In this study, only 38% of cases had a CT-Scan done. Patients with a high clinical suspicion or non immediate availability of CT-Scan were taken directly to surgery. Bowel dilatation was the main finding on the CT-Scan has a 93% sensitivity and 100% specificity for AMI [1]. In this study, only 38% of cases had a CT-Scan done. Patients with a high clinical suspicion or non immediate availability of CT-Scan were taken directly to surgery. Bowel dilatation was the main finding on the CT-Scan has a 93% sensitivity and 100% specificity for AMI [1].

Table 3 (continued)

| Surgical Findings and Outcomes | Non-Survivors − 53 (72) n (%) | Survivors − 21 (28) n (%) | Effect measure (95%CI) | p-value* |
|--------------------------------|-------------------------------|--------------------------|------------------------|---------|
| Time from diagnosis to surgery, median (IQRs) | Bowel necrosis length, median (IQRs) | Bowel resection | | |
| No | 258 (273) | 100 (100) | – | .16 |
| Yes | 22 (42) | 15 (71) | 1 (Reference) | >.99 |
| No | 31 (58) | 6 (29) | 0.2 (0.09–0.85) | >.99 |
| NOMI | Yes | 11 (21) | 1 (Reference) | >.99 |
| No | 42 (79) | 17 (21) | 0.87 (0.31–3.5) | >.99 |
| Vessel Occlusion | Yes | 39 (93) | 9 (53) | 1 (Reference) | >.99 |
| No | 3 (7) | 8 (47) | 0.65 (2.4,4.22) | >.99 |
| Post-surgical death day, median (IQRs) | Yes | 1 (1) | 2 (0) | 1.7 (1.43–10.8) | >.99 |
| No | 35 (67) | 0 (0) | 1 (Reference) | >.99 |
| Pathology Findings | Yes | 110 (100) | 75 (107) | – | >.99 |
| No | 17 (33) | 1 (100) | 0 (0.006–4) | >.99 |
| Acute Inflammation | Yes | 18 (78) | 14 (93) | 1 (Reference) | >.99 |
| No | 5 (22) | 1 (6) | 0.2 (0.05–2) | >.99 |
| Cellular necrosis in pathology | Yes | 18 (78) | 14 (93) | 1 (Reference) | >.99 |
| No | 5 (22) | 1 (6) | 0.2 (0.05–2) | >.99 |
| Transmural hemorrhage in pathology | Yes | 18 (78) | 12 (80) | 1 (Reference) | >.99 |
| No | 5 (22) | 3 (20) | 0.69 (0.2–4.3) | >.99 |

COPD: Chronic obstructive pulmonary disease, SLAL: Serum lactate admission levels, WBC: White blood cells, CPR: c-reactive protein, CT: Computed tomography, NOMI: non-obstructive mesenteric ischemia. Effect measure corresponds to odds ratios for categorical variables and mean difference for continuous variables if normality assumption held, otherwise medians and IQRs are reported. *p-value corrected by the Bonferroni method.

Fig. 1. ROC Curve for mortality prognosis of serum lactate admission levels. Colored scale corresponds to SLAL threshold values. Area under the curve 0.8055, 95% CI 0.6901–0.9209, LR + 3.41 (1.57–7.40), LR− 0.25 (0.13–0.45).
Among the limitations of this study are its retrospective nature, non-systematic measurement of serum lactate levels according to symptoms onset but only on arrival to the emergency department and biased serum lactate levels due to sepsis, shock, impaired liver or kidney function, exposure to toxins, diabetes, or malignancies [37,47].

5. Conclusion

SLAL and bowel necrosis length did not evidence a statistically significant correlation. However, SLAL had the highest importance value in the prediction of mortality using CART with 5 different profiles. Implementation of this new tool, can provide a feasible instrument for prognostic expectations. Nonetheless, given our work limitations, more studies are needed to replicate and validate these results.

Statements

The authors have no relevant financial or non-financial interests to disclose.

The authors have no competing interests to declare that are relevant to the content of this article.

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Ethical approval

Ethical approval was reached.

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Author contribution
D.C Research idea.
D.C, F.G, L.R, A.D Data analysis, manuscript writing.
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Registration of research
1. Name of the registry:
2. Unique Identifying number or registration ID:
3. Hyperlink to your specific registration (must be publicly accessible and will be checked):

Guarantor
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None declared.

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Appendix A. Supplementary data
Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2022.104922.

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