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ORIGINAL ARTICLE

# Intestinal ischemia in patients with incarcerated groin hernia: proposal and validation of a score

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## Abstract

**Purpose** Intestinal ischemia (II) is the most critical factor to determine in patients with incarcerated groin hernia (IGH) because II could be reversible, and it is considered as a "time sensitive condition." Although predictive factors of II were identified in several previous studies, preoperative diagnosis of II cannot be reliably made or excluded by any known parameter. The aims of this study were: to devise and to validate a clinic-biologic score, with a strong discriminatory power, for predicting the risk of II in patients with IGH.

**Methods** We conducted a retrospective bicentric study including 335 patients with IGH. Logistic regression analysis was used to identify independent predictive factors of II. We assigned points for the score according to the regression coefficient. The area under the curve (AUC) was determined using receiver operating characteristic (ROC) curves. The scoring system was then prospectively validated on a second independent population of 45 patients admitted for IGH in the same departments (internal validation).

**Results** Four independent predictive factors of II were identified: heart rate, duration of symptoms before admission, prothrombin, and neutrophil-to-lymphocyte ratio (NLR). A predictive score of II was established based on these independent predictive factors. Sensitivity was 94.50%; specificity was 92.70%. The AUC of this score was 0.97. The AUC was 0.96 when the score was applied on the second population of patients.

**Conclusions** We performed a score to predict the risk of intestinal II with a good accuracy (the AUC of our score was 0.97). This score is reliable and reproducible, so it can help a surgeon to prioritize patients with II for surgery (especially at this time of COVID-19 pandemic), because ischemia could be reversible, avoiding thus intestinal necrosis.

**Keywords** Groin hernia · Incarceration · Intestinal ischemia · Score · Validation

## Introduction

Groin hernia repair is the most common elective operation performed worldwide with over 20 million operations per year [1, 2]. Around 5–15% of hernia patients have incarceration [1].

The management of incarcerated groin hernia (IGH) is still a subject of debate: although the majority of authors indicate an emergent surgery, some authors still indicate a manual reduction of hernia under analgesia/sedation (Taxis) in selected cases; this attitude is of growing interest mainly in this area of COVID-19 [3].

The accurate and early recognition of the presence intestinal ischemia (II) in patients with IGH is important, to plan an early surgical intervention as ischemia could be reversible [4], but delayed diagnosis and intervention can result in higher incidence of bowel resections and postoperative morbidity and mortality [5]. Incarcerated groin hernia, with suspected II should be considered as a "time sensitive condition", and the patients should be prioritized in surgery; in such cases, manual reduction of hernia becomes formally contraindicated.

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Predictive factors of II were identified in several previous studies, but, to date, preoperative diagnosis of II cannot be reliably made or excluded by any known parameter. Thus, the objectives of this study were:

- To devise clinic-biologic score, with a strong discriminatory power, for predicting the risk of II in patients with IGH.
- To validate this score on an independent population (internal validation).

## Material and methods

### Patients

We conducted a bicentric analytic, longitudinal, observational, retrospective cohort study with 335 adult patients undergoing emergency treatment for incarcerated groin hernias (IGH) at Mohamed Tahar Maamouri Hospital, Nabeul, Tunisia and at the department of surgery B23, Charles Nicole Hospital, Tunis, Tunisia, between 2008 and 2017. This study was carried out in compliance with the Declaration of Helsinki and the current ethical guidelines and was approved by the institutional research and ethics board of our hospital. This work was fully compliant with the STROBE criteria.

Exclusion criteria for this study were age younger than 18 years, patients with concomitant bowel disease which can lead to obstruction (colic or rectal tumor, Crohn's disease…), and patients with IGH with spontaneous reduction.

### Data collection

Demographic data, medical history (duration of hernia, previous herniorrhaphy, previous incarceration, and concomitant diseases), duration of symptoms, clinical presentation (symptoms of bowel obstruction, signs of peritonitis, body temperature, skin changes, and heart rate). Preoperative laboratory values including serum chemistry and complete blood count were collected.

Because incarcerated hernia is mainly determined by a clinical diagnosis, other radiologic studies (ultrasonography, a computed tomography scan, and magnetic resonance imaging) were deemed unnecessary [6]. Attempts for the manual reduction of IGH are forbidden in our hospital.

The outcome of ischemic bowel or perforation was confirmed by reviewing intra-operative findings and pathology reports.

Postoperative complications, wound infection and the presence of fistula, the surgical technique used (herniorraphy or mesh repair), the length of hospital stay, and mortality were also recorded.

### Subgroup definitions

Patients with IGH validated during operation as having intestinal ischemia (II), including bowel necrosis, were compared to patients with IGH validated during operation as having no II.

### Statistical analysis

All statistical analyses were carried out using the IBM SPSS Statistics software program, version 22.0 (SPSS Inc., Chicago, Illinois, USA). Continuous variables were presented as the median and range. Categorical variables were presented as numbers and percentages. Univariate analysis was performed with the Student *t* test for continuous variables and with the chi-square test for categorical variables. Logistic regression analysis was used to identify independent predictive factors of II by calculation of odds ratios and its 95% CI. A $p \leq 0.05$ was considered statistically significant. Significant continuous variables were transformed into categorical variables using receiver operating characteristic (ROC) curves. The optimal cut-off point with the highest sum of sensitivity and specificity was chosen for each variable.

### Score derivation

A score was calculated for each patient according to the regression coefficient of variables identified in multivariate analysis. A ROC curve was drawn to assess the ability of the score to predict II. The resulting statistical information was presented using forest plots. The optimal cut-off points of the factors were evaluated using ROC curves. Comparison of the AUC of variables to predict II was performed using Delong test [7] and Hanley and McNeil test [8]. Finally, the patients were divided into three groups: (1) a low-probability group with a low risk of II < 5%; (2) a high-probability group with high risk of II > 90%; and (3) an intermediate-probability group.

### Internal prospective validation

The scoring system was then prospectively validated on a second population of patients admitted for IGH in the department of surgery at Mohamed Tahar Maamouri Hospital from January 2018 until December 2019.

## Results

### Study population

During the study period, a total of 335 patients who underwent emergency operations for IGH, were included. Sex-ratio (men/women) was 4.31. The average age of the patients was 61.46 ± 17.27 years (range 19 to 93 years). The leading concomitant diseases were arterial hypertension (18.50%), diabetes mellitus (9.90%), cardiovascular disorders (10.70%), and chronic obstructive pulmonary disease (4.50%).

The average duration of symptoms before admission was 19.12 h (range 1 to 360 h).

The most common complaint was pain in 326 cases (97.30%), followed by nausea and vomiting in 118 cases (35.20%). On examination, 75 patients had abdominal distention (22.38%); 10 patients had abdominal tenderness (2.98%); and 15 patients had skin changes (2.50%).

The hernia was inguinal in 73.74% of cases and femoral in 26.26% of cases.

At the time of surgery, 73 (21.80%) patients were noted to have ischemic bowel (Fig. 1). Among these patients, 42 patients were successfully managed without intestinal resection because the II was reversible after reintegration of the loop in the abdominal cavity and irrigation of the ischemic loop with warm saline solution, the ischemic bowel improved in color and peristalsis.

Thirty one patients had irreversible ischemia complicated by perforation in 11 cases. Bowel resection was required in these 31 patients (Table 1).

When compared to patients without II, the patients with II had a higher rate of postoperative overall morbidity (24.65% vs. 5.79; $p = 0.0001$), a longer postoperative hospital stay (5.32 ± 0.78 days vs. 1.68 ± 0.14 days; $p = 0.0001$), and a longer total hospital stay (5.88 ± 0.79 days vs. 2.40 ± 0.16 days; $p = 0.0001$).

### Univariate analysis

Univariate analysis identified a number of parameters present at a higher frequency in patients with II (Table 2).

On univariate analysis, II was significantly associated with age ($p = 0.002$), female gender ($p = 0.0001$), arterial hypertension ($p = 0.0001$), diabetes mellitus ($p = 0.033$), cardiac disorders ($p = 0.009$), duration of symptoms before admission ($p = 0.0001$), body temperature ($p = 0.0001$), heart rate ($p = 0.001$), vomiting ($p = 0.0001$), abdominal distention ($p = 0.0001$), abdominal tenderness ($p = 0.001$), bowel obstruction ($p = 0.0001$), skin changes ($p = 0.0001$), femoral hernias ($p = 0.0001$), WBC ($p = 0.01$), neutrophil-to-lymphocyte ratio (NLR) ($p = 0.0001$), urea ($p = 0.0001$), sodium levels ($p = 0.035$), and prothrombin ($p = 0.0001$).

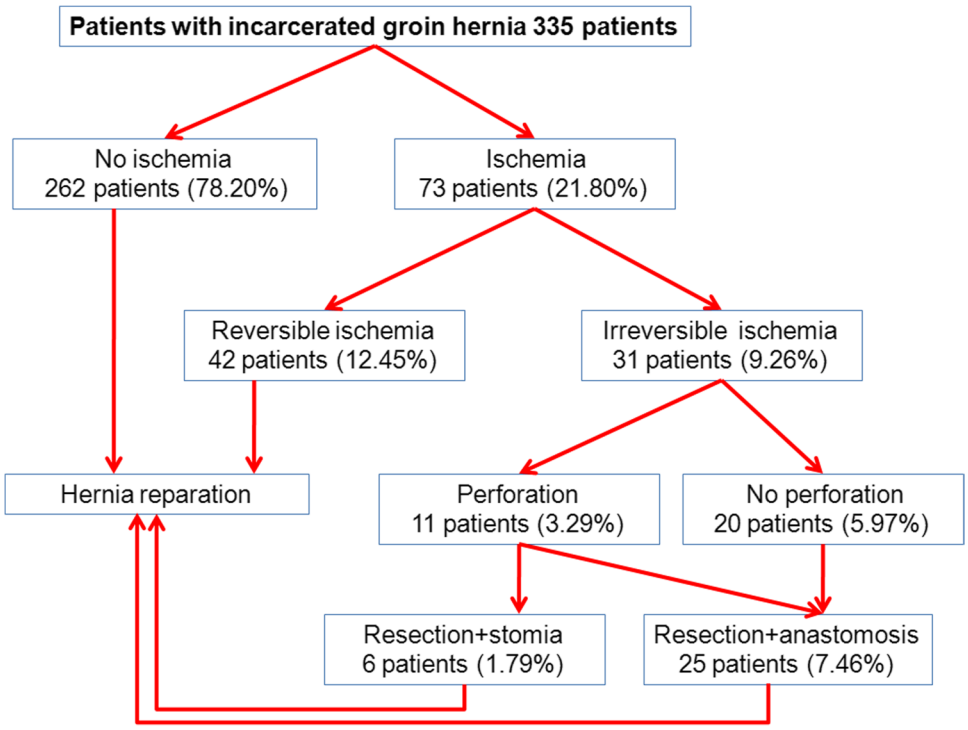


**Fig. 1** Management of patients with incarcerated groin hernia in our departments

**Table 1** Characteristics of the study population and of the internal validation population

| | Study population | Internal validation population |
|---|---|---|
| Department of Surgy | Nabeul/B23 Charles Nicole | Nabeul |
| Study period | 2008–2017 | 2018–2019 |
| Number of cases | 335 | 45 |
| Age (years) | 61.46 (19–93) | 58.38 (20–103) |
| Sex-ratio | 4.31 | 3.50 |
| Diabetes mellitus | 9.90% | 13.30% |
| Arterial hypertension | 18.50% | 11.10% |
| Cardiovascular disorders | 10.70% | 8.90% |
| Pulmonary disease | 4.50% | 4.40% |
| Time from symptoms to admission (hours) | 19.12 (1–360) | 5.80 (1–24) |
| Time from symptoms to operation (hours) | 30.25 (2-–364) | 12.16 (3.5–76) |
| Time from admission to operation (hours) | 11.48 (0–312) | 6.83 (0.5–72) |
| Pain | 97.30% | 100% |
| Vomiting | 35.20% | 33.30% |
| Abdominal distention | 22.38% | 33.30% |
| Abdominal tenderness | 2.98% | 2.20% |
| Skin changes | 2.50% | 2.20% |
| Femoral/inguinal hernia | 26.26%/73.74% | 22.23%/77.77% |
| Bowel ischemia | 21.80% | 17.80% |
| Bowel necrosis | 9.26% | 2.20% |
| Intestinal perforation | 3.29% | 2.20% |
| Intestinal resection + anastomosis | 7.46% | 0% |
| Intestinal resection + stomia | 1.79% | 2.20% |
| Hernioplasty/mesh repair | 90.75%/9.25% | 100%/0% |

## Multivariate analysis

Four independent predictive factors significantly associated with II were identified in multivariate analysis (Table 2).

- Heart rate: OR = 1.20, CI 95% [1.15–1.88].
- Duration of symptoms before admission: OR = 1.09, CI 95% [1.031–1.15].
- Prothrombin: OR = 0.87, CI 95% [1.35–3.45].
- NLR: OR = 2.16, CI 95% [1.01–1.71].

## Discriminative ability of each parameter to predict II

ROC curves were generated for diagnosing II (Fig. 2). Cutoff value of heart rate in diagnosing II was 82.5/min (Fig. 2A). Sensitivity at the cutoff point was 70%, specificity 73%, and the AUC at the cutoff point 0.78. Cutoff value of the duration of symptoms before admission in diagnosing II was 8.5 h (Fig. 2B). Sensitivity at the cutoff point was 75%, specificity 77.5%, and the AUC at the cutoff point 0.76. NLR cutoff value in diagnosing II was 5.32 (Fig. 2C). Sensitivity at the cutoff point was 75.8%, specificity 76.4%, and the AUC at the cutoff point 0.80. Prothrombin cutoff value was 94.5% in predicting the absence of II (Fig. 2D). Sensitivity at the cutoff point was 75.1%, specificity 63.6%, and the AUC at the cutoff point 0.68.

## Elaboration of a score for prediction of II

Significant continuous variables were transformed into categorical variables using receiver operating characteristic (ROC) curves. The optimal cutoff point with the highest sum of sensitivity and specificity was chosen for each variable.

According to the weight of the identified parameters, as estimated by OR of the regression, coefficient points were assigned to each of the 4 variables:

- Heart rate ≥ 82.5/min: 1 point (OR of heart rate = 1.20)
- Duration of symptoms before admission ≥ 8.5 h: 1 point (OR of duration of symptoms = 1.09)
- Prothrombin ≤ 94.5%: 1 point (OR of prothrombin = 0.87)
- NLR ≥ 5.32: 2 points (OR of NLR = 2.16)

The estimated rates of II were calculated for the total scores ranging from 0 to 5. ROC curve was generated to assess the predictive ability of this score for prediction of II (Fig. 3).

**Table 2** Predictive factors of intestinal ischemia in patients with incarcerated groin hernia

| | Intestinal ischemia | No intestinal ischemia | P univariate | P multivariate | OR |
|---|---|---|---|---|---|
| Age (years) | 71.81 ± 1.52 | 58.58 ± 1.06 | 0.02 | Ns | - |
| Female gender | 36.98% | 13.74% | 0.0001 | Ns | - |
| Diabetes | 16.43% | 8.01% | 0.033 | Ns | - |
| Arterial hypertension | 38.35% | 12.97% | 0.0001 | Ns | |
| Cardiac disease | 19.17% | 8.39% | 0.009 | Ns | - |
| Pulmonary disease | 4.58% | 4.10% | 0.86 | - | - |
| Time from symptoms to admission (hours) | 40.93 ± 1.86 | 13.04 ± 4.88 | 0.0001 | 0.0001 | 1.09 |
| Time from admission to operation (hours) | 47.31 ± 5.37 | 25.50 ± 2.73 | 0.054 | - | - |
| Vomiting | 67.12% | 26.33% | 0.0001 | Ns | - |
| Abdominal distention | 55.55% | 14.28% | 0.0001 | Ns | - |
| Temperature (°C) | 37.77 ± 0.37 | 37.11 ± 0.2 | 0.0001 | Ns | - |
| Heart rate/min | 91.84 ± 2.14 | 78.04 ± 0.69 | 0.001 | 0.0001 | 1.20 |
| Abdominal tenderness | 9.72% | 1.14% | 0.001 | Ns | - |
| Bowel obstruction | 53.42% | 10.68% | 0.0001 | Ns | - |
| Skin changes | 17.80% | 0.76% | 0.0001 | Ns | - |
| Femoral hernia | 47.94% | 20.22% | 0.0001 | Ns | - |
| WBC ($\times 10^9$/L) | 13.57 ± 0.64 | 10.40 ± 0.23 | 0.01 | Ns | - |
| NLR | 8.67 ± 0.67 | 4.16 ± 0.19 | 0.0001 | 0.0001 | 2.16 |
| Urea (mmol/L) | 12.97 ± 1.20 | 6.11 ± 0.24 | 0.0001 | Ns | - |
| Sodium (mmol/L) | 136.44 ± 0.66 | 137.41 ± 0.30 | 0.035 | Ns | - |
| Prothrombin (%) | 85.74 ± 2.30 | 94.12 ± 0.85 | 0.0001 | 0.005 | 0.87 |

*OR* odds-ratio, *WBC* white blood count, *min* minutes, *NLR* neutrophil-to-lymphocyte ratio

The optimal cutoff point, with the highest sensitivity and specificity, was for the score of 2.5. Sensitivity at the cutoff point was 94.5%, specificity was 92.7%, and the AUC at the cutoff point was 0.97 (CI 95% [0.95–0.99]).

When compared to each predictive factor of II taken alone, the AUC of our score was significantly higher than the AUC of heart rate (0.97 vs. 0.78; $p < 0.0001$ using Delong test or Hanley and McNeil test), than the AUC of the duration of symptoms before admission (0.97 vs. 0.76; $p < 0.0001$ using Delong test or Hanley and McNeil test), than the AUC of NLR (0.97 vs. 0.80; $p < 0.0001$ using Delong test or Hanley and McNeil test), and higher than the AUC of prothrombin (0.97 vs. 0.68; $p < 0.0001$ using Delong test or Hanley and McNeil test).

Probability categories (low-, intermediate-, or high probability) were then divided using cutoffs to create the low or high incidence of II in each category (Fig. 4):

- A cutoff score of 1 was used for the low-probability group, 1/178 patients had II; PPV in this group was 0.56%; and NPV was 54.14%.
- A score ranging from 2 to 3 defined intermediate probability group, 24/107 patients had II; PPV in this group was 22.40%; and NPV was 78.50%.
- A score ≥ 4 defined high-probability group, 48/50 patients had II; PPV in this group was 96%; and NPV was 91%.

The probability of II is significantly higher in patients in the intermediate probability group when compared to patients in the low probability group (22.43% vs. 0.56%; $p = 0.0001$).

The probability of II is significantly higher in patients in the high probability group when compared to patients in the intermediate probability group (96% vs. 22.43%; $p = 0.0001$).

## Internal validation of the score

The internal validation population consisted of 45 patients operated on IGH, in the department of surgery at Mohamed Tahar Maamouri Hospital, between January 1, 2018 and December 31, 2019. The average age of the patients was 58.38 ± 16.99 years (range 20 to 103 years). Sex-ratio (men/women) was 3.50. About 77.77% of the patients had inguinal hernia. Eight patients had II (17.77%). The II was reversible in 7 patients (15.55%), while one patient had bowel necrosis (Table 1).

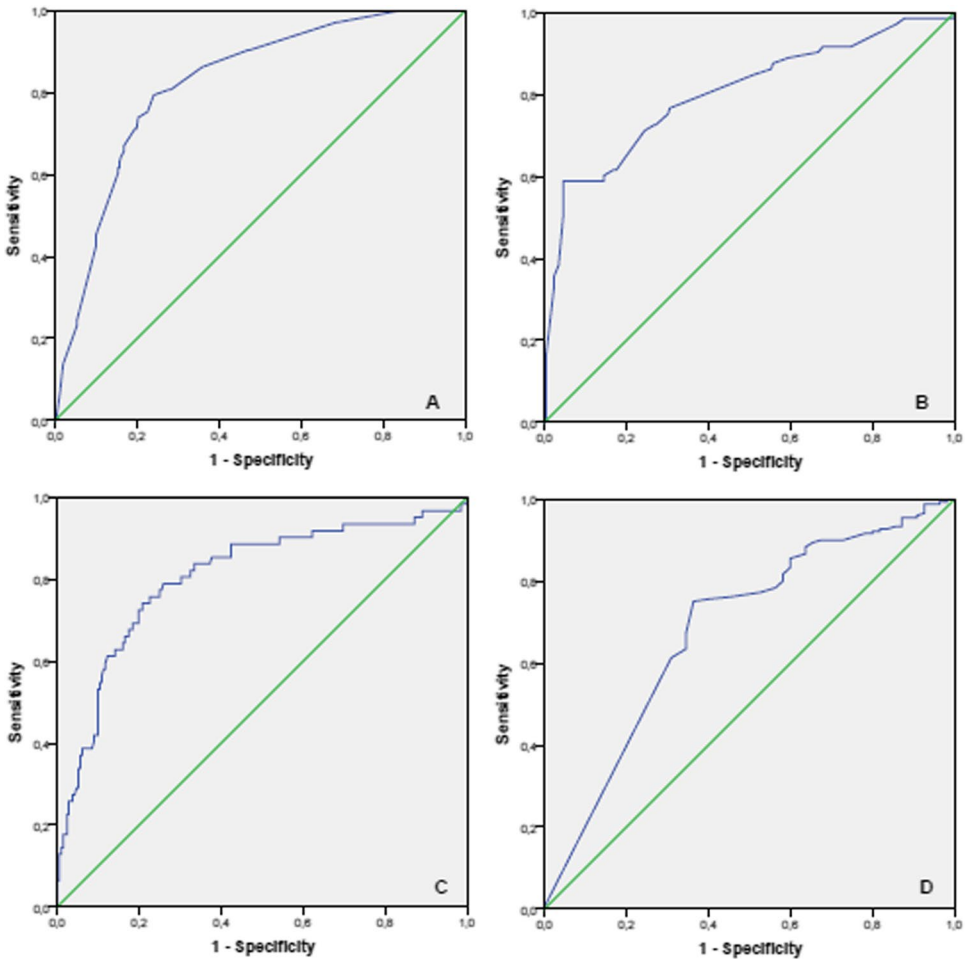


**Fig. 2** A: ROC curve of heart rate in predicting intestinal ischemia. B: ROC curve of the duration of symptoms before admission in predicting intestinal ischemia. C: ROC curve of NLR in predicting intestinal ischemia. D: ROC curve of prothrombin in predicting the absence of intestinal ischemia

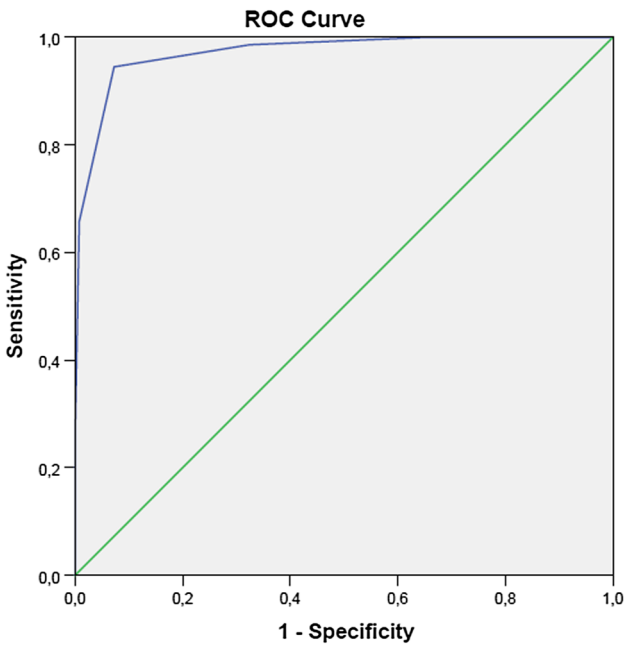


**Fig. 3** ROC curve of our score for predicting intestinal ischemia

Similarly, a total score was then prospectively calculated for each of the 45 patients in the validation population. ROC curve was also generated to validate the predictive ability of this score for prediction of II (Fig. 5).

AUC was 0.96 (CI 95% [0.90–0.99]). The positive predictive value of II in the high-probability group was 100% (6/6 patients), and 9.09% (2/22 patients) in the intermediate probability group, whereas, in the low-probability group, the positive predictive value of II was 0% (0/17 patients).

## Discussion

In the current study, four independent predictive factors of II in patients with IGH were identified: heart rate, duration of symptoms before admission, prothrombin, and NLR.

To date, preoperative diagnosis of II cannot be reliably made or excluded by any known parameter or combination of parameters [9]. This fact was clearly shown in our study: by considering each factor alone; the ability of these factors to predict II can be judged insufficient (the AUC was 0.78 for heart rate, 0.76 for the duration of symptoms, 0.68 for

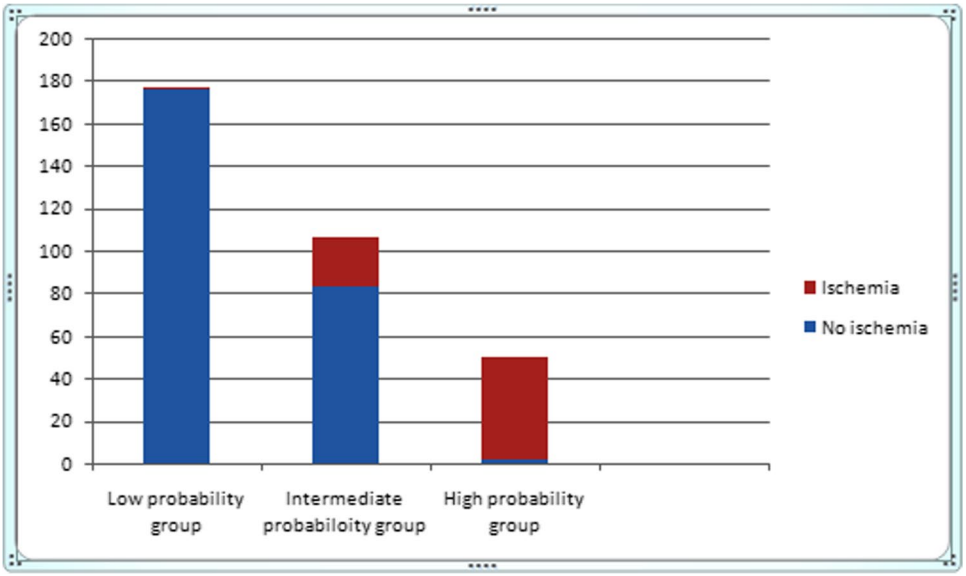


**Fig. 4** Distribution of intestinal ischemia according to probability group

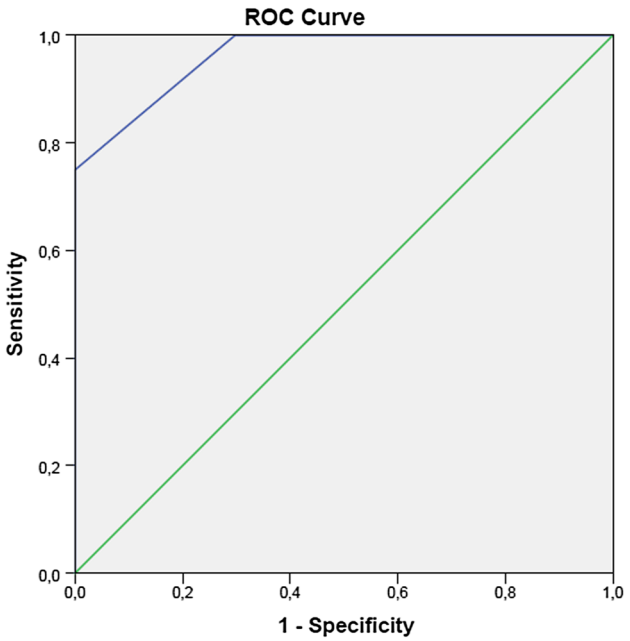


**Fig. 5** ROC curve of our score for predicting intestinal ischemia in the internal validation independent group

prothrombin, and 0.80 for NLR). It was the first study which attempted to establish a clinico-biologic score predicting II. We can say that this score is efficient to predict II, as the AUC was 0.97 with a high sensitivity and specificity at the cutoff point (94.5% and 92.7%, respectively).

In order to evaluate this new scoring system, internal validation was prospectively performed on an independent population.

It has been reported that up to 15% of patients with IGH develop intestinal necrosis requiring surgical resection [10, 11]. The development of bowel necrosis and subsequent bowel resection has been associated with longer hospital stays and worse outcomes for patients with incarcerated groin hernia; indeed, some studies have shown that bowel resection had a direct effect on morbidity and mortality [12, 13].

We think that II is the most critical factor to determine in patients with IGH. Thus, II requires prompt recognition and early intervention to avoid resections, because II could be reversible (42 cases in our study). However, due to limited medical resources in some hospitals, there may be circumstances where a number of patients need emergency surgery simultaneously. In such cases, incarcerated groin hernia, with suspected II should be considered as a "time sensitive condition," and the patients should be prioritized in surgery [14, 15]. Nowadays, at this time of COVID-19 pandemics, some authors consider that reduction of the hernia contents with analgesia/sedation in the emergency setting may be an option worth considering [3]. At times, hospitals and health services have been overwhelmed, in addition to the individual risk to the patient positive for COVID-19 from general anesthesia. So, we think that our score is very helpful to select patients with high risk of II with whom any attempt of reduction should be considered formally contraindicated.

Like our study, several previous publications found a significant correlation between II (and/or strangulation and/or bowel resection) on the one hand, and time from incarceration to admission [1, 10, 13, 16], prothrombin [11], and NLR [1, 14].

Chen et al. [1], in a recent metaanalysis, including seven studies, identified eight predictive factors of bowel resection in patient with incarcerated groin hernia: female sex, age, age (≥65 years), femoral hernia, bowel obstruction, duration of incarceration (hours), white blood cell count, and NLR.

In this metaanalysis, the cutoff point of NLR was 6.5 (5.32 in our study) and the cutoff point of the duration of incarceration was 26 h (8.5 h in our study). These differences could be due to the main outcome which was the need of bowel resection in the study of Chen et al. [1] and bowel ischemia (which could be reversible), in our study.

Xie et al. [17] found that NLR was an independent factor predicting bowel necrosis and resection (the cutoff point was 6.5), and duration of symptoms was also an independent factor of bowel resection (the cutoff point was 26 h).

In the current study, we proposed and validated a clinicobiologic score to predict II in patients with IGH. The association between this score and II was highly predictive, with an AUC of 0.97. Any tests' value for AUC $\geq$ 0.95 is considered to have strong discriminatory power [18]. Our score is most useful in the high- and low-probability groups. The intermediate-probability group requires more careful interpretation.

This study included 335 patients with IGH. To the best of our knowledge, it was the biggest series recorded in the literature. In fact, only one previous metaanalysis, including seven studies recorded 762 patients [1].

This study had some limitations: first as some inflammatory biomarkers were not frequently used in our department such as CRP, procalcitonin, erythrocyte sedimentation, and lactate. Second as CT-scan was not used in front of an IGH in our department.

## Conclusions

Four independent predictive factors of II in patients with IGH were identified: heart rate, duration of symptoms before admission, prothrombin, and NLR. We elaborated and validated the first predicting model which can help in evaluating the risk of II in patients with IGH, and thus, this would help the surgeon in prioritizing patients with II for an emergent surgery to avoid intestinal necrosis and to decrease the need of intestinal resections, especially at this time of COVID-19 pandemic.

**Authors' contributions** Mahdi Bouassida, Mohamed Wejih Dougaz, and Hazem Beji did the conception and the design of the work. Haroun Guermazi, Slim Zribi, Neirouz Kammoun, Ibtissem Bouasker, and Mohamed Mongi Mighri did the acquisition and the analysis of the data. Ramzi Nuouira, Hassen Touinsi revised the work critically.

## Declarations

**Competing interests** The authors declare no competing interests.

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