# Predictivity of aspartate aminotransferase to alanine aminotransferase (De Ritis) ratio for detecting bowel necrosis in incarcerated inguinal hernia patients

*Predicción de la proporción de aspartato aminotransferasa a alanina aminotransferasa (De Ritis) para detectar necrosis intestinal en pacientes con hernia inguinal incarcerada*

Umit Turan[1] and Ahmet Baris-Dirim[2]*

[1]Department of General Surgery, Adana City Research and Training Hospital, Adana; [2]Department of General Surgery, Balıklıgol Government Hospital, Sanlıurfa. Turkey

## Abstract

**Purpose:** *Early diagnosis of necrotic bowel segment resulting from incarcerated inguinal hernia (IIH) is crucial for reducing morbidity and mortality. The aim of this study was to investigate the efficacy of the De Ritis ratio (DRR), also known as the ratio of aspartate aminotransferase to alanine aminotransferase, as a biomarker for intestinal necrosis.* **Methods:** *This retrospective study included 132 patients who underwent emergency surgery for IIH. Patients were divided into two groups: those who underwent bowel resection for necrosis (Group 1) and those who did not (Group 2). Patients' demographic and clinical data were recorded. Using laboratory test results, DRR, neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), lymphocyte-to-monocyte ratio (LMR), and lymphocyte-to-CRP ratio (LCR) were calculated.* **Results:** *The morbidity and mortality rates and the length of stay for Group 1 were statistically significantly different (p < 0.0001). The DRR, NLR, PLR, LMR, and LCR values of the same group were also significantly different (p < 0.05).* **Conclusion:** *DRR can be used as a biomarker for early diagnosis of bowel necrosis in patients with IIH.*

**Keywords:** *De Ritis ratio. Bowel necrosis. Incarcerated. Inguinal. Hernia.*

## Resumen

**Antecedentes:** *El diagnóstico temprano del segmento intestinal necrótico resultante de una hernia inguinal incarcerada es crucial para reducir la morbilidad y la mortalidad.* **Objetivo:** *Investigar la eficacia del índice de De Ritis (IDR), también conocido como cociente de aspartato aminotransferasa a alanina aminotransferasa, como biomarcador de necrosis intestinal.* **Método:** *Estudio retrospectivo que incluyó a 132 pacientes que fueron intervenidos de urgencia por hernia inguinal incarcerada. Los pacientes se dividieron en dos grupos: los que se sometieron a resección intestinal por necrosis (grupo 1) y los que no (grupo 2). Se registraron los datos demográficos y clínicos de los pacientes. Usando los resultados de las pruebas de laboratorio, se calcularon el IDR, el índice neutrófilos-linfocitos (INL), el índice plaquetas-linfocitos (IPL), el índice linfocitos-monocitos (ILM) y el índice linfocitos-proteína C reactiva (ILPCR).* **Resultados:** *Las tasas de morbilidad, mortalidad y duración de la estancia para el grupo 1 fueron estadísticamente significativas (p < 0.0001). Los valores de IDR, INL, IPL, ILM, ILPCR del mismo grupo también fueron significativamente diferentes (p < 0.05).* **Conclusiones:** *El IDR puede utilizarse como biomarcador para el diagnóstico precoz de necrosis intestinal en pacientes con hernia inguinal incarcerada.*

**Palabras clave:** *Índice de De Ritis. Necrosis intestinal. Incarcerado. Inguinal. Hernia.*

# Introduction

Inguinal hernia repair is one of the most frequently performed surgical operations in general surgery practice. Inguinal hernias usually require emergency surgery if any serious complications develop. The most common complications include incarceration, strangulation, and obstruction[1]. Of patients with inguinal hernia, 10-15% require surgery for incarceration and about 15% require resection for intestinal necrosis due to strangulation[1-3]. Bowel necrosis is the most significant factor that predicts morbidity and mortality in incarcerated hernias[4]. The reported risk factors for intestinal necrosis are female gender, advanced age (> 65 years), intestinal obstruction, and femoral hernia[5]. Previous studies have reported a morbidity rate ranging from 6% to 43%, and a mortality rate ranging from 1% to 7% in patients operated for incarcerated inguinal hernia (IIH)[1,5-7]. In cases of IIH requiring emergency surgery, the time from incarceration to operation is the major prognostic factor for morbidity and mortality[7]. Therefore, early diagnosis and treatment of intestinal necrosis caused by incarcerated hernias are critical for reducing morbidity and mortality.

De Ritis ratio (DRR) was first described by Fernando De Ritis in 1957 to differentiate viral hepatitis from other icteric and anicteric liver diseases[8]. Aspartate aminotransferase (AST) is predominantly expressed in mitochondria and is abundantly present in many organs including the liver, kidney, brain, heart, and skeletal musculature, while alanine aminotransferase (ALT) is mainly found in the hepatocyte cytoplasm[9]. These two enzymes play critical roles in biological processes and reflect the link between protein and carbohydrate metabolisms[10]. These enzymes are normally released into plasma at a constant rate in healthy humans depending on the programmed hepatocyte regeneration, with a DRR of approximately 1[11]. In clinical conditions such as intestinal ischemia, where oxidative stress and mitochondrial damage occur, there is an increase in possible hepatocyte damage, altering the ratios of AST and ALT measured in blood[12].

Complete blood count (CBC) and biochemical tests such as white blood cell (WBC), neutrophil count, and C-reactive protein (CRP) have traditionally been used as markers of systemic inflammation. There are recent studies demonstrating the feasibility of neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), lymphocyte-to-monocyte ratio (LMR), and lymphocyte-to-CRP (LCR) parameters as good markers of systemic inflammation[13-15]. Yildirim et al. reported that LCR could be used as a marker of intestinal necrosis in incarcerated hernias[16], while Xie et al.[17] reported that NLR could be used for the same purpose.

The primary aim of this study was to investigate the efficacy of DRR as an inflammatory marker for detecting intestinal necrosis in IIHs and to compare the efficacy of preoperatively measured systemic inflammatory markers with DRR for predicting intestinal necrosis.

## Materials and methods

This single-center retrospective cohort study included patients who underwent an emergency operation for IIH in the General Surgery Clinic between March 11, 2015, and July 25, 2021. Only the data of patients who underwent open surgery were analyzed from the hospital data system. Patients' age, gender, hernia type, whether bowel resection was performed, mesh use, post-operative complications, length of hospital stay, and mortality status were evaluated. Moreover, CBC parameters such as WBC, platelet, neutrophil, and lymphocyte counts and biochemical parameters of AST, ALT, and CRP were recorded at the time of admission to the emergency department. NLR, PLR, LMR, LCR, and DRR were calculated using these parameters. Patients were divided into two groups: those who underwent bowel resection for necrosis (Group 1) and those who did not (Group 2). These groups were statistically compared by calculated systemic inflammatory markers and biochemical parameters to investigate their efficacy for determining intestinal necrosis.

Based on the evaluation of clinical, laboratory, and imaging examinations at emergency admission, patients with IIH who were eligible for TAXIS (a manual reduction of hernia under analgesia/sedation) procedure were attempted to be treated with reduction under analgesia and sedation, and those who achieved reduction were observed in the surgical unit for 24-48 h. Asymptomatic patients were discharged and scheduled for an elective operation. Patients with an unsuccessful TAXIS procedure underwent an emergency operation.

In the operation, bowel resection was performed on patients with intestinal necrosis due to strangulation, and mesh was used for hernia repair depending

upon the surgeon's preference. Patients undergoing laparoscopic surgery, aged < 18 years, having a recurrent inguinal hernia, scheduled for emergency surgery for reasons other than incarceration, and those with missing blood results were excluded from the study.

This study was approved by the Institutional Review Board with the approval number 86/1509. The study has been reported in line with the Strengthening The Reporting of Cohort Studies in Surgery criteria[18].

## Statistical analysis

The statistical analyses of the study were carried out using the Statistical Package for the Social Sciences version 25 software. The Chi-square test was used to compare categorical variables between the groups. The Shapiro–Wilk normality test was used to check the normality distribution of continuous variables. The nonparametric Mann–Whitney U test was used to compare non-normally distributed continuous variables. The student's t-test was used if continuous variables were normally distributed.

The cutoff value of inflammatory markers for detecting necrosis was evaluated by the receiver operating characteristic (ROC) analysis. The area under the curve (AUC), ROC curves, and 95% confidence interval (CI) of the AUC were calculated. $p < 0.05$ was considered statistically significant.

## Results

The mean age of the 132 patients who were operated for IIH was 61.7 (± 18.3) years. Of the patients, 111 (84.1%) had inguinal hernias and 21 (15.9%) had femoral hernias. Thirty-five patients (26.5%) had developed early post-operative complications, and 10 patients died (7.6%).

There were 45 patients (34.1%) (8 female and 37 male patients) in Group 1 (resection group) and 87 patients (65.9%) (11 female and 76 male patients) in Group 2 (non-resection group). While the mean age of the patients in Group 1 was 66.7 (± 19.4) years, the mean age of the patients in Group 2 was 59.2 (± 17.3). Although there was no statistically significant difference, the mean age and male sex ratio of the patients in Group 1 were higher ($p = 0.346$ and $p = 0.426$, respectively).

There was a statistically significant difference between the two groups in terms of morbidity, mortality, mesh use, and length of hospital stay ($p < 0.001$, $p < 0.001$, $p < 0.001$, and $p < 0.001$, respectively). While the morbidity and mortality rates were higher and the length of hospital stay was longer in Group 1, the rate of mesh use was higher in Group 2. Table 1 illustrates detailed information on the demographic and clinical parameters of the patients.

In Group 1 patients, the morbidity rate was 51.1%. The most common complication was infection with 22.2%, and the mean length of hospital stay was 9.3 (± 8.2) days. In Group 2 patients, the morbidity rate was 14.9%. Pulmonary complications (4.6%) and wound site hematoma (4.6%) were the most common complications, and the mean length of hospital stay was 3.8 (± 3) days.

Of the 10 patients (7.6%) who postoperatively died, 6 were male and 4 were female, with a mean age of 76.7 (± 13.6) years. Nine of these patients were in the resection group, and 3 of them had femoral hernias. One patient had a positive test result for COVID-19 in the post-operative period and died from pulmonary complications on day 13 of hospitalization. One patient in the non-resection group had severe heart failure and died at the third post-operative hour. Table 2 shows the clinical information of the patients who postoperatively died.

The median (± IQRs) values of inflammatory markers at diagnosis were as follows: WBC, 12.05 (8.5-15.5) in Group 1 and 9.3 (7.2-12.5) in Group 2; CRP, 8.4 (1.5-17.9) in Group 1 and 2.1 (0.9-6.5) in Group 2; NLR, 9.25 (6.2-15.7) in Group 1 and 3.9 (2.6-7.9) in Group 2; PLR, 279.37 (145.2-427.4) in Group 1 and 160.5 (118-206.6) in Group 2; LMR, 1.475 (0.8-2.5) in Group 1 and 2.39 (1.5-3.2) in Group 2; LCR, 0.121 (0.05-0.4) in Group 1 and 0.76 (0.2-1.7) in Group 2; and DRR, 1.945 (1.3-2.2) in Group 1 and 1.36 (1.05-1.7) in Group 2. The comparison of these values showed a statistically significant difference between the two groups ($p = 0.027$, $p = 0.04$, $p < 0.0001$, $p < 0.0001$, $p = 0.001$, $p < 0.0001$, and $p = 0.001$, respectively) (Table 3).

The comparison of inflammatory markers by ROC analysis results showed NLR, PLR, and DRR as the most significant markers for predicting bowel necrosis (AUC = 0.767, 0.697, 0.684, and respectively). The ROC analysis results of these three markers are shown in Figure 1.

A DRR cutoff value of 1.94 had a sensitivity of 50% and a specificity of 83.9% (AUC, 0.684; 95% CI, 0.588-0.781; $p = 0.001$), an NLR cutoff value of 6.66 had a sensitivity of 71.1% and a specificity of 92%

**Table 1. Comparative demographic and clinical characteristics of patients who underwent emergency inguinal hernia surgery**

| Characteristics | Total<br>n = 132 (%) | Group 1<br>(with intestinal resection)<br>n = 45 (34.1%) | Group 2<br>(without intestinal resection)<br>n = 87 (65.9%) | p-value |
|---|---|---|---|---|
| Age, mean year (± SD) | 61.7 (± 18.3) | 66.7 (± 19.4) | 59.2 (± 17.3) | 0.346* |
| Gender | | | | |
| Male | 113 (85.6) | 37 (82.2) | 76 (87.4) | 0.426† |
| Female | 19 (14.4) | 8 (17.8) | 11 (12.6) | |
| Post-operative complications | | | | |
| Enfection | 12 (9.1) | 10 (22.2) | 2 (2.3) | **< 0.0001†** |
| Pulmonary | 10 (7.6) | 6 (13.3) | 4 (4.6) | |
| Hematoma | 6 (4.5) | 2 (4.4) | 4 (4.6) | |
| Seroma | 4 (3.0) | 2 (4.4) | 2 (2.3) | |
| Cardiac | 3 (2.3) | 2 (4.4) | 1 (1.1) | |
| Morbidity | | | | |
| Yes | 36 (27.3) | 23 (51.1) | 13 (14.9) | **< 0.0001†** |
| No | 96 (72.7) | 22 (48.9) | 74 (85.1) | |
| Hernia type | | | | |
| Inguinal | 111 (84.1) | 36 (80) | 75 (86.2) | 0.355† |
| Femoral | 21 (15.9) | 9 (20) | 12 (13.8) | |
| Mesh | | | | |
| Yes | 81 (61.4) | 16 (35.6) | 65 (74.7) | **< 0.0001†** |
| No | 51 (38.6) | 29 (64.4) | 22 (25.3) | |
| Mortality | | | | |
| Yes | 10 (7.6) | 9 (20) | 1 (1.1) | **< 0.0001†** |
| No | 122 (92.4) | 36 (80) | 86 (98.9) | |
| Length of hospital stay, mean day (± SD) | 5.68 (± 6) | 9.3 (± 8.2) | 3.8 (± 3) | **< 0.0001*** |

*Mann–Whitney U test.
†Pearson Chi square test.
Bold fonts designate statistical significance.

**Table 2. Characteristics of patients who underwent emergency inguinal hernia surgery with post-operative mortality**

| Patients | Gender | Age (year) | Hernia type | Comorbidity | Surgical Procedure | Morbidity | Length of hospital stay (day) |
|---|---|---|---|---|---|---|---|
| 1. | Male | 91 | Femoral | Cardiac | SSBRA | Pulmonary (COVID test result positivity) | 13 |
| 2. | Male | 75 | İnguinal | Pulmonary | SSBRA | Sepsis | 2 |
| 3. | Female | 89 | Femoral | Cardiac | SSBRI | Neurological | 42 |
| 4. | Male | 45 | İnguinal | - | SSBRI | Sepsis | 2 |
| 5. | Male | 78 | İnguinal | Cardiac | - | Cardiac | 3 h |
| 6. | Male | 63 | İnguinal | - | SSBRI | Sepsis | 12 |
| 7. | Male | 83 | Femoral | Diabetes, Cardiac | SSBRA | Cardiac | 2 |
| 8. | Male | 76 | İnguinal | Cardiac | SSBRA | Pulmonary | 9 |
| 9. | Female | 84 | İnguinal | Cardiac | SSBRA | Pulmonary | 18 |
| 10. | Female | 85 | İnguinal | Renal, Cardiac | SSBRA | Pulmonary | 11 |

SSBRA: segmenter small bowel resection and anastomosis; SSBRI: segmenter small bowel resection and ileostomy.

(AUC, 0.768; 95% CI, 0.681-0.855; p < 0.0001), and a PLR cutoff value of 289.1 had a sensitivity of 51.1% and a specificity of 92% (AUC, 0.703; 95% CI, 0.602-0.804; p < 0.0001) for predicting necrosis in patients with IIH undergoing small bowel resection (Table 4).
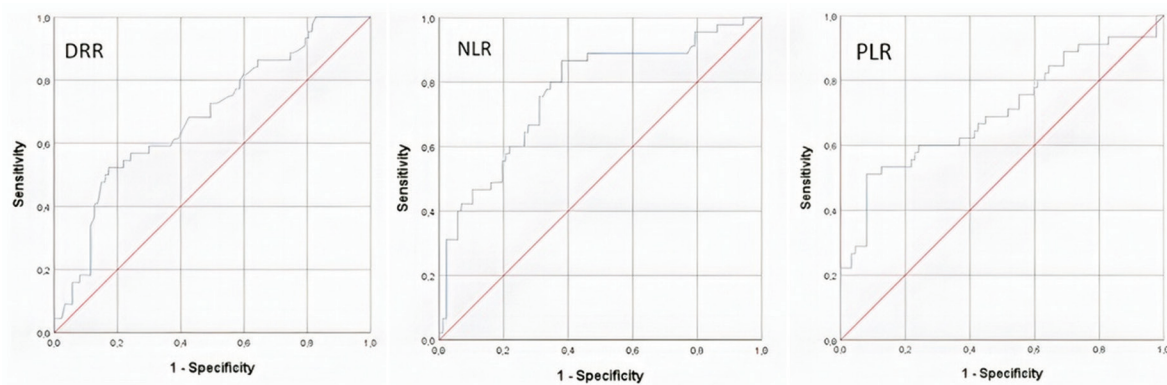
**Figure 1.** *ROC analysis for De Ritis ratio, neutrophil-to-lymphocyte ratio, and platelet-to-lymphocyte ratio.*

**Table 3. Comparison of the laboratory test results of the groups at the time of diagnosis**

| Inflammatory marker | Group I (with intestinal resection) n: 45 Median (± IQRs) | Group II (without intestinal resection) n: 87 Median (± IQRs) | p |
|---|---|---|---|
| WBC | 12.05 (8.5-15.5) | 9.3 (7.2-12.5) | **0.027*** |
| CRP (mg/dL) | 8.4 (1.5-17.9) | 2.1 (0.9-6.5) | **0.04*** |
| NLR | 9.25 (6.2-15.7) | 3.9 (2.6-7.9) | **< 0.0001*** |
| PLR | 279.37 (145.2-427.4) | 160.5 (118-206.6) | **< 0.0001*** |
| LMR | 1.475 (0.8-2.5) | 2.39 (1.5-3.2) | **0.001*** |
| LCR | 0.121 (0.05-0.4) | 0.76 (0.2-1.7) | **< 0.0001*** |
| DRR | 1.945 (1.3-2.2) | 1.36 (1.05-1.7) | **0.001*** |

Bold fonts designate statistical significance.
*Mann–Whitney U test.
IQRs: interquartile ranges; NLR: neutrophil-to-lymphocyte ratio; PLR: platelet-to-lymphocyte ratio; LMR: lymphocyte-to-monocyte ratio; LCR: lymphocyte-to-CRP ratio; DRR: De Ritis ratio.

**Table 4. ROC curve results and sensitivity and specificity values**

| Values | NLR | PLR | DRR |
|---|---|---|---|
| Cutoff | 6.66 | 289.10 | 1.94 |
| p-value | < 0.0001 | < 0.0001 | 0.001 |
| AUC (95% CI) | 0.768 (0.681-0.855) | 0.703 (0.602-0.804) | 0.684 (0.588-0.781) |

CI: confidence interval.

## Discussion

An incarcerated hernia is the entrapment of abdominal tissue within the hernial sac. The risk of strangulation due to incarceration increases as the emergency surgery is delayed. Perforation and sepsis may develop secondary to necrosis, leading to a life-threatening clinical situation[6].

Comorbid diseases and post-operative mortality increase with age[19]. In this study, the mean age of the resection group was higher than that of the non-resection group, while the rate of femoral hernia was lower. Both of these results contradict some reported literature data[16,17]. This is thought to be due to the fact that elective inguinal hernia surgeries may have been postponed due to the number of increased comorbid diseases with age and the COVID-19 pandemic.

Previous studies have reported that emergency hernia surgery was performed more frequently in men and bowel necrosis was higher in women. In the current study, emergency hernia repair and bowel resection were performed more frequently in male patients[20,21]. The rate of mesh use was significantly higher in Group 2 patients who did not undergo bowel resection (p < 0.0001). This can be attributed to not preferring the use of mesh in Group 1 patients due to the risk of infection by the surgeon.

In the present study, the rate of performing bowel resection was 34.1% among patients with IIH who underwent emergency surgery, and the mortality rate

was 7.6%, which was higher than those reported in the literature[1,16]. This high mortality rate may be due to the fact that our hospital is a tertiary referral center serving a population of 4.5 million people, where complicated patients are referred for management, and that the study period covers approximately 1.5 years of the COVID-19 pandemic when hospital admissions were delayed[1,22].

In the case of inflammation, an increase in neutrophil count, accordingly associated lymphopenia, and an increase in CRP levels are expected[16]. Most of the previous studies conducted to predict bowel necrosis have focused on acute mesenteric ischemia, reporting that CRP, WBC, and NLR values are significant for prognosis[23,24]. Performing bowel resection for necrosis in incarcerated hernias increases post-operative morbidity and length of hospital stay, as in our study[2].

The present study demonstrates the feasibility of a novel biomarker, DRR, as an inflammatory biomarker for early prediction of bowel necrosis in patients with IIH, unlike the literature data reported so far. In addition to DRR, the resection group had significantly different WBC, CRP, NLR, PLR, LMR, and LCR values, which is consistent with the literature data.

In some studies, an increased DRR has been associated with the prognosis of urothelial carcinoma, cholangiocarcinoma, renal cell carcinoma, gastric adenocarcinoma, and head-and-neck cancer[25-30]. Cancer cells exhibit a higher rate of aerobic glycolysis in order to multiply faster than normal cells[31]. AST plays an essential role in the mitochondrial displacement of nicotinamide adenine dinucleotide hydrogen in aerobic glycolysis via the malate aspartate shuttle[10]. Therefore, an increase is observed in AST activation of fast-growing tissues such as cancer cells[32]. Some studies have also used DRR to predict the risk of liver fibrosis and liver damage secondary to the hepatitis C virus[33,34].

Weng et al. found that an increased DRR was independently associated with the risk of developing cardiovascular disease, especially in men[35]. An elevated serum AST level is also an important marker in systemic conditions such as metabolic syndrome, sarcopenia, and increased oxidative stress, which are risk factors for mortality apart from liver damage[36]. Elinav et al. found a decrease in ALT levels, especially in men over 70 years of age, throughout a 12-year follow-up period, reporting that it was significantly associated with mortality, although multivariate regression analysis revealed that diabetes, chronic renal failure, and malignancy were strong predictors of mortality[37].

We think that the higher male ratio and the higher mean age of patients in the resection group than the non-resection group in the present study may be associated with increased DRR, which is in line with the literature data, indicating that ALT values may be decreased in the male gender and elderly population[37].

Although we cannot clearly reveal the underlying mechanism of increased DRR for predicting intestinal necrosis in light of the literature, we can consider that the development of intestinal necrosis may have triggered the dysfunction of the hepatic inflammatory pathway activated by catecholamines at the mitochondrial level, leading to liver damage with increased oxidative stress[38,39].

This study has some limitations. First, the study has a retrospective design. Second, it was not known whether the patients included in the study had a history of liver disease. However, this study is the first to propose that the DRR can be used as a predictor of bowel necrosis in IIHs. In this sense, we believe that our work is valuable.

## Conclusion

Based on all clinical findings, laboratory and radiological imaging results obtained by the examination of patients with IIH, the prognosis can be predicted and a decision can be made. We are of the opinion that in addition to the examination findings to predict bowel necrosis, monitoring the DRR with serial AST and ALT measurements during the follow-up when radiological imaging fails to provide adequate results or after manual reduction of the hernia is successful may shorten the diagnosis time and speed up the surgical intervention in these patients.

## Funding

## Conflicts of interest

The authors declare no conflicts of interest.

## Ethical disclosures

**Protection of human and animal subjects.** The authors declare that no experiments were performed on humans or animals for this study.

**Confidentiality of data.** The authors declare that no patient data appear in this article.

**Right to privacy and informed consent.** Right to privacy and informed consent. The authors have obtained approval from the Ethics Committee for analysis and publication of routinely acquired clinical data and informed consent was not required for this retrospective observational study.

## References

1. Kurt N, Oncel M, Ozkan Z, Bingul S. Risk and outcome of bowel resection in patients with incarcerated groin hernias: retrospective study. World J Surg. 2003;27:741-3.
2. Kulah B, Kulacoglu IH, Oruc MT, Duzgun AP, Moran M, Ozmen MM, et al. Presentation and outcome of incarcerated external hernias in adults. Am J Surg. 2001;181:101-4.
3. Bekoe S. Prospective analysis of the management of incarcerated and strangulated inguinal hernias. Am J Surg. 1973;126:665-8.
4. Dai W, Chen Z, Zuo J, Tan J, Tan M, Yuan Y. Risk factors of postoperative complications after emergency repair of incarcerated groin hernia for adult patients: a retrospective cohort study. Hernia. 2019;23:267-76.
5. Chen P, Huang L, Yang W, He D, Liu X, Wang Y, et al. Risk factors for bowel resection among patients with incarcerated groin hernias: a meta-analysis. Am J Emerg Med. 2020;38:376-83.
6. Ge BJ, Huang Q, Liu LM, Bian HP, Fan YZ. Risk factors for bowel resection and outcome in patients with incarcerated groin hernias. Hernia. 2010;14:259-64.
7. Koizumi M, Sata N, Kaneda Y, Endo K, Sasanuma H, Sakuma Y, et al. Optimal timeline for emergency surgery in patients with strangulated groin hernias. Hernia. 2014;18:845-8.
8. De Ritis F, Coltorti M, Giusti G. An enzymic test for the diagnosis of viral hepatitis: the transaminase serum activities. 1957. Clin Chim Acta. 2006;369:148-52.
9. Botros M, Sikaris KA. The de ritis ratio: the test of time. Clin Biochem Rev. 2013;34:117-30.
10. Sookoian S, Pirola CJ. Liver enzymes, metabolomics and genome-wide association studies: from systems biology to the personalized medicine. World J Gastroenterol. 2015;21:711-25.
11. Horiuchi S, Kamimoto Y, Morino Y. Hepatic clearance of rat liver aspartate aminotransferase isozymes: evidence for endocytotic uptake via different binding sites on sinusoidal liver cells. Hepatology. 1985;5:376-82.
12. Kojima H, Sakurai S, Uemura M, Fukui H, Morimoto H, Tamagawa Y. Mitochondrial abnormality and oxidative stress in nonalcoholic steatohepatitis. Alcohol Clin Exp Res. 2007;31(1 Suppl):S61-6.
13. Yao C, Liu X, Tang Z. Prognostic role of neutrophil-lymphocyte ratio and platelet-lymphocyte ratio for hospital mortality in patients with AECOPD. Int J Chron Obstruct Pulmon Dis. 2017;12:2285-90.
14. Zhuo Y, Cai D, Chen J, Zhang Q, Li X. Pre-surgical peripheral blood inflammation markers predict surgical site infection following mesh repair of groin hernia. Medicine (Baltimore). 2021;100:e25007.
15. Batur AF, Aydogan MF, Kilic O, Korez MK, Gul M, Kaynar M, et al. Comparison of De Ritis Ratio and other systemic inflammatory parameters for the prediction of prognosis of patients with transitional cell bladder cancer. Int J Clin Pract. 2021;75:e13743.
16. Yildirim M, Dasiran F, Angin YS, Okan I. Lymphocyte-C-reactive protein ratio: a putative predictive factor for intestinal ischemia in strangulated abdominal wall hernias. Hernia. 2021;25:733-9.
17. Xie X, Feng S, Tang Z, Chen L, Huang Y, Yang X. Neutrophil-to-lymphocyte ratio predicts the severity of ıncarcerated groin hernia. Med Sci Monit. 2017;23:5558-63.
18. Agha R, Abdall-Razak A, Crossley E, Dowlut N, Iosifdis C, Mathew G, et al. The STROCSS 2019 guideline: strengthening the reporting of cohort studies in surgery. Int J Surg. 2019;72:156-65.
19. Martínez-Serrano MA, Pereira JA, Sancho J, Argudo N, López-Cano M, Grande L. Specific improvement measures to reduce complications and mortality after urgent surgery in complicated abdominal wall hernia. Hernia. 2012;16:171-7.
20. Oishi SN, Page CP, Schwesinger WH. Complicated presentations of groin hernias. Am J Surg. 1991;162:568-70; discussion 571.
21. Heydorn WH, Velanovich V. A five-year US army experience with 36,250 abdominal hernia repairs. Am Surg. 1990;56:596-600.
22. Turan U, Dirim AB. The effects of COVID-19 pandemic on emergency anterior abdominal wall hernia surgery: is it safe to postpone elective hernia surgery in the pandemic? Eur J Trauma Emerg Surg. 2021;48:833-9.
23. Tanrıkulu Y, Tanrıkulu CS, Sabuncuoğlu MZ, Temiz A, Köktürk F, Yalçın B. Diagnostic utility of the neutrophil-lymphocyte ratio in patients with acute mesenteric ischemia: a retrospective cohort study. Ulus Travma Acil Cerrahi Derg. 2016;22:344-9.
24. Aktimur R, Cetinkunar S, Yildirim K, Aktimur SH, Ugurlucan M, Ozlem N. Neutrophil-to-lymphocyte ratio as a diagnostic biomarker for the diagnosis of acute mesenteric ischemia. Eur J Trauma Emerg Surg. 2016;42:363-8.
25. Tan X, Xiao K, Liu W, Chang S, Zhang T, Tang H. Prognostic factors of distal cholangiocarcinoma after curative surgery: a series of 84 cases. Hepatogastroenterology. 2013;60:1892-5.
26. Bezan A, Mrsic E, Krieger D, Stojakovic T, Pummer K, Zigeuner R, et al. The preoperative AST/ALT (De Ritis) ratio represents a poor prognostic factor in a cohort of patients with nonmetastatic renal cell carcinoma. J Urol. 2015;194:30-5.
27. Lee H, Choi YH, Sung HH, Han DH, Jeon HG, Jeong BC, et al. De Ritis Ratio (AST/ALT) as a significant prognostic factor in patients with upper tract urothelial cancer treated with surgery. Clin Genitourin Cancer. 2017;15:e379-85.
28. Wang H, Fang K, Zhang J, Jiang Y, Wang G, Zhang H, et al. The significance of De Ritis (aspartate transaminase/alanine transaminase) ratio in predicting pathological outcomes and prognosis in localized prostate cancer patients. Int Urol Nephrol. 2017;49:1391-8.
29. Takenaka Y, Takemoto N, Yasui T, Yamamoto Y, Uno A, Miyabe H, et al. Transaminase activity predicts survival in patients with head and neck cancer. PLoS One. 2016;11:e0164057.
30. Chen SL, Li JP, Li LF, Zeng T, He X. Elevated preoperative serum alanine aminotransferase/aspartate aminotransferase (ALT/AST) ratio ıs associated with better prognosis in patients undergoing curative treatment for gastric adenocarcinoma. Int J Mol Sci. 2016;17:911.
31. Dang CV. Links between metabolism and cancer. Genes Dev. 2012;26:877-90.
32. Proctor MJ, Morrison DS, Talwar D, Balmer SM, O'Reilly DS, Foulis AK, et al. An inflammation-based prognostic score (mGPS) predicts cancer survival independent of tumour site: a Glasgow Inflammation Outcome Study. Br J Cancer. 2011;104:726-34.
33. Angulo P. Nonalcoholic fatty liver disease. N Engl J Med. 2002;346:1221-31.
34. Sheth SG, Flamm SL, Gordon FD, Chopra S. AST/ALT ratio predicts cirrhosis in patients with chronic hepatitis C virus infection. Am J Gastroenterol. 1998;93:44-8.
35. Weng SF, Kai J, Guha IN, Qureshi N. The value of aspartate aminotransferase and alanine aminotransferase in cardiovascular disease risk assessment. Open Heart. 2015;2:e000272.
36. Sookoian S, Pirola CJ. Alanine and aspartate aminotransferase and glutamine-cycling pathway: their roles in pathogenesis of metabolic syndrome. World J Gastroenterol. 2012;18:3775-81.
37. Elinav E, Ackerman Z, Maaravi Y, Ben-Dov IZ, Ein-Mor E, Stessman J. Low alanine aminotransferase activity in older people is associated with greater long-term mortality. J Am Geriatr Soc. 2006;54:1719-24.
38. Zoppini G, Cacciatori V, Negri C, Stoico V, Lippi G, Targher G, et al. The aspartate aminotransferase-to-alanine aminotransferase ratio predicts all-cause and cardiovascular mortality in patients with Type 2 diabetes. Medicine (Baltimore). 2016;95:e4821.
39. Ruart M, Chavarria L, Campreciós G, Suárez-Herrera N, Montironi C, Guixé-Munet S, et al. Impaired endothelial autophagy promotes liver fibrosis by aggravating the oxidative stress response during acute liver injury. J Hepatol. 2019;70:458-69.