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# INTRA-ABDOMINAL PRESSURE AS A MODULATOR OF BIOCHEMICAL INDICATORS OF HEPATIC FUNCTION AFTER LAPAROSCOPIC CHOLECYSTECTOMY

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Laparoscopic cholecystectomy is the standard treatment for gallbladder disease; the carbon dioxide pneumoperitoneum required for the procedure may transiently affect liver function. The aim is to examine the evaluation of the impact of different levels of intra-abdominal pressure (IAP) and ASA score on postoperative liver biochemical parameters. A prospective study included 90 patients divided into three groups according to IAP (13, 14, and 15 mmHg; 30 subjects each), with analysis of preoperative and postoperative parameters of liver function. The groups were comparable in terms of age, sex, and body weight, while differences were observed in the type of inflammation and total protein values. After surgery, changes in several biochemical parameters of liver function were recorded, including an increase in the values of direct bilirubin, AST, ALT, and ALP, as well as a decrease in LDH values. The values of total bilirubin, albumin, and total protein did not show significant postoperative changes. Comparison of the groups according to different values of intra-abdominal pressure did not show significant differences in most of the parameters examined, while a statistically significant difference was observed for LDH between the groups. ASA score was associated with postoperative changes in some biochemical parameters of liver function. Laparoscopic cholecystectomy leads to transient changes in liver biochemical parameters without clinically significant damage, whereby intra-abdominal pressure in the usual range has no significant effect, while the general condition of the patient has a greater role in the postoperative response.

Keywords: laparoscopic cholecystectomy, intra-abdominal pressure, liver function, pneumoperitoneum

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## INTRODUCTION

Intra-abdominal pressure (IAP) is the static pressure within the abdominal cavity, which physiologically remains low but increases during pneumoperitoneum in laparoscopic surgery and in pathological conditions such as intra-abdominal hypertension and abdominal compartment syndrome. Elevated IAP may reduce splanchnic blood flow, including hepatic perfusion, leading to alterations in organ function. Intra-abdominal hypertension is defined as sustained IAP ≥12 mmHg, while pressures exceeding 20 mmHg are associated with impaired organ perfusion and dysfunction, including potential liver injury (1).

In the context of laparoscopic surgery, carbon dioxide pneumoperitoneum increases IAP to provide adequate visual and working space. Standard IAP values used in practice are usually between 12 and 15 mmHg, but there is evidence that even modest increases in IAP can have short-term effects on regional perfusion and physiological parameters, including hepatic blood flow and portal pressure. Studies have shown that increased IAP can lead to decreased hepatic blood flow and transient increases in liver enzymes (aspartate aminotransferase (AST) and alanine aminotransferase (ALT)) (2).

A recent meta-analysis of included studies suggests that the use of lower IAP values (<10 mmHg) during laparoscopic procedures may be associated with fewer postoperative complications, lower pain scores, and shorter hospital stays, without increasing intraoperative risk. Although this analysis does not directly assess liver function, it supports the safety of using lower IAP values while highlighting the need for further investigation of the physiological effects of different IAP values on specific parameters of organ function (3).

Therefore, the aim of this study is to investigate the effect of different values of intra-abdominal pressure (13, 14, and 15 mmHg) on postoperative values of biochemical parameters of liver function and ASA score in patients undergoing laparoscopic cholecystectomy.

## METHODS

This study was designed as a prospective, observational clinical study conducted to evaluate the effect of different values of intra-abdominal pressure (IAP) during laparoscopic cholecystectomy on postoperative liver function. The research was conducted at the Clinical Hospital Center Kosovska Mitrovica during a defined period of time of June 2025 to March 2026, with patients monitored from the time of admission to the early postoperative period and with the approval of the Ethics Committee of the institution (No. 3634, issued on June 2, 2025).

A total of 90 patients who underwent elective or urgent laparoscopic cholecystectomy due to acute or chronic cholecystitis were included in the study. Patients were divided into three groups (n = 30 in each group) according to the value of intra-abdominal pressure applied during surgery: 13 mmHg, 14 mmHg, and 15 mmHg. The distribution into groups was based on the pneumoperitoneum parameters set intraoperatively.

Criteria for inclusion in the study included adult patients of both sexes with a diagnosis of cholecystitis who were candidates for laparoscopic operative treatment. Exclusion criteria from the study included previously known chronic liver diseases, presence of malignant diseases, conversion to open surgery, and incomplete laboratory or clinical data.

Demographic data (age, gender), anthropometric data (body mass), as well as clinical parameters including type of inflammation (acute or chronic form of cholecystitis), presence of comorbidities (arterial hypertension, obesity, diabetes), and ASA score as an indicator of the general preoperative status of the patient were collected from all patients.

Laboratory analyses included the determination of biochemical parameters of liver function, which were measured at two time intervals: before surgery and in the early postoperative period. The analyzed parameters included direct and total bilirubin (μmol/l), aspartate aminotransferase (AST) (U/l), alanine aminotransferase (ALT) (U/l), alkaline phosphatase (ALP)v(U/l), albumin (g/l), total proteins (g/l), and lactate dehydrogenase (LDH) (U/l).

Biochemical parameters of liver function were determined from venous blood samples taken at two time intervals: preoperatively, as part of routine laboratory preparation within 24 hours before surgery, and postoperatively, on the first postoperative day. One limitation of this study is that the duration of the surgical procedure was not systematically recorded, which made it impossible to analyze its potential impact on postoperative biochemical parameters of liver function. Parameters such as duration of surgery, duration of pneumoperitoneum, and postoperative outcomes were not monitored because they were outside the primary research protocol of this study.

Statistical data processing was performed using the software package SPSS (Statistical Package for the Social Sciences), version 21. The normality of data distribution was tested with the Shapiro–Wilk test. Given the distribution of the data, continuous variables are presented as mean ± standard deviation or as median with interquartile range.

To compare continuous variables between multiple groups, a one-factor ANOVA test or Kruskal–Wallis test was used, depending on the normality of the distribution. A paired t-test or Wilcoxon test was used to compare dependent samples (preoperative and postoperative values). Categorical variables were analyzed using the Chi-square test. Statistical significance is defined as a value of $p < 0.05$.

## RESULTS

In this research, a total of 90 patients undergoing laparoscopic cholecystectomy were analyzed; they were divided into three groups according to the value of intra-abdominal pressure during the operation (13, 14, and 15 mmHg). Demographic and clinical characteristics of patients, as well as changes in biochemical parameters of liver function before and after surgery, were examined. A special focus of the analysis was aimed at evaluating the impact of different levels of intra-abdominal pressure on the postoperative values of liver enzymes and other laboratory indicators, as well as the potential impact of the general health status of patients expressed through the ASA score.

Table 1 shows the preoperative demographic and clinical characteristics of patients distributed according to intra-abdominal pressure groups. The analysis of the basic characteristics did not reveal a statistically significant difference between the groups in terms of age, gender, and body weight, which indicates a good homogeneity of the studied groups. Also, most of the preoperative biochemical parameters of liver function did not differ significantly between the groups, which additionally confirms the comparability of the groups before the operation. However, a statistically significant difference was observed in the values of total proteins, as well as in the distribution of the type of inflammation, where certain groups had a higher prevalence of the acute or chronic form of cholecystitis. In terms of comorbidity and ASA score, no statistically significant difference was recorded between the groups. These findings indicate that the groups were largely uniform preoperatively, with some differences that should be considered when interpreting postoperative results.

By analyzing the preoperative and postoperative values of the biochemical parameters of the liver in the total sample, significant changes in certain parameters were observed

**Table 1.** *Preoperative demographic and clinical characteristics of patients according to intra-abdominal pressure (IAP) groups*

| Variable | IAP 13 mmHg (n = 30) | IAP 14 mmHg (n = 30) | IAP 15 mmHg (n = 30) | p |
|---|---|---|---|---|
| Age, mean±SD | 46.40 ± 16.64 | 51.07 ± 14.47 | 54.30 ± 12.83 | 0.096 |
| Gender, n(%)<br>Male<br>Female | <br>14 (37.8%)<br>16 (30.2%) | <br>11 (29.7%)<br>19 (35.8%) | <br>12 (32.4%)<br>18 (34%) | 0.725 |
| Body mass, mean ± SD | 85.53 ± 20.81 | 84.93 ± 12.45 | 83.57 ± 20.68 | 0.914 |
| Direct bilirubin, med. (min-max) | 3.3 (1.4-13.9) | 3.35 (1.5-25.3) | 2.8 (1.7-5.9) | 0.407 |
| Total bilirubin, med. (min-max) | 11.6 (5.8-33.5) | 11.8 (2.7-38.4) | 15.45 (2.6-22.7) | 0.157 |
| AST, med. (min-max) | 32.5 (3-137) | 26.5 (2-91) | 23 (8-61) | 0.198 |
| ALT, med. (min-max) | 30 (2-167) | 25 (2-61) | 21.5 (3-84) | 0.381 |
| ALP, med. (min-max) | 106.5 (38-412) | 86 (7-402) | 80 (8-412) | 0.107 |
| Albumin, mean ± SD | 45.23 ± 6.27 | 45.27 ± 6.97 | 44.87 ± 6.61 | 0.967 |
| Proteins, med. (min-max) | 76.05 (45-84) | 70.95 (54-83) | 70.6 (59.7-84) | 0.029* |
| LDH, med. (min-max) | 674.5 (199-947) | 609.5 (176-1846) | 640.5 (128-1420) | 0.558 |
| Type of inflammation, n(%)<br>Acute form<br>Chronic form | <br>17 (51.5%)<br>13 (22.8%) | <br>8 (24.2%)<br>22 (38.6%) | <br>8 (24.2%)<br>22 (38.6%) | 0.021* |
| Comorbidities, n(%)<br>There is none<br>Arterial hypertension<br>Obesity<br>Diabetes | <br>14 (38.9%)<br>9 (31%)<br>5 (38.5%)<br>2 (16.7%) | <br>15 (41.7%)<br>8 (27.6%)<br>1 (7.7%)<br>6 (50%) | <br>7 (19.4%)<br>12 (41.4%)<br>7 (53.8%)<br>4 (33.3%) | 0.11 |
| ASA score, n(%)<br>0<br>1<br>2<br>3<br>4 | <br>7 (50%)<br>9 (29%)<br>10 (34.5%)<br>4 (30.8%)<br>0 (0%) | <br>4 (28.6%)<br>14 (45.2%)<br>8 (27.6%)<br>3 (23.1%)<br>1 (33.3%) | <br>3 (21.4%)<br>8 (25.8%)<br>11 (37.9%)<br>6 (46.2%)<br>2 (66.7%) | 0.492 |

Statistical significance is defined as $p < 0.05$

after the operation. A statistically significant increase was recorded in direct bilirubin, as well as in the transaminases AST and ALT, which indicates the presence of postoperative hepatocellular damage. In addition, alkaline phosphatase (ALP) values increased significantly after surgery, which may indicate a cholestatic component or the effect of pneumoperitoneum. On the other hand, total bilirubin, albumin, and total proteins did not show statistically significant changes. Interestingly, LDH values decreased significantly after surgery. These results indicate that laparoscopic cholecystectomy leads to significant but selective changes in biochemical parameters of liver function (Table 2).

By comparing postoperative values of biochemical parameters between groups with different intra-abdominal pressure, no statistically significant difference was found for most of the analyzed parameters. The values of direct and total bilirubin and transaminases AST and ALT, as well as ALP, albumin, and total proteins, were comparable between the groups. However, a statistically significant difference was observed in LDH values, which indicates a possible influence of intra-abdominal pressure on this parameter. However, the absence of significant differences in most biochemical indicators suggests that different levels of intra-abdominal pressure during laparoscopic cholecystectomy do not have a significant effect on postoperative liver function as a whole (Table 3).

Analysis of postoperative biochemical parameters in relation to the ASA score revealed statistically significant differences in certain indicators of liver function. Direct bilirubin values differed significantly between groups, as did AST and ALP values, indicating a possible influence of the general preoperative status of patients on the degree of postoperative liver damage. Also, a statistically significant difference in albumin values was recorded, which may reflect differences in the nutritional and functional status of patients according to the ASA classification. On the other hand, total bilirubin, ALT, total proteins, and LDH did not show statistically significant differences between the groups. These results suggest that the ASA score, as an indicator of the general state of health, can have an impact on certain postoperative parameters of liver function, but not on all analyzed biochemical indicators (Table 4).

## DISCUSSION

In this research, the high homogeneity of the examined groups was confirmed in terms of key demographic and clinical characteristics, which represents a significant methodological advantage and enables a reliable

**Table 2.** *Comparison of preoperative and postoperative values of biochemical parameters*

| Parameter | Before surgery | After surgery | p |
|---|---|---|---|
| Direct bilirubin, med. (min-max) | 3.1 (1.4-25.3) | 3.99 (1.12-6.69) | 0.002* |
| Total bilirubin, med. (min-max) | 12.3 (2.6-38.4) | 13.05 (4.2-24.4) | 0.261 |
| AST, med. (min-max) | 26.5 (2-137) | 59 (11-112) | 0.000* |
| ALT, med. (min-max) | 26 (2-167) | 57.5 (16-94) | 0.000* |
| ALP, med. (min-max) | 90.5 (7-412) | 290 (51-510) | 0.000* |
| Albumin, med. (min-max) | 46 (31-58) | 44 (31-57) | 0.203 |
| Proteins, med. (min-max) | 72 (45-84) | 71.35 (60-84) | 0.237 |
| LDH, med. (min-max) | 648 (128-1846) | 483.5 (124-809) | 0.000* |

Statistical significance is defined as $p < 0.05$

**Table 3.** *Comparison of postoperative biochemical parameters between groups of different intra-abdominal pressure (IAP)*

| Parameter | IAP 13 mmHg (n = 30) | IAP 14 mmHg (n = 30) | IAP 15 mmHg (n = 30) | p |
|---|---|---|---|---|
| Direct bilirubin, mean ± SD | 3.95 ± 1.78 | 3.34 (1.29-6.69) | 4.04 ± 1.67 | 0.991 |
| Total bilirubin, med. (min-max) | 12.5 (5-24.4) | 11.35 (4.2-23.6) | 14.05 (4.5-24.2) | 0.739 |
| AST, med. (min-max) | 62.5 (14-107) | 64.47 ± 30.57 | 53.5 (13-111) | 0.589 |
| ALT, med. (min-max) | 53.5 (16-93) | 61.3 ± 23.21 | 52.7 ± 21.87 | 0.304 |
| ALP, mean ± SD | 297.2 ± 149.91 | 287.5 ± 142.53 | 268.5 (54-508) | 0.727 |
| Albumin, mean ± SD | 42.1 ± 7.71 | 45.87 ± 7.21 | 43 (31-57) | 0.213 |
| Proteins, med. (min-max) | 71.5 (60.5-84) | 72.58 ± 7.41 | 72.55 (60.7-84) | 0.775 |
| LDH, med. (min-max) | 647 (131-809) | 324.5 (124-771) | 444.5 (138-799) | 0.012* |

Statistical significance is defined as $p < 0.05$

**Table 4.** *Postoperative liver function parameters according to ASA score*

| Parameter | ASA 0 | ASA 1 | ASA 2 | ASA 3 | ASA 4 | p |
|---|---|---|---|---|---|---|
| Direct bilirubin | 4.28 ± 1.57 | 5.07 (1.29-6.61) | 2.48 (1.12-6.66) | 4.12 ± 1.65 | 4.85 ± 1.62 | 0.020* |
| Total bilirubin | 12.75 ± 5.35 | 10.9 (4.2-24) | 14.94 ± 6.48 | 18 (4.7-22.9) | 8.86 ± 4.56 | 0.486 |
| AST | 64.29 ± 27.09 | 74 (11-112) | 58.59 ± 30.46 | 39.85 ± 18.27 | 37 ± 28.47 | 0.023* |
| ALT | 66.43 ± 18.51 | 58 (20-94) | 55 (16-93) | 45 ± 22.02 | 57.67 ± 26.95 | 0.2 |
| ALP | 129.5 (51-485) | 236 (53-505) | 341 ± 132.04 | 314.92 ± 164.49 | 220.33 ± 101 | 0.021* |
| Albumin | 38.93 ± 7.45 | 46.58 ± 6.95 | 44 (31-57) | 41.46 ± 8.02 | 54 (33-54) | 0.037* |
| Proteins | 73.38 ± 7.70 | 69 (60-84) | 72.59 ± 7.08 | 74.08 ± 7.5 | 68.63 ± 5.63 | 0.425 |
| LDH | 491.36 ± 233.56 | 458 (131-809) | 495 (144-799) | 493.15 ± 246.35 | 341.33 ± 232.29 | 0.745 |

Statistical significance is defined as $p < 0.05$

comparison of postoperative outcomes. Although differences in total protein and type of inflammation were observed, the absence of differences in age, sex, body mass, and most biochemical parameters indicated that these variables likely did not have a significant confounding effect on the results. A similar approach to the selection of homogeneous groups was applied in other studies examining the impact of pneumoperitoneum on the liver, thus minimizing the impact of external factors and enabling the focus on intra-abdominal pressure as the main investigated parameter (4).

The results of this study demonstrate that laparoscopic cholecystectomy is associated with significant postoperative changes in selected biochemical parameters of liver function, including increases in AST, ALT, ALP, and direct bilirubin levels. These findings represent transient postoperative biochemical changes rather than clinically significant liver injury. This observation is consistent with previous studies suggesting that pneumoperitoneum may reduce hepatic blood flow through portal vein compression and decreased splanchnic circulation, resulting in temporary alterations in hepatocellular metabolism. In the present study, postoperative increases in liver enzymes were observed, followed by spontaneous normalization, supporting the interpretation that these changes are transient and clinically benign (4).

On the other hand, the absence of significant changes in total bilirubin, albumin, and total proteins indicates that the synthetic function of the liver remains preserved despite the biochemical changes. This finding has important clinical significance because it suggests that although biochemical abnormalities occur, they do not reflect actual functional liver damage. Similar results have been described in other studies which emphasized that enzyme changes do not correlate with clinical worsening of liver function, which further confirms the safety of laparoscopic cholecystectomy as a standard procedure (4).

One of the most important findings of this research is the absence of statistically significant differences in most postoperative parameters between groups with different levels of intra-abdominal pressure (13, 14, and 15 mmHg), which indicates that in this range of pressures, no significant additional liver damage occurs. This result partially contradicts some studies that indicate greater harm with higher values of pneumoperitoneum, but it can be explained by the fact that the pressure differences in our research are relatively small and within standard clinical values. This implies that a clinically relevant difference probably exists only at significantly higher pressure values, which were not routinely used in this work (4).

A particularly interesting finding is the statistically significant difference in LDH values between the groups, as well as its overall reduction postoperatively. This result deviates from the expected pattern and is not often described in the literature, which may indicate specific metabolic or hemodynamic changes during surgery and anesthesia. Given that most studies do not analyze LDH as a primary parameter, this finding may represent a potential new field of research and require additional prospective trials with larger samples (4).

The finding of a statistically significant decrease in serum LDH in the early postoperative period, from the preoperative median of 648 U/L to the postoperative median of 483.5 U/L, deserves special attention. This result is inconsistent with most previously published studies that described a transient increase in LDH, along with AST and ALT, after laparoscopic cholecystectomy, which is mainly related to changes in splanchnic perfusion during pneumoperitoneum (5, 6). However, the results of the literature are not completely consistent, as some studies show that LDH after laparoscopic cholecystectomy can remain without significant changes compared to preoperative values (7). In our research, the decrease in LDH cannot be directly interpreted as a specific indicator of

liver regeneration, bearing in mind the non-specificity of this enzyme and the fact that various extrahepatic sources can influence its serum concentration. One of the possible explanations is that elevated preoperative LDH values reflected an inflammatory and metabolic response associated with the underlying disease, especially if we consider that our sample included a significant number of patients with an acute inflammatory process. After resolution of the underlying pathologic process and surgical treatment, the decrease in LDH could reflect the withdrawal of this preoperative systemic response. However, this interpretation remains hypothetical and cannot be confirmed without additional measurements of LDH over a longer postoperative period and without analysis of other indicators of liver inflammation and regeneration.

Additionally, our analysis showed that the ASA score significantly influenced several postoperative liver function parameters, including direct bilirubin, AST, ALP, and albumin, suggesting that the patient's general health status may have a greater impact on postoperative biochemical changes than intra-abdominal pressure alone. This finding is consistent with recent studies indicating that the hepatic response to $CO_2$ pneumoperitoneum is modified by comorbidities and baseline liver condition, emphasizing that postoperative biochemical changes should be interpreted within the overall clinical context rather than solely in relation to pneumoperitoneum pressure (4, 9).

In addition, recent research confirms that the increase in liver enzymes after laparoscopic cholecystectomy is an almost universal phenomenon, but with clear temporal dynamics and no clinical significance in most patients. In large reviews, AST and ALT elevations are reported to occur in as many as 75–82% of patients within the first 24–48 hours, with spontaneous normalization within a week. These findings directly correspond with the results of our research, where a significant increase in transaminases was also recorded without signs of permanent damage. This further confirms that the observed biochemical changes are part of the expected physiological response to pneumoperitoneum and not an indicator of clinically relevant hepatopathy (10).

Recent studies also indicate the importance of the duration of pneumoperitoneum as a factor that may have a greater impact than the level of intra-abdominal pressure itself. It has been shown that a longer duration of surgery (>60 minutes) leads to a more pronounced increase in AST, ALT, and ALP, which is explained by the prolonged reduction of splanchnic flow and the effect of ischemia-reperfusion. This finding may help in the interpretation of the results of our study, where no significant difference was found between different pressure levels, suggesting that the duration of exposure may be a more important factor than the pressure level itself. This opens up space for additional analyses in which pressure and duration of pneumoperitoneum would be considered in combination as key determinants of postoperative changes (10).

The advantages of this study include a prospective design, clearly defined groups according to intra-abdominal pressure, and relatively uniform demographic characteristics of the subjects, which allows reliable interpretation of the results. Also, the analysis of a number of biochemical parameters provides a comprehensive insight into liver function after laparoscopic cholecystectomy. Compared to other studies, the inclusion of the ASA score as a factor in the analysis is an advantage, which further expands the understanding of the influence of the patient's general condition.

On the other hand, limitations of the study include a relatively small range of intra-abdominal pressure between groups, which may reduce the possibility of detecting differences in the impact of pneumoperitoneum, as well as a relatively limited number of subjects. Also, the lack of long-term follow-up makes it impossible to assess the durability of the observed changes. Nevertheless, the results provide a significant contribution to the understanding of the effects of laparoscopic cholecystectomy on liver function and indicate the need for further research with a wider range of pressures and a larger sample of subjects.

It should be emphasized that this study included only patients operated on at standard values of intra-abdominal pressure (13–15 mmHg), which represent the routinely applied range in our institution. Therefore, the aim was not to compare standard and low pneumoperitoneum but to assess whether small differences within the clinically most commonly used range could affect postoperative biochemical parameters of liver function. The obtained results indicate that there are no significant differences in liver function in this pressure range. Future randomized trials involving lower values of intra-abdominal pressure (6–10 mmHg), which are now increasingly recommended in selected patients, could provide additional information on the potential benefits of low-pressure pneumoperitoneum.

A limitation of this study is that certain intraoperative factors that may influence postoperative changes in liver function parameters, such as duration of surgery, duration of pneumoperitoneum, total $CO_2$ insufflation time, intraoperative blood loss, anesthetic regimen, and episodes of intraoperative hypotension, were not analyzed. Future

studies should include these parameters to more accurately assess their impact on transient changes in liver enzymes after laparoscopic cholecystectomy. An a priori analysis of sample power was not performed in this study, which is a limitation in the interpretation of negative findings. However, the sample size was determined by the availability of patients who met the inclusion criteria during the study period. The results obtained should be interpreted in the context of the study design, and future prospective studies with a larger number of subjects and the inclusion of additional intraoperative factors should confirm these findings.

Laparoscopic cholecystectomy leads to transient and selective changes in biochemical parameters of liver function, which appear to be clinically insignificant. Variations of intra-abdominal pressure within the commonly used operative range did not result in significant differences in postoperative liver function parameters, supporting the safety of standard pneumoperitoneum pressures. Patient-related factors, including ASA score, may contribute to postoperative biochemical variations; however, further studies are required to determine their independent influence relative to intra-abdominal pressure. These findings highlight the importance of careful preoperative patient assessment and individualized risk evaluation in laparoscopic surgery.

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## Author Contributions

Conceptualization: M.K.; Data collection: G.I, A.J.and M.M.; Statistical analysis: S.D.; Final manuscript approval: N.M.and Z.E.

## Statement of Ethics

The study was approved by the Ethics Committee of the Clinical Hospital Center of Kosovska Mitrovica, No. 3634, issued on June 2, 2025.

## Statement of Competing Interest

The authors declare no relevant conflicts of interest.

## Statement of Data Availability

All data analyzed during this study are included in this article.

## Statement of Generative AI Use

No generative AI was used.

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