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Original Research Article

Intercepting Sepsis: The Predictive Value of Drain Fluid Biochemistry in Gastrointestinal Surgery

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Abstract:

Background: Postoperative peritonitis is a serious complication following surgery for hollow viscus perforation and may progress to sepsis and multiorgan dysfunction if not recognized early. Conventional clinical and systemic laboratory investigations may not always identify localized intra-abdominal infection during its early stages. Biochemical analysis of peritoneal fluid may provide additional information regarding local inflammatory and metabolic changes.

Aim: To evaluate the diagnostic and prognostic significance of peritoneal fluid biochemical parameters in patients undergoing surgery for hollow viscus perforation, with particular emphasis on their association with postoperative peritonitis.

Materials and Methods: A prospective observational cohort study was conducted at a tertiary care centre in Hingoli, Maharashtra, from May 2025 to July 2026. A total of 63 patients undergoing emergency exploratory laparotomy for confirmed hollow viscus perforation were included. Peritoneal fluid and corresponding blood samples were collected on postoperative days (POD) 1, 3 and 5. Biochemical parameters, including lactate dehydrogenase (LDH), lactate, glucose, pH, total protein, albumin, amylase and bilirubin, were evaluated. Microbiological examination included Gram staining and aerobic and anaerobic cultures. Statistical analysis was performed using SPSS version 26.0, with ROC curve analysis used to assess the diagnostic performance of selected biomarkers.

Results: Of the 63 patients, 48 (76.2%) experienced uncomplicated recovery, while 15 (23.8%) developed postoperative peritonitis. Significant biochemical differences emerged by POD 3. Patients with peritonitis demonstrated higher LDH (845.6 ± 140.5 versus 285.1 ± 60.4 U/L) and lactate (6.9 ± 1.4 versus 2.0 ± 0.5 mmol/L), along with lower glucose concentrations (42.8 ± 15.3 versus 92.1 ± 10.2 mg/dL; all $p < 0.001$). These differences persisted on POD 5. Total protein was also significantly higher in the peritonitis group on POD 5 (4.2 ± 0.7 versus 2.8 ± 0.4 g/dL; $p < 0.001$). Elevated amylase and bilirubin ratios were associated with surgically confirmed leakage in four and three patients, respectively. ROC analysis demonstrated the highest diagnostic performance for lactate (AUC 0.924), followed by pH (0.891), LDH (0.865) and glucose (0.822).

Conclusion: Serial biochemical assessment of peritoneal fluid may provide useful additional information for identifying postoperative peritonitis. Lactate demonstrated the strongest discriminatory performance, while pH, LDH and glucose provided complementary information. Further larger studies are required to validate the proposed diagnostic cut-off values.

Keywords: Postoperative Peritonitis; Hollow Viscus Perforation; Peritoneal Fluid; Lactate; Lactate Dehydrogenase; Biochemical Markers; Anastomotic Leakage.

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Introduction

Postoperative perforation peritonitis is a life-threatening complication of gastrointestinal surgery that can rapidly escalate into systemic sepsis and organ failure. It typically occurs when a hollow organ leaks—often due to anastomotic breakdown, intestinal ischemia, or an unnoticed surgical injury—spilling gastrointestinal contents directly into the abdominal cavity [1, 2]. This leakage of acid, bile, and bacteria triggers intense local inflammation and drastically alters the biochemical makeup of peritoneal fluid, causing noticeable shifts in local glucose, lactate, and lactate dehydrogenase (LDH) levels [3]. Catching this catastrophic event early is a matter of life and death, making rapid source control essential [4].

Unfortunately, diagnosing postoperative peritonitis is notoriously difficult. Standard post-surgery pain, analgesic medications, and the body's natural response to surgical trauma easily mask the classic physical signs of an acute abdomen. While clinicians traditionally rely on systemic blood tests—such as white blood cell counts, C-reactive protein (CRP), and serum lactate—these markers only reflect a generalized bodily stress response rather than pinpointing a localized abdominal crisis. By the time systemic markers spike, the infection is often already advanced. Consequently, researchers are now looking directly at peritoneal drain fluid. Testing this localized fluid for CRP, cytokines, or matrix metalloproteinases can reveal anastomotic leaks much earlier than standard blood tests [5, 6].

The peritoneal cavity acts as the frontline in the immune system's battle against leaked pathogens. Analyzing fluid obtained from surgical drains or paracentesis provides a real-time snapshot of local tissue injury and microbial activity. Clinical studies confirm that localized biochemical shifts accurately distinguish infected environments from sterile, normal postoperative inflammation [3]. Furthermore, specific inflammatory cytokines found directly in the fluid strongly correlate with overall sepsis severity and patient outcomes [7].

Basic fluid analysis traditionally looks at total protein, albumin, glucose, and LDH. The serum-ascites albumin gradient (SAAG) helps identify portal hypertension [8], while LDH flags cellular damage [8, 9]. However, these parameters must be interpreted carefully, as surgery itself causes baseline tissue injury.

More precise fluid markers can actually map a leak's anatomical origin. A sharp rise in peritoneal amylase strongly suggests a pancreatic or upper gastrointestinal leak [8, 9]. Similarly, checking the peritoneal fluid-to-serum bilirubin ratio can accurately identify biliary leaks. While a ratio above 5 is a standard red flag for bile leaks, evidence shows a lower threshold of 3.25 is more accurate for liver transplant patients, proving that clinical context is key [10].

The metabolic trio of fluid lactate, pH, and glucose offers some of the most vital clues about tissue oxygen starvation and bacterial growth. As bacteria multiply and tissue becomes ischemic, local glucose drops rapidly while lactate accumulates. Studies show that localized lactate spikes [11] and pH drops [2] often occur days before a patient shows outward clinical symptoms of a leak. Furthermore, advanced inflammatory markers like interleukins and tumor necrosis factor gauge the severity of abdominal sepsis, though standardized diagnostic cut-offs are still evolving [7, 12]. Finally, biochemical data must always be paired with microbiological cultures. While gut bacteria drive most infections, fungal pathogens like Candida are increasingly recognized in perforation cases, making comprehensive microbial testing essential [13].

Because systemic markers are often too slow or vague, direct biochemical evaluation of peritoneal fluid offers a much clearer window into the abdomen's health. This review examines the current clinical evidence surrounding these localized fluid biomarkers to help surgical teams detect postoperative complications earlier, streamline their diagnostic approach, and ultimately improve patient survival.

Study Design and Setting: The present study was designed as a prospective, observational cohort study conducted exclusively among human patients at a tertiary care centre and medical college located in Hingoli, Maharashtra. The study was carried out over a period of 15 months, from May 2025 to July 2026. It aimed to evaluate the diagnostic and prognostic significance of peritoneal fluid biochemical analysis in patients undergoing emergency surgery for hollow viscus perforation, with particular emphasis on the early identification of postoperative peritonitis and associated intra-abdominal complications.

The prospective design facilitated systematic clinical assessment and sequential collection of peritoneal fluid and corresponding blood samples during the postoperative period. No additional experimental intervention was introduced, and patients received treatment according to standard clinical practices.

Study Population: The study included 63 adult patients (N = 63) admitted to the Department of General Surgery and surgical emergency services who underwent exploratory laparotomy for surgically confirmed hollow viscus perforation involving the stomach, duodenum, small intestine or colorectum.

Inclusion Criteria

1. Patients aged 18–75 years.
2. Surgically confirmed gastrointestinal perforation.
3. Patients undergoing primary repair or resection with anastomosis.
4. Placement of at least one intra-abdominal drain following surgery.
5. Written informed consent from the patient or legally authorized representative.

Exclusion Criteria

1. Patients below 18 years of age and pregnant women.
2. Patients with primary spontaneous bacterial peritonitis.
3. Traumatic abdominal injuries without hollow viscus perforation.

4. Patients with pre-existing end-stage liver disease with baseline ascites.
5. Patients with end-stage renal disease.
6. Patients who expired within the first 24 hours following surgery, preventing the planned sequential postoperative assessment.

Sample Size Estimation: The sample size was determined using established statistical methods for observational studies in human clinical research [14]. The calculation considered a 95% confidence level, a 5% margin of error and an anticipated 10% dropout or loss-to-follow-up rate. Based on the study planning and eligibility criteria, a total of 63 patients were included in the final study population.

Surgical Management and Clinical Data Collection: All eligible patients underwent emergency exploratory laparotomy for surgical management of hollow viscus perforation. Following identification and control of the perforation, the affected segment was managed by primary repair or resection with anastomosis, as clinically indicated. Thorough peritoneal lavage was performed, followed by placement of closed-suction intra-abdominal drains in dependent areas of the peritoneal cavity, such as the pelvis or Morrison's pouch, according to the operating surgeon's judgment [15].

Relevant demographic, clinical, operative and postoperative information was recorded in a standardized study proforma. Patients were monitored for evidence of postoperative peritonitis and other intra-abdominal complications throughout the observation period.

Peritoneal Fluid Sampling and Blood Collection: Peritoneal fluid samples were collected on postoperative days (POD) 1, 3 and 5. At each scheduled interval, approximately 10 mL of peritoneal fluid was aspirated aseptically from the fresh output of the intra-abdominal drain tubing rather than from the collection bag, to minimize changes associated with prolonged fluid stagnation.

Simultaneously, approximately 5 mL of peripheral venous blood was collected from each patient for corresponding serum biochemical investigations. The paired specimens allowed comparison of localized peritoneal fluid biochemical parameters with systemic serum values and facilitated calculation of selected fluid-to-serum ratios.

The samples were promptly transported to the central biochemistry laboratory under appropriate cold-chain conditions for further processing and analysis.

Laboratory and Biochemical Analysis: Peritoneal fluid specimens intended for biochemical examination were centrifuged at 3,000 rpm for 10 minutes to separate cellular debris from the supernatant. The supernatant was analyzed using an automated clinical chemistry analyzer. Peritoneal fluid pH and lactate were assessed using a point-of-care blood gas analyzer.

The following biochemical parameters were evaluated:

a. **Total Protein and Albumin:** Total protein and albumin concentrations were measured separately to characterize the biochemical composition of peritoneal fluid. Serum-ascites albumin gradient (SAAG) was calculated using the following formula:

SAAG = Serum albumin − Peritoneal fluid albumin.

Total protein was assessed as an independent biochemical parameter and was not included in the SAAG calculation.

b. **Lactate Dehydrogenase (LDH):** Peritoneal fluid LDH was measured as an indicator of cellular injury and tissue damage.

c. **Amylase:** Peritoneal fluid amylase was estimated to investigate possible pancreatic involvement or leakage of enzyme-rich gastrointestinal secretions.

d. **Bilirubin:** Peritoneal fluid and corresponding serum bilirubin concentrations were measured to calculate the fluid-to-serum bilirubin ratio and assess suspected biliary leakage.

e. **Glucose:** Peritoneal fluid glucose was measured to identify metabolic alterations potentially associated with local inflammation and bacterial activity.

f. **pH:** Peritoneal fluid pH was assessed to evaluate changes in the local metabolic environment associated with infection and inflammation.

g. **Lactate:** Peritoneal fluid lactate was measured to assess metabolic alterations potentially associated with impaired tissue perfusion and anaerobic metabolism.

Microbiological Examination: Peritoneal fluid specimens were also subjected to microbiological examination to identify bacterial contamination and characterize the organisms associated with intra-abdominal infection.

The investigations included Gram staining, total and differential leukocyte counts, and aerobic and anaerobic bacterial cultures. These findings were evaluated alongside the patients' clinical condition, laboratory investigations and postoperative course.

Microbiological culture positivity was considered supportive evidence of infection and was not used as the sole criterion for diagnosing postoperative peritonitis. Culture-negative results were not

considered sufficient to exclude infection, particularly in patients who had received antimicrobial therapy before sample collection. The final clinical classification of postoperative peritonitis was based on the overall clinical assessment and available supporting investigations.

Statistical Analysis: All collected data were entered into a standardized digital spreadsheet and analyzed using Graph pad prism 11.0.1 and tabulations were done using Microsoft Excel 2011.

Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages.

The independent samples t-test was used for comparing normally distributed continuous variables between patients who developed postoperative peritonitis and those who experienced an uncomplicated recovery. The Mann–Whitney U test was applied for non-normally distributed variables.

Receiver Operating Characteristic (ROC) curve analysis was performed to assess the diagnostic and predictive potential of selected peritoneal fluid biochemical parameters. The area under the curve (AUC), sensitivity and specificity were calculated, and appropriate cut-off values were identified to evaluate the discriminatory performance of individual biomarkers. The analytical approach was guided by established predictive methods used in clinical research involving perforation peritonitis and intra-abdominal infections [16].

A two-sided p-value of less than 0.05 was considered statistically significant.

Ethical Considerations: The study protocol was reviewed and approved by the Institutional Ethics Committee (IEC) of the participating tertiary care centre and medical college in Hingoli, Maharashtra, before commencement of data collection.

Written informed consent was obtained from all participating patients. For critically ill, unconscious or intubated patients who were unable to provide consent, permission was obtained from their legally authorized representatives in accordance with the approved ethical protocol.

Patient confidentiality was maintained throughout the study, and collected information was used exclusively for research purposes. Participation was voluntary, and withdrawal from the study did not affect the treatment or medical care provided to any patient. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Results

Demographic and Baseline Clinical Characteristics: A total of 63 patients fulfilling the predefined inclusion and exclusion criteria were included in the final analysis during the 15-month study period, extending from May 2025 to July 2026. The study population comprised 41 males (65.1%) and 22 females (34.9%), indicating a higher representation of male patients. The overall mean age of the study population was 48.4 ± 14.2 years.

Following emergency exploratory laparotomy and appropriate surgical management in the form of primary repair or resection with anastomosis, patients were monitored throughout the postoperative period. Based on their clinical course, the participants were divided into two groups. Forty-eight patients (76.2%) experienced an uncomplicated postoperative recovery, whereas 15 patients (23.8%) developed postoperative peritonitis.

Thus, approximately one-fourth of the study population developed postoperative peritonitis during the observation period.

Table 1: Distribution of patients according to postoperative clinical outcome

Postoperative outcome	Number of patients	Percentage
Uncomplicated postoperative recovery	48	76.2%
Postoperative peritonitis	15	23.8%
Total	**63**	**100%**

The mean age of patients who developed postoperative peritonitis was 50.3 ± 15.1 years, compared with 47.8 ± 13.9 years among patients with an uncomplicated recovery. Although the peritonitis group had a slightly higher mean age, the difference was not statistically significant (p = 0.552).

Regarding gender distribution, males constituted 64.6% of the uncomplicated group and 66.7% of the peritonitis group. The corresponding female proportions were 35.4% and 33.3%, respectively. No statistically significant difference was observed in gender distribution between the two groups (p = 0.881).

With respect to the anatomical distribution of hollow viscus perforations, duodenal perforation was the most frequently reported site, accounting for 31 patients (49.2%) in the overall cohort. Small intestinal perforations were recorded in 16 patients (25.4%), while gastric perforations accounted for 9 patients (14.3%).

Duodenal perforations were similarly distributed between the uncomplicated recovery group (50.0%)

and the postoperative peritonitis group (46.7%). Small intestinal perforations accounted for 25.0% and 26.7% of the respective groups, while gastric perforations accounted for 14.6% and 13.3%.

The supplied anatomical distribution accounts for 56 of the 63 patients. The remaining seven patients have therefore been retained as a separate category in the table, without assigning them an anatomical site that was not specified in the available data.

Table 2: Demographic and anatomical distribution of perforation sites according to postoperative outcome

Characteristic	Total cohort (n=63)	Uncomplicated (n=48)	Peritonitis (n=15)	p-value
Age (years), mean ± SD	48.4 ± 14.2	47.8 ± 13.9	50.3 ± 15.1	0.552
Gender				
Male	41 (65.1%)	31 (64.6%)	10 (66.7%)	0.881
Female	22 (34.9%)	17 (35.4%)	5 (33.3%)	—
Anatomical site of perforation				
Duodenum	31 (49.2%)	24 (50.0%)	7 (46.7%)	0.825
Small intestine	16 (25.4%)	12 (25.0%)	4 (26.7%)	0.895
Stomach	9 (14.3%)	7 (14.6%)	2 (13.3%)	0.902
Site not specified in supplied data	7 (11.1%)	5 (10.4%)	2 (13.3%)	Not available
Total	**63 (100%)**	**48 (100%)**	**15 (100%)**	—

The baseline findings indicated that the two postoperative outcome groups were broadly comparable with respect to the reported demographic characteristics and anatomical distribution of perforations. None of the reported comparisons demonstrated a statistically significant difference ($p > 0.05$). Although a slightly higher mean age was observed in the peritonitis group, this difference did not reach statistical significance.

Serial Assessment of Peritoneal Fluid Biochemical Parameters: Sequential biochemical evaluation of peritoneal fluid was performed on postoperative days (POD) 1, 3 and 5 to assess the changes occurring during the early postoperative period.

The assessment particularly focused on lactate dehydrogenase (LDH), lactate and glucose concentrations, which provide information regarding cellular injury, local metabolic activity and glucose utilization within the peritoneal cavity.

The findings demonstrated distinct differences in the biochemical profiles of patients who experienced uncomplicated recovery and those who developed postoperative peritonitis.

On POD 1, the concentrations of LDH and lactate were relatively comparable between the two groups. Similarly, peritoneal fluid glucose levels did not demonstrate a statistically significant difference. However, by POD 3, considerable differences were observed in all three parameters.

Patients with uncomplicated recovery demonstrated declining LDH and lactate concentrations, accompanied by relatively stable or increasing glucose levels. In contrast, patients with postoperative peritonitis showed marked increases in LDH and lactate concentrations, together with a substantial reduction in glucose.

These differences persisted on POD 5, indicating a contrasting biochemical pattern between the two postoperative outcome groups.

Peritoneal Fluid Lactate Dehydrogenase (LDH): LDH was evaluated as an indicator of cellular injury and tissue damage within the peritoneal cavity.

On POD 1, the mean peritoneal fluid LDH concentration was 412.4 ± 85.2 U/L in the uncomplicated group and 430.2 ± 92.1 U/L in the peritonitis group. Although a slightly higher value was observed among patients who subsequently developed peritonitis, the difference was not statistically significant ($p = 0.493$).

By POD 3, a marked divergence was observed. The mean LDH concentration decreased to 285.1 ± 60.4 U/L among patients with uncomplicated recovery, whereas the peritonitis group demonstrated a substantial increase to 845.6 ± 140.5 U/L. The difference between the groups was highly statistically significant ($p < 0.001$).

The divergence became more pronounced on POD 5. Patients with uncomplicated recovery showed a further reduction in LDH to 180.5 ± 45.3 U/L, whereas the peritonitis group demonstrated a considerable rise to 1120.3 ± 210.8 U/L ($p < 0.001$).

The mean LDH concentration in the peritonitis group was approximately three times that of the uncomplicated group on POD 3 and more than six times the corresponding value on POD 5.

These observations indicate that persistent elevation of peritoneal fluid LDH was associated with an adverse postoperative clinical course, whereas

declining concentrations were observed among patients recovering without complications.

Peritoneal Fluid Lactate: Peritoneal fluid lactate was measured to evaluate localized metabolic alterations potentially associated with tissue hypoxia, impaired perfusion and increased anaerobic metabolic activity.

On POD 1, the mean lactate concentration was 3.1 ± 0.8 mmol/L in patients with uncomplicated recovery and 3.4 ± 0.9 mmol/L in patients who subsequently developed peritonitis. The difference was not statistically significant ($p = 0.231$).

By POD 3, the mean lactate concentration in the uncomplicated group had decreased to 2.0 ± 0.5 mmol/L. In contrast, the peritonitis group demonstrated a marked increase to 6.9 ± 1.4 mmol/L ($p < 0.001$).

The difference was further accentuated on POD 5, when the mean lactate concentration declined to 1.3 ± 0.4 mmol/L in the uncomplicated group but increased to 8.7 ± 1.9 mmol/L in the peritonitis group ($p < 0.001$).

The lactate concentration in the peritonitis group was approximately 3.5 times higher than that of the uncomplicated group on POD 3 and nearly 6.7 times higher on POD 5.

This progressive increase in localized lactate concentration represented one of the most prominent biochemical findings in the study. The contrasting patterns between the two groups suggest an association between persistent intra-abdominal pathological activity and alterations in local metabolic conditions.

Peritoneal Fluid Glucose: Peritoneal fluid glucose concentration was evaluated to identify metabolic alterations associated with local inflammation and possible bacterial activity.

On POD 1, the mean glucose concentration was 88.5 ± 12.4 mg/dL in the uncomplicated group and 82.1 ± 14.6 mg/dL in the peritonitis group. Although the peritonitis group demonstrated a slightly lower concentration, the difference was not statistically significant ($p = 0.110$).

By POD 3, the uncomplicated group demonstrated an increase in mean glucose concentration to 92.1 ± 10.2 mg/dL, whereas the peritonitis group showed a substantial reduction to 42.8 ± 15.3 mg/dL ($p < 0.001$).

On POD 5, glucose levels in the uncomplicated group increased further to 95.4 ± 8.8 mg/dL. In comparison, the peritonitis group demonstrated a further decline to 28.1 ± 11.2 mg/dL ($p < 0.001$).

The mean glucose concentration in the peritonitis group was approximately 53.5% lower than that in the uncomplicated group on POD 3 and 70.5% lower on POD 5.

These findings demonstrate a marked difference in the postoperative glucose profile between the two groups. The substantial reduction in glucose among patients with postoperative peritonitis may reflect increased glucose utilization by inflammatory cells and microorganisms, together with altered metabolic activity within the infected peritoneal environment.

Table 3: Serial changes in peritoneal fluid biochemical parameters

Parameter	Postoperative day	Uncomplicated (n=48)	Peritonitis (n=15)	p-value
LDH (U/L)	POD 1	412.4 ± 85.2	430.2 ± 92.1	0.493
	POD 3	285.1 ± 60.4	845.6 ± 140.5	<0.001
	POD 5	180.5 ± 45.3	1120.3 ± 210.8	<0.001
Lactate (mmol/L)	POD 1	3.1 ± 0.8	3.4 ± 0.9	0.231
	POD 3	2.0 ± 0.5	6.9 ± 1.4	<0.001
	POD 5	1.3 ± 0.4	8.7 ± 1.9	<0.001
Glucose (mg/dL)	POD 1	88.5 ± 12.4	82.1 ± 14.6	0.110
	POD 3	92.1 ± 10.2	42.8 ± 15.3	<0.001
	POD 5	95.4 ± 8.8	28.1 ± 11.2	<0.001

Table 4: Magnitude of biochemical differences between the two postoperative outcome groups

Parameter	POD 3 mean difference	POD 5 mean difference
LDH (U/L)	560.5	939.8
Lactate (mmol/L)	4.9	7.4
Glucose (mg/dL)	49.3	67.3

Overall, the serial biochemical findings demonstrated that the two clinical outcome groups had relatively comparable measurements on POD 1, followed by substantial differences on POD 3 and POD 5. Rising LDH and lactate concentrations, together with declining glucose levels, were characteristic of the peritonitis group.

Formal statistical testing of within-patient changes over time was not included in the supplied analysis; therefore, the observed longitudinal patterns are

presented descriptively, while the reported p-values represent comparisons between groups at individual postoperative intervals.

Assessment of Total Protein and Serum-Ascites Albumin Gradient (SAAG): Total protein and albumin were assessed as separate biochemical parameters to characterize the composition of peritoneal fluid.

Albumin concentrations in the paired serum and peritoneal fluid specimens were used to calculate the serum-ascites albumin gradient (SAAG), using the following formula:

SAAG = Serum albumin − Peritoneal fluid albumin.

All 63 patients demonstrated a SAAG value below 1.1 g/dL on POD 1. Thus, a low SAAG pattern was observed throughout the study population.

This finding indicated a low serum-to-peritoneal fluid albumin gradient. However, SAAG was not considered an independent confirmation of postoperative infection or perforation peritonitis, as its established clinical application is primarily in the evaluation of portal hypertensive ascites.

Total protein concentrations were evaluated independently and demonstrated a significant difference between the two postoperative outcome groups on POD 5.

The mean peritoneal fluid total protein concentration was 2.8 ± 0.4 g/dL among patients with uncomplicated recovery, compared with 4.2 ± 0.7 g/dL among patients with postoperative peritonitis. This difference was statistically highly significant ($p < 0.001$).

The mean total protein concentration in the peritonitis group was approximately 50% higher than that in the uncomplicated group.

Table 5: SAAG and total protein findings in the study population

Parameter	Uncomplicated recovery	Postoperative peritonitis	Overall finding	p-value
SAAG on POD 1	—	—	All 63 patients had SAAG <1.1 g/dL	Not available
Total protein on POD 5 (g/dL)	2.8 ± 0.4	4.2 ± 0.7	Higher concentration in peritonitis group	<0.001

The findings indicate that a low SAAG pattern was common across the study population, whereas persistent elevation of total protein on POD 5 was associated with postoperative peritonitis. These parameters provided complementary biochemical information and were interpreted separately.

Evaluation of Organ-Specific Biochemical Indicators: In addition to routine biochemical markers, peritoneal fluid amylase and bilirubin were assessed to identify possible leakage involving specific gastrointestinal or hepatobiliary structures.

Peritoneal Fluid Amylase: Peritoneal fluid amylase was evaluated to investigate possible pancreatic involvement or leakage of enzyme-containing gastrointestinal secretions.

Marked elevations in peritoneal fluid amylase, defined in the supplied results as greater than three times the upper limit of the normal serum reference value, were observed in four patients belonging to the postoperative peritonitis group.

These four patients represented 26.7% of the peritonitis group and 6.3% of the overall study population.

Subsequent surgical evaluation reportedly confirmed occult leakage involving the pancreatico-duodenal region in all four patients.

These findings suggest that elevated peritoneal fluid amylase may provide additional diagnostic information in selected patients with suspected pancreatic or upper gastrointestinal leakage. Its usefulness was particularly relevant when interpreted alongside the operative findings and other clinical observations.

Peritoneal Fluid Bilirubin and Fluid-to-Serum Bilirubin Ratio: Peritoneal fluid bilirubin concentration was measured alongside corresponding serum bilirubin to calculate the fluid-to-serum bilirubin ratio.

A ratio greater than 5.0 was identified in three patients belonging to the postoperative peritonitis group. These patients accounted for 20.0% of the peritonitis group and 4.8% of the total study population.

Subsequent surgical re-exploration reportedly confirmed biliary leakage associated with compromised duodenal repairs in all three patients.

The localized elevation in the fluid-to-serum bilirubin ratio was reported to precede the development of systemic hyperbilirubinemia by a mean interval of approximately 36 hours.

This observation suggests that bilirubin estimation directly in peritoneal fluid may provide useful information regarding localized biliary leakage and

may identify selected complications before corresponding systemic biochemical abnormalities become evident.

Table 6: Distribution of specific biochemical abnormalities and surgically confirmed leakage

Biochemical parameter	Observed abnormality	Number of patients	Percentage of peritonitis group (n=15)	Percentage of total cohort (n=63)	Subsequent finding
Peritoneal fluid amylase	>3 times upper normal serum reference limit	4	26.7%	6.3%	Occult leakage involving the pancreatico-duodenal region
Fluid-to-serum bilirubin ratio	>5.0	3	20.0%	4.8%	Biliary leakage associated with compromised duodenal repairs

The findings demonstrated that organ-associated biochemical markers could provide additional information beyond generalized inflammatory parameters. In selected patients, increased amylase and bilirubin ratios were associated with surgically identified leakage involving specific anatomical regions.

Microbiological Evaluation of Peritoneal Fluid: Microbiological examination was performed to identify bacterial contamination within the peritoneal cavity and assess its relationship with postoperative biochemical alterations.

The microbiological findings demonstrated a change in culture results during the postoperative observation period.

On POD 1, peritoneal fluid cultures were predominantly negative, with 87.3% of the samples showing no microbial growth. This corresponded to approximately 55 of the 63 patients. Eight patients (12.7%) demonstrated positive cultures.

The high proportion of culture-negative samples during the initial postoperative assessment may have been influenced by intraoperative peritoneal lavage and previous antimicrobial exposure. However, the individual contribution of these factors could not be established from the available observations.

During subsequent postoperative assessment on POD 3 and POD 5, positive aerobic and/or anaerobic cultures were reported in all 15 patients classified as having postoperative peritonitis. The exact number of positive cultures separately on POD 3 and POD 5 was not available in the supplied summary.

The culture findings were accompanied by marked biochemical alterations, particularly rising peritoneal fluid lactate and LDH concentrations and declining glucose levels.

These observations demonstrated an association between positive microbiological findings and abnormal localized biochemical profiles in patients with postoperative peritonitis.

Distribution of Isolated Microorganisms: A total of 22 microbial isolates were reported from the 15 patients with postoperative peritonitis.

Escherichia coli was the most frequently isolated organism, accounting for 10 isolates (45.5% of the total isolates). This was followed by Klebsiella pneumoniae, with six isolates (27.3%).

Enterococcus faecalis accounted for three isolates (13.6%), while Pseudomonas aeruginosa was identified in two isolates (9.1%). A single isolate of Bacteroides fragilis was also reported, accounting for 4.5% of the total isolates.

Thus, Escherichia coli and Klebsiella pneumoniae together accounted for approximately 72.7% of the total microbial isolates.

Polymicrobial infection was reported in five patients, representing 33.3% of the peritonitis group. The total number of isolates exceeded the number of affected patients because more than one organism was isolated in some patients.

Table 7: Microbiological profile of peritoneal fluid in patients with postoperative peritonitis

Isolated organism	Number of isolates	Percentage of total isolates
Escherichia coli	10	45.5%
Klebsiella pneumoniae	6	27.3%
Enterococcus faecalis	3	13.6%
Pseudomonas aeruginosa	2	9.1%
Bacteroides fragilis	1	4.5%
Total	**22**	**100%**

Percentages are calculated using 22 as the denominator, representing the total number of microbial isolates rather than the number of patients.

Table 8: Summary of microbiological culture findings during the postoperative period

Microbiological finding	Number of patients	Percentage
Culture-negative on POD 1	55	87.3%
Culture-positive on POD 1	8	12.7%
Positive follow-up cultures among peritonitis patients by POD 3/POD 5 assessment	15	100%
Polymicrobial infection among peritonitis patients	5	33.3%

The microbiological profile demonstrated a predominance of Gram-negative organisms, particularly E. coli and K. pneumoniae. The presence of polymicrobial infection in approximately one-third of the peritonitis group further indicated the varied microbial composition of postoperative intra-abdominal infections.

Importantly, culture-negative results were not considered sufficient to exclude postoperative infection. The microbiological findings were evaluated alongside clinical assessment, operative observations and the biochemical profile of peritoneal fluid.

Diagnostic Performance of Peritoneal Fluid Biochemical Parameters: Receiver Operating Characteristic (ROC) curve analysis was performed using peritoneal fluid biochemical measurements obtained on POD 3 to assess the ability of individual parameters to distinguish between patients with postoperative peritonitis and those with an uncomplicated recovery.

The analysis included lactate, pH, LDH and glucose. The area under the curve (AUC), sensitivity and specificity were used to evaluate their discriminatory performance.

Among the evaluated parameters, lactate demonstrated the highest AUC, followed by pH, LDH and glucose.

Peritoneal Fluid Lactate: Peritoneal fluid lactate demonstrated the highest discriminatory performance among the evaluated biochemical parameters.

At a cut-off value greater than 4.2 mmol/L on POD 3, lactate demonstrated an AUC of 0.924, with a 95% confidence interval of 0.86–0.98.

The reported sensitivity was 86.7%, while the specificity, recalculated to one decimal place using 48 uncomplicated patients as the denominator, was 91.7%.

These findings suggest that lactate was able to correctly identify a substantial proportion of patients with postoperative peritonitis while also demonstrating a high proportion of correctly classified uncomplicated recoveries.

Peritoneal Fluid pH: Peritoneal fluid pH demonstrated the second-highest discriminatory performance.

A cut-off value of less than 7.26 on POD 3 yielded an AUC of 0.891, with a 95% confidence interval of 0.81–0.96.

The sensitivity was 80.0%, while the recalculated specificity was 89.6%.

These findings indicate that a reduction in peritoneal fluid pH may provide useful information regarding the development of local inflammatory and metabolic disturbances. Its diagnostic performance was slightly lower than that of lactate but remained comparatively high.

Peritoneal Fluid Lactate Dehydrogenase: LDH also demonstrated good discriminatory ability in the diagnosis of postoperative peritonitis.

At a cut-off value greater than 600 U/L, the AUC was 0.865, with a 95% confidence interval of 0.78–0.94.

The sensitivity was 80.0%, while the specificity was 85.4%.

These findings suggest that increased peritoneal fluid LDH may help identify patients with substantial localized cellular injury and inflammatory activity. Although its discriminatory performance was lower than that of lactate and pH, it remained an important biochemical parameter.

Peritoneal Fluid Glucose: Peritoneal fluid glucose demonstrated an AUC of 0.822, with a 95% confidence interval of 0.71–0.91, at a cut-off value below 50 mg/dL.

The sensitivity was 73.3%, while the specificity was 83.3%.

The reduction in peritoneal glucose observed among patients with postoperative peritonitis was consistent with the pattern demonstrated in the serial biochemical analysis.

Although glucose showed comparatively lower discriminatory performance than lactate, pH and LDH, its estimation provided additional information regarding local metabolic alterations and possible bacterial glucose utilization.

Table 9: ROC analysis of peritoneal fluid biochemical parameters on POD 3

Biomarker	Cut-off value	AUC	95% confidence interval	Sensitivity	Specificity
Lactate	>4.2 mmol/L	0.924	0.86–0.98	86.7%	91.7%*
pH	<7.26	0.891	0.81–0.96	80.0%	89.6%*
LDH	>600 U/L	0.865	0.78–0.94	80.0%	85.4%
Glucose	<50 mg/dL	0.822	0.71–0.91	73.3%	83.3%

Comparison of the four biomarkers demonstrated that peritoneal fluid lactate had the highest AUC (0.924), suggesting the strongest discriminatory ability among the parameters evaluated.

Peritoneal fluid pH demonstrated the next-highest AUC (0.891), followed by LDH (0.865) and glucose (0.822).

All four parameters demonstrated AUC values greater than 0.80, indicating good discriminatory performance within the study population. However, the small number of patients with postoperative peritonitis and the absence of external validation should be considered when interpreting these findings.

The ROC analysis therefore identified localized lactate as the leading biochemical discriminator, with pH, LDH and glucose providing complementary diagnostic information.

Overall Summary of Principal Findings: The present study evaluated the clinical and biochemical characteristics of 63 patients undergoing emergency surgery for hollow viscus perforation and examined the association between peritoneal fluid biochemical parameters and postoperative clinical outcomes.

Of the 63 patients, 48 (76.2%) experienced uncomplicated postoperative recovery, whereas 15 (23.8%) developed postoperative peritonitis.

Baseline demographic characteristics, including age and gender, were comparable between the two groups. The reported anatomical distribution of perforations also did not demonstrate statistically significant differences.

Serial biochemical analysis showed that LDH, lactate and glucose concentrations were relatively comparable between the two groups on POD 1. However, substantial differences were observed by POD 3, which persisted on POD 5.

Patients with postoperative peritonitis demonstrated progressive increases in LDH and lactate, accompanied by marked reductions in peritoneal fluid glucose.

Total protein concentration on POD 5 was significantly higher in the peritonitis group. All patients demonstrated a SAAG below 1.1 g/dL on POD 1, although this finding was not considered independently diagnostic of postoperative infection.

Organ-specific biochemical assessment identified elevated peritoneal fluid amylase in four patients and an increased fluid-to-serum bilirubin ratio in three patients. Subsequent surgical evaluation reportedly confirmed leakage involving the corresponding anatomical regions.

Microbiological assessment demonstrated a predominance of Gram-negative organisms, particularly Escherichia coli and Klebsiella pneumoniae. Polymicrobial infection was reported in five patients.

Finally, ROC curve analysis demonstrated that peritoneal fluid lactate had the highest discriminatory performance, followed by pH, LDH and glucose.

Table 10: Consolidated summary of major study findings

Study parameter	Principal finding
Total study population	63 patients
Uncomplicated postoperative recovery	48 (76.2%)
Postoperative peritonitis	15 (23.8%)
Mean age	48.4 ± 14.2 years
Male patients	41 (65.1%)
Most frequently reported perforation site	Duodenum (49.2%)
SAAG on POD 1	<1.1 g/dL in all 63 patients
Total protein on POD 5	2.8 ± 0.4 g/dL in uncomplicated group; 4.2 ± 0.7 g/dL in peritonitis group
Elevated peritoneal amylase	4 patients in the peritonitis group
Elevated fluid-to-serum bilirubin ratio	3 patients in the peritonitis group
Total microbial isolates	22
Most frequently isolated organism	Escherichia coli (10 isolates)
Polymicrobial infections	5 patients (33.3% of peritonitis group)
Highest ROC AUC	Lactate: 0.924

Second-highest ROC AUC	pH: 0.891
ROC AUC for LDH	0.865
ROC AUC for glucose	0.822

Overall, the findings suggest that serial assessment of peritoneal fluid biochemical parameters may provide useful complementary information in the evaluation of patients following surgery for hollow viscus perforation. In particular, elevated lactate and LDH concentrations, together with declining glucose levels, were associated with postoperative peritonitis. The combination of these biochemical findings with clinical evaluation, microbiological investigations and operative observations may improve the assessment of postoperative intra-abdominal complications.

Discussion

The present study was undertaken to evaluate the diagnostic and prognostic value of peritoneal fluid biochemical analysis in patients undergoing emergency surgery for hollow viscus perforation. A total of 63 patients were included, of whom 48 (76.2%) had an uncomplicated postoperative recovery, while 15 (23.8%) developed postoperative peritonitis. The most important finding was the difference in the serial biochemical profiles of these two groups. Patients who developed postoperative peritonitis showed increasing levels of lactate dehydrogenase (LDH) and lactate, along with a considerable reduction in glucose concentration, particularly from postoperative day (POD) 3 onwards. Among the investigated parameters, peritoneal fluid lactate demonstrated the highest discriminatory performance, followed by pH, LDH and glucose.

Demographic Characteristics and Postoperative Outcomes: The study population showed a male predominance, with 41 males (65.1%) and 22 females (34.9%). The mean age was 48.4 ± 14.2 years. Duodenal perforation was the most frequently reported anatomical site, accounting for 49.2% of cases, followed by small intestinal and gastric perforations.

These findings are broadly comparable with those of Ramakrishnaiah et al., who reported a male predominance and frequent gastroduodenal involvement in their study of patients with secondary bacterial peritonitis in South India [30].

Postoperative peritonitis occurred in 23.8% of the present study population. Although patients with peritonitis had a slightly higher mean age than those with uncomplicated recovery (50.3 ± 15.1 versus 47.8 ± 13.9 years), the difference was not statistically significant. Gender and the reported anatomical distribution of perforations were also comparable between the two groups.

Secondary peritonitis remains a serious surgical complication, and delayed recognition or inadequate source control may lead to sepsis and organ dysfunction. Bohnen et al. highlighted the poor prognosis associated with generalized and postoperative peritonitis, particularly when surgical intervention is delayed [17]. Similarly, the World Society of Emergency Surgery and Surgical Infection Society guidelines emphasize early diagnosis, adequate source control and appropriate antimicrobial treatment in the management of complicated intra-abdominal infections [18,19]. These considerations highlight the importance of identifying additional biochemical indicators that may help recognize patients developing postoperative complications.

Serial Changes in Peritoneal Fluid Biochemical Parameters: One of the most important observations was the difference in the postoperative progression of biochemical parameters between the two groups. On POD 1, LDH, lactate and glucose values were relatively comparable. However, by POD 3, significant differences had developed and persisted on POD 5.

Simmen et al. demonstrated that patients with intra-abdominal bacterial infection had increased peritoneal fluid lactate and LDH concentrations, along with reduced glucose levels [3]. These findings closely resemble the biochemical pattern observed in the present study. Akriviadis and Runyon also demonstrated the usefulness of biochemical assessment, including peritoneal fluid protein, glucose and LDH, in identifying secondary bacterial peritonitis associated with gastrointestinal perforation [20]. Their findings support the value of combining biochemical parameters rather than relying on a single measurement.

LDH increased progressively in the peritonitis group, reaching 1120.3 ± 210.8 U/L on POD 5, compared with 180.5 ± 45.3 U/L in the uncomplicated group. Similarly, lactate increased to 8.7 ± 1.9 mmol/L, whereas it declined to 1.3 ± 0.4 mmol/L among patients with uncomplicated recovery.

Ellebaek et al. evaluated intraperitoneal microdialysis in 129 patients undergoing low anterior resection and reported that increasing intraperitoneal lactate concentrations were associated with anastomotic leakage. Their ROC analysis demonstrated an AUC of 0.90 for lactate, supporting the potential importance of localized metabolic changes in postoperative complications [21].

Glucose showed the opposite pattern. On POD 5, the mean peritoneal fluid glucose concentration was 28.1 ± 11.2 mg/dL in the peritonitis group compared with 95.4 ± 8.8 mg/dL in the uncomplicated group. This reduction may be related to increased glucose utilization by inflammatory cells and microorganisms within the infected peritoneal environment.

Taken together, these findings suggest that rising lactate and LDH, accompanied by falling glucose, may reflect continuing inflammatory and metabolic disturbances in patients developing postoperative peritonitis.

Significance of Peritoneal Fluid pH and Inflammatory Biomarkers: Peritoneal fluid pH demonstrated good discriminatory performance in the present study, with an AUC of 0.891 at a cut-off below 7.26 on POD 3.

Molinari et al., in a prospective study involving patients undergoing colorectal surgery, reported lower drain-fluid pH values among patients with anastomotic leakage. Their POD 3 ROC analysis demonstrated an AUC of 0.86, which is broadly comparable with the finding of the present study [24].

Uğraş et al. investigated peritoneal cytokines in patients undergoing colorectal surgery and reported significantly higher concentrations of inflammatory cytokines, including interleukin-6, interleukin-10 and tumour necrosis factor-alpha, among patients who developed anastomotic leakage [23]. Similarly, Sammour et al. demonstrated the potential usefulness of early peritoneal cytokine measurements in predicting postoperative anastomotic leakage [25].

Reeves et al., in their systematic review and meta-analysis, further reported that peritoneal interleukin-10 was significantly elevated on POD 1 among patients who subsequently developed colorectal anastomotic leakage. However, the authors also highlighted the heterogeneity of available studies and the need for further research [31].

Although inflammatory cytokines were not measured in the present study, these investigations support the importance of examining localized biochemical and inflammatory changes within the peritoneal cavity. Parameters such as pH, lactate and LDH may offer a practical approach to assessing these changes in routine surgical settings.

Total Protein, SAAG and Organ-Specific Biochemical Markers: Total protein concentration on POD 5 was significantly higher in the peritonitis group than in the uncomplicated group (4.2 ± 0.7 versus 2.8 ± 0.4 g/dL; $p < 0.001$). This difference may be related to increased vascular permeability and inflammatory exudation associated with ongoing intra-abdominal inflammation.

All patients demonstrated a SAAG below 1.1 g/dL on POD 1. However, this finding represents a low albumin-gradient pattern and should not be considered independent evidence of postoperative infection. Runyon et al. established the usefulness of SAAG in differentiating the underlying causes of ascites, particularly portal hypertensive and non-portal hypertensive ascites [27]. Aithal et al., in their clinical guidelines on ascites management, also emphasized the importance of SAAG in the evaluation of patients with cirrhosis and ascites [26]. The biochemical interpretation of peritoneal and ascitic fluid should therefore take into account the underlying clinical condition [9].

Peritoneal fluid amylase was markedly elevated in four patients with postoperative peritonitis, and subsequent surgical assessment reportedly confirmed leakage involving the pancreatico-duodenal region in all four cases. Amylase estimation has an established role in the evaluation of pancreatic leakage. The International Study Group on Pancreatic Surgery has incorporated drain-fluid amylase into its definition of postoperative pancreatic fistula [28].

Similarly, a peritoneal fluid-to-serum bilirubin ratio greater than 5 was identified in three patients, with subsequent confirmation of biliary leakage. Darwin et al. demonstrated the usefulness of this ratio in diagnosing bile leaks in their clinical study [29]. DeBenedet et al. also evaluated the fluid-to-serum bilirubin ratio in patients undergoing orthotopic liver transplantation, highlighting its potential diagnostic application in postoperative biliary complications [10].

These findings suggest that amylase and bilirubin measurements may provide additional information when specific pancreatic, gastrointestinal or biliary leakage is suspected.

Microbiological Profile of Postoperative Peritonitis: Microbiological examination yielded 22 isolates from the 15 patients with postoperative peritonitis. Escherichia coli was the most frequently isolated organism (45.5%), followed by Klebsiella pneumoniae (27.3%). Together, Gram-negative organisms accounted for 86.4% of the isolates. Polymicrobial infection was observed in five patients (33.3%).

These findings are consistent with the observations of Ramakrishnaiah et al., who identified E. coli and Klebsiella species as predominant organisms in patients with community-acquired secondary bacterial peritonitis in South India [30].

In the present study, all 15 patients with postoperative peritonitis reportedly yielded positive

aerobic and/or anaerobic cultures during follow-up assessment. However, culture positivity was considered supportive evidence rather than the sole basis for diagnosing infection. Patients with genuine intra-abdominal infection may have negative cultures, particularly following antimicrobial treatment.

The Surgical Infection Society guidelines emphasize appropriate microbiological sampling in complicated intra-abdominal infections to help identify causative organisms and guide antimicrobial treatment [19]. Similarly, the 2024 Infectious Diseases Society of America guideline update highlights the importance of microbiological evaluation in the management of complicated intra-abdominal infections [34].

The predominance of Gram-negative organisms in the present study further highlights the importance of culture and antimicrobial susceptibility testing in postoperative patients.

Diagnostic Performance of Peritoneal Fluid Biomarkers: ROC analysis demonstrated that lactate had the highest discriminatory performance among the investigated parameters, with an AUC of 0.924 at a cut-off greater than 4.2 mmol/L on POD 3. Its sensitivity was 86.7%, with a recalculated specificity of approximately 91.7%.

Peritoneal fluid pH followed with an AUC of 0.891, while LDH and glucose demonstrated AUC values of 0.865 and 0.822, respectively.

These findings are broadly comparable with the study by Ellebaek et al., who demonstrated the diagnostic potential of intraperitoneal lactate for detecting colorectal anastomotic leakage [21]. Wright et al., in their systematic review, also identified lactate and pH as promising markers for detecting anastomotic leakage, although further clinical validation was recommended [22].

Regarding localized C-reactive protein assessment, Mužina Mišić et al. compared serum and peritoneal fluid CRP concentrations in 59 patients undergoing colorectal surgery. Interestingly, their findings indicated that serum CRP performed better than intraperitoneal CRP in predicting anastomotic leakage [33]. This suggests that localized biochemical markers should not automatically be considered superior to systemic markers and that their diagnostic usefulness may vary according to the parameter being measured and the clinical setting.

In the present study, lactate emerged as the strongest individual biochemical discriminator, followed by pH, LDH and glucose. Koperna and Schulz also emphasized the importance of prognostic assessment and the limitations of existing scoring systems in patients with secondary bacterial peritonitis [32]. The addition of localized biochemical measurements may therefore provide complementary information to conventional clinical assessment.

However, the cut-off values identified in the present study were derived from a relatively small cohort containing only 15 patients with postoperative peritonitis. They should consequently be considered preliminary findings requiring validation in larger and independent patient populations.

Clinical Implications, Strengths and Limitations: The findings suggest that serial peritoneal fluid biochemical assessment may provide useful additional information during postoperative monitoring following surgery for hollow viscus perforation. In particular, rising lactate and LDH concentrations, together with declining glucose levels, may indicate an adverse biochemical pattern by POD 3.

The prospective design, sequential sampling on POD 1, POD 3 and POD 5, and paired peritoneal fluid and blood collection are important strengths of the present study. Assessment of multiple biochemical parameters also provided a broader understanding of local changes within the peritoneal cavity.

However, the study has certain limitations. The sample size was relatively small, particularly the postoperative peritonitis group (n = 15), and the study was conducted at a single tertiary care centre. The diagnostic cut-off values were derived and assessed within the same study population and therefore require external validation. Incomplete anatomical classification for seven patients, the absence of serial total protein and pH measurements in the available results, and the lack of formal repeated-measures analysis are additional limitations. Variations in drain position, sample collection and previous antimicrobial exposure may also have influenced the findings.

Further multicentre prospective studies involving larger populations, standardized diagnostic criteria and appropriate statistical validation are required to establish the reliability and clinical usefulness of these biochemical parameters.

Conclusion

The present study demonstrates that postoperative peritonitis is associated with distinct biochemical changes within the peritoneal cavity. The most notable findings were increasing LDH and lactate concentrations, declining glucose levels and higher total protein concentrations among patients with postoperative peritonitis.

Lactate demonstrated the highest discriminatory performance, followed by pH, LDH and glucose. Amylase and bilirubin provided additional

information in selected cases of organ-specific leakage, while microbiological examination revealed a predominance of Gram-negative organisms.

Overall, serial biochemical analysis of peritoneal fluid may serve as a useful adjunct to clinical assessment, imaging and microbiological investigations in patients undergoing surgery for hollow viscus perforation. Larger studies are necessary to establish standardized diagnostic thresholds and determine their applicability in routine surgical practice.

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