

Frailty-Related and Hepatic Prognostic Markers in Acute Biliary Tract Infections: A Diagnosis-Stratified Retrospective Cohort Study

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Research Article

Keywords: biliary tract infection, sarcopenia, psoas muscle area, prognostic nutritional index, FIB-4, acute cholangitis, 30-day mortality

Posted Date: April 7th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-8419683/v1>

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Additional Declarations: No competing interests reported.

Abstract

Background:

Acute biliary tract infections (BTIs), including acute cholecystitis and acute cholangitis, show substantial clinical heterogeneity and variable short-term outcomes. Prognostic markers reflecting frailty, nutritional reserve and hepatic dysfunction may improve early risk stratification. In this context, the present study aimed to evaluate the prognostic value of computed tomography (CT)-derived psoas muscle area (PMA), FIB-4 score, prognostic nutritional index (PNI) and systemic inflammatory indices in predicting intensive care unit (ICU) admission, 30-day mortality and length of hospital stay (LOS) in patients hospitalized with acute BTIs.

Methods:

We retrospectively analyzed 94 adults hospitalized with acute biliary tract infections between 2022 and 2023. Analyses were performed in a diagnosis-stratified manner (acute cholecystitis vs acute cholangitis). Psoas muscle area (PMA) was measured on admission CT at the L3 level, while FIB-4, prognostic nutritional index (PNI) and systemic inflammatory ratios were calculated from admission laboratory data. Outcomes included ICU admission, 30-day all-cause mortality and length of hospital stay. Logistic regression and linear regression analyses were used to identify prognostic factors and receiver operating characteristic (ROC) curves were applied to assess model discrimination.

Results:

Patients with acute cholangitis exhibited substantially higher 30-day mortality than those with acute cholecystitis (30.0% vs 4.1%), along with lower PNI, higher FIB-4 values, lower albumin and hemoglobin levels and a higher prevalence of low PMA. Age was associated with lower PMA and PNI and higher FIB-4 scores. In parsimonious multivariable logistic regression analysis, a diagnosis of acute cholangitis emerged as the strongest predictor of 30-day mortality. Although age and psoas muscle area (PMA) demonstrated directionally consistent associations with mortality, these did not reach statistical significance, likely owing to the limited number of outcome events. The resulting model showed good discriminatory performance for 30-day mortality (AUC $\approx$ 0.84).

Conclusions:

Frailty-related parameters, particularly impaired nutritional status and reduced muscle mass, cluster in patients with acute cholangitis and are associated with worse short-term outcomes. CT-based PMA assessment, together with nutritional and hepatic indices, may support early risk stratification in acute biliary tract infections.

Introduction / Background

Acute biliary tract infections (BTIs), including acute cholecystitis and cholangitis, constitute a significant clinical challenge due to their heterogeneous presentations and variable prognoses(1–5). Despite advances in antimicrobial therapy and minimally invasive interventions, patient outcomes remain strongly influenced by host-related factors such as age, comorbidities and baseline physiological reserve. Increasing evidence suggests that integrating nutritional status, hepatic function and systemic inflammatory burden into clinical assessment may improve risk stratification and guide management strategies (1, 6).

In this context, composite indices combining clinical and laboratory parameters have gained attention for their potential prognostic value in BTIs. The prognostic nutritional index (PNI) reflects nutritional and immune status (7), while computed tomography (CT)–derived measurements of muscle mass, particularly psoas muscle area (PMA), are widely used as surrogate markers of sarcopenia (8–10). Sarcopenia has been increasingly recognized as an independent predictor of adverse postoperative and infectious outcomes (11–14). Liver-related scores, particularly the FIB-4 fibrosis index, may provide additional value for risk stratification by reflecting underlying hepatic dysfunction (15, 16). However, data examining the association between FIB-4 and acute cholecystitis or acute cholangitis are currently scarce.

Evidence evaluating the relationship between sarcopenia and acute biliary tract infections remains limited. To date, only a small number of studies have explored the prognostic implications of skeletal muscle depletion in acute cholecystitis, with most focusing on postoperative outcomes, recurrence after conservative management or the development of cholecystitis in patients with gallstones (8, 10, 17). Data addressing sarcopenia in relation to acute infectious severity and short-term outcomes in acute cholecystitis are sparse and the association between sarcopenia and acute cholangitis has not been systematically investigated. Existing studies have primarily focused on chronic cholangiopathies, such as primary sclerosing cholangitis, rather than acute infectious cholangitis (18–20). Similarly, although FIB-4 is widely used to estimate chronic liver fibrosis, its prognostic relevance in acute biliary tract infections remains largely unexplored.

Several inflammatory markers and derived ratios, such as C-reactive protein-to-albumin ratio (CAR) and platelet-to-albumin ratios (PAR), are being evaluated for their correlation with morbidity and mortality in acute illness (21). C-reactive protein-to-albumin ratio (CAR) may serve as a useful marker for assessing disease severity in acute cholecystitis and for estimating morbidity risk in affected patients (22). The platelet-to-albumin ratio (PAR) has been identified as an important prognostic marker in critically ill patients, where higher values are linked to worse clinical outcomes. (23). Hemoglobin × albumin × lymphocyte / platelet index (HALP) score appears to be a valuable tool for supporting treatment planning and management strategies in patients with acute cholecystitis (24). C-reactive protein–to–lymphocyte ratio (CLR) demonstrates greater discriminatory ability than conventional inflammatory markers for assessing treatment response in acute cholangitis (25). Elevated C-reactive protein–to–

platelet ratio (CPR) has showed the strongest performance in predicting clinical outcomes among patients with pyogenic liver abscess (26). Platelet-to-lymphocyte ratio (PLR), C-reactive protein (CRP) have been linked to disease severity and bacteremia in acute cholangitis while the platelet-to-lymphocyte ratio (PLR) was most closely linked to blood culture positivity (27). However, the clinical utility of these markers in BTIs remains inconsistent.

Despite these advances, the optimal integration of nutritional, hepatic, sarcopenia-related and inflammatory metrics for outcome prediction in BTIs is unclear. Therefore, this study investigates the prognostic utility of CT-derived PMA, FIB-4 score, prognostic nutritional index and systemic inflammatory ratios in patients hospitalized with acute biliary tract infections.

Methods

This retrospective cohort study included 94 adult patients diagnosed with acute biliary tract infections (BTIs), specifically acute cholecystitis and acute cholangitis, who were hospitalized at Rize Recep Tayyip Erdoğan University Education and Research Hospital between 2022 and 2023. Inclusion criteria encompassed adults with confirmed acute cholangitis or acute cholecystitis. Patients were excluded if they were younger than 18 years, had acute pancreatitis (biliary or non-biliary), incomplete or missing data, extra-biliary malignancy or if treatment could not be continued at our institution. Patients with active malignancy other than biliary tract malignancy were excluded to reduce heterogeneity and avoid confounding related to cancer-associated inflammation and cachexia, whereas patients with biliary tract malignancy were retained due to its direct association with biliary obstruction and acute cholangitis.

Demographic characteristics (age and sex), diagnostic category, presence of biliary tract malignancy and treatment modality datas were recorded. Admission laboratory data included liver function tests, complete blood count parameters, inflammatory markers and serum albumin levels.

Because standardized skeletal muscle indices such as the skeletal muscle index (SMI) could not be calculated due to missing height and body weight data, psoas muscle area (PMA) measured on admission CT scans at the L3 level was used as a pragmatic and reproducible surrogate marker of skeletal muscle mass to assess the presence of sarcopenia. PMA was analyzed as a continuous variable and dichotomized using sex-specific cut-off values ($< 20.3 \text{ cm}^2$ for males and $< 11.8 \text{ cm}^2$ for females) (8, 28, 29).

Hepatic fibrosis was assessed using the FIB-4 score, calculated as follows:

$\text{FIB-4} = (\text{Age (years)} \times \text{AST (U/L)}) / (\text{Platelet Count} (10^9 / \text{L}) \times \sqrt{\text{ALT (U/L)}})$ with thresholds for no/minimal fibrosis (< 1.3), intermediate fibrosis ($1.3\text{--}2.67$) and advanced fibrosis risk (> 2.67)(15).

Nutritional and immunological status was evaluated using the Prognostic Nutritional Index (PNI):

$PNI = 10 \times \text{serum albumin (g/dL)} + 0.005 \times \text{total lymphocyte count (/mm}^3\text{)}$ with categories < 45, 45–50 and > 50 (7, 30).

Systemic inflammatory ratios included: Platelet/albumin ratio (PAR), CRP/albumin ratio (CAR), CRP/lymphocyte ratio (CLR), Hemoglobin $\times$ albumin $\times$ lymphocyte / platelet index (HALP), Platelet/lymphocyte ratio (PLR) and CRP/platelet ratio (CPR)

The primary outcomes were ICU admission, hospital length of stay (LOS) and 30-day all-cause mortality. Associations of PMA, FIB-4, PNI and systemic inflammatory indices with short-term outcomes were evaluated as secondary analyses. Intervention modalities (percutaneous cholecystostomy, percutaneous transhepatic biliary drainage and cholecystectomy) were recorded and interpreted as descriptive indicators of disease severity and surgical eligibility rather than causal exposures.

Continuous variables were assessed for normality using visual inspection and the Shapiro–Wilk test and are presented as mean $\pm$ standard deviation or median with interquartile range (IQR), as appropriate. Categorical variables are reported as counts and percentages.

Comparisons between patients with acute cholecystitis and acute cholangitis were performed using the Student's t-test or Mann–Whitney U test for continuous variables, according to data distribution, and the chi-square test or Fisher's exact test for categorical variables.

Given the limited number of outcome events, multivariable models were kept parsimonious to minimize overfitting, with priority given to clinically relevant variables. Logistic regression was used to evaluate predictors of ICU admission and 30-day mortality, while linear regression was applied to identify predictors of length of stay (LOS). Model discrimination was assessed using receiver operating characteristic (ROC) curves and the area under the curve (AUC).

All analyses were performed in a diagnosis-stratified manner (acute cholecystitis vs acute cholangitis) to account for clinical heterogeneity. Statistical analyses were performed using IBM SPSS Statistics, version 29.0 (IBM Corp., Armonk, NY, USA), and a two-sided p-value < 0.05 was considered statistically significant.

Results

Ninety-four patients were included: 74 with acute cholecystitis and 20 with acute cholangitis. Marked clinical and laboratory heterogeneity was observed between the two diagnostic groups (Table 1). Patients with cholangitis were more frequently male and had a markedly higher prevalence of biliary tract malignancy. Thirty-day mortality was substantially higher in cholangitis (30.0%) than in cholecystitis (4.1%). ICU admission was uncommon in both groups. Percutaneous cholecystostomy was performed in 70.2% of patients, percutaneous transhepatic biliary drainage (PTBD) in 21.3% and cholecystectomy in 8.5%.

Laboratory profiles differed between diagnoses (Table 2). Cholangitis was associated with higher transaminases and bilirubin, lower albumin, lower hemoglobin and lymphocyte counts and higher blood urea nitrogen consistent with greater hepatobiliary dysfunction and impaired nutritional–immune reserve.

Muscle mass, nutritional status, and fibrosis-related indices stratified by diagnosis are summarized in Table 3. Although median PMA values showed overlap between acute cholecystitis and acute cholangitis, categorization using sex-specific cut-off values revealed a significantly higher prevalence of low PMA among patients with acute cholangitis. Nutritional impairment was markedly more pronounced in the cholangitis group, with significantly lower median PNI values and a substantially higher proportion of patients classified as severely malnourished. Similarly, fibrosis-related risk differed between diagnoses, with patients with acute cholangitis demonstrating significantly higher median FIB-4 scores and a greater proportion categorized as having advanced fibrosis risk. Overall, Table 3 illustrates a clear clustering of sarcopenia, malnutrition and increased hepatic fibrosis risk among patients with acute cholangitis compared with those with acute cholecystitis.

Systemic inflammatory and composite indices stratified by diagnosis are summarized in Table 4. Among systemic inflammatory ratios, PAR was higher in cholangitis while CAR was higher in cholecystitis. HALP was lower in cholangitis, suggesting combined anemia, inflammation and malnutrition. Other ratios showed no statistically significant between-group differences.

Continuous PMA showed overlap between groups; however, low PMA was more frequent in cholangitis. Violin plots with embedded boxplots show lower PNI and higher FIB-4 in cholangitis, while continuous PMA overlaps between groups (Fig. 1).

Increasing age was associated with higher FIB-4 scores, while higher FIB-4 values were inversely correlated with PNI. Lower PNI was associated with prolonged LOS. PMA showed significant associations with both PNI and age, highlighting the link between sarcopenia, nutritional status and aging. In addition, PNI was positively correlated with hemoglobin levels. Scatter plots illustrate correlations; regression lines with 95% confidence intervals are shown in Fig. 2.

In parsimonious multivariable logistic regression, cholangitis diagnosis remained the strongest predictor of 30-day mortality, while age and PMA showed directionally consistent effects but did not reach statistical significance, likely due to the limited number of events. The primary multivariable model demonstrated good discrimination for 30-day mortality (AUC $\approx$ 0.84).

Table 1
Baseline demographic and clinical characteristics of patients with acute cholecystitis and acute cholangitis

Variable	Acute cholecystitis (n = 74)	Acute cholangitis (n = 20)	p-value
Age, years	68.50 [58.00–79.75]	66.00 [60.00–79.25]	0.796
Female sex, n (%)	41 (55.4)	5 (25.0)	0.023
Male sex, n (%)	33 (44.6)	15 (75.0)	0.023
Biliary tract malignancy, n (%)	5 (6.8)	17 (85.0)	< 0.001
ICU admission, n (%)	3 (4.1)	2 (10.0)	0.287
30-day mortality, n (%)	3 (4.1)	6 (30.0)	0.003
Length of stay, days	12.0 [10.0–14.0]	14.0 [10.0–15.5]	0.168

Values are presented as median [interquartile range] or number (%), as appropriate. P-values were calculated using the Mann–Whitney U test for continuous variables and the chi-square or Fisher's exact test for categorical variables. Length of stay was defined as total treatment duration in days. ICU, intensive care unit.

Laboratory parameters stratified by diagnosis are summarized in Table 2.

Table 2
Laboratory parameters according to diagnosis

Variable	Acute cholecystitis	Acute cholangitis	p-value
AST (U/L)	46.0 [26.0–88.0]	95.0 [46.0–169.0]	0.008
ALT (U/L)	34.0 [21.0–68.0]	76.0 [33.0–122.0]	0.012
Total bilirubin (mg/dL)	1.16 [0.68–2.21]	3.00 [1.35–5.99]	0.007
Direct bilirubin (mg/dL)	0.26 [0.14–0.67]	1.46 [0.41–3.48]	0.003
Albumin (g/L)	35.0 [30.3–39.0]	28.7 [23.0–31.7]	< 0.001
Blood urea nitrogen (mg/dL)	43.0 [27.0–64.0]	59.5 [41.0–82.0]	0.041
Creatinine (mg/dL)	0.96 [0.74–1.26]	1.10 [0.82–1.54]	0.187
White blood cell count ($\times 10^3/\mu\text{L}$)	13.4 [9.8–17.9]	15.8 [11.2–21.4]	0.093
Hemoglobin (g/dL)	12.4 [10.9–13.7]	11.1 [9.8–12.6]	0.018
Lymphocyte count ($\times 10^3/\mu\text{L}$)	1.30 [0.86–1.88]	1.02 [0.61–1.46]	0.044
Platelet count ($\times 10^3/\mu\text{L}$)	252 [186–318]	282 [214–361]	0.241
CRP (mg/L)	171.7 [87.0–264.3]	88.1 [27.8–177.2]	0.021

Values are presented as median [interquartile range]. P-values were calculated using the Mann–Whitney U test. AST, aspartate aminotransferase; ALT, alanine aminotransferase; CRP, C-reactive protein.

Laboratory parameters differed significantly between diagnoses. Acute cholangitis was associated with higher transaminase and bilirubin levels, lower albumin and hemoglobin concentrations, and reduced lymphocyte counts, indicating more pronounced hepatobiliary dysfunction and impaired nutritional–immune reserve compared with acute cholecystitis.

Table 3
Muscle mass, nutritional status and fibrosis-related indices according to diagnosis

Variable	Acute cholecystitis (n = 74)	Acute cholangitis (n = 20)	p-value
PMA (cm ²)	11.94 [9.29–15.92]	10.20 [7.98–14.47]	0.153
Low PMA, n (%) (< 20.3 cm ² for males and < 11.8 cm ² for females).	53 (71.6)	19 (95.0)	0.036
Prognostic Nutritional Index (PNI)	41.75 [36.86–46.99]	33.92 [29.15–38.70]	< 0.001
PNI category, n (%)			0.015
PNI Severe (< 40), n (%)	30 (40.5)	16 (80)	
PNI Moderate (40–44.9), n (%)	20 (27)	2 (10)	
PNI Mild (45–49.9), n (%)	14 (18.9)	2 (10)	
PNI Normal (≥ 50), n (%)	10 (13.5)	0 (0)	
FIB-4 score	1.56 [0.91–2.80]	2.92 [1.92–5.39]	0.005
FIB-4 category, n (%)			0.036
FIB-4 No/minimal (< 1.3), n (%)	32 (43.2)	3 (15)	
FIB-4 Intermediate (1.3–2.67), n (%)	21 (28.4)	6 (30)	
FIB-4 Advanced (> 2.67), n (%)	21 (28.4)	11 (55)	

Values are presented as median [interquartile range] or number (%), as appropriate. P-values were calculated using the Mann–Whitney U test for continuous variables and the chi-square or Fisher’s exact test for categorical variables.

Table 4
Systemic inflammatory and composite indices according to diagnosis

Variable	Acute cholecystitis	Acute cholangitis	p-value
Platelet-to-albumin ratio (PAR)	7.32 [5.01–9.63]	9.41 [6.77–13.09]	0.028
CRP-to-albumin ratio (CAR)	5.21 [2.70–7.81]	3.62 [1.05–6.44]	0.047
CRP-to-lymphocyte ratio (CLR)	2038 [984–2875]	1468 [495–2550]	0.112
HALP index	23.7 [14.3–33.8]	15.4 [9.1–21.8]	0.009
Platelet-to-lymphocyte ratio (PLR)	255 [178–340]	289 [201–415]	0.158
CRP-to-platelet ratio (CPR)	0.79 [0.41–1.05]	0.63 [0.23–0.96]	0.214

Values are presented as median [interquartile range]. P-values were calculated using the Mann–Whitney U test. PAR, platelet-to-albumin ratio; CAR, C-reactive protein-to-albumin ratio; CLR, C-reactive protein-to-lymphocyte ratio; HALP, hemoglobin–albumin–lymphocyte–platelet index; PLR, platelet-to-lymphocyte ratio; CPR, C-reactive protein-to-platelet ratio.

Figure 1. Violin plots illustrating the distribution of psoas muscle area (PMA), prognostic nutritional index (PNI), and FIB-4 score according to diagnosis. Panels display PMA (cm²), PNI, and FIB-4 values in patients with acute cholangitis and acute cholecystitis. Violin plots represent the full distribution of each variable, with embedded boxplots indicating the median and interquartile range. Although continuous PMA values show substantial overlap between diagnostic groups, patients with acute cholangitis demonstrate a higher prevalence of low PMA when categorized using sex-specific cut-off values. Nutritional status, reflected by PNI, is markedly impaired in acute cholangitis, with lower median values compared with acute cholecystitis. Similarly, FIB-4 scores are higher in acute cholangitis, indicating an increased burden of hepatic fibrosis risk. Overall, the figure highlights clustering of sarcopenia-related muscle loss, malnutrition, and hepatic vulnerability in acute cholangitis relative to acute cholecystitis.

Figure 2. Scatter plots demonstrating correlations between frailty-related, nutritional, hepatic, and clinical parameters in patients with acute biliary tract infections. Panels illustrate the relationships between FIB-4 and age, FIB-4 and prognostic nutritional index (PNI), PNI and length of hospital stay (LOS), PNI and psoas muscle area (PMA), PMA and age, and PNI and hemoglobin levels. Solid lines represent linear regression fits with shaded areas indicating 95% confidence intervals. Correlation coefficients (r) and corresponding p-values are displayed for each comparison. Advancing age was positively correlated with higher FIB-4 scores and inversely correlated with PMA, indicating the coexistence of hepatic vulnerability and sarcopenia with aging. Higher FIB-4 values were associated with lower PNI, reflecting an inverse relationship between hepatic dysfunction and nutritional status. Lower PNI was modestly associated with prolonged LOS. PMA showed positive correlation with PNI and negative correlation with age, highlighting the interdependence of muscle mass, nutritional reserve, and aging. In addition, PNI

demonstrated a strong positive association with hemoglobin levels, supporting its role as an integrated marker of nutritional and hematological status. Collectively, these correlations illustrate a coherent frailty-related axis linking aging, sarcopenia, impaired nutrition, hepatic vulnerability, and adverse short-term clinical outcomes.

Figure 3 illustrates the predicted probability of 30-day mortality according to age and psoas muscle area (PMA), derived from a parsimonious logistic regression model including diagnosis (cholangitis), age and PMA.

Low PMA was observed in 76.6% of patients. FIB-4 risk categories were distributed as follows: low risk (≤ 1.3) in 37.2%, indeterminate (1.3–2.67) in 28.7%, and high risk (> 2.67) in 34.0%. According to PNI, 48.9% of patients had severe nutritional risk, 23.4% moderate, 17.0% mild, and 10.6% no nutritional risk.

Overall, advancing age was associated with a progressive increase in the estimated risk of 30-day mortality. Importantly, this age-related increase was markedly more pronounced among patients with low PMA.

At younger ages, the predicted mortality risk remained low in both groups. However, with increasing age, patients with reduced muscle mass demonstrated a steeper rise in predicted mortality compared with those with preserved PMA. This divergence became particularly evident in older age ranges, indicating that sarcopenia substantially amplifies the adverse prognostic impact of aging in acute biliary tract infections.

These findings suggest a synergistic effect between advanced age and reduced skeletal muscle mass on short-term mortality risk, supporting the role of frailty-related parameters in early risk stratification.

Female patients had significantly higher PNI values compared with males ($p = 0.027$), indicating better nutritional status. Male patients tended to have higher FIB-4 scores, although this difference did not reach statistical significance ($p = 0.070$). Hospital length of stay was longer in male patients than in females ($p = 0.036$), whereas ICU admission and 30-day mortality did not differ significantly by sex.

Advanced age was positively associated with longer hospital stay ($p < 0.05$). Although older age showed non-significant trends toward higher ICU admission and 30-day mortality, patients aged ≥ 65 years had significantly lower PMA and PNI values and higher FIB-4 scores (all $p < 0.05$).

Comparison between ICU and non-ICU patients revealed that FIB-4 was significantly higher in ICU patients ($p = 0.001$), while PMA and PNI showed no significant difference ($p = 0.589$ and $p = 0.094$, respectively). The ROC analysis for ICU admission prediction incorporating PMA, FIB-4, and PNI achieved an AUC of 0.78, indicating good model discrimination. However, the very small number of ICU cases ($n = 5$) limits the reliability of statistical analyses.

Among the three main markers, only FIB-4 showed a significant discriminatory ability for predicting 30-day mortality, with an AUC of 0.78. PMA and PNI did not demonstrate meaningful predictive value (AUC $<$

0.30) in this analysis. FIB-4 values were higher in non-survivors, while PMA and PNI tended to be lower compared to survivors; nonetheless, the limited number of deaths ($n = 9$) reduced the statistical power.

In univariate logistic regression, PNI showed a borderline association with prolonged length of stay, but in the multivariate model, it emerged as an independent predictor ($OR = 0.94$, $p = 0.045$). PMA and FIB-4 were not significant for LOS prediction ($AUC \approx 0.47$ and 0.60 , respectively). Low PNI was associated with prolonged hospital stay and may serve as an independent predictor of LOS, whereas PMA and FIB-4 were not reliable markers.

Systemic inflammatory ratios (PAR, CAR, CLR, HALP, PLR, CPR) did not provide reliable prediction for hospital stay duration or 30-day mortality in this dataset. Their association with major outcomes was not statistically significant.

Discussion

In this retrospective cohort of patients hospitalized with acute biliary tract infections, we assessed the prognostic relevance of CT-derived PMA, FIB-4, nutritional status (PNI) and systemic inflammatory indices. The key finding is that acute cholangitis and acute cholecystitis are clinically and biologically distinct entities, and that frailty-related markers—particularly low PMA and impaired nutritional reserve—cluster in the higher-risk cholangitis group. Cholangitis was associated with markedly higher 30-day mortality and more frequent low PMA, lower PNI, lower albumin and higher FIB-4.

One of the key observations of this study is the strong association between advanced age and adverse clinical characteristics, including lower PMA, reduced PNI, higher FIB-4 scores and prolonged hospital stay. Aging is known to be associated with progressive muscle loss, impaired nutritional reserve and reduced physiological resilience, all of which may limit the ability to tolerate acute infection and inflammatory stress (31, 32). Our findings are consistent with previous studies demonstrating the adverse impact of frailty and sarcopenia on outcomes in acute surgical and infectious conditions (10, 17, 33-35).

Among the evaluated parameters, FIB-4 demonstrated the best discriminatory ability for predicting 30-day mortality. Although originally developed as a non-invasive marker of chronic liver fibrosis, FIB-4 may also reflect hepatic vulnerability and systemic stress in the acute setting (15, 16). In our cohort, higher FIB-4 values were observed in non-survivors, suggesting that underlying hepatic dysfunction may amplify the severity of acute biliary infections. However, the limited number of mortality events restricted the statistical power of multivariable analyses and FIB-4 did not retain independent predictive value after adjustment for key clinical variables. Although the FIB-4 score is well established as a non-invasive marker of chronic liver fibrosis, its role in acute biliary tract infections has not been previously defined. We were unable to identify published studies examining the relationship between FIB-4 and either acute cholecystitis or acute cholangitis. Our findings suggest that higher FIB-4 values may reflect hepatic vulnerability and systemic stress in the acute setting, warranting further investigation in larger cohorts.

Psoas muscle area was frequently reduced in this cohort, indicating a high burden of sarcopenia. PMA was inversely correlated with age and FIB-4, supporting the concept that muscle depletion, hepatic dysfunction, and aging are interrelated components of frailty (36, 37). Although PMA did not independently predict mortality or ICU admission in multivariable models, directionally consistent associations were observed. These findings suggest that PMA may contribute to risk stratification but may require larger cohorts or standardized muscle indices to demonstrate independent prognostic significance. Our findings extend this limited body of evidence by demonstrating a high prevalence of low psoas muscle area in patients hospitalized with acute biliary tract infections and by highlighting the close relationship between sarcopenia, aging, nutritional impairment and hepatic vulnerability. In this context, our study provides novel exploratory data suggesting that sarcopenia is highly prevalent among patients with acute cholangitis and may reflect reduced physiological reserve in this high-risk population.

Nutritional status, assessed using the prognostic nutritional index, emerged as a clinically relevant determinant of hospital length of stay. Low PNI was independently associated with prolonged hospitalization, underscoring the role of malnutrition and immune compromise in delayed recovery. Similar associations between poor nutritional status and adverse outcomes have been reported in acute biliary infections and other inflammatory conditions (7, 38, 39). These results support the integration of nutritional assessment into routine clinical evaluation of patients with BTIs.

In contrast, systemic inflammatory ratios, including CAR, PAR, CLR, HALP, PLR and CPR, did not demonstrate independent prognostic value for major outcomes in this dataset. While these markers have shown promise in selected populations and disease-specific contexts their utility in acute biliary tract infections may be limited by disease heterogeneity and the dominant influence of host reserve and baseline vulnerability (21-27). Our findings suggest that isolated inflammatory markers may be insufficient to capture the complex biological determinants of short-term outcomes in BTIs.

Although several of the presented analyses were stratified by diagnosis, the primary contribution of this study lies not in a direct comparison between acute cholecystitis and acute cholangitis, but in demonstrating that markers of frailty, malnutrition and hepatic vulnerability are highly prevalent across the spectrum of acute biliary tract infections. By simultaneously evaluating CT-derived psoas muscle area, nutritional status (PNI), and fibrosis-related risk (FIB-4), our findings highlight that sarcopenia, impaired nutritional reserve and increased fibrosis risk frequently coexist in both conditions and are closely linked to short-term prognosis. The diagnosis-stratified analyses primarily serve to illustrate clinical heterogeneity, whereas the overarching message is that host-related vulnerability, rather than diagnostic category alone, plays a central role in determining outcomes in acute biliary tract infections. Correlation analyses revealed a coherent axis linking aging, higher FIB-4, lower PNI, lower PMA, and longer LOS. This pattern supports the concept that frailty-related parameters integrate hepatic, nutritional, and inflammatory burdens and may add clinically meaningful information beyond single laboratory markers (40, 41).

This study has several limitations. Its retrospective, single-center design limits generalizability. The small number of ICU admissions and mortality events constrained multivariable modeling and may have resulted in imprecise estimates. In addition, missing anthropometric data precluded calculation of standardized skeletal muscle indices, necessitating the use of PMA as a surrogate marker of sarcopenia. Finally, external validation in larger, prospective cohorts is required.

Conclusion

Acute biliary tract infections are clinically heterogeneous and associated with variable short-term outcomes. In this retrospective cohort, host-related vulnerability—particularly impaired nutritional status and sarcopenia-related muscle loss—was highly prevalent and closely linked to aging and hepatic dysfunction. Among the evaluated markers, the prognostic nutritional index was associated with prolonged hospital stay, while the FIB-4 score demonstrated moderate discriminatory ability for short-term mortality, suggesting that hepatic vulnerability may contribute to adverse outcomes in the acute setting.

By jointly assessing CT-derived psoas muscle area, nutritional status, and fibrosis-related indices in both acute cholecystitis and acute cholangitis, this study provides novel exploratory insights into an under-investigated area. CT-based PMA assessment and simple laboratory-derived indices such as PNI and FIB-4 are readily available in routine clinical practice and may support early risk stratification. Larger prospective multicenter studies are warranted to validate these findings and to clarify the role of frailty-based assessment in guiding clinical decision-making in acute biliary tract infections.

Abbreviations

ALT — Alanine aminotransferase

AST — Aspartate aminotransferase

AUC — Area under the curve

BTI(s) — Biliary tract infection(s)

CAR — C-reactive protein-to-albumin ratio

CPR — C-reactive protein-to-platelet ratio

CRP — C-reactive protein

CT — Computed tomography

CLR — C-reactive protein-to-lymphocyte ratio

FIB-4 — Fibrosis-4 index

HALP — Hemoglobin–albumin–lymphocyte–platelet index

ICU — Intensive care unit

IQR — Interquartile range

LOS — Length of stay

PAR — Platelet–to–albumin ratio

PMA — Psoas muscle area

PLR — Platelet–to–lymphocyte ratio

PNI — Prognostic nutritional index

PTBD — Percutaneous transhepatic biliary drainage

ROC — Receiver operating characteristic

SMI — Skeletal muscle index

Declarations

Ethics approval / Consent to participate: This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Recep Tayyip Erdoğan University Faculty of Medicine (approval number: 2024/255). Due to the retrospective design of the study, the requirement for informed consent was waived.

Consent for publication: Not applicable

Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests

Funding: This study received no external funding.

Authors' contributions: ZZK conceptualized and designed the study, supervised data collection, contributed to data interpretation, and was the major contributor in writing and revising the manuscript.

CK contributed to study design, data acquisition, and interpretation, and critically revised the manuscript for important intellectual content.

AO and TI contributed to data collection, clinical data interpretation, and literature review.

MAO assisted with data organization, statistical preparation, and manuscript drafting.

FT performed and supervised radiological assessments, including CT-based psoas muscle area measurements, and contributed to data interpretation.

All authors read and approved the final manuscript.

Acknowledgements: Not applicable

Footnotes: Not applicable

Additional Information : Scientific Presentation

This study was presented as an oral presentation at the 17th Turkish Hepato Pancreato Biliary Surgery Congress 2025, Antalya, Türkiye.

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Figures

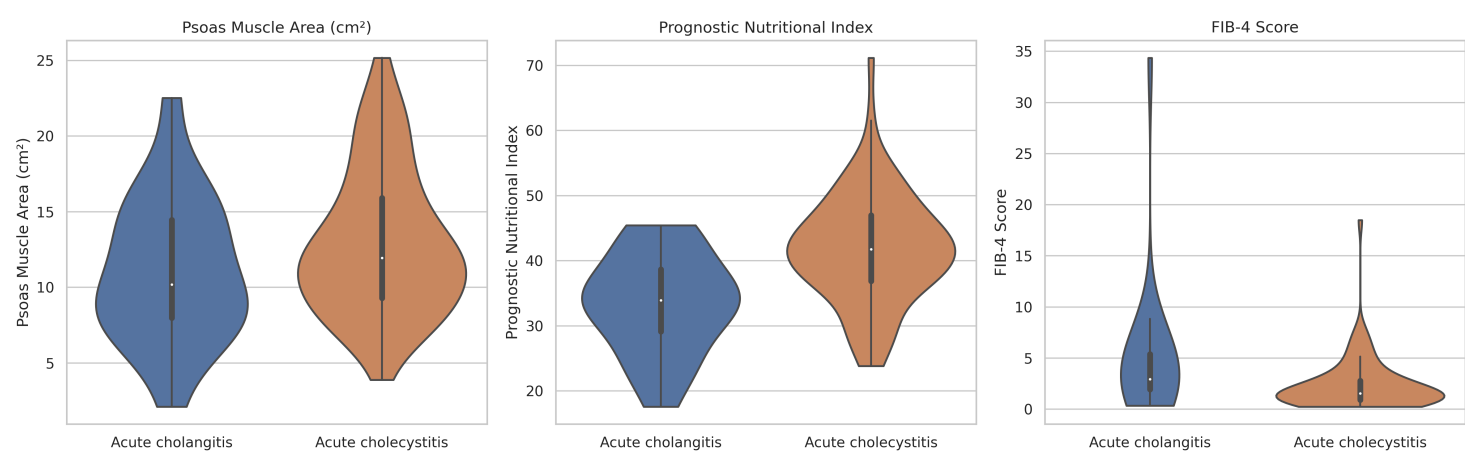


Figure 1

Distribution of PMA, PNI and FIB-4 by diagnosis.

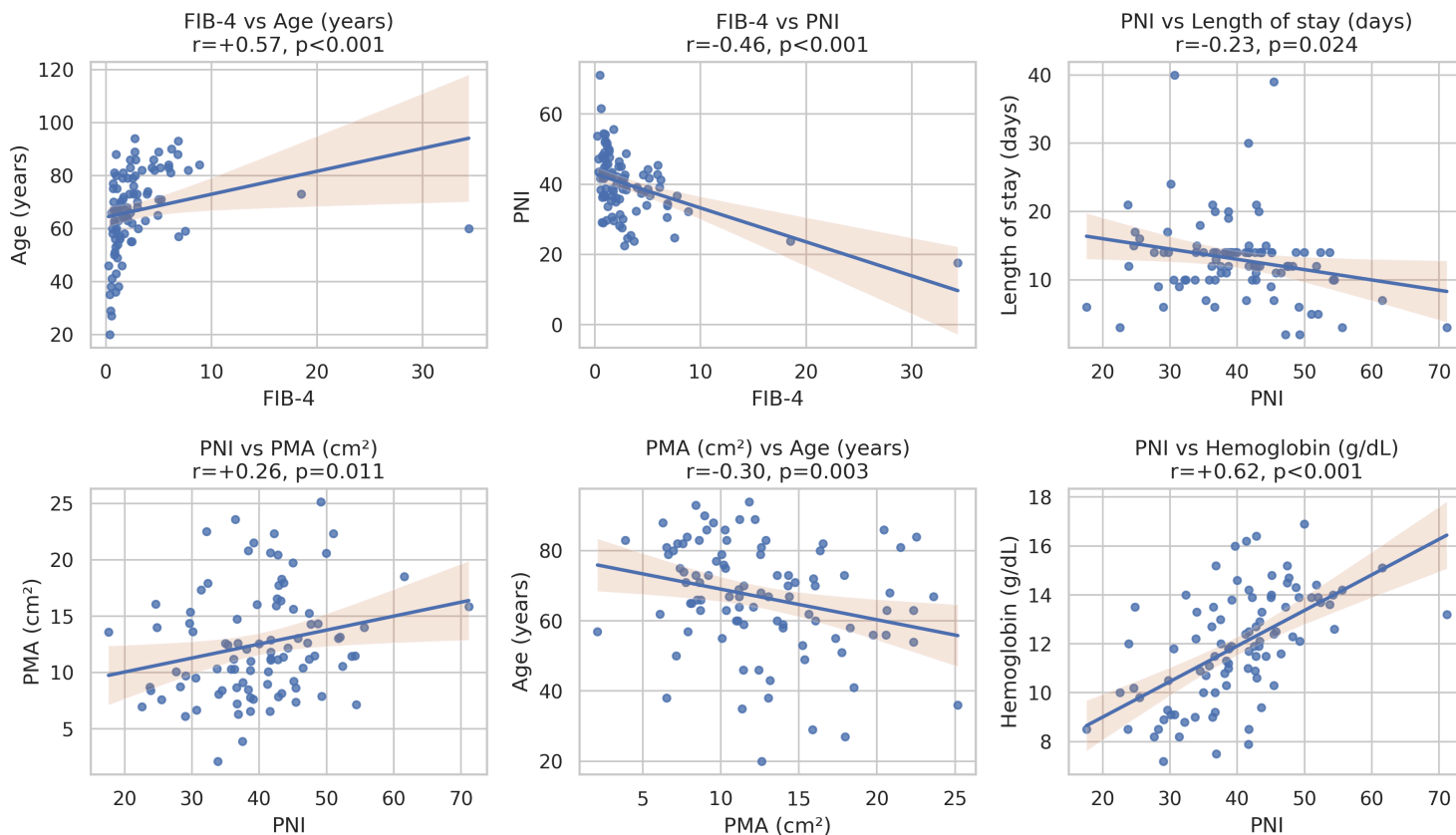


Figure 2

Correlations between Age, FIB-4, PNI, PMA, hemoglobin and LOS.

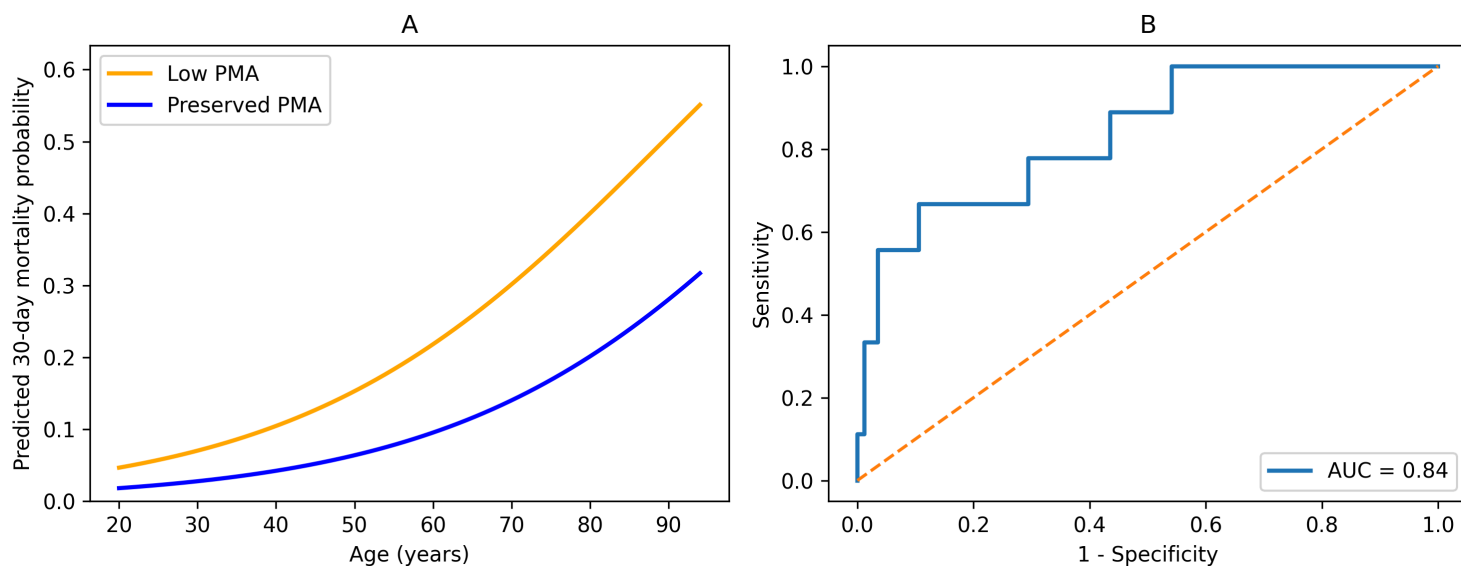


Figure 3

Clinical interpretability and discrimination of the primary multivariable model for 30-day mortality.

(A) Predicted probability of 30-day mortality according to age for patients with low psoas muscle area (PMA; orange) and preserved PMA (blue). Predictions were derived from the primary multivariable logistic regression model including diagnosis (cholangitis), age, and PMA, with diagnosis fixed to cholangitis to facilitate clinical interpretability.

(B) Receiver operating characteristic (ROC) curve of the same multivariable model demonstrating good discrimination for 30-day mortality (AUC = 0.84; 95% confidence interval: 0.72–0.98).

Abbreviations: PMA, psoas muscle area; AUC, area under the curve.