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Analysis of the clinical characteristics of 202 patients with liver abscess associated with diabetes mellitus and biliary tract disease

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Abstract

Objective: Clinical characteristics of patients with pyogenic liver abscess (PLA) of varying etiologies may be different. This study aimed to analyze the clinical characteristics, pathogenic bacteria, treatment, and prognosis of patients with PLA associated with diabetes and biliary disease.

Methods: Clinical, imaging, and laboratory data from 202 inpatients with PLA were retrospectively analyzed.

Results: Eighty-eight patients (43.6%) had a history of diabetes, 73 (36.1%) had a history of underlying biliary tract disease, and 24 (11.9%) had both the diseases. The level of C-reactive protein (CRP) increased in 99.2% (119/120) patients, and the level of procalcitonin (PCT) increased in 95.5% (148/155) patients. The main pathogen of PLA was *Klebsiella pneumoniae*. The incidence of bloodstream infection increased by 34.4% (22/64) in patients with PLA that was associated with diabetes mellitus, and that of *K. pneumoniae* infection was 88.6% (39/44). The readmission rate for patients with PLA with underlying biliary diseases was 10.2 to 12.5%.

Conclusion: The main pathogen of PLA is *K. pneumoniae*, which is sensitive to most antibiotics. Patients with PLA associated with diabetes were more likely to have bloodstream infections, and the recurrence rate of PLA with underlying biliary diseases was higher than without biliary duct disease.

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C-reactive protein, diabetes, liver abscess, *Klebsiella pneumoniae*, procalcitonin, biliary duct disease

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Introduction

Pyogenic liver abscess (PLA) is a common infectious disease leading to a bloodstream infection, septic shock, liver and kidney failure, and even multiple-organ failure in severe cases, and it has a mortality rate of 2.1%.[1] An epidemiological survey showed that the incidence of liver abscess was relatively high in Asia, with an increasing trend,[2,3] and the incidence was higher than that in western countries (about 11.99 to 17.59/100,000 people per year[4] vs. 1.0, 2.3, and 2.7 to 4.1/100,000 people in Denmark, Canada, and the United States, respectively[5–7]). The number of patients with immune impairment, such as diabetes mellitus and malignant tumor, has increased with an aging population and wide application of antibiotics. Multidrug resistance and high-virulence pathogens continue to emerge. The etiology, diagnosis, and treatment of PLA have changed a lot, and, therefore, the clinical diagnosis and treatment of PLA are facing new challenges.

Diabetes mellitus, biliary disease, pneumonia, proton pump inhibitors, alcoholism, and malignant tumors are the risk factors for PLA.[4,8–10] The common pathogenic bacteria of PLA dynamically change,[11] and *Klebsiella* has gradually become the main pathogen of bacterial liver abscess in Asia. Although Enterobacteriaceae producing superspectrum β-lactamases (ESBLs) have been reported to cause liver abscesses, they are still rare.[12] C-reactive protein (CRP) is a plasma protein with increased total circulation volume during inflammation and after tissue injury. The CRP level can be used to guide the course of antimicrobial treatment of liver abscess,[13,14] but large-scale clinical studies are needed for confirmation. Serum procalcitonin (PCT) is a commonly used biomarker of bacterial infection. It has a guiding significance for diagnosis and anti-infection treatment of infectious diseases. Few clinical studies have been conducted on the treatment value of PCT in the diagnosis and anti-infection treatment of liver abscess.

The differences in the clinical characteristics of liver abscess with diabetes and biliary diseases were analyzed to understand the changes in clinical characteristics and pathogen distribution of liver abscess in recent years. Moreover, the value of CRP and PCT in the diagnosis and treatment of liver abscess was investigated to provide a reference for the clinical diagnosis and treatment. The present study was a retrospective analysis of the clinical data from 202 patients with PLA who were admitted to Sanming First Hospital Affiliated with Fujian Medical University from July 2013 to June 2019.

Study participants and methods

Study participants

From July 2013 to June 2019, 202 patients with liver abscess who were admitted to Sanming First Hospital Affiliated with Fujian Medical University (including the Department of Infection, Department of Gastroenterology, and Department of Hepatobiliary Surgery) were selected as the study participants (Figure 1). The inclusion criteria were as follows: (1) patients

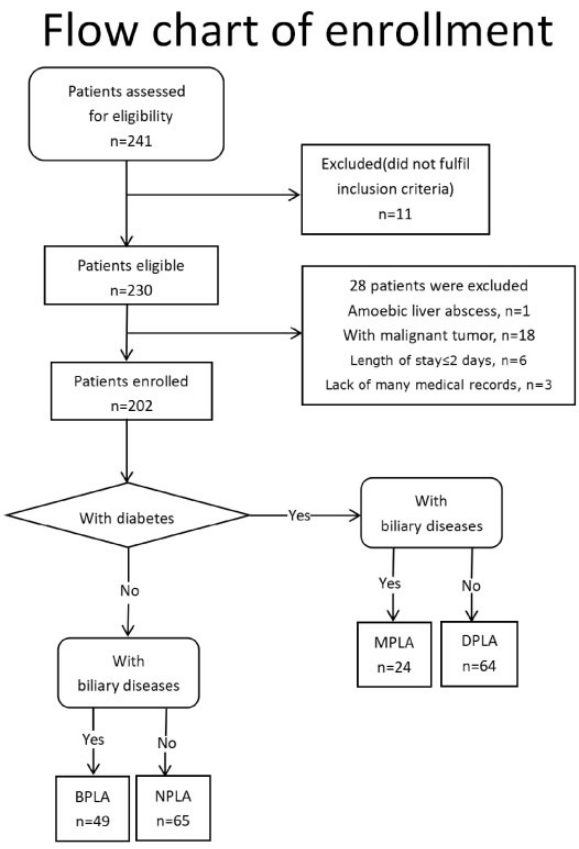

Figure 1. Flow chart of enrollment

with clinical manifestations, such as fever, chills, discomfort, and pain in the liver area; (2) imaging examination of the abdomen that was consistent with the manifestations of liver abscess; (3) positive bacterial culture of peripheral blood or pus; (4) effective antibiotic treatment; and (5) diagnosis confirmed by percutaneous liver puncture or surgery. The diagnostic standard and etiology classification of PLA were in accordance with the 9th edition of Surgery.[15] The exclusion criteria were as follows: (1) infection of specific pathogens, such as amoeba, *Mycobacterium tuberculosis*, or fungi, which was proven by pathogen culture; (2) patients with liver cancer or other malignant tumors; (3) length of hospital stay was too short; and (4) lack of complete medical records. This study was reviewed and approved by the hospital ethics committee. Written informed consent from patients was exempted by the ethics committee (Permit Number 2020[1]).

Methods

The medical records from 202 inpatients with PLA were retrospectively analyzed. A patient who was admitted many times because of a liver abscess was included as one case, and the first medical record was collected. Based on the combination with diabetes or underlying biliary tract disease (including extrahepatic and intrahepatic bile duct stones, chronic cholecystitis, cholangitis, and cholecystectomy), the patients

were classified into the following groups: DPLA (combined with diabetes; 64 cases), BPLA (combined with underlying biliary tract disease; 49 cases), MPLA (combined with diabetes and underlying biliary tract disease; 24 cases), or NPLA (without diabetes or underlying biliary tract disease; 65 cases). The characteristics of clinical symptoms, underlying complications, length of hospital stay, outcome, method of discharge, and readmission within 90 days were recorded. The inflammatory markers and biochemical indices (if the same index was checked many times, the highest value was recorded, except for the serum albumin level, in which case the lowest value was recorded) included the white blood cell (WBC) count, proportion of neutrophils (N%), and PCT, CRP, alanine aminotransferase (ALT), alkaline phosphatase (ALP), total bilirubin (TBIL), γ-glutamyltransferase (GGT), serum creatinine, and serum albumin levels. Pathogenic microorganism test results (including bacterial resistance), imaging results (X-ray, ultrasound, computed tomography, and magnetic resonance imaging), and invasive treatment methods (liver puncture drainage, liver puncture aspiration, and surgical incision drainage) were collected. The differences in etiology, laboratory index, complication incidence, abscess size, treatment, and prognosis were analyzed and compared between groups.

Statistical analysis

SPSS version 23.0 software (IBM Corp., Armonk, NY, USA) was used to analyze the data. A P value of less than 0.05 indicated statistical significance. The measurement data were tested for the normality of distribution. Data without a normal distribution were expressed as the median (M) (min, max) and analyzed using a nonparametric Kruskal–Wallis test. Measurement data with normal distribution were expressed as the mean ± standard deviation (SD). The analysis of variance (ANOVA) method was used for a multigroup comparison, and the least significant differences (LSD) method was used for comparisons between groups. The Chi-square test was used to compare between groups.

Results

Clinical information

Among the 202 patients with PLA, 110 (54.5%) were men and 92 (45.5%) were women, with a ratio of 1.2:1. The average age was 59.0 ± 13.31 years, with 150 patients (74.3%) in the range of 45 to 75 years (Figure 2). The average ages of DPLA, BPLA, MPLA, and NPLA group were 57.3±12.45 years, 62.0±11.89 years, 59.9±10.38 years, and 58.2±15.75 years, respectively. The ratios of men to women in the DPLA, BPLA, MPLA, and NPLA groups were 1.1:1, 1:1, 1.2:1, and 1.5:1, respectively. No significant difference was observed in the age ($F = 1.295$, $P = 0.277$) and the sex composition ratio ($\chi^2 = 1.445$,

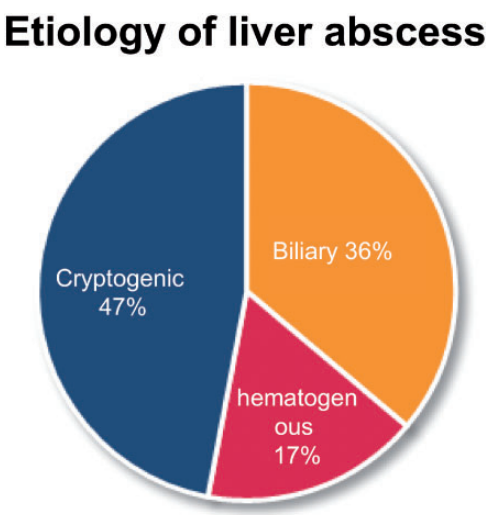

Figure 2. Etiology of liver abscess.

$P = 0.695$) among different groups. Further, 88 patients (43.6%) had a history of diabetes, 73 (36.1%) had a history of underlying biliary tract disease (including hepatolithiasis, chronic cholecystitis, cholangitis, and cholecystectomy), 38 (18.8%) had a history of fatty liver, 25 (12.4%) had cardiovascular diseases (including hypertension and coronary heart disease), and 12 (5.9%) had viral hepatitis. Additionally, 61 patients (30.2%) had pleural effusion, 55 (27.2%) had pneumonia, 44 (21.8%) had bloodstream infection, 23 (11.4%) had peritoneal effusion, five had septic shock, four had multiple-organ dysfunction syndrome (MODS), three had liver abscess rupture and underwent surgery, and two had endophthalmitis (Table 1). Ninety-five patients had the highest proportion of cryptogenic liver abscess, followed by 73 patients who had liver abscess secondary to biliary disease, and 34 patients who had a hematogenous infection via the hepatic artery or portal vein (Figure 3). Moreover, 40 (42.1%) had diabetes, 22 (23.1%) had fatty liver, and 28 (29.4%) had pneumonia. The mean diameter of the abscess cavity was 6.6 ± 2.45 cm in 202 patients with PLA, and 137 patients (67.8%) had an abscess cavity of 5 to 10 cm. Additionally, 120 patients (59.4%) were treated with antibiotics and 79 patients (39.1%) were treated with local drainage or aspiration combined with antibiotics.

Table 1. General information of patients with PLA.

Clinical information	Number of patients	Percentage (%)
Sex		
Male	110	54.5
Female	92	45.5
Age (years)		
<18	2	1
18 to <35	5	2.5
35 to <45	20	1
45 to <55	43	21.3
55 to <65	63	31.2
65 to <75	44	21.8
≥75	25	12.4
Underlying disease		
Diabetes	88	43.6
Underlying biliary tract disease	73	36.1
Fatty liver disease	38	18.8
Cardiovascular disease	25	12.4
Viral hepatitis	12	5.9
Complications		
Bloodstream infection	44	21.8
Pleural effusion	61	30.2
Pneumonia	55	27.2
Abdominal cavity effusion	23	11.4
Septic shock	5	2.5
MODS	4	2.0
Abscesses rupture	3	1.5
Endophthalmitis	2	1
Size of abscess cavity (cm)		
<5 cm	52	25.8
5 to 10 cm	137	67.8
≥10 cm	13	6.4
Therapy method		
Medication + drainage/ Aspiration	79	39.1
Medication + surgical incision and drainage	3	1.5
Antibiotic therapy alone	120	59.4

PLA, pyogenic liver abscess; MODS, multiple-organ dysfunction syndrome.

Laboratory indices

The median PCT level was 3.14 (range, <0.05, 200) ng/mL in 155 patients with PLA, including seven (4.5%) with PCT <0.05 ng/mL, 39 (25.2%) with 0.05 ≤PCT < 0.5 ng/mL, 57 (36.8%) with 0.5 < PCT <10 ng/mL, 42 (27.0%) with 10 <PCT <100 ng/mL, and 10 (6.5%) with PCT >100 ng/mL. Except for one patient with a CRP level in the normal range after treatment, CRP significantly increased in the other patients with PLA (99.2%, 119/120). The mean, minimum, and maximum values of the CRP level were

153.5 ± 87.60 mg/L, 0.6 mg/L, and 362 mg/L, respectively. The mean, minimum, and maximum values of the WBC count were $12.4 \pm 5.18 \times 10^9$/L, 2.0×10^9/L, and 32.5×10^9/L, respectively. Abnormal ALT, ALP, and TBIL levels in the BPLA and MPLA groups were higher than those in the DPLA and NPLA groups ($P < 0.05$, Table 2). No statistically significant difference was observed in the WBC count and the PCT, CRP, and other inflammatory marker levels between groups, and abnormal proportions of GGT, serum albumin, and serum creatinine were also not significant (Table 2).

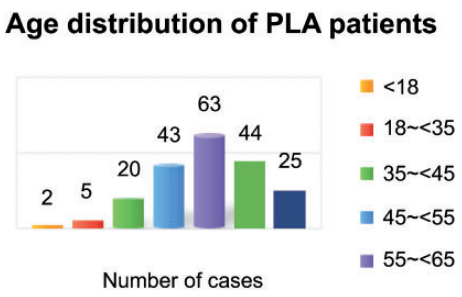

Figure 3. Age distribution of patients with PLA. PLA, pyogenic liver abscess.

Complications

The incidence of bloodstream infection was significantly higher in the DPLA group than in the BPLA and NPLA groups ($P = 0.018$ and $P = 0.004$, respectively). The incidence of pneumonia, pleural effusion, and peritoneal effusion in patients with PLA had no statistically significant difference between the groups (Table 3).

Etiology

Forty-four patients were positive for pathogenic microorganisms in blood culture, and 39 were positive in liver puncture pus culture. Among them, 60 were infected with *Klebsiella pneumoniae* (72.3%), 13 with *Escherichia coli* (15.7%), and four with Gram-positive coccus (4.8%). In the DPLA group, the positive rate of pathogenic microorganisms was 50% (32/64). Among them, 30 (93.8%) were infected with *K. pneumoniae*, two (6.3%) with

Table 2. Age and laboratory indices of patients with PLA.

	DPLA	BPLA	MPLA	NPLA	*P*
Age (years)	57.33 ± 12.45	62.0 ± 11.89	59.88 ± 10.38	58.15 ± 15.75	0.277
PCT (ng/mL)	5.23 (<0.05, 200)	3.71 (<0.05, 141.4)	1.1 (0.06, 200)	2.5 (0.05, 171.7)	0.632
CRP (mg/L)	150.1 ± 86.75	170.0 ± 86.07	181.6 ± 75.83	139.6 ± 91.88	0.326
WBC (10^9/L)	12.4 ± 4.93	12.0 ± 5.09	13.6 ± 4.91	12.2 ± 5.61	0.648
N (%)	82.03 ± 9.93	81.43 ± 10.71	84.26 ± 7.13	81.05 ± 11.34	0.618
ALT >40 U/L	33 (51.6%)	40 (81.6%)[a,b]	19 (79.2%)[c,d]	29 (44.6%)	0.000
ALP >125 U/L	23 (35.9%)	38 (77.6%)[e,f]	15 (62.5%)[g]	30 (46.2%)	0.000
GGT >60 U/L	48 (75%)	45 (91.8%)	17 (70.8%)	50 (76.9%)	0.084
TBIL >26.0 μmol/L	10 (15.6%)	35 (71.4%)[h,j]	11 (45.8%)[k,l]	7 (10.8%)	0.000
Serum albumin <35 g/L	50 (78.1%)	36 (73.5%)	19 (79.2%)	46 (70.8%)	0.748
Serum creatinine >115 μmol/L	3 (4.7%)	2 (4.1%)	1 (4.2%)	2 (3.3%)	0.973

PCT, procalcitonin; CRP, C-reactive protein; ALP, alkaline phosphatase; ALT, alanine aminotransferase; GGT, γ-glutamyltransferase; N, neutrophil percentage; WBC, white blood cell count; TBIL, total bilirubin; PLA, pyogenic liver abscess; DPLA, diabetes and pyogenic liver abscess; BPLA, biliary tract disease and pyogenic liver abscess; MPLA, diabetes, biliary tract disease, and pyogenic liver abscess; NPLA, pyogenic liver abscess with no diabetes or biliary tract infection

[a,e,h]DPLA vs. BPLA, $P < 0.05$.

[b,f,j]BPLA vs. NPLA, $P < 0.05$.

[c,g,k]MPLA vs. DPLA, $P < 0.05$.

[d,l]MPLA vs. NPLA, $P < 0.05$.

Table 3. Complications in patients with PLA.

	DPLA (n = 64)	BPLA (*n* = 49)	MPLA (*n* = 24)	NPLA (*n* = 65)	χ^2	*P*
Bloodstream infection	22 (34.4%)[a,b]	7 (14.3%)	7 (29.2%)	8 (12.3%)	11.766	0.008
Pneumonia	21 (32.8%)	7 (14.3%)	8 (33.3%)	19 (29.2%)	5.733	0.125
Pleural effusion	20 (31.3%)	13 (26.5%)	7 (29.2%)	21 (32.3%)	0.496	0.920
Abdominal cavity effusion	6 (9.4%)	7 (14.3%)	5 (20.8%)	5 (7.7%)	3.667	0.300
Abscesses rupture	1 (1.6%)	0 (0%)	1 (4.2%)	1 (1.5%)	–	–
Septic shock	2 (3.1%)	1 (2.0%)	1 (4.2%)	1 (1.5%)	–	–
MODS	2 (3.1%)	0 (0%)	1 (4.2%)	1 (1.5%)	–	–
Endophthalmitis	1 (1.6%)	0 (0%)	1 (4.2%)	0 (0%)	–	–

PLA, pyogenic liver abscess; DPLA, diabetes and pyogenic liver abscess; BPLA, biliary tract disease and pyogenic liver abscess; MPLA, diabetes, biliary tract disease, and pyogenic liver abscess; NPLA, pyogenic liver abscess with no diabetes or biliary tract infection; MODS, MODS, multiple-organ dysfunction syndrome.
[a]DPLA vs. BPLA, $P = 0.018$.
[b]DPLA vs. NPLA, $P = 0.004$.

E. coli, one (3.1%) with *Enterobacter cloacae*, three with multiple bacteria (over two kinds of bacteria were detected in the same sample or over two kinds of bacteria were detected in different samples within 72 hours), one with *K. pneumoniae* + *K. ozaenae*, one with *K. pneumoniae* + *E. coli*, and one with *K. pneumoniae* + *Staphylococcus aureus*. In the BPLA group, the positive rate of pathogenic microorganisms was 30.6% (15/49), including seven strains of *K. pneumoniae* (46.7%), four strains of *E. coli* (26.7%), and one strain each of *Enterococcus faecalis*, *Proteus strangularis*, *Eikenella corrodens*, and *Edwardsiella tarda*. In the MPLA group, the positive rate of pathogenic microorganisms was 50.0% (12/24), including nine strains of *K. pneumoniae* (75.0%), two strains of *E. coli* (16.7%), and one strain of *Pseudomonas aeruginosa*. In the NPLA group, the positive rate of pathogenic microorganisms was 36.9% (24/65), including 14 strains of *K. pneumoniae* (58.3%), five strains of *E. coli* (20.8%), two strains of *Oligotrophomonas maltophilia* (8.3%), and one strain each of *S. aureus*, *Proteus mirabilis*, and *Enterococcus faecium*. The infection rate of *K. pneumoniae* was higher in the DPLA group than in the BPLA and NPLA groups ($P < 0.05$, Table 4).

Bacterial susceptibility to drugs

The detection rate of ESBL in 60 strains of *K. pneumoniae* was 8.3% (5/60), and no carbapenem-resistant *K. pneumoniae* (CRKP) was detected. *K. pneumoniae* has good sensitivity to imipenem, meropenem, ceftriaxone, amikacin, cefoperazone/sulbactam, and ciprofloxacin (Table 5).

Treatment and prognosis

Among the 202 patients with PLA, the average hospital stay was 18.1±11.09 days, and 79 (39.1%) were treated with local puncture drainage or aspiration combined with antibiotics, three (59.4%) with surgical incision drainage, and 120 (59.4%) only with antibiotics. Based on clinical experience and the results of drug sensitivity test, all patients received intravenous or oral antibiotics, including broad-spectrum penicillin, third-generation cephalosporins, and carbapenems (alone or in combination with nitroimidazoles or quinolones). There were 185 patients (91.6%) who were discharged after recovery, and

Table 4. Pathogenic bacteria in patients with PLA.

	DPLA	BPLA	MPLA	NPLA	χ^2	*P*
Microbial positive rate	32/64 (50%)	15/49 (30.6%)	12/24 (50.0%)	24/65 (36.9%)	5.575	N.S.
Klebsiella pneumoniae	30/32 (93.8%)[a,b]	7/15 (46.7%)	9/12 (75.0%)	14/24 (58.3%)	14.651	0.002
Escherichia coli	2/32 (6.3%)	4/15 (26.7%)	2/12 (16.7%)	5/24 (20.8%)	3.846	N.S.
Enterobacter cloacae	1/32 (3.1%)	–	–	–	–	–
Klebsiella ozaenae	1/32 (3.1%)	–	–	–	–	–
Proteus singular	–	1/15 (6.7%)		1/24 (4.2%)	–	–
Pseudomonas aeruginosa	–	–	1/12 (8.3%)	–	–	–
Oligotrophomonas maltophilia	–	–	–	2/24 (8.3%)	–	–
Staphylococcus aureus	1/32 (3.1%)	–	–	1/24 (4.2%)	–	–
Enterococcus faecalis	–	1/16 (6.7%)	–	–	–	–
Enterococcus faecium	–	–	–	1/24 (4.2%)	–	–
Eikenella corrodens	–	1/15 (6.7%)	–	–	–	–
Edwardsiella tarda	–	1/15 (6.7%)	–	–	–	–

PLA, pyogenic liver abscess; DPLA, diabetes and pyogenic liver abscess; BPLA, biliary tract disease and pyogenic liver abscess; MPLA, diabetes, biliary tract disease, and pyogenic liver abscess; NPLA, pyogenic liver abscess with no diabetes or biliary tract infection.
[a]DPLA vs. BPLA, $P = 0.001$.
[b]DPLA vs. NPLA, $P = 0.002$.

Table 5. Sensitivity of bacteria to antimicrobial agents.

	Klebsiella pneumoniae (%)	*Escherichia coli* (%)
Piperacillin	24 (40%)	9 (69.2%)
Piperacillin + tazobactam	52 (86.7%)	12 (92.3%)
Ampicillin + sulbactam	40 (66.7%)	4 (30.8%)
Cefoperazone + sulbactam	55 (91.7%)	13 (100%)
Cefuroxime	44 (73.3%)	1 (7.7%)
Ceftriaxone	55 (91.7%)	8 (61.5%)
Imipenem	60 (100%)	13 (100%)
Meropenem	60 (100%)	13 (100%)
Ertapenem	60 (100%)	13 (100%)
Aztreonam	48 (80%)	9 (69.2%)
Gentamicin	50 (83.3%)	10 (76.9%)
Amikacin	58 (96.7%)	12 (92.3%)
Ciprofloxacin	49 (81.7%)	8 (61.5%)
Sulfamethoxazole + trimethoprim	47 (78.3%)	7 (53.8%)

nine (4.5%) were readmitted within 90 days after discharge, seven (3.5%) were discharged willingly without recovery, and only one patient died during hospitalization. The proportion of abscess drainage/puncture was higher in the DPLA group compared with the BPLA group ($P < 0.05$, Table 5). The readmission rates with underlying biliary diseases within 90 days were higher in the BPLA and MPLA groups compared with the DPLA and NPLA groups ($P < 0.05$, Table 6).

Table 6. Treatment and prognosis of patients with PLA.

	DPLA ($n=64$)	BPLA ($n=49$)	MPLA ($n=24$)	NPLA ($n=65$)	*P*
Length of stay (days)	19.6 ± 11.33	14.3 ± 8.46	19.3 ± 10.83	19.0 ± 12.23	0.052
Diameter of abscess cavity (cm)	7.2 ± 2.74	6.6 ± 2.43	6.4 ± 2.39	6.2 ± 2.12	N.S.
Treatment					
Medication + drainage/aspiration	30 (46.9%)[a]	11 (22.4%)	9 (37.5%)	29 (43.1%)	0.042
Antibiotic therapy alone	33 (51.5%)	38 (77.6%)	14 (58.3%)	35 (53.8%)	0.027
Surgical incision and drainage + medication	1 (1.6%)	0 (0%)	1 (4.2%)	1 (1.5%)	–
Prognosis					
Recovery and discharge	60 (93.7%)	41 (83.7%)	21 (87.5%)	63 (96.9%)	N.S.
Readmission within 90 days	1 (1.6%)	5 (10.2%)[b,c]	3 (12.5%)[d,e]	0 (0%)	0.027
Discharge without recovery	2 (3.1%)	3 (6.1%)	0 (0%)	2 (3.1%)	–
Died	1 (1.6%)	0 (0%)	0 (0%)	0 (0%)	–

PLA, pyogenic liver abscess; DPLA, diabetes and pyogenic liver abscess; BPLA, biliary tract disease and pyogenic liver abscess; MPLA, diabetes, biliary tract disease, and pyogenic liver abscess; NPLA, pyogenic liver abscess with no diabetes or biliary tract infection; N.S., not significant.
[a]DPLA vs. BPLA, $P=0.007$.
[b]DPLA vs. BPLA, $P=0.042$.
[c]BPLA vs. NPLA, $P=0.038$.
[d]MPLA vs. DPLA, $P=0.028$
[e]MPLA vs. NPLA, $P=0.022$.

Discussion

This study showed that PLA was more likely to occur in elderly patients with diabetes mellitus and underlying biliary tract disease, which is consistent with the results of relevant reports.[3,16] Autoimmunity in patients with diabetes mellitus was damaged, and their response to invading microorganisms could be easily inhibited, including neutralization of chemical toxins and the bactericidal effect of phagocytes, serum opsonin, and cellular immunity. A high sugar level also provides a good internal environment for bacterial growth. Therefore, patients with diabetes mellitus are very susceptible to infection, and the infection is often severe and easily complicated by infectious shock and multiple-organ dysfunction. Changes in the anatomical structure of intrahepatic and extrahepatic bile duct stones and biliary tract surgery lead to blocked bile excretion, which is complicated by pyogenic cholangitis. The bacteria move upward along the bile duct, resulting in pyogenic liver abscess.

This study found that the most common etiology of PLA was cryptogenic ($n=95$, 47%) and biliary ($n=73$, 36.1%), which was consistent with Shi et al.'s findings.[17] Additionally, abnormal ALT, ALP, and TBIL levels were higher in the BPLA and MPLA groups compared with the non-BPLA group. ALT, ALP, and TBIL may help to determine the etiology of liver abscess.

CRP is a sensitive inflammation index that usually increases 6 to 8 hours after the onset of the disease, reaching the peak at 24 to 48 hours.[18] The range is positively related to the severity of infection or inflammation. When the CRP level is 10 to 99 mg/L, it often indicates focal or superficial infection.[18] When it is $\geq$100 mg/L, the CRP level indicates sepsis or invasive infection. In the process of anti-infection

treatment, dynamically monitoring the CRP level can help to judge the curative effect; a decrease in the CRP level to normal can be used as one of the indices of drug withdrawal.[18] CRP in patients with PLA increases to different degrees. CRP is considered to be a simple, effective, and sensitive index to reflect the degree of inflammation of PLA and evaluate the effect of anti-infection treatment.[19,20] The results of this study show that the mean CRP level was 153.5 ± 87.60 mg/L and the sensitivity was 99.2%. The CRP level of only one patient was in the normal range (the patient had used antibiotics before admission), and it showed a significant increase in other patients, which was consistent with relevant reports.[21] The specificity of the CRP level is not high, and it significantly increases in many noninfectious diseases, such as trauma, surgery, myocardial infarction, malignant tumors, and especially rheumatic diseases.

The PCT level increases in the early stage (2 to 3 hours) of the systemic inflammatory response that is caused by a bacterial infection. After 12 to 24 hours of infection, the PCT level reached the peak and positively correlates with the severity of infection. After the infection disappears, the PCT level returns to normal. Therefore, it has high clinical value in the early diagnosis of severe bacterial infection, judgment on disease severity, prognosis, evaluation of anti-infection effect, and guidance of the application of antibiotics.[18] When the PCT level is 0.05 to 0.5 ng/mL, patients have no reaction or only a mild systemic inflammatory reaction, which may be caused by local inflammation or local infection. When the PCT level is 0.5 to 2.0 ng/mL, it indicates a moderate systemic inflammatory reaction, which may be caused by infection, severe trauma, large-scale operation, and cardiogenic shock.[22] In this study, 95.5% (148/155) of patients with PLA had PCT >0.05 ng/mL, which was lower than that reported by Serranino et al.[21] (100%, 34/34). Moreover, 4.5% (7/155) of the patients had normal PCT test results. This was because the half-life of PCT was not long (20 to 24 hours) and it was usually normal or slightly increased in local bacterial infection. Therefore, the diagnosis and evaluation of bacterial infectious diseases, such as PLA, should be combined with multiple inflammatory markers.

Recently, *K. pneumoniae* has replaced *E. coli* as the main pathogen of PLA.[3,23] *Klebsiella* is mainly distributed in developed areas, where the incidence of diabetes is high. Diabetes is related to *K. pneumoniae* infection. Lin et al.[24] found a high probability of *K. pneumoniae* serum K1/K2 colonization in the feces of Chinese people in Asia, suggesting that the high incidence of *K. pneumoniae* infection was related to the environment and race. Among Gram-positive cocci, S*taphylococcus* was the most common (13%), followed by *Streptococcus* (8%) and *Enterococcus* (7%). In accordance with reports in China, the main pathogen of PLA was *K. pneumoniae*. The infection rate of *K. pneumoniae* in the DPLA group was 88.6% (39/44). Zhang et al.[25] reported that *E. coli* PLA was mostly related to a history of biliary tract disease or biliary tract surgery. However, this study found that *K. pneumoniae* was the main pathogenic bacteria in patients with PLA, irrespective of the presence of underlying diseases including diabetes or biliary tract diseases. This study also showed that the infection rate of *K. pneumoniae* was higher in the DPLA group with diabetes than in the BPLA and NPLA groups without diabetes. The DPLA group was more likely to have a bloodstream infection, which was consistent with Foo et al.[16] *K. pneumoniae* produces about 10% of ESBLs. This study indicated that 8.3% of ESBLs were produced in *K. pneumoniae*, which was highly sensitive to most antimicrobial agents.

These findings were consistent with reports from China. [25,26]

The PLA treatment protocol involves early diagnosis, early empiric antiinfection treatment, and focal drainage. The dose of antibiotics is adjusted based on the results pathogenic drug sensitivity testing results. Percutaneous puncture drainage can be divided into percutaneous aspiration and catheter drainage. It has become an important treatment for PLA because of the small trauma, accurate location, and rapid recovery. In this study, 79 patients (39.1%) received local puncture drainage or purulent treatment, and 120 patients (59.4%) received antibiotics only. The proportion of abscess drainage was significantly higher in the DPLA group with diabetes compared with the BPLA group, probably because the BPLA group had more biliary obstruction or inflammation. When the inflammatory inducement was removed, unobstructed bile excretion was restored and the bacteria could not reproduce in the bile duct. Thus, the condition was controlled to reduce the possibility of puncture. The overall prognosis of 202 patients with PLA was satisfactory. Generally, 91.6% of patients showed an improvement and were discharged; 4.5% had reoccurrence within 90 days after discharge. Shi et al.[17] reported that the incidence of bacteremia and recurrence after discharge of PLA of biliary origin was higher compared with the PLA without biliary diseases. This study also found that the readmission rate of patients with BPLA within 90 days was significantly higher than that of the non-BPLA patients, but the bloodstream infection rate of patients with BPLA in this study was lower ($n = 7$, 14.3%) than that of patients with DPLA.

PLA has many risk factors. In this study, it was considered that patients with a tumor had lower immunity and more complex conditions and complications. Therefore, patients with PLA combined with malignant tumors were not included. The clinical characteristics of patients with PLA associated with fatty liver, cardiovascular disease, and viral hepatitis were not analyzed because of the small sample size. This was a single-center study. Some groups had a small sample size with more interference factors in this retrospective study, which affected the results. However, the findings provide direction and ideas for future investigations.

Conclusions

PLA often occurs in elderly patients with diabetes and underlying biliary tract disease. The PCT and CRP levels and the liver function index might help to diagnose liver abscess and determine the cause of the disease. The main pathogen of PLA is *K. pneumoniae*, which is sensitive to most antibiotics. Patients with PLA that is associated with diabetes are more likely to have bloodstream infections, and the recurrence rate of PLA with underlying biliary diseases is higher. The data from this study were all from the same hospital in China. Thus, these results for PLA apply to the Chinese population, and they may not be generalizable to other populations.

Author contributions

WXB collected the data. SHW and LYB wrote the manuscript. WTE helped with data analysis and making the charts. All authors provided approval for this manuscript.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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