Int J Clin Exp Pathol 2021;14(2):252-260
www.ijcep.com /ISSN:1936-2625/IJCEP0122329

Original Article

Retrospective study of characteristics and management of pyogenic liver abscess during 5 years' experience

Yuanyuan Zhou*, Guanzhu Lu*, Yupan Bai, Yujie Bao, Jie Xu

*Department of Infectious Disease, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, 639 Zhizao Ju Road, Huangpu District, Shanghai 200011, China. *Equal contributors.*

Received September 14, 2020; Accepted December 3, 2020; Epub February 1, 2021; Published February 15, 2021

Abstract: Pyogenic liver abscess is a life-threatening disease. It is urgent to review the clinical patterns, risk factors, and management of the disease in order to improve the outcome. We retrospectively analyzed 70 cases of pyogenic liver abscess diagnosed and treated at Shanghai Ninth People's Hospital over five years, including the clinical features, management, and outcome. The average age was 63.06 ± 12.33 y. 71.4% (50/70) were males. 85.7% (60/70) patients presented with fever. The major abnormalities in laboratory were increased CRP and liver dysfunction. 77.8% (14/18) pus cultures came with positive reports, while 26.5% (9/34) blood cultures were positive. *K. pneumoniae* was the predominant pathogen both in blood (66.7%, 6/9) and pus (64.3%, 9/14) cultures. 42.9% (30/70) patients also had diabetes. Patients with diabetes presented with significantly larger size of abscess ($P = 0.014$) and were more susceptible to *K. pneumoniae* infection ($P = 0.002$). We revealed HbA1c ($P = 0.047$), accompanying malignancy ($P = 0.030$), and septic shock ($P = 0.045$) were three independent risk factors for PLA. In conclusion: pyrogenic liver abscess was atypical; microbiologic positivity of pus culture was higher than that of blood culture; *K. pneumoniae* was the predominant pathogen in pyrogenic liver abscesses, especially in patients with diabetes; and patients with hyperglycemia had poor outcome.

Keywords: Pyogenic liver abscess, clinical manifestation, *klebsiella pneumoniae*, management, diabetes mellitus

Introduction

Pyogenic liver abscess (PLA) is a life-threatening disease with high morbidity and mortality [1]. Recent studies reported a worldwide increase of PLA to 11-31% mortality rates with nearly 10,000 acute morbidities annually [2]. It is a suppurating infection of the hepatic parenchyma in both district and metropolitan hospitals [3]. The clinical manifestations in the initial stage of PLA are usually atypical, and can easily be misdiagnosed or ignored. With the aging of the population, and wide use of broad-spectrum antibiotics and immunosuppressants, the etiology of PLA has undergone a major change from intra-abdominal infections to biliary tract infections caused by opportunistic pathogens. PLA is accompanied by many chronic diseases or risk factors, including diabetes mellitus, cardiovascular diseases, malignancies, cholangitis, urinary tract disease, pneumonia, autoimmune disease, and malnutrition [4]. However, up to 55% of patients with PLA have no obvious risk factors [5]. Some studies have indicated DM is a concomitant condition in approximately 29.3-44.3% of PLA cases [6, 7]. Hyperglycemia has been indicated as a major factor for higher risk of infection.

From previous experience, the predominant pathogens in PLA infection were *Escherichia. Coli* (*E. coli*), *Streptococcus spp*, *Enterococcus spp,* and *anaerobic bacteria*. In South Asia, *Klebsiella pneumoniae* (*K. pneumoniae*) was predominant [8-10]. Liver abscesses in patients infected with *K. pneumoniae* were first described in the 1980s in case series from Taiwan [11], usually causing an invasive syndrome, due to its virulence factors, including capsular serotype, mucoviscosity-associated gene A (magA), rmpA, and aerobactin [12]. For infectious patients with diabetes, such as necrotizing fasciitis, *K. pneumoniae* was considered to be a common pathogen [13]. However, it has rarely been reported whether *K. pneumoniae* is the major pathogen in PLA patients with DM.

Historically, surgical drainage was the only definitive supplement to antimicrobial therapy. With advances in cross-sectional imaging, percutaneous drainage has now become the first choice while surgical intervention is reserved as a salvage therapy [14]. However, there is a lack of standards for percutaneous treatment of liver abscess, especially the optimal timing of drainage [14].

This study retrospectively reviewed our 5 years' experience with 70 PLA patients diagnosed and treated in Shanghai Ninth People's Hospital, aiming to reveal the risk factors, common pathogens, and optimal management in order to improve the prognosis.

Materials and methods

Study population

70 hospitalized patients diagnosed with PLA (International Classification of Disease, Clinical Modification 572.0) [15] and treated in Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, were enrolled, from March 2014 to September 2019. All 70 patients conformed to the following criteria: 1) Clinical features, such as fever, chills, and abdominal pain; 2) Microbiological identification for the blood and the pus; 3) Image examinations for abscess in the liver judged by abdominal ultrasonography (US), computerized tomography (CT), or magnetic resonance imaging (MRI). We excluded patients who were 1) diagnosed with amoebic liver abscess or infected liver cyst; 2) without clear records or who did not receive any treatment; 3) pregnant.

A comprehensive analysis of demographic characteristics, clinical manifestations, microbiological identification, auxiliary examinations, management and outcome was performed. Data were collected by reviewing the medical records of each patient. The clinical records included demographic characteristics (age and sex), length of hospital stays, accompanying diseases, clinical patterns (signs and symptoms), laboratory values (hematologic, biochemical), microbiological reports, imaging features, diagnosis, management (antimicrobial therapies, interventional drainages, surgeries) and outcome.

Microbiologic sample collection and cultivation

Blood and pus obtained from patients was injected into blood culture bottles (BD Biosciences, CA, USA) for microbial cultures. Samples from each patient were cultured by both aerobic and anaerobic conditions. We collected the peripheral blood samples when patients were in the following situations: 1) body temperature above 38°C or less than 36°C; 2) had chills; 3) leukocyte count above 10×10^9/L or less than 4×10^9/L. The culture bottles were placed in BD BACTEC FX blood culture system, the incubation temperature was set at 35°C, and humidity was 50%. After 48-72 h, the system showed a positive result, and the strain was inoculated into a petri dish for further identification.

Antibiotics treatments

All patients received intravenous antibiotic therapy empirically at the beginning. Individualized treatments were selected according to the condition. Antibiotics included the third generation of Cephalosporin, Fluoroquinolone, Carbapenems and Metronidazole. If there was no response to the initial treatments, the antibiotics were adjusted according to the results of cultures. The course of intravenous antibiotic therapy lasted from two to four weeks individually.

Statistical analysis

Analyzsis used the SPSS version 22.0 statistical software. All the categorical variables were described as percentages. Continuous data were presented as the mean with the standard deviation (SD) and Standard Error of Mean (SEM). The Student's t-test and Chi-square test were used to evaluate the differences in variables. Logistic regression analysis was applied to analyze the risk factors for disease outcomes. Statistical tests were performed with a two-tailed significance level of 0.05.

Results

Demographic and clinical characteristics

From March 2014 to September 2019, 70 patients were diagnosed with PLA at Shanghai Ninth People's Hospital. 71.4% (50/70) were males. Ages ranged from 20 y to 82 y with a mean age of 63.06 ± 12.33 y, of which 48.6% (34/70) patients were in the range of 61-70 y (**Table 1**). The average length of hospital stay was 15.72 ± 3.16 days. Infection of biliary tract (51.4%, 36/70) was the main cause of PLA.

Table 1. Demographic characteristics of patients with PLA

Variable	N (%)
Gender	
Male	50 (71.4)
Female	20 (28.6)
Age (mean ± SD) (year)	63.06 ± 12.33
20-40	3 (4.3)
41-50	11 (15.7)
51-60	16 (22.9)
61-70	34 (48.6)
71-82	6 (8.5)

Other patients (48.6%, 34/70) had no definite cause for PLA.

To observe the accompanying diseases in these PLA patients, we found most of them had hepatobiliary diseases (51.4%, 36/70), including gallstones, choledocholithiasis, chronic cholecystitis, or post-cholecystectomy). Other accompanying chronic diseases were hypertension (44.3%, 31/70), diabetes mellitus (42.9%, 30/70), various liver diseases (22.9%, 16/70) (including fatty liver disease, chronic hepatitis B), malignancy (21.4%, 15/70), and history of abdominal surgery (25.7%, 18/70) (including hepatobiliary surgery, tumor resection of gastrointestinal tract or other systems) (**Figure 1A**).

Clinical manifestations of these 70 patients included fever (85.7%, 60/70), upper right abdominal pain (32.9%, 23/70), nausea or vomiting (22.9%, 16/70), and chills (20.0%, 14/70), whereas jaundice was not common and only presented in two cases (2.8%, 2/70) (**Figure 1B**).

Laboratory examinations and imaging features

In the 70 patients, inflammatory biomarkers were generally elevated, including C-reactive protein (CRP, 95.7%, 67/70), leukocyte counts (58.6%, 41/70), neutrophil counts (62.9%, 44/70), and procalcitonin (PCT, 45.7%, 32/70). 64.3% (45/70) patients presented with lowered hemoglobin. Liver dysfunctions included elevated alkaline phosphatase (ALP) in 55.7% (39/70) cases and γ-glutamyl transferase (γ-GT) in 74.3% (52/70) cases, respectively. 40 PLA patients underwent $CD4^+$ T lymphocyte analysis, of which 25% (10/40) patients were below normal $CD4^+$ T cell cutoff value. 54 patients underwent D-D dimer testing. 87.0% (47/54) patients presented elevated D-D dimer levels (**Table 2**).

All of the 70 patients underwent abdominal B-ultrasound, and some patients were further investigated by CT scan (30/70), and/or MR imaging (35/70) for differential diagnosis. The mean size of the liver abscess was 6.09±2.69 cm (range from 1.0 to 13.4 cm). 51.4% (36/70) cases were large size (size ≥ 5 cm). 8.6% (6/70) cases were huge size (size ≥ 10 cm). 64.3% (45/70) were a single abscess. 35.7% (25/70) cases were multiple lesions. 72.9% (51/70) lesions were located in the right hepatic lobe (**Table 3**).

Microbiologic identifications

We performed microbiologic blood culture in 34 patients. 26.5% (9/34) cases showed positive reports. Of the 9 positive blood culture cases, 66.7% (6/9) were *K. pneumoniae*, and 33.3% (3/9) cases were *E. coli* (**Figure 2A**). Pus cultures were performed in 18 patients with a positive rate of 77.8% (14/18). Of the 14 positive cases, 64.3% (9/14) pathogens were also *K. pneumoniae*, followed by *E. coli* (14.3%, 2/14), *Streptococcus* (7.1%, 1/14), *Staphylococcus* (7.1%, 1/14) and *Enterococcus* (7.1%, 1/14) (**Figure 2B**).

Treatment and outcome

All patients were treated with intravenous antimicrobiological therapy. 87.1% (61/70) patients received the regimens of combination antibiotics, with third generation cephalosporin or carbapenem combined with fluoroquinolones and metronidazole (**Table 3**), while only 9 patients received a single-antibiotic regimens. 32.9% (23/70) cases required additional interventions, due to an unsatisfactory response. CT or ultrasound guided percutaneous drainage was performed in 28.6% (20/70) cases. Open surgical drainage was done in 4.3% (3/70) cases (**Table 3**).

With different regimens for the 70 patients, we found patients who received surgery presented with the largest diameter of liver abscess, reaching 10.02 ± 2.56 cm, and it required the shortest time for leukocyte recovery (5.43 ± 1.68 days), whereas the length of hospital stay was the longest (19.23 ± 7.45 days). Patients who received antibiotics alone showed the smallest abscess diameter (5.39 ± 1.04 cm), and required the longest time (8.39 ± 1.45 days) for leukocytes to recover. Patients who

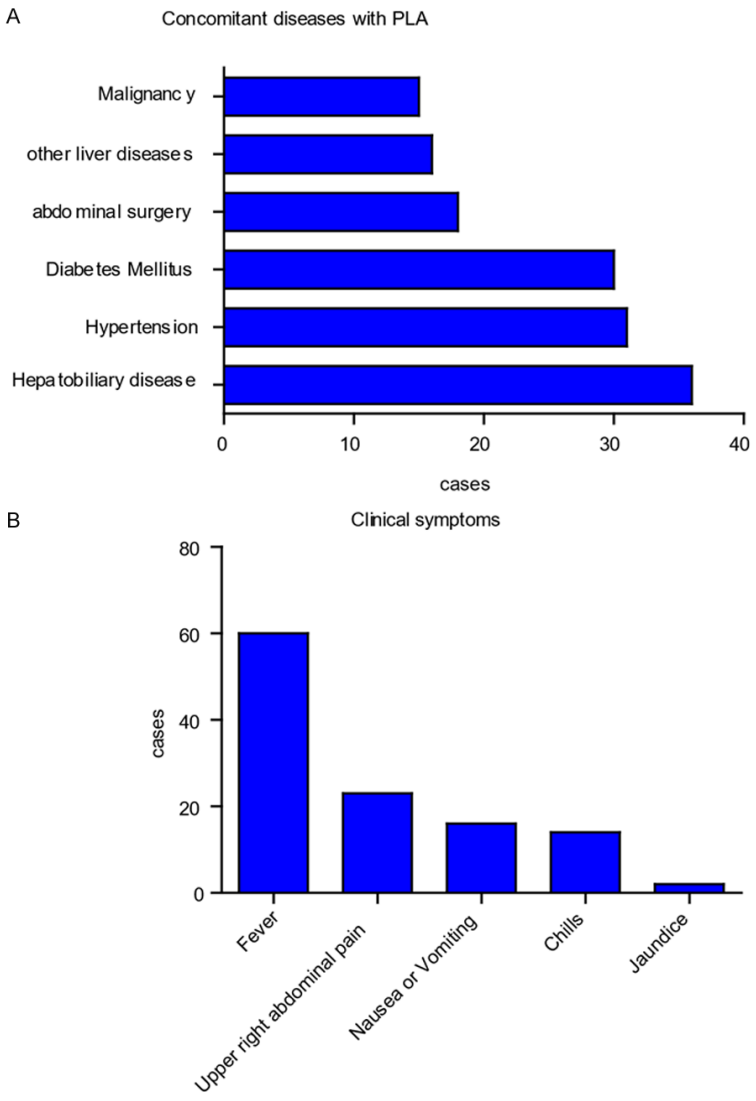

Figure 1. Clinical pattern of 70 cases with PLA. A. Accompanying diseases of 70 patients with PLA. Hepatobiliary diseases in 36 cases, hypertension in 31 cases, diabetes mellitus in 30 cases, abdominal surgery in 18 cases, other liver diseases in 16 cases, and malignancy in 15 cases. B. Clinical manifestations of the 70 patients with PLA. 60 cases presented with fever (85.7%); 23 cases presented with upper right abdominal pain (32.9%); 16 cases had nausea or vomiting (22.9%); 14 cases had chills (20.0%); 2 cases had jaundice (2.8%).

received percutaneous drainage took 6.47 ± 1.51 days for leukocytes to return to normal, and they had the shortest length of hospital stay (13.95 ± 3.33 days) ($P < 0.01$) among the three kinds of treatment (**Table 4**).

Risk factors for PLA outcome

94.3% (66/70) patients were improved after treatment. 4.3% (3/70) patients had no improvement in the pus absorption and 1.4% (1/70) patient died. We performed univariate analyses to screen out the risk factors for PLA. It was revealed that hepatobiliary disease ($P = 0.049$), malignancies ($P = 0.007$), history of abdominal surgeries ($P = 0.022$), septic shock ($P = 0.044$), HbA1c ($P = 0.036$), liver dysfunctions ($P = 0.037$) and PCT level ($P = 0.043$) were risk factors for poor prognosis (**Table 5**). Further, multivariate logistic regression analyses identified that malignancies ($P = 0.003$, 95% CI: 1.290-141.275), septic shock ($P = 0.045$, 95% CI: 3.688-103.702) and HbA1c ($P = 0.047$, 95% CI: 1.562-251.620) were independent risk factors for poor prognosis (**Table 6**).

In our study, 42.9% (30/70) patients had accompanying DM, all of whom had type 2 Diabetes Mellitus (T2DM). Among these patients, 50% (15/30) patients presented with uncontrolled high glucose levels, characterized as HbA1c > 7%. 47.5% (19/40) of non-DM patients had abscesses of larger size. More DM patients (76.7%, 23/30) presented with a larger size than non-DM patients (47.5%, 19/40) ($P = 0.014$). Microbiological yield showed an obvious difference between DM and non-DM patients. *K. pneumoniae* was the predominant pathogen in 52.4% (11/21) of DM patients, which was significantly higher than non-DM patients (11.5%, 3/26) ($P = 0.002$). 77.5% (31/40) of non-DM patients received antibiotics only. However, 46.7% (14/30) DM patients underwent additional intervention drainage versus 22.5%, (9/40) of non-DM patients ($P = 0.033$). In addition, the only patient who died due to septic shock in our study had uncontrolled DM, and HbA1c reached 7% (**Table 7**).

Table 2. Laboratory findings for pyogenic liver abscess patients

Variable	Cutoff range	Mean ± SEM	NO. of cases outside range (%)
WBC ($\times 10^9$/L)	3.9-9.5	10.97 ± 0.67	41 (58.6)
NEUT (%)	40-75	76.78 ± 1.44	44 (62.9)
Hemoglobin (g/L)	115-150	120.97 ± 2.11	45 (64.3)
Platelet ($\times 10^9$/L)	125-350	210.90 ± 14.38	33 (47.1)
ALT (U/L)	9-50	68.20 ± 9.42	33 (47.1)
AST (U/L)	15-40	59.77 ± 10.24	26 (37.1)
GGT (U/L)	10-60	146.80 ± 15.28	52 (74.3)
ALP (U/L)	30-120	164.33 ± 13.01	39 (55.7)
CRP (mg/L)	0-8	108.57 ± 8.32	67 (95.7)
PCT (ng/ml)	0-0.5	14.45 ± 4.67	32 (45.7)
Count of $CD4^+$ T (n = 40, cell/ul)†	478-1440	709.69 ± 174.86	12 (30)
D-D dimer (n = 54, ug/ml)	0-0.5	3.26 ± 0.53	47 (87.0)

†below the lower cutoff value.

Table 3. Imaging features and treatment in PLA patients

Variable	PLA (n = 70) N (%)
Location of abscess	
Left hepatic lobe	12 (17.1)
Right hepatic lobe	51 (72.9)
≥ 2 lobes	7 (10.0)
Size of abscess	
Size < 5 cm	28 (40.0)
5 cm ≤ Size ≤ 10 cm	36 (51.4)
Size > 10 cm	6 (8.6)
Antibiotic option	
Combined	61 (87.1)
Single	9 (12.9)
Antibiotic drugs	
Third generation cephalosporin	47 (67.1)
Fluoroquinolone	25 (35.7)
Carbapenems	20 (28.5)
Metronidazole	29 (41.4)
Treatment	
Antibiotics only	47 (67.1)
Percutaneous drainage	20 (28.6)
Surgical drainage	3 (4.3)
Clinical outcome	
Cure and improvement	66 (94.3)
Non-improvement and death	4 (5.7)

Discussion

The anatomic structure of the liver has double blood supplies. The biliary system communicates with the intestinal tract through enterohepatic circulation. Bacteria easily translocate and invade the liver through the biliary system or blood circulation, initiating inflammatory reactions and necrosis in the hepatic tissues, and finally forming pyogenic liver abscesses [16].

In recent years, pyogenic liver abscesses were more common in the middle-aged and elderly population [1]. In our research, 57.1% patients were over 60 years old, and males were predominant. Symptoms of PLA in the initial stage were various and atypical. From our observations, elevated inflammatory factors (CRP, PCT, WBC) and liver dysfunction (GGT, ALP, ALT, AST) might indicate PLA. However, the confirmed diagnosis of PLA relied on image investigation. As we reported, 72.9% PLA lesions were in the right hepatic lobe, mainly due to the portal vein anatomy.

Nowadays, biliary system diseases has become the main pathogenic factor causing PLA instead of adjacent abdominal organ infection, possibly associated with gut microbiota translocation through the biliary system [17]. In our study, 51.4% cases were accompanied by hepatobiliary diseases, such as holelithiasis and cholangitis. Taking the high risks for PLA into account, we demonstrated that HbA1c was an independent risk factor for PLA. The impaired host defense mechanisms in DM were highly associated with PLA. Our result showed that patients with DM presented with larger abscesses than non-DM patients (P = 0.014), and required more additional interventional drainages than non-DM patients (P = 0.033). These observa-

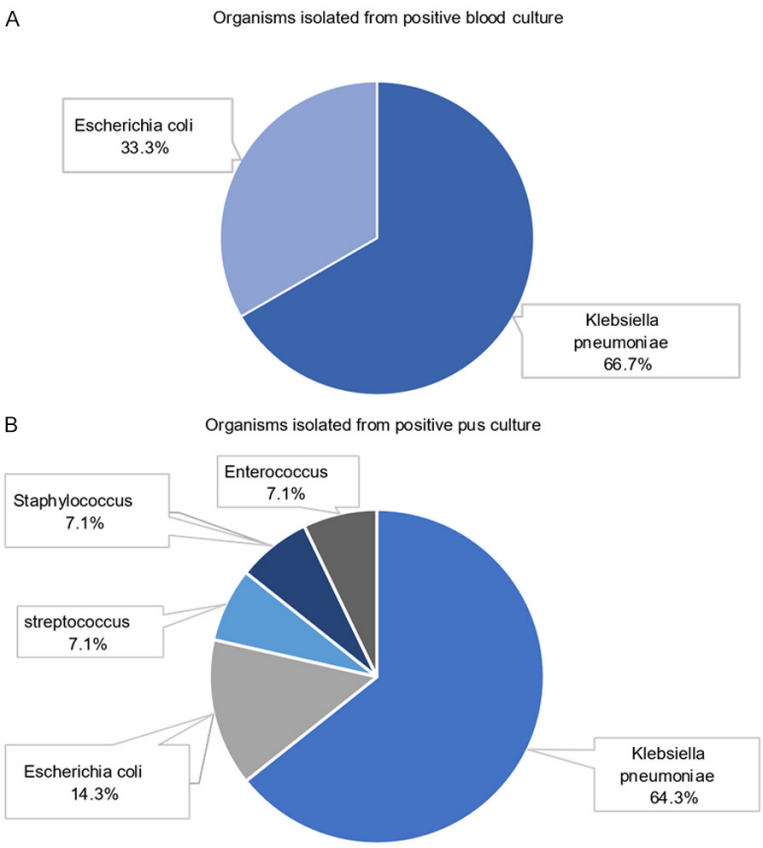

Figure 2. Bacterial spectrum of 70 cases with PLA from blood and pus cultures. A. Organisms isolated from positive blood culture. N = 9, *K. pneumoniae* in 6 cases and *E. coli* in 3 cases. B. Organisms isolated from positive pus cultures. N = 14, *K. pneumoniae* in 9 cases, *E. coli* in 2 cases. *Streptococcus*, *Staphylococcus,* and *Enterococcus* were 1 case, each.

tions indicated that uncontrolled hyperglycemia markedly worsened PLA outcomes.

In our study, the microbiologic yield positivity in blood and pus were 26.5% and 77.8%, respectively, indicating that abscess culture positivity was significantly higher than blood culture. A contributory factor to this low blood culture yield might be the early use of antibiotics, while the microbiota in the pus were protected by the wall of the abscess, requiring a longer time for the antibiotics to enter the abscess. The bacterial spectrum identified in our study showed that *K. pneumoniae* was the most common organism in both blood (66.7%) and pus cultures (64.3%). We highlighted in our research that DM patients tended to be more susceptible to *K. pneumoniae* ($P = 0.002$). Several studies have proven that exogenous glucose can stimulate the production of virulence factors of *K. pneumoniae*, suggesting that a high-glucose environment enhances the pathogenesis of bacteria and also contributes to the susceptibility to *K. pneumoniae* infection in DM patients [18, 19]. In the diabetic mouse urinary tract, hyperglycosuria induced a high bacterial burden of *K. pneumoniae* in the urinary bladder. *K. pneumoniae* seems to be most likely to invade patients with uncontrolled blood glucose [20]. Mechanistically, an intensive study has uncovered that high glucose inactivates the cAMP-CRP regulatory system and alters the cell length of *K. pneumoniae* to enhance its growth [18]. Thus, our study disclosed the most common pathogen in PLA patients with DM, and might provide an early and precise antibiotic regimen for these patients.

Percutaneous needle aspiration and catheter drainage has been shown in this study to be beneficial in the treatment of PLA when combined with antibiotics. We demonstrated that percutaneous aspiration and catheter drainage was mainly used to treat medium-sized abscesses with antibiotics. Compared to antibiotic treatment and surgical treatment, the hospital stay with percutaneous drainage was significantly shorter. For huge abscesses, surgical procedures were needed. Although surgery could quickly reduce the elevated leukocytes and relieve symptoms, the invasive procedures had adverse effects of higher complication rates, longer hospital stay, and higher cost. For small abscesses, single antibiotic treatments were recommended. In addition to the size of the abscess, PLA regimens should be selected precisely, based on the characteristics and location of the abscess and concomitant chronic diseases, especially DM. Most patients have good outcomes, depending on the age, abscess size, management, and chronic diseases.

In conclusion, pyrogenic liver abscesses mostly occur in elderly male patients and patients with hepatobiliary disease. Diabetes is an underly-

Table 4. Comparison of different managements for 70 patients with PLA (Mean ± SD)

Treatment	Antibiotics only	Percutaneous drainage	Surgical drainage	*P* value
Abscess diameter (cm)	5.39 ± 1.04	8.21 ± 3.37	10.02 ± 2.56	< 0.01**
Leukocyte recovery (days)	8.39 ± 1.45	6.47 ± 1.51	5.43 ± 1.68	< 0.01**
Hospital stay (days)	16.01 ± 1.89	13.95 ± 3.33	19.23 ± 7.45	< 0.01**

***P* < 0.01.

Table 5. Univariate analysis of risk factors for PLA

Variable	Score	*P*	Variable	Score	*P*
Age	0.600	0.438	Anemia	0.003	0.959
Size of abscess	0.045	0.831	Platelet	0.000	0.987
Hepatobiliary diseases	2.719	0.049	CRP	0.065	0.799
Malignancy	7.231	0.007	D-D dimer	0.278	0.598
History of abdominal surgery	5.224	0.022	Liver dysfunction	4.344	0.037
Symptom of digestive tract	0.355	0.552	PCT	3.747	0.043
Septic shock	3.711	0.044	$CD4^+/CD8^+$	0.955	0.329
HbA1c	3.139	0.036	*K. pneumoniae*	0.442	0.506
WBC	1.395	0.238	Management	0.707	0.400

Table 6. Multivariate analysis of risk factors for PLA

Variable	B	*P*	OR	95.0% CI for OR	
				Lower	Upper
Malignancy	2.603	0.030	13.500	1.290	141.275
Septic shock	2.134	0.045	8.444	3.688	103.702
HBA1C	2.644	0.047	14.063	1.562	251.620

Table 7. Comparison of clinical patterns in DM patients and non-DM patients

Variable	DM cases (%)	Non-DM cases (%)	*P* value
Size of abscess			
Size < 5 cm	7/30 (23.3)	21/40 (52.5)	0.014*
Size ≥ 5 cm	23/30 (76.7)	19/40 (47.5)	0.014*
Microbiologic isolates			
Positive growth	16/21 (76.2%)	8/26 (30.8%)	0.002**
Klebsiella pneumonia	11/21 (52.4%)	3/26 (11.5%)	0.002**
Escherichia coli	2/21 (9.5%)	3/26 (11.5%)	1
Other microorganism	3/21 (14.3%)	2/26 (7.7%)	0.644
Treatment			
Antibiotics only	16/30 (53.3%)	31/40 (77.5%)	0.033*
Intervention drainage	14/30 (46.7%)	9/40 (22.5%)	0.033*
Outcome			
Cure and improvement	28/30 (93.3%)	38/40 (95%)	1
Death	1/30 (3.3%)	0/40 (0%)	0.884

*P < 0.05, **P < 0.01.

ing risk factor for PLA. The major clinical symptoms are various and nonspecific. Inflammatory biomarkers are generally elevated. Dysfunction of the liver is common. Abdominal ultrasound, CT scan, or MR imaging can identify the abscess effectively. In addition, the predominant pathogen in PLA is *K. pneumoniae*, especially in DM patients. Percutaneous needle aspiration and catheter drainage is an effective intervention for large abscesses. Diabetes carries high risk of PLA. HbA1c is an independent risk factor for PLA outcome. Patients with poorly controlled hyperglycemia tend to be more susceptible to *K. pneumoniae* infection and may suffer with larger lesions and poor outcomes, so additional interventional treatments need to be considered.

This was a single center retrospective study and the results might not be generalizable. Nevertheless, the results were based on 70 cases and still may provide solid medical evidence to improve the diagnosis and treatment of pyogenic liver abscess.

Acknowledgements

This study was financially supported by the funding "Clinical Research Project of Multi-Disciplinary Team, Shanghai Ninth People's Hospital, Shanghai JiaoTong University School of Medicine (201908)".

We are extremely grateful for all the participants in this study from our team. We especially thank Professor Zhengrong Zhong for providing the laboratory tests results.

Disclosure of conflict of interest

None.

Abbreviations

PLA, pyrogenic liver abscess; DM, Diabetes Mellitus; CRP, C reactive protein; PCT, procalcitonin; *K. pneumoniae, Klebsiella pneumoniae*; *E. coli, Escherichia coli*; US, abdominal ultrasonography; CT, computerized tomography; MRI, magnetic resonance imaging; ALP, alkaline phosphatase; γ-GT, γ-glutamyl transferase; HbA1c, glycosylated hemoglobin.

Address correspondence to: Drs. Yujie Bao and Jie Xu, Department of Infectious Disease, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai 200011, China. Tel: +86-021-56691101-6711; E-mail: yujie.bao@shsmu.edu.cn (YJB); xujie@shsmu.edu.cn (JX)

References

[1] Luo M, Yang XX, Tan B, Zhou XP, Xia HM, Xue J, Xu X, Qing Y, Li CR, Qiu JF and Li YL. Distribution of common pathogens in patients with pyogenic liver abscess in China: a meta-analysis. Eur J Clin Microbiol Infect Dis 2016; 35: 1557-65.

[2] Kubo H, Taniguchi F, Shimomura K, Nanishi K, Ueshima Y, Takahashi A, Shioaki Y and Otsuji E. Inferior vena caval thrombosis complicating pyogenic liver abscess after pancreatoduodenectomy: a case report. Surg Case Rep 2015; 1: 77.

[3] Li W, Chen H, Wu S and Peng J. A comparison of pyogenic liver abscess in patients with or without diabetes: a retrospective study of 246 cases. BMC Gastroenterol 2018; 18: 144.

[4] Li W, Wu C, Qin M, Cai F and Huang J. The aura of malignant tumor: Clinical analysis of malignant tumor-related pyogenic liver abscess. Medicine (Baltimore) 2020; 99: e19282.

[5] Serraino C, Elia C, Bracco C, Rinaldi G, Pomero F, Silvestri A, Melchio R and Fenoglio LM. Characteristics and management of pyogenic liver abscess: a European experience. Medicine (Baltimore) 2018; 7: e0628.

[6] Lee KT, Wong SR and Sheen PC. Pyogenic liver abscess: an audit of 10 years' experience and analysis of risk factors. Dig Surg 2001; 18: 459-65; discussion 465-6.

[7] Tian LT, Yao K, Zhang XY, Zhang ZD, Liang YJ, Yin DL, Lee L, Jiang HC and Liu LX. Liver abscesses in adult patients with and without diabetes mellitus: an analysis of the clinical characteristics, features of the causative pathogens, outcomes and predictors of fatality: a report based on a large population, retrospective study in China. Clin Microbiol Infect 2012; 18: E314-30.

[8] Qian Y, Wong CC, Lai S, Chen H, He X, Sun L, Wu J, Zhou J, Yu J, Liu W, Zhou D and Si J. A retrospective study of pyogenic liver abscess focusing on Klebsiella pneumoniae as a primary pathogen in China from 1994 to 2015. Sci Rep 2016; 6: 38587.

[9] Lin WH, Tseng CC, Wu AB, Yang DC, Cheng SW, Wang MC and Wu JJ. Clinical and microbiological characteristics of peritoneal dialysis-related peritonitis caused by Klebsiella pneumoniae in southern Taiwan. J Microbiol Immunol Infect 2015; 48: 276-83.

[10] Lederman ER and Crum NF. Pyogenic liver abscess with a focus on Klebsiella pneumoniae as a primary pathogen: an emerging disease with unique clinical characteristics. Am J Gastroenterol 2015; 100: 322-31.

[11] Cheng DL, Liu YC, Yen MY, Liu CY and Wang RS. Septic metastatic lesions of pyogenic liver abscess. Their association with Klebsiella pneumoniae bacteremia in diabetic patients. Arch Intern Med 1991; 151: 1557-9.

[12] Tan TY, Ong M, Cheng Y and Ng LSY. Hypermucoviscosity, rmpA, and aerobactin are associated with community-acquired Klebsiella pneumoniae bacteremic isolates causing liver abscess in Singapore. J Microbiol Immunol Infect 2019; 52: 30-34.

[13] Siu LK, Yeh KM, Lin JC, Fung CP and Chang FY. Klebsiella pneumoniae liver abscess: a new invasive syndrome. Lancet Infect Dis 2015; 12: 881-7.

[14] Osman K, Srinivasa S and Koea J. Liver abscess: contemporary presentation and management in a Western population. N Z Med J 2018; 131: 65-70.

[15] (WHO) WHO. International Classification of Diseases (ICD). Accessed September 2016; 21.

[16] Wang WJ, Tao Z and Wu HL. Etiology and clinical manifestations of bacterial liver abscess: a study of 102 cases. Medicine (Baltimore) 2018; 97: e12326.

[17] Shi SH, Zhai ZL and Zheng SS. Pyogenic liver abscess of biliary origin: the existing problems and their strategies. Semin Liver Dis 2018; 8: 270-283.

[18] Liu L, Li F, Xu L, Wang J, Li M, Yuan J, Wang H, Yang R and Li B. Cyclic AMP-CRP modulates

the cell morphology of klebsiella pneumoniae in high-glucose environment. Front Microbiol 2020; 10: 2984.

[19] Lee CH, Chen IL, Chuah SK, Tai WC, Chang CC, Chen FJ and Chen JF. Impact of glycemic control on capsular polysaccharide biosynthesis and opsonophagocytosis of Klebsiella pneumoniae: implications for invasive syndrome in patients with diabetes mellitus. Virulence 2016; 7: 770-8.

[20] Rosen DA, Hung CS, Kline KA and Hultgren SJ. Streptozocin-induced diabetic mouse model of urinary tract infection. Infect Immun 2008; 76: 4290-8.