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MAJOR ARTICLE

A Population-Based Study of Unfavorable Prognostic Factors Associated With Pyogenic Liver Abscess

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Background. Pyogenic liver abscess (PLA) is a rare entity that is associated with substantial mortality and morbidity. Our objective was to investigate variables associated with mortality and subsequent PLA in patients diagnosed with PLA in southern Sweden.

Methods. We conducted a population-based observational study comprising all episodes of PLA that occurred between 2011 and 2020 in the county of Skåne, southern Sweden. The primary outcome was defined as all-cause 90-day mortality and the secondary outcome was defined as the occurrence of a subsequent PLA.

Results. A total of 452 episodes of PLA occurred in 360 patients during the study period. The 90-day mortality rate was 16% (n = 58) and the subsequent PLA rate was 20% (n = 92). In a multivariable logistic regression model, female sex (odds ratio [OR], 2.0 [95% confidence interval {CI}, 1.1–3.9]), malignancy (OR, 3.7 [95% CI, 1.9–7.1]), liver failure (OR, 6.3 [95% CI, 2.7–14.5]), and polymicrobial findings (OR, 3.8 [95% CI, 2.2–6.9]) were associated with death within 90 days ($P < .05$). Male sex (OR, 2.1 [95% CI, 1.2–3.6]), malignancy (OR, 2.1 [95% CI, 1.3–3.6]), age (64–74 years: OR, 2.5 [95% CI, 1.3–4.8]), and chronic liver disease (OR, 3.0 [95% CI, 1.4–6.5]) were associated with the risk of subsequent PLA ($P \leq .01$).

Conclusions. Identifying different clinical variables associated with an unfavorable outcome may improve the management and treatment of patients with PLA and thus prevent the risk of death and subsequent PLA.

Keywords. bacterial infection; liver abscess; outcome; prognosis; risk factors.

Pyogenic liver abscess (PLA) is a rare entity but can be a life-threatening disease. The incidence of PLA has been reported to range between 1.1 and 3.6 per 100 000 person-years in Scandinavian countries [1, 2] and the United States [3, 4]. Symptoms of PLA may be unspecific such as fever and abdominal pain, and the diagnosis of PLA is most often established by diagnostic imaging and or through microbiological findings from abscess and/or blood cultures. The microbiological findings of PLA have been attributed to streptococci, *Escherichia coli*, and *Klebsiella* species [5]; however, the microbiological etiology varies, which often results in the empirical usage of broad-spectrum antibiotics.

Estimates of case-fatality rates have ranged from 3% up to 30% worldwide and several risk factors have been attributed to these substantial mortality rates [1, 2, 4]. Multiple population-based studies have established an association between older age, development of sepsis, renal failure, and mortality in patients with PLA [4, 6, 7]. Other factors associated with mortality in PLA have been attributed to the presence of hypoalbuminemia [8], leukocytosis [9], and diabetes mellitus [10].

Complicated factors in patients with PLA may be portal vein thrombosis (PVT) [6] and the development of difficult-to-treat hepatogastric or enterohepatic fistulas [11, 12]. The risk of recurrence of PLA has been estimated to be 10%, in which biliary etiology has been reported to be a related factor [13, 14]. Isolation of multiresistant organisms and any history of cholangitis have also been implicated in the risk of recurrent PLA [14].

Although there are a few retrospective studies investigating factors associated with mortality in patients with PLA, knowledge of factors related to the risk of recurrence is limited.

The objective of this study was to assess mortality and recurrence in a cohort of patients with PLA and to determine different variables associated with mortality and investigate predictive factors for subsequent PLA.

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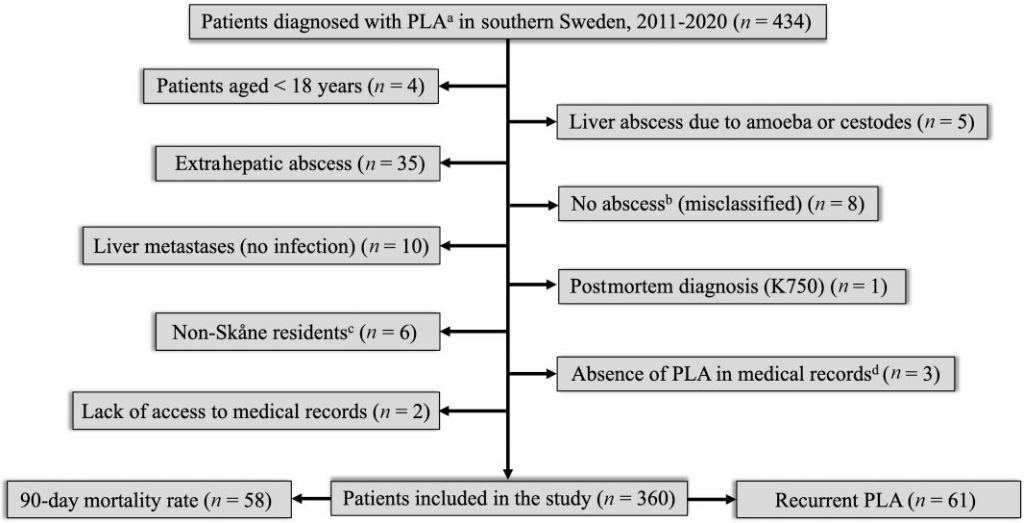

Figure 1. Flowchart of inclusion and exclusion criteria. [a]International Classification of Diseases, Tenth Revision diagnosis code K750. [b]Patients were diagnosed with K750, but no record of abscess could be found. [c]Non-Skåne residents transferred to hospitals outside of Skåne. [d]The diagnosis K750 was nowhere to be found in the medical record. Abbreviation: PLA, pyogenic liver abscess.

METHODS

Study Design

This population-based observational study included all individuals (>18 years) diagnosed with PLA in the county of Skåne in southern Sweden between 2011 and 2020. Medical records of included cases were retrospectively reviewed according to prespecified study protocol including demographic data, clinical variables, and clinical outcome. Logistic regression analyses were used to assess the risk of 90-day mortality rate and subsequent PLA and determine different predictive factors associated with mortality and subsequent PLA. The authors have recently performed a cohort study describing the incidence and microbiological etiology of PLA during the same period [15].

Study Population

A consort diagram detailing the construction of the study population is shown in Figure 1.

Episodes of PLA, registered in the Swedish National Patient Register (NPR) according to *International Classification of Diseases, Tenth Revision* code K750, were identified. Exclusion criteria comprised <18 years of age; lack of access to medical records; radiological imaging showing extrahepatic location of the abscess; which was per definition located outside the liver parenchyma; abscesses due to amoebic infection; and misclassification of the diagnosis of PLA. Other exclusion criteria were the presence of liver metastasis without any infection-related etiology or if the diagnosis of PLA was established by autopsy. In addition, patients who were not residents of the county of Skåne were also excluded from the study, due to a lack of follow-up data.

Outcomes

The primary outcome was defined as death from any cause within 90 days, and the secondary outcome was defined as the occurrence of a subsequent PLA. This was defined as the return of symptoms due to an already known liver abscess or having an entirely new abscess of the liver, in a patient previously diagnosed with PLA during the study period. Hence, PLA recurrence could occur at any time throughout the study period. Since death by definition could not occur with the first episode if there was a recurrence, only the latest episode of PLA was included in the analyses concerning 90-day mortality rate. All included episodes of PLA were encompassed in the analysis concerning the risk of subsequent PLA.

Covariates

Collected data included demographic characteristics such as age, sex, main symptoms, length of hospital stay, antibiotic treatment, and place of acquisition (community, hospital, or healthcare related). Other clinical features registered were Charlson comorbidity index (CCI) [16], any immunosuppression, laboratory data, and the utilization of percutaneous catheter drainage (PCD) or percutaneous needle aspiration (PNA) of the abscess. Imaging techniques included ultrasonography and computed tomography (CT), in which findings of the number of abscesses (solitary/multiple), maximum size, PVT, and formation of any fistulas were recorded. Liver failure at diagnosis was defined as elevated transaminases together with elevated pyruvate kinase. Chronic liver disease was defined as an active hepatitis and/or documentation in medical records of any known liver cirrhosis. Laboratory values were retrieved from the visit at the emergency department. The durations of

antimicrobial treatment and hospitalization were stated. In addition to the 90-day mortality rate (the primary outcome), 30-day, 1-year, and hospital mortality rates were also reported. Microbiological findings from both blood and abscess cultures were included in the univariate and multivariable logistic regression models, dichotomized into poly- or monomicrobial.

Data Sources

The Swedish NPR was used to identify all episodes of PLA in Skåne county in southern Sweden. The NPR is a register held by the Swedish National Board of Health and Welfare and contains close to 100% of medical inpatient data in Sweden since 1987 and all outpatient specialist care data since 2001. It is considered highly reliable and valid [17]. Medical records of all identified cases were reviewed according to a predefined study protocol in order to collect data on outcomes and covariates. Linkage was performed through the personal identification number that identifies every legal resident in Sweden.

Statistical Analysis

Continuous variables were presented as median with interquartile range (IQR) and analyzed using Mann-Whitney *U* test. Categorical data were presented as numbers and percentages, and the χ^2 test was applied for the analysis of categorical data. A simple logistic regression model was undertaken for the analysis of univariate data. Factors with a univariate *P* value <.05 were included in the multivariable logistic regression analyses to assess the risk of 90-day mortality rate or subsequent PLA. Results were reported as odds ratio (OR) with a 95% confidence interval (CI). Statistical analysis was performed utilizing R statistical software, version 3 (R Foundation for Statistical Computing: https://www.r-project.org/). A *P* value <.05 was considered statistically significant.

RESULTS

Population Characteristics

In total, 360 patients diagnosed with PLA were included in the study, with a total of 452 episodes of PLA during the study period. Median age of included patients was 71 years (IQR, 61–79 years) and 56% (n = 202) were men. A total of 29% (n = 103) and 31% (n = 111) had diabetes mellitus and malignancy, respectively. Table 1 summarizes the clinical features of the study cohort.

Table 1. Clinical Features of Patients With Pyogenic Liver Abscess (n = 360)

Characteristic	No. (%)
Demographics	
Male, sex	202 (56)
Age, y, median	71 (61–79)
Smoking	76 (21)
Comorbidities	
CCI score, median (IQR)	5 (3–7)
Myocardial infarction	59 (16)
Congestive heart failure	58 (16)
Peripheral vascular disease	19 (5)
Cerebrovascular accident or transient ischemic attack	54 (15)
Dementia	11 (3)
COPD	40 (11)
Connective tissue disease	20 (6)
Peptic ulcer disease	50 (14)
Chronic liver disease[a]	19 (5)
Diabetes mellitus	103 (29)
Hemiplegia	1 (0)
Moderate to severe CKD[b]	21 (6)
Solid tumor	111 (31)
Leukemia	4 (1)
Lymphoma	4 (1)
Immunosuppression[c]	85 (24)
Clinical presentation	
Fever	156 (43)
Abdominal pain	109 (30)
Fatigue	27 (8)
Dyspnea	11 (3)
No symptom	10 (3)
History of abdominal pain	207 (58)
Duration of symptoms prior to admission, d, median (IQR)	3.0 (2.0–7.0)
qSOFA score, median (IQR)	0 (0–1)
Outcome	
Subsequent PLA[d]	92 (20)
In-hospital mortality	41 (11)
30-d mortality	37 (10)
90-d mortality	58 (16)
1-y mortality	77 (21)

Data are presented as No. (%) unless otherwise indicated.

Abbreviations: CCI, Charlson comorbidity index; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; IQR, interquartile range; PLA, pyogenic liver abscess; qSOFA, quick Sequential Organ Failure Assessment.

[a]Chronic hepatitis or cirrhosis with or without portal hypertension.

[b]Status post–kidney transplantation, dialysis, uremia, or creatinine >270 µmol/L.

[c]Immunosuppression included patients who were organ or stem cell transplant recipients, had ongoing immunosuppressive medication, were treated with corticosteroids >15 mg/day, had ongoing or recently terminated chemotherapy for cancer, had dialysis or severe chronic kidney disease, had primary immunodeficiency or ongoing treatment for autoimmune disease, or if the physician in charge considered the patient severely immunosuppressed.

[d]Return of symptoms due to an already known abscess or having an entirely new abscess.

Clinical Presentation

Median duration between onset of symptoms to hospitalization was 3 days (IQR, 2–7 days) in which fever was the most common presentation (43%, n = 156), followed by abdominal pain (30%, n = 109), and fatigue (8%, n = 27). A total of 58% (n = 207) reported history of abdominal pain. Recurrent PLA and relapse PLA were pooled together into 1 group, called subsequent PLA. Variables of the clinical presentation are presented in Table 1.

Upon admission, median C-reactive protein was 179 mg/L (IQR, 90.3–266 mg/L). Diagnostic imaging with CT detected PLA in 82% of the cases, followed by ultrasound (14%). Multiple abscesses were detected in 38% of the cases and

PVT was confirmed in 10% of the cases. Development of fistulas to/from the liver occurred in 6% of the cases (n = 23). Median length of hospitalization was 14 days (IQR, 8–22 days). PCD was applied in 48% (n = 172) of the cases, whereas PNA was performed in 14% (n = 48) of the cases. In 2% of cases (n = 7), open surgery was performed. In some cases patients received both PCD and PNA. Additionally, microbiological culturing was not obtained from all patients receiving PCD and/or PNA. Table 2 summarizes laboratory findings, diagnostic imaging, and treatment.

Table 2. Laboratory Findings, Diagnostic Imaging, and Treatment (n = 360)

Characteristic	No. (%)
Laboratory findings	
CRP, median (IQR)	179.0 (93.3–266.0)
WBC, median (IQR)	13.7 (9.6–17.7)
Diagnostic imaging	
CT	294 (82)
Ultrasound	52 (14)
MRI	8 (2)
Clinical[a]	6 (2)
Positive blood culture	167 (46)
No blood culture taken	36 (10)
Positive abscess culture	155 (43)
No abscess culture taken	159 (44)
Abscess features	
Solitary abscess	216 (60)
Multiple abscesses	138 (38)
Unknown	6 (2)
Size of abscess, cm, median (range)	6.0 (4.0–8.0)
Right lobe	239 (66)
Left lobe	67 (19)
Both lobes	39 (11)
Unknown	15 (4)
Portal vein thrombosis	35 (10)
Formation of fistula from the abscess	23 (6)
Treatment	
Percutaneous aspiration	48 (14)
Percutaneous drainage	172 (48)
Duration of percutaneous drainage, d, median (range)	7.0 (4.0–17.8)
Open liver surgery	7 (2)
Antibiotics	353 (98)
Duration of antibiotics, d, median (range)	35 (20.0–52.0)
Length of hospitalization, d, median (range)	14 (8.0–22.0)

Data are presented as No. (%) unless otherwise indicated.

Abbreviation: CRP, C-reactive protein; CT, computed tomography; IQR, interquartile range; MRI, magnetic resonance imaging; WBC, white blood cell count.

[a]Refers to when no imaging was done, but the diagnosis was made based on clinical signs and symptoms.

Clinical Outcome

The overall in-hospital mortality rate was 11% whereas 30-day, 90-day, and 1-year mortality rates were 10%, 16% and 21%, respectively. A total of 61 patients experienced at least 1 subsequent PLA episode, which comprised a total of 92 subsequent PLAs (20%) (Table 1). Most of the patients with subsequent PLA had 1 episode of PLA (n = 45), followed by 2 episodes (n = 8) and 3 episodes (n = 6). At the most, 2 patients experienced 6 subsequent PLAs each.

Risk Factors Associated With 90-day Mortality Rate

The association between different risk factors and the primary outcome, 90-day mortality rate, is shown in Table 3. In the univariate analysis, female sex was associated with the 90-day mortality (OR, 2.0 [95% CI, 1.1–3.6]; $P < .05$). In addition to female sex, malignancy (OR, 4.3 [95% CI, 2.6–8.5]), liver failure during the hospitalization (OR, 6.9 [95% CI, 3.4–14.0]), polymicrobial findings (OR, 3.8 [95% CI, 2.2–6.9]), and development of fistula (OR, 3.8 [95% CI, 1.6–9.2]) were associated with 90-day mortality rate ($P < .01$). Female sex (OR, 2.1 [95% CI, 1.1–4.0]), malignancy (OR, 4.3 [95% CI, 2.3–8.1]), liver failure during hospitalization (OR, 6.4 [95% CI, 3.0–14.3]), and polymicrobial findings (OR, 2.8 [95% CI, 1.5–5.4]) remained associated with the 90-day mortality in the multivariate logistic regression model ($P < .05$). Neither PNA nor PCD was associated with 90-day mortality. In addition, still no association was found with either 30-day or 90-day mortality rate when pooling both PNA and PCD into 1 group (OR, 0.8 [95% CI, .4–1.6], $P = .5$ and OR, 1.2 [95% CI, .6–2.1], $P = .6$, respectively). A total of 12 patients had undergone liver transplantation, and none of them died within 90 days from the diagnosis of PLA.

Risk Factors Associated With Subsequent PLA

The association between different risk factors and the secondary outcome, subsequent PLA, is shown in Table 4. In the univariate analysis, male sex was associated with subsequent PLA (OR, 2.1 [95% CI, 1.3–3.5]), age (64–74 years: OR, 2.3 [95% CI, 1.3–4.3]), (<64 years: OR, 2.4 [95% CI, 1.3–4.4]), chronic liver disease (OR, 4.1 [95% CI, 2.1–8.2]), immunosuppression (OR, 1.8 [95% CI, 1.1–2.9]), malignancy (OR, 2.1 [95% CI, 1.3–3.4]), and development of fistula (OR, 2.2 [95% CI, 1.0–4.6]). Male sex (OR, 2.5 [95% CI, 1.3–4.8]), malignancy (OR, 2.1 [95% CI, 1.3–3.6]), age (64–74 years: OR, 2.5 [95% CI, 1.3–4.8]), (<64 years: OR, 2.0 [95% CI, 1.1–3.9]), and chronic liver disease (OR, 3.0 [95% CI, 1.4–6.5]) remained associated with subsequent PLA in the multivariate logistic regression model ($P \leq .01$).

Microbial Findings

Microbiological findings in relation to the primary and secondary outcomes are detailed in Supplementary Tables *A* and *B*. The most common findings in monomicrobial cultures of recurrent episodes of PLA were Enterobacterales, followed by streptococci (Supplementary Table *A*). Polymicrobial cultures with enterococci were common in subsequent PLA episodes (Supplementary Table *A*). Findings of enterococci in both monomicrobial cultures and polymicrobial cultures were also

Table 3. Variables Associated With the 90-Day Mortality Rate

Characteristic	90-Day Mortality (n = 58)	Alive (n = 302)	OR (95% CI)	*P* Value[a]	AOR (95% CI)	*P* Value[b]
Sex						
Male	24	178	Ref		Ref	
Female	34	124	2.0 (1.1–3.6)	.03	2.0 (1.1–3.9)	.03
Diabetes						
No	38	219	Ref		…	
Yes	20	83	1.4 (.8–2.5)	.3	…	
Malignancy						
No	21	220	Ref		…	
Yes	37	82	4.3 (2.6–8.5)	.003	3.7 (1.9–7.1)	.0007
Kidney disease						
No	17	322	Ref	.7	…	
Yes	4	17	1.2 (.4–3.8)	.7	…	
Immunosuppression						
No	33	242	…		…	
Yes	25	60	…		…	
Chronic liver disease						
No	52	289	Ref		…	
Yes	6	13	2.5 (.9–7.1)	.07	…	
Treatment with aspiration						
No	53	259	Ref		…	
Yes	5	43	0.6 (.2–1.5)	.3	…	
Treatment with drainage						
No	27	161	Ref		…	
Yes	31	141	1.3 (.7–2.3)	.3	…	
Portal thrombosis						
No	55	270	Ref		…	
Yes	3	32	0.5 (.1–1.6)	.2	…	
Formation of fistula						
No	49	288	Ref		…	
Yes	9	14	3.8 (1.6–9.2)	.003	2.0 (.7–6.0)	.2
Liver failure during treatment						
No	39	282	Ref		…	
Yes	19	20	6.9 (3.4–14.0)	.001	6.3 (2.7–14.5)	.0001
Multiple abscesses						
No	30	186	Ref		…	
Yes	25	113	1.4 (.8–2.4)	.3	…	
Age, y						
≤65	15	105	Ref		…	
66–75	19	99	1.3 (.6–2.8)	.4	…	
>75	24	98	1.7 (.8–3.5)	.1	…	
Positive blood culture						
No	18	139	1.6 (.9–3.1)	.1	…	
Yes	29	138	…		…	
Findings from microbiology						
No	17	95	…		…	
Yes	41	205	1.1 (.6–2.0)	.7	…	
Polymicrobial						
No	26	229	Ref		…	
Yes	32	73	3.8 (2.2–6.9)	.005	2.8 (1.5–5.4)	.002

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, odds ratio.

[a]Univariate test of significance was performed by simple logistic regression.

[b]Multivariable testing of significance was established by using binary logistic regression, and the following variables were included in the model; sex, malignancy, formation of fistula, and liver failure.

Table 4. Secondary Outcome Defined as Recurrent Pyogenic Liver Abscess

Characteristic	Subsequent PLA	No Subsequent PLA	OR (95% CI)	*P* Value[a]	AOR (95% CI)	*P* Value[b]
Sex						
Female	25	158	Ref		…	
Male	67	202	2.1 (1.3–3.5)	.004	2.1 (1.2–3.6)	.01
Blood culture positivity						
No	167	157	Ref		…	
Yes	46	167	1.1 (.7–1.7)	.8	…	
Age, y						
>74	18	131	Ref		…	
64–74	36	108	2.3 (1.3–4.3)	.01	2.5 (1.3–4.8)	.005
<64	38	121	2.4 (1.3–4.4)	.01	2.0 (1.0–4.0)	.05
Diabetes						
No	58	257	Ref		…	
Yes	34	103	1.5 (.9–2.4)	.1	…	
Chronic liver disease						
No	74	340			…	
Yes	18	20	4.1 (2.1–8.2)	.005	3.0 (1.4–6.5)	.006
Malignancy						
No	45	242			…	
Yes	47	118	2.1 (1.3–3.4)	.001	2.1 (1.3–3.6)	.003
Immunosuppression						
No	59	274	Ref		…	
Yes	33	86	1.8 (1.1–2.9)	.004	1.3 (.8–2.3)	.3
Multiple abscesses						
No	46	215	Ref		…	
Yes	42	139	1.4 (.9–2.3)	.2	…	
Treatment with aspiration						
No	74	308	…		…	
Yes	17	47	1.5 (.8–2.8)	.2	…	
Treatment with drainage						
No	41	183			…	
Yes	51	173	1.3 (.8–2.1)	.2	…	
Formation of fistula						
No	80	337	…		…	
Yes	12	23	2.2 (1.0–4.6)	.04	1.2 (.5–3.0)	.6
Portal thrombosis						
No	80	319	…		…	
Yes	10	36	1.1 (.5–2.3)	.8	…	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, odds ratio; PLA, pyogenic liver abscess.

[a]Univariate test of significance was performed by simple logistic regression.

[b]Multivariable testing of significance was established by using binary logistic regression, and following variables were included in the model; sex, liver disease, malignancy, immunosuppression, and formation of fistula.

common in patients with 90-day mortality (Supplementary Table *B*). A total of 100 episodes of streptococci was observed among episodes of PLA, of which *Streptococcus anginosus* was found in 69 episodes (40 in monomicrobial culture and 29 in polymicrobial culture). *Streptococcus anginosus* was found in 13 subsequent PLA episodes (data not shown).

DISCUSSION

This population-based study in southern Sweden aimed to investigate the all-cause mortality rate and subsequent PLA rate of pyogenic abscess and variables associated with mortality and subsequent PLA. We showed that female sex, malignancy, liver failure, and polymicrobial findings were independently associated with 90-day mortality rate. In addition, male sex, malignancy, and chronic liver disease were associated with the risk of PLA recurrence.

The 90-day all-cause mortality rate was 16%, which is marginally higher compared to previous retrospective-based studies: Rossi et al found a mortality rate of 11% among 302 patients with PLA [18], and Serraino et al reported a 10% mortality rate including 109 patients from Italy [19].

However, a mortality rate of 16% is significantly higher than then the overall hospital mortality rate of 6% previously

reported from Taiwan [20] and 4% from South Korea [21]. The patients included in our study suffered from several comorbidities (the median CCI score was 5), and 24% were considered immunosuppressed. This may have influenced the higher mortality rate found in our study. Still, higher mortality rates (19%) has been described from Spain [7].

We found that female sex, malignancy, development of liver failure, and polymicrobial findings in cultures were associated with 90-day mortality in patients with PLA. In concordance with our results, 2 other studies have reported that female sex was associated with mortality rate [2, 10]. Additionally, the presence of malignancy and liver failure were associated with 90-day mortality, which is in agreement with results from other studies, suggesting that patients with PLA and with malignancy or development of liver failure at the time of treatment have a higher mortality rate [4, 10, 22–24]. Liver failure is often complicated by or associated with multiorgan failure, with dire mortality rates [25].

An association between PLA and malignancy has previously been described, specifically the occurrence of colon cancer in cryptogenic PLA [21]. The higher risk for mortality among cancer patients could be explained by general poor physical health and the unfavorable effect of cancer and chemotherapy on the immune system [26]. Another possible explanation is that cancer patients are, to a greater extent, subject to care restrictions and might not receive the same treatment as patients without cancer. Unfortunately, we were not possible to extract data on specific tumor subtypes and were therefore not able to make any analysis whether some malignancies such as hepatic-biliary tumors were more associated with an unfavorable outcome in our material. Additionally, due to the retrospective study design, we were not able to establish the mechanisms or condition for the development of a PLA.

In contrast to other studies [4, 10], we did not associate diabetes mellitus or higher age with mortality. This is, however, in agreement with a Danish study conducted by Thomsen et al [27]. Neither did we observe any association between hypoalbuminemia and mortality, although our results could be hampered by the fact that albumin in plasma was not registered in the majority of the PLA episodes. In addition, Chu et al showed that female sex was associated with mortality in the univariate analysis, but this did not remain associated after adjustments in the multivariate logistic regression [28]. The study only included 83 patients; however, malignancy, hyperbilirubinemia, and elevated activated partial thromboplastin remained associated with mortality, though the latter 2 factors were not investigated in our study.

Furthermore, we did not find an association between mortality and severity of disease, in contrast to other studies [20, 29].

In our study, 17% of the patients had subsequent PLA, which is a higher rate compared to findings from other studies [14, 18]. In our study, subsequent PLA was associated with male sex, malignancy, age 64–74 years, and chronic liver disease. Rossi et al found that ischemic cholangitis and findings of *Streptococcus* species were associated with the risk of recurrence [18]. We did not detect similar findings; however, 11 patients with subsequent PLA had findings of *Streptococcus* species, albeit in polymicrobial cultures. In addition, we did not observe any difference in the size of the pyogenic abscess and the risk of subsequent PLA.

A minority of the patients with PLA (2%) in our study underwent surgery, but the rate of either PNA or PCD was 61%. Most PLAs in our study were solitary (60%), two-thirds occurring in the right lobe with a median size of 6 cm, making them available for PNA or PCD. PCD is superior to PNA and should always be considered in the management of PLA, both for securing the microbiological etiology and for therapeutical drainage [30]. Two previous studies have associated treatment with percutaneous drainage to a decreased mortality rate [4, 18], an association we did not find. Even though PNA or PCD is preferred in the management of PLA, open or laparoscopic surgery should still be considered in selected cases, such as the presence of a fistula, or simultaneous gallbladder empyema [31]. In our study, the rate of fistulas from the abscess was 6%, but we could not associate this to an unfavorable outcome.

Compared to other pathogens, enterococcal etiology could indicate an unfavorable outcome in our study, with a high rate of *Enterococcus* spp in patients who died within 90 days and who experienced a relapse. This is in accordance with a study from France, where enterococcal etiology was associated with death but not recurrence [32]. We were not able to establish the number of patients who received appropriate empiric therapy for their PLA. Since polymicrobial cultures were associated with an unfavorable outcome, it is important to consult physicians in infection medicine at an early stage in the disease to individualize antibiotic treatment. Previously, streptococcal etiology has been associated with PLA recurrence, but not death [18].

Strengths of this study include the population-based study design, a decade of observation, and a relatively large population size. However, the study is limited by its retrospective design and several risk factors that may be important in the prognosis of PLA; for example, levels of albumin and bilirubin were not registered in most of the cases.

Identifying different clinical variables associated with an unfavorable outcome may improve the management and treatment of patients with PLA and thus prevent the risk of death and subsequent PLA.

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the

authors, so questions or comments should be addressed to the corresponding author.

Notes

Author contributions. O. L. and A. J. initiated the study design. A. B. and A. J. performed the statistical analyses. A. J. and E. S. extracted data from medical records. A. B. and O. L. drafted the manuscript. O. L., A. B., T. S., and A. K. performed data analysis and visualization. O. L. supervised the study. All authors approved the final version of the manuscript.

Patient consent. The study was granted ethical approval by the Swedish Ethical Review Authority (reference number 202006526). Obtaining individual patient consent was not needed due to the retrospective nature of the study.

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Potential conflicts of interest. All authors: No reported conflicts.

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