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Treatment of bronchobiliary fistula: a 13-year experience

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Abstract

Background Bronchobiliary fistula (BBF) is a rare but fatal disease. Due to its rarity, only a limited number of cases have been reported, leading to a lack of consensus on appropriate treatment strategies.

Methods We conducted a retrospective analysis of clinical data of 17 patients diagnosed with BBF between January 1, 2012, and May 30, 2025, focusing on the the presenting symptoms, diagnostic approaches, treatment modalities, and outcomes.

Results All 17 patients had cough and pathognomonic biliptysis. Sputum analysis confirmed bile components in all samples from 3 patients, and fiber bronchoscopy revealed yellow-green bilious sputum in 6 patients. Computed tomography (CT) or magnetic resonance imaging (MRI) demonstrated communication between the bile duct and the bronchial tree in 9 patients. Cholangiography showed contrast medium passing through a fistulous tract into the bronchi in 10 patients. Surgical intervention was performed in 6 patients, 3 of whom achieved long-term survival (> 24 months). Minimally invasive interventions provided effective symptomatic palliation in 10 of 11 patients. Among these 10 patients, 3 achieved long-term survival (> 24 months), with an additional 3 remaining alive and under ongoing follow-up (though not yet reaching the 24-month threshold). Of the 8 fatalities, 2 were directly attributed to uncontrolled BBF and its complications (sepsis or hepatic failure). The remaining deaths resulted from progressive malignancy ($n = 3$), postoperative complications (pneumothorax/respiratory failure, $n = 1$; hemorrhagic shock/disseminated intravascular coagulation, $n = 1$), and post-transplant septic shock ($n = 1$).

Conclusions BBF is associated with poor prognosis. Minimally invasive therapies offer effective palliation in malignant cases, whereas surgical intervention may provide curative potential in selected benign cases. Individualized, multidisciplinary management is essential for optimizing outcomes.

Keywords Bronchobiliary fistulas (BBF), Diagnosis, Surgery, Minimally invasive treatment, Prognosis

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Introduction

Bronchobiliary fistula (BBF) is an abnormal channel between the bronchial tree and the biliary system [1]. This rare clinical disease can be classified as either congenital or acquired. The etiologies of acquired BBF are diverse, including liver hydatid [2], thoracic and abdominal trauma [3], liver malignancies [4], complications following transcatheter arterial chemoembolization(TACE) or liver radiofrequency ablation [5, 6] as well as biliary obstruction [7, 8].

BBF classically manifests as refractory cough with bilioptysis, recurrent pulmonary infections, jaundice, and chest/abdominal pain [9]. Critically, delayed recognition may progress to life-threatening sepsis or respiratory failure [10, 11]. Given symptom overlap with pulmonary conditions and frequent misdiagnosis, BBF should be considered in patients with recurrent cough and bitter-tasting sputum, particularly those with hepatobiliary history [12]. While morphologic differentiation from infectious sputum is challenging, bile component analysis via sputum bilirubin testing offers specificity. Furthermore, fiberoptic bronchoscopy offers direct visualization of both bilious secretions and fistula tracts [11], with recent evidence supporting bronchoalveolar lavage bilirubin crystals as diagnostic markers [13]. Imaging examinations such as computed tomography (CT), magnetic resonance imaging (MRI), magnetic resonance cholangiopancreatography (MRCP) and cholangiography also play key roles in evaluating the location and extent of BBF, thus helping assess the disease severity and patient prognosis [14–16].

Historically, BBF has been managed surgically, often involving drainage of subphrenic abscesses and, when necessary, resection of the fistula tract, affected lung tissue, and the primary lesion [17]. Recently, minimally invasive and endoscopic techniques have broadened treatment options for BBF. For example, endoscopic sphincterotomy and placement of biliary stent has been reported to be an effective treatment method that can relieve biliary obstruction and promote fistula closure [15, 18, 19]. In addition, nasobiliary drainage and percutaneous transhepatic cholangial drainage (PTCD) are used for biliary drainage in patients with poor general conditions and complex conditions [18]. Other conservative methods, such as abscess drainage, can also enhance the healing of BBF lesions [12]. Recent years, some studies have shown that bronchial occlusion devices such as glue and coils can effectively eliminate the sinus tract [15, 20–22].

Despite these advancements, a consensus on the management of BBF remains elusive, and no definitive treatment exists for those complex cases. This study aims to review the characteristics and treatment experiences of 17 patients with BBF in our center from 2012 to 2025, providing insights and guidance for the management of this challenging disease.

Materials and methods

Study population and design

We retrospectively reviewed the medical records of all patients with suspected or confirmed BBF at our institution between January 1, 2012, and May 30, 2025. During this period, 19 patients were initially identified based on keywords related to BBF, bilioptysis, or relevant imaging findings. After thorough evaluation, 17 patients who met the predefined diagnostic criteria were included in the final analysis; two patients were excluded due to insufficient confirmatory evidence. Based on the underlying liver pathology, patients were categorized into benign ($n = 4$) and malignant ($n = 13$) etiology groups.

Diagnostic criteria

Based on the literature [11, 13], the diagnosis of BBF was established if at least one of the following criteria was fulfilled: (1) direct visualization of bilious secretion during bronchoscopy; (2) cholangiographic demonstration of contrast material passing from the biliary tree into the bronchial tree; (3) biochemical detection of bilirubin in sputum or bronchoalveolar lavage fluid.

Imaging modalities and diagnostic pathway

The diagnostic workup for suspected BBF followed a structured, stepwise approach aimed at progressing from initial suspicion to definitive confirmation. The evaluation began with chest and abdominal computed tomography (CT), which served as the primary imaging modality. CT was instrumental in identifying characteristic sequelae of BBF, including pulmonary consolidation, pleural effusion, hepatic or subphrenic abscesses, and biliary duct dilation. Critically, CT frequently provided the first radiological evidence of a fistulous tract, thereby guiding subsequent diagnostic steps [13].

In cases where CT findings were suggestive or required anatomical clarification, magnetic resonance imaging with MR cholangiopancreatography (MRI/MRCP) was utilized. This modality provided unparalleled, non-invasive visualization of the biliary tree, enabling precise mapping of the abnormal communication between the biliary and bronchial systems. The high soft-tissue contrast of MRI/MRCP was critical in confirming the presence of the fistula and delineating its anatomical course, thereby offering an essential roadmap for therapeutic planning [23].

The diagnostic pathway culminated in direct cholangiography via endoscopic retrograde cholangiopancreatography (ERCP) or percutaneous transhepatic cholangiography (PTC), which served as the definitive diagnostic standard. Visualization of contrast medium

passing directly from the biliary system into the bronchial tree provided incontrovertible evidence of the biliary-bronchial fistula (BBF). Beyond its primary diagnostic role, this procedure concurrently enabled immediate therapeutic intervention through biliary decompression via stenting or drainage, establishing it as a cornerstone in both diagnosis and initial management [24].

Therapeutic management

The treatment strategy for BBF was determined through multidisciplinary team discussion, with selection between surgical intervention and minimally invasive biliary drainage based on the patient's overall clinical status and fistula characteristics. Antimicrobial therapy was initiated empirically upon diagnosis and subsequently tailored according to culture and sensitivity results. Antibiotics were typically continued until resolution of clinical symptoms and normalization of inflammatory markers, often supported by radiological evidence of infection control.

Outcome evaluation

Treatment success was defined as resolution of cardinal symptoms of BBF—biliptysis and productive cough—and fever, along with radiological improvement, including resolution or marked reduction of pneumonia or pleural effusion and shrinkage of associated abscesses.

Follow-up duration was calculated from the date of definitive BBF diagnosis to either the date of death or the last documented clinical follow-up for surviving patients. Overall survival (OS) was defined as the time interval from the date of definitive BBF diagnosis to the date of death from any cause or the last follow-up.

Statistical analysis

Statistical analyses were performed using SPSS 25.0 (IBM SPSS Inc., Chicago, IL, USA) and R 4.0.3 software (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables are presented as median (interquartile range), and categorical variables as number (percentage). OS was estimated using the Kaplan-Meier method, and comparisons between benign and malignant subgroups were conducted using the log-rank test. Confidence intervals are reported at the 95% level.

Ethical approval

This study was approved by the Institutional Review Board of The First Affiliated Hospital of Sun Yat-sen University (Approval No.: [2023]554). Informed consent was waived due to the retrospective nature of the study.

Results

Patient characteristics

The final cohort included 13 male and 4 female patients, with a median age of 53.5 years. All patients had a history of prior treatment for underlying liver diseases. Four patients were divided into the benign group and 13 into the malignant group. Etiologies included intrahepatic and extrahepatic bile duct stones ($n=4$), hilar cholangiocarcinoma ($n=1$), intrahepatic cholangiocarcinoma (ICC, $n=1$), and hepatocellular carcinoma (HCC, $n=11$). All primary diagnoses were confirmed by postoperative pathological examination. Prior treatments for primary conditions included surgery ($n=14$), transcatheter arterial chemoembolization (TACE, $n=8$), radiofrequency ablation ($n=6$), and radiotherapy ($n=1$). Additional patient details are summarized in Tables 1 and 2.

Table 1 Baseline characteristics of BBF patients

Number	Sex	Age group	Primary disease	BBF Etiology	Treatment of primary disease	Other symptom
1	M	≤40	Bile duct stones	Benign	Surgery	No
2	F	41–50	Bile duct stones	Benign	Surgery	No
3	M	≤40	Bile duct stones	Benign	Surgery	Vomit
4	M	51–60	Bile duct stones	Benign	Surgery	Vomit
5	M	≥71	HCC	Malignant	TACE/Radiofrequency ablation	No
6	M	61–70	HCC	Malignant	Surgery/TACE	No
7	F	51–60	Hilar cholangiocarcinoma	Malignant	Surgery	Chest distress
8	M	61–70	HCC	Malignant	Radiofrequency ablation	No
9	M	41–50	HCC	Malignant	Surgery/Radiofrequency ablation	No
10	M	61–70	ICC	Malignant	Surgery	No
11	M	≤40	HCC	Malignant	Surgery/TACE/Radiofrequency ablation /Anhydrous alcohol ablation	Chest pain
12	M	51–60	HCC	Malignant	TACE/Radiofrequency ablation	Chest distress
13	M	51–60	HCC	Malignant	Surgery/TACE	No
14	M	51–60	HCC	Malignant	Surgery/TACE/Radiotherapy	Gastrointestinal bleeding
15	F	51–60	HCC	Malignant	Surgery/TACE	No
16	M	51–60	HCC	Malignant	Surgery/TACE/Radiofrequency ablation	Vomit
17	F	51–60	HCC	Malignant	Surgery	No

Table 2 Treatment modalities and outcomes of BBF patients

Number	Treatment	State	Overall survival	Cause of death
1	Surgery	Alive	13 years	
2	Surgery	Alive	2 years	
3	Surgery	Alive	3 years	
4	Surgery	Dead	2 years	BBF, liver failure, acute obstructive suppurative cholangitis and hepatorenal syndrome
5	Surgery	Dead	1 week	pulmonary infection, pneumothorax, respiratory failure
6	Surgery	Dead	2 week	DIC, hemorrhagic shock, septic shock
7	Replace the PTCD tube	Dead	4 months	BBF, pneumonia and liver failure
8	Abscess catheter drainage PTCD	Dead	2 years	HCC
9	Abscess catheter drainage ERCP+Placement of bile duct stent	Alive	4 years	
10	PTCD	Dead	1 year	ICC
11	Replace the PTCD tube	Alive	2 years	
12	ERCP+Placement of the nasobiliary duct Abscess catheter drainage	Alive	2 years	
13	PTCD	Dead	1 year	HCC
14	Placement of bile duct stent	Dead	6 months	Failure of liver transplantation, septic shock, MODS and gastrointestinal bleeding
15	Replace the PTCD tube	Alive	11 months	
16	ERCP+Placement of the nasobiliary duct PTCD	Alive	10 months	
17	Placement of bile duct stent	Alive	5 months	

Fig. 1 Characteristic bilious sputum from a patient with BBF. The specimen shows typical yellow-green coloration and mucinous consistency, which is pathognomonic for this condition

Time intervals from primary disease to BBF

We analyzed the timeline from management of the underlying liver disease to the development and treatment of BBF. The median interval from primary disease treatment to onset of BBF symptoms was 10 months (range: 0–64 months), while the median time from symptom onset to initiation of BBF treatment was 2 months (range: 0–6 months).

Symptoms and clinical presentation

All 17 patients (100%) presented with the pathognomonic triad of cough, bilioptysis, and recurrent fever. Right upper quadrant abdominal pain was reported in 10 patients (58.8%), and jaundice was observed in 4 (23.5%). Associated complications included liver abscesses in 8 patients (47.1%), subphrenic abscesses in 8 (47.1%), pleural effusion in 13 (76.5%), and ascites in 13 (76.5%). Imaging confirmed bile duct dilation in 16 patients (94.1%) and bile leakage in 12 (70.6%).

Sputum analysis was performed in 3 patients (17.6%) and detected bile components in all samples. Figure 1 shows the characteristic yellow, mucinous sputum with a bilious odor observed in patients with BBF. Imaging findings were consistent with BBF in 9 patients (52.9%), with representative images shown in Fig. 2. Bronchoscopy, performed in 6 patients (35.3%), confirmed the diagnosis of BBF (Fig. 3). Cholangiography was conducted in 14 patients (82.4%), revealing evidence of BBF in 10 (58.8%) (Fig. 4).

Sputum culture was performed in 10 patients (58.8%), of whom 7 (70%) were found to have bacterial infection and 1 (10%) was found to have fungal infection. The most commonly identified bacteria were Escherichia coli ($n=4$), Acinetobacter baumannii ($n=3$), and Klebsiella pneumoniae ($n=1$). Fungal infections involved Candida species. Culture of drainage fluid was performed in 11 patients (64.7%), of which 6 (54.5%) were found to have

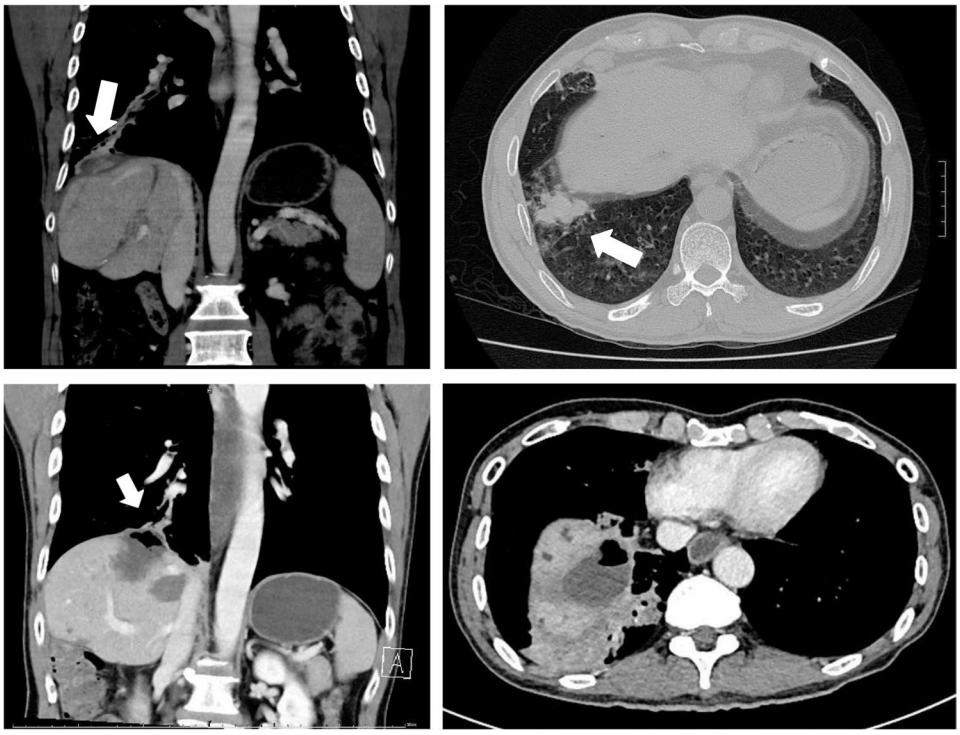

Fig. 2 Contrast-enhanced CT demonstrating BBF. The white arrow indicates the fistulous tract connecting the hepatic duct to the right lower lobe bronchus

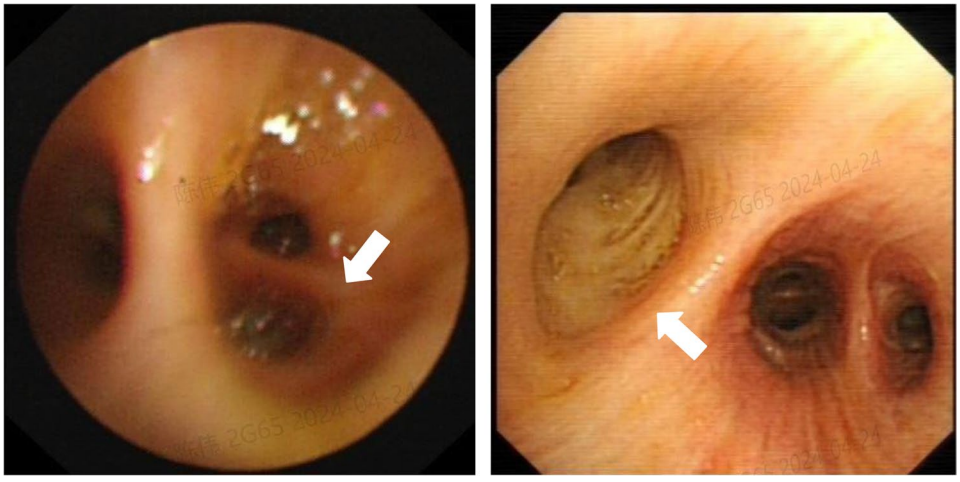

Fig. 3 Bronchoscopic view of the right lower lobe bronchus in a BBF patient. Yellowish-green bilious secretion is seen emanating from the bronchial orifice (arrow), confirming the diagnosis

bacterial infection and 2 (18.2%) were found to have fungal infection.

Treatment and outcome

The median follow-up duration for the entire cohort was 36 months (range: 5 months to 13 years). The decision between surgical and minimally invasive treatment was made via multidisciplinary team discussion, based on the patient's overall condition, etiology and anatomical complexity of the fistula, and the presence of resectable underlying disease. Surgery was primarily considered for patients with benign etiologies (e.g., bile duct stones) and adequate physiological reserve when curative resection was feasible. Minimally invasive approaches were preferred for patients with advanced malignancy, high surgical risk, or as a bridge to stabilize clinical status. Six patients underwent surgery. Patient 1 underwent fistula resection, diaphragmatic repair, right hepatic abscess excision, and placement of subphrenic drainage, resulting in resolution of symptoms and uneventful discharge.

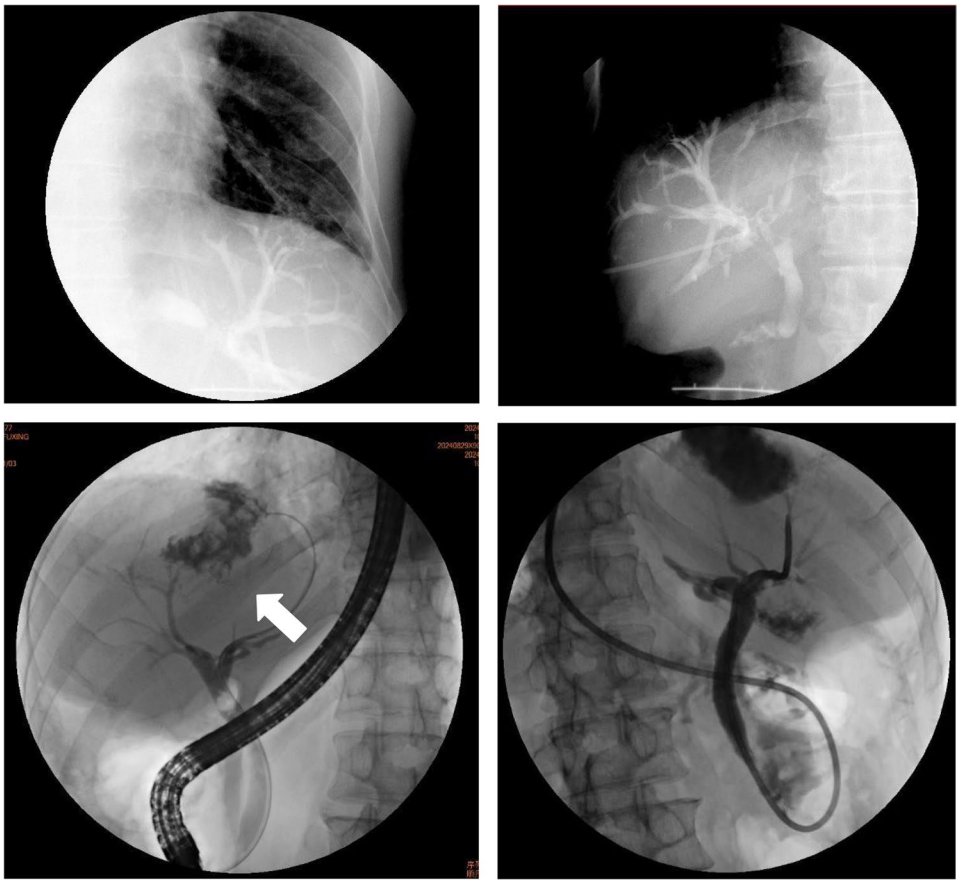

Fig. 4 ERCP in a BBF patient. The contrast medium is observed to extravasate from the hepatic duct and enter the bronchial tree (arrow), establishing the diagnosis

Patient 2 underwent resection of segments VII/VIII, choledocholithotomy, and T-tube drainage, with postoperative symptom relief. Patient 3 received percutaneous transhepatic cholangial drainage (PTCD) one month prior to surgery to improve liver function, followed by choledocholithotomy and Roux-en-Y choledochojejunostomy, achieving effective symptom control. All three patients showed resolution of thoracic and abdominal infections on 1-year follow-up CT scans and maintained long-term symptom remission with survival exceeding 24 months.

Patient 4 underwent two fistula resections within four years. The initial procedure, consisting of choledocholithotomy and fistula resection, failed to alleviate symptoms (cough, bilioptysis, and fever), necessitating reoperation with right posterior sectionectomy, fistula closure, and common bile duct exploration with stone extraction. Two years postoperatively, the patient was readmitted for liver abscess, which progressed to septic shock and pleural effusion, ultimately resulting in death due to acute obstructive suppurative cholangitis and hepatorenal syndrome. Patient 5 underwent right hemihepatectomy and choledochobronchial fistulectomy. However, the patient developed massive pneumothorax and respiratory failure postoperatively, leading to death from respiratory failure two weeks after surgery. Patient 6 underwent partial hepatectomy, partial diaphragm resection, and repair. Postoperatively, biliary leakage, septic shock, and hemothorax occurred, and the patient died two weeks later from disseminated intravascular coagulation (DIC), hypovolemic shock, and septic shock.

Eleven patients received biliary decompression as the primary treatment for BBF. When abscess formation was present, interventional drainage was performed. Among these patients, PTCD was used for biliary drainage in seven, nasobiliary drainage in two, and bile duct stent placement in three. All patients experienced immediate resolution of cough and fever following initiation of drainage and antimicrobial therapy. Post-drainage imaging demonstrated improvement in hepatic and pulmonary findings in nine patients. However, one patient died four months after PTCD tube replacement due to uncontrolled lung infection and liver failure, one patient died six months after stent placement from post-transplant septic shock complicated by gastrointestinal hemorrhage,

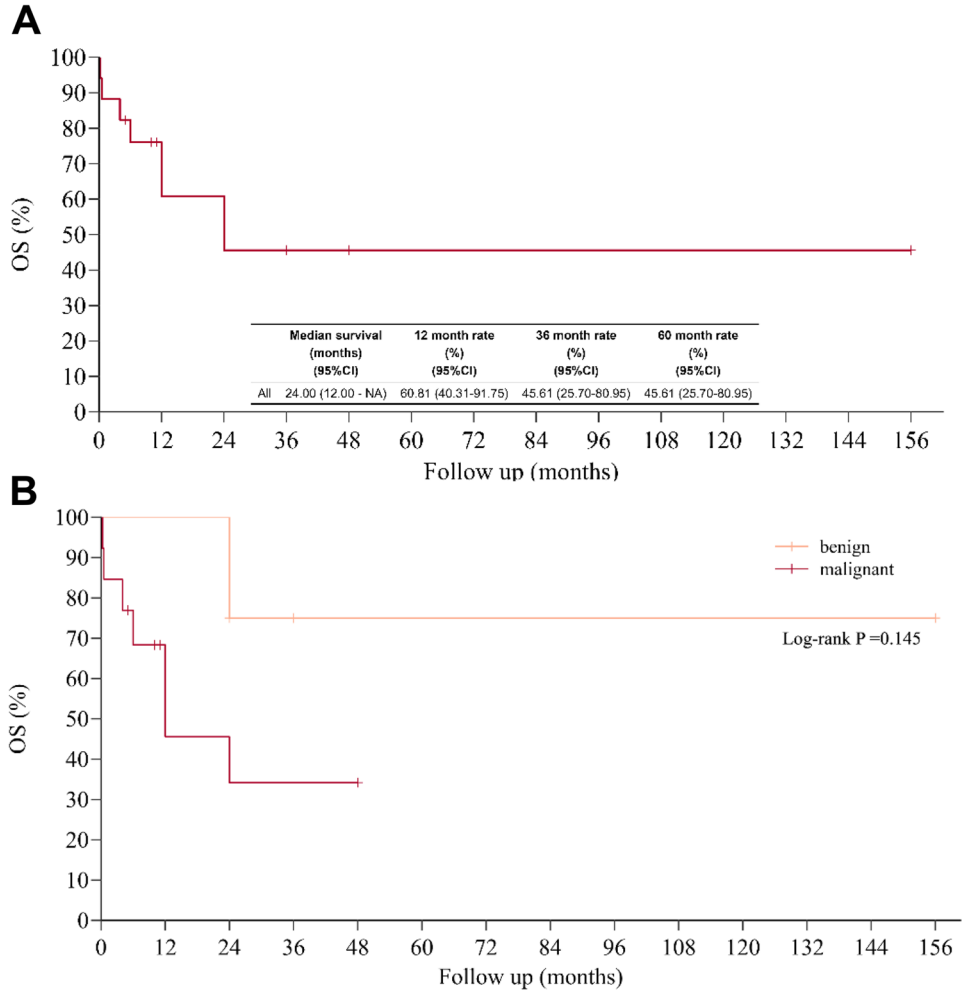

Fig. 5 Kaplan-Meier overall survival curves. **A** OS for the entire cohort of 17 patients with BBF. **B** Comparison of OS between patients with benign (*n*=4) and malignant (*n*=13) etiologies

and three patients died due to progression of their primary malignancy.

Survival analysis

The median OS for the entire cohort was 24.0 months (95% CI: 12.0 to not reached). The actuarial survival rates at 12, 36, and 60 months were 60.8% (95% CI: 40.31–91.75), 45.6% (95% CI: 25.7–81.0), and 45.6% (95% CI: 25.7–81.0), respectively (Fig. 5A). In the benign subgroup ($n=4$), prognosis was excellent, with median survival not reached (95% CI: 24.0 to not reached); survival rates were 100% at 12 months and 75.0% at both 36 and 60 months. In contrast, the malignant subgroup ($n=13$) had a median survival of 12.0 months (95% CI: 6.0 to not reached), with survival rates of 45.6% at 12 months and 34.2% at 36 months. The 60-month survival rate in the malignant subgroup was not estimable due to insufficient numbers at risk at this time point ($P>0.05$) (Fig. 5B).

Discussion

BBF is a complex clinical condition resulting from pathological communication between the biliary and bronchial systems. Analysis of our cohort, combined with existing literature, confirms the triad of pathogenic factors underlying BBF development: accumulation of intra-abdominal necrotic material, pre-existing diaphragmatic injury, and persistent biliary obstruction [5, 7, 11, 18, 24]. The interaction of these factors facilitates translocation of bile or infected material into the thoracic cavity, promoting fistula tract formation and explaining the strong association of BBF with hepatic malignancies and its generally poor prognosis [18, 25].

Our cohort highlights a critical distinction in outcomes based on etiology. Patients with benign BBF who underwent surgical intervention achieved 75% long-term survival, confirming the curative potential of surgery in anatomically suitable cases. In contrast, malignant BBF was associated with a markedly poorer prognosis, with 34.2% survival at 36 months, and both surgically treated

patients in this subgroup died in the postoperative period, underscoring the prohibitive risk of major resection in physiologically compromised individuals. This pronounced disparity firmly establishes disease etiology as the cornerstone of therapeutic decision-making.

These findings support a stratified treatment approach. For patients with malignant BBF or significant comorbidities, minimally invasive biliary drainage—via PTCD, stenting, or nasobiliary drainage—should be considered as first-line therapy. This strategy enables rapid symptom control and reduces infection through biliary decompression and, when possible, fistula occlusion [15, 22]. The primary technical goal is to divert bile flow away from the fistulous tract, thereby minimizing bronchobiliary contamination and facilitating spontaneous closure. Endoscopic sphincterotomy or stenting is particularly effective in reducing the choledochoduodenal pressure gradient [26, 27], although it is important to recognize that prolonged external drainage may lead to electrolyte imbalances and an increased risk of ascending cholangitis [28, 29].

Surgery remains the mainstay of management for patients with benign, complex fistulas who are physiologically fit for intervention. A detailed review of our six surgical cases reveals that all long-term survivors had benign disease, whereas postoperative mortality occurred either in patients with hepatocellular carcinoma or in a benign case complicated by recurrent sepsis and hepatic failure. This contrast emphasizes that surgical success depends not only on technical precision but also critically on appropriate patient selection—surgical intervention should be reserved for those with benign, resectable pathology and sufficient physiological reserve. These procedures are inherently complex, often necessitating concurrent management of hepatic abscesses, biliary obstruction, diaphragmatic defects, and affected lung tissue, which contributes to the high perioperative mortality reported in the literature and observed in our cohort [17].

In comparison with previous studies, our overall mortality rate of 47.1% is consistent with the severe prognosis associated with BBF, albeit at the higher end of published ranges, likely reflecting the high proportion (76.5%) of malignant cases in our series [11, 17]. The 50% postoperative mortality rate further highlights the substantial risks associated with surgery in this context [17]. In contrast, minimally invasive management achieved 100% immediate symptom resolution and 54.5% long-term survival, supporting its role as a safe and effective first-line option, particularly in high-risk patients [15, 18, 24]. The efficacy of this approach—even in a cohort predominantly composed of patients with advanced malignancy—emphasizes the essential role of palliative interventions in improving quality of life and, in some cases, prolonging survival.

The therapeutic landscape for BBF continues to evolve. Emerging techniques such as bronchoscopic glue or coil embolization and percutaneous gelatin sponge occlusion offer promising alternatives for refractory cases [3, 15, 20–22]. These interventions enable precise, minimally invasive closure of the fistula, aligning with the principles of precision medicine. Although bronchoscopic occlusion was not utilized in our cohort, this reflects institutional preferences favoring initial biliary source control and the complexity of decision-making in critically ill patients. In one representative case (Patient 15), bronchoscopic closure was recommended as a potential definitive intervention; however, the family declined due to concerns regarding procedural risks in the context of the patient's critical condition. Subsequent percutaneous biliary drainage was successfully performed. This case highlights that while bronchoscopic techniques represent valuable tools in the management armamentarium, their application may be influenced by patient and surrogate decision-maker preferences, particularly in individuals with severe comorbidities. Therefore, our institutional strategy prioritizes comprehensive management of the biliary source—considered the primary driver of fistula formation—while reserving bronchoscopic or percutaneous occlusion for instances where biliary decompression is insufficient or as adjunctive therapy. Our clinical experience supports this approach: among 11 patients who underwent minimally invasive biliary decompression, 10 achieved significant symptomatic improvement, with 3 demonstrating long-term survival. It is important to emphasize that minimally invasive modalities and surgical intervention are not mutually exclusive but rather complementary. For patients with adequate physiological reserve and resectable pathology, curative surgical resection remains a viable and essential option [5, 27].

Our study has several limitations. First, it is a single-center, retrospective analysis with a limited number of cases, although it represents the largest cohort reported to date in the existing literature. Second, our cohort primarily included patients with acquired BBF, with minimal experience in the management of congenital forms. Third, most BBFs in this series were secondary to hepatic malignancy, and patient outcomes were significantly influenced by cancer progression and the complexity of oncologic treatment. Multicenter prospective studies are warranted to strengthen methodological rigor and improve the generalizability of our findings.

Conclusion

In conclusion, BBF demands a stratified, multidisciplinary management approach. For most patients, particularly those with malignant or high-risk benign disease,

minimally invasive strategies should be considered as first-line interventions to achieve rapid symptom control and mitigate infection risk. This approach may serve as definitive therapy or as a bridge to further intervention. Conversely, surgical repair remains the cornerstone of curative treatment in physiologically fit patients with resectable benign disease or complex fistulas unresponsive to minimally invasive measures. Ultimately, treatment decisions must be individualized, integrating expertise from endoscopy, interventional radiology, and surgery to address the dual thoracic and biliary pathophysiology. Future efforts should focus on refining patient selection criteria and advancing targeted fistula closure technologies.

Abbreviations

BBF	Bronchobiliary fistulas
HCC	Hepatocellular carcinoma
TACE	Transcatheter arterial chemoembolization
ICC	Intrahepatic cholangiocarcinoma
CT	Computerized tomography
MRI	Magnetic resonance imaging
PTCD	Percutaneous transhepatic cholangial drainage
MRCP	Magnetic resonance cholangiopancreatography

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Authors' contributions
XY, YD and YZ prepared figures and tables and wrote the manuscript text. BC, YPH and SQL participated in data collection. SLS, JFL and ZHD participated in the design of the subject. All authors reviewed the manuscript.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The present study was carried out in accordance with the principles of the Declaration of Helsinki. This retrospective study was approved by the institutional review board of the First Affiliated Hospital of Sun Yat-sen University. Written informed consent was obtained from all patients prior to treatment.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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