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Technical review of a single-center experience of biliary recanalization for liver transplantation-related benign biliary stricture

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A R T I C L E I N F O

Keywords:
Liver transplantation
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A B S T R A C T

Purpose: To review a single-center experience of percutaneous biliary recanalization for liver transplantation-related benign biliary stricture, particularly focusing on the technical aspect
Method: Twenty-three recipients of liver transplantation (LT) with 27 benign biliary strictures underwent percutaneous recanalization using a step-by-step technique from June 2017 to March 2020. The step-by-step technique includes a hairy wire or an usual 0.035-inch wire passage, a coaxial system, supporting catheters of various shapes and wires, and an extraluminal passage. The success rate of percutaneous biliary recanalization, degree of stricture, interval between LT and biliary recanalization, procedure time, number of sessions, and recanalization techniques were analyzed.
Results: Among the 27 lesions, 26 (96 %) were successfully recanalized using a percutaneous approach without major complications. Of the 27 lesions, 8 were complete obstructions and 19 were partial obstructions. Consequently, the average interval between LT and biliary recanalization was 28.8 ± 42.7 months (range, 2–192 months). The average procedure time was 50 ± 65 min (range, 8–345 min). The average number of sessions was 1.4 ± 1 (range, 1–6). The case distribution for the used recanalization techniques was as follows: twelve cases utilized step 1, 10 utilized step 2, 4 utilized step 3, and only 1 case utilized step 4. The complete obstruction group required a more advanced technique and spent more recanalization time than the partial obstruction group.
Conclusions: The step-by-step percutaneous biliary recanalization technique had a high success rate without major complications. According to the patient's biliary anatomy appropriate selection of an angled 5-Fr support catheter and wire is essential in increasing the recanalization success rate.

1. Introduction

In orthotopic liver transplantation (LT), postoperative biliary strictures occur in 5%–37 % of patients and have a major impact on morbidity and survival [1]. Patients with biliary strictures often require prolonged hospital stay, which can lead to physical and economic issues over a long time. Therefore, the early and precise diagnosis and proper management of biliary strictures are mandatory [1].

For the treatment of biliary stricture following LT, endoscopic retrograde cholangiopancreatography (ERCP) with balloon dilatation and plastic stents is the first-line therapy. If biliary anatomy is unfavorable or inaccessible for ERCP, various techniques are used including

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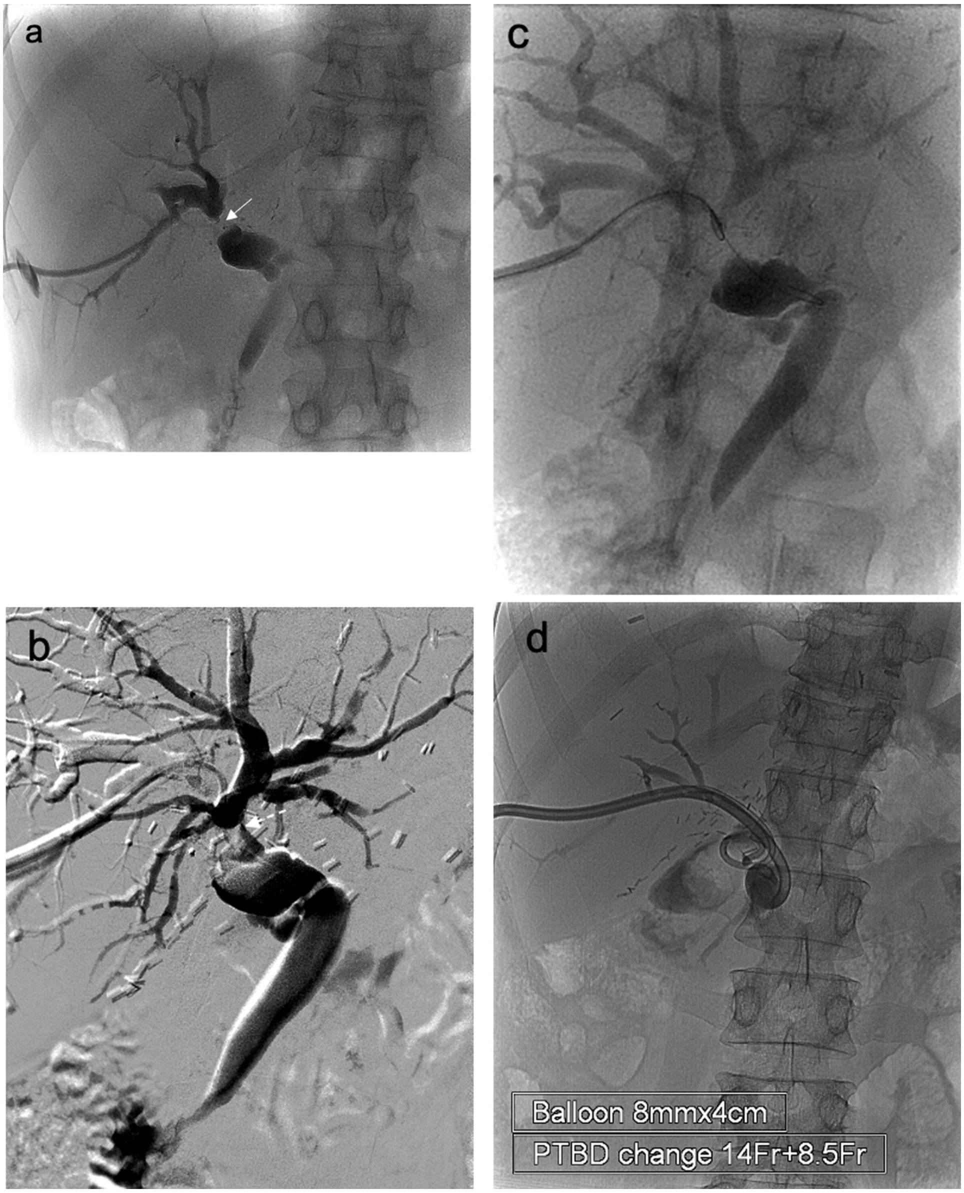

Fig. 1. (A) Cholangiography via a percutaneous transhepatic biliary drainage (PTBD) catheter in the posterior duct shows partial obstruction of biliary anastomosis (arrow). (B) Digital subtraction cholangiography with manual contrast medium injection shows detailed information of the opening point (dashed arrow) of partial obstruction. (C) Spot radiograph shows successful biliary recanalization using a coaxial catheter system (5-Fr catheter and microcatheter). (D) In the next session, for upsizing, a dual catheter (14 Fr + 8.5 Fr) was placed through the recanalized tract.

percutaneous transhepatic recanalization [2], magnetic compression anastomosis [3], yttrium aluminum garnet laser [4], and radiofrequency puncture wire [5]. However, the reported recanalization success rate (61.4 %–90.9 %) is unsatisfactory with various techniques [2,4–9]. Regardless of approach used (antegrade or retrograde), wire passage distal to the stricture is essential in biliary recanalization. From the ischemic damage of bile duct anastomosis during LT, tight fibrotic obstruction with altered normal anatomy decreases the recanalization rate despite various technical attempts. In this study, the authors reviewed a single-center experience of percutaneous biliary recanalization for LT-related benign biliary stricture, particularly focusing on the technical aspect.

2. Materials and methods

2.1. Study population and characteristics

This retrospective study was approved by the institutional review board, and the requirement for informed consent was waived owing to the retrospective nature of the study. Between June 2017 and March 2020, 23 recipients of LT with 27 benign biliary strictures, who presented with fever and jaundice; increased liver biochemical parameters including total bilirubin and alkaline phosphatase; and imaging findings of biliary obstruction, were referred to the authors' institution for percutaneous transhepatic recanalization of the strictures.

2.2. Percutaneous biliary recanalization technique

Under ultrasound or fluoroscopic guidance, a 22-G styletted needle was used to access the peripheral bile duct. A 0.018-inch guidewire (hairy wire) was then advanced through the needle into the biliary tree, and the needle was exchanged for a coaxial set that was advanced into

Table 1
Step-by-step biliary recanalization techniques.

Step	Techniques and instruments for recanalization
1	Hairy wire or 5-Fr KMP catheter and 0.035-inch angled hydrophilic wire
2	Coaxial system: 5-Fr KMP catheter, microcatheter, and micro-guidewire
3	Any other shaped 5-Fr catheters or support catheters and any other wire combinations
4	Extraluminal passage using trans-septal needle or stiff back end of wire

Table 2
Details of biliary recanalization procedures.

Patient number	Lesion number	Sex	Age	Liver transplantation	Biliary anastomosis	Interval (LT-biliary recanalization, months)	Target bile duct	Session number	Total procedure time (minute)	Degree of obstruction	Recanalization techniques used in each session
1	1	M	059Y	DDLT	Duct-to-duct	2	B6	6	345	Complete	Step 1 + 2 > Step 2 + 3 (micro-guidewire end tip) > Step 2 + 3 (Headhunter, Cobra, JIM, straight-tip wire) > Step 2 + 3 > Step 2 > Step 4 – trans-septal needle
1	2	M	059Y	DDLT	Duct-to-duct	3	B5	1	8	Partial	Step 1 - KMP + 0.035 regular wire)
2	3	M	061Y	LDLT	Hepaticojejunostomy	3	B6	1	23	Complete	Step 1 + 2 - Coaxial (KMP + microcatheter)
2	4	M	061Y	LDLT	Hepaticojejunostomy	5	B7	1	21	Complete	Step 1 + 2 - Coaxial (KMP + microcatheter)
3	5	M	053Y	LDLT	Duct-to-duct	18	B3	1	26	Partial	Step 1 - KMP + 0.035 regular wire
4	6	F	060Y	LDLT	Duct-to-duct	8	B3	1	6	Partial	Step 1 - KMP + 0.035 regular wire
5	7	M	051Y	LDLT	Duct-to-duct	33	B6	1	36	Partial	Step 1 > Step 2 - Coaxial (KMP + microcatheter)
6	8	F	047Y	LDLT	Duct-to-duct	46	B6	1	70	Partial	Step 1 + 2 - Coaxial (KMP + microcatheter)
7	9	F	058Y	LDLT	Duct-to-duct	31	B3	1	21	Partial	Step 1 - KMP + 0.035 regular wire
8	10	M	055Y	LDLT	Duct-to-duct	51	B5	1	56	Partial	Step 1 + 2 - Coaxial (KMP + microcatheter)
9	11	F	048Y	LDLT	Duct-to-duct	7	B5	1	42	Partial	Step 1 - KMP + 0.035 regular wire
10	12	F	065Y	LDLT	Duct-to-duct	13	B6	1	32	Partial	Step 1 + 2 - Coaxial (KMP + microcatheter)
11	13	F	066Y	LDLT	Duct-to-duct	11	B6	1	26	Partial	Step 1 - Hairy wire
12	14	M	048Y	LDLT	Duct-to-duct	9	B6	2	71	Partial	Step 1 + 2 > Step 3–0.035 stiff wire
12	15	M	048Y	LDLT	Duct-to-duct	17	B5	2	41	Partial	Step 1 > Step 2 - Coaxial (KMP + microcatheter)
13	16	M	055Y	LDLT	Duct-to-duct	15	B6	1	33	Partial	Step 1 - KMP + 0.035 regular wire
13	17*	M	055Y	LDLT	Duct-to-duct	15	B5	1	8	Complete	Step 1 + 2 - Coaxial (KMP + microcatheter)
14	18	M	057Y	LDLT	Duct-to-duct	38	B6	2	138	Partial	Step 1 + 2 + 3 (KMP, Cobra, GT wire, Meister wire, Transend wire, straight-tip wire) > Step 2 - Coaxial (KMP + microcatheter)
15	19	M	050Y	LDLT	Hepaticojejunostomy	45	B6	1	21	Complete	Step 1 + 2 - KMP + 0.035 regular wire
16	20	M	056Y	LDLT	Duct-to-duct	3	B3	2	53	Complete	Step 1 + 3 – KMP, Headhunter + 0.035 regular wire
17	21	F	037Y	LDLT	Duct-to-duct	12	B5	1	9	Partial	Step 1 - Hairy wire
18	22	M	063Y	LDLT	Duct-to-duct	148	B3	1	11	Partial	Step 1 - KMP + 0.035 regular wire
19	23	M	017M	DDLT	Hepaticojejunostomy	13	B6	2	97	Complete	Step 1 + 2 (V14 wire, Transend wire) > Step 3 (JIM + 0.035 regular wire)
20	24	M	050Y	LDLT	Duct-to-duct	3	B6	1	8	Partial	Step 1 - KMP + 0.035 regular wire
21	25	M	060Y	LDLT	Duct-to-duct	24	B3	1	25	Partial	Step 1 - KMP + 0.035 regular wire
22	26	M	068Y	LDLT	Hepaticojejunostomy	192	B5	1	43	Complete	Step 1 + 2 - Coaxial (KMP + microcatheter)
23	27	F	053Y	LDLT	Duct-to-duct	14	B6	2	78	Partial	Step 1 + 2 + 3 (KMP, Berenstein, GT wire, Transend wire) > Step 3 - Berenstein + 2.6-Fr support catheter

LDLT, living donor liver transplantation; DDLT, deceased donor liver transplantation; lesion 17*, failed recanalization case.

Table 3
Comparison of recanalization profile according to the degree of obstruction.

	Partial obstruction	Complete obstruction	*P* value
Lesion number	N = 19	N = 8	
Procedural time	39 ± 33	76 ± 112	0.38
Session number	1.2 ± 0.4	1.9 ± 1.7	0.282
Technical score	1.5 ± 0.7	2.4 ± 0.9	0.039

the biliary tree. Then, cholangiography was performed and determined the degrees of biliary stricture and anatomy. Based on the cholangiography findings, percutaneous biliary recanalization was attempted. To identify the anatomy and fine route of the biliary stricture, digital subtraction cholangiography is often performed (Fig. 1).

To recanalize the biliary obstruction, step-by-step percutaneous biliary recanalization techniques were used. First, a hairy wire was initially used. If traversing the biliary stricture using a hairy wire failed, then a 5-Fr angled catheter) and a 0.035-inch angled hydrophilic guidewire were used. Then, if the 0.035-inch angled hydrophilic wire failed, a coaxial catheter system was used. It contained a combination of micro-guidewires, microcatheters, and various angled 5-Fr catheters. To transmit the axial penetration load to the micro-guidewire tip, various angled 5-F supporting catheters were used based on the biliary anatomy and position of the anastomosis site. Finally, when intraluminal recanalization failed, as the last resort, extraluminal recanalization was attempted using a trans-septal needle. Higher step means difficulty in

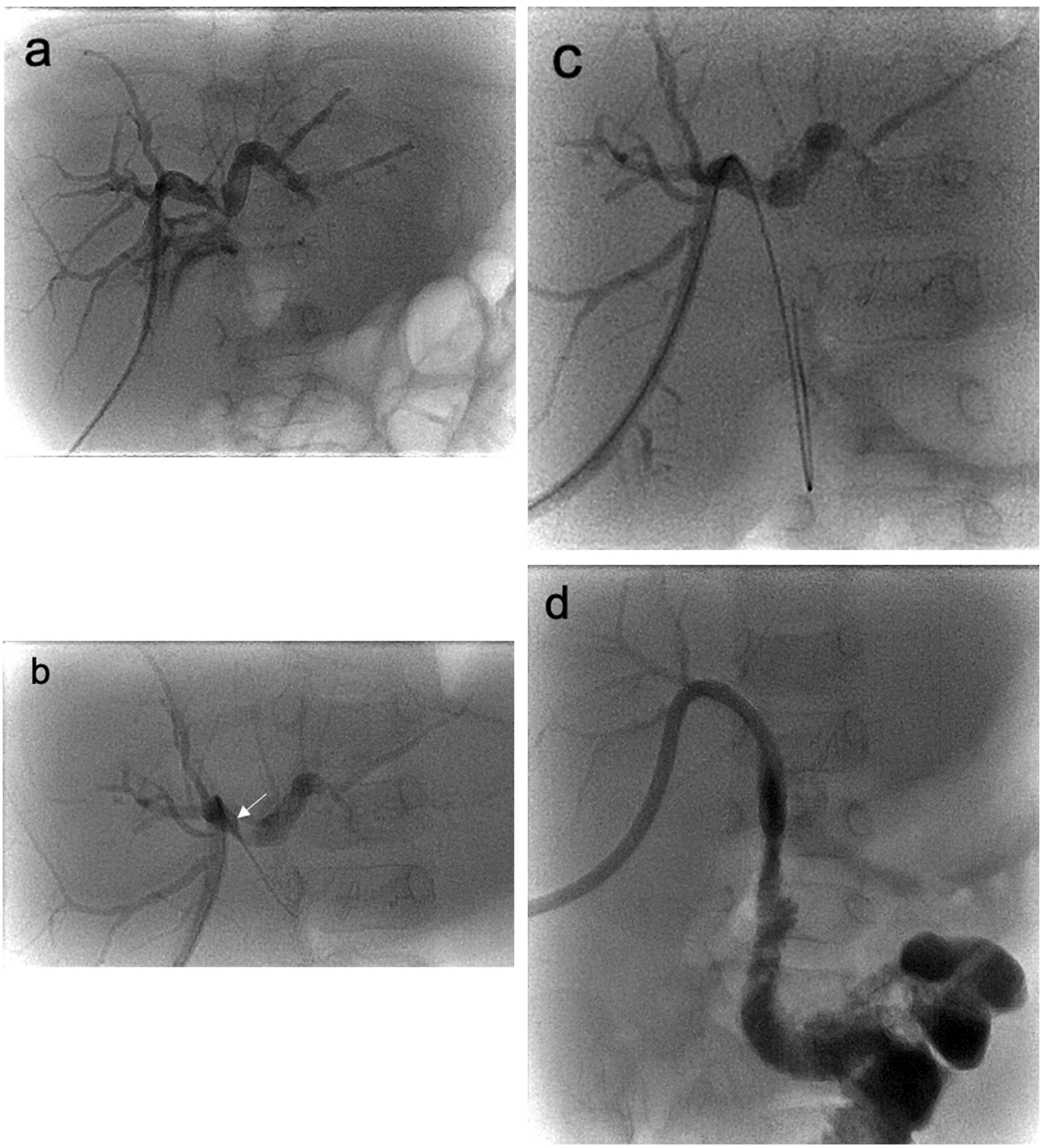

Fig. 2. A case of anastomotic stricture treated with the step 3 technique. (A) At the first session, percutaneous recanalization using a 5-Fr KMP catheter (Cook Medical, Bloomington, IN, USA) and a 0.035-inch angled hydrophilic guidewire (Terumo Corporation, Tokyo, Japan) failed. Cholangiography shows an acute angle between the right duct and hepaticojejunostomy anastomosis. (B) At the second session, wire traversing was successful using a JIM catheter (Cook Medical, Bloomington, IN, USA) (arrow) and 0.035-inch angled hydrophilic guidewire. (C, D) After wire advancing and serial dilatation, an internal–external percutaneous transhepatic biliary drainage (PTBD) catheter (10.2 Fr) was placed.

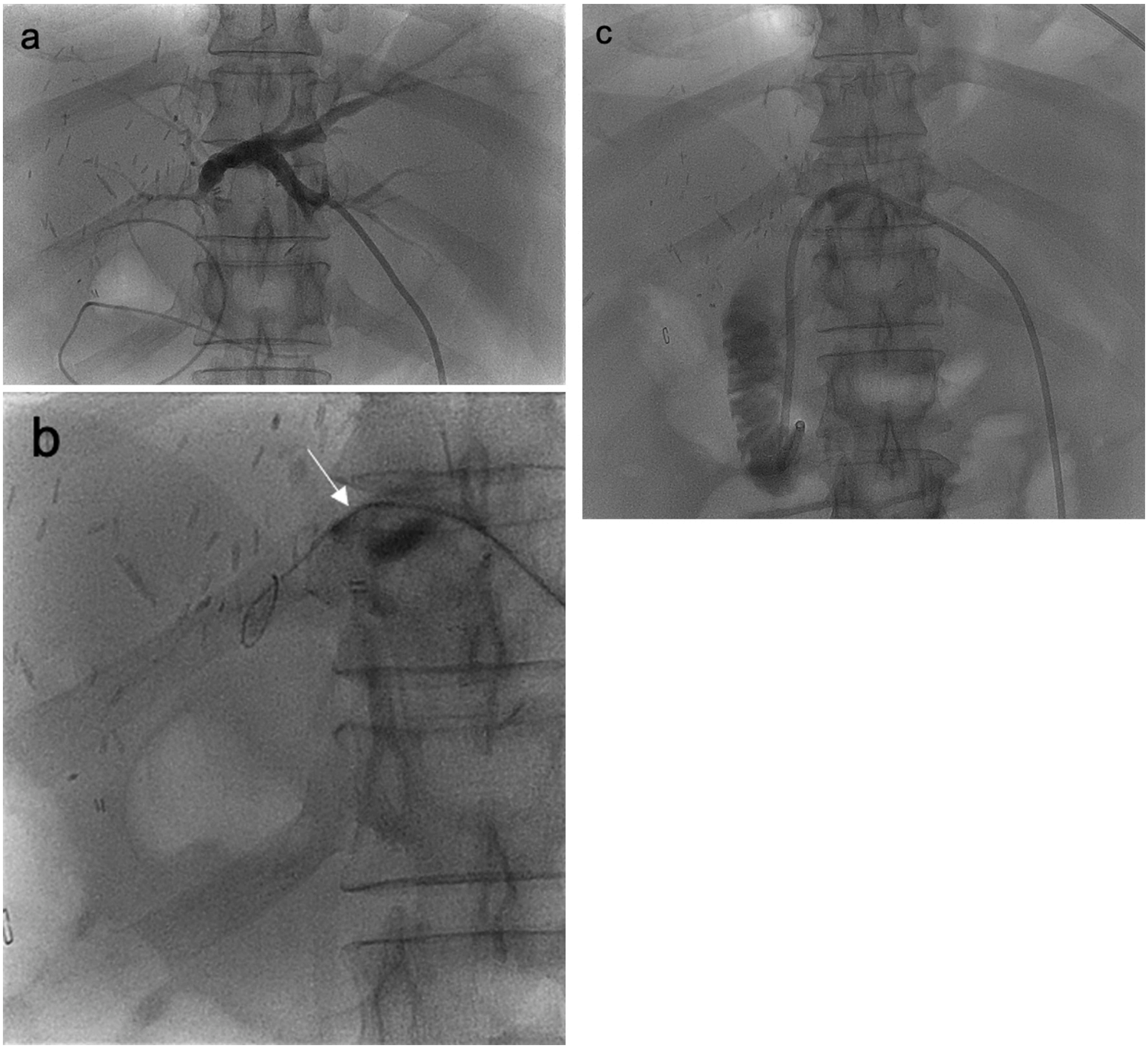

Fig. 3. A case of anastomotic stricture treated with the step 3 technique. (A) During the first session, percutaneous recanalization using a 5-Fr KMP catheter (Cook Medical, Bloomington, IN, USA) and 0.035-inch angled hydrophilic guidewire (Terumo Corporation, Tokyo, Japan) failed. Cholangiography via a percutaneous transhepatic biliary drainage (PTBD) catheter in the left duct shows that the route between the target B3 duct and anastomosis looks similar to a Headhunter catheter (Cook Medical, Bloomington, IN, USA). (B) During the second session, wire traversing was successful using a Headhunter catheter (arrow) and 0.035-inch angled hydrophilic guidewire (C) After wire advancing and serial dilatation, an internal–external PTBD catheter (10.2 Fr) was placed.

recanalization procedure than lower step and each step is summarized in Table 1.

2.3. Data collection and analysis

Retrospective data collection was performed using electronic medical charts and the picture archiving and communication system. The patients' demographic data, type of LT, and transplanted hepatic lobe and bile duct anastomosis methods were reviewed. When initial percutaneous cholangiography showed a contrast passage to the distal part of the stricture, we defined it as partial obstruction, and when there was no distal passage, we defined it as complete obstruction. In addition, procedural factors of biliary recanalization, which include the number of sessions, procedural time, used instruments, recanalization route (intraluminal or extraluminal passage), and recanalization technique, were reviewed. Consequently, the data were compared according to the degree of biliary anastomosis obstruction using *t*-test. Biliary recanalization steps were digitized and compared according to the degree of biliary obstruction, and procedure-related complications were analyzed. Data analysis was performed using Statistical Package for the Social Sciences, version 21.0 (IBM Corp., Chicago, Illinois, USA).

3. Results

3.1. Patient demographics and liver transplantation-related findings

The mean age of the patients was 52.9 ± 12.4 years (range, 2–66 years). The male–female ratio was 15:8. Of the 23 L T patients, 21 underwent living donor liver transplantation (LDLT), and 2 underwent deceased donor liver transplantation (DDLT). Twenty-two patients underwent LT at our hospital and one patient at another hospital. In the biliary anastomosis method, 4 were hepaticojejunostomies and 19 were duct-to-duct anastomoses. Of the 27 lesions, 8 were complete obstructions and 19 were partial obstructions. Consequently, the average interval between LT and biliary recanalization was 28.8 ± 42.7 months (range, 2–192 months). The patients' demographics and biliary recanalization techniques are summarized in Table 2.

3.2. Percutaneous biliary recanalization

All ultrasound- or fluoroscopy-guided percutaneous biliary accesses were successful. Among 27 lesions, 26 (96 %) were successfully recanalized using the percutaneous approach. Twenty-five of 26 lesions were

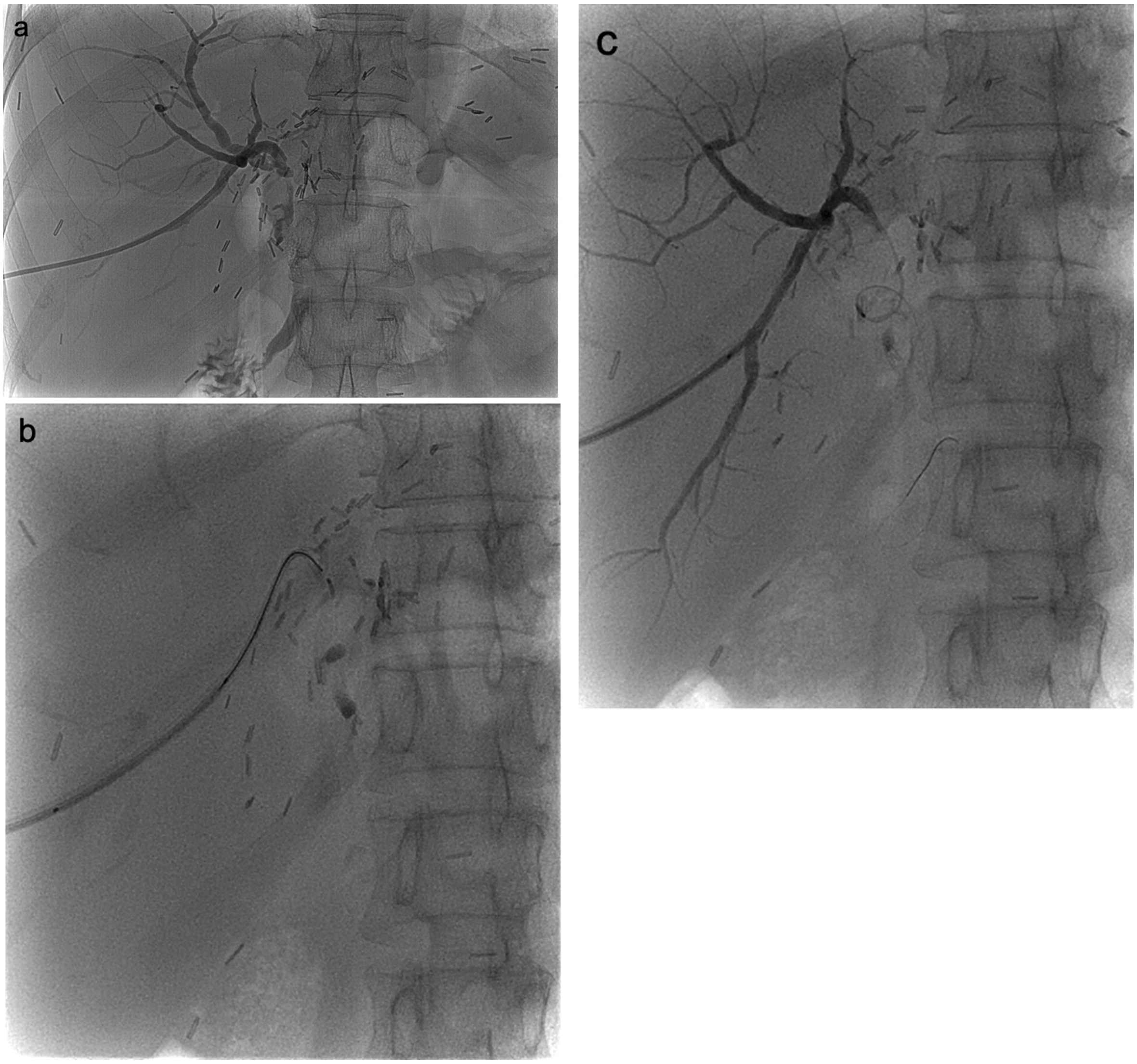

Fig. 4. A case of anastomotic stricture treated with the step 3 technique. (A) Cholangiography via a percutaneous transhepatic biliary drainage (PTBD) catheter in the posterior duct shows partial obstruction of the biliary anastomosis site. During the first session, percutaneous recanalization using a 5-Fr KMP catheter (Cook Medical, Bloomington, IN, USA) and 0.035-inch angled hydrophilic guidewire (Terumo Corporation, Tokyo, Japan). (B, C) Using a 5-Fr catheter, 2.6-Fr supporting catheter, and micro-guidewire, successful biliary recanalization was performed.

recanalized with intraluminal passage, and only one lesion was recanalized with a septal needle through the extraluminal course. The average procedure time was 50 ± 65 min (range, 8–345 min). The average number of sessions was 1.4 ± 1 (range, 1–6). No major complications related to the procedure were observed. Regarding the recanalization technique, 12 cases utilized step 1, 10 utilized step 2, 4 utilized step 3, and only 1 case utilized step 4. In step 3, we used various 5-Fr catheters according to each patient's characteristics, including Headhunter (Cook Medical, Bloomington, IN, USA), JIM (Cook Medical, Bloomington, IN, USA), and angled taper angiographic catheter (Radifocus Glidecath®; Terumo Corporation, Tokyo, Japan) and in one case, we used a 2.6-Fr CXI support catheter (Cook Medical, Bloomington, IN, USA), which is usually used in lower extremity interventions to have more supporting power.

3.3. Biliary recanalization according to the degree of biliary obstruction

Data were analyzed according to the degree of biliary obstruction. The mean overall procedure time was longer in the complete obstruction group (76 ± 112 min) than the partial obstruction group (39 ± 33 min) ($p = 0.38$). In addition, more sessions were required for recanalization in the complete obstruction group (1.9 ± 1.7 sessions) than the partial obstruction (1.2 ± 0.4 sessions) ($p = 0.282$). However, those parameters did not show statistical significance. Consequently, for the procedure difficulty, the technical score was higher in the complete obstruction group (2.4 ± 0.9) than the partial obstruction group (1.5 ± 0.7) ($p = 0.039$). Data are summarized in Table 3.

4. Discussion

LT is the most effective treatment in patients with end-stage liver diseases [10]. However, biliary anastomotic strictures following duct-to-duct biliary anastomoses or hepaticojejunostomies are the most common and serious complication, occurring in up to 30 % of patients [11]. Although various procedures have been reported to overcome benign biliary anastomotic strictures, the reported success rate is still 61.4 %–90.9 % [2,4–9]. Therefore, percutaneous biliary recanalization is important as a rescue treatment for patients after failure or contraindication of the retrograde endoscopic approach [2,7,12–15]. In this study, 96 % of the patients had successful recanalization of biliary

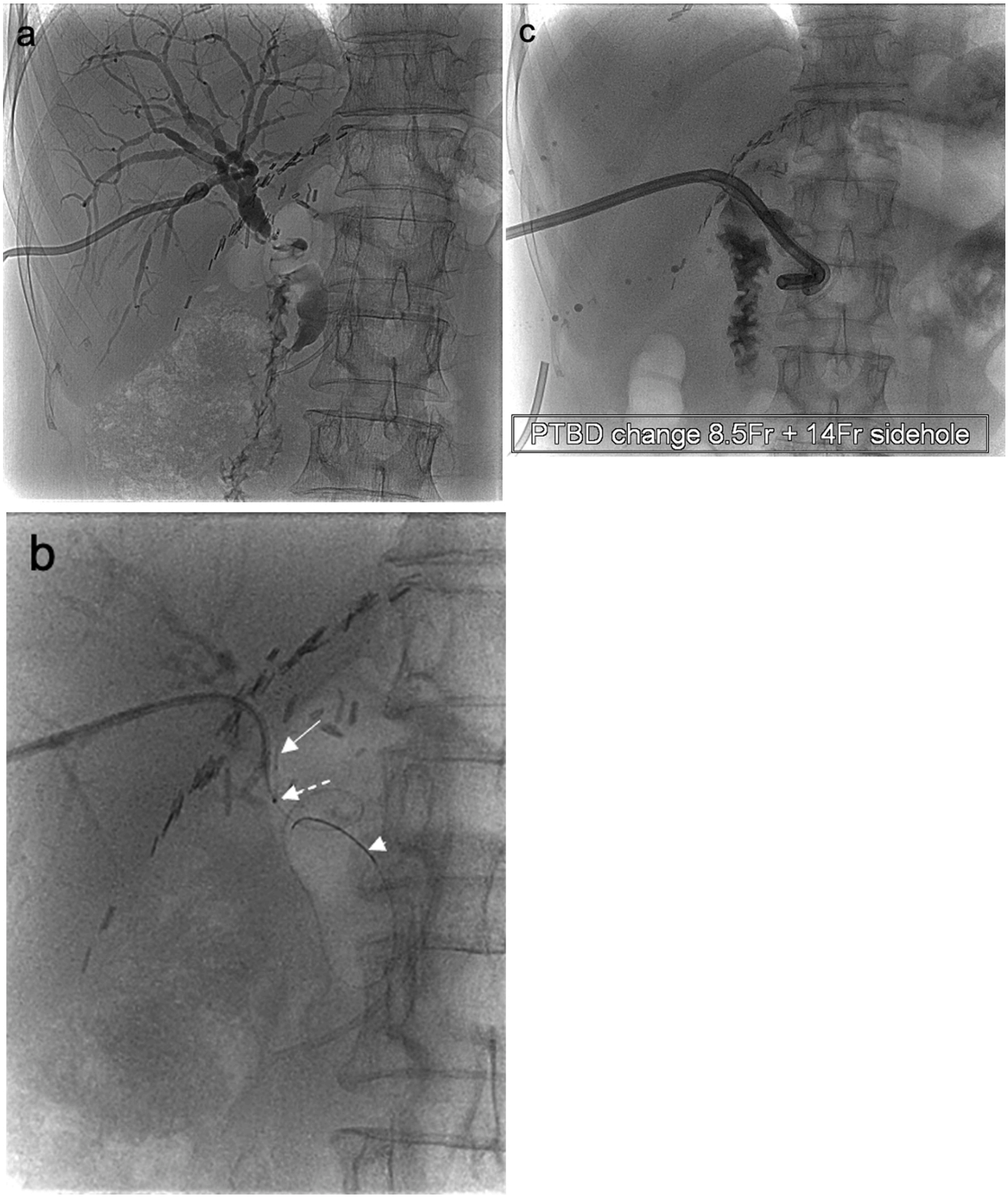

Fig. 5. A case of anastomotic stricture treated with the step 2 technique. (A) Cholangiography via a percutaneous transhepatic biliary drainage (PTBD) catheter in the posterior duct shows partial obstruction at the biliary anastomosis site. (B) In the first session, stricture was recanalized using a 5-Fr KMP catheter (Cook Medical, Bloomington, IN, USA) (arrow), microcatheter (dashed arrow), and micro-guidewire (arrowhead). (C) In the next session, for upsizing, a dual catheter (14 Fr + 8.5 Fr) was placed through the recanalized tract.

obstruction after LT using the step-by-step percutaneous biliary recanalization technique. The recanalization rate in this study is higher than that of other studies (61.4 %–90.9 %) [2,4–9]. Several tips on how to increase the success rate of recanalization of challenging biliary strictures exist.

Identifying the obstruction route is the first consideration in a biliary recanalization procedure. In case of partial obstruction, digital subtraction cholangiography with manual contrast injection into a 5-Fr catheter is useful in finding stenotic routes for recanalization. This technique provides a visualization of fine stenotic routes and identifies the exact opening point in dense soft tissue and fibrotic environments (Fig. 1).

Selecting an appropriate angled 5-F support catheter is important. After performing cholangiography or cone-beam CT cholangiography, according to the biliary anatomy and shape of the stricture, an appropriate angled 5-Fr catheter should be selected. The direction and shape of the tip and position of the 5-Fr catheter played an important role in supporting the overall system (Figs. 2 and 3). Additionally, to provide a more stable supporting force to the tip of the wire, a 2.6-Fr support catheter, which is usually used in peripheral vascular obstruction, could be considered (Fig. 4).

After gaining proper support with an appropriate 5-Fr catheter,

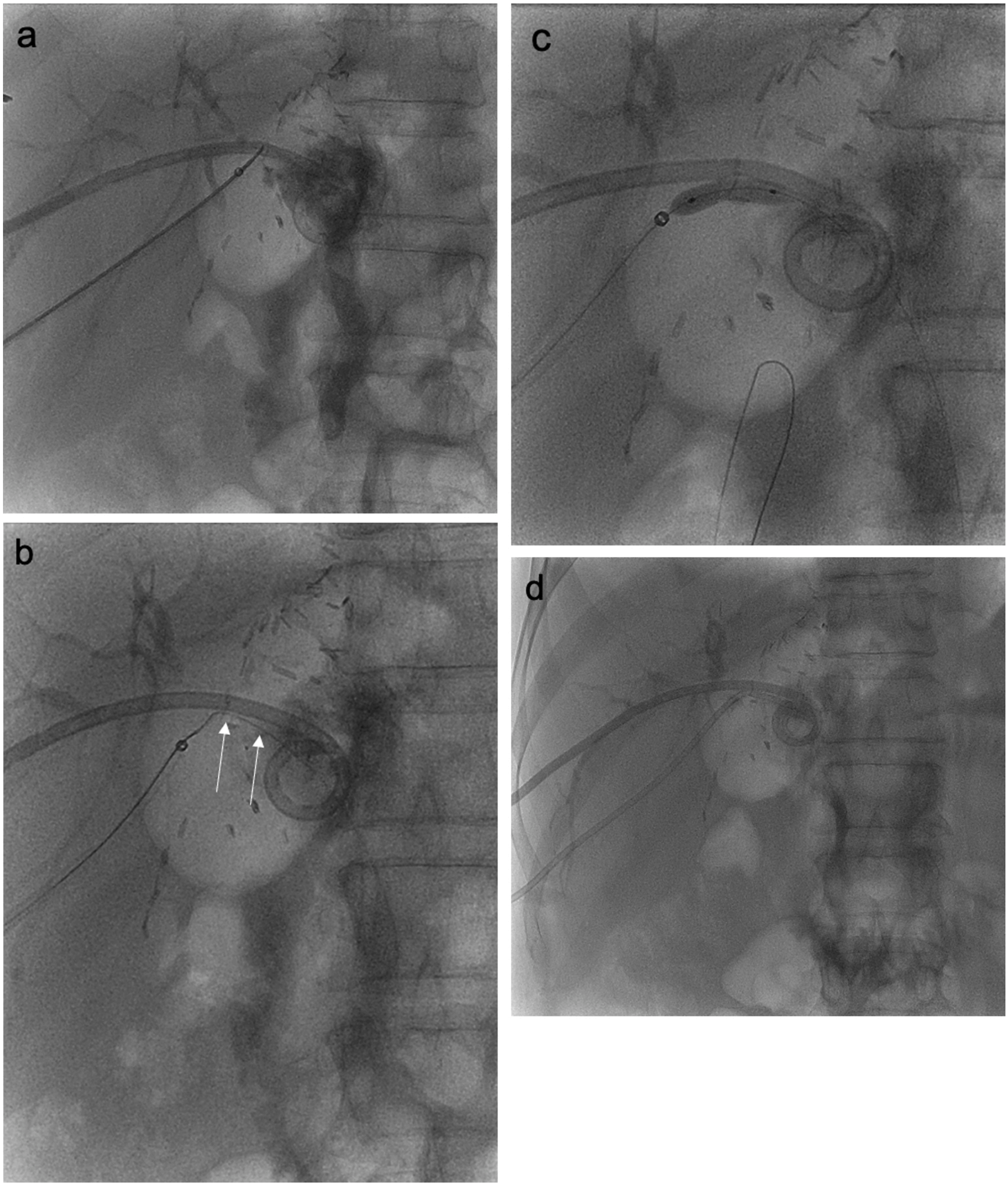

Fig. 6. A case of extraluminal biliary recanalization at the sixth session. (A) Spot radiography shows successful puncture from the posterior duct, targeting the percutaneous transhepatic biliary drainage (PTBD) catheter placed between the anterior and common bile ducts, using a Brockenbrough needle (Abbott Vascular, Abbott Park, Illinois, USA) and 6-Fr Ansel guiding sheath (Cook Medical, Bloomington, IN, USA). (B) After successful puncture, the wire is advanced into the same lumen of the PTBD catheter (arrows), which was inserted through the anterior duct. (C) Over the advanced wire, the stenotic lesion was dilated using a balloon. (D) An external PTBD catheter was placed through the recanalized tract.

selecting a correct micro-guidewire is also an important factor for successful percutaneous recanalization (Fig. 5). In our experience, a micro-guidewire with high torquability had a better performance in biliary recanalization. These wires have high steerable properties, which facilitate drilling of fibro-stenotic lesions. In addition, the shapable guidewire has high torquability, enabling much shaping. Occasionally, dedicate wires for chronic total occlusion in peripheral intervention can be utilized in case of tight stenosis. In other words, during biliary recanalization, the microcatheter system should be actively considered, and selecting an appropriate micro-guidewire is important.

If the aforementioned methods fail, an extraluminal approach could be considered. However, to avoid devastating complications such as adjacent vascular injury, the use of a guiding target is essential. Several methods to guide the extraluminal passage exist, such as using a balloon catheter as the reentry target with ERCP assistance or targeting the previously placed stent or catheter. Additionally, various-angled fluoroscopic imaging and cone-beam CT during the procedure are useful methods. In this study, a drainage catheter was inserted via the other segmental duct used as a target. Then, using a trans-septal needle (Brockenbrough needle; Abbott Laboratories, Abbott Park, Illinois, USA), extraluminal recanalization was safely performed without any complications (Fig. 6).

This study has several limitations. First, this study included a small number of patients. Second, this is a retrospective study, which may have resulted in bias. Third, it only focused on the technical aspect of biliary recanalization; there is a lack of overall outcome of biliary dilatation and patency of the stenosis after recanalization. Finally, our data focused on the percutaneous transhepatic approach; therefore, direct comparison of other approaches and techniques is difficult.

In conclusion, the step-by-step percutaneous biliary recanalization technique showed a high success rate without complications. According to the patient's biliary anatomy and shape of the stricture, an appropriately selected angled 5-Fr support catheter and wire are essential to increase the recanalization rate.

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Transparency document

The Transparency document associated with this article can be found in the online version.

CRediT authorship contribution statement

Jung Guen Cha: Conceptualization, Methodology, Writing - original draft. **Sang Yub Lee:** Conceptualization, Methodology, Supervision, Funding acquisition, Writing - review & editing. **Young Seok Han:** Resources, Validation. **Jae Min Chun:** Investigation, Data curation. **Ja Ryung Han:** Investigation, Data curation. **Jihoon Hong:** Investigation, Data curation. **Hun Kyu Ryeom:** Investigation, Data curation. **Min Kyu Jung:** Investigation, Data curation. **Jun Heo:** Investigation, Data curation. **Kyoung Hoon Lim:** Software, Validation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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