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Management Strategies for Benign Biliary Strictures

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Abstract

Biliary stricture is the abnormal narrowing of the biliary ductal system, leading to bile stasis and eventual ductal obstruction and dilatation. Common etiologies of biliary strictures can be broadly classified based on benign or malignant causes. The pathogenesis of benign biliary strictures (BBSs) can be a sequela of several causes, including iatrogenic, inflammatory, ischemic, infectious, and immunologic etiologies. Among the common causes of BBS, an iatrogenic biliary ductal injury sustained during hepatobiliary surgeries is the most frequently reported cause of BBS. Clinically, patients with BBS can present with obstructive biliary symptoms, and urgent biliary decompressive interventions are frequently required to prevent fatal complications. Cross-sectional imaging such as MR cholangiopancreatography enables timely evaluation of the stricture and facilitates therapeutic planning. The primary objective in managing biliary strictures (both benign and malignant) is to achieve permanent ductal patency and minimize the need for repeated interventions. A multidisciplinary team of gastroenterologists, interventional radiologists, and hepatobiliary surgeons is generally involved in caring for patients with BBS. This review provides a summary of clinically available endoscopic, percutaneous, and surgical biliary interventions for the management of patients with BBS.

Keywords
- benign biliary strictures
- biliary stenting
- biliary drainage

Etiologies

Common etiologies of biliary strictures can be broadly classified based on benign or malignant causes. The pathogenesis of benign biliary strictures (BBSs) can be a sequela of several causes, including iatrogenic, inflammatory, ischemic, infectious, and immunologic etiologies.[1] Iatrogenic biliary ductal injury sustained during hepatobiliary surgeries is the most frequently reported cause, with cholecystectomy and orthotopic liver transplantation (OLT) being the leading causes of BBS.[2] Though less common, other causes of BBS include post-cholangitis or pancreatitis-related biliary ductal inflammation, autoimmune cholangiopathies (immunoglobulin G4 mediated), biliary infections (including bacterial, parasitic, and human immunodeficiency virus), choledocholithiasis, Mirizzi

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syndrome, choledochal cysts, radiation-induced sclerosing cholangitis, biliary ductal ischemia, and trauma[1] (►Table 1).

Biliary Stricture Classification

Over the years, two classification systems of BBSs were developed based on the location of the stricture and are used to help surgeons identify the stenotic segment for repair and anastomosis. The Bismuth classification is the most commonly used classification for BBSs and malignant biliary strictures (MBSs) secondary to hilar cholangiocarcinoma[3] (►Table 2). Another commonly used classification is the Strasberg classification, which was initially developed to characterize biliary ductal injuries during laparoscopic cholecystectomy and considers the presence of a bile leak and lateral ductal injuries[4] (►Table 3).

Endoscopic Management Approaches

Endoscopic retrograde cholangiopancreatography with endoscopic biliary interventions is the gold standard diagnostic modality for evaluating biliary strictures and is frequently the first-line therapeutic intervention offered to patients with BBS. The primary goals of endoscopic management of BBS are diagnosing the underlying etiology with the exclusion of malignancy and providing biliary decompression. In practice, most patients with BBS require multiple endoscopic interventions for a sustained response, with a higher incidence of stricture recurrence associated with specific etiologies with BBS, including patients with chronic calcific pancreatitis.[5,6] During endoscopic retrograde cholangiopancreatography (ERCP), successful endoscopic cannulation of the common bile duct (CBD) is required for the complete evaluation of BBS and subsequent therapeutic biliary interventions. After CBD cannulation is achieved, the endoscopist must consider several critical technical factors that could alter patient outcomes, including the choice of the guidewire, the method of tissue sampling, the size of dilation, the selection of stent (type, diameter, length), and the need for bilateral stenting for hilar BBS.[7] Furthermore, a biliary sphincterotomy is frequently performed to place multiple plastic stents and ensure biliary access for future interventions (►Table 4).

Table 1 Common etiologies of benign biliary strictures

Type of disease	Examples of diseases
Iatrogenic	• Cholecystectomy • Orthotopic liver transplantation • Biliary reconstructive surgeries • Biliary-enteric anastomosis • Other hepatobiliary surgeries
Inflammatory	• Acute or chronic pancreatitis • Primary and secondary sclerosing cholangitis
Ischemic	• Hepatic artery stenosis or thrombosis
Infectious	• Recurrent pyogenic cholangitis • Human immunodeficiency virus cholangiopathy • Tuberculosis • Sarcoidosis • Parasitic infections • Choledocholithiasis
Autoimmune	• Immunoglobulin G4 cholangitis
Miscellaneous	• Portal biliopathy • Papillary stenosis • Trauma

Table 2 Bismuth classification of benign biliary stricture[48]

Bismuth classification	Stricture location
I	>2 cm distal to hepatic confluence
II	<2 cm distal to hepatic confluence
III	Hilar stricture; hepatic confluence is preserved
IV	Involves the hepatic confluence; bile ducts are separated
V	Type I, II, or III plus stricture of an isolated right duct

Table 3 Strasberg classification of intragenic biliary stricture[48]

Strasberg classification	Stricture locations
A	Injury to small ducts in continuity with biliary system, with cystic duct leak
B	Injury to sectoral duct with consequent obstruction
C	Injury to sectoral duct with consequent bile leak from a duct not in continuity with biliary system
D	Injury lateral to extrahepatic ducts
E1	Stricture located >2 cm from bile duct confluence
E2	Stricture located <2 cm from bile duct confluence
E3	Stricture located at bile duct confluence

Endoscopic Stricture Dilation

The endoscopic dilation of BBS via balloon or bougie is typically performed before biliary stenting using large-bore plastic stents and can be performed in conjunction with biliary sphincterotomy.[7] Endoscopic biliary duct balloon dilation with or without sphincterotomy is often required before placing multiple large-diameter plastic stents. The size of dilating balloon is determined by the size of the bile duct distal to the stricture, and typically range from 4 to 12 mm in diameter.[8] The dilating balloon is advanced over a guidewire across the stricture under fluoroscopic guidance and is maintained fully inflated for 30 to 60 seconds. Dilatation soon after biliary anastomosis (<30 days after surgery) carries a higher risk of dehiscence and resultant bile leak; so, a less aggressive approach is recommended in this setting.

Table 4 Diagnostic sensitivity of cross-sectional imaging modalities[1]

Modality	Sensitivity for detection of obstruction (%)	Specificity for classification as benign or malignant (%)	Accuracy in determining extent of stricture (%)
US	90–95	30–70	Lower (no published data)
CT	>90	60–90	75
MRI or MRCP	95–98	30–90	88–96

Abbreviations: CT, computed tomography; MRCP, magnetic resonance cholangiopancreatography; MRI, magnetic resonance imaging; US, ultrasonography.

Endoscopic Plastic Stents

For several decades, endoscopically placed plastic biliary stents have remained the stent of choice for most patients with BBS. A large collection of endoscopic plastic stents (EPSs) is commercially available with different stent characteristics varying in their construction material, coating (to reduce biofilm formation), length, angulation, and antimigration properties. Previous studies have attempted but failed to establish consistent superiority of one type over another[7] (►**Tables 5** and **6**). In practice, one or two EPSs are initially placed side by side depending on the stricture diameter and diameter of the distal bile duct. Stent exchange and periodic dilation with the placement of the increasing number of stents (up to six) is performed every 3 to 4 months over the next 12 to 18 months. The placement of multiple side-by-side, large-bore plastic stents has been shown to improve long-term outcomes of BBS compared with one or two stents alone.[9–11]

Endoscopic Metal Stents

Despite EPS's decade-long popularity, endoscopic covered self-expandable metal stents (ECSEMSs) are increasingly being used for BBS treatment with emerging data supporting their utility.[12] Compared with EPS, ECSEMSs have a larger expansion diameter with a narrow deployment system that does not require aggressive dilation before stent placement, and this can be advantageous in the treatment of postoperative biliary anastomotic strictures with a high risk of dehiscence and bile leak. The relatively larger diameters of ECSEMSs also minimizes the risk of stent occlusion resulting in the longer duration of stent patency and reduced need for frequent ERCP procedures for stent exchanges.[12]

Three main types of self-expandable metal stents (SEMSs) are commercially available: uncovered, partially covered, and fully covered stents. Endoscopically placed uncovered SEMSs (USEMSs) have median patency of approximately 20 months, and frequent reintervention is required to manage stent occlusions from reactive tissue hyperplasia. USEMSs are generally not recommended for BBS due to the problem of stent embedment, making future retrieval technically challenging (46–100% successful stent removal rates).[13–16] Fully covered SEMSs (FCSEMSs) have a complete external covering to prevent stent occlusion from reactive tissue hyperplasia, enabling enhanced stent patency, and improved stent retrievability (65–100% successful stent removal rates) compared with uncovered stents. Patients with BBS treated with endoscopic FCSEMS have a reported stricture resolution ranging from 60 to 100% at the time of stent removal.[12] Two drawbacks of FCSEMSs are the high rates of stent migration (5–40%) and the development of proximal stent strictures with long indwell times.[7,12] Partially covered SEMSs have uncovered proximal and distal ends in an effort to decrease the rate of stent migration but have been associated with difficulty in stent removal because of the increased risk of tissue embedment in the end portions.[17]

Endoscopic Intraductal Radiofrequency Ablation

More recently, endoscopic intraductal radiofrequency ablation (RFA) of refractory BBS has demonstrated encouraging preliminary outcomes in a small case series.[18,19] Since biliary ductal fibrous hyperplasia is a BBS pathogenic component, traditional balloon dilation and stent placement is not adequately treated. When used in conjunction with standard dilation and stenting techniques, intraductal RFA could target ductal fibrosis and hyperplasia and in theory could provide synergistic therapeutic outcomes in refractory cases of BBS.

Percutaneous Image-Guided Management Approaches

Fluoroscopic-guided percutaneous biliary interventions include large-bore biliary catheterization, cutting-balloon dilation, and the use of retrievable covered stents. These techniques have demonstrated improved outcomes compared with traditional interventions in the treatment of BBS. Percutaneous biliary therapy offered by interventional radiologists is indicated in patients with BBS not amenable to endoscopic treatments. Contraindications to endoscopic biliary therapy include failed ERCP or conditions that prevent endoscope passage through the proximal small bowel for CBD cannulation, such as postsurgical anatomic variations of the proximal bowel or duodenal or papillary stenosis. Patients with sepsis or strictures more accessible by the percutaneous technique may also be indicated[20] (►**Table 7**).

Percutaneous Transhepatic Biliary Drainage

Percutaneous transhepatic biliary drainage (PTBD) is a fluoroscopic-guided biliary decompressive procedure involving percutaneous bile duct cannulation, followed by internal and/or external catheter drainage of bile contents to alleviate obstruction.[21] If the stricture cannot be crossed safely, such

Table 5 Reported outcomes of endoscopically placed biliary stent for benign biliary strictures

Author, year	Endoscopic stent type	Cohort size	Stent size	Stricture etiology	Stricture resolution rate	Stricture recurrence rate	Follow-up
van Berkel et al,[49] 2004	SEMS	13	30 Fr expanding to 8–10 mm	Chronic pancreatitis	69%	31% at median of 50 mo	50 mo
Costamagna et al,[50] 2010	Large bore plastic replaced every 3 mo	42	Variable	Post-cholecystectomy	80%	11% at mean of 6.8 y	Median: 13.7 y
Tuvignon et al,[51] 2011	2× Poly-ethylene replaced every 3 mo	96	Variable	Post-cholecystectomy	82%	17% at median of 5.5 mo	Median: 6.1 y
Parlak et al,[52] 2015	2× plastic replaced every 3–4 mo	156	10 Fr	BDI-related stricture	88%	11% at median duration of 9 mo	Median: 6.5 y
Haapamäki et al,[53] 2015	Single covered SEMS or 3× plastic replaced every 3 mo	60	10 Fr (plastic) 10 mm CSEMS	Chronic pancreatitis	89%	4% at 6 mo 12% at 2 y	Median: 37 mo

Abbreviations: BDI, bile duct injury; CSEMS, covered self-expandable metal stents; SEMS, self-expandable metal stents.

as in the setting of severe cholangitis, an external drain may be placed temporarily to allow for bile decompression, and the patient may be brought back in several weeks to attempt another crossing. In practice, PTBD is generally reserved for patients with BBS who cannot tolerate or failed ERCP. PTBD placement can be performed using a right- or left-sided approach and is determined based on biliary stricture/obstruction site. While the left-sided approach is more comfortable for patients and has a low risk of pulmonary complications, it is also associated with a more acute angle in the CBD that is difficult for catheter manipulation.[21] For biliary strictures located in the common hepatic duct (CHD) or the CBD, the right midaxillary approach is the preferred technique and is associated with lower complication rates.[1]

Percutaneous Transhepatic Biliary Drainage Using Large-Bore Catheters

Over the years, several strategies have been proposed to reduce the restenosis rate of PTBD catheters in the management of BBS. First described in the 1970s, Ring et al[22] proposed the progressive upsizing of biliary drainage catheters (every 1–2 weeks) to a final size range of 18- to 20-Fr and maintained in place for 6 to 12 months is an effective way to reduce the restenosis rate. The large-bore catheter approach continues to be endorsed by some authors, and in a recent study of 47 patients who underwent large-bore catheter biliary drainage, stricture resolution was observed in 64% of patients with post-OLT strictures and 86% of patients with BBS from other etiologies.[23] Ludwig et al[23] also reported a catheter primary patency rate ranging from 81.3 to 89.5% at 20.3 months of follow-up. In a similar study, patients with long-term follow-up data exhibited a stricture patency probability of 75 and 67% at 5 and 10 years after treatment, respectively.[24] The dual-catheter approach proposed by Gwon et al[25] is another attempt to improve catheter long-term patency rate. In this technique, an 8.5-Fr drainage catheter is advanced into a 14-Fr catheter and then out of the catheter's side hole to place two parallel catheters at the level of the stricture. Based on a 78-patient cohort, Gwon et al reported primary patency rates of 96, 92, and 91% at 1, 2, and 3 years, respectively.[25] Recurrence was reported in 9% of the patients at a mean of 15.4 months (►**Table 8**).

Percutaneous Stricture Dilation

Percutaneous balloon dilation is frequently used in patients with BBS, in which an 8- to 10-mm-wide and 2- to 4-cm-long balloon is often used to dilate a proximal CBD or CHD stricture; however, larger balloons can be used in matured bilioenteric anastomotic strictures (►**Fig. 1**). Balloon dilation is contraindicated in postoperative edema-related bilioenteric anastomotic strictures (< 1-month-old) and new surgical anastomoses due to a higher risk of bile leak.[1,20] After crossing the stricture, the balloon is inflated for 30 to 60 seconds and is usually reinflated several times to perform cholangioplasty. Short-segment strictures respond better to balloon dilation than long-segment strictures, with reported short-term patency rates of 50 to 90% and long-term patency

Table 6 Endoscopically placed biliary stent–related complications

Author, year	Endoscopic stent type	Cohort size	*N* (%)		
			Major complication	Minor complication	Overall complication
van Boeckel et al,[27] 2009	USEMS and single or multiple plastic	1,116	USEMS: 79.5% clinical success rate Single plastic: 59.6% clinical success rate Multiple plastic: 94.3% clinical success rate		USEMS: 39.5% Single plastic: 36.0% Multiple plastic: 20.3% 0.8% overall mortality rate
Tarantino et al,[54] 2012	FCSEMS	62	0/62 (0%)	15/62 (24.1%)	15/62 (24.1%)
Saxena et al,[55] 2015	FCSEMS	123	13/123 (10.5%)[a]	21/123 (17%)	34/123 (27.6%)
Coté et al,[56] 2016	Plastic and CSEMS	55 plastic 57 CSEMS	6/55 plastic (10.9%) 7/57 CSEMS (12.2%)	10/55 plastic (18.1%) 16/57 CSEMS (28%)	16/55 plastic (29%) 23/57 CSEMS (40.3%)
Siiki et al,[57] 2018	SE biodegradable	13	2/13 (15%)	3/13 (23%)	5/13 (38.4%)

Abbreviations: CSEMS, covered self-expandable metal stents; FCSEMS, fully covered SEMS; SEMS, self-expandable metal stents; USEMS, uncovered SEMS.
Notes: Major complications included postprocedural cholangitis, pancreatitis, biliary obstruction, death. Minor complications included stent migration, occlusion, fracture, tissue ingrowth, and embedded stent; *abdominal pain excluded.*
[a]Major complication included three deaths unrelated to biliary intervention.

rates of 56 to 74%.[20] Finally, a drainage catheter or biliary stent can be placed to reexpand the stenotic segment.

In the setting of failed standard balloon dilation attempts, a cutting balloon can be used and has demonstrated favorable results compared with standard balloon dilation (100% primary success rate for primary stenosis and 90% for restenosis, based on a study of 22 OLT patients).[26] Cutting balloons have four long blades attached to the balloon and might be effective in treating recalcitrant restenosis, in which subsequent balloon dilations might have resulted in more focal fibrosis and scarring. Notably, no major complications occurred with this approach based on the same study.

Table 7 Indications and contraindications for percutaneous biliary cholangiography and drainage

Indications and contraindications for PTC and PTBD	
PTC indications	• Define level(s) of obstruction • Evaluate for presence of bile duct stones • Determine etiology of cholangitis • Evaluate suspected bile duct inflammatory disorders • Demonstrate site(s) of bile duct leak
PTBD indications	• Decompress obstructed biliary tree • Dilate biliary strictures • Remove bile duct stones • Divert bile from stent bile duct defect
PTC/PTBD contraindications	• Unfavorable anatomy (ascites, colon interposition, and liver masses) • Uncorrectable severe coagulopathy or thrombocytopenia or both

Abbreviations: PTBD, percutaneous transhepatic biliary drainage; PTC, percutaneous transhepatic cholangiography.

Percutaneous Biliary Stenting

Stricture recurrence after dilation may be reduced by the placement of a biliary stent. Similar to PTBD procedures, biliary stents are placed after fluoroscopic localization of the stenotic segment via percutaneous transhepatic cholangiography (PTC) and provides another treatment option for BBS (►**Fig. 2**, ►**Tables 9** and **10**). The material, configuration, biodegradability, and size of the biliary stents vary significantly, and some stent types are better suited in specific clinical circumstances than others. For example, despite its effectiveness in treating MBSs, uncovered self-expanding metal stents (SEMSs) are unsuitable for treating BBS, as reactive tissue ingrowth into the bare-wire lattice complicates their later retrievability. Conversely, covered SEMSs (CSEMSs) can be used to treat BBS with encouraging reported outcomes (75–90% stricture resolution at 10–36 months of follow-up),[27–29] as their silicone covering prevents tissue ingrowth and stent embedment into the duct wall.

Traditionally, extrahepatic BBS has been treated by placing multiple plastic stents side by side across a stricture following balloon dilatation. Long-term outcomes using this method in extrahepatic BBS resulted in higher clinical success (94.3 vs. 59.6%) and fewer adverse events (20.3 vs. 36.0%) compared with placement of a single plastic stent, respectively.[15,27,30] Although CSEMSs are more expensive than plastic stents, they have significantly wider diameters (10 vs. 3.3 mm, respectively) and are technically easier to insert than placing multiple plastic stents. In the last decade, multiple randomized trials comparing CSEMSs and multiple plastic stents for the treatment of post-OLT BBS have observed higher stricture resolution (81–92% vs. 76–90%),

Table 8 Reported outcomes of percutaneous transhepatic biliary drainage

Author, year	Patients	Mean dilation attempts	Technique	Drainage duration (mo)	Technical success rate	Stricture patency rate(s)	Stricture recurrence rate	Complication rate	Follow-up (mo)
Köcher et al,[58] 2007	20	NR	10–12 mm balloon dilation and internal biliary drainage	Mean: 10.3	95% (20/21)	94% at 1 y 83% at 2 y 77% at 3 y	20% (4/20)	10% (2/20)	Mean: 62
Glas et al,[59] 2008	39	3	7–14 mm balloon dilation and internal biliary drainage (15 Fr)	Mean: 11.5	97% (38/39)	98% at 1 y 94% at 2 y 71% at 34 mo	NR	Minor: 44% (17/39) Major: 8% (3/39)	Median: 28
Cantwell et al,[60] 2008	63	2	10–12 mm balloon dilation and internal biliary drainage (7–10 Fr)	Mean: 1.1	100% (205/205 procedures)	52% at 5 y 49% at 15 y 41% at 25 y	NR	Major: 2% (4/205 procedures)	Mean: 96
Bonnel and Fingerhut,[61] 2012	110	5	10 mm balloon dilation and internal biliary drainage (15 Fr)	Median: 8.5	99% (109/110)	85%	12–32%	10% (11/110)	Median 59
Janssen et al,[62] 2014	98	1.4	4–10 mm balloon dilation and internal biliary drainage (8.5–12 Fr)	Median: 3.3	98.5% (132/134)	95% at 1 y 92% at 5 y 72% at 10 y	9.7% (13/134)	8%	Median: 35
DePietro et al,[24] 2015	71	2	3–14 mm balloon dilation and internal biliary drainage upsizing to 16–18 Fr, then stenting	Upsizing mean: 2.4 Stenting mean: 3.9	87% (46/53)	84% at 1 y 74% at 5 y 67% at 10 y	9.4% (5/53)	Minor: 82% Major: 1%	Mean: 56

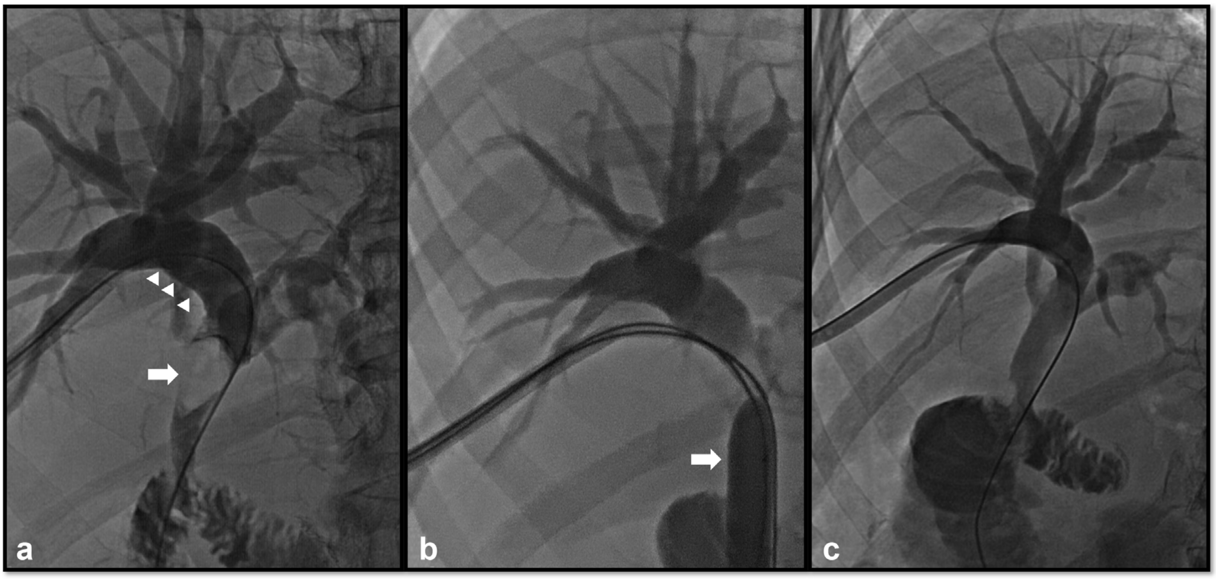

Fig. 1 Percutaneous transhepatic cholangiographic images of a female patient with a large choledocholithiasis resulting in biliary ductal obstruction. **(a)** The obstructing gallstone is visualized as an oval-shape radiolucent area (arrow) within the stenotic segment with no contrast filling. Biliary ductal dilation (arrowheads) of the intrahepatic bile ducts proximal to the gallstone is also noted on this image. **(b)** After percutaneous balloon (arrow) cholangioplasty of the obstructed biliary ductal segment, the stone was crushed, and bile flow was restored distally **(c)**.

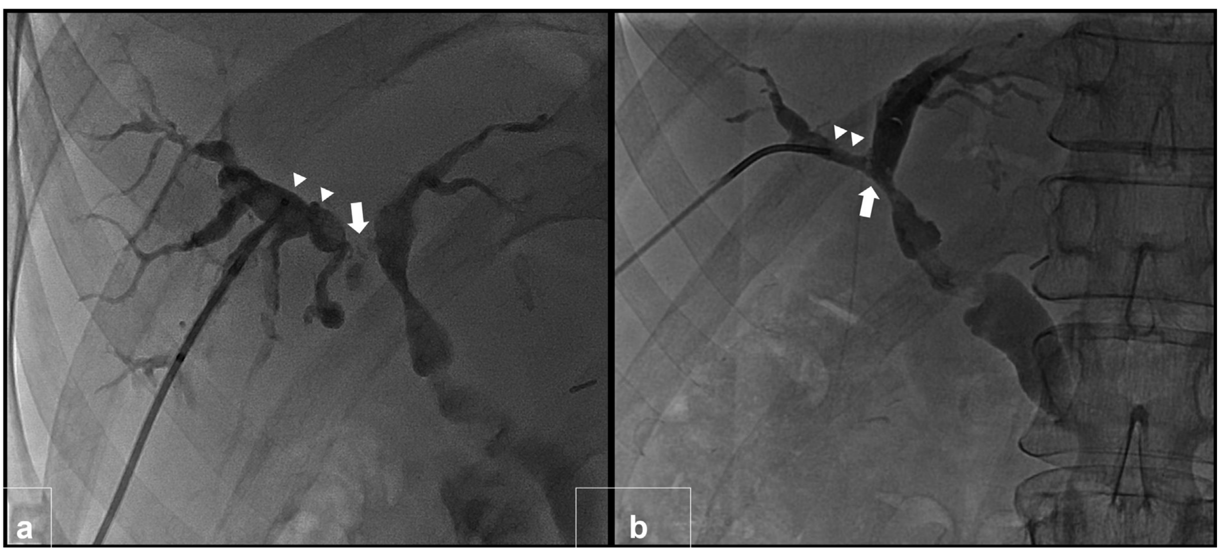

Fig. 2 Percutaneous transhepatic cholangiographic images of a male patient with an intrahepatic benign biliary stricture after orthotopic liver transplantation. **(a)** Intraprocedural cholangiographic image demonstrating a complete intrahepatic biliary duct stricture (arrow) causing bile stasis and proximal ductal dilation (arrowheads). **(b)** After successful balloon dilation and biliary stenting of the stenotic segment (arrow), there is complete resolution of the proximal ductal dilation (arrowheads).

decreased indwelling time (3.8 vs. 10.1 months), fewer endoscopic procedures (median: 2.0 vs. 4.5), fewer complications (10 vs. 50%), and ultimately lower cost for the CSEMS group.[31,32]

A major pitfall of covered biliary stents is the risk of stent migration, which may reduce the rate of stricture resolution (odds ratio: 0.22)[33] and increase the risk of adverse events (14.7–27.3%),[33–35] with a reported migration rate of 14 to 16.2% over 10 to 36 months of follow-up.[34,35] Although several strategies have been devised to minimize stent migration, such as inserting a smaller anchoring pigtail catheter or CSEMSs with an anchored flap design, long-term data regarding their efficacy remain limited.

Finally, investigative biodegradable stents composed of polydioxanone, a material often used to make surgical sutures, are currently under evaluation in Europe to treat BBS refractory to cholangioplasty. In a recent multicenter study,[36] stricture recurrence occurred in 18% of patients with at least 6 months of follow-up, with an estimated mean time to stricture recurrence of 38 months. The estimated stricture recurrence rates were 7.2, 26.4, and 29.4% at 1, 2, and 3 years, respectively. Biodegradable stents may represent a

Table 9 Reported outcomes of percutaneously placed biliary stent for benign biliary strictures

Author, year	Percutaneous method	Patients	Stent size	Stricture etiology	Stricture resolution rate	Stricture recurrence rate	Follow-up
Citron and Martin,[63] 1991	PTBD dilation and stenting	17	10–16 Fr	Variable	86%	18%	Mean: 32 mo
Born et al,[64] 1999	PTBD with Yamakawa type plastic drain; 1 Wallstent	31	14 or 16 Fr	Postsurgical	90%	7%	40, 46, and 51 mo
Ramos-De la Medina et al,[65] 2008	Locking-loop drainage catheter after dilation; 1 PIRT SEMS	27	8.5 or 10 Fr	Variable	63%	37% treatment failure overall	Mean: 42 mo
Gwon et al,[34] 2013	PTBD dilation and stenting	68	8.5 Fr	Variable	91% at 1 y 76% at 3 y 68% at 5 y	20% at mean of 20.8 mo	Mean: 3 y
DePietro et al,[24] 2015	PTBD dilation and stenting	71	12–18 Fr	Postsurgical	87% at protocol completion	11% at mean of 34.7 mo	1, 2, 5, 10 y

Abbreviations: PTBD, percutaneous transhepatic biliary drainage; SEMS, self-expanding metallic stent.

Table 10 Percutaneously placed biliary stenting related complications

Author, year	Percutaneous method	Patients	*N* (%)		
			Major complication	Minor complication	Overall complication
Zajko et al,[66] 1995	PTBD dilation and stenting	72	9/72 (12%)	Not reported	9/72 (12%)
Roumilhac et al,[67] 2003	PTBD dilation and stenting	34	7/34 (21%)	7/34 (20.5%)	14/34 (41%)
Cantwell et al,[60] 2008	PTBD dilation and stenting	75	4/205 (2.1%)	Not reported	4/205 (2.1%)
Janssen et al,[62] 2013	PTBD dilation and stenting	98	6/98 (6.1%)	5/98 (5.1%)	11/98 (11%)
DePietro et al,[24] 2015	PTBD dilation and stenting	71	1/71 (1.4%)	32/71 (45%)	33/71 (46%)

Abbreviation: PTBD, percutaneous transhepatic biliary drainage.
Notes: Major complications included cholangitis, pancreatitis, biliary obstruction, death, liver abscess, sepsis requiring admission, hemobilia, hepatic artery pseudoaneurysm, and acute portal vein thrombosis. Minor complications included stent or catheter migration/occlusion/fracture, tissue ingrowth, embedded stent, increase in portal hypertension; *abdominal pain, isolated fever, and cholelithiasis excluded.*

promising alternative treatment option for BBS, potentially offering better technical results and a better quality of life for patients, thanks to the reduced invasiveness of this strategy.

Surgical Management Approaches

Bile duct injury secondary to hepatobiliary surgery is a well-recognized cause of BBS. In particular, the incidence of stricture secondary to iatrogenic bile duct injury has increased since laparoscopic cholecystectomy has become the standard of care over the open technique.[37] Postoperative BBS following liver transplantation is another important cause of surgical origin.[20]

Intraoperative bile duct injuries may be recognized immediately; however, such injuries are often not identified during the initial operation leading to stricture development. When identified, immediate surgical evaluation by conversion to open operation and early cholangiography is indicated.[38,39] Following a thorough evaluation, elective repair has been shown to be superior to immediate/early repair for preventing stricture formation.[39,40]

Despite contributing to the incidence of BBS, surgery plays a vital role in its management. Reported stricture recurrence rates of surgical and endoscopic techniques are comparable, between 15 and 45% at 4 to 9 years of follow-up.[41] The choice of a surgical versus minimally invasive approach should be based on the location and severity of the stricture and the patient's general health and clinical status, including the presence and severity of infection, the presence of bilioenteric continuity, the timing of repair, and the and the need for repeated intervention.[38,42] For many lesions, endoscopic management is considered the first line. Surgical repair is recommended for failed repair of complex strictures (Bismuth types III, IV, V).[43] Multidisciplinary approaches between surgeons, radiologists, and gastroenterologists determine the best intervention for each patient.

Elective surgical management of BBS aims to reestablish bile flow from the biliary tree into the proximal gastrointestinal tract. Viable tissues with preserved blood supply are used to create a tension-free anastomosis that will prevent obstructive complications and subsequent cholangitis.[44] Procedures can be broadly divided into bilioenteric anastomoses and end-to-end bile duct anastomoses. Comparing all the procedures, surgery has the highest long-term stricture resolution rate, followed by the percutaneous transhepatic treatment, the multiple plastic stent insertion, and covered SEMSs, the difference being least significant. Surgical success rates have been reported to range from 65 to 95% based on one recently conducted meta-analysis with a follow-up duration of up to 13 years.[45]

End-to-End Bile Duct Anastomoses

Stricture excision and end-to-end bile duct anastomosis aim to reestablish bile drainage with the least possible disruption of biliary tree anatomy. However, the repair is rarely successful due to loss of duct length resulting from lesion-associated fibrosis, placing tension on the anastomosis.[44] Duct repair with ileal mucosal grafting is another technique that has not demonstrated success.[38] Bilioenteric anastomosis is more commonly used, as the type of repair can be tailored to lesion characteristics.

Hepaticojejunostomy

Roux-en-Y hepaticojejunostomy is the most commonly employed form of surgical bilioenteric anastomosis. It can be used to treat strictures situated high or low in the biliary tree.[44] Following resection of the affected duct system, bile flows from the transected right and left hepatic ducts are diverted into the jejunum's "roux" limb through the mucosal-to-mucosal anastomosis.

Choledochojejunostomy

For lower strictures of the CBD where the hepatocystic junction is patent, Roux-en-Y choledochojejunostomy has been used. However, it is associated with higher rates of restricture and cholangitis; thus, bilioenteric anastomosis by way of hepaticojejunostomy, which forms an anastomosis higher in the biliary tree, is favored.[38,40,44]

Choledochoduodenostomy

Choledochoduodenostomy is technically less complex than other bilioenteric anastomoses, as it does not require the construction of a roux limb. It also maintains endoscopic access to the biliary tree and allows for future endoscopic interventions.[38] However, to create a tension-free anastomosis, this method can only be used for lesions in the retropancreatic portion of the biliary tree, and generous kocherization of the duodenum is required. A dilated CBD of $\geq$15 mm is a predictor of success for this technique.[38,44]

Surgical Complications

The most common complications following surgical repair of BBS include jaundice with or without cholangitis, bile leak with possible bile peritonitis, subphrenic abscesses, biliary stone development, and biliary cirrhosis. Unfortunately, stricture recurrence over time remains a significant issue. In one study of patients with BBS who underwent end-to-end bile ductal anastomosis or bilioenteric anastomosis, the rate of stricture recurrence, presenting clinically as pain and jaundice, was observed in 22% of the patient cohort. Clinically, two-thirds of patients with recurrent strictures presented 2 years after surgery, and 90% were evident by 7 years. The recurrence of stricture several years (including over a decade) after initial surgical treatment is a well-documented phenomenon.[44,46,47] Hepaticojejunostomy is the preferred surgical treatment for recurrent stricture.[46]

Summary

Endoscopic management of BBS remains the preferred first-line intervention for many cases. Following endoscopy, percutaneous transhepatic intervention is often tried prior to surgical intervention. However, surgery plays an important role for managing anatomically complex or recurrent lesions, with Roux-en-Y hepaticojejunostomy being the treatment of choice.

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Conflict of Interests
The authors have no conflict of interest to declare.

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