Over the past few decades, remarkable advances in imaging technology have been made that allow more accurate diagnosis of biliary tract diseases and better planning of surgical procedures and other interventions aimed at managing these conditions. Operative techniques have also improved as a result of a better understanding of biliary and hepatic anatomy and physiology. Moreover, the continuing evolution of minimally invasive surgery has promoted the gradual adoption of laparoscopic approaches to these complex operations. Accordingly, biliary tract surgery, like many other areas of modern surgery, is constantly changing.

In what follows, we describe common operations performed to treat diseases of the biliary tract, emphasizing details of operative planning and intraoperative technique and suggesting specific strategies for preventing common problems. It should be remembered that complex biliary tract procedures, whether open or laparoscopic, are best done in specialized units where surgeons, anesthetists, intensivists, and nursing staff all are accustomed to handling the special problems and requirements of patients undergoing such procedures.

### Preoperative Evaluation

#### Imaging Studies

It is essential to define the pathologic anatomy accurately before embarking on any operation on the biliary tract. Extensive familiarity with the numerous variations of ductal and vascular anatomy in this region is crucial. High-quality ultrasonography and computed tomography are noninvasive and usually provide excellent information regarding mass lesions, the presence or absence of ductal dilatation, the extent and level of duct obstruction, and the extent of vessel involvement. Cholangiography—percutaneous transhepatic cholangiography (PTC), endoscopic retrograde cholangiopancreatography (ERCP), or magnetic resonance cholangiopancreatography (MRCP) [see 5.3 Jaundice]—can supply more detailed information about ductal anatomy and is used when CT and ultrasonography yield insufficient information. Angiography is rarely required to determine resectability. Magnetic resonance imaging and MRCP, which are noninvasive, are preferred where available. As newer MRCP technology becomes available, further improvements in definition of biliary anatomy appear to be obtainable. It may eventually prove possible to avoid the complications associated with ERCP (a more invasive alternative) entirely, at least for diagnostic indications.

#### Management of Biliary Obstruction

Although jaundice by itself does not increase operative risk, biliary obstruction has secondary effects that may increase operative mortality and the incidence of complications. There is little evidence to support the practice of routine preoperative biliary drainage in all jaundiced patients, but there are some elective situations in which preoperative drainage is required.

#### Infection

Patients with clinical cholangitis, whether spontaneous or induced by duct intubation (via PTC or ERCP), should be treated with biliary drainage and appropriate antibiotics until they are infection free; the recommended duration of treatment is at least 3 weeks. In addition, perioperative antibiotic prophylaxis with cefazolin or another agent with a comparable spectrum of activity should be employed routinely before any intervention or operation involving the biliary tract. For certain patients with biliary tract infection (e.g., associated with choledocholithiasis), urgent surgical decompression may be necessary, especially if antibiotics and endoscopic or transhepatic drainage are not immediately effective. If the patient was referred with a stent already in place (a frequent occurrence in our practice), broad-spectrum antibiotics should be given preoperatively to cover the anaerobes inevitably present.

#### Renal Dysfunction

The combination of a high bilirubin level and hypovolemia is a significant risk factor for acute renal failure, which can occur in the presence of a number of additional factors, such as acute infection, hypotension, and the infusion of contrast material. Patients with biliary obstruction should therefore be well hydrated before receiving I.V. contrast agents or undergoing operative procedures. In patients with acute renal dysfunction secondary to biliary obstruction, decompression of the bile duct until renal function returns to normal is advisable before any major elective procedure for malignant disease.

#### Impaired Immunologic Function or Malnutrition

Patients with long-standing biliary obstruction have impaired immune function and may become malnourished. Decompression of the bile duct until immune function and nutritional status are restored to normal is indicated before any major elective procedure is undertaken; this may take as long as 4 to 6 weeks.

#### Coagulation Dysfunction

Prolonged bile duct obstruction may lead to significant deficits in clotting factors. These deficits should be corrected with fresh frozen plasma and vitamin K before an operative procedure is begun. Even if there is no measurable coagulation dysfunction, vitamin K should be given to all patients with obstructive jaundice at least 24 hours before operation to replenish their depleted vitamin K stores.

#### Projected Major Liver Resection

If resection of an obstructing bile duct tumor is likely to necessitate major liver resection (e.g., a right trisectionectomy), it may be advisable to decompress the liver segments that are to be retained for approximately 4 to 6 weeks; a “normalized” area of the liver presumably regenerates more quickly than an obstructed one.

### Operative Planning

#### Patient Positioning

The patient is placed in the supine position on an operating
Exposure of Subhepatic Field in Open Procedures

A right subcostal incision provides excellent exposure for most open procedures on the gallbladder and biliary tract. For more extensive resections or reconstructions, the right subcostal incision can be extended laterally below the costal margin and across the midline to the left as a chevron incision. In patients with very narrow costal margins, a vertical midline incision may be more suitable for limited operations on the gallbladder and biliary tract, and a combination of a unilateral or bilateral subcostal incision and a midline vertical extension to the xiphoid may be required for more extensive operations. In any case, the incision must be long enough to allow sufficient visualization for safe performance of the procedure.

Adequate exposure and lighting are essential. The best retractors are those that can be fixed to the table while remaining flexible in terms of placement and angles of retraction. Modern high-intensity lights with focusing capabilities and headlamps are especially useful when the surgeon wears magnifying glasses.

Good access to the hepatoduodenal ligament and the structures in the porta hepatitis is critical. In patients who have never undergone an abdominal procedure, identification of these structures is straightforward. In patients who have undergone previous operations or have a local inflammatory process, however, there may be considerable obliteration of planes. If this is the case, the following techniques may be useful in defining the anatomy.

1. **Using the falciform ligament as a landmark.** In reoperative surgery, the key to opening up the upper abdomen is the falciform ligament. This structure should be found immediately after the opening of the abdominal wall and retracted superiorly. The omentum, the colon, and the stomach are then dissected inferiorly, and a plane that leads to the hepatoduodenal ligament and the porta hepatitis is thereby opened.

2. **Taking the right posterolateral approach.** When the colon and the duodenum are adherent to the undersurface of the right hemi-liver, separation may be difficult. In most patients, an open space remains that can be approached by sliding the left hand posteriorly to the right of these adhesions and into the (usually open) subhepatic space in front of the kidney and behind the adhesions. Anterior retraction allows identification of the adherent structures by palpation and permits dissection of the adhesions in a lateral-to-medial direction. The undersurface of the liver is thus cleared, and the hepatoduodenal ligament can be approached.

3. **Taking the lesser sac approach.** Ordinarily, the foramen of Winslow is open, and the left index finger can be passed through it from the right subhepatic space. When the foramen of Winslow is obliterated, however, one should approach it from the left, dividing the lesser omentum and passing an index finger from the lesser sac behind the hepatoduodenal ligament to reopen the foramen of Winslow by blunt dissection.

4. **Using the round ligament to find the true porta hepatitis.** Patients who have already undergone one or more operations on the bile duct often have adhesions between the hepatoduodenal ligament and segment 4 of the liver. If one dissects this area via the anterior approach, one may think that the actual porta hepatitis has been reached but notice that the hepatoduodenal ligament looks unusually short. In most cases, one can find the true porta more easily by tracing the round ligament to the point where it joins the left portal pedicle (including the ascending branch of the left portal vein) and then following that to the right along the true porta. The adhesions between the hepatoduodenal ligament and segment 4 can then be more easily divided from the left than from the front.

5. **Using aids to dissection.** Usually, structures in the hepatoduodenal ligament can be identified by inspection and palpation, especially if there is a biliary stent in place. In cases in which such identification is not easily accomplished, an intraoperative Doppler flow detector may be useful in identifying the hepatic artery and the portal vein, intraoperative ultrasonography may be helpful in identifying the bile duct (as well as vessels), and needle aspiration may also be used before the duct is incised if there is any doubt about its location. Either blunt or sharp dissection is effective in this area. Our preference is to use a long right-angle clamp (Mixon) to obtain exposure in a layer-by-layer fashion; we then electrocoagulate or ligate and divide the exposed tissue.

**Guidelines for Biliary Anastomosis**

As a rule, biliary anastomoses, whether of duct to bowel or of duct to duct, heal very well provided that the principles of preservation of adequate blood supply, avoidance of tension, and accurate placement of sutures are followed. In preparing the bile duct for anastomosis, it is essential to define adequate margins while avoiding excessive dissection that might compromise the blood supply to the duct. In repairs that follow acute injuries, it is important to resect crushed or devascularized tissue; however, in late repairs, it is not necessary to resect all scar tissue as long as an adequate opening can be made in the proximal obstructed duct through normal healthy tissue and as long as mucosa, rather than granulation tissue, is present at the duct margin. The length of the corresponding opening in the jejunal loop should be significantly smaller than the bile duct opening because the bowel opening tends to enlarge during the procedure.

Mucosa-to-mucosa apposition is essential for good healing and the prevention of late stricture. Sutures should be of a monofilament synthetic material (preferably absorbable) and should be as fine as is practical (e.g., 5-0 for a normal duct and 4-0 for a thickened duct). Because the bile duct wall has only one layer, biliary anastomoses should all be single layer. Sutures should pass through all layers of the bowel, taking sizable bites of the seromuscular layer and much smaller bites of the mucosa, and should take moderate-sized (1 to 3 mm, depending on duct diameter) bites in the bile duct. Interrupted sutures are used when access is difficult or the duct is small; continuous sutures, when access is easy and the duct is larger. Sutures should be securely placed but should not be so tight as to injure the tissues. It is sometimes wise to vary the spacing of the stitches: placing many stitches close together may cause ischemia of the suture line in a postage-stamp pattern. Magnification with loupes is particularly useful in anastomosing small ducts during open procedures. Stents are not routinely required for biliary anastomoses, and drainage of the operative field is seldom necessary.

There are several principles of suture placement that can be applied to most biliary anastomoses, whether end to side or side to side.
When the bile duct opening has a vertical configuration (as in side-to-side cholecdochuodenostomy or choledochojejuno- stomy), stay sutures are placed inferiorly and superiorly in the duct and at corresponding points in the intestine. Traction is placed on these sutures to line up the adjacent walls. One side of the anastomosis is done first; the bowel is then rotated 180°, and the other side is completed [see Figure 1]. This maneuver may be facilitated by retracting the first interrupted posterior stitch to the opposite side to serve as a pivotal stitch. It is advisable to sew about two thirds of the first wall and two thirds of the second, leaving the anterior third of the circumference (the easiest part) to be closed last. This technique can also be used for end-to-side choledochojejunostomy and allows all the knots to be tied outside the lumen. When the bile duct opening lies transversely, as in bifurcation reconstruction, lateral stay sutures are placed first, and the posterior wall stitches are placed from inside the lumen. If interrupted sutures are used, they are all placed individually before any of them are tied, with the untied tails carefully arranged in order. When the posterior wall sutures have been tied, the anterior wall can then be sutured with either continuous or interrupted sutures [see Figure 2].

When the intended anastomosis is intrahepatic and access is particularly difficult because of some combination of an unfavorable position, a previous scar, or, perhaps, a stiffer liver that is difficult to retract, another technique may be useful. All of the anterior wall stitches are placed into the duct, grouped together on a single retracting forceps with the needles left attached, and retracted superiorly to promote better exposure of the posterior duct wall [see Figure 2c]. The posterior stitches are placed into the duct and the bowel as described, tied in order, and cut; the anterior wall stitches are then completed by being placed into the bowel and tied.

When the duct is small, there are three techniques that may be useful for increasing the size of the lumen.

1. An anterior longitudinal incision can be made in a small common bile duct (CBD), and the sharp corners can be trimmed to enlarge the opening [see Figure 3a].
2. If the cystic duct is present alongside a divided CBD, an incision can be made in the shared wall to create a single larger lumen [see Figure 3b].
3. If the bifurcation has been resected, two small ducts can be brought together and sutures placed into their adjoining walls to form a single larger lumen [see Figure 3c].

**Construction of Roux Loop**

When the jejunum is used for long-term biliary drainage, a Roux loop is used to prevent reflux of small bowel content into the biliary system. In the creation of the loop, it is important to select a segment of jejunum with a well-defined vascular arcade that will be long enough to support a tension-free anastomosis. If access to the biliary system will be required in the future (e.g., in an operation for recurrent intrahepatic stones), the loop should be long enough to allow one to place a tube jejunostomy, fixing the loop to the abdominal wall with nonabsorbable sutures. The site of attachment should be marked with metallic clips to facilitate future percuta-
neous puncture and cannulation and removal of recurrent or persisting stones. The tube can be removed after postoperative imaging studies confirm that the biliary tree is free of stones.

Principles of Laparoscopic Biliary Tract Procedures

The surgical principles that lead to successful outcomes are much the same for laparoscopic biliary tract procedures as for their open counterparts. An anastomosis that is done under excellent exposure and lighting, that is fashioned with meticulously placed sutures, and that is completed without tension usually heals without complications and remains patent, regardless of the approach followed. However, because stricturing can occur many years after operation, biliary tract anastomoses must be followed for relatively long periods before success can be claimed. Accordingly, the long-term results of biliary-enteric anastomoses remain to be established.

As a rule, laparoscopic biliary procedures should be performed by surgeons with substantial expertise and experience in both hepatobiliary surgery and minimally invasive surgery.

Most of the conventional biliary tract operations—including choledochoduodenostomy, cholecystojejunostomy, choledochojejunostomy, and choledochal cyst resection—have been successfully performed in small numbers by laparoscopic means. The laparoscopic approach may become a particularly attractive option in the palliative setting if it proves more reliable than endoscopic stenting or percutaneous transhepatic cholangiography and drainage (PTCD) with respect to safety and speed of postoperative recovery.

The laparoscopic approach to biliary anastomosis involves placement of four or five ports in a fan pattern and usually is associated with a longer operating time than the open approach. Liver retraction is achieved with an articulated retractor (e.g., Endoflex; New Dynamics in Medicine, Dayton, Ohio), and dissection may be carried out with sharp instruments and an electrocautery, with or without an ultrasonic scalpel (e.g., Harmonic Scalpel; Ethicon Endo-Surgery, Inc., Cincinnati, Ohio).

Magnification may enhance the surgeon’s ability to perform these demanding anastomoses in a meticulous fashion, and robotic assistance (in the form of wrist-type end-effectors) may further improve precision. Advanced intracorporeal knot-tying and suturing skills are a prerequisite, along with personal expertise in intraoperative laparoscopic ultrasonography, which is often helpful in assessing the liver and the porta hepatis. During intracorporeal creation of a biliary anastomosis, small clips may be used to organize multiple interrupted sutures, much as hemostats are used in the corresponding open procedures.

**Choledochoduodenostomy**

Choledochoduodenostomy is a relatively straightforward side-to-side biliary-enteric bypass procedure that is effective in certain restricted circumstances and has the advantage of being simpler and safer than transduodenal sphincteroplasty. It is most commonly used in patients with multiple bile duct stones when there is concern about leaving residual stones at the time of CBD exploration as well as in patients with recurrent bile duct stones when endoscopic papillotomy either cannot be done or has been unsuccessful. It is also used in patients with benign distal biliary obstruction (e.g., from chronic pancreatitis) and occasionally in patients with malignant distal CBD obstruction whose life expectancy is short. Choledochoduodenostomy works best if the CBD is at least 1 cm in diameter; it should not be used in patients with actual or potential duodenal obstruction.

**OPERATIVE TECHNIQUE**

The duodenum is mobilized to allow approximation to the CBD without tension. Ordinarily, the first part of the duodenum can easily be rolled up against the CBD; however, in patients who have chronic pancreatitis or have previously undergone an abdominal procedure, extensive Kocherization may be required. If satisfactory approximation is not achieved with this maneuver, a choledochojejunostomy should be performed.

The CBD is exposed as described elsewhere [see 5:21 Cholecys-
tectomy and Common Bile Duct Exploration]. Longitudinal incisions are made in both the duodenum and the duct [see Figure 1], and the anastomosis is carried out as described previously [see Operative Planning, General Technical Considerations, Guidelines for Biliary Anastomosis, above].

Laparoscopic Considerations

Laparoscopic choledochoduodenostomy, like all minimally invasive surgical procedures, follows the same principles proven in its open procedural counterpart—namely, adequate exposure, sufficient size of the CBD, and meticulous attention to creating a tension-free anastomosis with intracorporeally placed interrupted sutures. The diamond-shaped anastomosis fashioned should be indistinguishable from that fashioned in the corresponding open procedure.

COMPLICATIONS

Late closure or stricture of the anastomosis may occur if the CBD is small or malignant disease is present. Alternative methods of biliary decompression should be considered in these situations. Cholangitis related to the presence of food in the CBD distal to the anastomosis (so-called sump syndrome) is an uncommon occurrence. The larger the anastomosis, the smaller the likelihood that this complication will occur.

Cholecystojejunostomy

Cholecystojejunostomy may be performed to treat malignant biliary obstruction in selected patients whose lesions are found to be unresectable at operation and whose life expectancy is expected to be short. Occasionally, it is indicated for patients in whom endoscopic or percutaneous stenting has been unsuccessful. This operation is not the preferred procedure for long-term decompression.

OPERATIVE TECHNIQUE

Step 1: Verification of Feasibility of Procedure

The cystic duct must be patent. Its junction with the CBD must be at least 1 cm above the tumor obstruction [see Figure 4]. The suitability of the anatomy for cholecystojejunostomy may have been verified by preoperative cholangiography; if not, intraoperative cholangiography via the gallbladder or the CBD is mandatory. If one still cannot be certain that the operation is feasible, the CBD should be opened and a choledochoenterostomy performed. The finding of a bile-filled gallbladder is not sufficient evidence that the patient is a suitable candidate for a cholecystojejunostomy. The gallbladder should be normal: there should be no evidence of cholecystitis or stones. Normal status is verified by inspection, palpation (in the open setting), and, if necessary, needle cholecystography. Finally, for the anastomosis to be feasible, one should be able to approximate the jejunum to the gallbladder easily.

Step 2: Preparation for Anastomosis

A site near the fundus is selected for the anastomosis, and an appropriate segment of proximal jejunum is anchored to the gallbladder with two fine stay sutures in anticipation of a transverse incision in the gallbladder and a longitudinal incision in the antimesenteric border of the bowel.

Step 3: Anastomosis

A 2 cm opening is made in the gallbladder and the adjacent segment of the jejunum, and a single-layer anastomosis is constructed with a continuous monofilament absorbable suture or a stapler.

Step 4: Optional Additional Procedures

A Roux loop, rather than a simple jejunal loop, may be used in the construction of the choledochojejunostomy, and a gastroje-
incision and oversewing their common wall. The lumina of the CBD and the cystic duct may be combined by incising the ducts, the temporary placement of a small T tube at the anastomosis will allow most of the circumference to be completed without the risk of either picking up the opposite wall or placing sutures incorrectly. The T tube is then removed and the anastomosis completed. Routine postoperative stenting is unnecessary, but stents may be helpful in those rare cases in which mucosal apposition cannot be accomplished. In these situations, sutures may have to be placed in surrounding liver or scar tissue in much the same way as in a Kasai procedure. In difficult cases of proximal stricture, the surgeon may incise the liver plate and seek out viable duct above the bifurcation.

COMPLICATIONS

The main complications of choledochojunostomy are bile leakage, late stricture, and recurrent jaundice as a result of tumor extension [see Cholecystojejunostomy and Choledochoduodenostomy, above].
Transduodenal Sphincteroplasty

Transduodenal sphincteroplasty is occasionally indicated when an impacted stone at the ampulla of Vater cannot be removed via a choledochotomy. It is also sometimes useful for clarifying the nature of an obstructive process at the ampulla, definitively treating ampullary stenosis, and gaining access to the main pancreatic duct if ERCP has been unsuccessful. Pancreatic sphincteroplasty may be added in selected cases.

Endoscopic techniques are usually successful for these purposes. A frequent use of the transduodenal approach is for local resection of a benign ampullary tumor (e.g., a villous adenoma) with reconstruction of the medial duodenal wall.

OPERATIVE TECHNIQUE

Step 1: Exposure of Ampulla

Mobilization of the duodenum and the pancreatic head is necessary for obtaining exposure of the lateral portion of the second part of the duodenum. The ampulla is located by palpation, which may be facilitated by passage of a sound down the CBD, out the ampulla, and into the duodenum. A longitudinal incision is made on the lateral surface of the duodenum; it should be at least 3 cm long to ensure good exposure. The duodenal edges are retracted gently. Crushing forceps should not be used; they may cause hematomas.

Step 2: Cannulation

If the bile duct has been opened, cannulation of the CBD is done from above. A metal sound may be used, but we generally prefer to insert a fine catheter and pass it through the ampulla, which can then be gently elevated into the field [see Figure 5]. This step facilitates accurate placement of an incision in the ampulla. If the duct has not been opened, cannulation is accomplished from below with a sound. Use of a grooved director may simplify the sphincterotomy.

Figure 5  Transduodenal sphincteroplasty. (a) A longitudinal incision is made in the duodenum, and a filiform catheter and a follower are used to find and elevate the ampulla. (b) An incision is made at the 11 o’clock position with either scissors or a scalpel. (c) Interrupted sutures are placed through the bile duct wall and the duodenal wall. Lateral traction is applied.
TROUBLESHOOTING

There may be an impacted stone at the distal end of the CBD that prevents cannulation from either above or below. Such a stone can usually be felt through the duodenal wall, in which case a vertical incision can be made in the medial duodenal wall directly onto the stone. Once the stone has been extracted, the incision can be extended down through the ampulla with a sound used as a guide.

Occasionally (e.g., in some patients with chronic pancreatitis), a long stricture of the CBD may extend above the ampulla. In such cases, the sphincteroplasty may have to be extended proximally to the point where it communicates with the retroperitoneal space. This will not be a problem as long as the duodenum-to-CBD repair is carefully executed. If the obstruction cannot be managed with an extended sphincteroplasty, a different decompressive procedure, such as choledochojejunostomy or choledochoduodenostomy, must be chosen.

Postoperative pancreatitis may develop if there was excessive manipulation of the ampulla, if the electrocautery was used at the ampulla, or if the pancreatic duct orifice is occluded by one of the sphincteroplasty sutures.

Choledochal Cyst Resection

Choledochal cysts are generally categorized according to the Todani classification [see Figure 6]. More than 80% are type I cysts that involve the CBD in its accessible portion. The following discussion addresses the resection of type I cysts and those type IV cysts that include the proximal right or left hepatic ducts.

Most choledochal cysts are related to an abnormal junction of the pancreatic duct and the distal CBD. Preoperative cholangiography to clarify the anatomy is important for preventing injury to the pancreatic duct, especially when an intrapancreatic resection may be required. Occasionally, intraoperative cholangiography is required to clarify abnormal anatomy. Patients may be symptomatic as a result of stones within the cyst, infection, or malignancy, any of which is an indication for operation. Because of the high incidence of such conditions and the extremely high mortality associated with carcinoma in this setting, prophylactic cyst resection seems justified even in asymptomatic patients.

The objectives of treatment are (1) to remove the cyst completely, along with the gallbladder and any stones that remain in the bile ducts proximal to the cyst, and (2) to achieve free biliary drainage. Resection of a choledochal cyst may be made more difficult by several factors, such as previous operations, recurrent bouts of infection and inflammation in the cyst, and portal hypertension, which may develop as a result of long-standing cholangitis or portal vein thrombosis.

OPERATIVE TECHNIQUE

Resection of a choledochal cyst may be difficult and bloody, especially if inflammation is present. In addition, dissection of a choledochal cyst in its intrapancreatic portion may be hazardous because of the vascularity of this region and the difficulty of identifying anatomic structures.

Step 1: Clarification of Anatomy

The proximal and distal extent of the cyst and the presence or absence of stones or tumor may be determined preoperatively, as noted, but in many cases, intraoperative verification of the findings is necessary. Intraoperative cholangiography can be carried out by
inserting a catheter through the gallbladder, by directly needling the cyst, or both. If cholangiography does not yield an accurate definition of the anatomy of the cyst, the cyst may then be opened and digital exploration and choledochoscopy used to clarify the anatomy.

**Step 2: Initial Dissection**

If the gallbladder is still in place, it is dissected free of the liver and left attached to the cyst via the cystic duct, then retracted to the right. If the patient has already undergone a cystoenteric anastomosis, this should be taken down at the beginning of the procedure, and the opening in the bowel should be carefully closed.

**Step 3: Mobilization of Cyst**

As noted, the vascularity of the region and the presence of inflammation may render dissection difficult. Rather than cleaning off the hepatic artery and the portal vein and dissecting them off the cyst, the surgeon should find a plane immediately adjacent to the wall of the cyst and remain close to it. This approach differs significantly from the corresponding approach in resection of a bile duct malignancy. If necessary, the cyst may be opened and the dissection continued with a finger inside the cyst to yield a more accurate definition of its boundaries. The cyst should be cleared circumferentially in the middle third of the CBD so that a tape can be passed around it and traction applied to separate the cyst from the hepatic artery, the portal vein, and any remaining soft tissue in the hepatoduodenal ligament.

**Step 4: Distal Dissection**

Dissection then proceeds distally along the wall of the cyst until the junction of the cyst with the normal portion of the CBD is reached. If the intrapancreatic portion of the CBD is involved, the cyst must be separated from pancreatic tissue. There are a number of small vessels that must be individually identified and ligated to minimize the risk of early or delayed bleeding. If the cyst is close to the pancreatic duct junction, considerable care must be exercised not to injure the pancreatic duct.

**Step 5: Proximal Dissection**

If the proximal common hepatic duct is normal (as in a type I cyst), it is transected above the cyst. If the cystic dilatation includes the bifurcation (as in a type IVa cyst), a small button of proximal cyst is usually left attached to the intrahepatic ducts.

**Step 6: Reconstruction**

Reconstruction is accomplished via an end-to-side anastomosis to a Roux jejunal loop to minimize the likelihood of reflux of enteric contents into the biliary tract.

**Step 7: Closure**

The abdomen is closed in the standard fashion. Stenting is not required, but the area should be drained with closed suction drains if an intrapancreatic resection has been done.

**Laparoscopic Considerations**

If the appropriate principles and techniques are used, choledochal cyst excision can be performed laparoscopically with excellent results. A laparoscopic approach faces essentially the same challenges that an open approach does.

**TROUBLESHOOTING**

If dissection of the cyst is carried distally into the pancreas, care must be taken to keep from injuring the pancreatic duct. The cyst should be transected as distally as possible, and the end should be carefully oversewn with absorbable sutures. Somatostatin, 100 µg subcutaneously during the operation and every 8 hours for 5 days afterward, should be given to reduce the likelihood of pancreatitis and pancreatic fistula. Occasionally, intraoperative cholangiography is useful to confirm the relationship of the cyst and the CBD to the pancreatic duct.

If the cystic process extends to include the bifurcation (type IVa), the hepatic ducts should be identified from within the cyst and their orifices preserved by leaving a small button of cyst wall in situ; this is preferable to performing an intrahepatic dissection to remove the entire cyst. The presence of this button simplifies and facilitates the anastomosis to the Roux loop.

**COMPLICATIONS**

Bleeding and pancreatitis are the main early complications of cystectomy. These can be largely prevented by meticulous dissection and ligation of all fine bleeding vessels as well as tissue adjacent to an intrapancreatic cyst. Late stricture of the anastomosis is an uncommon complication but may occur, especially if a small button of proximal cyst is left in place for the anastomosis; this particular complication is considered an acceptable hazard in a difficult situation.

**OUTCOME EVALUATION**

The immediate expected outcome is the relief of pain, jaundice, and cholangitis and the return of liver function to normal. The long-term expected outcome is the absence of any recurrence of symptoms of stone disease, cholangitis, or malignancy. Because of the rarity of this condition, no good data on the recurrence rate of problems are available.
Resection of Middle-Third and Proximal Bile Duct Tumors

The most common bile duct tumor is adenocarcinoma [see 5:9 Tumors of the Pancreas, Biliary Tract, and Liver]. Because this tumor responds poorly to irradiation and chemotherapy, surgical resection offers the best opportunity for cure. The appropriate operative approach depends on the location and extent of the tumor [see Figure 9]. Tumors in the distal third of the CBD (the pancreatic portion) are treated by means of a Whipple procedure that includes bile duct and periductal tissues right up to the bifurcation [see 5:24 Pancreatic Disease]. Those in the middle third or the proximal third are treated by means of bile duct resection, with or without liver resection [see 5:23 Hepatic Resection].

There are certain basic principles underlying bile duct resection for tumor that must be followed. First, the proximal extent of the tumor must be identified so that the correct procedure can be planned. Preoperative PTC is usually not required for staging if high-quality ultrasonography and MRCP are available. Some authorities advocate bilateral percutaneous drainage to facilitate intraoperative dissection. We do not routinely use preoperative drainage tubes, because of the risk of cholangitis.

Second, given that bile duct tumors spread by local extension to lymphatics, along perineural spaces, and along the bile radicles themselves directly into the liver, wide local excision beyond the visible edges of the tumor is required in the performance of curative resections. In proximal tumors, such excision necessitates resection of the adjacent segments of the liver. The principles of en bloc resection beyond tumor margins must be closely adhered to: dissection into or even close to the tumor must be avoided.

Third, intraoperative biopsy of the tumor should not be done, because of the difficulty of making a firm pathologic diagnosis on the basis of frozen-section examination and because of the risk of tumor dissemination.

Finally, given that liver resection is required in most cases, one must be careful to preserve enough healthy liver tissue to allow regeneration of the remnant. If there has been long-standing obstruction, biliary drainage on the side to be preserved is important for recovery of function in that portion of the liver. Some surgeons advocate preoperative portal vein embolization on the contralateral side to stimulate hepatic regeneration in the segments to be preserved, especially if the future remnant is marginal in size [see 5:9 Tumors of the Pancreas, Biliary Tract, and Liver].

On the whole, we are currently more aggressive in treating proximal tumors than we once were, for two main reasons: (1) the accompanying liver resection can now be done with greater safety, and (2) this more radical approach has been shown to yield improved long-term results. For middle-third or type I proximal tumors, we favor resection of the bifurcation in conjunction with intrahepatic cholangiojejunostomy. For types II, III, and IV, we...

![Figure 9](image-url) Resection of middle-third and proximal bile duct tumors. The appropriate operation depends on the location and extent of the tumor. (a) Broadly, tumors may be localized to the proximal third, the middle third, or the distal third of the biliary tract. (b through f) Proximal tumors may be further categorized according to the Bismuth classification.
recommend additional liver resection: a right trisectionectomy (resection of segments 4, 5, 6, 7, and 8, along with the caudate lobe) for types II, IIIa, and IV and a formal left hepatectomy (resection of segments 1, 2, 3, and 4) for type IIIb [see 5:23 Hepatic Resection]. There is some controversy as to whether patients with these complex proximal biliary tumors have a better chance of long-term survival with liver transplantation than with a right trisectionectomy. This controversy has yet to be resolved, but given that organ availability remains a major issue, we continue to prefer radical resection in this setting.

**OPERATIVE TECHNIQUE**

*Step 1: Assessment of Resectability*

Before any dissection of the tumor or the CBD is done, a careful search for peritoneal metastases is undertaken. Spread within the liver is evaluated via palpation and intraoperative ultrasonography. Lymph nodes are assessed in the immediate and secondary drainage areas. Biopsies of any suspicious areas outside the planned resection margins are carried out. If tumor is found, stenting or a bypass procedure is indicated.

During dissection, determination of resectability is often difficult, especially with respect to assessment of tumor extension into the liver and the degree of vessel involvement. Therefore, any firm commitment to resection (e.g., dividing the blood supply) should be deferred until resectability is confirmed.

The gallbladder is mobilized from the liver bed by entering the usual plane superficial to the liver capsule without dissecting or dividing the cystic artery and the cystic duct. Exposure is improved by mobilizing the gallbladder and, if necessary, emptying the gallbladder of bile. The gallbladder can also be used as a retractor on the bile duct.

Dissection is then begun from below. The common hepatic artery and the portal vein are identified just above the neck of the pancreas and circumferentially cleared of all tissue. Dissection then proceeds proximally, with the hepatic artery retracted to the left and the portal vein to the right. Adjacent areolar tissue, nerve trunks, and lymph nodes are left in place around the CBD and the tumor [see Figure 10]. As noted, this approach differs from that used in resection of choledochal cysts [see Choledochal Cyst Resection, Operative Technique, above].

*Step 2: Division of CBD*

Once resectability is confirmed, the CBD is divided at the level of the pancreas. A clamp is placed on the upper end of the divided duct, which is then used as a retractor to facilitate the most proximal dissection of the CBD and the tumor away from the hepatic artery and the portal vein [see Figure 11].

*Step 3: Proximal Dissection*

With middle-third tumors or Bismuth type I proximal tumors, it is usually possible to palpate the proximal tumor margin and identify uninvolved right and left hepatic ducts. If this is not the case, the possibility of a type II or III tumor should be considered, and complete excision of the bifurcation, with or without part of the liver, should be planned.

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*Figure 10* Resection of middle-third and proximal bile duct tumors. Shown is the proper plane of dissection in the removal of a bile duct cancer. Except for the hepatic artery and the portal vein, all tissue stays with the CBD to be resected.

*Figure 11* Resection of middle-third and proximal bile duct tumors. When resectability is confirmed, the CBD is transected at the duodenum. The proximal portion of the divided duct is retracted anteriorly, and the CBD is cleaned off the portal vein up to a point above the bifurcation.
The hepatic artery is dissected by retracting the vessel anteriorly and to the left, dividing and ligating the cystic artery where it originates from the right hepatic artery, and clearing all tissue off the right and left branches at least 1 cm proximal to the proximal margin of the tumor. Involvement of the right or left hepatic artery by tumor is almost always a sign of extensive spread on the corresponding side and an indication for resection of that half of the liver.

The portal vein is dissected by retracting the bile duct and the tumor anteriorly and the hepatic artery to the left. All tissue is then cleanly dissected away from the portal vein to expose the bifurcation and the region proximal to it [see Figure 11]. At this point, the duct may be found to be tethered down to the caudate lobe by several small branches. If these branches are clearly proximal to the tumor, they are divided and carefully ligated, and the caudate lobe is preserved. If there is tumor in this area, the caudate lobe is resected along with the bifurcation tumor.

The level at which the proximal bile ducts are transected depends on the proximal extent of the tumor. For all middle-third or proximal tumors that are at least 1 cm beyond the bifurcation, proximal resection should usually be above the level of the bifurcation. For type I or type II proximal tumors, proximal resection should always include all of the bifurcation along with the proximal right and left bile ducts out as far as the first major branch [see Figure 12]. With type III or IV proximal tumors, the proximal extent of the tumor cannot be determined in both right and left ducts unless the main pedicles are dissected out of the liver. Because these tumors tend to infiltrate locally, such dissection is not advisable. A decision on whether liver resection is indicated should be made at an early stage so that the chances of a cure are not compromised. Intraoperative ultrasonography may help verify the extent of tumor at this point in the operation. Any major liver resection for type III or IV bile duct cancer should include the caudate lobe [see Figure 13].

Once the decision to resect part of the liver has been made, the operation consists of dissecting the hepatic artery and the portal vein branch to the part of the liver to be saved away from the tumor area. The hepatic artery and the portal vein branch to the side to be resected are then divided; this allows the tumor to be retracted further and provides better exposure of the duct to the side to be preserved [see Figures 14 and 15]. In selected cases, resection of an involved portal vein bifurcation may be carried out at this point [see Figure 16]; an end-to-end anastomosis is then fashioned.

The point at which the hepatic parenchyma will be divided is marked, and the parenchymal transection is performed. Division of the hepatic duct (or ducts) to the part of the liver being preserved is done as far from the tumor as possible.

Step 4: Reconstruction

After resection of the bifurcation or intrahepatic bile ducts, an intrahepatic cholangiojejunostomy is performed [see Intrahepatic Cholangiojejunostomy, below]. The duct tissue is usually healthy enough and the duct lumen large enough to allow mucosa-to-mucosa repair without stenting. Some surgeons place transhepatic tubes through these anastomoses to facilitate postoperative treatment with internal radiation sources; however, there is no evidence that this practice reduces local recurrence or prolongs survival.
Figure 14  Resection of middle-third and proximal bile duct tumors. Shown is the resection of type IIIb proximal tumors. (a) The CBD is retracted upward and to the left; the left hepatic artery is divided; and the right portal vein and the right hepatic artery, which are to be saved, are exposed. (b) The left portal vein is divided.

Figure 15  Resection of middle-third and proximal bile duct tumors. Shown is the resection of types II, IIIa, and IV proximal tumors. (a) The CBD is retracted upward and to the right; the right hepatic artery is divided; and the left portal vein and the left hepatic artery, which are to be saved, are exposed. (b) The right portal vein is divided.
Step 5: Closure and Postoperative Care

The abdomen is closed in the standard fashion, and closed suction drains are placed. Liver function is monitored, particularly when a major liver resection has been done. Mild abnormalities in coagulation test results are common, and soluble coagulation factors are given only if there is evidence of bleeding.

COMPLICATIONS

Bile leakage, bleeding, and infection are the most important complications of bile duct resection for tumor. Parahepatic collections are treated with percutaneous drainage, and significant early bleeding is usually best managed by reexploration.

Intrahepatic Cholangiojejunostomy

Intrahepatic cholangiojejunostomy is commonly performed after resection of the bifurcation for a more proximal tumor; it is also performed to manage injury or stricture at the level of the bifurcation and to bypass an unresectable bifurcation tumor. Because the ducts are smaller, have thinner walls, and are more adherent to the areolar tissue of the pedicles than either the portal vein branches or the hepatic artery branches, dissection of the ducts must be more meticulous. Magnification is an important aid, particularly in dealing with undilated ducts. Good exposure is essential; if necessary, the liver may be split to allow adequate visualization, access, and lighting. Anatomic mucosal suturing can be achieved in most situations. In rare instances, excessive inflammation, scarring, or tumor makes such suturing impossible, in which case periductal sutures are used and a stent is placed. As described [see General Considerations, Technical Issues in Biliary Anastomosis, above], separate ducts that are close together can be first sutured together at their adjacent walls to create a single larger proximal duct lumen so that a safer anastomosis can be created [see Figure 3c].

Operative Technique

Step 1: Definition of Tissues for Anastomosis

In the case of injury, crushed, cauterized, or devitalized tissue must be debrided back to normal healthy tissue before reconstruction is begun. In the case of bile duct resection for tumor, there should be no attempt to clear a length of duct from surrounding areolar or liver tissue; the suturing should take place in situ, with the stitches passed through the duct wall and the areolar tissue of the portal pedicles. In the case of bypass for unresectable cancer, the duct being used should be opened as far from the tumor as possible. The left main hepatic duct can be approached between the bifurcation and the umbilical fissure. If the tumor involves the left main hepatic duct, the branch to segment 3 of the liver can be used instead; it can be approached in the umbilical fissure, above the round ligament. Occasionally, incision into the liver or excision of a wedge of liver tissue is necessary to
provide adequate exposure [see Figure 17].

If an intrahepatic anastomosis is required for a bifurcation stricture, resection of the stricture is not necessary; however, it is important to identify a normal duct above the level of the bifurcation. If there is no communication from right to left, a horizontal incision can be made in the left duct and carried across into the right duct just above or through the bifurcation stricture, so that a single anastomosis can be made that incorporates both ducts. It is possible to enlarge duct openings by making a small longitudinal incision in the most accessible portion of the duct. This is easier to accomplish in the left hepatic duct (because of its extrahepatic transverse position) than in the right hepatic duct (which tends to run laterally and posteriorly directly in the liver substance).

**Step 2: Anastomosis**

A Roux-en-Y loop of sufficient length to make a tension-free anastomosis is constructed, and a biliary-enteric anastomosis is then performed. When adequate access is difficult to obtain, interrupted sutures are first placed in the anterior wall of the bile duct. This allows retraction of that wall, and it facilitates the accurate placement of interrupted sutures in the back wall.

**Postoperative Care**

In a patient who has impaired liver function or has undergone a major hepatic resection, the results of liver function tests, particularly coagulation studies, should be carefully monitored postoperatively. Transient worsening of these results is not unusual, especially if the procedure was long. Moderately elevated results from coagulation studies (e.g., international normalized ratio < 2.0) are not an indication for treatment with fresh frozen plasma or concentrated coagulation factors unless clinical bleeding is evident.

Postoperative infections may occur as a result of biliary tract contamination, especially if a bile duct stent was placed preoperatively. Antibiotic prophylaxis with broad-spectrum agents for periods longer than usual for perioperative treatment may be appropriate in such cases. If postoperative fever occurs, especially if it is accompanied by unusual pain and tenderness, imaging studies should be promptly obtained and fluid collections sought. In most cases, bile or pus can be drained satisfactorily through percutaneously placed tubes.

**References**


**Recommended Reading**


**Acknowledgment**

Figures 1 through 17  Tom Moore.