Liver transplantation has become a standard medical treatment as a result of many advances in surgical technique, organ preservation, and immunosuppression. Despite this progress, problems of the bile duct remain a significant cause of short-term and long-term morbidity. Biliary complications can extend the hospital stay significantly, and they often require invasive procedures such as endoscopic retrograde cholangiopancreatography (ERCP), percutaneous transhepatic cholangiography (PTC), re-operation, or even retransplantation. In this article, we discuss the two major biliary reconstructions, choledocho-choledochostomy (CC) and Roux-en-Y choledocho-jejunostomy (RYCJ), with their respective advantages and shortcomings. In addition, options for management of biliary complications are addressed. Because of the lack of consensus in the preferred types of biliary reconstruction and management of common complications, we have conducted a survey of 65 of the largest adult liver transplant centers in the United States to supplement this overview. Centers were identified based on participation in the United Network of Organ Sharing (UNOS) Liver Transplant Registry. Data were collected from April 19, 1994 to May 25, 1994. Forty-nine of sixty-five (75%) directors of liver transplantation responded to the survey representing over 90% of all adult orthotopic liver transplants (OLT) performed yearly in the United States.

Historical Perspective of Biliary Reconstruction in Adult OLT

Liver transplantation has advanced rapidly since the National Institute of Health Consensus Development Conference Statement of 1983. Improved graft survival has resulted from breakthroughs in immunosuppression (cyclosporine), the introduction of University of Wisconsin (UW) solution, and better standardization of surgical technique. Despite these advances, biliary complications, mainly biliary leaks and strictures, remain a serious concern. High complication rates have prompted numerous innovative surgical modifications in biliary tract reconstruction. In the 1970s, the loop choledocho-jejunostomy, choledocho-jejunostomy with Roux-en-Y, and the gallbladder conduit were the most widely used anastomosis. In 1982, Starzl and colleagues reported better results of the bile duct in patients undergoing a CC with the use of a T-tube. The duct-to-duct anastomosis emerged as the procedure of choice and was widely used subsequently. Despite a lower incidence of bile leaks, the use of the gallbladder conduit fell out of favor in the United States secondary to an unacceptably high incidence of sludge and calculi formation, as well as cholangitis. Today the CC and the RYCJ are the two most commonly used surgical techniques for biliary reconstruction.

Incidence of Biliary Complications Following OLT

A major challenge in discussing complications obtained from retrospective reviews is to ensure that all investigators use the same definitions. It is difficult to interpret the most recent figures for biliary complications (6% to 47%), because complications may range from a major life threatening problem to a minor incident (Table 1). A common method of reporting outcome following transplantation is highly desirable. Some general trends, however, can be learned from the literature; biliary tract complica-
Devascularization of the biliary system is probably more frequent than is usually recognized. Immuneologic, infectious, sphincter of Oddi dysfunction, vascular, secondary to preservation injury, or OLT. The importance of surgical technique in per-anastomotic leaks, strictures and stent-related problems. Specific problems related to biliary stents include biliary fistula from stent migration, biliary leak at the T-tube exit site, and biliary ascites. Stent-related obstruction can be secondary to stone or sludge formation, stent breakage, kinking or, rarely, migration. Biliary complications have attracted considerable attention because they contribute to an important part of the morbidity seen with OLT, with sometimes fatal outcomes. Most centers thought that excessive length of the donor common bile duct predisposed to biliary complications. Vicente and colleagues demonstrated that brisk capillary bleeding was more important to the success of the graft than was duct length. Important to the success of the graft than was duct length. Important. Important, this can occur either at the site of the biliary anastomosis or in any part of the donor bile duct. Zyajko reported that 86% of patients (30/35) with nonfatal hepatic artery thrombosis (HAT) had biliary complications and that most nonanastomotic biliary strictures were due to ischemia. As a rule, any evidence of biliary stricture or leak should prompt an evaluation of the hepatic artery blood flow. In contrast, the distal (recipient) duct is spared, secondary to the rich collateral circulation from the celiac trunk and superior mesenteric artery, even though the gastro-duodenal artery is ligated at the time of surgery in most cases. Surgical approaches that may prevent biliary tract complications include: (1) avoidance of excessive cleaning of the ducts; (2) trimming back the donor common bile duct until the blood supply is satisfactory; and (3) using a short length of donor common bile duct for the RYCJ reconstruction. As part of our survey, we questioned whether surgeons had a preferred length of donor common bile duct for the RYCJ anastomosis. Eighty percent of centers commented that brisk capillary bleeding was more important to the success of the graft than was duct length. Most centers thought that excessive length of the donor common bile duct predisposed to biliary

Pathophysiology of Biliary Complications

Mechanisms of bile duct complications can be classified as vascular, secondary to preservation injury, immunologic, infectious, sphincter of Oddi dysfunction (SOD) or technical. Combinations of these are probably more frequent than is usually recognized.

Vascular

Devascularization of the biliary system is probably the major cause of biliary complications following OLT. The importance of surgical technique in forming the hepatic artery anastomosis to reduce vascular complications cannot be overstated. Data from Northover and Terblanche suggest that the viability of the donor bile duct is entirely dependent on the integrity of the hepatic artery anastomosis for its blood supply. Loss of vascular integrity of the proximal (donor) bile duct results in stricturing and/or necrosis. Importantly, this can occur either at the site of the biliary anastomosis or in any part of the donor bile tree. Vicente (1994) reported that 86% of patients (30/35) with nonfatal hepatic artery thrombosis (HAT) had biliary complications and that most nonanastomotic biliary strictures were due to ischemia. As a rule, any evidence of biliary stricture or leak should prompt an evaluation of the hepatic artery blood flow. In contrast, the distal (recipient) duct is spared, secondary to the rich collateral circulation from the celiac trunk and superior mesenteric artery, even though the gastro-duodenal artery is ligated at the time of surgery in most cases.

Table 1. Incidence of Biliary Complications Following Orthotopic Liver Transplantation: Retrospective Reviews

<table>
<thead>
<tr>
<th>Author</th>
<th>Number of Transplants</th>
<th>Biliary Complications (%)</th>
<th>Percent of Biliary Complications for Specific Biliary Reconstruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graff (1994)</td>
<td>1792</td>
<td>12</td>
<td>CC</td>
</tr>
<tr>
<td>Rolfes (1994)</td>
<td>123</td>
<td>20 (20/90)</td>
<td>CC-T</td>
</tr>
<tr>
<td>Neuhaus (1994)</td>
<td>335</td>
<td>6 (6/2300)</td>
<td>CC-S</td>
</tr>
<tr>
<td>Clavien (1994)</td>
<td>215</td>
<td>21</td>
<td>CC-Str</td>
</tr>
<tr>
<td>Lopez (1992)</td>
<td>62</td>
<td>27 (27/52)</td>
<td>RYCJ</td>
</tr>
<tr>
<td>Klein (1991)</td>
<td>105</td>
<td>6 (6/204)</td>
<td>RYCJ-S</td>
</tr>
<tr>
<td>Anselmi (1990)</td>
<td>120</td>
<td>47</td>
<td>GC</td>
</tr>
<tr>
<td>Roux (1990)</td>
<td>136</td>
<td>23 (7/38)</td>
<td>NR</td>
</tr>
<tr>
<td>Stratta (1994)</td>
<td>262</td>
<td>19</td>
<td>NR</td>
</tr>
<tr>
<td>Lerut (1987)</td>
<td>365</td>
<td>13 (13/159)</td>
<td>NR</td>
</tr>
<tr>
<td>Hiatt (1987)</td>
<td>76</td>
<td>28 (27/41)</td>
<td>NR</td>
</tr>
<tr>
<td>Vicente (1994)</td>
<td>50</td>
<td>34</td>
<td>NR</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>3669</strong></td>
<td><strong>18% (3361/1850)</strong></td>
<td><strong>NR</strong></td>
</tr>
</tbody>
</table>

NOTE: Values are for percentage of patients with biliary complications for the respective type of reconstruction.

Abbreviations: CC, choledocho-choledochostomy; CC-T, CC with T-tube; CC-S, CC with internal stent; CC-Str, CC with externalized straight stent; RYCJ, Roux-en-Y choledocho-jejunostomy; RYCJ-S, RYCJ with internal stent; GC, gallbladder conduit.

*Modified technique using side-to-side CC.
complications. Still, two centers, which perform 12 and 70 transplants per year respectively, routinely leave up to 5 cm of donor-common bile duct to facilitate reconstruction in case of leak or anastomotic stricture. All centers agree that the presence of bleeding from the donor-common bile duct at the time of the anastomosis is critical to a successful outcome.

**Preservation Injury**

The development of multiple and/or late (30 days to 1 year) intrahepatic strictures in the absence of HAT or stenosis is suggestive of preservation injury, specifically prolonged donor cold ischemia time. In addition to intrahepatic strictures, biliary tract injury of this type has also been associated with ductal dilations, fluid collections, and intrahepatic abscesses. In livers preserved with UW solution, ischemic biliary complications were nearly absent if the livers were preserved for fewer than 11.5 hours. The incidence of strictures increased to 35% for ischemia times longer than 11.5 hours. Others have demonstrated an association between prolonged cold ischemia time and HAT. Although the mechanisms of preservation injury have not been fully elucidated, this entity was seldom seen before the introduction of UW solution and subsequently longer cold ischemia times.

Because most livers with prolonged ischemia times do not develop these injuries, a multifactorial etiology has been implicated. Many surgeons consider that stagnant bile during preservation contributes to the development of intrahepatic strictures, although no data on this mechanism of injury are available. At the time of harvesting, it is current practice in many institutions to wash the biliary tree through a hole in the gallbladder with warm saline and then with cold UW solution after in-situ cooling. The beneficial effect of this technique, however, remains speculative.

**Immunologic**

The role of immunologic mechanisms in the pathogenesis of biliary complications may be more important than usually recognized. ABO blood group antigens are expressed on the epithelial cells of both large and small bile ducts, as well as the endothelium of arteries, veins and sinusoidal cells for long periods of time following transplantation. This might be an important target for immunologic injury. Sanchez-Urdazpal et al reported biliary complications in 82% of ABO incompatible donors, compared with 6% of ABO-matched controls. In addition, HAT was noted in 24% of their ABO incompatible patients. A recent retrospective study from UCLA confirms the higher incidence of HAT and biliary strictures seen in patients with ABO incompatible allografts. This simultaneous injury to the bile duct epithelium and vascular endothelium makes it difficult to determine whether the biliary injury is primarily an immunologic event or a result of devascularization.

**Sphincter of Oddi Dysfunction**

In 1988, Stieber et al reported an unusual complication secondary to CC repair. In a series of 491 CC reconstructions, 34.5% (23/65) of patients with biliary complications had diffuse ductal dilatation without significant stricturing on cholangiography. They postulated that the “diffuse dilatation is the result of papillary dyskinesia that is caused by either devascularization or denervation of the Papilla of Vater during the recipient hepatectomy.” Little data have since appeared in the literature on sphincter of Oddi dysfunction (SOD) following OLT. Douzdjian et al reported four of five post-OLT patients with suspected SOD had either abnormally elevated sphincter of Oddi basal pressures, slow simultaneous phasic activity, and/or paradoxical response to cholecystokinin. Although denervation or devascularization of the porta-hepatis during OLT may account for SOD, the fact that only some patients develop this dysfunction is intriguing. In addition, in the non-transplant setting, Tououli has suggested that operative damage to the sphincter of Oddi seems an unlikely important predisposing factor for SOD. The pathophysiology of this entity remains unclear; preexisting dysfunction of the sphincter of Oddi may play a role.

**Technical Problems Leading to Complications**

Although technical problems may be the most important factor leading to the development of biliary complications, data are not readily available. To delineate current surgical practice, directors of transplantation were asked to comment on suture material and size, running versus interrupted suture placement, stenting practices, and stent materials used in the biliary anastomosis. We did not question centers about technical complications relating to anastomotic leaks and strictures because validation was not possible. Their responses are summarized in Table 2.

As evident from Table 2, PDS (Ethicon, NJ) and Maxon (Davis and Geck, NJ), are two widely used
Table 2. Suture Preference for Biliary Anastomoses

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Material</th>
<th>% Size</th>
<th>% Size</th>
<th>% Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>PDS*</td>
<td>53</td>
<td>32</td>
<td>6'0</td>
</tr>
<tr>
<td></td>
<td>Maxon</td>
<td>29</td>
<td>24</td>
<td>6'0</td>
</tr>
<tr>
<td></td>
<td>Dexon</td>
<td>2</td>
<td>2</td>
<td>6'0</td>
</tr>
<tr>
<td></td>
<td>Vicryl</td>
<td>8</td>
<td>6</td>
<td>6'0</td>
</tr>
<tr>
<td></td>
<td>Prolene</td>
<td>6</td>
<td>3</td>
<td>6'0</td>
</tr>
<tr>
<td>RYCJ</td>
<td>PDS</td>
<td>49</td>
<td>41</td>
<td>6'0</td>
</tr>
<tr>
<td></td>
<td>Maxon</td>
<td>33</td>
<td>29</td>
<td>6'0</td>
</tr>
<tr>
<td></td>
<td>Vicryl</td>
<td>8</td>
<td>6</td>
<td>6'0</td>
</tr>
<tr>
<td></td>
<td>Prolene</td>
<td>6</td>
<td>4</td>
<td>6'0</td>
</tr>
</tbody>
</table>

NOTE. Values represent % of centers surveyed.

Abbreviations: PDS, absorbable, monofilament, polydioxaznone (Ethicon, NJ); Maxon, absorbable, monofilament, polyglyconate (Davis and Geck, NJ); Dexon, absorbable, braided polyglyconate coated with polycaprolate (Davis and Geck, NJ); Vicryl, absorbable, braided polyglyconate and Calcium stearate (Ethicon, NJ); Prolene, non-absorbable, monofilament, polypropylene (Ethicon, NJ).

One center (7 transplants/year) performs CC biliary anastomosis with 4'0 PDS.

suture materials. These monofilament, synthetic, absorbable sutures undergo a process of nonenzymatic hydrolysis without activation of proteolytic enzymes and thus are not felt to elicit the inflammatory response seen with other materials. In 1989, the Pittsburgh group showed statistically fewer biliary complications with monofilament as compared with braided, absorbable sutures. Nonabsorbable, monofilament sutures such as Prolene (polypropylene, Ethicon, NJ) may cause a chronic inflammatory reaction providing a focus for stone formation. In our survey, the size of the suture used in the biliary anastomosis was more variable. Most centers used the same suture size for CC and RYCJ biliary reconstructions. Some reported needle-hole leaks with 5'0 (versus 6'0) if used in the CC anastomosis. Likewise, some think that 6'0 dissolves too early to be used for the RYCJ anastomosis. In addition to suture material, centers were also asked to comment on preferred distance between sutures and choice of running versus interrupted suture placement. All but three centers use interrupted sutures for the CC and RYCJ biliary anastomosis. Thirty-seven percent of centers thought the distance between sutures should be approximately 2 mm. Forty-five percent thought that the distance between sutures was not relevant to the integrity of the anastomosis.

Currently Preferred Biliary Reconstruction in Liver Transplantation

There is still controversy about whether CC is better than RYCJ for primary biliary reconstruction in OLT. No randomized controlled study has been conducted to date comparing these procedures. Instances in which a RYCJ is usually required include primary sclerosing cholangitis, cholangiocarcinoma, biliary atresia, inadequate bile duct size, a large disparity between the donor and recipient ducts, an inability to properly insert or position a T-tube, and most cases of retransplantation. When not faced with these anatomical constraints, the CC is usually “preferred” because it deals with a physiological biliary reconstruction, allows one to visualize the quantity and quality (color and viscosity) of the bile, preserves the sphincter of Oddi, allows easy access for conventional

Table 3. Incidence of Biliary Complications According to Surgical Reconstruction: CC Versus RYCJ

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>% Leaks</th>
<th>% Strictures or Obstruction</th>
<th>% SOD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CC</td>
<td>CC-T</td>
<td>RYCJ</td>
</tr>
<tr>
<td>Rolles/1994</td>
<td>11</td>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td>Neuhaus/1994</td>
<td>N/A</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Orsorio/1993</td>
<td>N/A</td>
<td>26</td>
<td>13</td>
</tr>
<tr>
<td>Lopez/1992</td>
<td>15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Klein/1991</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Roux/1990</td>
<td>3</td>
<td>19</td>
<td>13</td>
</tr>
</tbody>
</table>

NOTE. Values are for percent of patients with complications for the respective type of reconstruction.
Abbreviations: CC, choledocho-choledochostomy; CC-S, Choledocho-choledochostomy with straight stent; CC-T, Choledocho-choledochostomy with T-tube; NR, not reported; RYCJ, Roux-en-Y choledocho-jejunostomy.
endoscopic or radiological procedures to be performed, has a reduced operative time, and can at any time be converted to a RYCJ.

The RYCJ is more time consuming to perform than a CC and requires an extra jejunal anastomosis. Gastrointestinal bleeding at the site of the enterocutaneous anastomosis can be a serious problem. In our experience, this complication has been noted only when the anastomosis was performed with a stapler rather than a hand-sewn technique. In addition, RYCJ is a nonanatomical anastomosis, which prevents ready access using endoscopic procedures. Investigations of RYCJ require either a hepatobiliary radionuclide scan or PTC for evaluation. Although the sensitivity for detection of biliary complications of the radionuclide scan is similar to T-tube cholangiography (63% for both), the latter has better specificity (79% v 60%) and accuracy (74% versus 60%). PTC is associated with the possibility of serious complications such as bleeding (hemobilia). Some complications seen with CC such as bile leak after T-tube removal and those related to sphincter of Oddi dysfunction are not seen in patients with RYCJ. Mucocele formation, which is usually associated with CC anastomoses, can occur in RYCJ only if the cystic duct has not been excised. Table 3 summarizes the most recent large retrospective reviews, with particular reference to the type of reconstruction and common complications with each.

Prefer the CC was not an absolute finding in our survey. Two notable exceptions to the use of the CC biliary anastomosis included one small center (seven transplantations per year) in which the RYCJ is preferred in all cases, and a second, larger center (80 transplantations per year) that uses CC in only 25% to 40% of cases. The latter reports excellent results using the RYCJ in the majority of cases despite having adequate ducts for a CC anastomosis. All centers in our study use an end-to-end anastomosis for their choledocho-choledochostomy.

**To Stent or Not to Stent**

**CC Without the Use of a Stent**

Because about half of the biliary complications in patients with a CC reconstruction are directly related to the use of the T-tube, some investigators have proposed abandoning its use. Although data on duct-to-duct reconstructions without the use of T-tubes have been from small series with mixed results, several centers have recently adopted this practice. In 1988, Wall et al reported a series of 92 consecutive OLTs in which 80 had an end-to-end, duct-to-duct anastomosis without the use of a T-tube or stent. Instead, the donor gallbladder was left undisturbed whenever possible, and an external choledochojunostomy constructed. They noted 13.8% biliary complications. In 1990, Rouch et al reported a statistically significant difference in complication rates between 25 patients undergoing OLT with CC-T (35%) and 38 patients with CC alone (18%). The cohorts were not randomized, and decisions on specific surgical procedures were based on duct size, patient age and surgeon preference. Of the early complications noted in the adult patients with CC-T, 4 had dislodged T-tubes with leak, 1 obstruction, and 1 case of cholangitis compared with 1 leak and one obstruction with CC alone. Late complications occurred in no patient with CC-T and in 5 patients with CC alone. These included 4 obstructions secondary to sludge and one obstruction/cholangitis with resultant death. The investigators concluded that CC without T-tube is safe and had a significantly lower early complication rate than did CC-T and recommended its use whenever possible. Finally, Rolles et al retrospectively reviewed 106 CC reconstructions. They noted 10 of 90 (11.1%) leaks with CC alone compared with 4 of 16 (25%) leaks with T-tube. They concluded that direct CC anastomosis can be performed safely without T-tube. It is of note that 10 patients developed strictures in the group without T-tubes requiring further invasive procedures.

The technique of using a CC anastomosis without a T-tube has not been widely applied until recently. Traditional reasons cited include loss of easy access to the biliary tree, potential for increased postoperative strictures and increased biliary tract pressure in cases of SOD. This increased pressure may result in anastomotic bile leak in the absence of prompt endoscopic drainage. Also, T-tubes allow one to visualize bile during the early postoperative period. Dark green or brown bile is an excellent indicator of proper graft function. The lack of a T-tube precludes easy bile drainage in the case of cholestasis or cholangitis. The only access both radiologically and therapeutically appears to be through the use of the ERCP or PTC.

Data from our survey indicate a marked change in methods for duct-to-duct reconstructions. Seven transplant centers in the United States (14% of centers from our survey), currently perform CC reconstructions without the use of a T-tube or stent. Two of these centers perform over 100 adult liver transplants per year. Six centers have abandoned their use over
the past 6 months. A large, randomized trial of CC-T versus CC without stenting is currently in progress. Such a study is greatly welcome to conclusively define the role of a T-tube in CC. In addition, three centers (6% of centers surveyed) have changed from the use of T-tubes to the use of a long, straight stent that exists via the cystic remnant and is externalized to maintain cholangiographic access. The remainder (80% of centers) continue to use a T-tube.

Many have questioned whether the material used for the T-tube predisposes to biliary complications. A significant number of leaks have been reported with the use of silastic tubes. Neuhaus et al suggest that with a CC anastomosis, some investigators have tried stenting of an anastomosis is traditionally indicated when the surgeon foresees the potential of downstream obstruction. Contrary to CC reconstruction that embodies the risk of sphincter of Oddi dysfunction, there is no downstream obstruction in RYCJ reconstruction. In addition, a stent is of no help in the presence of early leaks because re-operation is usually preferred whether or not a stent is present. Strictures can be treated surgically or by percutaneous dilation. From our survey, 38 centers (78% of centers surveyed) continue to use stents for their RY anastomosis. These stents are usually made from a polyethylene pediatric feeding catheter that is externalized (55%; 21/38) or cut to be an internal stent (45%; 17/38). Externalized RYCJ stents are usually removed 30 days after surgery. Fifteen of the 17 centers using internal stents allow normal peristalsis to eject it from the duct. Most of these centers place a single catgut suture to secure this internal stent to the bowel wall to prevent premature ejection. Some have experienced major problems with retained internal stents including delayed obstruction and sepsis. Two of the 17 centers using internal stents ‘milk’ the stent into the Roux limb after constructing the anastomosis.

The main argument for use of a stent in the RYCJ anastomosis is to ease the biliary-enteric anastomosis, particularly in the presence of a small hepatic duct. Clearly, magnification loupes allow surgeons to perform perfect mucosa-to-mucosa anastomosis without the use of a stent even between minute ducts. Stenting of an anastomosis is traditionally indicated when the surgeon foresees the potential of downstream obstruction. Contrary to CC reconstruction that embodies the risk of sphincter of Oddi dysfunction, there is no downstream obstruction in RYCJ reconstruction. In addition, a stent is of no help in the presence of early leaks because re-operation is usually preferred whether or not a stent is present. Strictures can be treated surgically or by percutaneous dilation. From our survey, 38 centers (78% of centers surveyed) continue to use stents for their RY anastomosis. These stents are usually made from a polyethylene pediatric feeding catheter that is externalized (55%; 21/38) or cut to be an internal stent (45%; 17/38). Externalized RYCJ stents are usually removed 30 days after surgery. Fifteen of the 17 centers using internal stents allow normal peristalsis to eject it from the duct. Most of these centers place a single catgut suture to secure this internal stent to the bowel wall to prevent premature ejection. Some have experienced major problems with retained internal stents including delayed obstruction and sepsis. Two of the 17 centers using internal stents ‘milk’ the stent into the Roux limb after constructing the anastomosis.

**Diagnosis and Treatment of Biliary Tract Complications**

It is widely accepted that significant reductions in morbidity have resulted from early recognition, diag-
nosis, and treatment of biliary problems. Cholangiograms, whether intraoperative, via T-tubes, percutaneous or endoscopic, are vital tools. From our survey, routine intraoperative cholangiograms (IOC) are performed at the time of the initial anastomosis by 65% (32/49) of surgeons performing CC and 27% (13/49) of those performing RYJC reconstructions. Those that use IOC report detecting problems in 2% to 10% of cases. This low-yield and time-consuming procedure has caused many surgeons to abandon its routine use. Others report testing the integrity of the anastomosis with saline only. In the postoperative setting, routine intervals for cholangiograms are highly influenced by the presence of a T-tube or externalized stent. When present, most centers check a routine cholangiogram between day 4 to 7 (65%; 32/49) and clamp the tube at that time if no problems are detected. This permits the enterohepatic circulation of bile to resume, and oral cyclosporine is usually started at this time. Seventy-one percent (35/49) of respondents report checking a cholangiogram routinely before removal of the T-tube.

Much debate exists over the proper time for T-tube removal. The range from our survey is from 6 weeks to 6 months after transplantation. Most centers remove the T-tube at 3 months (54% of centers; 21/39), 4 months (18%; 7/39), or 6 months (15%; 6/39). The appropriate time for T-tube removal has not been determined by randomized trials. T-tubes are removed by external traction in all but 6 centers; the latter use fluoroscopy with guide wires (5/6) or transpapillary removal with ERCP (1/6). Transplant centers that use an externalized stent that exits via the cystic remnant remove these tubes by external traction from 6 weeks to 6 months after surgery.

Investigations of RYJC require either a hepatobiliary radionuclide scan or PTC for evaluation. Centers which perform the biliary anastomosis without radiographic access via a stent usually follow patients clinically for evidence of biliary complications. Some perform routine biliary scintigraphy 1 week after transplantation.

Clinical and laboratory manifestations of biliary tract complications include increasing serum bilirubin, alkaline phosphatase, white blood cell count, fluctuations in cyclosporine levels, fever, abdominal pain, acute cholangitis, or septicemia. Such abnormalities should prompt an investigation related to the potential causes of biliary problems. Unless the clinical and histological evidence are obviously indicative of rejection, an early attempt at visualization of the biliary anatomy is mandatory. Doppler ultrasound (US) and angiography are used to exclude HAT. Transabdominal sonography has often been the first imaging technique used to rule out biliary obstruction, although it has variable sensitivities ranging from 54% to 100%. In particular, US has been shown to be of little value in ruling out biliary tract dilation in the patient after transplantation. The high incidence of false negative exams in some series results from the frequent lack of bile duct dilation in patients with biliary complications. Biliary sludge, bowel gas, or inadequate scans are also cited as reasons for failure of this technique. If a T-tube is used and still in place, T-tube cholangiography will allow for visualization of the biliary tree. In the absence of a T-tube, the choice of procedure depends on the type of reconstruction. In patients with CC anastomosis, PTC or ERCP can be attempted. Some investigators think that PTC is the best method to evaluate the biliary tract when the T-tube is not in place whereas others routinely use ERCP. In fact, the imaging modality selected usually reflects the abilities at each institution. We favor the endoscopic approach over the percutaneous approach in all CC reconstruction cases to avoid liver parenchymal injury and to decrease pain and discomfort. In the setting of a RYJC reconstruction, doppler US is used as the initial test to assess the hepatic artery and biliary tree. PTC or radionuclide scans are reserved for a strong suspicion of obstruction with no or questionable bile duct dilation.

**Treatment of Anastomotic Leaks**

No definitive study has been performed on the treatment of anastomotic biliary leaks following transplantation. Although diagnostic and therapeutic ERCP is not considered feasible in patients with RY anastomosis, its limited use in patients with CC anastomosis presumably reflects a preference by many centers for re-operation rather than an endoscopic or percutaneous approach. Percutaneous therapy may be difficult secondary to the frequent lack of biliary tract dilation. Endoscopic techniques provide an alternative to reoperation when faced with biliary leaks. Options include endoscopic sphincterotomy, nasobiliary catheter drainage or endoprosthesis placement. When an endoprosthesis is placed, it is necessary to transverse the anastomosis for proper drainage and healing. Associated large bile collections outside of the biliary tree (bilomas) usually require percutaneous drainage, although the endoscopic management of bilomas has been described.
survey indicate that CC anastomotic leaks (not secondary to hepatic artery occlusion) are managed quite differently at the various institutions, further emphasizing the lack of consensus. Fifty-one percent of centers (25/49) will re-operate if the cholangiogram suggests an CC anastomotic leak, whereas others try therapeutic endoscopy (16%; 8/49), conservative management (12%; 6/49), nasobiliary drainage (10%; 5/49), and percutaneous therapy (2%; 1/49). Sixty-one percent of centers (30/49) re-operate when faced with RYCJ anastomotic biliary leaks, whereas 18% (9/49) use a percutaneous approach and 10% of centers (5/49) attempt conservative measures.

### Treatment of Anastomotic Strictures

Anastomotic strictures usually present after T-tube clamping, removal, or internal stent migration. Some anastomotic strictures respond to percutaneous or endoscopic therapy, whereas others require surgical revision. Multiple dilations and endoprosthesis exchanges may be required if nonsurgical modalities are used. McDonald et al found percutaneous balloon dilation to be useful in the treatment of anastomotic strictures. Wolfsen et al described the successful management of isolated bile duct anastomotic strictures with endoscopic dilation and stent placement. Forty-five percent (22/49) of transplant centers rely on therapeutic ERCP when faced with CC anastomotic strictures, whereas 29% (14/49) choose to re-operate, and 22% (11/49) use percutaneous techniques. If the endoscopist or radiologist fails to achieve adequate drainage despite repeated attempts at dilation and stenting, options include surgical revision or the placement of a larger, expandable stent. Several centers have placed indwelling, self-expanding metal stents for intrahepatic and common bile duct anastomotic strictures. Although some investigators report long-term success with this technique, others note a high incidence of sludge and debris with subsequent stent blockage from 1 month to several years following insertion (survey information, and personal unpublished data). The importance of using ursodeoxycholic acid to prevent this problem is often suggested, although no data are available. RYCJ anastomotic strictures are usually treated by biliary decompression through PTC and balloon dilation (63% of centers; 31/49), although 33% of centers (16/49) choose surgical revision as the initial therapy.

### Treatment of T-tube leaks

T-tube leaks are reported in 0 to 40% of liver transplants. Early postoperative leak at the T-tube insertion site is an uncommon complication which usually occurs while the T-tube is still in place. This is usually treated by leaving the T-tube open until the leak heals. A relatively high incidence of leaks at the T-tube exit site when the T-tube is removed has been reported. This has led to the dissatisfaction with T-tubes at a number of centers. Preferred treatments for these leaks are more variable and consist of observation, surgical correction, or endoscopic management. Lopez et al advocate re-operation for uncontrolled T-tube leaks with bile accumulation before T-tube removal, whereas bile leaks after T-tube removal can be managed nonoperatively. Other centers have reported favorable experience with endoscopic therapy. Ostroff et al used nasobiliary drains as initial therapy in 12 patients with biliary leak following T-tube removal. Seven French (F) pigtail-shaped nasobiliary draining tubes were left in place for 3 to 14 days with no reported complications. Nasobiliary tubes are used because of their ease of insertion and removal and for the radiological access provided. Lastly, Wolfsen et al successfully treated patients having T-tube leaks with endoscopic sphincterotomy alone.

In 1993, investigators from UCLA reported the only prospective study to evaluate the efficacy and safety of endoscopic management of biliary leaks following liver transplantation. The series included 18 patients with evidence of bile peritonitis after migration or removal of a T-tube. Leaks healed in 94% of patients after placement of nasobiliary drain (n = 13), internal stent, and endoscopic sphincterotomy (n = 2), or internal stent alone (n = 2). All patients were followed for 9 months for evidence of biliary complications, which occurred in 11.1%. Our survey indicates that although 55% of centers (27/49) treat T-tube related leaks conservatively, 12% (6/49) place a 7 to 10-F internal stent, 12% (6/49) place nasobiliary catheters, and 6% (3/49) choose to re-operate.

### Conclusion

Biliary complications following orthotopic liver transplantation are numerous and complex. The lack of prospective, randomized data on the best type of biliary reconstruction and treatment of choice for these complications has lead to significant confusion.
in this area. The diverse techniques identified by our survey highlight the magnitude of the problem.

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