Choledochal Cysts

5

Mark D. Stringer

Abbreviations

CBD	Common bile duct
CC	Choledochal cyst
CHD	Common hepatic duct
ERCP	Endoscopic retrograde cholangiopancreatography
GGT	Gamma-glutamyltransferase
MRCP	Magnetic resonance cholangiopancreatography
PBM	Pancreaticobiliary malunion

5.1 Introduction

A choledochal 'cyst' is a congenital dilatation of the bile duct(s). A better term would be congenital choledochal dilatation, but the 'cyst' nomenclature is so embedded in the literature that this chapter will refer to choledochal cysts (CCs).

5.2 Epidemiology

Choledochal cysts are particularly common among people from the Orient. It is estimated that pancreaticobiliary malunion (PBM), which is commonly associated with CCs, affects as many as 1 in 1000 Japanese [1]. The incidence of CCs was

M. D. Stringer
Department of Paediatric Surgery, Wellington Hospital, Wellington, New Zealand

Department of Paediatrics and Child Health, University of Otago, Wellington, New Zealand
e-mail: mark.stringer@ccdhb.org.nz

S. G. Barreto, J. A. Windsor (eds.), *Surgical Diseases of the Pancreas and Biliary Tree*,
https://doi.org/10.1007/978-981-10-8755-4_5

previously reported to be about 1 in 100,000 live births in Western populations but may be increasing, either because of better detection or a genuine increase in incidence [2, 3]. More than two-thirds of CCs are diagnosed in children under 10 years, and girls outnumber boys by 3 or 4:1.

5.3 Classification

CCs are traditionally divided into five types (Fig. 5.1) [4]. Type I cysts are cystic or fusiform and account for at least 70% in most series [3, 5] (Fig. 5.2). Next in frequency are type IVa cysts, which consist of multiple cystic dilatations of the extra- and intrahepatic bile ducts (Fig. 5.2). Collectively, types I and IVa account for more than 90% of CCs. A type II diverticulum may affect the common bile duct but is most often seen at the level of the common hepatic duct [6]. A type III cyst (choledochocele) is a dilatation of the terminal common bile duct within the duodenal wall. Ziegler et al. suggest that type III cysts are not CCs because they may be acquired, may be lined by duodenal mucosa, are less prone to malignant change, have a more equal sex incidence and are not usually associated with PBM [7]. Type IVb (multiple extrahepatic duct cysts) and type V (single or multiple intrahepatic duct cysts) are rare. Multiple saccular dilatations of the intrahepatic bile ducts (Caroli's disease) may affect the liver diffusely or be localised to a lobe. When combined with renal anomalies and hepatic fibrosis, it is known as Caroli's syndrome. PBM can occur with minimal or no bile duct dilatation and has been termed a 'forme fruste' CC [8, 9] (Fig. 5.3). Isolated congenital cystic duct dilatation is exceptionally rare but should probably be included within the spectrum of CCs because of its association with PBM [10].

5.4 Pathology

There are three components to the pathology of a CC: the duct dilatation itself which may be complicated by inflammation, bile duct obstruction, infection, stones, perforation or malignancy; PBM, present in most but not all cases; and the potential for secondary liver disease (fibrosis, cirrhosis and abscess formation). Type Ic cysts typically extend from just below the origin of the common hepatic duct (CHD) to where the common bile duct (CBD) becomes embedded in the pancreas; at this level the CBD may be stenotic. Distal CBD obstruction is associated with higher intracholedochal pressures and more severe liver damage [11]. The gallbladder is often normal in size. Type If cysts are typically associated with PBM which may be further complicated by protein plugs within the common pancreaticobiliary channel. A stricture, or strictures, may involve the CHD or hilar ducts, particularly with type IVa cysts [12]. The epithelial lining of the CC may be ulcerated and exhibit metaplasia or dysplasia in older patients [13]. Hepatic histology may be normal or show

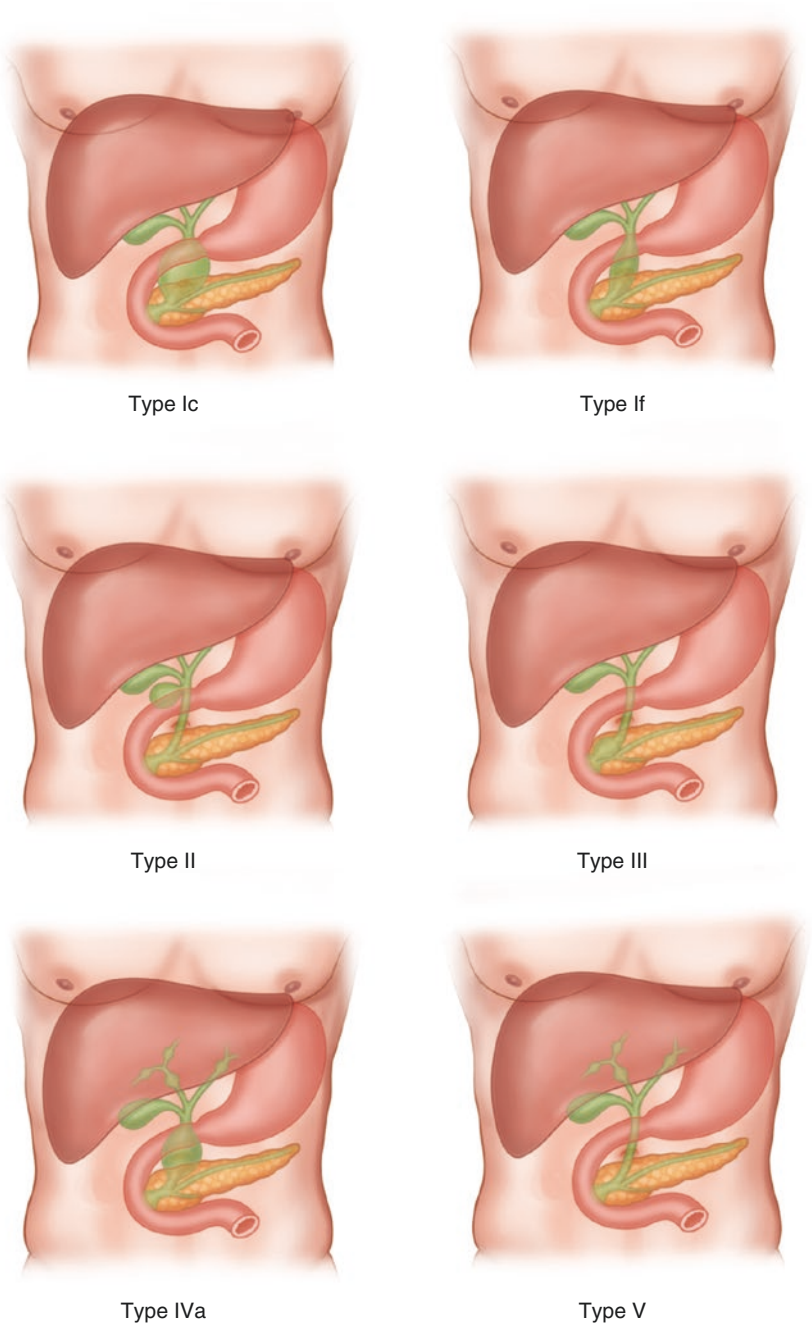

Fig. 5.1 Classification of choledochal cysts (based on Todani et al. 1977) [4]. Type I, cystic (Ic) or fusiform (If); type II, diverticulum of the extrahepatic bile duct, type III, choledochocele (dilatation of the terminal common bile duct within the duodenal wall); type IV, multiple cystic dilatations of the extra- and intrahepatic bile ducts (IVa) or multiple extrahepatic duct cysts (IVb); type V, intrahepatic duct cysts (single or multiple)

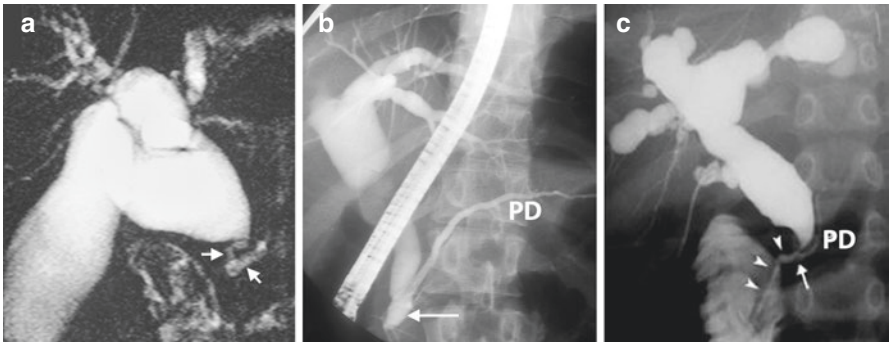

Fig. 5.2 (**a**) MRCP in an infant demonstrating a type Ic cyst with PBM (white arrows). (**b**) ERCP showing a type If cyst with PBM (white arrow). (**c**) Intraoperative cholangiogram of a type IVa cyst with PBM (white arrows). *PD* pancreatic duct

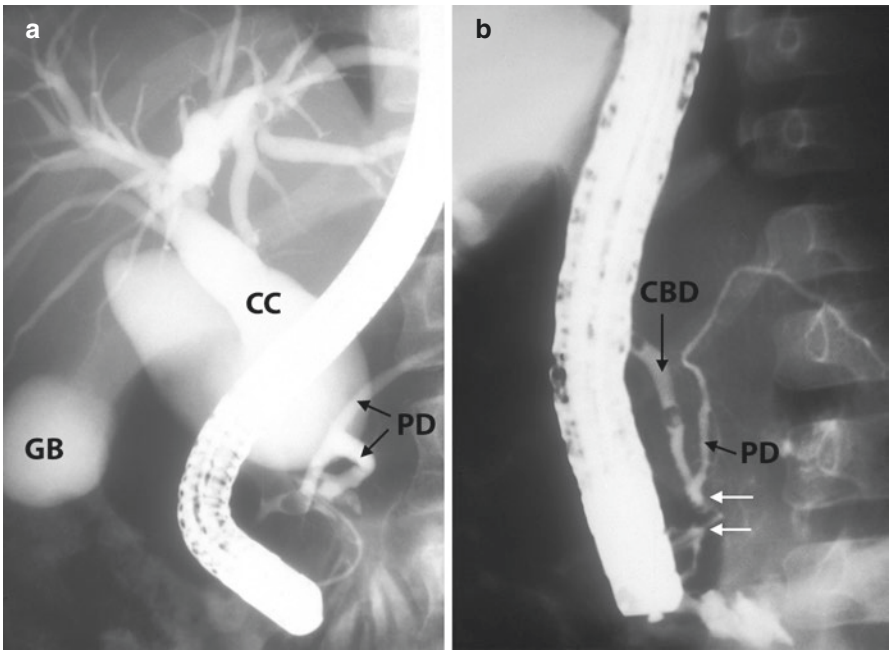

Fig. 5.3 (**a**) ERCP demonstrating complex pancreaticobiliary malunion associated with a fusiform CC. *GB* gallbladder, *PD* pancreatic duct, *CC* choledochal cyst. (**b**) ERCP showing pancreaticobiliary malunion (white arrows) with no CBD dilatation, the so-called 'forme fruste' CC. The filling defects in the CBD are air bubbles. *CBD* common bile duct

mild cholestasis and intrahepatic bile duct inflammation; periportal fibrosis and secondary biliary cirrhosis may develop in response to chronic bile duct obstruction [14]. The major duodenal papilla may be situated more distally in the second or even third part of the duodenum, particularly in the presence of PBM [15]. Other associated anatomical variants include an aberrant right sectoral or segmental bile duct joining the CHD or the cyst itself and a right hepatic artery crossing the cyst anteriorly [16]. Portal hypertension can develop as a result of portal vein compression by the cyst, hepatic fibrosis or cirrhosis.

5.4.1 Pancreaticobiliary Malunion

Choledochal cysts are frequently associated with an abnormal junction between the pancreatic duct and terminal CBD, such that the ducts join outside the wall of the duodenum and are not surrounded by a normal sphincter [17]. The anatomy of PBM (also known as anomalous pancreaticobiliary junction or a common pancreaticobiliary channel) varies depending on whether the CBD appears to join the pancreatic duct, or vice versa, or whether the junction is more complex [18] (Fig. 5.3). The abnormally long common channel often exceeds 5–10 mm in children [19] and 10–15 mm in adults. Because pancreatic ductal pressure normally exceeds that in the bile duct, PBM favours reflux of pancreatic juice into the biliary tract [20], leading to high concentrations of pancreatic enzymes within the bile. Reflux of pancreatic fluid into the bile duct has been observed by dynamic imaging during secretin-stimulated MRCP [21]. On occasions, bile enters the pancreatic duct [22] and may cause pancreatitis. PBM is present in about 70% of type I and IVa cysts [23] and in an even greater proportion of type If cysts [24]. It may also occur in the absence of choledochal dilatation [9, 25]. Chronic pancreaticobiliary reflux predisposes to the development of cancer in the gallbladder and CC [26].

Malformations outside the biliary tree in patients with a CC are rare. There are sporadic reports of associations with congenital cardiac disease, intestinal malrotation, duodenal atresia/stenosis, pancreas divisum and renal abnormalities [27–31].

5.5 Aetiology and Pathogenesis

Two main theories concern the origin of CC. The first of these suggests that a CC develops from an acquired weakness in the wall of the bile duct consequent on reflux of pancreatic juice and bile duct inflammation [32, 33]. However, PBM is not present in all patients with a CC, and it can occur in individuals without duct dilatation. Further, some CCs are detected prenatally or in early infancy before pancreatic enzyme secretion is mature [34–36]. The second theory states that a CC arises from distal obstruction of the CBD. In support of this, a stenosis is often seen immediately below a type Ic cyst. Ligation of the distal CBD in foetal lambs causes cystic

dilatation of the proximal bile duct [37]. Faulty development of the pancreaticobiliary junction and/or distal CBD may cause the obstruction. There is growing evidence to suggest that the cause of PBM is abnormal development of the ventral pancreatic anlage during embryogenesis [1]. Yet another theory suggests that a CC arises from a deficiency of interstitial cells of Cajal (the cells involved in regulating smooth muscle motility) in the wall of the bile duct [38]. However, any reduction in the density of these cells might be secondary to choledochal dilatation/inflammation. Such a mechanism has been postulated to explain the reduced density of ganglion cells in the wall of CCs [39]. None of these theories adequately explain the development of type IVa cysts.

In summary, whilst no individual theory is entirely convincing, the pathogenesis of a CC is probably related to faulty development of the pancreaticobiliary junction and/or distal bile duct leading to a variable degree of bile duct obstruction.

Genetic factors are presumably involved considering the ethnic variations and female preponderance of CC. However, familial CC is extremely rare [40], and twin studies have not identified an obvious genetic predisposition [41]. Gene sequencing suggests that CCs are genetically heterogeneous and mutations in several genes are probably necessary for their development [42].

5.6 Clinical Presentation

CC can present at any age, but approximately 80% are diagnosed before 10 years [27, 43]. Typical presenting symptoms include abdominal pain, vomiting, jaundice and/or fever. There are age-related variations in presentation:

5.6.1 Prenatal

A CC may be detected by prenatal ultrasound scan as early as 15 weeks of gestation [27, 44]. Most are type Ic although a few are type V. If a type Ic cyst is confirmed postnatally, early surgical treatment is advisable, particularly if the infant is jaundiced.

5.6.2 Infants

Infants are more likely than older children or adults to have a type Ic cyst and to present with obstructive jaundice [36, 45]. Vomiting, fever, failure to thrive and an abdominal mass are sometimes noted. In those with PBM, hyperamylasaemia is uncommon because the amylase concentration in bile is often low until about 1 year of age [34–36]. However, biliary concentrations of pancreatic lipase, elastase and trypsin are often significantly elevated [35, 46]. Liver fibrosis and cirrhosis from biliary obstruction can develop rapidly at this age but are reversible by early surgery [36, 47, 48]. Results of surgical treatment in infants are generally excellent [44, 49, 50].

An important differential diagnosis of a type Ic cyst in a jaundiced infant is a cystic variant of biliary atresia. If the cyst was detected prenatally, then enlargement of the cyst on serial scans favours CC pathology [51] as does the presence of dilated intrahepatic bile ducts postnatally [52]. A dynamic biliary radioisotope scan may help to distinguish the two conditions (there being no isotope excretion into the gut in biliary atresia), but if there is diagnostic doubt, the infant must be assumed to have biliary atresia until proven otherwise.

5.6.3 Older Children

Abdominal pain is a common presenting symptom in this age group [36, 45]. This may be accompanied by hyperamylasaemia [53]. If jaundice is present, it tends to be intermittent. The classic triad of jaundice, pain and a right upper quadrant mass is uncommon [27].

Diagnostic delay may be due to inadequate investigation of jaundice or pancreatitis or a failure to appreciate the significance of a dilated CBD [27]. A CC must be considered in the differential diagnosis of obstructive jaundice and/or pancreatitis. A child with recurrent or severe abdominal pain should have a plasma amylase checked. Hyperamylasaemia associated with a CC and PBM may be secondary to acute pancreatitis but is often a biochemical finding alone, with no clinical or radiological signs of pancreatitis [35, 46]. In these cases, hyperamylasaemia may be from diffusion of pancreatic amylase through the cyst epithelial lining or from pressure-induced cholangiovenous reflux of pancreatic amylase.

5.6.4 Adults

Most CCs in adults present with abdominal pain [3]. Adult CCs are more likely to be complicated by gallstones, cholangitis or pancreatitis than children [5]. Previous biliary intervention for stones or infection prior to diagnosis is not uncommon [3, 54]. In up to 10% of adults presenting with a CC, there may be complications such as hepatolithiasis, biliary malignancy or portal hypertension [5]. Malignancy at presentation is rare in patients younger than 30 years [3, 54]. Compared to children, adults have a greater proportion of type IV cysts [3, 54]. The relatively rare type II and III cysts are also more often seen in adults, and frequently present with pancreatitis [6, 7].

5.7 Complications

Choledochal cysts are associated with numerous complications (Fig. 5.4) which include:

- *Cholangitis*—This presents with jaundice, abdominal pain and fever. The causative organism is usually a Gram-negative bacterium.

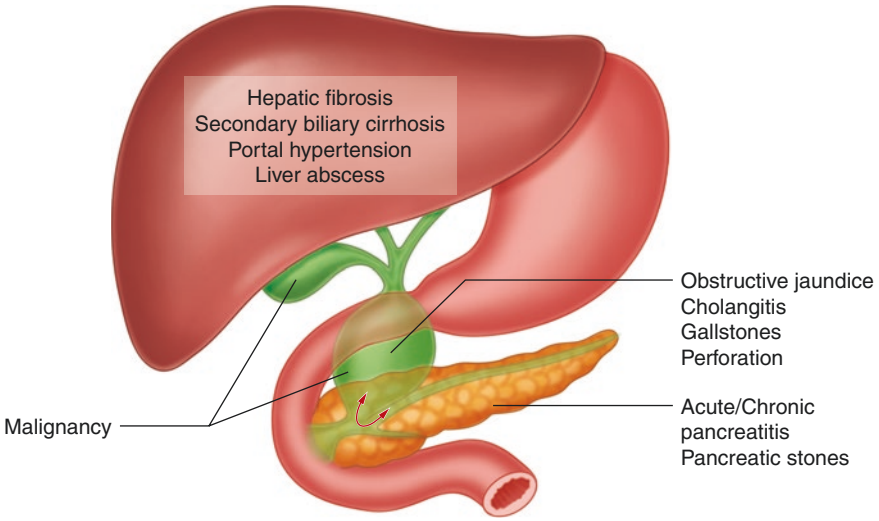

Fig. 5.4 Potential complications of choledochal cysts

- *Perforation/rupture*—This usually occurs spontaneously and mostly in children under 5 years [3, 27, 55, 56]. Perforation is the presenting feature in about 4% of paediatric CCs [3, 56]. The perforation may occur in any part of the wall of the cyst and is usually single (Fig. 5.5). Intraperitoneal rupture with biliary peritonitis is more common than retroperitoneal rupture, which presents more insidiously. Clinical symptoms and signs include abdominal pain, distension, vomiting, fever, mild jaundice and biliary ascites. Diagnosis is usually made by clinical assessment, abdominal ultrasound scan and a peritoneal tap [56, 57]. A biliary isotope excretion scan is occasionally helpful in diagnosis in atypical presentations. If the expertise is available, definitive surgery is associated with a good outcome [56]. In less-experienced centres or if the child is critically ill, temporary drainage of the cyst (e.g. repair of the perforation over a T-tube) followed by definitive surgery once the patient has recovered and the anatomy has been clearly defined is a safer option.
- *Pancreatic disease*—Recurrent acute or chronic pancreatitis may be caused by PBM, particularly if the common pancreaticobiliary channel is dilated or anatomically complex when it is more likely to contain protein plugs and calculi (Fig. 5.6).
- *Gallstones*—Gallstones or biliary sludge may develop from stasis within the biliary system. Yamaguchi (1980) reported an 8% prevalence among 1433 Japanese patients with a CC [43].
- *Portal hypertension*—This may develop from portal vein compression by a large CC, hepatic fibrosis/biliary cirrhosis from prolonged biliary obstruction or,

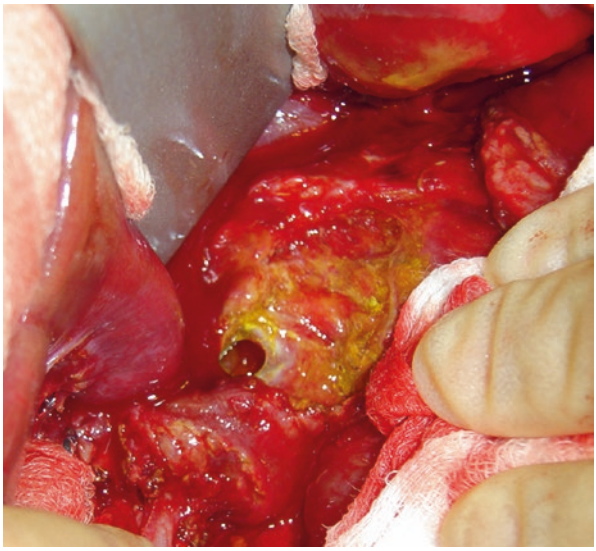

Fig. 5.5 Operative appearance of a perforated CC

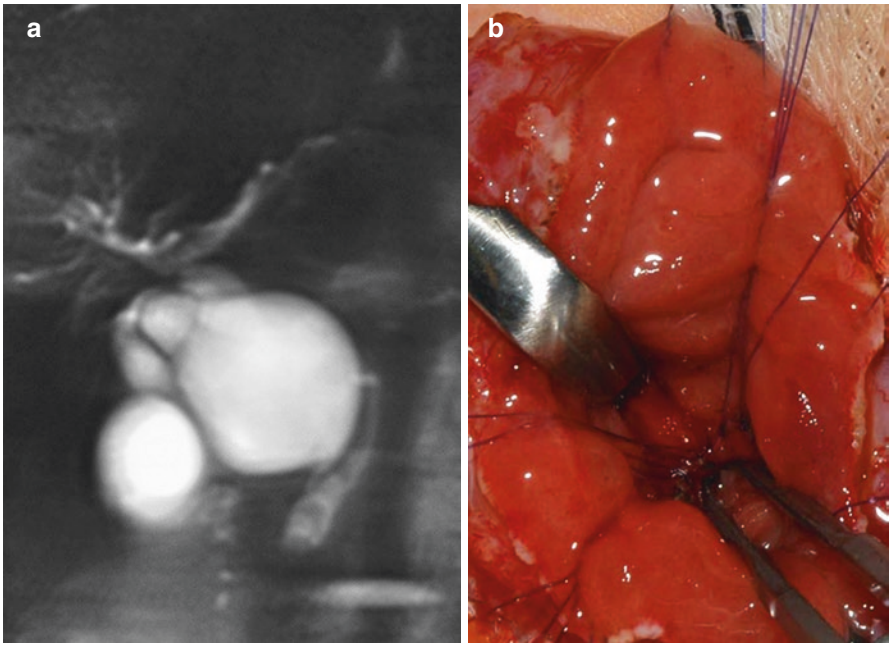

Fig. 5.6 (**a**) MRCP demonstrating a type Ic cyst with PBM in a child. The common pancreaticobiliary channel contained protein plugs and when the CC was excised a sphincteroplasty was performed (**b**) to enable clearance and drainage of the dilated common channel

rarely, portal vein thrombosis. Severe portal hypertension with large varices must be controlled prior to CC surgery [5, 58]. Transjugular intrahepatic portosystemic shunting is a useful approach unless the patient has advanced cirrhosis, when liver transplantation may be necessary.

- *Secondary biliary cirrhosis*—Liver fibrosis or cirrhosis arising from chronic biliary obstruction by a CC is more commonly seen in infants than in children and adults [14, 36, 59]. Liver fibrosis has been documented as early as 4 weeks of age [48] and cirrhosis within 2–3 months [48, 60, 61]. Liver fibrosis and early cirrhosis are potentially reversible if the obstructing CC is treated promptly and appropriately, although these patients may develop transient postoperative ascites [61] (author's unpublished observations). Liver transplantation is occasionally required for a CC with advanced liver disease [59, 61].
- *Malignancy*—This complication mainly affects adults although it has been described in a few children [43, 62]. In type Ic cysts, malignancy affects the cyst wall or gallbladder, whereas in type If, the gallbladder is the dominant site. In type IVa CCs, hilar or intrahepatic ducts may be affected. Histology of these cholangiocarcinomas or gallbladder cancers is usually that of an adenocarcinoma but squamous cell cancers have occasionally been reported [62–64]. The cancer risk increases with age. In a large retrospective Korean multicentre study, 10% of adults operated for a CC had a concurrent biliary tract malignancy [65]. Factors predicting malignancy were age >40 years and PBM. PBM without choledochal dilatation predisposes to gallbladder cancer in adults [66]. Reflux of pancreatic enzymes into the bile ducts causes inflammation, increases biliary epithelial turnover [67] and may induce oncogene mutations [25]; epithelial damage is further exacerbated by stones and infection. Malignant change may be preceded by epithelial metaplasia and/or dysplasia [68]. The risk of malignancy is particularly high in patients who have been treated inappropriately by internal drainage of a CC (cystenterostomy) [69].

5.8 Investigations

Biochemical liver function tests can be normal or may show obstructive jaundice. Hyperamylasaemia may be present during an episode of abdominal pain. Clotting disturbances must be excluded in patients with jaundice.

Ultrasonography is the initial imaging modality of choice. The position, size and contour of the CC, the calibre and morphology of the proximal bile ducts, vascular anatomy and hepatic echotexture can be evaluated together with any disease complications. Mild but abnormal dilatation of the CBD/CHD must not be overlooked or dismissed: the diameter of the normal CBD measured by ultrasound is up to 2 mm in infants, up to 4 mm in children under 12 years and up to 10 mm in adults [70–72].

Magnetic resonance cholangiopancreatography (MRCP) is the next imaging investigation (Figs. 5.2 and 5.6). Bile and pancreatic juice have high signal intensity on T2-weighted images. Adequate definition of the pancreatic duct and PBM was

previously a concern, but this is now increasingly possible, even in infants, if modern scanners and image acquisition techniques are used [73, 74]. Thin-slice maximum-intensity projections provide the surgeon with an anatomical road map. MRCP may also detect associated gallstones and cholangiocarcinoma [74].

Endoscopic retrograde cholangiopancreatography (ERCP) provides excellent visualisation of the cyst, bile duct anatomy and pancreaticobiliary junction (Figs. 5.2 and 5.3) but is associated with a small risk of complications including acute pancreatitis and biliary sepsis. ERCP is useful when the degree of biliary dilatation is minimal or if an MRCP has failed to clarify the anatomy of the pancreaticobiliary junction. These instances are becoming increasingly uncommon with modern MRI scanners and techniques.

Hepatobiliary scintigraphy may occasionally be useful in selected patients, e.g. the jaundiced infant with a suspected cystic variant of biliary atresia. Contrast-enhanced CT may be helpful in evaluating pancreatitis or a suspected tumour.

Distinguishing type I cysts with intrahepatic dilatation from type IVa cysts on preoperative imaging can be difficult, resulting in a tendency to overcall type IVa cysts [45, 75]. The intrahepatic ducts in type IVa are often irregular with sacculations and stenoses unlike the smooth intrahepatic duct dilatation seen with obstructing type Ic cysts (although type I cysts may be associated with hilar duct strictures). Resolution of the intrahepatic duct dilatation after successful treatment of the extrahepatic CC indicates a type I cyst [76].

A full blood count, liver function tests, plasma amylase, clotting studies and blood group are routinely checked prior to surgery and the imaging reviewed. In most cases the latter will be a high quality MRCP. The possibility of variant anatomy should be considered, e.g. an aberrant right sectoral duct joining the CHD or cyst and/or a replaced or accessory right hepatic artery [16].

5.9 Differential Diagnosis (Table 5.1) [3, 45, 77–80]

Table 5.1 Differential diagnosis of a choledochal cyst

Biliary atresia (with extrahepatic cyst)	In infants with obstructive jaundice
Embryonal rhabdomyosarcoma of the bile duct	In preschool children, this malignant tumour may masquerade as a CC [3, 77, 78]. Imaging evidence of intraductal solid tissue extending into the liver should prompt suspicion [79]
Primary sclerosing cholangitis with a dilated bile duct proximal to a dominant stricture	In older children and adults. Clues to this possibility include irregular intrahepatic ducts, a history of inflammatory bowel disease and/or abnormal immunological findings
Choledocholithiasis	A CC containing stones may be misdiagnosed as primary gallstone disease. In one series of children with CC, 11% had undergone cholecystectomy for gallstones prior to diagnosis [45]. It can sometimes be difficult to distinguish a dilated CBD with a distal obstructing stone/debris from a fusiform CC although the bile duct in a CC tends to be wider [80]. An MRCP usually provides the answer

CC choledochal cyst, *CBD* common bile duct

5.10 Surgical Management

Radical cyst excision and reconstruction by wide hilar hepaticoenterostomy is the optimum treatment for the more common types of CC, namely, types I and IVa [81, 82]. Surgery can be performed safely at all ages with minimal morbidity by experienced surgeons. Early surgery is advisable for infants with bile duct obstruction. Simple anastomosis of a loop of bowel to the CC (cystenterostomy) should never be performed because of the inevitable severe long-term morbidity (cholangitis, pancreatitis, cholelithiasis, anastomotic stricture, biliary cirrhosis and malignancy) [83]. Mild pancreatitis need not delay surgery [84], but severe pancreatitis, cholangitis or portal hypertension will require staged management [5].

Most types of choledochal cyst are best treated surgically by radical cyst excision and reconstruction with a wide hilar hepaticoenterostomy.

5.10.1 Preoperative Assessment and Preparation

A nasogastric tube is inserted intraoperatively but can be removed at the end of the operation in most patients. Broad-spectrum intravenous antibiotics are given at induction of anaesthesia and continued for up to 5 days postoperatively.

5.10.2 Operative Technique (Open Approach)

An oblique or transverse right upper quadrant incision affords adequate exposure. The duodenum and head of pancreas may be displaced anteriorly by the cyst. The appearance of the liver, spleen and pancreas should be recorded. If the anatomy of the bile ducts and pancreaticobiliary junction has not been adequately defined preoperatively, then an intraoperative cholangiogram is performed. Transcystic cholangiography provides good definition with small cysts. With large cysts, cholangiography is best performed by injecting contrast directly into the lower end of the CBD *and* into the CHD using a butterfly needle. Bile is aspirated from the cyst with a fine needle and sent for culture and biliary amylase concentration (often > 100,000 U/l).

A plane is developed between the anterior wall of the cyst and the overlying peritoneum. The dissection extends medially and laterally, staying on the wall of the cyst, and inferiorly between the cyst and duodenum; bipolar cautery provides safe and accurate haemostasis. Large cysts are best decompressed to facilitate dissection (Fig. 5.7). The gallbladder and cystic duct are mobilised but left in continuity with the cyst, and the cystic artery is ligated and divided. Where the bile duct narrows down inferiorly, it is dissected circumferentially and encircled with a silastic loop (Fig. 5.8). In this region, small blood vessels arising from the pancreas need careful cautery. The distal common bile duct is dissected along the retroduodenal area to within the head of the pancreas where it is transected. The cholangiogram gives a

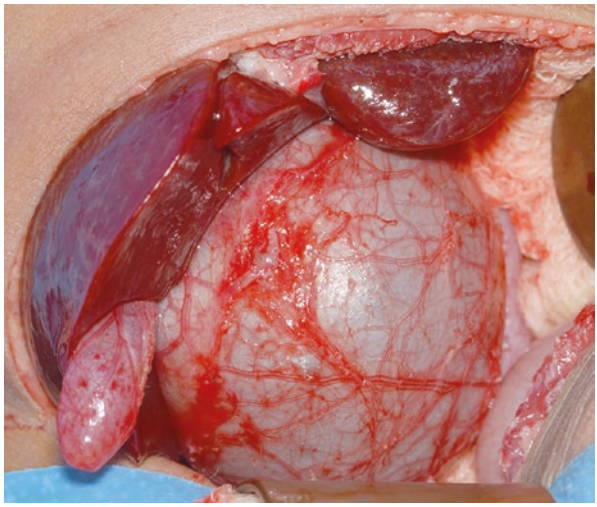

Fig. 5.7 A large type Ic cyst that was decompressed to facilitate further dissection

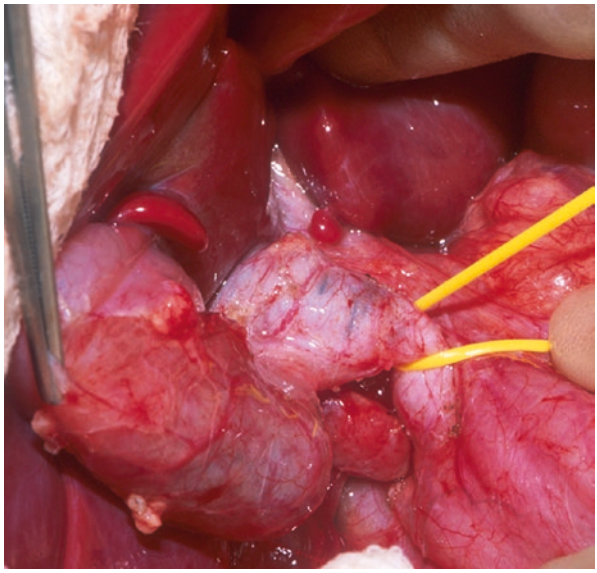

Fig. 5.8 The CBD has been slung prior to distal dissection to within the head of the pancreas

useful indication of the appropriate distal level of bile duct transection. Calculi or protein plugs within a dilated common channel should be cleared using saline irrigation, biliary balloon catheters and, in older children and adults, intraoperative endoscopy with a narrow irrigating endoscope. The stump of the distal bile duct is then ligated or oversewn with an absorbable suture.

The cyst and gallbladder are elevated forward, exposing the portal vein behind. Occasionally, the right hepatic artery crosses anterior to the cyst and is adherent to its wall, when it should be carefully freed and preserved (Fig. 5.9). The common hepatic duct is divided at the level of the bifurcation with scissors or scalpel rather than electrocautery; it should look healthy and well vascularised. The aim should be

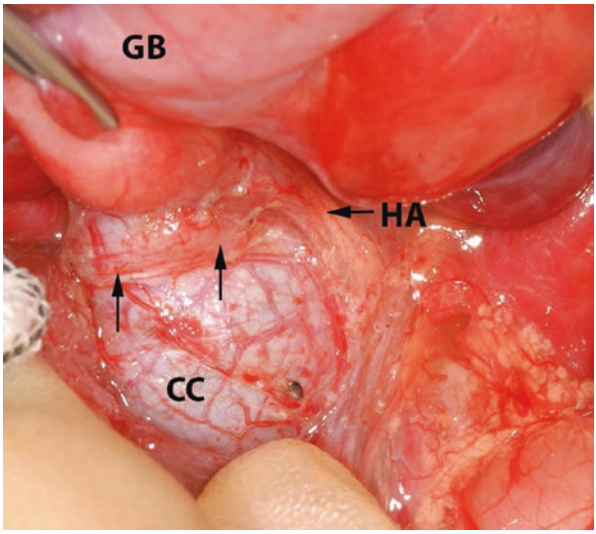

Fig. 5.9 Occasionally, the right hepatic artery crosses anterior to the CC and is adherent to its wall (arrows), when it must be carefully freed and preserved. *CC* choledochal cyst, *GB* gallbladder, *HA* hepatic artery

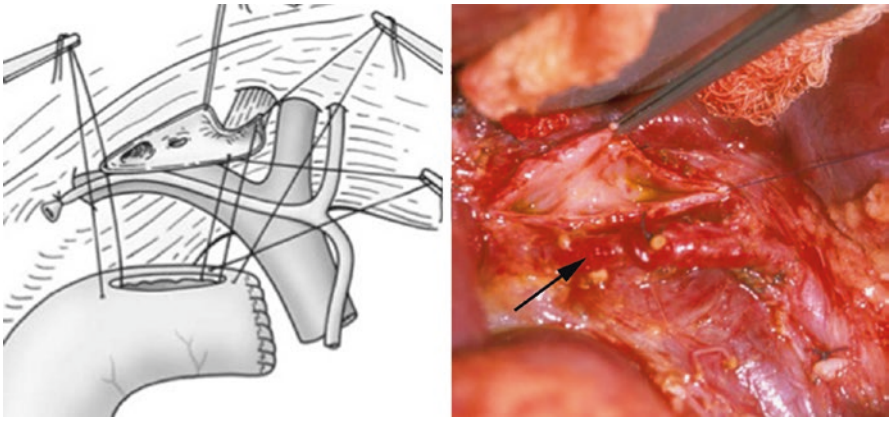

Fig. 5.10 Wide hilar hepaticojejunostomy (modified from Stringer 2007). The arrow indicates the right hepatic artery that was crossing posterior to the CHD

to excise all the CHD whilst preserving the hilar duct confluence. Debris is cleared from any dilated hilar or intrahepatic ducts by catheter irrigation with normal saline and, in larger ducts, with a choledochoscope [85]. The extrahepatic segment of the left hepatic duct is incised for a variable distance (5–10 mm) to enable a wide hilar hepaticoenterostomy (Fig. 5.10) [86, 87]. Anastomosis to the narrow common hepatic duct must be avoided because of the subsequent risk of stricture and malignancy. Opening the hilar duct confluence and left hepatic duct in this way allows identification and treatment of any associated hepatic duct stricture that may be part of the choledochal pathology [88].

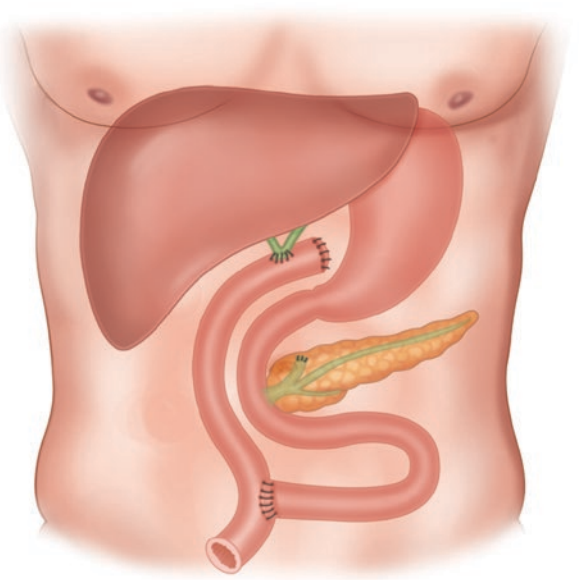

Fig. 5.11 Schematic representation of Roux-en-Y hepaticojejunostomy with a wide hilar anastomosis. Note that the bilioenteric anastomosis is fashioned close to the stapled end of the retrocolic Roux loop to avoid later redundancy

The duodenojejunal flexure is identified, and the jejunum divided approximately 15–20 cm downstream with a linear stapler, at a site where there is a suitable vascular arcade to fashion a Roux loop which will reach the hilum of the liver without tension. The stapled end of the Roux loop is oversewn with an absorbable suture and passed through a window created in the transverse mesocolon just to the right of the middle colic vessels. The jejunal Roux loop is widely anastomosed to the hepatic duct bifurcation at the liver hilum using fine interrupted monofilament absorbable sutures (e.g. 6/0 PDS) (Fig. 5.11). Magnifying loupes enable a precise anastomosis to be constructed. The width of the anastomosis should ideally be 2 cm or more in adults, 1.5 cm or more in children and a minimum of 6mm in neonates [87]. The anastomosis is fashioned a few millimetres from the end of the Roux loop to avoid the risk of developing a blind pouch or sump with future growth of the bowel. The author uses a 30 cm Roux loop in older children and a 20 cm loop in infants. Cholangitis after CC surgery is related to inadequate bilioenteric drainage (avoided by a wide hilar hepaticoenterostomy) rather than ascending infection via the Roux loop. Other authors have found no increased rate of cholangitis with Roux loops shorter than 40 cm [89].

The proximal jejunum is anastomosed in an oblique end-to-side manner to the Roux loop using a single layer of interrupted extramucosal absorbable sutures. Bowel handling and exposure are kept to a minimum to minimise the risk of adhesions. The mesenteric defects in the small bowel mesentery and transverse mesocolon are closed with fine interrupted sutures. A liver biopsy is taken at the end of the operation to document hepatic histology. The operative field is irrigated with warm saline, and, in straightforward operations, the abdomen is closed without drainage. If a drain is inserted, it is placed in Morison's pouch rather than in direct contact with the hepaticoenterostomy.

5.10.3 Laparoscopic Approach

After insertion of a urinary catheter and nasogastric tube and with the patient 30° head up, a 5 or 10 mm camera port is inserted at the umbilicus using an open Hasson technique. Three working 5 mm ports are inserted in the right and left flanks and right side of the abdomen, respectively. The pneumoperitoneum is set at 8–12 mm Hg. In children, a combination of 3 mm and 5 mm instruments is used. Operative steps are as follows: liver suspension by a suture around the round ligament close to the umbilical recess; needle puncture of the cyst and cholangiography if the anatomy has not been adequately defined preoperatively; needle decompression of larger cysts; ligation and division of the cystic artery; cholecystectomy; dissection of the lower part of the CC, opening it transversely; cautery dissection of the cyst staying close to its wall; division and ligation/clipping of the distal common bile duct; proximal dissection of the cyst; and transection of the bile duct at the hilar bifurcation. If a Roux-en-Y loop anastomosis is planned, this can be fashioned manually after exteriorising a segment of jejunum through an extended incision at the umbilical trocar site [90]. Alternatively, an entirely intracorporeal technique can be used [91]. The jejunum is anastomosed to the hepatic duct bifurcation with interrupted or continuous sutures. Hepaticoduodenostomy is a popular alternative since it is quicker and avoids an extracorporeal procedure [90, 92]. There have been recent reports of single-incision laparoscopic repair [93].

Additional/alternative operative techniques are shown in Table 5.2 [3, 15, 93, 94], and operative approaches to less common types of choledochal cyst are outlined in Table 5.3 [6, 7, 9, 25, 95].

Table 5.2 Additional/alternative operative techniques

Hepaticoenterostomy	An end-to-end hilar hepaticojejunostomy can be used instead of an end-to-side anastomosis. Some surgeons advocate hepaticoduodenostomy rather than hepaticojejunostomy, arguing that it is more physiological, is associated with a lower risk of adhesion obstruction and minimises the loss of absorptive mucosa, but there are concerns about bile gastritis and the long-term potential for anastomotic malignancy. The appendix should not be used as a conduit (hepatico-appendico-duodenostomy) because of a high incidence of biliary obstruction. An intussusception 'valve' offers no advantage in the Roux loop
Hilar ductal strictures	Can be managed by ductoplasty or an extended hilar anastomosis
Aberrant extrahepatic bile ducts	Should be incorporated into the bilioenteric anastomosis [16]
Dilated common pancreaticobiliary channel containing debris	The channel must be cleared of debris. A transduodenal sphincteroplasty may be considered
Portal hypertension or dense inflammation from previous infection/surgery	May make radical cyst excision hazardous. Intramural resection of the posterior wall of the cyst (excising only the mucosa and inner wall) reduces the risk of severe haemorrhage and injury to the portal vein [94, 114]
Severe cholangitis	Temporary preoperative endoscopic stenting and drainage may be useful in affected patients [5]
Possibility of malignancy	Intraoperative frozen section histology should be available [3]

Table 5.3 Operative approaches to less common types of choledochal cyst

PBM with minimal or no bile duct dilatation	Should not be treated by endoscopic sphincterotomy, transduodenal sphincteroplasty or cholecystectomy alone because these patients are at risk of recurrent pancreatitis and biliary tract malignancy. The extrahepatic bile ducts and gallbladder should be excised [9, 25]
Type II cysts	Excision of the diverticulum and repair of the bile duct are described but only really applicable to a CBD diverticulum. A type II diverticulum of the CHD or a diverticulum complicated by severe inflammation or malignancy is best treated by complete extrahepatic bile duct resection and bilioenteric drainage [6]. Laparoscopic excision of the diverticulum is challenging because of potential damage to native bile ducts [6]
Type III cysts	No consensus on surgical management [7]. Large choledochoceles have been marsupialised transduodenally or treated by extrahepatic bile duct excision and Roux-en-Y hepaticojejunostomy. Smaller choledochoceles have been treated by open sphincteroplasty or endoscopic sphincterotomy, but this is only appropriate if there is no PBM
Type IVa cysts	After treatment of the extrahepatic component, residual intrahepatic ductal disease may lead to recurrent cholangitis, stones, abscesses and cancer. Liver resection is an option for intrahepatic disease confined to one lobe [95]. For bilobar involvement, liver transplantation may eventually be required
Type V cysts	Solitary asymptomatic cysts can be left untreated. For multiple symptomatic cysts confined to one lobe, hepatic lobectomy may be curative. Diffuse bilobar disease not controlled by antibiotics and drainage procedures is an indication for liver transplantation

CBD common bile duct, *CHD* common hepatic duct, *PBM* pancreaticobiliary malunion

5.11 Results and Complications of Surgery

Radical cyst excision and wide hilar hepaticoenterostomy achieves consistently good results, particularly when performed in children with uncomplicated cysts [12, 87, 96]. Complications after CC resection are more common in adults than children [3, 97], and outcomes are distinctly worse in the small proportion of adults with concomitant liver disease, portal hypertension or malignancy.

After successful surgery, hepatic cholestasis, bile duct proliferation and inflammation resolve. Regression of hepatic fibrosis and early biliary cirrhosis have been documented by some [61, 98] but not all authors [14]. Biochemical liver function tests including gamma-glutamyltransferase (GGT) should become normal postoperatively. Early postoperative complications such as anastomotic bile leak, bleeding, acute pancreatitis, wound infection and intestinal obstruction are uncommon. A bile leak usually resolves with external drainage and intravenous antibiotics.

Late complications include bilioenteric anastomotic stricture (Fig. 5.12), stone formation (especially within dilated intrahepatic ducts in type IVa cysts), pancreatitis, adhesive bowel obstruction and malignancy. Chronic low-grade biliary obstruction can progress to secondary biliary cirrhosis. These long-term complications may present clinically (e.g. cholangitis) or with abnormal liver function tests or follow-up ultrasound scans. An anastomotic stricture may develop 10 years or more, postoperatively [99]. Todani reported a 10% reoperation rate among 103 children

followed for a median of 14 years, and Yamataka et al. noted a 9% major complication rate in another 200 Japanese children followed for a mean of 11 years [12, 97]. In both series, revisional surgery was required to treat cholangitis secondary to anastomotic or ductal strictures, ductal calculi, common channel calculi and adhesive small bowel obstruction. Complications were more common with type IVa cysts or after bilioenteric anastomosis to the CHD [96] (Fig. 5.13). Complications after wide hilar hepaticojejunostomy are rare [87].

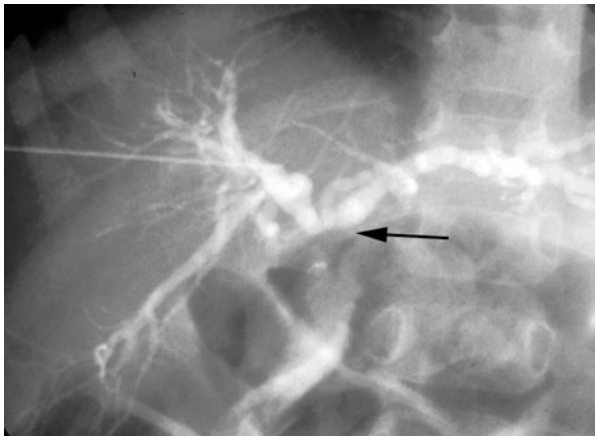

Fig. 5.12 A percutaneous transhepatic cholangiogram demonstrating dilated intrahepatic ducts proximal to a bilioenteric stricture (arrow) in a 14-year-old girl presenting 12 years after surgery elsewhere for a type I CC

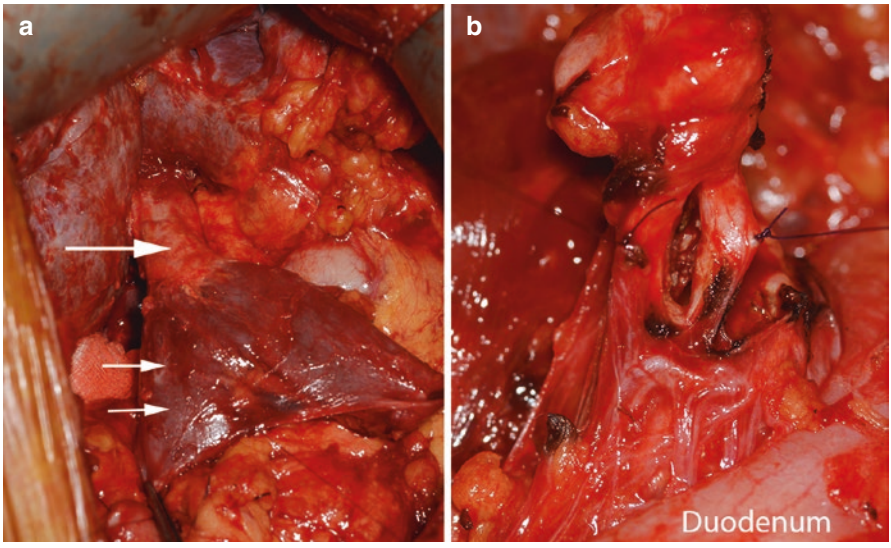

Fig. 5.13 (**a**) Redo surgery for an incompletely excised CC in an adult. Note the residual CHD (large arrow) and upper end of the previous Roux loop (small arrows) which has been divided and is therefore devascularised. (**b**) The residual CHD and attached end of the Roux loop have been elevated and opened to reveal contained debris. The right hepatic artery is visible crossing posterior to the CHD

Cholangitis may signify an anastomotic bilioenteric stricture, an intrahepatic ductal stricture or stone, debris/obstruction within the Roux loop or, rarely, a malignancy. Interventional radiology may enable stones to be cleared and strictures dilated and can also provide temporary percutaneous transhepatic biliary drainage of infected bile [100], but surgery is often required for definitive treatment of these problems.

Pancreatitis may develop years later in individuals with a residual complex or dilated common channel containing protein plugs or calculi or in patients with a significant residual distal bile duct remnant [101] (Fig. 5.14). ERCP is useful in assessment, and endoscopic sphincterotomy may be curative.

Malignancy can still develop after CC excision, particularly if the CC has been incompletely excised [65, 102–105]. Even after adequate cyst excision, malignancy can develop in residual extrahepatic ducts such as the intrapancreatic remnant of the distal CBD or in abnormal intrahepatic ducts, particularly in type IVa cysts [106–109]. Lee and Jang reviewed 54 cases of malignancy following CC excision (60% type IVa and 40% type I): the most frequent site of involvement was the hepatic duct at, or near, the bilioenteric anastomosis, followed by the intrahepatic ducts and the

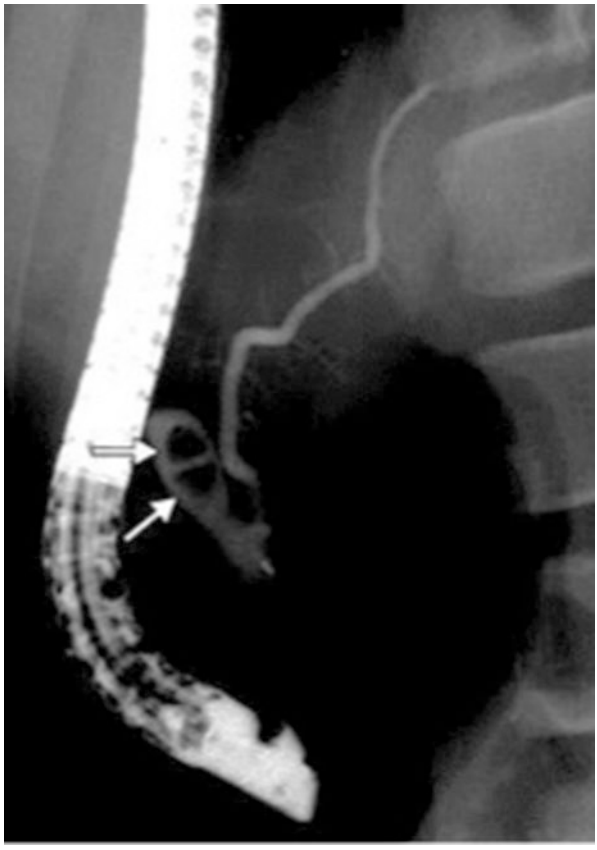

Fig. 5.14 Intrapancreatic remnant of distal CBD containing gallstones following CC excision many years previously. The patient represented with acute pancreatitis. This can usually be avoided by adequate primary surgery

distal remnant CBD [104]. The mean interval between initial surgery and the cancer was 10 years (range 1–32 years). The authors concluded that '… wide anastomosis with free drainage of bile as well as complete excision of dilated bile duct(s) appears essential to prevent development of carcinoma'. Malignant change typically carries a poor prognosis, even worse than cholangiocarcinoma in general, largely due to late-stage tumours [64, 104, 108]. Type IVa cysts and adults >30 years are at greater risk of long-term complications [110]. Outcomes may be improved by earlier tumour detection using routine surveillance imaging, liver function tests and tumour markers such as carbohydrate antigen 19-9 (CA19-9) [104] and by appropriately investigating patients with cholangitis or hepatolithiasis after cyst excision [65]. Currently, there is no consensus on how best to follow up patients after CC excision [111].

5.11.1 Should Choledochal Cysts Be Treated by Specialist Hepatobiliary Surgeons?

Excising a CC is usually straightforward. However, a good long-term outcome requires radical cyst excision and a wide hilar hepaticoenterostomy. A survey of Dutch paediatric surgeons found that two-thirds encountered a CC no more than twice a year; evidence-based management was less likely when compared to those with greater experience [112]. Surgical complications are probably more likely if the operation is performed occasionally. In a recent series from the USA, seven surgeons managed 62 paediatric CC over 22 years [45]. Complications occurred in 31% of patients during a median follow-up of only 2 years: these included anastomotic leaks requiring revision, laparotomies for adhesion obstruction, residual cysts, cholangitis, pancreatic duct stones and anastomotic stricture.

The need for hepatobiliary expertise is also highlighted by the laparoscopic literature. Laparoscopic excision of a CC was first reported in 1995 [113]. Since then, numerous articles have described the results of surgery using minimally invasive techniques (including robotic surgery) in children and adults [90, 114–128]. Purported benefits of laparoscopic approaches include reduced postoperative pain, shorter length of hospital stay, fewer postoperative adhesions, better cosmesis and earlier return to activity, but most reports have been retrospective with historical controls, ignoring the fact that open surgical techniques have improved. Operative times have generally been longer with laparoscopy. Other major concerns about current laparoscopic results are:

1. The bilioenteric anastomosis is frequently at the level of the CHD rather than a wide hilar hepaticoenterostomy [90–92, 114, 121, 122]. This has led to a high incidence of bilioenteric stricture and redo surgery within relatively short follow-up periods [90, 129, 130].
2. The level at which the distal CBD is transected is often poorly described [116, 118, 119, 121, 128] raising concerns about the length of the remaining intrapancreatic bile duct remnant.

3. Intraoperative injuries to the portal vein [90, 131], right hepatic artery [117] and hepatic duct [90, 92] have been reported. In some series, blood transfusion has been necessary in 5–13% of patients [116, 119, 121].
4. Hepaticoduodenostomy has been promoted over hepaticojejunostomy predominantly because it is technically quicker and easier to perform laparoscopically and can be completed without the need for an extracorporeal enteric anastomosis [92, 132]. Issues related to duodenogastric bile reflux and gastritis [133] have been downplayed. Concerns have been expressed about the long-term risk of cholangiocarcinoma and gastric cancer after hepaticoduodenostomy [134, 135].

Laparoscopic techniques continue to be refined. Examples include using a ureteroscope to gauge the length of intrapancreatic bile duct [136] and to clear the common channel of any protein plugs [137] and performing a ductoplasty to widen the bilioenteric anastomosis [138].

In summary, CCs are relatively rare and complex and should ideally be managed by hepatopancreaticobiliary surgeons. For most types of CC, the goal of surgery is to achieve radical cyst excision and wide hilar hepaticojejunostomy. Surgeons must avoid the short-term attractions of laparoscopic approaches (principally cosmetic with a potentially faster recovery) if the long-term results of best practice open surgery cannot be replicated using minimally invasive techniques [139]. It is crucial to understand that the outcomes of CC surgery in young individuals are not fully evident for decades. In the future, it will be important to develop optimum follow-up protocols such that late complications after surgery are detected early and cost-effectively.

Conclusion

Congenital dilatation of the bile duct(s), otherwise known as a choledochal cyst, may affect the extrahepatic or intrahepatic bile ducts or both. It is frequently associated with an abnormal union between the pancreatic and bile ducts, which allows reflux of pancreatic juice into the bile duct and predisposes to pancreatitis. Most patients with a CC present with abdominal pain and/or jaundice in childhood. The condition is more common in females and Orientals. Potential complications of the malformation include obstructive jaundice, cholangitis, cyst rupture, gallstones, pancreatic disease, secondary biliary cirrhosis and bile duct malignancy. For most types of choledochal cyst, optimum management involves accurate imaging of the bile and pancreatic ducts and associated pathology followed by radical excision of the extrahepatic bile ducts and reconstruction by wide hilar hepaticoenterostomy. Long-term follow-up is essential to detect late complications such as bilioenteric strictures and malignancy which are more likely to occur if the original excision and reconstruction was insufficiently radical or if the original bile duct pathology involved both the intrahepatic and extrahepatic bile ducts.

References

1. Ishibashi H, Shimada M, Kamisawa T, et al. Japanese clinical practice guidelines for congenital biliary dilatation. J Hepatobiliary Pancreat Sci. 2017;24:1–16.
2. Hukkinen M, Koivusalo A, Lindahl H, et al. Increasing occurrence of choledochal malformations in children: a single-center 37-year experience from Finland. Scand J Gastroenterol. 2014;49:1255–60.
3. Soares KC, Kim Y, Spolverato G, et al. Presentation and clinical outcomes of choledochal cysts in children and adults: a multi-institutional analysis. JAMA Surg. 2015;150:577–84.
4. Todani T, Watanabe Y, Narusue M, et al. Classification, operative procedures and review of 37 cases including cancer arising from choledochal cyst. Am J Surg. 1977;134:263–9.
5. Saluja SS, Nayeem M, Sharma BC, et al. Management of choledochal cysts and their complications. Am Surg. 2012;78:284–90.
6. Ouaïssi M, Kianmanesh R, Belghiti J, et al. Todani Type II congenital bile duct cyst: European Multicenter Study of the French Surgical Association and literature review. Ann Surg. 2015;262:130–8.
7. Ziegler KM, Pitt HA, Zyromski NJ, et al. Choledochoceles: are they choledochal cysts? Ann Surg. 2010;252:683–90.
8. Lilly JR, Stellin GP, Karrer FM. Formefruste choledochal cyst. J Pediatr Surg. 1985;20:449–51.
9. Ono Y, Kaneko K, Tainaka T, et al. Pancreaticobiliary maljunction without bile duct dilatation in children: distinction from choledochal cyst. J Pediatr Gastroenterol Nutr. 2008;46:555–60.
10. De U, Das S, Sarkar S. Type VI choledochal cyst revisited. Singapore Med J. 2011;52:e91–3.
11. Davenport M, Basu R. Under pressure: choledochal malformation manometry. J Pediatr Surg. 2005;40:331–5.
12. Todani T. Choledochal cysts. In: Stringer MD, Oldham KT, Mouriquand PDE, Howard ER, editors. Pediatric surgery and urology: long-term outcomes. Philadelphia: WB Saunders; 1998. p. 417–29.
13. Komi N, Tamura T, Tsuge S, et al. Relation of patient age to premalignant alterations in choledochal cyst epithelium: histochemical and immunohistochemical studies. J Pediatr Surg. 1986;21:430–3.
14. Sugandhi N, Agarwala S, Bhatnagar V, et al. Liver histology in choledochal cyst- pathological changes and response to surgery: the overlooked aspect? Pediatr Surg Int. 2014;30:205–11.
15. Li L, Yamataka A, Yian-Xia W, et al. Ectopic distal location of the papilla of Vater in congenital biliary dilatation: implications for pathogenesis. J Pediatr Surg. 2001;36:1617–22.
16. Lal R, Behari A, Hari RH, et al. Variations in biliary ductal and hepatic vascular anatomy and their relevance to the surgical management of choledochal cysts. Pediatr Surg Int. 2013;29:777–86.
17. Iwai N, Yanagihara J, Tokiwa K, et al. Congenital choledochal dilatation with emphasis on pathophysiology of the biliary tract. Ann Surg. 1992;215:27–30.
18. Ono S, Fumino S, Iwai N. Diagnosis and treatment of pancreaticobiliary maljunction in children. Surg Today. 2011;41:601–5.
19. Guelrud M, Morera C, Rodriguez M, et al. Normal and anomalous pancreaticobiliary union in children and adolescents. Gastrointest Endosc. 1999;50:189–93.
20. Tanaka M, Ikeda S, Kawakami K, et al. The presence of a positive pressure gradient from pancreatic duct to choledochal cyst demonstrated by duodenoscopic microtransducer manometry: clue to pancreaticobiliary reflux. Endoscopy. 1982;14:45–7.
21. Matsufuji H, Araki Y, Nakamura A, et al. Dynamic study of pancreaticobiliary reflux using secretin-stimulated magnetic resonance cholangiopancreatography in patients with choledochal cysts. J Pediatr Surg. 2006;41:1652–6.
22. Fumino S, Tokiwa K, Katoh T, et al. New insight into bile flow dynamics in anomalous arrangement of the pancreaticobiliary duct. Br J Surg. 2002;89:865–9.

23. Park SW, Koh H, Oh JT, et al. Relationship between anomalous pancreaticobiliary ductal union and pathologic inflammation of bile duct in choledochal cyst. Pediatr Gastroenterol Hepatol Nutr. 2014;17:170–7.
24. Fujishiro J, Masumoto K, Urita Y, et al. Pancreatic complications in pediatric choledochal cysts. J Pediatr Surg. 2013;48:1897–902.
25. Funabiki T, Matsubara T, Miyakawa S, et al. Pancreaticobiliary maljunction and carcinogenesis to biliary and pancreatic malignancy. Langenbecks Arch Surg. 2009;394:159–69.
26. Yamauchi S, Koga A, Matsumoto S, et al. Anomalous junction of pancreaticobiliary duct without congenital choledochal cyst: a possible risk factor for gallbladder cancer. Am J Gastroenterol. 1987;82:20–4.
27. Stringer MD, Dhawan A, Davenport M, et al. Choledochal cysts: lessons from a 20-year experience. Arch Dis Child. 1995;73:528–31.
28. Samuel M, Spitz L. Choledochal cyst: varied clinical presentations and long-term results of surgery. Eur J Pediatr Surg. 1996;6:78–81.
29. Iwai A, Hamada Y, Takada K, et al. Choledochal cyst associated with duodenal atresia: case report and review of the literature. Pediatr Surg Int. 2009;25:995–8.
30. Ellerkamp V, Kirschner HJ, Warmann SW, et al. Bilateral single-system ectopic ureter associated with choledochal cyst: report of 2 cases. J Pediatr Surg. 2010;45:2450–3.
31. Murphy AJ, Axt JR, Lovvorn HN 3rd. Associations between pediatric choledochal cysts, biliary atresia, and congenital cardiac anomalies. J Surg Res. 2012;177:e59–63.
32. Babbitt DP. Congenital choledochal cysts: new etiological concept based on anomalous relationships of common bile duct and pancreatic bulb. Ann Radiol. 1969;12:231–40.
33. Han SJ, Hwang EH, Chung KS, et al. Acquired choledochal cyst from an anomalous pancreatobiliary duct union. J Pediatr Surg. 1997;32:1735–8.
34. Davenport M, Stringer MD, Howard ER. Biliary amylase and congenital choledochal dilatation. J Pediatr Surg. 1995;30:474–7.
35. Todani T, Urushihara N, Morotomi Y, et al. Characteristics of choledochal cysts in neonates and early infants. Eur J Pediatr Surg. 1995;5:143–5.
36. Niramis R, Narumitsuthon R, Watanatittan S, et al. Clinical differences between choledochal cysts in infancy and childhood: an analysis of 160 patients. J Med Assoc Thai. 2014;97(Suppl 11):S122–8.
37. Spitz L. Experimental production of cystic dilatation of the common bile duct in neonatal lambs. J Pediatr Surg. 1977;12:39–42.
38. Karakuş OZ, Ulusoy O, Aktürk G, et al. The density of interstitial cells of Cajal is diminished in choledochal cysts. Dig Dis Sci. 2016;61:900–4.
39. Shimotake T, Iwai N, Yanagihara J, et al. Innervation patterns in congenital biliary dilatation. Eur J Pediatr Surg. 1995;5:265–70.
40. Clifton MS, Goldstein RB, Slavotinek A, et al. Prenatal diagnosis of familial type I choledochal cyst. Pediatrics. 2006;117:e596–600.
41. Lane GJ, Yamataka A, Kobayashi H, et al. Different types of congenital biliary dilatation in dizygotic twins. Pediatr Surg Int. 1999;15:403–4.
42. Wong JK, Campbell D, Ngo ND, et al. Genetic study of congenital bile-duct dilatation identifies de novo and inherited variants in functionally related genes. BMC Med Genomics. 2016;9:75.
43. Yamaguchi M. Congenital choledochal cyst. Analysis of 1433 patients in the Japanese literature. Am J Surg. 1980;140:653–7.
44. Redkar R, Davenport M, Howard ER. Antenatal diagnosis of biliary lesions. J Pediatr Surg. 1998;33:700–4.
45. Acker SN, Bruny JL, Narkewicz MR, et al. Preoperative imaging does not predict intrahepatic involvement in choledochal cysts. J Pediatr Surg. 2013;48:2378–82.
46. Urushihara N, Todani T, Watanabe Y, et al. Does hyperamylasemia in choledochal cyst indicate true pancreatitis? An experimental study. Eur J Pediatr Surg. 1995;5:139–42.
47. Lugo-Vincente HL. Prenatally diagnosed choledochal cysts: observation or early surgery? J Pediatr Surg. 1995;30:1288–90.

48. Vijayaraghavan P, Lal R, Sikora SS, et al. Experience with choledochal cysts in infants. Pediatr Surg Int. 2006;22:803–7.
49. Suita S, Shono K, Kinugasa Y, et al. Influence of age on the presentation and outcome of choledochal cyst. J Pediatr Surg. 1999;34:1765–8.
50. Foo DC, Wong KK, Lan LC, et al. Impact of prenatal diagnosis on choledochal cysts and the benefits of early excision. J Paediatr Child Health. 2009;45:28–30.
51. Matsubara H, Oya N, Suzuki Y, et al. Is it possible to differentiate between choledochal cyst and congenital biliary atresia (type I cyst) by antenatal ultrasonography? Fetal Diag Ther. 1997;12:306–8.
52. Kim WS, Kim IO, Yeon KM, et al. Choledochal cyst with or without biliary atresia in neonates and young infants: US differentiation. Radiology. 1998;209:465–9.
53. Muthucumaru M, Ljuhar D, Panabokke G, et al. Acute pancreatitis complicating choledochal cysts in children. J Paediatr Child Health. 2017;53:291–4. https://doi.org/10.1111/jpc.13380.
54. Nicholl M, Pitt HA, Wolf P, et al. Choledochal cysts in western adults: complexities compared to children. J Gastrointest Surg. 2004;8:245–52.
55. Ando K, Miyano T, Kohno S, et al. Spontaneous perforation of choledochal cyst: a study of 13 cases. Eur J Pediatr Surg. 1998;8:23–5.
56. Ngoc Son T, Thanh Liem N, Manh Hoan V. One-staged or two-staged surgery for perforated choledochal cyst with bile peritonitis in children? A single center experience with 27 cases. Pediatr Surg Int. 2014;30:287–90.
57. Chen J, Tang Y, Wang Z, et al. Clinical value of ultrasound in diagnosing pediatric choledochal cyst perforation. AJR Am J Roentgenol. 2015;204:630–5.
58. Lal R, Agarwal S, Shivhare R, et al. Management of complicated choledochal cysts. Dig Surg. 2007;24:456–62.
59. Ishimaru T, Kitano Y, Uchida H, et al. Histopathologic improvement in biliary cirrhosis after definitive surgery for choledochal cyst. J Pediatr Surg. 2010;45:e11–4.
60. Fujishiro J, Urita Y, Shinkai T, et al. Clinical characteristics of liver fibrosis in patients with choledochal cysts. J Pediatr Surg. 2011;46:2296–300.
61. Fumino S, Higuchi K, Aoi S, et al. Clinical analysis of liver fibrosis in choledochal cyst. Pediatr Surg Int. 2013;29:1097–102.
62. Bismuth H, Krissat J. Choledochal cystic malignancies. Ann Oncol. 1999;10(Suppl 4):S94–8.
63. Voyles CR, Smadja WC, Shands WC, et al. Carcinoma in choledochal cysts. Age related incidence. Arch Surg. 1983;118:986–8.
64. Sastry AV, Abbadessa B, Wayne MG, et al. What is the incidence of biliary carcinoma in choledochal cysts, when do they develop, and how should it affect management? World J Surg. 2015;39:487–92.
65. Lee SE, Jang JY, Lee YJ, et al. Choledochal cyst and associated malignant tumors in adults: a multicenter survey in South Korea. Arch Surg. 2011;146:1178–84.
66. Tashiro S, Imaizumi T, Ohkawa H, et al. Pancreaticobiliary maljunction: retrospective and nationwide survey in Japan. J Hepatobiliary Pancreat Surg. 2003;10:345–51.
67. Kaneko K, Ando H, Watanabe Y, et al. Pathologic changes in the common bile duct of an experimental model with pancreaticobiliary maljunction without biliary dilatation. Pediatr Surg Int. 2000;16:26–8.
68. Katabi N, Pillarisetty VG, DeMatteo R, et al. Choledochal cysts: a clinicopathologic study of 36 cases with emphasis on the morphologic and the immunohistochemical features of premalignant and malignant alterations. Hum Pathol. 2014;45:2107–14.
69. Todani T, Watanabe Y, Toki A, et al. Carcinoma related to choledochal cyst with internal drainage operations. Surg Gynecol Obstet. 1987;164:61–4.
70. Hernanz-Schulman M, Ambrosino MM, Freeman PC, et al. Common bile duct in children: sonographic dimensions. Radiology. 1995;195:193–5
71. Bachar GN, Cohen M, Belenky A, et al. Effect of aging on the adult extrahepatic bile duct: a sonographic study. J Ultrasound Med. 2003;22:879–82.
72. Feng A, O'Hara SM, Gupta R, et al. Normograms for the extrahepatic bile duct diameter in children. J Pediatr Gastroenterol Nutr. 2017;64:e61–4.

73. Guo WL, Huang SG, Wang J, et al. Imaging findings in 75 pediatric patients with pancreaticobiliary maljunction: a retrospective case study. Pediatr Surg Int. 2012;28:983–8.
74. Sacher VY, Davis JS, Sleeman D, et al. Role of magnetic resonance cholangiopancreatography in diagnosing choledochal cysts: case series and review. World J Radiol. 2013;5:304–12.
75. Wiseman K, Buczkowski AK, Chung SW, et al. Epidemiology, presentation, diagnosis and outcomes of choledochal cysts in adults in an urban environment. Am J Surg. 2005;189: 527–31.
76. Hill R, Parsons C, Farrant P, et al. Intrahepatic duct dilatation in type 4 choledochal malformation: pressure-related, postoperative resolution. J Pediatr Surg. 2011;46:299–303.
77. Margain-Deslandes L, Gelas T, Bergeron C, et al. A botryoid rhabdomyosarcoma diagnosed as a choledochal cyst. Pediatr Blood Cancer. 2013;60:2089–90.
78. Elwahab MA, Hamed H, Shehta A, et al. Hepatobiliary rhabdomyosarcoma mimicking choledochal cyst: lessons learned. Int J Surg Case Rep. 2014;5:196–9.
79. Roebuck DJ, Yang WT, Lam WW, et al. Hepatobiliary rhabdomyosarcoma in children: diagnostic radiology. Pediatr Radiol. 1998;28:101–8.
80. Oh SH, Chang SH, Kim HJ, et al. Cholangiographic characteristics of common bile duct dilatation in children. World J Gastroenterol. 2015;21:6229–35.
81. Miyano T, Yamataka A, Kato Y, et al. Hepaticoenterostomy after excision of choledochal cyst in children: a 30-year experience with 180 cases. J Pediatr Surg. 1996;31:1417–21.
82. Stringer MD. Choledochal cysts. In: Howard ER, Stringer MD, Colombani PM, editors. Surgery of the liver bile ducts and pancreas in children. London: Arnold; 2002. p. 149–68.
83. Kaneko K, Ando H, Watanabe Y, et al. Secondary excision of choledochal cysts after previous cystenterostomies. Hepatogastroenterology. 1999;46:2772–5.
84. Cho MJ, Kim DY, Kim SC, et al. Early vs. delayed surgery for choledochal cyst with acute pancreatitis in children. Hepatogastroenterology. 2011;58:709–12.
85. Takahashi T, Shimotakahara A, Okazaki T, et al. Intraoperative endoscopy during choledochal cyst excision: extended long-term follow-up compared with recent cases. J Pediatr Surg. 2010;45:379–82.
86. Stringer MD. Choledochal cyst. In: Spitz L, Coran AG, editors. Operative pediatric surgery. 6th ed. London: Hodder Arnold; 2006. p. 673–82.
87. Stringer MD. Wide hilar hepaticojejunostomy: the optimum method of reconstruction after choledochal cyst excision. Pediatr Surg Int. 2007;23:529–32.
88. Kemmotsu H, Mouri T, Muraji T. Congenital stenosis of the hepatic duct at the porta hepatis in children with choledochal cyst. J Pediatr Surg. 2009;44:512–6.
89. Diao M, Li L, Zhang JZ, Cheng W. A shorter loop in Roux-Y hepatojejunostomy reconstruction for choledochal cysts is equally effective: preliminary results of a prospective randomized study. J Pediatr Surg. 2010;45:845–7.
90. Yeung F, Chung PH, Wong KK, et al. Biliary-enteric reconstruction with hepaticoduodenostomy following laparoscopic excision of choledochal cyst is associated with better postoperative outcomes: a single-centre experience. Pediatr Surg Int. 2015;31:149–53.
91. Gander JW, Cowles RA, Gross ER, et al. Laparoscopic excision of choledochal cysts with total intracorporeal reconstruction. J Laparoendosc Adv Surg Tech A. 2010;20:877–81.
92. Liem NT, Pham HD, le Dung A, et al. Early and intermediate outcomes of laparoscopic surgery for choledochal cysts with 400 patients. J Laparoendosc Adv Surg Tech. 2012;22:599–603.
93. Diao M, Li L, Li Q, et al. Single-incision versus conventional laparoscopic cyst excision and Roux-Y hepaticojejunostomy for children with choledochal cysts: a case-control study. World J Surg. 2013;37:1707–13.
94. Lilly JR. The surgical treatment of choledochal cyst. Surg Gynecol Obstet. 1979;149:36–42.
95. Pal K, Singh VP, Mitra DK. Partial hepatectomy and total cyst excision is curative for localized type IV-a biliary duct cysts – report of four cases and review of management. Eur J Pediatr Surg. 2009;19:148–52.
96. Urushihara N, Fukumoto K, Fukuzawa H, et al. Long-term outcomes after excision of choledochal cysts in a single institution: operative procedures and late complications. J Pediatr Surg. 2012;47:2169–74.

97. Yamataka A, Ohshiro K, Okada Y, et al. Complications after cyst excision with hepaticoenterostomy for choledochal cysts and their surgical management in children versus adults. J Pediatr Surg. 1997;32:1097–102.
98. Yeong ML, Nicholson GI, Lee SP. Regression of biliary cirrhosis following choledochal cyst drainage. Gastroenterology. 1982;82:332–5.
99. Saing H, Han H, Chan K, et al. Early and late results of excision of choledochal cysts. J Pediatr Surg. 1997;32:1563–6.
100. Liu Y, Liu B, Zhou Y, et al. Treatment of long-term complications after primary surgery for congenital choledochal cysts. Am Surg. 2013;79:1221–4.
101. Koshinaga T, Wakabayashi K, Inoue M, et al. Pancreatitis after a primary and secondary excision of congenital choledochal cysts. Surg Today. 2006;36:686–91.
102. Yoshikawa K, Yoshida K, Shirai Y, et al. A case of carcinoma arising in the intrapancreatic terminal choledochus 12 years after primary excision of a giant choledocahal cyst. Am J Gastroenterol. 1986;81:378–84.
103. Yamamoto J, Shimamura Y, Ohtani I, et al. Bile duct carcinoma arising from the anastomotic site of hepaticojejunostomy after the excision of congenital biliary dilatation: a case report. Surgery. 1996;119:476–9.
104. Lee SE, Jang JY. Development of biliary malignancy after cyst excision for congenital choledochal cysts: what should we do? J Gastroenterol Hepatol. 2013;28:210–2.
105. Ohashi T, Wakai T, Kubota M, et al. Risk of subsequent biliary malignancy in patients undergoing cyst excision for congenital choledochal cysts. J Gastroenterol Hepatol. 2013;28:243–7.
106. Fujisaki S, Akiyama T, Miyake H, et al. A case of carcinoma associated with the remained intrapancreatic biliary tract 17 years after the primary excision of a choledochal cyst. Hepatogastroenterology. 1999;46:1655–9.
107. Kobayashi S, Asano T, Yamasaki M, et al. Risk of bile duct carcinogenesis after excision of extrahepatic bile ducts in pancreaticobiliary maljunction. Surgery. 1999;126:939–44.
108. He XD, Wang L, Liu W, et al. The risk of carcinogenesis in congenital choledochal cyst patients: an analysis of 214 cases. Ann Hepatol. 2014;13:819–26.
109. Kumamoto T, Tanaka K, Takeda K, et al. Intrahepatic cholangiocarcinoma arising 28 years after excision of a type IV-A congenital choledochal cyst: report of a case. Surg Today. 2014;44:354–8.
110. Ohtsuka H, Fukase K, Yoshida H, et al. Long-term outcomes after extrahepatic excision of congenital choladocal cysts: 30 years of experience at a single center. Hepatogastroenterology. 2015;62:1–5.
111. Linehan D, Galka E. Lingering questions on choledochal cysts. JAMA Surg. 2015;150:584.
112. van den Eijnden MH, de Kleine RH, Verkade HJ, et al. Controversies in choledochal malformations: a survey among Dutch pediatric surgeons. Eur J Pediatr Surg. 2015;25:441–8.
113. Farello GA, Cerofolini A, Rebonato M, et al. Congenital choledochal cyst: video-guided laparoscopic treatment. Surg Laparosc Endosc. 1995;5:354–8.
114. Senthilnathan P, Patel ND, Nair AS, et al. Laparoscopic management of choledochal cyst-technical modifications and outcome analysis. World J Surg. 2015;39:2550–6.
115. Li L, Feng W, Jing-Bo F, et al. Laparoscopic-assisted total cyst excision of choledochal cyst and Roux-en-Y hepatoenterostomy. J Pediatr Surg. 2004;39:1663–6.
116. Hong L, Wu Y, Yan Z, et al. Laparoscopic surgery for choledochal cyst in children: a case review of 31 patients. Eur J Pediatr Surg. 2008;18:67–71.
117. Lee KH, Tam YH, Yeung CK, et al. Laparoscopic excision of choledochal cysts in children: an intermediate-term report. Pediatr Surg Int. 2009;25:355–60.
118. Diao M, Li L, Cheng W. Laparoscopic versus open Roux-en-Y hepatojejunostomy for children with choledochal cysts: intermediate-term follow-up results. Surg Endosc. 2011;25:1567–73.
119. Tang ST, Yang Y, Wang Y, et al. Laparoscopic choledochal cyst excision, hepaticojejunostomy, and extracorporeal Roux-en-Y anastomosis: a technical skill and intermediate-term report in 62 cases. Surg Endosc. 2011;25:416–22.
120. Wang DC, Liu ZP, Li ZH, et al. Surgical treatment of congenital biliary duct cyst. BMC Gastroenterol. 2012;12:29.

121. Wang J, Zhang W, Sun D, et al. Laparoscopic treatment for choledochal cysts with stenosis of the common hepatic duct. J Am Coll Surg. 2012;214:e47–52.
122. Jang JY, Yoon YS, Kang MJ, et al. Laparoscopic excision of a choledochal cyst in 82 consecutive patients. Surg Endosc. 2013;27:1648–52.
123. Alizai NK, Dawrant MJ, Najmaldin AS. Robot-assisted resection of choledochal cysts and hepaticojejunostomy in children. Pediatr Surg Int. 2014;30:291–4.
124. Kim NY, Chang EY, Hong YJ, et al. Retrospective assessment of the validity of robotic surgery in comparison to open surgery for pediatric choledochal cyst. Yonsei Med J. 2015;56:737–43.
125. Margonis GA, Spolverato G, Kim Y, et al. Minimally invasive resection of choledochal cyst: a feasible and safe surgical option. J Gastrointest Surg. 2015;19:858–65.
126. Qiao G, Li L, Li S, et al. Laparoscopic cyst excision and Roux-Y hepaticojejunostomy for children with choledochal cysts in China: a multicenter study. Surg Endosc. 2015;29:140–4.
127. Shen HJ, Xu M, Zhu HY, et al. Laparoscopic versus open surgery in children with choledochal cysts: a meta-analysis. Pediatr Surg Int. 2015;31:529–34.
128. Dalton BG, Gonzalez KW, Dehmer JJ, et al. Transition of techniques to treat choledochal cysts in children. J Laparoendosc Adv Surg Tech A. 2016;26:62–5.
129. Diao M, Li L, Cheng W. Recurrence of biliary tract obstructions after primary laparoscopic hepaticojejunostomy in children with choledochal cysts. Surg Endosc. 2016;30:3910–5.
130. Diao M, Li L, Cheng W. Laparoscopic redo hepaticojejunostomy for children with choledochal cysts. Surg Endosc. 2016;30:5513–9.
131. Li S, Wang W, Yu Z, et al. Laparoscopically assisted extrahepatic bile duct excision with ductoplasty and a widened hepaticojejunostomy for complicated hepatobiliary dilatation. Pediatr Surg Int. 2014;30:593–8.
132. Narayanan SK, Chen Y, Narasimhan KL, et al. Hepaticoduodenostomy versus hepaticojejunostomy after resection of choledochal cyst: a systematic review and meta-analysis. J Pediatr Surg. 2013;48:2336–42.
133. Takada K, Hamada Y, et al. Duodenogastric reflux following biliary reconstruction after excision of choledochal cyst. Pediatr Surg Int. 2005;21:1–4.
134. Shimotakahara A, Yamataka A, Yanai T, et al. Roux-en-Y hepaticojejunostomy or hepaticoduodenostomy for biliary reconstruction during the surgical treatment of choledochal cyst: which is better? Pediatr Surg Int. 2005;21:5–7.
135. Takeshita N, Ota T, Yamamoto M. Forty-year experience with flow-diversion surgery for patients with choledochal cysts with pancreaticobiliary maljunction at a single institution. Ann Surg. 2011;254:1050–3.
136. Koga H, Okawada M, Doi T, et al. Refining the intraoperative measurement of the distal intrapancreatic part of a choledochal cyst during laparoscopic repair allows near total excision. Pediatr Surg Int. 2015;31:991–4.
137. Miyano G, Koga H, Shimotakahara A, et al. Intralaparoscopic endoscopy: its value during laparoscopic repair of choledochal cyst. Pediatr Surg Int. 2011;27:463–6.
138. Urushihara N, Fukumoto K, Nouso H, et al. Hepatic ductoplasty and hepaticojejunostomy to treat narrow common hepatic duct during laparoscopic surgery for choledochal cyst. Pediatr Surg Int. 2015;31:983–6.
139 Stringer MD. Laparoscopic management of choledochal cysts: is a keyhole view missing the big picture? Pediatr Surg Int. 2017;33(6):651–5