ANATOMIC VARIANTS OF CYSTIC DUCT AND DIAGNOSTIC PITFALLS

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ABSTRACT

The cystic duct can be depicted with a variety of imaging modalities, however is optimally visualized with direct cholangiography or magnetic resonance cholangiopancreatography. Nonetheless, unrecognized anatomic variants of the cystic duct may cause confusion on imaging studies and complicate subsequent surgical, endoscopic, and percutaneous procedures. Primary entities involving the cystic duct include calculous disease, Mirizzi syndrome, cystic duct–duodenal fistula, biliary obstruction, neoplasia, and primary sclerosing cholangitis. The cystic duct may also be secondarily involved by adjacent malignant or inflammatory processes. Postoperative alterations are seen after liver transplantation or cholecystectomy when a portion of the cystic duct is left behind as a remnant. Recognized postoperative complications include retained cystic duct stones, cystic duct leakage, and malposition of T tubes in the remnant. Difficulty encountered in cystic duct imaging include pseudocalculous defects from overlap of the cystic duct and common bile duct, underfilling of the cystic duct during direct cholangiography, and admixture defects at the cystic duct orifice. Pseudomass or pseudotumor defects may result from an impacted cystic duct stone or from a tortuous, redundant cystic duct. Familiarity with the imaging appearance of the normal cystic duct, its anatomic variants, and related disease processes facilitates accurate diagnosis and helps avoid misinterpretation.

Key words: *Cystic Duct, Variants, Radiologic Diagnosis*

INTRODUCTION

Although much has been written about the normal anatomy and related diseases of the gallbladder and biliary tract, few studies have focused on the cystic duct that connects the gallbladder to the extrahepatic bile duct. Anatomic variants of the cystic duct are common and are usually of no clinical significance. However, unrecognized variant anatomy can be a source of confusion on imaging studies. In addition, the cystic duct may be involved by a wide variety of both primary and secondary disease processes.

Multiple modalities permit depiction of the normal anatomy as well as disease processes of the cystic duct, including ultrasonography (US), computed tomography (CT), direct cholangiography (percutaneous transhepatic cholangiography [PTC], endoscopic retrograde cholangiopancreatography-ERCP, T tube and intraoperative cholangiography) in addition to magnetic resonance (MR) imaging, MR cholangiopancreatography, and cholescintigraphy. Although visualization of the dilated cystic duct is possible with US, CT, or cholescintigraphy, the normal-caliber cystic duct may be difficult to detect with these techniques. The small caliber of the cystic duct and its tortuosity make detection difficult with US and axial CT, and cholescintigraphy is further limited by low resolution. Optimal visualization of the cystic duct requires direct cholangiography or MR cholangiopancreatography, both of which depict the cystic duct in the coronal plane along its long axis. The cystic duct is seen at direct cholangiography or MR cholangiopancreatography in virtually all cases. At direct cholangiography, injection of contrast material into the biliary ductal system opacifies and outlines the long axis of the cystic duct; fluoroscopy with rotation of the patient projects the cystic duct away from the common bile duct, allowing visualization of the entire cystic duct. Similarly, the capacity of MR cholangiopancreatography to provide coronal images and to orient the angle of image acquisition along the long axis of the cystic duct optimizes duct visualization. Interventional procedures involving the biliary tract may be complicated by the presence of confusing imaging patterns related to the cystic duct.

This article, expresses the normal anatomy of the cystic duct as well as anatomic variants, related pathologic processes, postoperative alterations and abnormalities, and diagnostic pitfalls.

NORMAL ANATOMY

The cystic duct attaches the gallbladder to the extrahepatic bile duct; its point of insertion into the extrahepatic bile duct marks the division between the common hepatic duct and the common bile duct, fig. 1. The cystic duct usually measures 2–4 cm in length and contains prominent concentric folds known as the spiral valves of Heister. The cystic duct frequently exhibits a tortuous or serpentine course. The normal diameter of the cystic duct is variable, ranging from 1 to 5 mm.

The cystic duct usually joins the extrahepatic bile duct approximately halfway between the porta hepatis and the ampulla of Vater. However, the point at which the cystic duct joins the extrahepatic bile duct is variable, ranging from high at the level of the porta hepatis to low at the level of the ampulla. The cystic duct enters the extrahepatic bile duct from the right lateral aspect in 49.9% of cases, from the medial aspect in 18.4%, and from an anterior or posterior position in 31.7%. It usually runs parallel to the extrahepatic bile duct for a short distance and may spiral around the bile duct to insert medially. The cystic duct has a parallel course relative to the

extrahepatic bile duct in 10.6% of patients and varies in length from 1.5 to 9.5 cm (mean, 3–4 cm). Of these parallel cystic ducts, 17% have a spiral course.At direct cholangiography, whether the injection is performed with PTC, ERCP, surgical cholangiography, or T tube cholangiography, the normal cystic duct usually fills with adequate injection of contrast material into the biliary tract and optimal patient positioning, fig. 2. Absence of filling of the cystic duct at ERCP is usually related to patient positioning rather than cystic duct obstruction [1-5].

In most cases, the normal cystic duct is not seen at US. However, with optimal technique, the normal cystic duct can be visualized in up to 50% of cases as an anechoic tubular structure connecting the gallbladder and bile duct, fig. 3. A cystic duct that runs parallel to the distal extrahepatic bile duct may be confused with a vessel; however, differentiation is possible with Doppler US [6]. The cystic duct is not routinely visualized at CT. In some cases, the cystic duct can be traced to its point of insertion into the extrahepatic bile duct, fig. 4. The cystic duct appears as a low-attenuation tubular structure with thin, enhancing walls. The gallbladder neck and cystic duct are often folded or tortuous. When the cystic duct has a long, parallel course relative to the extrahepatic duct, the adjacent ducts seen at cross-sectional imaging are bilobular or septated [7].

MR cholangiopancreatography depicts the cystic duct and biliary tract as high-signal-intensity structures. The cystic duct is routinely seen at MR cholangiopancreatography and can be traced to its junction with the extrahepatic bile duct in most cases. If overlap of the cystic duct and extrahepatic bile duct occurs, a change in the angle of image acquisition allows differentiation of the two structures. In addition, alteration of the angle of image acquisition can result in improved visualization of the cystic duct and clarification of complex or aberrant ductal anatomy. As with CT, the cystic duct is not usually visualized at axial MR imaging. T2-weighted sequences that show high-signal-intensity bile in the gallbladder and ductal system are optimal for cystic duct delineation. The cystic duct may also be visualized on T1-weighted images when the cystic duct contains concentrated, high-signal-intensity bile [8-11].

Fig.1.

Fig 2.

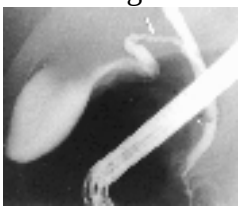


Fig 3 a

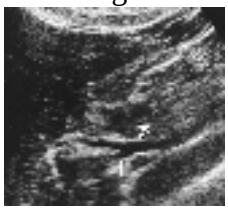
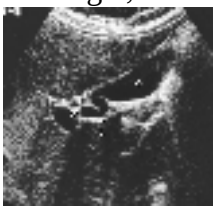


Fig 3, b



ANATOMIC VARIANTS

Variations in Cystic Duct Insertion

Congenital anatomic variants of the cystic duct are common, occurring in 18%–23% of cases. The cystic duct inserts into the middle one-third of the extrahepatic bile duct in 75% of cases and into the distal one-third in 10%. It most commonly inserts from a right lateral position but may have an anterior or posterior spiral insertion, low lateral insertion with a common sheath enclosing the cystic duct and common bile duct, proximal insertion, or low medial insertion at or near the ampulla of Vater [3,12-14]. The level of cystic duct insertion may vary, with an abnormal proximal or distal union accounting for 55% of biliary ductal anatomic variants. The

cystic duct may join the right hepatic duct, the left hepatic duct (rarely), or the common hepatic duct high in the porta hepatis. It empties into the proximal common hepatic duct or into the right hepatic duct on 0.3% of cholangiograms [12]. The insertion may be low in the intrapancreatic or intraduodenal portion or at the level of the ampulla of Vater. Rarely, the cystic duct inserts directly into the duodenum.

A cystic duct that parallels the extrahepatic bile duct is seen on approximately 10% of cholangiograms [3]. A long, parallel course implies a common fibrous sheath around the cystic duct and common hepatic duct. This anatomy may be problematic at cholecystectomy. Ligation of the cystic duct too close to the common hepatic duct may result in stricture of the latter. Similarly, mistaking the cystic duct for the bile duct can result in iatrogenic injury such as inadvertent ligation or transection of the extrahepatic bile duct. In addition, an unusually long cystic duct remnant (up to 6 cm in length) may be left after cholecystectomy. An enlarged or long cystic duct remnant may be associated with inflammatory changes and formation of calculi, resulting in postcholecystectomy syndrome, a cause of persistent or recurrent biliary symptoms in affected patients [15-17]. A long cystic duct remnant may also prove confusing at cross-sectional imaging, which depicts the parallel cystic duct and common hepatic duct as a septated cystic structure in or near the head of the pancreas [1,2,12-14,18].
Low medial insertion of the cystic duct deserves special attention because this anatomic variant may lead to misdiagnosis on imaging studies and thus affect therapeutic intervention. Low medial insertion of the cystic duct occurs when it joins the extrahepatic bile duct from the medial aspect at or near the ampulla of Vater. A parallel course of the cystic duct with a low medial insertion is seen at cross-sectional imaging (CT, MR imaging, US) as a rounded or elongated, septated cystic structure representing the closely apposed extrahepatic bile duct and cystic duct as they course through the head of the pancreas.

Superimposition of the cystic duct on the extrahepatic bile duct is commonly seen with this anatomic variant. Cystic duct stones in a low, medially inserting cystic duct that joins the common bile duct at the ampulla may be mistaken for stones in the distal bile duct or may result in bile duct obstruction or gallstone pancreatitis [13,14,19]. Retrograde filling of the low, medially inserting cystic duct at ERCP may mimic the common bile duct or pancreatic duct, particularly if the cystic duct is incompletely filled.
Because the low, medially inserting cystic duct frequently overlies the distal common bile duct, attempts to cannulate the common bile duct at ERCP can result in inadvertent introduction of the injection cannula, stone extraction basket, or extraction balloon into the cystic duct. Injury to the cystic duct may occur. Unsuccessful interventional procedures result if placement of stents or instruments into the cystic duct rather than the common bile duct goes unrecognized. A cystic duct remnant that is associated with a low medial insertion is usually longer than normal, either due to encasement in a common sheath with the extrahepatic bile duct or because the junction is in the intrapancreatic or periampullary area. Extraction of bile duct stones can be more problematic because the extraction attempt will frequently result in the stones slipping back and forth into the cystic duct remnant.

ANOMALOUS BILE DUCTS

Anomalous or aberrant bile ducts are usually of no clinical significance, unless they lead to diagnostic confusion on imaging studies or result in increased potential for iatrogenic injury.

Ducts at greatest risk for injury at cholecystectomy are those that course near the cystic duct or gallbladder or empty directly into these structures. Anomalous ducts that empty directly into the cystic duct (cysticohepatic ducts) are found in 1%–2% of individuals, fig 4 a. Accessory bile ducts, especially those arising from the right lobe, may join the common hepatic duct at its junction with the cystic duct or may insert directly into the cystic duct, fig 4 b. Up to 5% of patients will have a major right segmental bile duct joining the extrahepatic bile duct at or near the cystic duct. This anatomic variant creates a risk of inadvertent ligation or transection of the aberrant duct near the cystic duct insertion at cholecystectomy. Rare anomalies of the cystic duct include insertion into the right hepatic duct, double cystic ducts with or without a duplicated gallbladder, and absence of the cystic duct with the gallbladder emptying directly into the common bile duct [13,14, 18, 21-23]

PATHOLOGIC PROCESSES

Calculous Disease

In 95% of cases, acute cholecystitis is caused by a stone obstructing the cystic duct. Small stones (<3 mm) may pass readily through the cystic duct. However, when calculous obstruction occurs, inflammation and distention of the gallbladder result and may eventually lead to gallbladder ischemia and transmural necrosis if the obstruction persists.

Sometimes, the obstructing calculus and the distended gallbladder may be identified on conventional radiographs. However, only 15%–20% of gallstones are sufficiently dense to allow detection on conventional radiographs. While US permits diagnosis of acute cholecystitis with a high degree of confidence (positive predictive value = 92%, negative predictive value = 95%), the obstructing cystic duct stone may be difficult to visualize due to a minimal amount of surrounding bile and because cystic duct stones may be mistaken for bowel gas. Although CT often reveals gallbladder wall thickening and pericholecystic fluid, depicts complications of cholecystitis such as abscess formation and gallbladder perforation, it depicts only 79% of gallbladder stones seen at US and rarely depicts cystic duct stones [24-27].

In contrast to US and CT, which provide anatomic information about the gallbladder and cystic duct, cholescintigraphy provides functional information regarding cystic duct patency. Nonvisualization of the gallbladder 1 hour following administration of the radionuclide is considered evidence of cystic duct obstruction. Adjuvant use of low-dose intravenous morphine to contract the sphincter of Oddi, which diverts the isotope into the gallbladder if the cystic duct is patent, is helpful in reducing the prevalence of false-positive studies. Cholescintigraphy has a sensitivity of 95% and a specificity of 100% in the diagnosis of acute cholecystitis secondary to cystic duct obstruction [25,26,28,29].

At direct cholangiography, the cystic duct is usually readily opacified. Cystic duct stones are identified as sharply defined filling defects in the contrast material–filled lumen. Cystic duct stones may be identified at MR cholangiopancreatography as low-signal-intensity defects surrounded by high-signal-intensity bile. MR cholangiopancreatography has high sensitivity in detecting cystic duct stones (100% in a preliminary report) [30].

Mirizzi Syndrome

Mirizzi syndrome occurs when a gallstone impacted in the cystic duct results in extrinsic compression and obstruction of the extrahepatic bile duct, fig. 5. For this to occur, the cystic duct

usually must run parallel to the extrahepatic bile duct. Preoperative recognition of this condition is therefore important to avoid inadvertent ligation or severance of the bile duct [31,32].
The diagnosis of Mirizzi syndrome may be suggested at US or CT when a stone is identified at the junction of the cystic duct and extrahepatic bile duct and is seen in conjunction with dilatation of the bile duct proximal to the stone and a normal-caliber duct distal to the stone [33, 34]. ERCP or PTC is often necessary to confirm the diagnosis. MR cholangiopancreatography may provide a noninvasive alternative to ERCP and PTC in the diagnosis of Mirizzi syndrome [35].

Fig 4 a

Fig 4 b

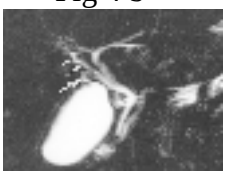


Fig 5

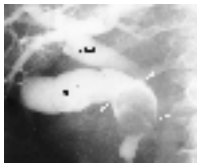


Fig 6

Cystic Duct–Duodenal Fistula

Fistulas between the duodenum and cystic duct or gallbladder occur most often due to erosion of an impacted gallstone but may also be seen in association with peptic ulcer disease, neoplasia, and trauma. Eighty percent of enterobiliary fistulas occur between the cystic duct or gallbladder neck and the postapical duodenum immediately beyond the duodenal bulb [36]. The gallbladder in cystic duct–duodenal fistula is frequently shrunken, mimicking a pseudodiverticulum of the duodenal bulb, fig.6. Direct cholangiography or an upper gastrointestinal series shows the fistula extending laterally or cephalad from the duodenal bulb. An “impending” cystic duct–duodenal fistula may be identified as a cystic duct stone compressing the duodenum prior to formation of a fistula.

Cystic Duct Changes Related to Biliary Obstruction

When the cystic duct insertion is located above an obstructing bile duct lesion, the cystic duct usually dilates in proportion to common bile duct dilatation. The cystic duct may dilate markedly so that it mimics the gallbladder or a dilated right hepatic branch. However, the cystic duct above an obstructing bile duct lesion does not always dilate as the proximal ducts dilate; it may remain normal in caliber even though the extrahepatic bile duct is markedly dilated. The dilated cystic duct in an obstructed, dilated ductal system usually returns to normal caliber if the ductal system is decompressed, similar to the decrease in caliber of the decompressed intrahepatic or extrahepatic bile ducts. The appearance of a dilated, tortuous cystic duct overlying the dilated common bile duct in biliary obstruction can be confusing at direct cholangiography and should be accurately identified to avoid inadvertent cannulation of the cystic duct at PTC or ERCP. Bile leakage, cystic duct injury, or mistaken placement of the proximal end of an endoscopic stent into the cystic duct are recognized complications [3,4,19 37].

The dilated cystic duct is readily identified at US, CT, and MR cholangiopancreatography. At CT, the dilated, tortuous cystic duct seen in cross-section on axial images may mimic a multilocu-lated cystic mass in the porta hepatis or in the head of the pancreas. MR cholangiopancreatography demonstrates the dilated cystic duct as a high-signal-intensity ductal

structure bridging the gallbladder and extrahepatic bile duct. Prominent valves of Heister may be visualized and recognition of stones made easier if the cystic duct is dilated [4,6,7].

Neoplastic Involvement of the Cystic Duct

The cystic duct may demonstrate direct neoplastic involvement by primary tumor arising in the cystic duct or adjacent gallbladder. Bile duct carcinomas are less common than gallbladder carcinomas; however, if the bile duct carcinoma originates near the cystic duct origin, the cystic duct may be occluded by tumor or directly invaded by the bile duct neoplasm, fig. 7a. Bile duct tumors more commonly involve the proximal bile ducts and are less frequently located in the middle or distal extrahepatic bile duct where the cystic duct usually inserts [4, 26]. The cystic duct may be invaded or compressed by primary or secondary liver tumors or, less commonly, by adjacent pancreatic head neoplasms, fig.7b. Regardless of its origin, a tumor affecting the cystic duct is usually visible at CT, US, or MR imaging.

Fig 7 a

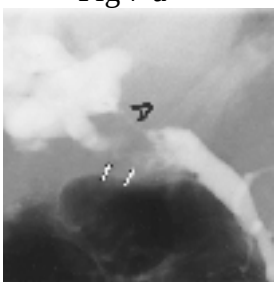


Fig 7 b

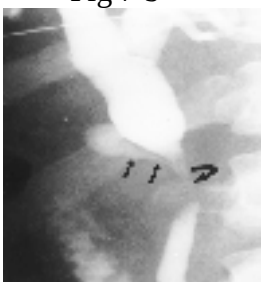


Fig 8

Cystic Duct Involvement by Primary Sclerosing Cholangitis

Primary sclerosing cholangitis is an uncommon disease of unknown cause characterized by inflammation and fibrosis of the biliary tract. Diffuse, multifocal strictures involving both intrahepatic and extrahepatic bile ducts are the most common finding in primary sclerosing cholangitis. The cystic duct may also be involved by primary sclerosing cholangitis. MacCarty et al [38] noted that in 60 of 86 patients with primary sclerosing cholangitis in whom the cystic duct was visualized at direct cholangiography, 18% (n = 11) had cystic duct involvement. Cystic duct abnormalities included strictures, mural irregularities, and diverticula similar to the changes seen in the intrahepatic and extrahepatic bile ducts, fig.8. The detection of cystic duct involvement by primary sclerosing cholangitis may be difficult due to the normal valves of Heister, which may obscure the findings. In addition, underfilling of the cystic duct can result in an appearance of the cystic duct that simulates primary sclerosing cholangitis.

DIAGNOSTIC PITFALLS

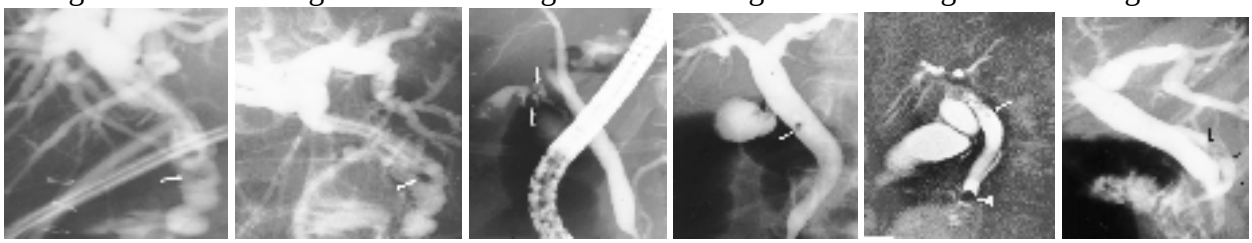
Pseudocalculous Defects

A pseudocalculous defect created by the bridge of tissue between the juxtaposed cystic duct and extrahepatic bile duct near the site of insertion of the cystic duct may be visualized at direct cholangiography or MR cholangiopancreatography, fig 9a,b. Rotation of the patient during cholangiography or rotation of the angle of acquisition at MR cholangiopancreatography will throw the bile duct away from the cystic duct, thereby allowing visualization of the bridge of

tissue that is causing the defect.A pseudocalculus may be seen in the cystic duct secondary to underfilling of the duct during direct cholangiography, fig 10. Additional images obtained after more complete filling of the duct or a change in patient position (prone to supine or vice versa) will help verify the absence of a stone.

A round, radiolucent defect mimicking a stone may be seen at the junction of the cystic duct and the bile duct during direct cholangiography, fig. 11a. This admixture defect is transient and is thought to result from a difference in flow density, with contrast material in the bile duct initially failing to mix and flowing around the more viscous bile in the cystic duct orifice [19,39]. A similar defect may be seen at MR cholangiopancreatography related to inspissated bile or tissue at the cystic duct orifice, fig.11b.

Fig. 9 a Fig. 9 b Fig. 10 Fig. 11a Fig. 11b Fig. 12



Cystic Duct Stones Mimicking Common Bile Duct Stones

Superimposition of the cystic duct on the extrahepatic bile duct, especially if the cystic duct has a parallel or low medial insertion, may create a confusing cholangiographic picture. Stones in a cystic duct or cystic duct remnant overlying the bile duct can lead to misdiagnosis and misguided or unsuccessful extraction attempts at ERCP if the stones are assumed to be in the bile duct. Rotation of the patient separates the superposed ducts and demonstrates the presence of a stone or stones in the cystic duct remnant rather than in the bile duct [3,19,20].

Cystic Duct Stones Mimicking Bile Duct Tumor

An unusual, irregular masslike defect apparently involving the bile duct can result from impacted stones in the cystic duct protruding from the cystic duct orifice into the lumen of the common bile duct, fig12. Soft, castlike calculi or calculi mixed with an amorphous bile plug may have irregular borders and simulate a fixed mural mass [19]. Injection and withdrawal of contrast material during direct cholangiography, retrograde injection of contrast material at ERCP, or an extraction attempt may dislodge the calculus, allowing filling of the cystic duct and exclusion of a bile duct tumor.

Cystic Duct Simulating a Multilocular Cystic Mass at CT

A tortuous, dilated cystic duct may simulate a multilocular cystic mass in the porta hepatis or in the head of the pancreas at cross-sectional imaging. This “pseudomass” is more commonly seen in cases of biliary obstruction, which causes the cystic duct to be dilated and tortuous. Multiplanar reconstructed images in the sagittal or coronal plane can be helpful in elucidating this finding so that misdiagnosis is avoided.

CONCLUSIONS

The cystic duct may be involved by a variety of disease processes affecting the biliary tract and gallbladder. Diagnostic accuracy relies on a clear understanding of the normal anatomy and anatomic variants of the cystic duct; the imaging features of calculous disease, biliary obstruction, and malignancy; and both typical and unusual postoperative manifestations. Difficulties that may result in misdiagnosis are related to pseudocalculous and pseudomass defects. Thus, a radiologist must be very caution and perform a proficient examination and an well written interpretation or add the appropriate examination test in order to minimize misdiagnosis and be as accurate as possible in diagnosis in order to have a better clinical assessment and treatment of the respective patients.

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