Normal variants of the biliary tree: What the surgeon needs to know

Poster No.: C-002
Congress: ECR 2009
Type: Educational Exhibit
Topic: Abdominal and Gastrointestinal
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Keywords: anatomy, MR cholangiopancreatography, biliary tree
DOI: 10.1594/ecr2009/C-002

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Learning objectives

To review the most frequent normal variants of the biliary ducts, as seen at Magnetic Resonance (MR) cholangiopancreatography, emphasizing their clinical relevance for surgical interventions.

Background

During the past decade, the increasing number of hepatobiliary surgical procedures, mainly laparoscopic cholecystectomies but also liver transplantations, has been associated with an increase in postoperative biliary complications.

MR cholangiopancreatography has become the imaging modality of choice at many institutions for the work-up of patients with suspected bile duct abnormalities but also for surgical planning.

There are wide anatomic variations in the intra and extrahepatic biliary tree, some of which may make surgical access difficult. It is imperative that the radiologist be familiar with normal variants, to report them and prevent possible complications.

Content Organization

1. In this exhibit, we present MR cholangiograms to illustrate normal and anatomic variants of the biliary tree, including:

- drainage of the right posterior duct into the left hepatic duct and common hepatic duct;

- triple confluence;

- low cystic duct insertion;

- medial cystic duct insertion;

- parallel course of the cystic duct and common hepatic duct.

2. Additionally, we present possible complications associated with unrecognized anatomic variations of the biliary tree.

Imaging findings OR Procedure details
"Knowledge of the normal and variant anatomy forms the basis for the interpretation of every imaging examination." adapted from Kadir 1991

CLASSIC BILIARY ANATOMY

Normally, the right and left hepatic ducts converge at the porta hepatis to form the common hepatic duct. The right duct branches into the right posterior hepatic duct (draining posterior segments VI and VII), and the right anterior hepatic duct (draining anterior segments V and VIII). The right posterior duct, which has a horizontal course, usually runs posterior to the right anterior duct, which is more vertically oriented, and fuses with it from a medial approach to constitute a short right hepatic duct. Segmental tributaries draining segments II-IV form the left hepatic duct. The caudate lobe usually drains to the origin of the left hepatic duct, or to the right hepatic duct.

Fig.: Three-dimensional rendered model of a liver with the common bile duct and its branches injected. Classic biliary anatomy is shown: the left hepatic duct has a transverse orientation and it is formed by the lateral branch (from segment II) and the medial branch (from segments III and IV). The right hepatic duct is short and almost
vertical and it is formed by a posterior branch (from segments VI and VII) and an anterior branch (from segments V and VIII). Reprinted with permission from P. Donato. Normal vascular and biliary hepatic anatomy: 3D demonstration by multidetector CT. Surg Radiol Anat (2007) 29:575 - 582

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. The cystic duct usually drains into the lateral aspect of the extrahepatic bile duct approximately halfway between the porta hepatis and the ampulla of Vater.

(Figure 2 on page)

Normal Variants

Anatomic variants of the biliary anatomy are common, with the classic anatomy being found in only 58% of the population.

The most common anatomic variants in the branching of the biliary tree described involve the right posterior duct and its fusion with the right anterior or left hepatic duct.

Drainage of the right posterior duct into the left hepatic duct before its confluence with the right anterior duct is the most common anatomic variant of the biliary system and reported to occur in 13-19% of the population (figure 3 on page).

In approximately 12% of the healthy population, the right posterior duct will not pass the right anterior duct posteriorly, but will empty into the right aspect of the right anterior duct.
Fig.: MR cholangiogram shows drainage of right posterior duct into left hepatic duct before joining right anterior duct. There is also another common variant of the pancreatic ductal system: pancreas divisum (dominance of the pancreas dorsal duct draining in the minor papilla).

Other common clinically relevant anatomic variants of the biliary tract include a biliary trifurcation. This is an anomaly characterized by simultaneous emptying of the right posterior duct, right anterior duct, and left hepatic duct into the common hepatic duct. In patients with this variant, the right hepatic duct is virtually nonexistent (figure 5 on page ).

In some centers, biliary trifurcation may preclude graft harvesting because of the increase in the postoperative complication rate.
Several less common and usually more complicated anatomic variations of the bile ducts have been described and consist of both **aberrant and accessory bile ducts**: an aberrant bile duct is the only bile duct draining a particular hepatic segment, whereas an accessory one is an additional bile duct draining the same area of the liver.

- An aberrant right hepatic duct drains part of the right lobe of the liver directly into the extrahepatic biliary tree (*figure 7 on page 7*) (*figure 8 on page 8*). Being close to the cystohepatic angle (formed by the cystic duct and gallbladder below, the right lobe of the liver above, and the common hepatic duct medially), the aberrant duct may undergo accidental transection or ligation during cholecystectomy and therefore complications may ensue.
Accessory hepatic ducts are observed in approximately 2% of patients and may originate from and run their course along both the left or right ductal system.

Fig.: MIP reconstruction from T2-weighted sequence shows drainage of right posterior duct into left hepatic duct just before joining right anterior duct, forming almost a trifurcation, and presence of accessory right posterior duct draining in the common hepatic duct.

Anomalous ducts arising from the left lobe are rare and are usually of no clinical significance.

Congenital anatomic variants of the cystic duct are common, occurring in 18%-23% of cases. Generally, there are three common variants in the cystic ductal anatomy:

- low cystic duct insertion (figure 10 on page): characterized by a fusion of the cystic duct with the distal third of the extrahepatic bile duct (9%);
- medial cystic duct insertion (figure 11 on page ...): in which the cystic duct drains into the left side of the common hepatic duct (10-17%);

- parallel course of the cystic duct and common hepatic duct (figure 12 on page ... (figure 13 on page ...), judged to be present when the cystic duct follows a closely adherent course, parallel to the common hepatic duct over at least a 2cm segment (1.5-25%).

**Surgical Complications**

Accurate preoperative assessment of the biliary anatomy is essential to ensure safe and successful hepatic surgery. Such surgical procedures range from the more complex, like tumor resection and partial hepatectomy for living donor liver transplantation, to others performed more routinely, like laparoscopic cholecystectomy. Bile duct injuries can occur after either open or laparoscopic cholecystectomy. The risks of bile duct injuries associated with the later technique are increased compared with open surgery.

Variant biliary anatomy is one of the factors that may contribute to the occurrence of bile duct injury after surgery. Failure to recognize these anatomic variants may result in inadvertent ductal ligation, biliary leaks, and strictures, especially at laparoscopic cholecystectomy and living donor right lobe liver transplantation.

**Bile duct excision and ligation** injuries may involve an aberrant right hepatic duct or the main bile ducts. The classic injury occurs when the surgeon mistakes the common hepatic duct (CHD) for a cystic duct; the CHD is then clipped, resulting in acute biliary obstruction.

Injuries to the main bile ducts are grouped according to the Bismuth classification system (figure 14 on page ...). The classification of an injury according to the Bismuth system is useful for surgical planning.

Radiologic studies usually show diffuse or segmental intrahepatic duct dilatation and surgical clips at the point of obstruction (figure 15a on page ...).
Fig.: Coronal T2-weighted HASTE sequence and MIP reconstruction from T2-weighted sequence show another patient with segmental biliary duct dilatation of the posterior segments of the right hepatic lobe. There is no dilatation of the other intra-hepatic biliary ducts or the common biliary duct.

Postoperative bile leakage can occur in different locations, but mainly occurs at the caudate branches in the hilar plate. Bile leakage may also occur at the repair site of the hepatic duct and rarely along the parenchymal transection surface of the liver. Bile collections are usually close to the site of the leak, but occasionally they may have a more remote location (figure 16 on page ). Several authors have described the use of intravenously administered mangafodipir trisodium for the detection and localization of bile duct leaks at MR cholangiography after bile duct surgery. This technique provides both anatomic and functional information about the biliary tract and enables the direct visualization of bile extravasation from injured bile ducts as well as the identification of bile collections (figure 17 on page ).
Fig.: Coronal 3D volumetric interpolated T1-weighted gradient-echo MR image obtained 30 minutes after injection of mangafodipir trisodium shows enhancement of the biliary tree, as well as extravasation to the subhepatic collection, confirming a biliary leakage.

After cholecystectomy, a variable length of the cystic duct is left as a remnant. Usually, a cystic duct remnant of 1-2 cm is left at surgery. A longer remnant may be left after cholecystectomy when a long, parallel cystic duct or low medial insertion is present. This **long cystic duct remnant** may be associated with inflammatory changes and formation of calculi (*figure 18 on page* ), resulting in postcholecystectomy syndrome, a cause of persistent or recurrent biliary symptoms in affected patients.

Fig.: Axial T2-weighted HASTE sequence (18a) and projective MR cholangiogram (18b) show a long cystic duct remnant, associated with two retained stones.
Images linked within the text of this section:

**Fig.** Normal hepatic ductal anatomy on projective MR cholangiogram.
**Fig.**: MR cholangiogram shows drainage of right posterior duct into left hepatic duct before joining right anterior duct.
Fig.: MR cholangiogram shows triple confluence of right anterior duct, right posterior duct, and left hepatic duct.
**Fig.**: MR cholangiogram shows aberrant drainage of right posterior duct into common hepatic duct.
**Fig.** Modified 3D rendered model of a liver with the common bile duct and its branches injected. The posterior branch from segments VI and VII drains directly into the common hepatic duct (arrow). Reprinted with permission from P. Donato. Normal vascular and biliary hepatic anatomy: 3D demonstration by multidetector CT. Surg Radiol Anat (2007) 29:575 - 582
**Fig.:** MR cholangiogram shows medial and relatively low insertion of the cystic duct (arrow). There is also a biliary trifurcation.
Fig.: Projective MR cholangiogram shows a medial insertion of the cystic duct into the extrahepatic bile duct.
**Fig.** MR cholangiogram shows parallel course of cystic duct and common hepatic duct, with the cystic duct entering the common bile duct on the left side.
Fig.: Axial T2-weighted HASTE sequence showing two hyperintense dots in the pancreatic head corresponding to the cystic and common bile ducts.
### Bismuth classifications of traumatic bile duct injury

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>Type I</td>
<td>Injury more than 2 cm distal to biliary bifurcation</td>
</tr>
<tr>
<td>Type II</td>
<td>Less than 2 cm from biliary confluence</td>
</tr>
<tr>
<td>Type III</td>
<td>Involves entire common hepatic duct and leaves confluence intact</td>
</tr>
<tr>
<td>Type IV</td>
<td>Complete or partial destruction of biliary bifurcation</td>
</tr>
<tr>
<td>Type V</td>
<td>Represents injury to a variant right segmental branch with or without involvement of the main duct</td>
</tr>
</tbody>
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**Fig.:** Bismuth classification system.
Fig.: Axial T2-weighted HASTE sequence and projective MR cholangiogram show segmental biliary duct dilatation (anterior segments of right hepatic lobe). Note the common biliary duct with normal caliber.
**Fig.:** Coronal T2-weighted HASTE sequence shows a fluid collection in gallbladder fossa and a retained stone in common hepatic duct.
**Fig.** Coronal 3D volumetric interpolated T1-weighted gradient-echo MR image obtained 30 minutes after injection of mangafodipir trisodium shows enhancement of the biliary tree, as well as extravasation to the subhepatic collection, confirming a biliary leakage.

**Fig.** Axial T2-weighted HASTE sequence (18a) and projective MR cholangiogram (18b) show a long cystic duct remnant, associated with two retained stones.
Conclusion

By reviewing this exhibit, users will be able to recognize the most frequent normal variants of the biliary tree, which are responsible for a significant number of surgical complications.

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