Review

Imaging in laparoscopic cholecystectomy—What a radiologist needs to know

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A B S T R A C T
Laparoscopic cholecystectomy is the gold standard treatment option for cholelithiasis. In order to properly assess for the complications related to the procedure, an understanding of the normal biliary anatomy, its variants and the normal postoperative imaging is essential. Radiologist must be aware of benefits and limitations of multiple imaging modalities in characterizing the complications of this procedure as each of these modalities have a critical role in evaluating a symptomatic post-cholecystectomy patient. The purpose of this article is describe the multi-modality imaging of normal biliary anatomy and its variants, as well as to illustrate the imaging features of biliary, vascular, cystic duct, infectious as well as miscellaneous complications of laparoscopic cholecystectomy. We focus on the information that the radiologist needs to know about the radiographic manifestations of potential complications of this procedure.

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1. Introduction

Laparoscopic cholecystectomy was first introduced in Europe in 1980s [1]. It immediately gained widespread popularity due to shorter hospital stay and earlier recovery to normal activities [2]. However, in the hands of less experienced practitioners, rates of complications secondary to the procedures have reported to be higher than traditional cholecystectomy [3]. Since laparoscopic cholecystectomy has become the gold standard treatment of choice for cholecystitis, an understanding of normal biliary anatomy, its variants and normal postoperative imaging of laparoscopic cholecystectomy is essential to properly assess for the complications related to the procedure. Additionally, as sonography, computed tomography (CT), Endoscopic retrograde cholangiopancreatography (ERCP), and Magnetic resonance cholangiopancreatography (MRCP) all have a role to play in evaluating a symptomatic post-cholecystectomy patient [4], radiologist must be aware of relative benefits and limitations of each modality in characterizing complications of the procedure. In this article, after describing the imaging of normal biliary anatomy and its variants, we systematically illustrate imaging features of biliary, vascular, cystic duct complications, along with infections and miscellaneous complications of laparoscopic cholecystectomy.

2. Technique of laparoscopic cholecystectomy

Basic surgical steps of performing a laparoscopic cholecystectomy are as follows [5]: after insufflating the peritoneal cavity with 3–4 L of carbon dioxide through a periumbilical incision, the primary trocar and laparoscope are placed. After ruling out any injury resulting from placing of the prime trocar, three accessory trocars are placed. Subsequently, the gallbladder is grasped at the fundus; retracted cephalad and both cystic duct and artery are isolated. A double clip is then placed on the cystic duct and artery. The cystic duct is incised; the gallbladder is dissected off the liver bed, and is subsequently removed.

Before ligating the cystic duct and artery, contents of the hepatocystic triangle, the area formed by the gallbladder and cystic duct medially, common hepatic duct laterally and inferior liver edge superiorly, should be carefully identified. Misidentification of anatomy in this area is in fact a major cause of complications.
during the surgery (Fig. 1) [6]. Calot’s triangle is the historic name for this space and was originally described to be bounded by the cystic duct, the common hepatic duct, and the cystic artery (Fig. 1). Calot’s triangle, containing the cystic artery, may also contain an aberrant/accessory hepatic artery or anomalous bile ducts. Dissection in the triangle of Calot is not recommended until the lateral-most structures have been clearly defined and identification of the cystic duct is ascertained.

3. Biliary anatomy and its variants

Gallbladder, located in the fossa on the undersurface of the liver, is approximately 10 cm long and 5 cm in diameter. It is attached to common bile duct (CBD) via the 2–4 cm long cystic duct. The cystic duct usually enters from the right, approximately half way between the porta hepatis and the ampulla of Vater. The insertion point of the cystic duct is variable [7]. In the first variation seen in 10–17% of cases, cystic duct joins CBD from the medial aspect (Fig. 2) and drains into its left side. In the second variation seen in 1.5–2.5% of cases, cystic duct has a parallel course relative to the CBD before it spirals around it to insert medially. In the third variation, there is a low cystic duct insertion, usually in the distal third of the CBD, in approximately 9% of cases (Fig. 3). After a laparoscopic cholecystectomy, cystic duct remnant is usually 1–2 cm long; however, remnants up to 6 cm in length have been seen in the case of long parallel or low and medial insertions.

The classic biliary anatomy, which is seen in 50–60% of patients, consists of the right hepatic duct draining the right hepatic lobe, and the left hepatic duct draining the left lobe (Fig. 4) [8]. The right hepatic duct branches into the right anterior duct (RAD), which drains segments V and VIII, and the right posterior duct
(RPD), which drains segments VI and VII. The right posterior duct runs posterior to the right anterior duct and fuses in a medially approach to form a short right hepatic duct [9]. Left hepatic duct (LHD) drains segments II–IV through smaller segmental ducts. Common hepatic duct is formed via the fusion of left and right hepatic ducts. The caudate lobe duct can drain directly either into the left or the right hepatic duct.

Variant biliary anatomy is one of the important causes of biliary duct injury during laparoscopic cholecystectomy [10]. There are three common variations to the classic biliary anatomy. Drainage of the RPD into the LHD before its confluence with RAD is one of the most common variants, seen in 15% of cases (Fig. 5A) [11]. Triple confluence pattern in which there is a simultaneous emptying of the RPD, RAD, and LHD is seen approximately 11% of cases (Fig. 5B) [11]. Direct drainage of the RPD into the common hepatic duct from the right (seen in 5%) or the left (seen in <1%) is called aberrant hepatic duct (Fig. 6). The close proximity of the aberrant hepatic duct to hepatic duct makes it vulnerable to injury, leading to biliary fistula, sepsis, and biloma [10].

Accessory hepatic ducts, seen in 2% of cases, may drain into the right or the left ductal system. They may be described by their location relative to the gallbladder as supravesicular (superior to the gallbladder body) or subvesicular (inferior to the gallbladder body). These can be accidently injured during cholecystectomy (Fig. 7). Thus, radiologists should always report variant biliary anatomy, as it is one of the leading causes of iatrogenic injuries during laparoscopic cholecystectomies.

4. Biliary complications

4.1. Biliary injury

Bile leakage secondary to bile duct injury is the most common complication of laparoscopic cholecystectomy [12]. In one series, there was a 0.6% overall rate of bile duct injury, with the rate for individual surgeons varying from 0.4% to 4% [13]. Most leaks occur from the cystic duct stump. Some common mechanisms of leak include dislodgement of clips from the cystic duct stump as well
as unintentional laceration, transection or thermal injuries of the duct. Hepatobiliary scintigraphy, ERCP, or mangafodipir trisodium enhanced T1-weighted MRCP have been shown to be effective in the diagnosis of bile leak [14].

Based on severity of the injury, biliary injury can be classified into Type A through Type E using the schema proposed by Strasberg SM et al. [15]. This classification describes spectrum of biliary injuries from asymptomatic bile leak, to complete obstruction of the biliary tree. In the type A injuries, there is leakage into the gall-bladder bed from injury to either the minor hepatic ducts or the cystic duct without injuries to major bile ducts or hepatic ducts (Fig. 8). There is no loss of continuity of the biliary tree. This type of injury is usually the least serious. In type B and C injuries, there is an occlusion (Type B) or transection (Type C) of the part of the biliary tree. These injuries are usually associated with occlusion/ligation of aberrant right hepatic duct when there is cystic duct drainage into the aberrant right hepatic duct and it is mistaken for the cystic duct [15]. Patients with Type B injury may be asymptomatic or present late with focal ductal dilatation and segmental atrophy of liver (Fig. 9). Patients with Type C injury usually present early with biloma. In type D injury, there is partial injury to common hepatic duct or common bile duct with a resultant biliary leak (Fig. 10). They can usually be managed with an endoscopic insertion of a t-tube. Type E injuries result from injury to the main biliary ducts and are

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Fig. 6. Coronal MRCP image (A) and axial T2W image (B) showing aberrant right posterior duct draining into the CBD (white arrow). Failure to recognize this anomaly is the most common cause of biliary injury in cholecystectomy.

Fig. 7. Endoscopic retrograde cholangiopancreatoscopy (ERCP) image showing accessory hepatic duct draining into the common hepatic duct (white arrow). Patient had injury during cholecystectomy resulting in active contrast extravasation (black arrow).

Fig. 8. ERCP image in a 46-year-old female with leak from the cystic duct remnant (white arrow) presenting 2 days after laparoscopic cholecystectomy. This represents Strasberg type A injury.
Fig. 9. 37-year-old female with post-laparoscopic transection of aberrant right posterior duct with persistent pain and elevated bilirubin levels post-operatively. (A) Axial T2W MRI done 1 week after laparoscopic cholecystectomy reveals mild prominence of the right posterior ducts (thick white arrow). (B and C) Axial T2W MRI done 1 year later reveals progressive dilatation of the right posterior hepatic ducts (thin white arrows) with segmental atrophy of the liver lobe (arrowhead). (D) VRT image from CT (thick white arrow) shows injury to right posterior hepatic duct. These findings are characteristic of Type B injury, may be asymptomatic or present late with focal ductal dilatation and segmental atrophy of liver.

Fig. 10. 42-year-old female presenting with abdominal pain and fever. (A) Coronal T2W MRI and (B) Heavily T2W MRCP reveals a collection/biloma in the gallbladder fossa (arrowhead) extending to the gastrohepatic region (arrow). (C) ERCP demonstrates contrast extravasation from the lateral aspect of the proximal CBD (arrow) representing partial transection. This represents a type D injury.

classified according to the level of injury: in E1, the injury occurs >2 cm from the confluence of left and right hepatic ducts (Fig. 11), while in E2, the injury occurs <2 cm from the confluence (Fig. 12). In E3, there is injury at the confluence, with the confluence being intact, while in E4, there is destruction of the biliary confluence with separation of the major ducts. In E5, there is transection of the aberrant right hepatic duct and the major ducts. With type E injuries, patients usually present with symptoms such as jaundice and abdominal pain weeks after the surgery and a hepaticojejunostomy is almost always required [16].

Fig. 11. 32-year-old female presenting with post-cholecystectomy pain with rising bilirubin and obstructive symptoms. (A) Coronal Fat-saturated heavily T2 WI MRI and (B) Coronal HASTE MRI reveal multiple clips placed across the CBD (arrows) and transecting it with resultant biliary tree dilatation. The transection is more than 2 cm distal to the confluence and is a Type E1 injury.
42-year-old female with abdominal pain and obstructive symptoms 1 day after laparoscopic cholecystectomy. (A) ERCP reveals a transection of the common hepatic duct (white arrow) (<2 cm from the confluence, representing type E2 injury) with contrast in the drain (white triangle) indicating active leak. (B) A stent (white arrow) was placed as a temporary measure; the patient subsequently underwent hepaticojejunostomy.

4.2. Stone retention and Mirizzi's syndrome

Stone retention is an important complication of laparoscopic cholecystectomy, with incidence between 1.1% and 7% [17]. Patients usually present with symptoms of biliary colic. Factors predisposing to retained stones include incomplete excision of gallbladder due to adhesions and a long cystic duct pedicle. Retained stone case lead to increased biliary pressure resulting in a stone remnant compressing the CBD.

Fig. 12. Mirizzi's syndrome secondary to calculus in the cystic duct remnant compressing the CBD. (A–D) Coronal TruFISP images reveal dilated biliary tree (arrows) secondary to compression by calculus (arrowhead in C) in the cystic duct remnant which is also dilated (dashed arrow).
in displacement of cystic duct clips and a bile leak. Additionally, gallstone impaction in the cystic duct remnant can cause an inflammatory reaction, leading to extrinsic bile duct compression thus resulting in Mirizzi’s syndrome (Fig. 13). Post-cholecystectomy Mirizzi’s syndrome can usually be successfully managed with ERCP [18]. Similarly, since CBD is not explored during laparoscopic cholecystectomy, a gallbladder stone can migrate into the CBD in patients with patulous cystic duct when gallbladder is pulled in a cephalad direction during cholecystectomy, causing biliary obstruction (Fig. 14). In patients with
suspected stone retention, MRCP is helpful in depicting these stones, while ERCP can allow for diagnosis and stone extraction.

4.3. Choledochoduodenal fistula

Although rare, choledochoduodenal fistula formation has been reported as one of the late complications of laparoscopic cholecystectomy [4]. Patients can present with fever and abdominal pain. CT without oral contrast may reveal pneumobilia, while addition of oral contrast exhibits opacification of biliary tree (Fig. 15). However, ERCP is the most accurate imaging modality for the diagnosis of choledochoduodenal fistula [19]. Such fistulous complications can be successfully managed using endo-stapling devices, thus avoiding peritoneal contamination [20].

4.4. Stricture formation

Due to widespread use of laparoscopic cholecystectomy in the management of cholelithiasis, the incidence of late biliary obstruction secondary to stricture formation has increased [21]. Biliary strictures usually develop a few months to many years after the initial surgery. Etiology of stricture formation includes thermal injury.

Fig. 16. 48-year-old female presenting with abdominal pain and elevated liver enzymes 6 months after laparoscopic cholecystectomy. (A) MRCP image reveals an eccentric smooth stricture (arrow) in the CHD with a non-obstructive calculus in the distal CBD (arrowhead). (B and C) ERCP reveals the non-obstructive calculus (arrowhead) and the smooth CHD stricture (arrow) causing biliary tree dilatation. Post-cholecystectomy clips (dashed arrow) are seen close to the stricture.

Fig. 17. 55-year-old female with elevated liver function tests and abdominal pain 6 months after laparoscopic cholecystectomy. (A) Abdominal X-ray reveals multiple cholecystectomy clips (circled) with an inferiorly displaced clip (arrow). (B–D) Axial and coronal CT images reveal the displaced clip (arrow) within the distal CBD with consequent CBD dilatation (arrowhead).
during the surgery and irritation from surgical clips causing fibrosis and eventually leading to stricture formation [22]. MRCP allows for accurate diagnosis, while ERCP provides both diagnostic and therapeutic options. Imaging findings include intra and extrahepatic ductal dilatation with gentle tapering, focal ductal narrowing, and non-depiction of a part of a duct (Fig. 16). The number and location of strictures is important to report since it is essential for surgical planning.

4.5. Post-cholecystectomy clip migration

Post-cholecystectomy clip migration (PCCM) is a rare but well-known complication of laparoscopic cholecystectomy [23]. Common presentations of PCCM include obstructive jaundice, cholangitis, biliary colic, and acute pancreatitis, usually secondary to clip-related biliary obstruction (Fig. 17). Most common site of migration is into the CBD. Many factors contribute to clip migration including inaccurate clip placements with resultant bile duct injuries, local suppurative inflammatory processes, bile leak with resultant biloma formation, and local infectious processes [24]. In most cases, ERCP is the treatment of choice for clearance of the clip and clip-related biliary stones.

4.6. Cystic duct complications

In addition to the aforementioned complications such as retained gallstone, Mirizzi’s syndrome and bile leak, mucocele formation in a cystic duct remnant should be in the differential diagnosis in a post-cholecystectomy patient with biliary colic. During the surgical removal of the gallbladder, a blind-ending cystic duct remnant is created that may become distended with mucous and impinge on the common hepatic duct, causing biliary colic. Thus, imaging modalities such as MRCP or ERCP are beneficial to diagnose this condition. Imaging findings include dilatation of the cystic duct remnant with gentle tapering and focal ductal narrowing (Fig. 18).

Fig. 18. Mucocele in a cystic duct remnant. 84-year-old male presenting with right hypochondrial pain with history of laparoscopic cholecystectomy. Contrast-enhanced CT reveals dilated cystic duct remnant (arrowhead) compressing the common hepatic duct (arrow).

Fig. 19. (A) 40 year-old female 1 day post-laparoscopic cholecystectomy with right upper quadrant pain. Axial CECT images demonstrate a large pseudoaneurysm with a largely thrombosed lumen (white triangle) arising from the common hepatic artery (white arrow). Subsequent angiography revealed the patent lumen of the aneurysm (arrow, B) arising from the common hepatic artery and coil embolization (arrow, C) was performed. Post-embolization CECT images does not reveal residual aneurysm lumen. The thrombosed lumen and coils are seen (arrow, D).
obstruction (Fig. 18) [25]. Treatment of cystic duct remnant mucocoele is usually surgical [26].

5. Vascular complications

Vascular complications secondary to laparoscopic cholecystectomy have been noted in 1.8–4.1% of cases and include vascular injury in the surgical bed, pseudoaneurysm formation (Fig. 19), and incision/trocar site injuries [27,28]. The right common hepatic artery followed by the portal vein are the two most common vessels injured during gallbladder fossa dissections [29]. Bleeding from injury to liver parenchyma may occur in 10–15% of patients secondary to close proximity of middle hepatic vein to the gallbladder fossa [30]. Inadequate ligation of the cystic artery or clip dislodgement after deployment can also result in hemorrhage.

Hepatic artery pseudoaneurysm formation has been described as a rare, but known complication of laparoscopic cholecystectomy, and is attributed to bile leak and subsequent infection [31]. If pseudoaneurysm formation is suspected, contrast-enhanced CT should be performed, which may show a hematoma or the pseudoaneurysm. Selective angiography of the celiac and SMA is usually helpful in confirmation of the diagnosis and employment of endovascular treatment.

While rare, blind insertion of the first trocar at the start of the procedure may cause perforation of abdominal wall vessels such as inferior epigastric vessels [32] and the great vessels [33]. Hematomas caused by these injuries can readily be diagnosed with a CT or sonogram. Late vascular complication can include portal vein thrombosis [34].

6. Infectious complications

Cholangitis and liver abscess are rare complications of laparoscopic cholecystectomy. Development of cholangitis occurs more often when there is biliary bacterial contamination, stagnant bile, and increased intra-biliary pressure (>20 mmHg), which can be seen with the various previously-described bile duct complications after laparoscopic cholecystectomy including mucocoele formation, Mirizzi’s syndrome, stone retention and PCCM [35]. With cholangitis, enhancement of intrahepatic biliary duct walls is a common finding on CT as well as MR [36]. Most common complications of cholangitis includes abscess formation and portal vein thrombosis (Fig. 20) [36]. It is essential not to mistake the postoperative appearance of Gelfoam on CT with abscess (Fig. 21).

Dropped gallstones are another important complication of laparoscopic cholecystectomy resulting in abdominal wall or peritoneal abscess formation (Fig. 22) [37]. Spillage of gallstones occurs infrequently with the procedure, with reported incidence of 0.1–20%, even though perforation of gallbladder is seen in 10–40% of cases [38]. Diagnosis of abscess secondary to dropped gallstones
is difficult to make, as it usually presents months to years after the procedure. On imaging, dropped gallstones are most commonly seen in the subhepatic or subdiaphragmatic space, but rarely can be seen in the pelvis (Fig. 23) [39]. If caused by calcified gallstones, abscesses may contain calcific densities in or around the abscess site on CT, which is the key to the diagnosis.

Infection at the port site after laparoscopic cholecystectomy has a reported incidence of 2.7% [40]. Patients usually present with pain at the site with fever and elevated WBC. Contrast-enhanced CT is usually diagnostic, revealing stranding with or without air (Fig. 24). Spillage of gallstone(s) may rarely be the cause of anterior abdominal wall inflammation (Fig. 25).

7. Other complications

Less prevalent complications of laparoscopic cholecystectomy can also be diagnosed via cross-sectional imaging. Reported incidence of trocar site hernia is between 0.02% and 3.6% [41]. Umbilical hernia at the site of the midline trocar is the most common type. It usually occurs between a few days to months after surgery, and rarely may be complicated by small bowel obstruction or panniculitis. Even though may be suggested by a herniating mass at the port site on physical exam, CT is usually diagnostic. Additionally, perforation of visceral organs and intestinal secondary to insufflation of gas as well as intestinal ischemia and delayed bowel perforation secondary to thermal injury have all been reported as complications of laparoscopic cholecystectomy (Fig. 26) [42,43].
8. Conclusion

Purported complication rate after laparoscopic cholecystectomy is only 3% [44]. However, since it has become the gold standard treatment of choice for cholelithiasis, an understanding of normal biliary anatomy, its variants and normal postoperative imaging of laparoscopic cholecystectomy is essential to properly assess the complications related to the procedure. Every radiologist needs to be knowledgeable about the radiographic manifestations and interventional radiologic management of the potential complications of this procedure.

Conflict of interest

None.

References


