Chapter 6
Gallbladder

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Gallstone Disease

Epidemiology

Cholelithiasis is common in the global population with an incidence that is approximately 10% for men and 18% for women [1]. In the United States, 10–20% of the population will have stones, potentially affecting up to 30 million people. However, only about 20% of those people will experience symptoms within 20 years of their diagnosis of cholelithiasis. The annual risk of progression to symptomatic gallstones causing biliary colic, cholecystitis, cholangitis, or pancreatitis is between 1% and 4%; therefore, prophylactic cholecystectomy is not routinely recommended.

With gallstone disease being so common, there are over 750,000 cholecystectomies performed in the United States annually, with the direct and indirect cost totaling over six billion dollars [2]. Cholecystectomy has become the most common elective abdominal surgery in the United States, especially when considering the marked increase in the number of surgeries performed with the advent of the laparoscopic cholecystectomy technique.

Although laparoscopic cholecystectomy is regarded as a relatively benign procedure, it is not risk-free. One report demonstrated a postoperative complication rate of 0.9% and intraoperative common bile duct injuries at 0.1% [3]. Although most complications can be treated conservatively or with endoscopic interventions, it is important to know the indications for surgery to avoid overuse and the options available to treat stone disease nonoperatively, if applicable.

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Biliary Colic

Biliary colic occurs when there is a temporary obstruction of the cystic duct by a gallstone or sludge. This typically occurs 1–3 h after eating with the subsequent release of cholecystokinin (CCK) stimulating gallbladder contraction. The stones are mobile and not impacted in the neck of the gallbladder, so the pain tends to resolve within 6 h once the obstruction has resolved. Stones that freely pass through the biliary tree do not cause inflammation or symptoms.

The pain in biliary colic is constant, so the term is a misnomer. It is usually localized to the right upper quadrant, but some patients may experience epigastric pain. The pain may radiate to their right shoulder or scapula. Nausea and vomiting are commonly associated symptoms. Patients do not present with jaundice or signs of obstructive hyperbilirubinemia because the common bile duct is patent.

Laboratory testing is usually normal in terms of white blood cell count and hepatic function panel. Transabdominal ultrasonography of the right upper quadrant is the study of choice when biliary colic is suspected and can reveal gallstones, sludge, or polyps. The size of the stones can be measured and it can be noted if they are impacted in the neck of gallbladder. It can also demonstrate if there is gallbladder wall thickening (>3 or 4 mm), pericholecystic fluid, sonographic Murphy's sign (pain in the right upper quadrant with the transducer), and the size of the common bile duct, which if dilated may be suspicious for a common bile duct stone if correlated with an elevated bilirubin and jaundice.

Treatment for symptomatic or minimally symptomatic cholelithiasis is usually nonoperative and includes lifestyle and dietary changes. The decision to operate should be based on a risk-benefit analysis. For patients who have mild symptoms, the risk of complications from gallstones is 1–4% a year, while those with more severe symptoms, the risk increases up to 7% [5]. Patients who are evaluated in the emergency department and present with signs and symptoms classic of biliary colic may safely be discharged home if their pain resolves and they can tolerate food without a recurrence of their pain. The workup should be negative, including normal vital signs, laboratory values, and imaging. On discharge, they are recommended to start a low-fat diet. If the patient has recurrent episodes of biliary colic despite dietary changes, they should be referred to a general surgeon to discuss elective cholecystectomy.

Acute Cholecystitis

Acute cholecystitis occurs when obstruction of the cystic duct leads to gallbladder inflammation and edema with subserosal hemorrhage. Infection is possible as the obstruction leads to bile stasis, and although bile is considered sterile, gallstones can serve as a nidus for bacteria. Since most biliary infections are gram-negative aerobes, it is thought that bacterial seeding occurs upward from the duodenum

through the biliary tree. Acute cholecystitis, if left untreated, can progress to acute gangrenous cholecystitis. At this stage, the gallbladder may perforate leading to bile peritonitis. If there is a superimposed infection with gas-forming organisms, it is termed acute emphysematous cholecystitis.

Patients suffering from acute cholecystitis typically present with unrelenting right upper quadrant pain and tenderness to palpation on examination with a positive Murphy's sign (cessation of deep inspiration while pressure is applied under the right costal margin). They may also present with fevers, chills, nausea, and vomiting.

The diagnosis of acute cholecystitis can be aided with laboratory testing and imaging. Patients with suspected acute cholecystitis may have a leukocytosis. Hyperbilirubinemia, as well as an elevation of alkaline phosphatase and transaminases, should raise suspicion for choledocholithiasis and even cholangitis if associated with fever and jaundice. Ultrasonography may reveal a distended gallbladder with wall thickening and pericholecystic fluid (Fig. 6.1a, b). A stone impacted in the neck of the gallbladder is commonly seen. A CT scan may show similar changes as the ultrasound, and it can also demonstrate emphysematous changes. A hepatic iminodiacetic acid scan (HIDA) can demonstrate if the cystic duct is obstructed.

The treatment for acute cholecystitis is cholecystectomy, with the laparoscopic approach being the gold standard. The timing of when to operate was a topic of debate, but studies have shown that early laparoscopic cholecystectomy (within a week of symptoms) compared to delayed cholecystectomy (after nonoperative treatment with antibiotics and a 6-week interval) can be performed with improved morbidity, a decrease in length of stay, and total hospital cost, with a similar conversion rate to open cholecystectomy [4]. Additionally, studies showed that a significant number of patients treated nonoperatively would return to the emergency department with a recurrent episode of cholecystitis or unremitting symptoms prior to their scheduled interval laparoscopic cholecystectomy.

A patient with suspected acute cholecystitis should be evaluated by a general surgeon. If the diagnosis is made, the patient should be admitted to the surgical

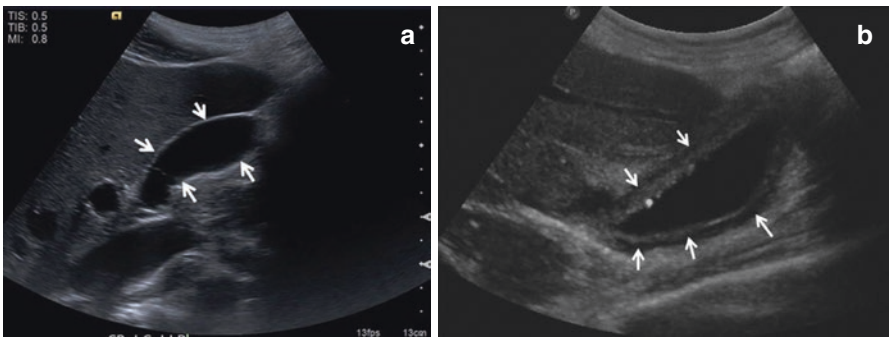

Fig. 6.1 **a** RUQ ultrasound of a normal thin-walled gallbladder. **b** RUQ ultrasound showing a thickened, edematous gallbladder wall consistent with acute cholecystitis. (Used with permission. de Virgilio [8])

service, made nothing per os, started on intravenous fluids and broad-spectrum antibiotics, and given parenteral pain medication and antiemetics to keep the patient comfortable while they await their cholecystectomy.

Chronic Cholecystitis

Chronic cholecystitis occurs when recurrent episodes of biliary colic and partial cystic duct obstruction eventually lead to fibrosis of the gallbladder neck and the cystic duct. Patients present with similar symptoms as biliary colic, although their pain may occur much more frequently and may no longer be associated with food. They may also present with bloating, nausea, and vomiting.

Laboratory findings may be normal, and ultrasonography may reveal stones and gallbladder wall thickening. The treatment is cholecystectomy.

Choledocholithiasis

Choledocholithiasis occurs when there is a stone in the common bile duct. The stones most commonly arise in the gallbladder (secondary stones) but, rarely, may arise in the bile duct itself (primary stones). Many common bile duct stones are silent, but when they are symptomatic, they can present along a spectrum of syndromes ranging from biliary colic to acute cholangitis. Patients may present with elevated alkaline phosphatase and hyperbilirubinemia along the symptomatology of obstructive jaundice, icterus, dark colored urine, and acholic stools.

Ultrasonography may show choledocholithiasis or an abnormally dilated common bile duct. Even if stones are not visualized, a patient presenting with cholelithiasis, a dilated common bile duct, and an elevated bilirubin should be evaluated for choledocholithiasis with further imaging. Magnetic resonance cholangiopancreatography (MRCP) is very sensitive (>90%) and specific (~100%) for evaluating choledocholithiasis. Since it is less invasive than endoscopic retrograde cholangiopancreatography (ERCP), many physicians and gastroenterologists will start with MRCP prior to deciding to utilize ERCP. Endoscopic ultrasound (EUS) is more accurate than MRCP for the detection of bile duct stones and does not carry the risk of iatrogenic pancreatitis, but it is only a diagnostic tool and is not therapeutic like ERCP.

ERCP is highly sensitive and specific for choledocholithiasis and can be therapeutic with its ability to clear out the stones. During the procedure, the gastroenterologist performs a cholangiogram in order to visualize the biliary anatomy and detect any filling defects within the ducts, presumably stones. They may perform a sphincterotomy and extract the stones. A temporary stent may be left. Important risks of ERCP include pancreatitis, intestinal perforation, and recurrence of choledocholithiasis.

Intraoperatively, a patient can undergo a laparoscopic cholangiogram to identify choledocholithiasis. Based on the surgeon's experience, they may be able to extract the stones by either laparoscopic or open common bile duct exploration. With the frequent use of laparoscopic and endoscopic techniques, open duct exploration is less common. Another common method is for the patient to undergo a postoperative ERCP to remove any stones identified in the operating room.

In patients with choledocholithiasis who are managed by ERCP and sphincterotomy alone, almost half will have a recurrence; therefore, it is recommended that the patient undergoes a laparoscopic cholecystectomy during the same admission. However, in patients older than 70 years of age, the rate of recurrence is about 15%, so a cholecystectomy may be selectively offered.

After a cholecystectomy, a patient may present with choledocholithiasis. If this occurs within 2 years of surgery, the stones are thought to be secondary and are termed *retained*. If it occurs after 2 years, then they are *recurrent* primary common bile duct stones.

Cholangitis

Cholangitis refers to a life-threatening ascending infection of the biliary tree caused by an acute biliary obstruction. There should be a high degree of suspicion in a patient who presents with right upper quadrant tenderness, jaundice, and fevers—commonly known as *Charcot's triad*. If left untreated, a patient can progress and display *Reynold's pentad*, which includes hypotension and altered mental status suggestive of shock.

Treatment of cholangitis includes intravenous broad-spectrum antibiotics and fluid resuscitation and emergent decompression of the biliary tree either by percutaneous transhepatic cholangiography (PTC) or ERCP. It is not advised for the patient to undergo surgery as a first-line treatment. In some centers, it is possible to perform an intraoperative ERCP at the time of laparoscopic cholecystectomy, a procedure known as "laparoendoscopic rendezvous."

Gallstone Ileus

Gallstone ileus is a misnomer as it is in fact a small bowel obstruction caused by the erosion of a very large gallstone from the gallbladder into the duodenum creating a cholecystoduodenal fistula. The stone then travels through the gastrointestinal tract and becomes lodged in the ileocecal valve—the narrowest portion of the tract. Patients typically present with the signs and symptoms of a small bowel obstruction including abdominal pain, nausea, vomiting, and changes in bowel habits. Diagnosis can be made with imaging such as a CT scan showing pneumobilia and a large stone in the small intestine (Fig. 6.2). Since these patients tend to be older and very sick,

Fig. 6.2 Gallstone ileus showing large stone (red arrow) and pneumobilia (yellow arrow). (Used with permission. Liau et al. [9])

the primary goal of an operation is to relieve the obstruction by creating an enterotomy on the healthy bowel proximal to the stone and then milking it out. After ensuring there are no more stones in the small intestine, the enterotomy is closed. There may be very dense adhesions in the right upper quadrant, so cholecystectomy and fistula closure are usually postponed until the patient has improved, and the operation is deemed safe given a patient's comorbidities.

Gallstone Pancreatitis

Gallstone pancreatitis is another complication caused by cholelithiasis. Patients who present with pancreatitis should be treated medically. Surgical consultation should be requested for a planned cholecystectomy prior to discharge once the pancreatitis has resolved.

Biliary Dysfunction

Biliary Dyskinesia

Biliary dyskinesia is a motility disorder of the gallbladder. It typically presents with symptoms classic of calculous biliary disease, but there is no evidence of stones on

imaging. During workup, the patient should have other causes of right upper quadrant pain ruled out by imaging and upper endoscopy. If the workup remains negative and the patient's symptoms appear highly suggestive of biliary colic, a CCK-stimulated HIDA scan may be obtained to check for gallbladder dysfunction. If the scan shows an ejection fraction less than 35%, it is diagnostic for biliary dyskinesia. There is no effective medical treatment for dyskinesia, so laparoscopic cholecystectomy is the gold standard. It has been proven to be effective for 85% of patients [5]. If patients continue to have symptoms postoperatively, further evaluation with a gastroenterologist is indicated.

Sphincter of Oddi Dysfunction (SOD)

The sphincter of Oddi is the muscular sphincter found at the ampulla of Vater or the hepatopancreatic ampulla. Its primary functions are to control of the flow of biliary and digestive juices into the second portion of the duodenum, divert bile into the gallbladder, and prevent reflux of bile and intestinal content into the pancreatic duct. Abnormalities in the anatomy or function of the sphincter can lead to biliary pain. Dysfunction of the sphincter can be from abnormal spasms of the muscle or secondary to fibrosis of the sphincter due to trauma, pancreatitis, the passage of gallstones, or congenital anomalies.

Patients with SOD present with right upper quadrant or upper abdominal pain that is constant and lasts for at least 30 min. Patients may also present with recurrent episodes of pancreatitis. SOD should be suspected if a patient presents with upper abdominal pain, abnormal hepatopancreatic enzyme levels, and a common bile duct size greater than 12 mm on ultrasound. The diagnosis can be confirmed with manometry if the basal sphincter pressure is greater than 40 mmHg. However, this is a highly sophisticated technique only available at specialized gastroenterology centers.

Treatment for SOD is endoscopic sphincterotomy, which has been effective in 60–90% of patients [5].

Cholecystectomy

Laparoscopic Cholecystectomy

Since the 1990s, with the advent of laparoscopy surgery, cholecystectomies can be performed safely for biliary colic and for acute and chronic cholecystitis. Laparoscopy surgery is associated with decreased length of stay, decreased complications, and less postoperative pain. However, it has been associated with an increase in common bile duct injuries that may require extensive repair and reconstruction.

During the operation, the patient is placed in a supine position with both arms extended outward to the side. Perioperative antibiotics are administered if there is a concern for cholecystitis. Sequential compression devices are placed on both legs

unless there is a contraindication, and venous thromboembolism prophylaxis may be given at the surgeon's discretion. The patient then undergoes general endotracheal anesthesia and is prepped and draped in a sterile fashion. An orogastric tube may be inserted to decompress the stomach and improve visualization. A Foley catheter may be inserted.

There are a variety of methods to enter the abdomen, but the location of the incisions and laparoscopic ports tends to be standard. There are four incisions in total: one around the umbilicus, one located subxiphoid, and two on the patient's right lateral side. The periumbilical incision tends to be the largest incision at 10–12 mm, since this is where the specimen will be extracted. The remaining incisions are usually 5 mm. The periumbilical incision is created first in order to insert the laparoscope (camera) and the remaining ports under direct visual guidance.

Using graspers and blunt dissectors, the gallbladder is retracted and freed from peritoneal adhesions to expose the cystic duct and the cystic artery. Many surgeons urge achieving this critical view of safety before transecting any structures to avoid common bile duct injuries (Fig. 6.3). This generally entails clearing the hepatocystic triangle of any fibrous tissue and visualizing only two structures directly entering the gallbladder—presumably the cystic duct and artery. The liver bed should be seen in the space between these two structures.

At times, it may be necessary to perform an intraoperative cholangiogram to delineate the biliary anatomy as well as to determine whether there are any common bile duct stones. In order to do so, the presumed cystic duct is partially transected, and a catheter is inserted and secured with a clip. Contrast is injected into the duct and visualized using fluoroscopy. This can help the surgeon identify the cystic duct, common bile duct, and even choledocholithiasis. If there are stones present, the surgeon may attempt to flush them with the aid of glucagon as it relaxes the sphincter of Oddi.

If the surgeon is confident the cystic duct and cystic artery have been identified, then the structures are doubly clipped on the patient's side and singly clipped on the specimen side before being transected with scissors. Once they are divided, the gallbladder is freed from the liver bed using electrocautery. The gallbladder is then placed in a bag and extracted through the umbilical incision along with the trocar.

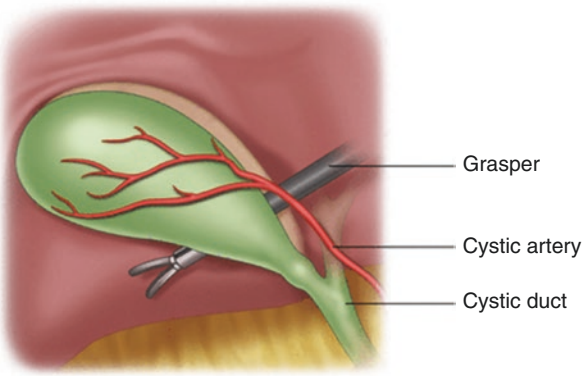

Fig. 6.3 The critical view showing the cystic duct, cystic artery, and the liver bed. (Used with permission. Halverson [10])

The periumbilical trocar and laparoscope are reinserted. The gallbladder fossa is inspected for hemostasis, and the clips on the stumps of the cystic artery and cystic duct are confirmed to be in proper place. The field can be irrigated if there was spillage of bile, stones, or pus. It is always important to note the spillage of stones, especially if they have not been retrieved, because they carry a risk of infection and complications later on. Once everything is satisfactory, the trocars are removed under direct visualization, and the abdomen is de-sufflated. A drain may be placed if there is a concern for potential bile leak. The fascia of the periumbilical incision is closed to prevent a port-site hernia since the defect is larger than 1 cm. The skin of all the incisions is usually approximated with a dissolvable subcuticular suture. Skin glue or a sterile gauze dressing is then applied to the incisions.

The operation can take anywhere from 30 min to 3–4 h depending on the severity of inflammation of the gallbladder. Patients can generally go home the same day or the following morning. Antibiotics postoperatively are at the discretion of the surgeon based on intraoperative findings, but usually 24 h of perioperative antibiotics is sufficient. Patients are instructed to restrict any lifting to 15–20 lbs. for 6 weeks to prevent an incisional hernia, especially at the umbilicus. Patients tend to return to work several days later. Although they do not have any dietary restrictions with the gallbladder removed, patients may experience loose stools or diarrhea with fatty meals initially, but it is self-limited.

In cases with severe inflammation from cholecystitis, the gallbladder may not be removed safely, laparoscopically or open. In these circumstances, a partial cholecystectomy may be performed. This may proceed in two ways. One method is to divide the gallbladder and leave behind the posterior wall adhered to the liver bed (Fig. 6.4a). The remnant gallbladder wall is cauterized to prevent a bile leak, and the internal opening of the cystic duct is over sewn (Fig. 6.4b, c). In these cases, and others where there is concern for a potential bile leak, a drain is placed.

The second method is to transect the gallbladder at the level of the infundibulum with a stapler if it is not possible to safely dissect out and identify the cystic artery and cystic duct (Fig. 6.5).

Single-Port Laparoscopic Cholecystectomy

It is possible to perform a laparoscopic cholecystectomy using a single 2 cm periumbilical incision and a specialized trocar that accommodates the camera and instruments. Studies have shown this technique has a greater learning curve than traditional laparoscopy, but experienced surgeons may have decreased operative times compared to a standard multi-port approach. In addition, the surgeon always has the capability to insert additional trocars in order to aid with retraction. There is also an improvement in cosmesis as the patient will have a single scar.

Single-port cholecystectomy is safe and comparable with the standard approach in terms of hospital length of stay; however, an increase in incisional hernias has been reported after single-port surgeries.

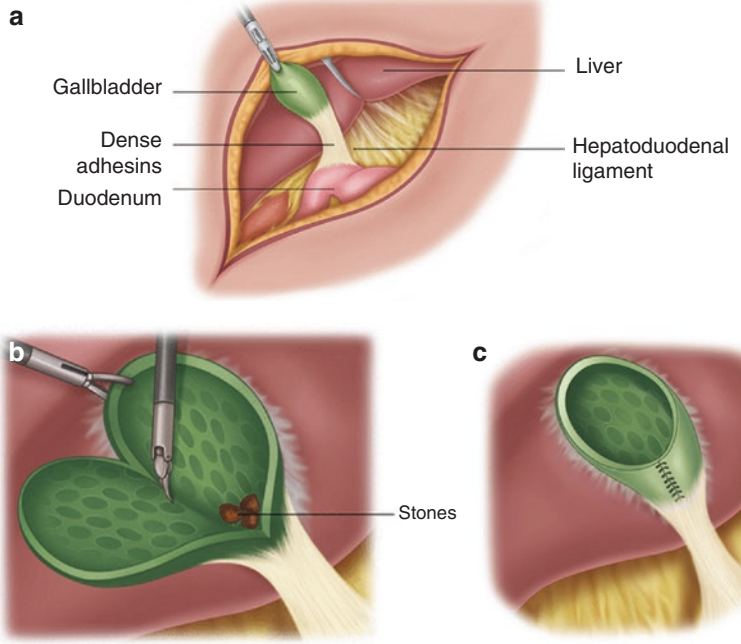

Fig. 6.4 **a** Dense adhesions impair ability to identify cystic structures and increase risk of biliary injuries. **b** The gallbladder is divided with electrocautery, leaving the posterior wall on the liver bed. **c** The remnant wall is cauterized, and the infundibulum sutured closed. (Used with permission. Halverson [10])

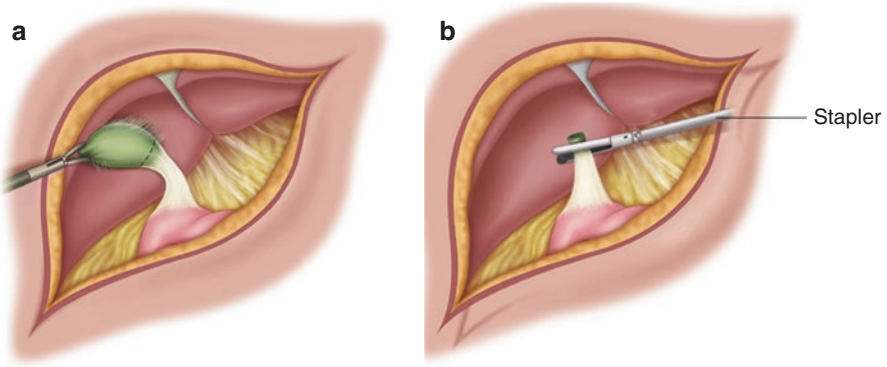

Fig. 6.5 **a** Full mobilization of the fundus of the gallbladder. **b** Stapled amputation of gallbladder. (Used with permission. Halverson [10])

da Vinci *Robotic-Assisted Cholecystectomy*

Robotic-assisted surgeries have provided surgeons with many benefits during an operation. They allow for a much more ergonomic, seated position, provide a three-dimensional operative view, and increase the surgeon's dexterity with articulated instruments.

As with laparoscopy, it is possible to perform the operation using a multi-port or single-port approach with the robot. Robotic cholecystectomies are safe to perform and have the added benefit of using fluorescent imaging to perform intraoperative cholangiograms to visualize difficult biliary anatomy. However, robotic cholecystectomies may be associated with longer operating room times in order to dock the machine, as well as higher hospital costs. Figure 6.6 demonstrates a typical setup for robotic- assisted surgery as well as the larger port for single-site operations.

Open Cholecystectomy

Open cholecystectomy is the traditional approach to removing the gallbladder. It involves a large right oblique incision that runs parallel to the costal margin. Conversion to open cholecystectomy is most commonly performed in order to avoid injuring the common bile duct because of unclear biliary anatomy. Although the conversion rate is as low as 1% [6], all patients should be consented and prepared for it. Other reasons for conversion include uncontrolled bleeding, the need for common bile duct exploration, and suspected common bile duct injury. After an open procedure, most patients will stay in the hospital for a couple of days for adequate pain control. They have the same weight lifting and exercising restrictions as the laparoscopic approach.

Common Bile Duct Exploration

Depending on surgical expertise, common bile duct exploration may be performed open or laparoscopically. Nowadays, many surgeons will elect to have the patient undergo postoperative ERCP if there is suspicion for choledocholithiasis.

Postcholecystectomy Considerations

Postcholecystectomy syndrome is used to describe when a patient experiences a recurrence of their biliary symptoms after cholecystectomy. It can occur in 10–15%

Fig. 6.6 **a** Full view of a *da Vinci S HD* system. **b** Single-Site™ final docked position. (© 2018 Intuitive Surgical, Inc.)

of patients after surgery. Patients experience abdominal pain, nausea, vomiting, dyspepsia, and diarrhea. One common thought is that there is an increase in the amount of bile that enters the intestines since the gallbladder no longer acts a reservoir. The diagnosis should be one of exclusion.

Bile Leak

A bile leak can occur from an injury to the bile duct, a cystic duct stump leak, or from the ducts of Lushka (small accessory ducts that drain directly into the

gallbladder from the liver). Patients may present with new, worsening abdominal pain, nausea, vomiting, a leukocytosis, and/or transaminitis.

Ultrasonography or CT imaging can show the presence of a biloma or abscess. The presence of an active leak can be made with a HIDA scan or an ERCP cholangiogram. ERCP can be therapeutic with its ability to perform a sphincterotomy and place a stent. This will redirect the flow of bile through the path of least resistance allowing the leak to heal. The biloma or abscess should then be drained percutaneously with the help of interventional radiologists.

Cystic stump leaks are rare, occurring after less than 1% of laparoscopic cholecystectomies [7]. They may occur if the clips on the cystic duct are displaced. This may be due to necrosis of the cystic duct stump or from back pressure of bile from stones in the common bile duct.

Leaks from the ducts of Lushka may also present in a similar form and are treated the same.

Bile Duct Injury

If a bile duct injury is recognized intraoperatively during a laparoscopic cholecystectomy, conversion to an operation is necessary in order to assess the degree of injury and formulate a plan. The goal is to preserve as much of the duct as possible and create a tension-free repair, either primarily over a T-tube or via a biliary-enteric reconstruction (e.g., hepaticojejunostomy, choledochojejunostomy). If the surgeon does not have the expertise, it is acceptable to leave a drain in order to control the bile leak and transfer the patient to a hepatobiliary specialist.

In patients in whom the injury is not diagnosed immediately, they may present with new onset pain, jaundice, elevated alkaline phosphate and bilirubin levels, and a bile leak. The bile leak may be in the form of a biloma or as bilious drainage from the incisions.

A CT scan may reveal a sterile biloma or abscess that would require percutaneous drainage. An ERCP or percutaneous transhepatic cholangiogram (PTC) is necessary to delineate the biliary anatomy in order to guide planning for operative repair. During a PTC, transhepatic drainage catheters may be placed to help control drainage and assist in operative dissection.

Spilled Gallstones

During laparoscopic surgery, it is not uncommon for the gallbladder to be inadvertently opened and for stones to be spilled. The surgeon should make an effort to irrigate the field and retrieve as many stones as possible. The stones can serve as a nidus for infection and cause complications in the long term such as abscess formation, bowel obstructions, and fistulas.

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