Laparoscopic cholecystectomy

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INTRODUCTION

Gallbladder and biliary diseases represent a significant public health concern. Globally, gallstones affect approximately 10 to 15 percent of the population, with about 20 percent of those individuals experiencing symptoms. Each year, 1 to 2 percent of affected individuals are at risk of developing complications such as acute cholecystitis, choledocholithiasis, or biliary pancreatitis [1].

Consequently, cholecystectomy is one of the most commonly performed abdominal surgical procedures, of which 98 percent are performed laparoscopically and 1 to 3 percent robotically [2]. Laparoscopic cholecystectomy is considered the "gold standard" for the surgical treatment of gallstone disease. Compared with open surgery, laparoscopic cholecystectomy results in lower mortality and morbidity rates, less postoperative pain, better cosmesis, and shorter hospital stays and disability from work [3].

Although laparoscopic cholecystectomy was associated with a greater number of bile duct injuries during the early years of its implementation [4,5], this is becoming less of an issue with more awareness and better training [6]. Complications of laparoscopic cholecystectomy and their management are discussed separately. (See "Complications of laparoscopic cholecystectomy" and "Repair of common bile duct injuries".)

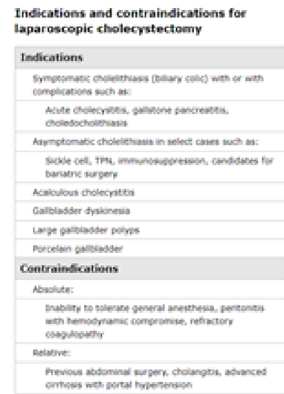
This topic will discuss the technique of a routine laparoscopic cholecystectomy. Cholecystectomy can be made difficult by processes that either obscure normal biliary anatomy (eg, acute or chronic inflammation) or operative exposure (eg, obesity or prior upper abdominal surgery). When a cholecystectomy incurs an increased surgical risk compared with standard cholecystectomy, it is commonly referred to as a "difficult gallbladder" [7]. Strategies to manage a difficult gallbladder are discussed in detail elsewhere. (See "Managing the difficult gallbladder".)

The diagnosis and overall treatment approach to cholecystitis are discussed elsewhere. (See "Acute calculous cholecystitis: Clinical features and diagnosis" and "Treatment of acute calculous cholecystitis".)

INDICATIONS

In resource-abundant countries such as the United States, laparoscopic cholecystectomy is the procedure of choice to remove the gallbladder for one of the following indications (table 1):

- Symptomatic cholelithiasis (biliary colic) with or without one of the complications (see "Clinical manifestations and evaluation of gallstone disease in adults"):
  - Acute calculus cholecystitis. (See "Treatment of acute calculous cholecystitis".)
  - Choledocholithiasis or biliary obstruction. (See "Choledocholithiasis: Clinical manifestations, diagnosis, and management".)
  - Gallstone pancreatitis. (See "Management of acute pancreatitis", section on 'Gallstone pancreatitis'.)
- Asymptomatic cholelithiasis in patients who are at increased risk for gallbladder carcinoma or gallstone complications (sickle cell anemia, immunosuppression, long-term total parenteral nutrition, candidates for bariatric surgery). (See "Approach to the management of gallstones".)
- Acalculous cholecystitis. (See "Acalculous cholecystitis".)
- Gallbladder (biliary) dyskinesia. (See "Functional gallbladder disorder in adults", section on 'Cholecystectomy'.)
- Large gallbladder polyps. (See "Gallbladder polyps and benign gallbladder conditions in adults".)
- Porcelain gallbladder. (See "Porcelain gallbladder".)



Indications and contraindications for laparoscopic cholecystectomy

Indications
Symptomatic cholelithiasis (biliary colic) with or with complications such as:
Acute cholecystitis, gallstone pancreatitis, choledocholithiasis
Asymptomatic cholelithiasis in select cases such as:
Sickle cell, TPN, immunosuppression, candidates for bariatric surgery
Acalculous cholecystitis
Gallbladder dyskinesia
Large gallbladder polyps
Porcelain gallbladder
Contraindications
Absolute:
Inability to tolerate general anesthesia, peritonitis with hemodynamic compromise, refractory coagulopathy
Relative:
Previous abdominal surgery, cholangitis, advanced cirrhosis with portal hypertension

Indications and contraindications for laparoscopic cholecystectomy

Table 1 - larger image below

Contraindications

- **Absolute contraindications** to laparoscopic cholecystectomy include inability to tolerate general anesthesia, peritonitis with hemodynamic compromise, and refractory coagulopathy [8] (table 1). Identification of poor cardiopulmonary reserve and bleeding diatheses will help identify patients who may not tolerate pneumoperitoneum or will have a higher likelihood of conversion to open operation [9].
- **Relative contraindications** are dependent on the surgeon's judgment and experience but include patients with previous extensive abdominal surgery, advanced cirrhosis with portal hypertension, and active cholangitis. (See "Managing the difficult gallbladder", section on 'Recognition'.)

TIMING OF SURGERY

The optimal timing of surgery will depend upon the patient's overall medical condition and underlying diagnosis:

- **Acute cholecystitis** – Patients with acute cholecystitis, who are surgical candidates, should undergo cholecystectomy as soon as they are fully resuscitated and the most qualified surgeon is available [10,11]. Early cholecystectomy has been associated with improved patient outcomes compared with interval cholecystectomy [12]. (See "Treatment of acute calculous cholecystitis", section on 'Timing of cholecystectomy'.)

  In patients with multiple comorbidities or acute medical problems (such as a recent myocardial infarction), a trial of antibiotics with consideration for a percutaneous cholecystostomy tube with delayed laparoscopic cholecystectomy in six to eight weeks may be preferable. (See "Treatment of acute calculous cholecystitis", section on 'Poor surgical candidates'.)

- **Gallstone pancreatitis** – Patients with gallstone pancreatitis have a high risk of recurrence within 30 days of their attack and therefore should undergo cholecystectomy during their index hospitalization after their symptoms resolve [13]. In a randomized trial of 266 patients with mild gallstone pancreatitis, same-admission cholecystectomy reduced the rate of readmission or mortality related to gallstones (5 versus 17 percent) without increasing the rate of perioperative complications compared with delayed cholecystectomy [14]. (See "Management of acute pancreatitis".)

- **Obstructive jaundice** – A history of pancreatitis or jaundice raises the likelihood of common bile duct (CBD) stones. Patients with isolated obstructive jaundice with or without cholangitis should either have their CBD cleared with urgent endoscopic retrograde cholangiopancreatography (ERCP) preoperatively or with cholangiography and laparoscopic common duct exploration at the time of surgery. If ERCP is successful, the patient should electively be scheduled for cholecystectomy. (See "Choledocholithiasis: Clinical manifestations, diagnosis, and management", section on 'Management'.)

- **Severely symptomatic cholelithiasis** – Although symptomatic cholelithiasis/biliary colic can usually be treated with elective laparoscopic cholecystectomy, those with severe symptoms from their gallstone disease (eg, nausea, vomiting, or oral intolerance) require urgent surgery for symptom control [15]. (See "Approach to the management of gallstones", section on 'Biliary colic'.)

PREOPERATIVE EVALUATION

Laboratory testing — Laboratory testing in patients being evaluated for laparoscopic cholecystectomy typically includes a complete blood count, liver enzymes, amylase, and lipase.

- For young, otherwise healthy patients with gallstones but no evidence of pericholecystic inflammation or bile duct dilation, additional preoperative laboratory testing is not routinely necessary, unless a new clinical event has occurred, such as significant pain, fever, or jaundice, or the physical examination suggests that an abnormality is present.

- For patients with complicated biliary tract disease, abnormal tests (eg, liver function tests, amylase, lipase) should be repeated shortly before surgery to serve as a baseline for postoperative comparison. Coagulation tests are not routinely needed but may be obtained if there is a reason to believe an abnormality may be present.

  Elevations in the serum total bilirubin and alkaline phosphatase concentrations are **not** common in uncomplicated cholecystitis, since biliary obstruction is limited to the gallbladder; if present, they should raise concerns about complicating conditions such as cholangitis, choledocholithiasis, or Mirizzi syndrome (a gallstone impacted in the distal cystic duct causing extrinsic compression of the common bile duct [CBD]). However, mild elevations have been reported even in the absence of these complications and may be due to the passage of small stones, sludge, or pus. (See "Acute calculous cholecystitis: Clinical features and diagnosis", section on 'Laboratory findings'.)

Imaging — Gallstones or other abnormalities of the biliary tree (including the gallbladder) are usually demonstrated by one of the following imaging studies [16]:

- **Ultrasonography (US)** of the right upper quadrant establishes the diagnosis of gallstones. The US may also demonstrate CBD dilatation, stones, or evidence of acute inflammation of the gallbladder including thickened gallbladder wall and pericholecystic fluid. (See "Clinical manifestations and evaluation of gallstone disease in adults", section on 'Transabdominal ultrasound'.)

- **Nuclear cholescintigraphy** may be useful if acute cholecystitis is suspected but the diagnosis remains uncertain after US (see "Acute calculous cholecystitis: Clinical features and diagnosis"). Nuclear cholescintigraphy with measurement of gallbladder ejection fraction may also diagnose biliary dyskinesia in patients with biliary symptoms without gallstones on US. The recreation of patient symptoms while the study is conducted is further corroboration of symptomatic biliary hypokinesia or hyperkinesia. (See "Functional gallbladder disorder in adults", section on 'CCK-stimulated cholescintigraphy'.)

- **Magnetic resonance cholangiopancreatography (MRCP)** may be useful to evaluate the common duct in patients with mild elevations of their transaminases or mild CBD dilatation on US. (See "Choledocholithiasis: Clinical manifestations, diagnosis, and management", section on 'Subsequent evaluation'.)

- **Computed tomography (CT)** of the abdomen is the least useful imaging test for gallstone disease per se, but it can exclude other (unrelated) intra-abdominal pathologies and alternative diagnoses. However, no visible gallstones on CT scan should not be interpreted as ruling out gallstones since a CT scan can only demonstrate calcified (radio-opaque) gallstones. (See "Overview of nonsurgical management of gallbladder stones", section on 'Computed tomography'.)

Role of endoscopic retrograde cholangiopancreatography — A combination of laboratory and imaging testing stratifies the patients in terms of their risk of harboring a CBD stone (algorithm 1):

- **High risk** – If a patient has acute cholangitis, a dilated CBD or CBD stones on abdominal US, or a total bilirubin >4 mg/dL, consideration should be given to a preoperative endoscopic retrograde cholangiopancreatography (ERCP) with clearing of the stones followed by laparoscopic cholecystectomy.

- **Intermediate to low risk** – In the absence of frank jaundice or cholangitis, mild abnormalities of liver enzymes and/or bile duct dilation may also be managed effectively with either preoperative MRCP or endoscopic US, or intraoperative cholangiogram at the time of cholecystectomy, rather than preoperative ERCP.

The indications and timing of ERCP for gallstone-related diseases are discussed in another topic. (See "Overview of endoscopic retrograde cholangiopancreatography (ERCP) in adults".)

PREPARATION

Informed consent — Patients should have the procedure described in detail with communication of the possibility of conversion to an open procedure. The patient should be informed about the risks of bile leak, bile duct injury, bowel injury, vascular injury, and reoperation or need for postoperative endoscopic retrograde cholangiopancreatography in case of certain complications. (See "Complications of laparoscopic cholecystectomy".)

Antibiotics — Although society guidelines generally recommend prophylactic antibiotics only for high-risk patients undergoing cholecystectomy [17,18], they are based on old data and inconsistently followed [19]. Some surgeons administer prophylactic antibiotics to low-risk patients as well.

High-risk patients or high-risk procedures — Antibiotic prophylaxis is indicated for high-risk patients undergoing laparoscopic cholecystectomy or any laparoscopic cholecystectomy performed with high-risk procedures. Appropriate choices of antibiotics are summarized in this table (table 2).

High-risk patients are defined by the Scottish Intercollegiate Guideline Network (SIGN) and Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) as being at increased risk of wound infection within 30 days of surgery and include patients over 60 years old; patients with diabetes; and patients with acute symptoms of biliary colic within 30 days of surgery, jaundice, acute cholecystitis, or cholangitis [18-20]. Other high-risk groups include patients who are immunosuppressed or pregnant.

High-risk procedures include intraoperative cholangiography (IOC), conversion to laparotomy, insertion of prosthetic devices, and intraoperative bile spillage.

Low-risk patients undergoing low-risk procedures — Practice differs regarding the use of antibiotics in low-risk settings:

- Consistent with society guidelines, some authorities believe that patients undergoing elective cholecystectomy who are at low risk for infection do not need prophylactic antibiotics [17,21-25]. Surgical site infection rates following laparoscopic cholecystectomy are generally lower compared with those following open cholecystectomy [26,27]. Infection rates after laparoscopic cholecystectomy have ranged from 0 to 4 percent without antimicrobial prophylaxis and 0 to 7 percent with prophylaxis [26-32].

  Multiple meta-analyses have demonstrated no significant differences in the incidence of surgical site infection for low-risk patients receiving or not receiving antimicrobial prophylaxis prior to elective laparoscopic cholecystectomy [21,22,31-34]. These trials have generally included 50 to 175 patients in each arm and have used a single dose of antibiotics administered just prior to surgery.

- However, some surgeons, including all contributors to this topic, routinely administer prophylactic antibiotics prior to all laparoscopic cholecystectomy procedures, including those that are considered low risk. In clinical practice, very few patients will undergo cholecystectomy without one of the risk factors defined above (eg, biliary colic symptoms within 30 days), and several of the high-risk procedures cannot always be anticipated preoperatively (eg, IOC, bile spillage, conversion to open surgery).

  In 2014, a Japanese unblinded randomized trial of 1000 low-risk patients found that the incidence rates of surgical site infection (0.8 versus 2.8 percent) and distant infection (0.2 versus 3.2 percent) were lower for those who received prophylactic antibiotics [28]. Several meta-analyses that included this trial have also found a benefit for prophylactic antibiotics in low-risk patients, although the results were heavily influenced by the Japanese trial because of its size [35-37].

Thromboprophylaxis — Thromboprophylaxis should be administered according to risk. Given that laparoscopic cholecystectomy is a relatively minor operation performed in mostly healthy patients, most surgeons use mechanical prophylaxis (eg, sequential compression devices) routinely but chemoprophylaxis selectively. (See "Prevention of venous thromboembolic disease in adult nonorthopedic surgical patients".)

In two European registry studies, systemic chemo-thromboprophylaxis was found to increase the incidence of intra- and postoperative bleeding without decreasing the already low rate of venous thromboembolic events [38,39].

Anticoagulant or antiplatelet agent — Prior to laparoscopic cholecystectomy, anticoagulants (eg, warfarin, direct oral anticoagulant) and antiplatelet agents (eg, clopidogrel) should be held for an appropriate period if there is no medical contraindication (algorithm 2). The authors of this topic usually hold clopidogrel for five days before laparoscopic cholecystectomy. There is evidence that continuing aspirin is safe [40].

Equipment — An angled laparoscope is recommended (typically 30 degrees) to facilitate alternative views of the operative field. Two grasping forceps are needed, one for the assistant and one for the surgeon. Toothed graspers may be helpful for particularly thick-walled, edematous gallbladders.

For the assistant, a ratchet mechanism, which locks the grasper closed, will help alleviate fatigue. A fine curved dissecting forceps can be used to dissect around delicate structures. Scissors are important for transection, and a hook or spatula with monopolar cautery is used for dissection. A clip applier is typically used to seal the cystic duct and artery.

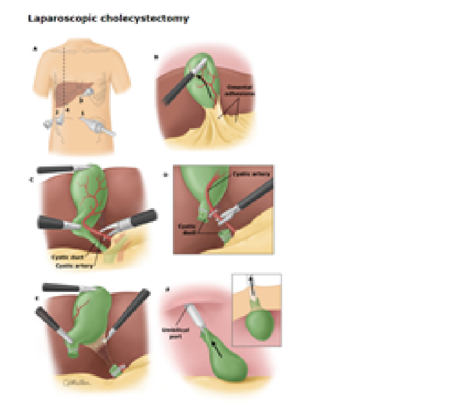
Other tools that are commonly used during laparoscopic cholecystectomy include a Veress needle (if percutaneous access used), appropriate trocars, a laparoscopic needle (to decompress a distended gallbladder), a suction/irrigation device, cholangiogram catheters (4 to 5 French), endoscopic ligating loops, retrieval bag, and a large stone spoon grasper (to pick up spilled stones).

Tools that are not commonly used but should be available include endoscopic needle holders, an endostapler for a very enlarged cystic duct, and an advanced energy device for a very thick-walled, inflamed gallbladder requiring transection of the wall.

STANDARD PROCEDURE

Laparoscopic cholecystectomy is performed under general anesthesia. The generally short duration of the procedure does not require routine placement of a urinary bladder catheter. The following sections describe the technique of a standard laparoscopic cholecystectomy. The technical details such as suture choice presented here reflect the authors' preferences and are not meant to imply that these are requirements for successful surgical outcomes.

Positioning — The patient is placed in a supine position on the operating room table. During abdominal access and insufflation of the abdomen, the table can remain flat. Thereafter, the patient should be placed in a reverse Trendelenburg position with left side down to allow gravity to aid with exposure of the gallbladder (figure 1).



Laparoscopic cholecystectomy

Figure 1 - larger image below

- In North American positioning, the patient is placed supine on the operating room table. The surgeon stands on the patient's left and the assistant on the right. The camera operator stands to the surgeon's left. The primary video monitor should be placed on the right at the level of the shoulder. A second monitor can be placed on the surgeon's right.
- In the European style, the patient is placed supine with legs abducted, and the surgeon stands between the legs. The camera operator is positioned to the patient's left and the assistant to the right.

Abdominal access — Initial entry into the abdomen is typically obtained at the umbilicus using either an open (Hasson) or closed (optical trocar with or without Veress needle insufflation) technique. Both techniques are discussed in detail elsewhere. (See "Abdominal access techniques used in minimally invasive surgery", section on 'Initial port placement'.)

In those with severe obesity, the umbilicus is displaced inferiorly. Thus, the camera port should be placed more cephalad at approximately 15 cm below the xiphoid process to provide better laparoscopic visualization (picture 1). Some surgeons also like to place trocars off-midline in patients with obesity to reduce the risk of incisional hernias [41].

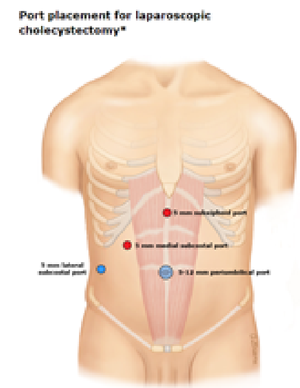
The laparoscope is introduced through the umbilical trocar. Once the abdomen has been inspected, three additional trocars are typically placed under direct vision (figure 2):

- The assistant's 5 mm trocar is usually placed at the midaxillary line halfway between the costal margin and the anterior superior iliac spine. A grasping forceps is placed to grasp the fundus of the gallbladder and retract it and the liver superiorly.

- A second 5 or 10 mm port, which will accommodate the surgeon's right-hand instruments, is placed in the high epigastric/subxiphoid region just to the right of the falciform ligament. The size of the trocar depends on the size of the clip applier to be used. This trocar is directed toward the gallbladder neck.

  A history of prior abdominal surgery may affect port placement. As an example, in patients who have had a prior coronary artery bypass graft (CABG) utilizing the right gastroepiploic artery, the epigastric port must be placed under direct vision to the right of the falciform ligament as the right gastroepiploic-coronary graft generally runs to the left of the falciform ligament [42]. Thus, preoperative detailed knowledge of the patient's past surgical history (eg, CABG) is essential to preventing iatrogenic injuries to the graft.

- A third trocar for the surgeon's left-hand instruments is placed at the right midclavicular line just below the liver edge.



Port placement for laparoscopic cholecystectomy*

Figure 2 - larger image below

Gallbladder exposure and dissection — The assistant using the ratcheted toothed grasper pushes the fundus of the gallbladder superiorly and laterally to reveal the infundibulum and porta hepatis.

If the gallbladder is distended, it can be difficult to grasp. Aspirating it with a large-bore needle or a sharp-tipped suction device facilitates purchase by the grasper. The grasper (or stitch or ligating loop) can then be used to close the hole to prevent further spillage of content of the gallbladder.

Occasionally, adhesions to the duodenum, omentum, or colon from previous surgery or inflammation impair this exposure. The surgeon can take down these adhesions safely by grasping the adhesions at their attachment high on the gallbladder and stripping them down bluntly toward the infundibulum. Cold scissors may also be used close to the bowel. Minimal electrocautery should be used in order to reduce the risk of thermal injury to the adjacent bowel.

Dissection of the hepatocystic triangle — The most important consideration in a cholecystectomy is the clear identification of the cystic artery and duct prior to division.

To this end, a thorough dissection of the hepatocystic triangle, bounded by the gallbladder wall, cystic duct, and common hepatic duct, to obtain the "critical view of safety" is a key step (figure 3) [43] (see 'Critical view of safety' below). The surgeon grasps the infundibulum with the left-hand forceps and retracts inferiorly and laterally to open the angle between the cystic duct and common duct. This instrument is used to provide retraction in various angles to give anterior and posterior exposure of the triangle.

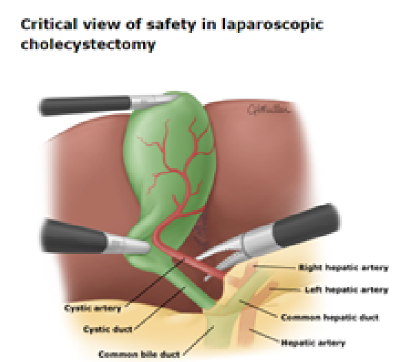
Occasionally, a large stone at the gallbladder neck prevents grasping of the infundibulum. This scenario can be managed by dislodging and "milking" the stone back up into the gallbladder body or by placing a stitch into the infundibulum and using that for retraction. The dissection of the junction of the gallbladder and cystic duct begins by the surgeon gently stripping the peritoneum starting high on the gallbladder. Keeping the dissection on a known safe structure (the gallbladder) to develop visualization of the unknown structures is an important principle. When visible, the Rouviere sulcus is a structure that can guide where to initiate the dissection (picture 2); it is generally safe to start the dissection above the level of the Rouviere sulcus [44].

The posterolateral aspect of the gallbladder is the safest area for initial dissection and can be exposed by retracting the infundibulum superior and medial. The surgeon can use minimal electrocautery or blunt dissection to incise the superficial layer of peritoneum attaching the gallbladder neck to the liver in order to allow further retraction of the infundibulum.

Critical view of safety — Anterior and posterior dissection continues with alternating inferolateral and superomedial retraction of the neck until the gallbladder is dissected away from the liver, creating a "window" crossed by two structures: the cystic duct and artery. Three criteria are required to achieve the "critical view of safety" (figure 3) [6,45]:

- The hepatocystic triangle is cleared of fat and fibrous tissue. The hepatocystic triangle is defined as the triangle formed by the cystic duct, the common hepatic duct, and the inferior edge of the liver. The modern definition of Calot triangle has expanded to be the same as the hepatocystic triangle.

- The lower one third of the gallbladder is separated from the liver to expose the cystic plate. The cystic plate is also known as the liver bed of the gallbladder and lies in the gallbladder fossa.



Critical view of safety in laparoscopic cholecystectomy

Figure 3 - larger image below

- Two and only two structures should be seen entering the gallbladder.

The critical view of safety should be achieved prior to clipping or dividing any tubular structures [43,46]. In a cohort study of >400 patients, the pooled incidence of bile duct injury was 2 in one million cases when the critical view of safety was used versus a pooled bile duct injury incidence of 1.5 in 1000 cases when the infundibular technique was used to ensure safe dissection [6].

There is no need to expose the common hepatic duct or the common bile duct (CBD) or dissect down to the cystic duct-CBD junction unless the cystic duct is very short. The cystic artery should be dissected in a similar fashion. Calot's node, or the cystic duct lymph node, is usually encountered adjacent and anterior to the artery and can be a useful landmark. Electrocautery may be needed for hemostasis before the node can be bluntly swept down.

The surgeon should be aware of certain anatomic variations in order to avoid misidentification of structures [47]. A common anomaly is the right hepatic artery looping onto the infundibulum and being mistaken for the cystic artery [48]. A short cystic duct is also seen quite frequently and can drain into the right hepatic duct [49], the common duct [50], or a low-lying aberrant right sectoral duct [51]. In the presence of severe, acute, or chronic inflammation, or with a large stone in the neck of the gallbladder, the infundibulum may be "tethered" to the hepatic duct, which may lead the surgeon to misidentify the CBD for the cystic duct [52]. Strategies specifically developed for difficult dissections are discussed elsewhere. (See "Managing the difficult gallbladder", section on 'Safe dissection techniques'.)

Division of cystic artery and cystic duct — Once the cystic duct and artery are fully dissected, a clip is placed laterally on the cystic duct adjacent to the gallbladder. The cystic duct is incised distal to the clip, and the side of a closed grasper is used to sweep the bile duct toward the ductotomy to assess cystic duct patency. Then, using a curved dissector, the cystic duct is "milked" retrograde by compressing it toward the ductotomy to identify any stones, bring out any small residual stones, and assess for free flow of bile. An intraoperative cholangiogram (IOC) can be performed at this time if indicated. (See 'Intraoperative cholangiogram' below.)

Once this is accomplished, two more clips are placed distal to the ductotomy. Both jaws of the clip should be seen to clearly encompass the duct to avoid inadvertent injuries to structures behind the clips and to ensure complete duct closure. The duct can then be transected with scissors.

Alternatives to clipping the cystic duct with non-locking metal clips include using locking polymer clips (eg, Hem-o-lock, Lapro-Clip), tying the duct closed with suture ligatures (eg, Endoloop), and sealing the cystic duct stump with advanced tissue sealing devices (eg, LigaSure, Harmonic scalpel, Enseal) [53]. Studies have shown a slightly higher leak rate with metal clips than other methods of occluding the cystic duct; however, the evidence is not conclusive enough to change practice (metal clips being the most widely used method of cystic duct occlusion) [54,55].

Occasionally, the cystic duct is quite enlarged and inflamed, and standard clips are inadequate to seal the duct. In these instances, preformed suture loops may be helpful in completely closing the duct. Some surgeons may suture ligate the cystic duct stump using intracorporeal suturing, while others use extracorporeal knot tying in order to control the duct before transecting it. Rarely, an endoscopic stapler is used to transect an unusually large cystic duct after assuring that the structure is not, in fact, the CBD.

The cystic artery is clipped and divided in a similar fashion. The anterior branch of the cystic artery is commonly mistaken for the main cystic artery; therefore, the tissue behind the clipped artery should be dissected to ensure that there is no posterior branch, which can cause troublesome bleeding during the subsequent removal of the gallbladder. In a study of 100 elective laparoscopic cholecystectomies, 57 contained two or more branches of the cystic artery [56]. The clipped stumps should be inspected for adequacy of closure.

Evaluation of biliary anatomy — If there is any concern for choledocholithiasis (elevated bilirubin, dilated bile duct) or uncertain anatomy, the CBD should be imaged intraoperatively. IOC is performed after the first clip is placed on the cystic duct. Once stones are found and retrieved, a completion cholangiogram should be obtained to verify clearance (image 1). Alternatively, laparoscopic ultrasound (LUS) or fluorescent cholangiogram can be performed anytime during laparoscopic cholecystectomy.

Intraoperative cholangiogram — IOC should be accomplished before beginning CBD exploration. The catheter for IOC is placed after careful dissection achieves the critical view of safety (figure 3). The technique of IOC and CBD exploration is discussed elsewhere in detail. (See "Surgical common bile duct exploration".)

Laparoscopic ultrasound — In experienced hands, LUS may alternatively be performed to evaluate the CBD. A retrospective study of 1381 patients who underwent laparoscopic cholecystectomy at five centers showed that LUS successfully delineated the bile duct anatomy in 98 percent of patients [57].

Fluorescent cholangiogram — Near-infrared fluorescence imaging is increasingly used to delineate the biliary anatomy during cholecystectomy [58]. Indocyanine green (ICG) (1.25 mg to 2.5 mg) is injected intravenously at least half an hour before surgery. Circulating ICG is eventually excreted into the bile by the liver, a process that permits imaging of the liver and biliary tree during hepatobiliary surgery (including cholecystectomy) (picture 3) [59].

Dissection of gallbladder from liver bed — Once the cystic duct and cystic artery have been divided, the attention is turned to removing the gallbladder from the liver bed. The assistant places continual cephalad traction on the gallbladder fundus while the surgeon alternates medial and lateral anteroposterior traction on the infundibulum with the left-hand grasper. This retraction exposes and maintains tension on the plane of tissue attaching the gallbladder to the liver. This tissue is gently divided using a hook or spatula cautery in a sweeping motion. This dissection continues from infundibulum to fundus, and bleeding should be minimal if dissection is performed in the correct plane. Prior to completely detaching the gallbladder, the liver should be inspected for areas of bleeding or bile leakage. The right upper quadrant is irrigated, and then the gallbladder is fully released.

Occasionally, persistent minimal bile leakage occurs from the liver bed. This leak may be from a transected duct of Luschka or, more likely, from a superficial duct within the liver that was unroofed during the dissection. If the end of the duct can be grasped, then the duct should be clipped. Otherwise, one may perform intracorporeal suturing of the opening of the duct but, if unsuccessful, leave a closed suction drain to control the leak. An active suction drain should be left beneath the liver if there is any question regarding the integrity of the cystic duct closure or any suspicion of bile leakage from the gallbladder bed. Otherwise, it is not necessary to routinely leave a drain [60]. We do not place a drain to monitor for bleeding.

Gallbladder extraction — The umbilical incision is the ideal location for extracting the gallbladder. The umbilical incision has no muscle layers and is easy to extend with minimal pain and cosmetic sequelae. To limit bile contamination of the abdomen and wound, many surgeons routinely use a specimen bag to extract the gallbladder; at a minimum, an extraction bag is used when the gallbladder is acutely inflamed and friable or when there is inadvertent perforation of the gallbladder. Any spilled stones can be placed in the bag as well.

To extract the gallbladder from the umbilical incision, the laparoscope is transferred to the subxiphoid trocar, and the bag or a large-toothed grasper is positioned within the umbilical trocar. The gallbladder is placed into the bag, or the infundibulum is grasped with the forceps. The trocar is removed, and the gallbladder is withdrawn through this incision under laparoscopic vision. If the gallbladder is very large or contains large stones, the peritoneal and fascial incisions may need to be stretched or enlarged.

The specimen can also be retrieved through the subxiphoid port site. There is some evidence that the subxiphoid site has a lower likelihood of hernia formation [61], but the umbilical site causes less pain [62].

Once the gallbladder is removed, the right upper quadrant can be irrigated if necessary, and the other trocars can be removed under direct vision while allowing the escape of CO_2. The umbilical fascia is then closed with the stay sutures originally placed or a suture passer under laparoscopic vision.

The skin is closed with subcuticular absorbable stitches and with adhesive strips. The access site incisions can be infiltrated with local anesthetic (eg, bupivacaine), which reduces postoperative pain [63]. Some surgeons also instill local anesthetic agents intraperitoneally; however, the benefit is uncertain [64]. Pharmacologic agents to manage postoperative pain are reviewed elsewhere [65]. (See "Approach to the management of acute pain in adults".)

ALTERNATIVE TECHNIQUES

Alternative techniques to standard, four-port laparoscopic cholecystectomy include reduced port surgery and robot-assisted laparoscopic surgery.

Reduced port surgery — Compared with standard laparoscopic cholecystectomy, reduced port surgery uses fewer or smaller trocars with the goal of reducing postoperative pain and improving cosmesis. In a systematic review and network analysis of 96 randomized trials comparing various cholecystectomy techniques, single-incision cholecystectomy required a longer operative time but no additional clinical benefit compared with standard laparoscopic cholecystectomy [66]. Needlescopic cholecystectomy was associated with the lowest wound infection rate and the shortest length of stay among all minimally invasive cholecystectomy techniques. However, acute cholecystitis, hepatomegaly, thick abdominal wall, and higher body mass index class are likely to exclude needlescopic and single-incision approaches.

Needlescopic cholecystectomy — Needlescopic surgery, or mini-laparoscopy, uses instruments that are thinner than the standard instruments (<3 versus 5 to 10 mm). These instruments are either placed directly through the abdominal wall without a trocar or through special low-friction trocars of small diameters (2 to 4 mm). Although needlescopic cholecystectomy requires the same four incisions as standard cholecystectomy, three of the incisions are smaller and therefore less invasive to the patient. The remaining umbilical incision has a standard size of 5 to 10 mm, which permits the use of a standard laparoscope and specimen extraction. About 10 percent of attempted needlescopic cholecystectomies require conversion, most often to standard laparoscopic cholecystectomy rather than open surgery [67]. (See "Instruments and devices used in minimally invasive surgery", section on 'Instruments for mini-laparoscopy'.)

In a meta-analysis of 12 randomized trials including 712 patients, needlescopic cholecystectomy resulted in less postoperative pain and better cosmesis than standard laparoscopic cholecystectomy [68]. Operative time and length of hospital stay were similar.

Single-incision laparoscopic cholecystectomy — Laparoscopic single-incision surgery (SIS) uses one rather than multiple skin incisions for trocar placement (picture 4). Through a single skin incision typically made periumbilically, multiple trocars are placed through one or more fascial punctures. (See "Abdominal access techniques used in minimally invasive surgery", section on 'Single-incision laparoscopic surgery'.)

SIS has been most widely used in gallbladder surgery and has been extensively studied in comparison with standard laparoscopic cholecystectomy. Overall, SIS offers little benefit over standard laparoscopic surgery. A 2017 meta-analysis of 37 trials comparing SIS with conventional laparoscopic cholecystectomy showed that SIS is associated with better cosmesis, body image, and wound satisfaction and less postoperative pain but a slightly longer operative time and a higher conversion rate (mostly to conventional laparoscopy). However, the risk of incisional hernia is four times higher after SIS than after conventional LC [69].

Robotic cholecystectomy — Robot-assisted cholecystectomy has also been performed (movie 1). There is very little technical difference between the major steps of a robotic and laparoscopic approaches. The trocar placement for robotic cholecystectomy is different from laparoscopy but has not been standardized.

Early results seem equivalent in the hands of experienced laparoscopists and robotic surgeons. There have been no randomized trials; systematic review and meta-analysis of observational series have not found robotic cholecystectomy to be more effective or safer than laparoscopy [70-73]. Although a few studies have reported a higher complication rate with robotic cholecystectomy [74-76], those data are retrospective and may reflect the learning curve similar to that of the earlier days of laparoscopic cholecystectomy. There seems to be a longer operating time and higher costs for the robotic approach in general, but these come down with a higher volume of robotic cases.

BAIL-OUT MANEUVERS

When encountering unforeseen challenges like severe inflammation, dense adhesions, or unclear anatomy during laparoscopic cholecystectomy, the surgeon must be prepared for bail-out maneuvers such as subtotal cholecystectomy or conversion to open surgery. These so-called "difficult gallbladders" are discussed in detail elsewhere. (See "Managing the difficult gallbladder".)

Subtotal cholecystectomy — Subtotal cholecystectomy may be required to prevent biliary injury when marked acute local inflammation or chronic tissue contraction prevents the safe identification of the cystic duct and artery. The gallbladder is opened above the neck, all stones are removed, and the neck of the gallbladder is left in situ to protect the area of the critical structures (eg, common bile duct). The techniques and outcomes of subtotal cholecystectomy and aftercare for patients who undergo subtotal cholecystectomy can be found elsewhere. (See "Managing the difficult gallbladder", section on 'Subtotal cholecystectomy'.)

Conversion to open surgery — A laparoscopic operation should be converted to an open procedure if the surgeon encounters a situation demanding manual palpation and direct vision for correction. Surgeons should convert to open operations without hesitation if the need arises. It is considered good surgical judgment in such situations rather than being viewed negatively as a surgical complication.

Conversion to an open operation is indicated for:

- Major complications, including vascular injury, bowel perforation, mesenteric injury, and bile duct injuries.
- Hemorrhage refractory to laparoscopic control.
- Unusual or confusing anatomy.
- Failure to progress laparoscopically in a timely fashion.
- Potentially resectable gallbladder cancer.
- Common bile duct stones that cannot be removed laparoscopically or endoscopically via endoscopic retrograde cholangiopancreatography.

In the literature, the rate of conversion from laparoscopic to open cholecystectomy ranges from 2.5 to 50 percent, with a median of 6 percent [9]. Older males with acute cholecystitis, previous abdominal surgery, symptom duration of more than 72 hours, previous history of acute cholecystitis, C-reactive protein value of more than 76 mg/L, diabetes, and obesity are significant preoperative risk factors for conversion. Significant intraoperative risk factors for conversion include gallbladder inflammation, adhesions, and difficult anatomy.

Open cholecystectomy is discussed in detail elsewhere. (See "Open cholecystectomy".)

ROUTINE POSTOPERATIVE CARE

After an uncomplicated elective laparoscopic cholecystectomy, patients can drink clear liquids once awake from anesthesia, and their diet can be advanced as tolerated.

Most otherwise healthy, reliable patients with good home support can leave the hospital within six hours after surgery. Cochrane reviews have found no significant differences for important clinical outcomes for patients discharged the same day versus admitted overnight following laparoscopic cholecystectomy [77,78].

A retrospective review of the American College of Surgeon's National Surgical Quality Improvement Program (NSQIP) database, which included 15,248 patients older than 65 years of age who underwent elective laparoscopic cholecystectomy, identified congestive heart failure, American Society of Anesthesiologists class 4, bleeding disorder, and renal failure requiring dialysis as significant independent predictors of inpatient admission and mortality [79].

The patient should have no activity restriction unless the umbilical incision was particularly large. Then, limited heavy lifting for a few weeks is advisable. Most patients can return to work within one week. Patients follow up in clinic two to four weeks after their operation.

Most patients have some abdominal pain that resolves within two to three days after surgery and can be managed with analgesics. Occasionally, patients have referred shoulder and neck pain from the CO_2 insufflation causing diaphragmatic irritation. This pain peaks around 24 hours but usually subsides within a few days as the gas is reabsorbed by the body [80]. On the contrary, severe abdominal pain that resurges in three to six days after the initial postoperative pain has already subsided is ominous and could indicate a bile leak; such patients should be directed to the emergency department for further work-up [81].

OUTCOMES

Symptom relief — Since most laparoscopic cholecystectomies are performed for benign gallstone disease, their success is primarily determined by symptom relief, with abdominal pain being the most common symptom addressed.

In a trial of over 1000 patients with abdominal pain and ultrasound (US)-proven gallstones or sludge, patients were randomly assigned to either usual care (control group) or laparoscopic cholecystectomy only if they fulfilled prespecified criteria based on the Rome III criteria of biliary colic (experimental group) [82]. Fewer patients in the experimental group received surgery (68 versus 75 percent). At 12 months, however, 40 and 44 percent of the control and experimental groups and 37 and 36 percent of those who underwent cholecystectomy in the two groups still had abdominal pain. A post hoc cost-effectiveness analysis reported that after 12 months, 56.2 percent of patients were pain free in the experimental group versus 59.8 percent after usual care. The restrictive strategy reduced the cholecystectomy rate by 7 percent and reduced surgical costs by €160 per patient but resulted in fewer pain-free patients [83]. At five years, 73 percent in the experimental group and 82 percent in the control group have undergone cholecystectomy; however, only 63 percent of both groups reported that they are pain free [84].

This trial showed suboptimal pain reduction regardless of whether patients were preselected for cholecystectomy. All can agree that a very accurate history and physical examination, in conjunction with good diagnostic testing, is critical for selecting the appropriate patients for cholecystectomy. Clearly, as gallstones and abdominal pain are both relatively common, there is a need for diagnostic tests that will allow a more accurate identification of those patients with gallstones who will benefit from cholecystectomy. Until such tests become available, surgeons need to warn patients that cholecystectomy may not relieve their pain.

Many patients with persistent or recurrent abdominal pain after laparoscopic cholecystectomy have postcholecystectomy syndrome (PCS). PCS is a complex of heterogeneous symptoms, including persistent abdominal pain and dyspepsia, that recur and persist after cholecystectomy [85,86]. In a prospective cohort study, only 60 percent of patients reported complete relief of abdominal pain at 12 weeks after cholecystectomy for uncomplicated symptomatic cholelithiasis [87].

PCS is defined as "early" if it occurs in the postoperative period and "late" if it occurs months or years after surgery. The symptoms of pain and dyspepsia referred to as PCS can be caused by a wide spectrum of conditions, both biliary and extra-biliary. About one-half of the patients with PCS are found to have biliary, pancreatic, or gastrointestinal disorders, while the remaining patients have extraintestinal disease [86].

- Biliary causes of PCS include:
  - Early PCS can be due to biliary injury, or retained cystic duct or common bile duct (CBD) stones.
  - Late PCS can be due to recurrent CBD stones, bile duct strictures, an inflamed cystic duct or gallbladder remnant, papillary stenosis, or biliary dyskinesia. Biliary dyskinesia refers to motor forms of sphincter of Oddi dysfunction. Sphincter of Oddi dysfunction can be evaluated with sphincter of Oddi manometry. (See "Functional gallbladder disorder in adults".)
- Extra-biliary causes of PCS include (see "Causes of abdominal pain in adults"):
  - Gastrointestinal causes such as irritable bowel syndrome, pancreatitis, pancreatic tumors, pancreas divisum, hepatitis, peptic ulcer disease, mesenteric ischemia, diverticulitis, or esophageal diseases.
  - Extraintestinal causes such as intercostal neuritis, wound neuroma, coronary artery disease, or psychosomatic disorders.

Diagnosis of the underlying problem can be accomplished in most cases with US and/or CT scanning followed by magnetic resonance cholangiopancreatography if necessary. The approach to the diagnosis of choledocholithiasis or biliary injury is discussed elsewhere. (See "Choledocholithiasis: Clinical manifestations, diagnosis, and management", section on 'Diagnosis'.)

Treatment for PCS is tailored to the specific cause of the symptoms. Patients with retained or recurrent stones or a biliary injury (eg, bile leak, stricture, or transection) are usually treated endoscopically or surgically. (See "Choledocholithiasis: Clinical manifestations, diagnosis, and management", section on 'Management' and "Complications of laparoscopic cholecystectomy", section on 'Biliary injury'.)

Patients without any recurrent or retained stone or biliary injury are usually referred to gastroenterology for further evaluation and treatment of possible function gastrointestinal disorders such as irritable bowel syndrome. (See "Clinical manifestations and diagnosis of irritable bowel syndrome in adults" and "Treatment of irritable bowel syndrome in adults".)

Surgical complications — Serious complications that occur with laparoscopic cholecystectomy, including bile duct injury, bile leaks, bleeding, and bowel injury are discussed in detail elsewhere. (See "Complications of laparoscopic cholecystectomy".)

SOCIETY GUIDELINE LINKS

Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Gallbladder surgery" and "Society guideline links: Minimally invasive general surgery".)

INFORMATION FOR PATIENTS

UpToDate offers two types of patient education materials, "The Basics" and "Beyond the Basics." The Basics patient education pieces are written in plain language, at the 5^{th} to 6^{th} grade reading level, and they answer the four or five key questions a patient might have about a given condition. These articles are best for patients who want a general overview and who prefer short, easy-to-read materials. Beyond the Basics patient education pieces are longer, more sophisticated, and more detailed. These articles are written at the 10^{th} to 12^{th} grade reading level and are best for patients who want in-depth information and are comfortable with some medical jargon.

Here are the patient education articles that are relevant to this topic. We encourage you to print or e-mail these topics to your patients. (You can also locate patient education articles on a variety of subjects by searching on "patient info" and the keyword(s) of interest.)

- Basics topics (see "Patient education: Choosing surgery to treat gallstones (The Basics)" and "Patient education: Cholecystectomy (The Basics)" and "Patient education: Cholecystectomy – Discharge instructions (The Basics)")

SUMMARY AND RECOMMENDATIONS

- **Indications and contraindications** – Laparoscopic cholecystectomy is considered the "gold standard" for the surgical treatment of gallstone diseases including symptomatic cholelithiasis, acute cholecystitis, choledocholithiasis, biliary pancreatitis, biliary dyskinesia, large gallbladder polyps, and porcelain gallbladder (table 1). (See 'Indications' above.)

Laparoscopic cholecystectomy is only contraindicated by the inability to tolerate general anesthesia, peritonitis with hemodynamic compromise, and refractory coagulopathy, although relative contraindications, such as prior abdominal surgery, cirrhosis, and cholangitis can vary by surgeon experiences. (See 'Contraindications' above.)

- **Timing of surgery** – In suitable surgical candidates, laparoscopic cholecystectomy should be performed during the same admissions for patients who present with acute cholecystitis, gallstone pancreatitis, or severe symptomatic cholelithiasis with intractable symptoms. Laparoscopic cholecystectomy can be performed electively for patients with biliary colic, or for choledocholithiasis if any common bile duct (CBD) stone has been addressed endoscopically. (See 'Timing of surgery' above.)

- **Preoperative evaluation** – (See 'Preoperative evaluation' above.)

  - Laboratory testing in patients being evaluated for laparoscopic cholecystectomy typically includes a complete blood count, liver enzymes, amylase, and lipase.

  - Imaging tests performed for gallstones or other abnormality of the biliary tree (including the gallbladder) usually include abdominal ultrasound (US), and may also include nuclear cholescintigraphy, magnetic resonance cholangiopancreatography (MRCP), and CT.

  - If a patient has cholangitis, dilated CBD or CBD stones on imaging, or jaundice (total bilirubin >4 mg/dL), preoperative endoscopic retrograde cholangiopancreatography (ERCP) or intraoperative cholangiography (IOC) and possible CBD exploration should be performed.

- **Prophylactic antibiotics** – For all patients undergoing laparoscopic cholecystectomy, we suggest prophylactic antibiotics (**Grade 2C**). Appropriate agents are in this table (table 2). (See 'Antibiotics' above.)

  Prophylactic antibiotics are required for high-risk patients or high-risk procedures. For low-risk patients undergoing low-risk laparoscopic cholecystectomy, the contributors to this topic also administer prophylactic antibiotics because it is not always possible to identify high risks prior to surgery, and a benefit for prophylactic antibiotics in low-risk patients has been shown in some studies. (See 'Low-risk patients undergoing low-risk procedures' above.)

- **Standard procedure** – The most important consideration in a cholecystectomy is the clear identification of the cystic artery and duct prior to division. For all patients undergoing laparoscopic cholecystectomy, we recommend that the surgeon achieve the "critical view of safety" before clipping or dividing any tubular structures in the hepatocystic triangle (**Grade 1B**). Failure to reach the critical view should prompt alternative techniques such as subtotal cholecystectomy to avoid catastrophic bile duct or vascular injuries. (See 'Standard procedure' above and "Managing the difficult gallbladder".)

- **Alternative techniques** – Reduced port laparoscopic cholecystectomy (eg, needlescopic, single-incision laparoscopic) can be used (where available) for select patients who desire minimal pain and optimal cosmesis. (See 'Reduced port surgery' above.)

  Robotic cholecystectomy is an emerging, equally valid technique compared with laparoscopic cholecystectomy based on the surgeon's experience and preference; however, it could require a longer operative time and be more costly. (See 'Robotic cholecystectomy' above.)

- **Bail-out maneuvers** – When encountering unforeseen challenges like severe inflammation, dense adhesions, or unclear anatomy during laparoscopic cholecystectomy, the surgeon must be prepared for bail-out maneuvers such as subtotal cholecystectomy or conversion to open surgery. These so-called "difficult gallbladders" are discussed in detail elsewhere. (See "Managing the difficult gallbladder".)

- **Outcomes** – In the literature, about two-thirds of patients achieve symptom relief from laparoscopic cholecystectomy for gallstone diseases. The remaining one-third have persistent or recurrent abdominal pain. Further evaluation (with US, CT, or MRCP) should aim at excluding biliary causes such as recurrent or retained gallstone, bile leak, or biliary stricture. (See 'Symptom relief' above.)

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Topic 3685 Version 54.0

GRAPHICS

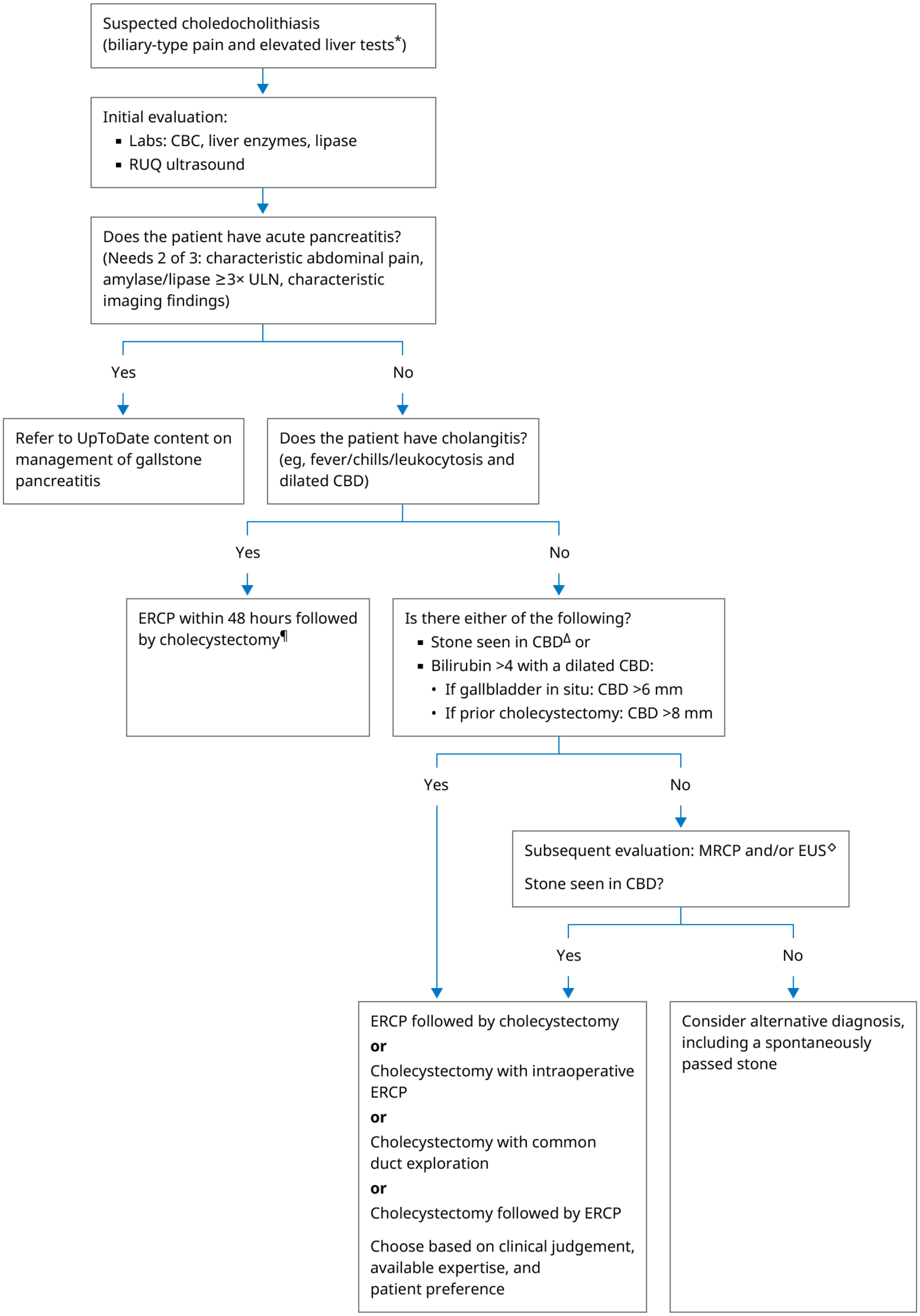
Table 1: **Indications and contraindications for laparoscopic cholecystectomy**

Indications
Symptomatic cholelithiasis (biliary colic) with or with complications such as:
Acute cholecystitis, gallstone pancreatitis, choledocholithiasis
Asymptomatic cholelithiasis in select cases such as:
Sickle cell, TPN, immunosuppression, candidates for bariatric surgery
Acalculous cholecystitis
Gallbladder dyskinesia
Large gallbladder polyps
Porcelain gallbladder
Contraindications
Absolute:
Inability to tolerate general anesthesia, peritonitis with hemodynamic compromise, refractory coagulopathy
Relative:
Previous abdominal surgery, cholangitis, advanced cirrhosis with portal hypertension

TPN: total parenteral nutrition.

Graphic 76254 Version 4.0

Algorithm 1: **Diagnosis and management of choledocholithiasis**



ALT: alanine transaminase; AST: aspartate aminotransferase; CBC: complete blood count; CBD: common bile duct; CT: computed tomography; ERCP: endoscopic retrograde cholangiopancreatography; EUS: endoscopic ultrasound; LFT: liver function tests; MRCP: magnetic resonance cholangiopancreatography; RUQ: right upper quadrant; ULN: upper limit of normal.

* LFT elevation is typically in hepatocellular pattern (AST/ALT-predominant) initially, then evolves into cholestatic pattern (alkaline phosphatase-predominant).

¶ Patients with cholangitis should also be treated with supportive care and antibiotics; refer to UpToDate content on management of acute cholangitis.

Δ CBD stone may be seen on ultrasound or on CT performed for another indication.

◊ If MRCP is negative but clinical suspicion for choledocholithiasis remains moderate to high (eg, in a patient whose laboratory tests are not improving), EUS is an appropriate next step.

Graphic 66945 Version 5.0

Table 2: **Antimicrobial prophylaxis for gastrointestinal surgery in adults**

Nature of operation	Common pathogens	Recommended antimicrobials	Usual adult dose*	Redose interval¶
Gastroduodenal surgery				
Procedures involving entry into lumen of gastrointestinal tract	Enteric gram-negative bacilli, gram-positive cocci	CefazolinΔ	<120 kg: 2 g IV ≥120 kg: 3 g IV	4 hours
Procedures not involving entry into lumen of gastrointestinal tract (selective vagotomy, antireflux)	Enteric gram-negative bacilli, gram-positive cocci	High risk◊ only: cefazolinΔ	<120 kg: 2 g IV ≥120 kg: 3 g IV	4 hours
Biliary tract surgery (including pancreatic procedures)				
Open procedure or laparoscopic procedure (high risk)§	Enteric gram-negative bacilli, enterococci, clostridia	CefazolinΔ¥ (preferred)	<120 kg: 2 g IV ≥120 kg: 3 g IV	4 hours
		or cefotetan	2 g IV	6 hours
		or cefoxitin	2 g IV	2 hours
		or ampicillin-sulbactam	3 g IV	2 hours
Laparoscopic procedure (low risk)	N/A	None	None	None
Appendectomy‡				
	Enteric gram-negative bacilli, anaerobes, enterococci	CefazolinΔ **plus** metronidazole (preferred)	*For cefazolin:* <120 kg: 2 g IV ≥120 kg: 3 g IV *For metronidazole:* 500 mg IV	*For cefazolin:* 4 hours *For metronidazole:* N/A
		or cefoxitinΔ	2 g IV	2 hours
		or cefotetanΔ	2 g IV	6 hours
Small intestine surgery				
Nonobstructed	Enteric gram-negative bacilli, gram-positive cocci	CefazolinΔ	<120 kg: 2 g IV ≥120 kg: 3 g IV	4 hours
Obstructed	Enteric gram-negative bacilli,	CefazolinΔ	*For cefazolin:*	*For cefazolin:*

	anaerobes, enterococci	**plus** metronidazole (preferred)	<120 kg: 2 g IV ≥120 kg: 3 g IV *For metronidazole:* 500 mg IV	4 hours *For metronidazole:* N/A
		or cefoxitin$^{\Delta}$	2 g IV	2 hours
		or cefotetan$^{\Delta}$	2 g IV	6 hours
Hernia repair				
	Aerobic gram-positive organisms	Cefazolin$^{\Delta}$	<120 kg: 2 g IV ≥120 kg: 3 g IV	4 hours
Colorectal surgery[†]				
	Enteric gram-negative bacilli, anaerobes, enterococci	Parenteral:		
		Cefazolin$^{\Delta}$ **plus** metronidazole (preferred)	*For cefazolin:* <120 kg: 2 g IV ≥120 kg: 3 g IV *For metronidazole:* 500 mg IV	*For cefazolin:* 4 hours *For metronidazole:* N/A
		or cefoxitin$^{\Delta}$	2 g IV	2 hours
		or cefotetan$^{\Delta}$	2 g IV	6 hours
		or ampicillin-sulbactam$^{\Delta,**}$	3 g IV (based on combination)	2 hours
		Oral (used in conjunction with mechanical bowel preparation):		
		Neomycin **plus** erythromycin base or metronidazole	¶¶	¶¶

GI: gastrointestinal; IV: intravenous.

* Parenteral prophylactic antimicrobials can be given as a single IV dose begun within 60 minutes before the procedure. If vancomycin or a fluoroquinolone is used, the infusion should be started within 60 to 120 minutes before the initial incision to have adequate tissue levels at the time of incision and to minimize the possibility of an infusion reaction close to the time of induction of anesthesia.

¶ For prolonged procedures (>3 hours) or those with major blood loss or in patients with extensive burns, additional intraoperative doses should be given at intervals 1 to 2 times the half-life of the drug.

Δ For patients allergic to penicillins and cephalosporins, clindamycin (900 mg) or vancomycin (15 mg/kg IV; not to exceed 2 g) with either gentamicin (5 mg/kg IV), ciprofloxacin (400 mg IV), levofloxacin (500 mg IV), or aztreonam (2 g IV) is a reasonable alternative. Metronidazole (500 mg IV) plus an aminoglycoside or fluoroquinolone is also an acceptable alternative regimen, although metronidazole plus aztreonam should not be used, since this regimen does not have aerobic gram-positive activity.

◇ Severe obesity, GI obstruction, decreased gastric acidity or GI motility, gastric bleeding, malignancy or perforation, or immunosuppression.

§ Factors that indicate high risk may include age >70 years, pregnancy, acute cholecystitis, nonfunctioning gallbladder, obstructive jaundice, common bile duct stones, immunosuppression.

¥ Cefotetan, cefoxitin, and ampicillin-sulbactam are reasonable alternatives.

‡ For a ruptured viscus, therapy is often continued for approximately 5 days.

† Use of ertapenem or other carbapenems not recommended due to concerns of resistance.

** Due to increasing resistance of *Escherichia coli* to fluoroquinolones and ampicillin-sulbactam, local sensitivity profiles should be reviewed prior to use.

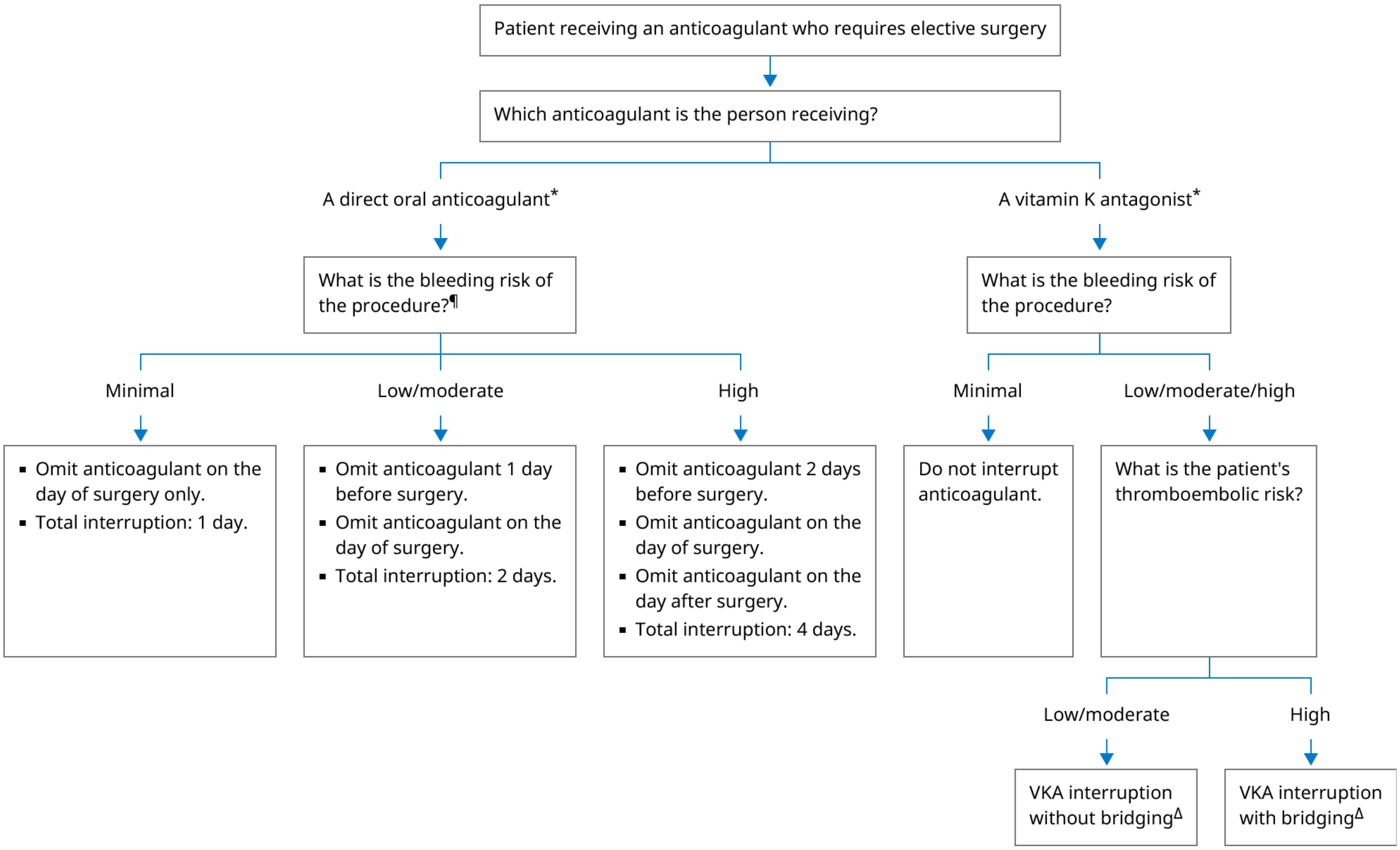
¶¶ In addition to mechanical bowel preparation, the following oral antibiotic regimen is administered: neomycin (1 g) plus erythromycin base (1 g) **or** neomycin (1 g) plus metronidazole (1 g or 500 mg depending on country and center). The oral regimen should be given as 3 doses over approximately 10 hours the afternoon and evening before the operation. Issues related to mechanical bowel preparation are discussed further separately; refer to the UpToDate topic on overview of colon resection.

Data from:

1. *Antimicrobial prophylaxis for surgery. Med Lett Drugs Ther 2016; 58:63.*
2. *Bratzler DW, Dellinger EP, Olsen KM, et al. Clinical practice guidelines for antimicrobial prophylaxis in surgery. Surg Infec (Larchmt) 2013; 14:73.*

Graphic 65369 Version 39.0

Algorithm 2: **Algorithm for anticoagulant discontinuation in individuals undergoing elective surgery**



Refer to UpToDate for further information on the bleeding risk of common procedures and the thromboembolic risk of common underlying conditions. High thromboembolic risk includes mechanical heart valve, high risk of stroke, or recent venous thromboembolism (within the prior 3 months).

CrCl: creatinine clearance; DOAC: direct oral anticoagulant; IVC: inferior vena cava; LMW: low molecular weight; VKA: vitamin K antagonist; VTE: venous thromboembolism.

* Anticoagulants:
  - Direct oral anticoagulants (DOACs) include dabigatran, apixaban, edoxaban, and rivaroxaban.
  - Vitamin K antagonists include warfarin, acenocoumarol, phenprocoumon, and fluindione.

¶ The following applies to DOAC interruption:
  - These intervals are for individuals with normal kidney function and factor Xa inhibitors regardless of kidney function.
  - For individuals with CrCl 30 to 50 mL/min receiving dabigatran, longer intervals are used (omit from 2 days before a low/moderate bleeding risk procedure; omit from 4 days before a high bleeding risk procedure).
  - The perioperative management from the PAUSE study (a population with atrial fibrillation) can be applied to individuals who are receiving a DOAC for VTE that was >30 days prior. If the individual had a VTE within the prior 30 days, DOAC interruption should be individualized and may include placement of a temporary IVC filter or shorter periods of DOAC interruption.
  - Bridging is not used for DOACs.

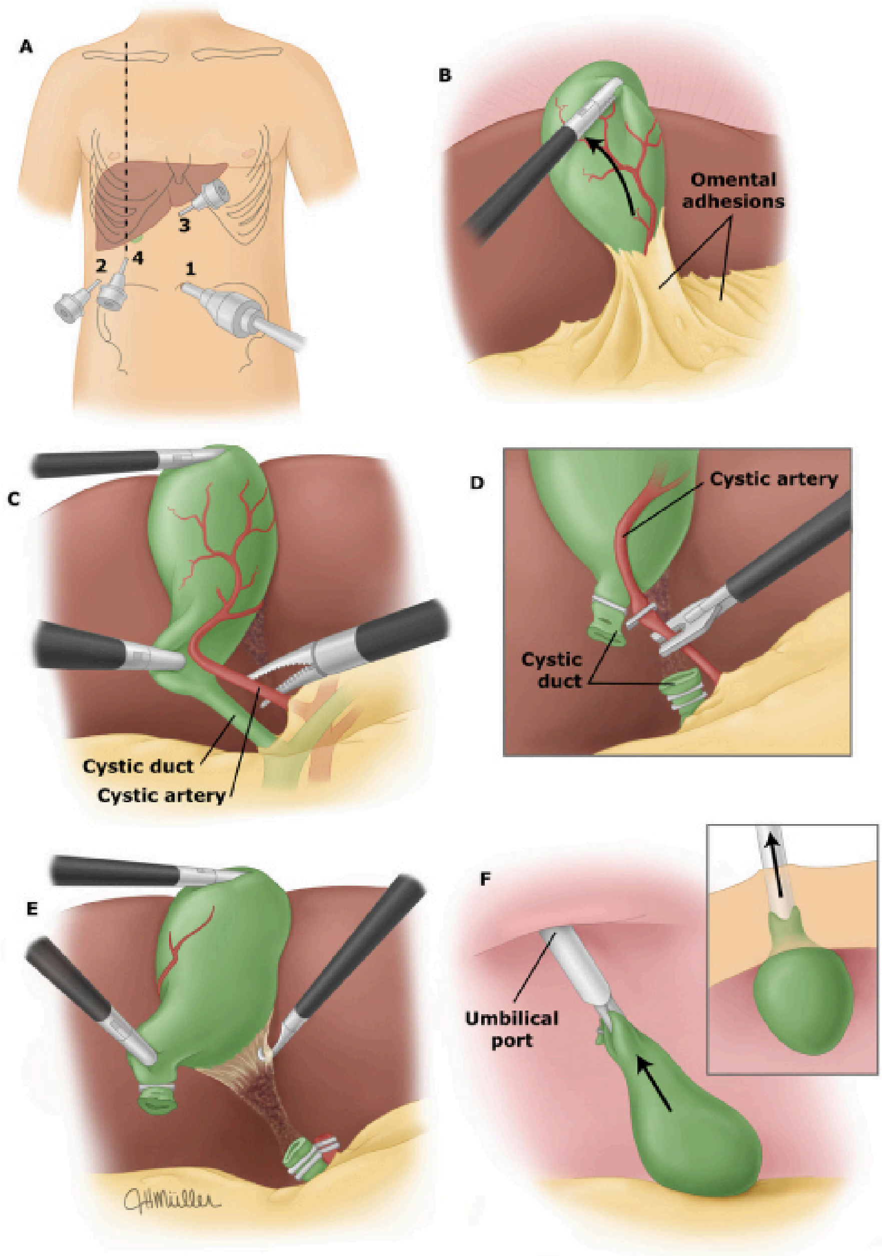
Δ The following applies to VKA interruption:
  - For warfarin, discontinue 5 days before the procedure.

- If bridging is needed for a high thromboembolic risk patient, start LMW heparin at therapeutic dose approximately 3 days before surgery, with the last preoperative dose approximately 24 hours before surgery.
- Resume warfarin postoperatively once hemostasis is assured (typically the evening of the day of surgery or the day after surgery). Resume LMW heparin approximately 2 to 3 days after surgery (determined by the bleeding risk of the procedure) and discontinue LMW heparin after stable warfarin anticoagulation.
- The overlap period between LMW heparin and warfarin depends on the patient's thromboembolic risk.

Based on guidance from A Tafur, J Douketis. Perioperative management of anticoagulant and antiplatelet therapy. Heart 2018; 104:1461.

Graphic 129999 Version 3.0

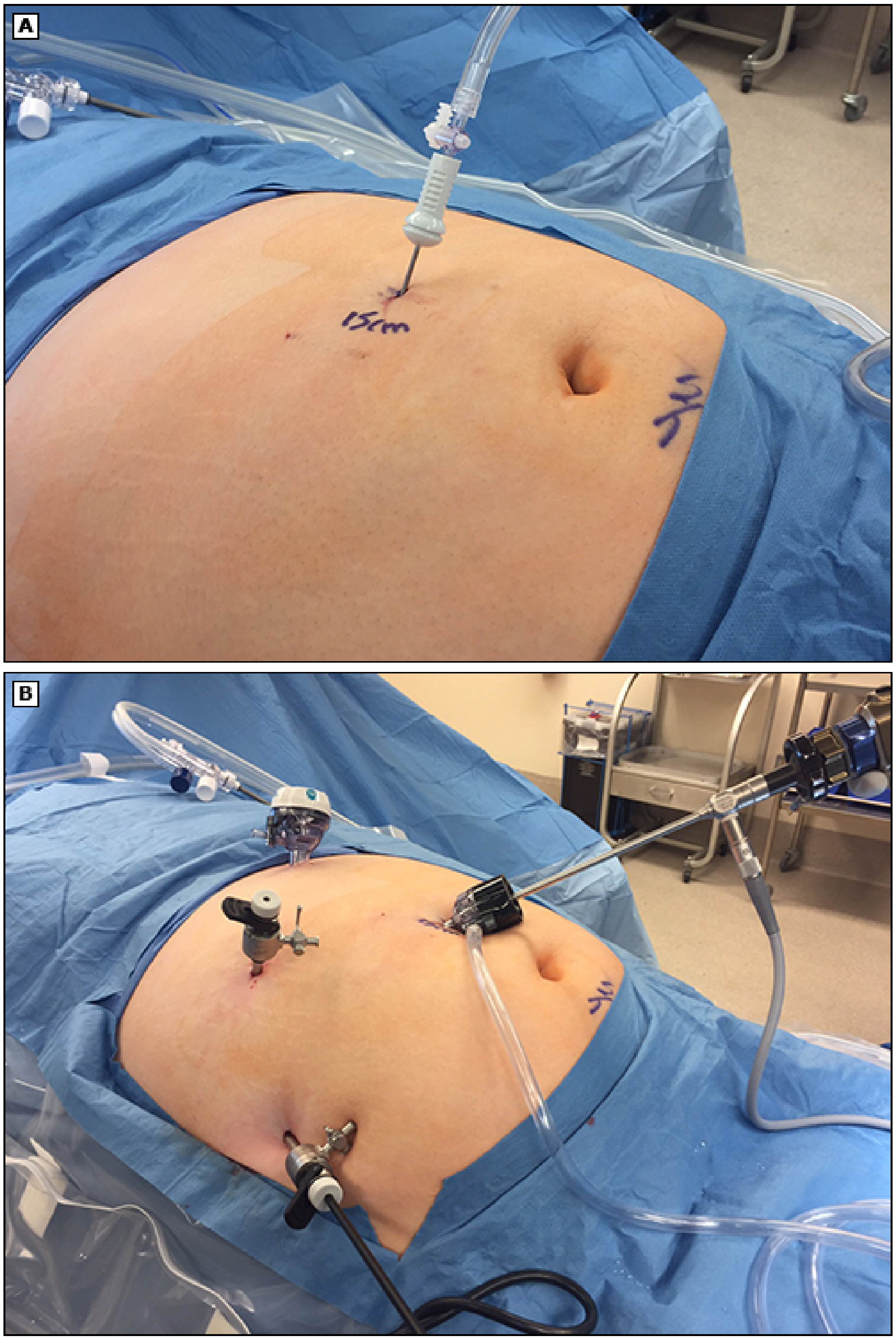
Figure 1: **Laparoscopic cholecystectomy**



(A) Port placement.
(B) Initial retraction of gallbladder.
(C) Critical view of safety.
(D) Clipping and division of cystic artery and duct.
(E) Dissection of gallbladder from liver bed.
(F) Extraction of gallbladder.

Graphic 52727 Version 3.0

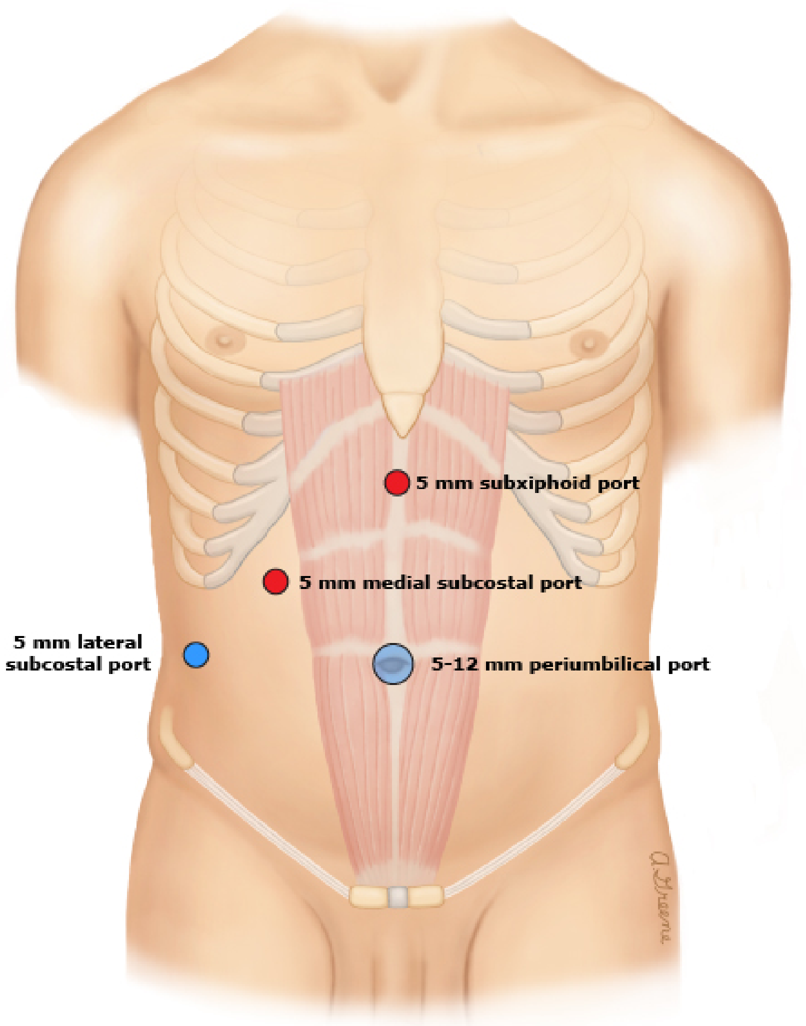
Picture 1: **Initial laparoscopic access in a patient with severe obesity**



Initial laparoscopic access in a patient with severe obesity.
(A) A closed Veress needle technique is used, inserted approximately 15 cm below the xiphoid for the initial camera port. The port should be 5 mm in size and placed under optical guidance.
(B) Position of the camera port and dissecting ports in this patient.

Graphic 113920 Version 2.0

Figure 2: **Port placement for laparoscopic cholecystectomy***



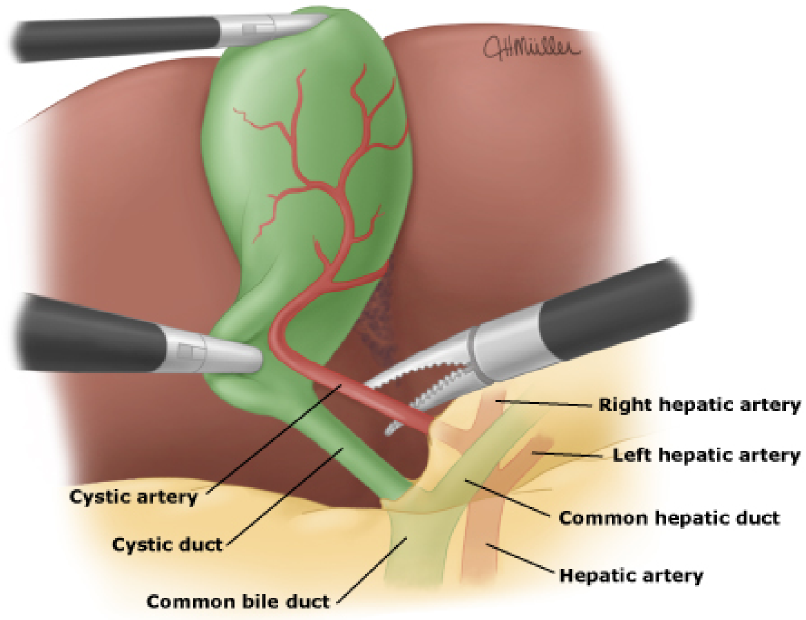
An open (Hasson) technique is used to enter the peritoneal cavity and place a 5 to 12 mm Hasson trocar at the umbilicus. The laparoscope is introduced through this port, and three additional 5 mm ports are placed under direct vision 1 to 2 cm inferior to the right subcostal margin. The surgeon operates from the patient's left side using the subxiphoid and typically the medial subcostal port (shown in red). The assistant works from the patient's right side using the lateral subcostal port and periumbilical port (shown in blue).

The surgeon manipulates the infundibulum of the gallbladder to provide counter-retraction with the left hand and uses a dissector with the right hand through the subxiphoid port. The assistant uses the left hand to retract the fundus superiorly and operates the camera with the right hand. The gallbladder is usually removed through the umbilical port.

* Port placement and technique may vary among laparoscopic surgeons.

Graphic 50974 Version 8.0

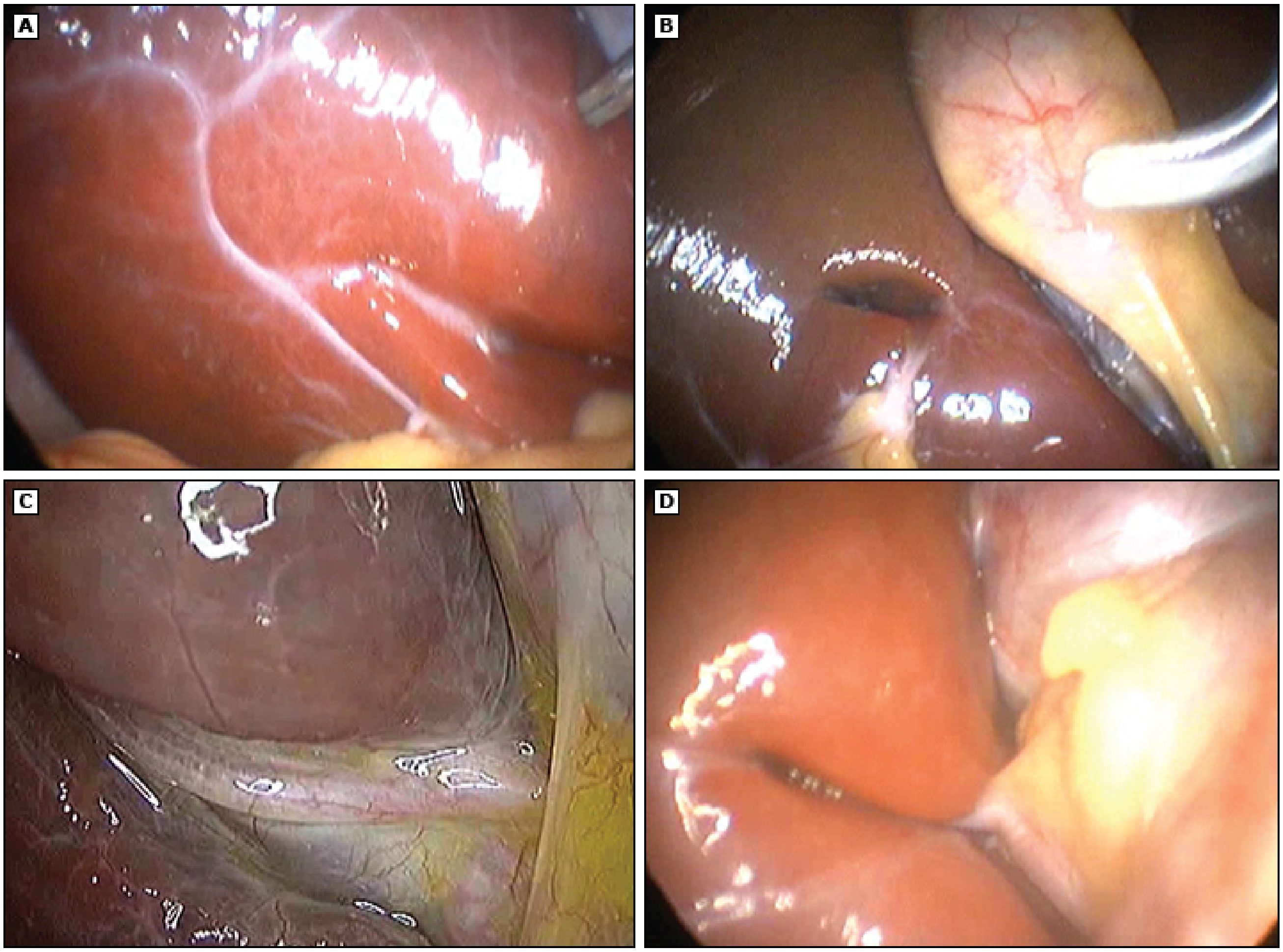
Figure 3: **Critical view of safety in laparoscopic cholecystectomy**



The critical view of safety is a "window" crossed by two structures: the cystic duct and artery. This is achieved by exposing the base of the liver bed and dissecting Calot's triangle free of all tissue except for the cystic duct and artery. The two structures emanating from the gallbladder (cystic duct and cystic artery) and the interface with the liver at the base of the gallbladder fossa should be definitively identified. The critical view of safety should be achieved prior to clipping or dividing any tubular structures in a laparoscopic cholecystectomy. Difficulty with identification of the critical view should lead the surgeon to consider performing cholangiography or converting the laparoscopic cholecystectomy into an open procedure.

Graphic 66207 Version 3.0

Picture 2: **Sulcus of Rouviere**



(A) The scar.

(B) The slit.

(C) The sulcus (open type).

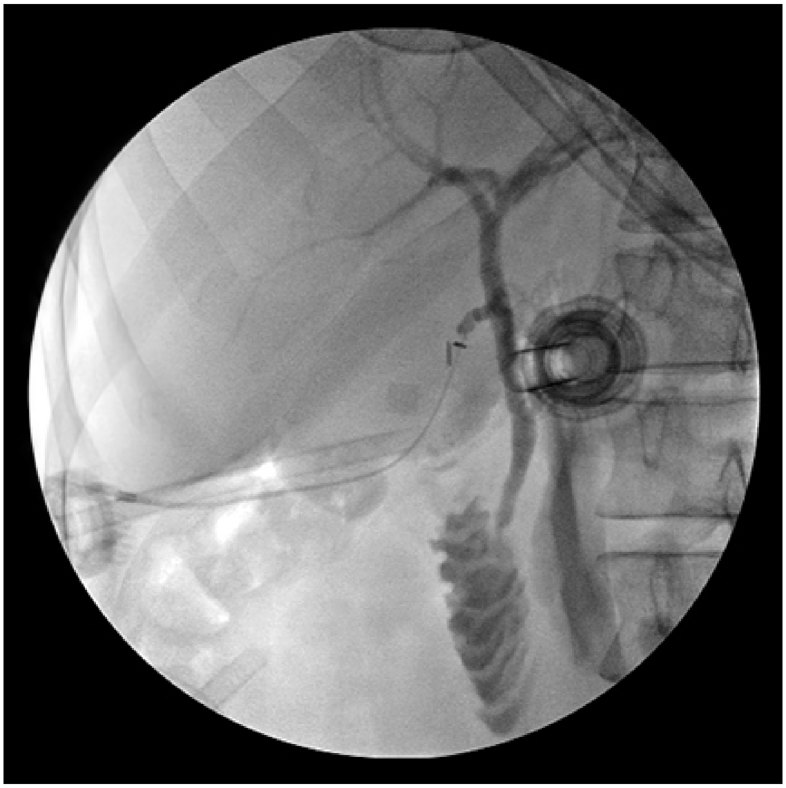
(D) The sulcus (closed type).

A good anatomic landmark to prevent bile duct injury during cholecystectomy is the sulcus of Rouviere, which may have different appearances in different patients. It is the anatomic location of the right posterior pedicle to segments 6 and 7 of the liver. Dissection of the gallbladder and cystic structures should be maintained above this location, which has been dubbed the "line of safety."

From: Singh M, Prasad N. The anatomy of Rouviere's sulcus as seen during laparoscopic cholecystectomy: A proposed classification. J Minim Access Surg 2017; 13:89. DOI: 10.4103/0972-9941.201731.

Graphic 135245 Version 2.0

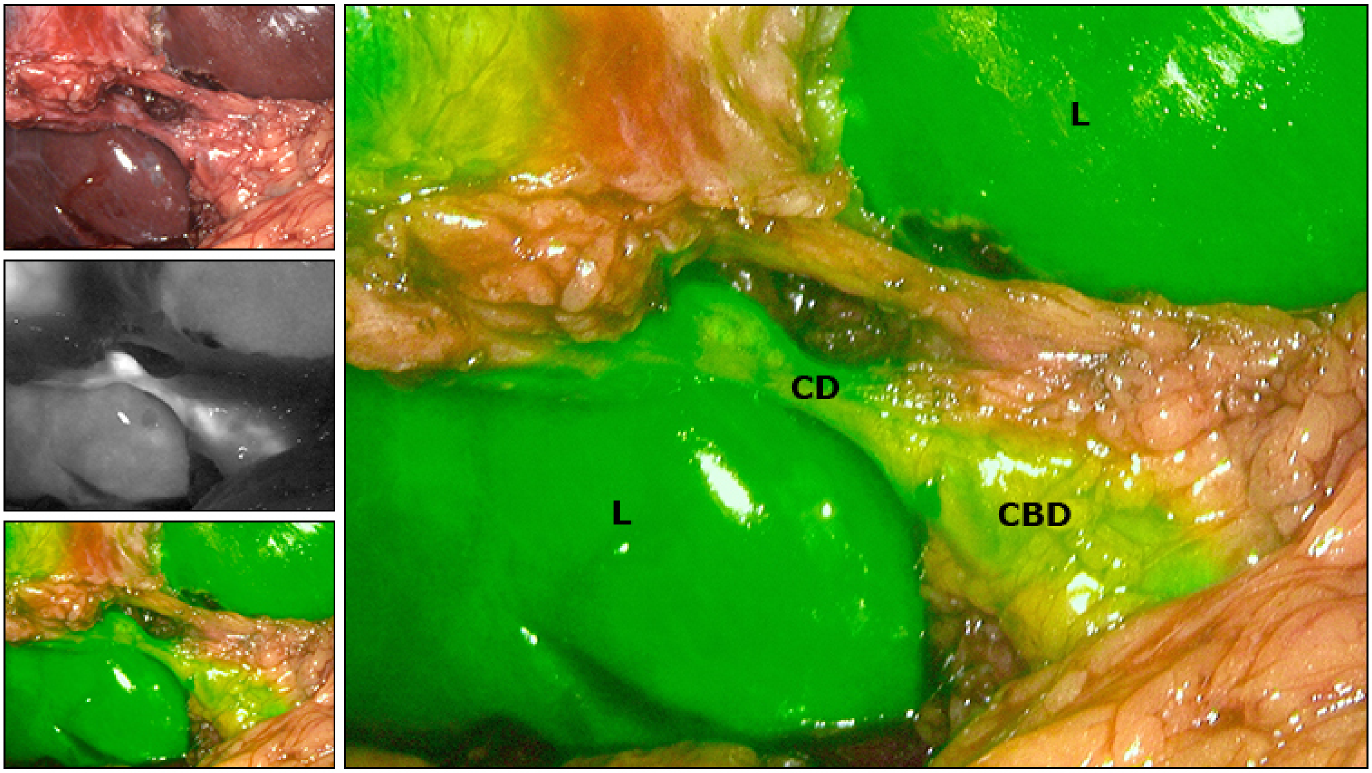
Image 1: **Normal intraoperative cholangiogram after cholecystectomy**



Courtesy of Nathaniel J Soper, MD, FACS.

Graphic 59179 Version 4.0

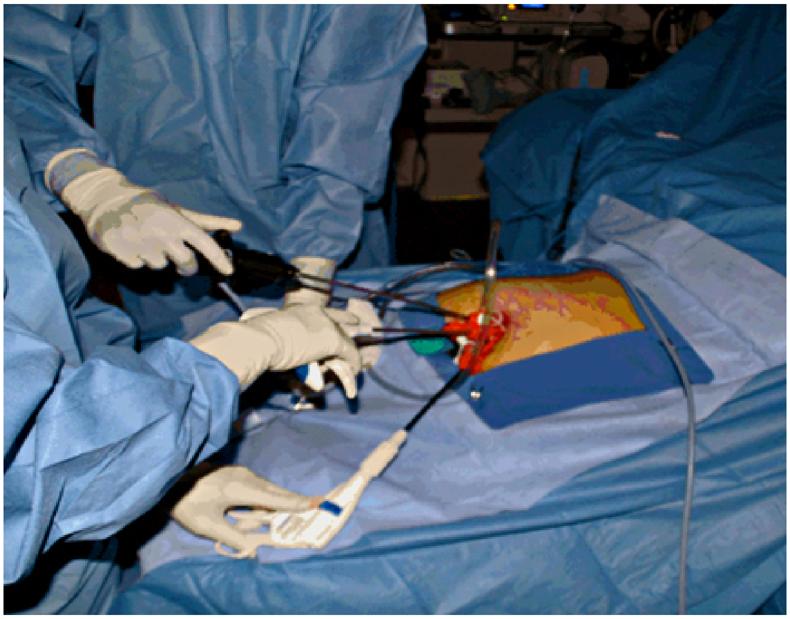
Picture 3: **ICG fluorescent cholangiography laparoscopic cholecystectomy.**



Indocyanine green (ICG) fluorescent cholangiography. The cystic duct (CD) and common bile duct (CBD) demonstrate green fluorescent appearance on the ICG mode. Note the background green fluorescence on the liver (L). The white light appearance is seen in the upper left hand panel.

Graphic 113925 Version 1.0

Picture 4: **Single incision laparoscopic surgery**



Three instruments have been introduced through a single umbilical port.

Courtesy of Dr. Aurora Pryor.

Graphic 64522 Version 1.0

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