Laparoscopic cholecystectomy

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INTRODUCTION

Cholecystectomy is one of the most commonly performed abdominal surgical procedures, and in developed countries many are performed laparoscopically. As an example, 90 percent of cholecystectomies in the United States are performed laparoscopically [1]. Laparoscopic cholecystectomy is considered the "gold standard" for the surgical treatment of gallstone disease. This procedure results in less postoperative pain, better cosmesis, and shorter hospital stays and disability from work than open cholecystectomy [2-8]. However, the overall serious complication rate in laparoscopic cholecystectomy remains higher than that seen in open cholecystectomy [9,10]. (See "Complications of laparoscopic cholecystectomy".)

This topic will discuss the technique of a routine laparoscopic cholecystectomy. Additional techniques that may be required to treat an inflamed gallbladder or common bile duct stone are discussed separately. (See "Managing the difficult gallbladder" and "Surgical common bile duct exploration".)

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

INDICATIONS

The indications for laparoscopic cholecystectomy are the same as for open cholecystectomy:

- Symptomatic cholelithiasis with or without complications. (See "Treatment of acute calculous cholecystitis" and "Overview of gallstone disease in adults".)

- Asymptomatic cholelithiasis in patients who are at increased risk for gallbladder carcinoma or gallstone complications. (See "Approach to the management of gallstones".)

- Acalculous cholecystitis. (See "Acalculous cholecystitis: Clinical manifestations, diagnosis, and management".)

- Gallbladder polyps >0.5 cm. (See "Gallbladder polyps".)

- Porcelain gallbladder. (See "Porcelain gallbladder".)

Contraindications — Contraindications to laparoscopic cholecystectomy are primarily related to anesthetic concerns and include diffuse peritonitis with hemodynamic compromise and uncontrolled bleeding disorders [11]. The inability to tolerate general anesthesia is considered a relative contraindication, but successful laparoscopic cholecystectomy under spinal anesthesia has been reported [12].

If there is suspicion of gallbladder cancer, open cholecystectomy should be performed [13]. (See "Prognosis and adjuvant treatment for localized, resected gallbladder cancer".)

Relative contraindications are dependent on the surgeon's judgment and experience but include patients with previous extensive abdominal surgery, cirrhosis with portal hypertension, severe cardiopulmonary disease, active cholangitis, and severe obesity (table 1).

TIMING OF SURGERY

The optimal timing of surgery will depend upon the patient's overall medical condition and underlying diagnosis [14]:

- 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 [15,16]. Early cholecystectomy has been associated with improved patient outcomes compared with interval cholecystectomy. (See "Treatment of acute calculous cholecystitis", section on 'Timing of cholecystectomy'.)

- 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. 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 [17]. (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 "Endoscopic management of bile duct stones".)
- Medical comorbidities – Identification of bleeding diatheses and poor cardiopulmonary reserve will help identify patients who may not tolerate pneumoperitoneum or will have higher likelihood for conversion to open operation. 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".)

PREOPERATIVE EVALUATION

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

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). 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'.)

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. An electrocardiogram or chest radiograph is obtained as appropriate. (See "Preoperative medical evaluation of the healthy adult patient", section on 'Laboratory evaluation'.)

For patients with complicated biliary tract disease, abnormal tests (eg, liver function tests, amylase, lipase) should be repeated 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.

Imaging — Ultrasonography (US) of the right upper quadrant establishes the diagnosis of gallstones or abnormalities of the gallbladder wall. The US may also demonstrate common bile duct (CBD) dilatation, stones, or evidence of acute inflammation of the gallbladder. Nuclear cholescintigraphy may be useful in cases in which the diagnosis remains uncertain after ultrasonography. (See "Acute calculous cholecystitis: Clinical features and diagnosis".)

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.

Endoscopic retrograde cholangiopancreatography — If a patient has a dilated CBD, CBD stones, or jaundice, consideration should be given to a preoperative endoscopic retrograde cholangiopancreatography (ERCP) with clearing of the stones followed by laparoscopic cholecystectomy. In the absence of frank jaundice or cholangitis, mild abnormalities of liver enzymes and/or bile duct dilation may also be managed effectively with intraoperative evaluation of the CBD (at the time of cholecystectomy), rather than preoperative ERCP. (See "Endoscopic management of bile duct stones".)

PREPARATION

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 duct injury, bowel injury, vascular injury, and reoperation or need for postoperative endoscopic retrograde cholangiopancreatography (ERCP). (See "Complications of laparoscopic cholecystectomy".)

Antibiotics — Although society guidelines generally recommend prophylactic antibiotics only for high-risk patients undergoing cholecystectomy [18,19], they are based on old data and inconsistently followed [20]. 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 [19-21]. Other high-risk groups include patients with immunosuppression and pregnant women. High-risk procedures include intraoperative cholangiography, 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 UpToDate contributors believe that patients undergoing elective cholecystectomy who are at low risk for infection do not need prophylactic antibiotics [18,22-26]. Surgical site infection rates following laparoscopic cholecystectomy are generally lower compared with those following open cholecystectomy [27,28]. Infection rates after laparoscopic cholecystectomy have ranged from 0 to 4 percent without antimicrobial prophylaxis and 0 to 7 percent with prophylaxis [27-33].

  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 [22,23,32-35]. 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, intraoperative cholangiography, 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 [29]. 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 [36-38].

Thromboprophylaxis — Thromboprophylaxis should be administered according to risk. (See "Prevention of venous thromboembolic disease in adult nonorthopedic surgical patients".)

In a large observational study, systemic thromboprophylaxis was found to increase the incidence of bleeding associated with laparoscopic, but not open, cholecystectomy [39]. Bleeding was defined as that which could not be controlled by standard surgical techniques; led to conversion to an open procedure; or necessitated transfusion, reoperation, or prolonged hospital stay.

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 should be available include a suction/irrigation device, cholangiogram catheters (4 to 5 French), retrieval bag, endoscopic ligating loops, appropriate trocars (we use a Hasson [blunt-tipped trocar for open insertion], 11 mm, and 2 x 5 mm), endoscopic needle holders, and a Veress needle (if percutaneous technique used).

STANDARD PROCEDURE

Laparoscopic cholecystectomy is performed under general anesthesia. The generally short duration of the procedure minimizes the need for gastric decompression or 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).

- 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 (figure 1).

Abdominal access — Initial entry into the abdomen is typically obtained at the umbilicus using either an open (Hasson) or closed (Veress needle) technique. Both techniques are discussed in detail elsewhere. (See "Abdominal access techniques used in laparoscopic surgery", section on 'Initial port placement'.)

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 and figure 3):

- 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 [40]. 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.

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.

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. Minimal electrocautery should be used in order to reduce the risk of thermal injury to the adjacent bowel (figure 1).

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 4) [41] (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.

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 cautery 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. This is the "critical view of safety" that should be achieved prior to clipping or dividing any tubular structures (figure 4) [41,42]. (See "Complications of laparoscopic cholecystectomy".)

There is no need to dissect down to the cystic duct-common bile 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 (figure 1).

The surgeon should be aware of certain anatomic variations in order to avoid misidentification of structures. A common anomaly is the right hepatic artery looping onto the infundibulum and being mistaken for the cystic artery. A short cystic duct is also seen quite frequently and can drain into the right hepatic duct, the common duct, or a low-lying aberrant right sectoral duct. 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.

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. 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 include tying the duct closed (eg, Endoloop) and the use of advanced tissue sealing devices (eg, Enseal). Monopolar electrocautery should not be used, since the electrical current can be transmitted to the clips and cause delayed necrosis of the stump.

The 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 [43]. The clipped stumps should be inspected for adequacy of closure.

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

Intraoperative cholangiogram — Intraoperative cholangiography (IOC) should be accomplished before beginning CBD exploration. The catheter for IOC is placed after careful dissection achieves the critical view of safety (figure 4). The technique of IOC and CBD exploration is discussed elsewhere in detail. (See "Surgical common bile duct exploration".)

Laparoscopic ultrasound — LUS may alternatively be performed to evaluate the CBD. It requires a certain comfort and skill level. A prospective multicenter study of 209 patients showed that in experienced hands, LUS can be equivalent to an IOC in detecting stones and can be performed almost 50 percent more quickly [44]. On the other hand, IOC is better at detecting intrahepatic anatomy and anatomic anomalies of the biliary tree [44]. 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 [45].

Dissection of gallbladder from 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.

The routine placement of drains is not necessary [46], but, 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.

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, an extraction bag is used when the gallbladder is acutely inflamed and friable or when there was inadvertent perforation of the gallbladder. Any remaining loose stones can be placed in the bag as well. The laparoscope is transferred to the subxiphoid position, 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 fascial incision may need to be stretched or enlarged. 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 escape of CO_2. The umbilical fascia is then closed with the stay sutures originally placed.

The specimen can also be retrieved through the subxiphoid port site. Some surgeons feel that the subxiphoid site may be better for specimen extraction as the subxiphoid site has a lower likelihood of hernia formation; however, formal study of this has not been performed [47].

The skin is closed with subcuticular absorbable stitches and with adhesive strips. The access site incisions can be infused with local anesthetic (eg, bupivacaine), which reduces postoperative pain [48]. Some surgeons also instill local anesthetic agents intraperitoneally; however, the benefit is uncertain [49]. Pharmacologic agents to manage postoperative pain are reviewed elsewhere [50]. (See "Approach to the management of acute pain in adults".)

ALTERNATIVE TECHNIQUES

Alternative techniques for cholecystectomy include needlescopic surgery, single-incision laparoscopic surgery, and robot-assisted laparoscopic surgery. Compared with standard laparoscopic cholecystectomy, these alternative techniques use fewer or smaller trocars with a 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 [51]. 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. Robotic cholecystectomy is an investigational technique. As such, standard laparoscopic cholecystectomy remains the routine approach for gallbladder surgery [52].

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 [53]. (See "Instruments and devices used in laparoscopic 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 [54]. 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 1). Through a single skin incision typically made periumbilically, multiple trocars are placed through one or more fascial punctures. (See "Abdominal access techniques used in laparoscopic 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 [55-72]. 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). Additionally, the risk of incisional hernia is four times higher after SIS than after conventional LC [73].

Robotic cholecystectomy — Robot-assisted cholecystectomy has also been performed (movie 1). Compared with conventional laparoscopic cholecystectomy, robotic cholecystectomy has not been found to be more effective or safer than for benign gallbladder diseases, but it incurs longer operative time and higher cost [74-77]. The use of robotic-assisted extended cholecystectomy for gallbladder cancer is currently being evaluated [78,79].

SPECIAL CONSIDERATIONS

Cirrhosis — Cirrhotic patients with portal hypertension pose a particular challenge to the surgeon [80,81]. They are at higher risk for any surgical procedure, and preoperative preparation is critical for good outcomes. These patients should have their liver function optimized prior to an elective cholecystectomy. Some may need replacement of clotting factors to minimize intraoperative bleeding. (See "Assessing surgical risk in patients with liver disease".)

Care should be taken when placing trocars to avoid the "caput medusa" of large collateral vessels in the abdominal wall. The cirrhotic liver itself is usually quite hard and easily injured just with retraction. Bleeding from a cirrhotic liver is difficult to control, so remaining in the correct plane during dissection of the gallbladder from the liver is particularly important.

Various hemostatic agents and energy sources (the argon cautery device can be quite useful) need to be available in case bleeding develops [82]. Particular care should be taken in making watertight closures for all incisions to minimize perioperative ascitic leak [83].

In a study of 349 cirrhotic patients undergoing cholecystectomy (59 percent laparoscopic), the morbidity and mortality rates were 18.7 and 3.8 percent, respectively. The Model for End-Stage Liver Disease (MELD) score was an independent factor of morbidity and mortality, while the laparoscopic approach had a protective effect on morbidity. A nomogram can be used to predict outcomes [84].

Pregnancy — There is a strong association between pregnancy and gallstones. In the past, elective laparoscopic cholecystectomy for symptomatic gallstones was deferred as much as possible until after pregnancy. For patients with severe biliary colic, however, waiting until after pregnancy can lead to repeated hospitalizations and complications [85]. Laparoscopic gallbladder surgery has been performed safely during pregnancy by experienced surgeons [86]. In the guidelines for diagnosis, treatment, and use of laparoscopy for surgical problems during pregnancy (2007), the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) organization stated that laparoscopic cholecystectomy can be performed safely during any trimester of pregnancy [87]. We concur with that statement.

When laparoscopic surgery is performed in pregnant patients, the trocars need to be placed higher in the abdomen due to the enlarged uterus. The CO_2 insufflation should be kept at the lowest possible pressure while maintaining an adequate working space. If common bile duct (CBD) imaging is necessary, laparoscopic ultrasound should be used in place of intraoperative cholangiogram to limit radiation exposure. Preoperative obstetric consultation and perioperative fetal monitoring are advisable [88]. Details of proper positioning for surgery and management of pregnant patients undergoing surgery are discussed elsewhere. (See "Anesthesia for nonobstetric surgery during pregnancy" and "Laparoscopic surgery in pregnancy".)

Obesity — Because patients with obesity have a thick abdominal wall, trocar placement is particularly important. The thickness of the wall inhibits the mobility of the trocars, so they should be placed at the angle most likely to be used during the cholecystectomy. Longer trocars may be needed to traverse the abdominal wall in order to avoid trocar displacement and subsequent insufflation within the abdominal wall and subcutaneous emphysema. Longer instruments may be required to reach the gallbladder, and the initial umbilical trocar may need to be placed at a supraumbilical position. The surgeon should not hesitate to place additional trocars if needed. Although laparoscopy may be more challenging in patients with severe obesity, it may offer advantages specific to these patients such as decreased wound infection, deep vein thrombosis (DVT), and incisional hernias, which may make laparoscopy the preferred approach [89,90].

Gangrenous cholecystitis — Laparoscopic cholecystectomy can be done safely in the setting of acute or gangrenous cholecystitis and should be done as soon as possible to fall within the "golden period" within 72 hours when edema is the primary manifestation of the inflammation. If the patient presents in a delayed fashion (>72 hours from onset of symptoms), the surgery can be performed if there are no contraindications to an open procedure, as conversion is a significant risk. In the face of acute cholecystitis with multiple comorbidities, it may be preferable to treat with intravenous antibiotics and possibly percutaneous drainage, with subsequent laparoscopic cholecystectomy six to eight weeks later. (See "Treatment of acute calculous cholecystitis".)

Different techniques may be needed when a gangrenous gallbladder or dense inflammation is encountered. A "top-down" approach to dissection of the gallbladder as in an open procedure may be necessary to appreciate the anatomy [91,92]. The surgeon may perform subtotal cholecystectomy by transecting the infundibulum as close to the cystic duct as possible and extracting all stones. The gallbladder neck is then sewn closed, if possible, and a drain is placed in the gallbladder bed. This transection of an edematous, friable wall may be facilitated by using the ultrasonic shears. In a gallbladder densely adherent to the liver where the plane between the two is obliterated and/or in the presence of portal hypertension, it may be preferable to leave the back wall of the gallbladder intact and fully cauterize its mucosa [93]. Blunt dissection with a suction irrigator or laparoscopic peanut is particularly useful in defining anatomy around a grossly inflamed duct. 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. We do not place a drain to monitor for bleeding.

Commonly referred to as a "difficult gallbladder" is a scenario in which a cholecystectomy incurs an increased surgical risk compared with standard cholecystectomy [94]. 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). Strategies to manage a difficult gallbladder are discussed in detail elsewhere. (See "Managing the difficult gallbladder".)

Large cystic duct — 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 common bile duct.

INTRAOPERATIVE COMPLICATIONS

Major complications, including vascular injury, bowel perforation, mesenteric injury, and bile duct injuries, often require immediate laparotomy. 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. Open cholecystectomy is discussed in detail elsewhere. (See "Open cholecystectomy".)

Conversion to an open operation is indicated for:

- Hemorrhage
- Unusual or confusing anatomy
- Failure to progress laparoscopically in a timely fashion
- Bowel perforation or major injury to the bile ducts
- Potentially resectable gallbladder cancer
- Common bile duct stones that cannot be removed laparoscopically or endoscopically (due to Billroth II anatomy, previously failed endoscopic retrograde cholangiopancreatography [ERCP], or lack of an experienced endoscopist)

Complications of laparoscopic cholecystectomy, particularly common bile duct injury, are discussed in detail separately but will be summarized here. (See "Complications of laparoscopic cholecystectomy" and "Repair of common bile duct injuries".)

- Gallbladder perforation – During the dissection of the gallbladder, the surgeon may enter the gallbladder inadvertently, causing spillage of bile and/or stones. The hole in the gallbladder can be closed by incorporating it within the grasping forceps or may be sutured closed to prevent further spillage. The bile should be suctioned and irrigated. Bile spillage, when not accompanied by stone spillage and promptly evacuated, has not been shown to increase postoperative infections [95].

  On the contrary, gallstones, particularly pigment stones, which harbor bacteria, can increase the risk of postoperative infection if left in the abdomen or port site [96-99]. Thus, any spilled gallstones should be extracted if at all possible. Large stone graspers are helpful in performing this task.

- Vascular injury – If a trocar impales a major blood vessel, the trocar should not be removed but allowed to tamponade the vessel while an immediate laparotomy is performed. Another site of hemorrhage is from lacerated abdominal wall vessels; therefore, trocars should be visualized with the laparoscope when removed. Bleeding from these sites can usually be controlled with cautery, Foley catheter balloon tamponade, or a figure-of-eight stitch placed directly or with a suture passer.

- Bowel injury – Bowel injuries should be marked and closely observed during and at the end of the case. If leakage occurs, the injury can be repaired laparoscopically or in an open fashion through extension of the umbilical incision. Then the procedure can proceed laparoscopically.

- Bile duct injuries – Major bile duct injuries should be immediately repaired if recognized. There is interest in using fluorescent imaging with indocyanine green to define biliary anatomy and prevent bile duct injuries. There is not enough evidence to recommend this, but the technique appears promising [100,101].

  Some bile duct injuries may be unrecognized at the time of surgery and present in a delayed fashion. These should all be referred to an experienced biliary surgeon since the greatest chance for successful repair is at the first operation. If the surgeon is at another facility, the patient should be externally drained prior to transfer. (See "Repair of common bile duct injuries".)

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 [102,103]. 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 [104].

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 are able to 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.

POSTOPERATIVE COMPLICATIONS

Serious complications that occur with laparoscopic cholecystectomy, including bile duct injury, bile leaks, bleeding, and bowel injury, result in part from patient selection, surgical inexperience, and the technical constraints that are inherent to the minimally invasive approach. These are discussed in detail elsewhere. (See "Complications of laparoscopic cholecystectomy".)

Other adverse outcomes, such as retained common bile duct (CBD) stones (incidence of around 10 percent), postcholecystectomy syndromes, and misdiagnoses (sphincter of Oddi dysfunction), occur with the same frequency with both laparoscopic and open cholecystectomy. (See "Choledocholithiasis: Clinical manifestations, diagnosis, and management".)

Postcholecystectomy syndrome — Postcholecystectomy syndrome (PCS) is a complex of heterogeneous symptoms, including persistent abdominal pain and dyspepsia, that recur and persist after cholecystectomy [105,106]. 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 [107].

In a trial of over 1000 patients with abdominal pain and ultrasound-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) [108]. 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 [109].

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.

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 extrabiliary. About one-half of the patients with PCS are found to have biliary, pancreatic, or gastrointestinal disorders, while the remaining patients have extraintestinal disease [106].

- Biliary causes of PCS include:
  - Early PCS can be due to biliary injury, retained cystic duct, or 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, which is discussed in detail elsewhere.
- Extrabiliary causes of PCS include:
  - 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.

Treatment for PCS is tailored to the specific cause of the symptoms. Diagnosis of the underlying problem causing PCS usually requires imaging to look for retained or recurrent stones or identify a bile duct leak, stricture, or transection. This can be accomplished in most cases with ultrasound and/or computed tomography (CT) scanning followed by direct cholangiography or magnetic resonance cholangiopancreatography (MRCP). MRCP provides a noninvasive alternative to direct cholangiography for evaluation of the biliary tract. The approach to the diagnosis of choledocholithiasis or biliary injury is discussed elsewhere. (See "Choledocholithiasis: Clinical manifestations, diagnosis, and management", section on 'Subsequent evaluation and management' and "Complications of laparoscopic cholecystectomy", section on 'Biliary injury'.)

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: Laparoscopic and robotic 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 5th to 6th 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 10th to 12th 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 topic (see "Patient education: Choosing surgery to treat gallstones (The Basics)")

SUMMARY AND RECOMMENDATIONS

- **Indications** – Laparoscopic cholecystectomy is considered the "gold standard" for the surgical treatment of gallstone disease. It has the same indications as for open cholecystectomy. The optimal timing of surgery will depend on the patient's overall medical condition and underlying diagnosis. (See 'Introduction' above and 'Indications' above and 'Timing of surgery' above.)

- **Preoperative evaluation**

  - Liver function tests (LFTs) should be obtained preoperatively. Elevation in the serum total bilirubin and alkaline phosphatase concentrations should raise concerns about complicating conditions. (See 'Preoperative evaluation' above.)

  - Ultrasonography (US) of the right upper quadrant establishes the diagnosis of gallstones, abnormalities of the gallbladder wall, common bile duct (CBD) dilatation, stones, or evidence of acute inflammation of the gallbladder. (See 'Preoperative evaluation' above.)

  - If a patient has a dilated CBD, CBD stones, or jaundice, preoperative endoscopic retrograde cholangiopancreatography (ERCP) or intraoperative cholangiography and possible CBD exploration should be performed. (See 'Preoperative evaluation' above.)

  - Preoperative discussion with the patient should include the possibility of conversion to an open procedure. The patient should be informed about the risks of bile duct injury, bowel injury, vascular injury, and reoperation or need for postoperative ERCP. (See 'Preoperative evaluation' above.)

  - For high-risk patients undergoing laparoscopic cholecystectomy or all patients undergoing laparoscopic cholecystectomy with a high-risk procedure defined above, we suggest prophylactic antibiotics (**Grade 2C**). Appropriate agents are in this table (table 2). (See 'High-risk patients or high-risk procedures' above.)

    For low-risk patients undergoing laparoscopic cholecystectomy without a high-risk procedure, some UpToDate contributors do, while other UpToDate contributors do not, administer prophylactic antibiotics. There are data to support either practice. (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. The "critical view of safety" should be achieved prior to clipping or dividing any tubular structures. (See 'Standard procedure' above.)

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

- **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. (See 'Intraoperative complications' above.)

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Topic 3685 Version 48.0

GRAPHICS

Indications and contraindications for laparoscopic cholecystectomy

Indications
Symptomatic cholelithiasis
Biliary colic, acute cholecystitis, gallstone pancreatitis
Asymptomatic cholelithiasis in select cases
Sickle cell, TPN, immunosuppression
Acalculous cholecystitis
Gallbladder dyskinesia
Large gallbladder polyps
Porcelain gallbladder
Contraindications
Absolute
Inability to tolerate general anesthesia, peritonitis with hemodynamic compromise, refractory coagulopathy, gallbladder cancer
Relative
Previous abdominal surgery, pregnancy, obesity, cholangitis, severe comorbidities

TPN: total parenteral nutrition.

Graphic 76254 Version 3.0

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
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 cefotetanΔ	2 g IV	6 hours
Small intestine surgery				
Nonobstructed	Enteric gram-negative bacilli,	CefazolinΔ	<120 kg: 2 g IV ≥120 kg: 3 g IV	4 hours

	gram-positive cocci			
Obstructed	Enteric gram-negative bacilli, anaerobes, enterococci	Cefazolin[Δ] 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 cefotetan[Δ]	2 g IV	6 hours
Hernia repair				
	Aerobic gram-positive organisms	Cefazolin[Δ]	<120 kg: 2 g IV ≥120 kg: 3 g IV	4 hours
Colorectal surgery[†]				
	Enteric gram-negative bacilli, anaerobes, enterococci	Parenteral:		
		Cefazolin[Δ] 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 cefotetan[Δ]	2 g IV	6 hours
		Oral (used in conjunction with mechanical bowel preparation):		
		Neomycin PLUS erythromycin base or metronidazole	**	**

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 one to two 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, gastrointestinal (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.

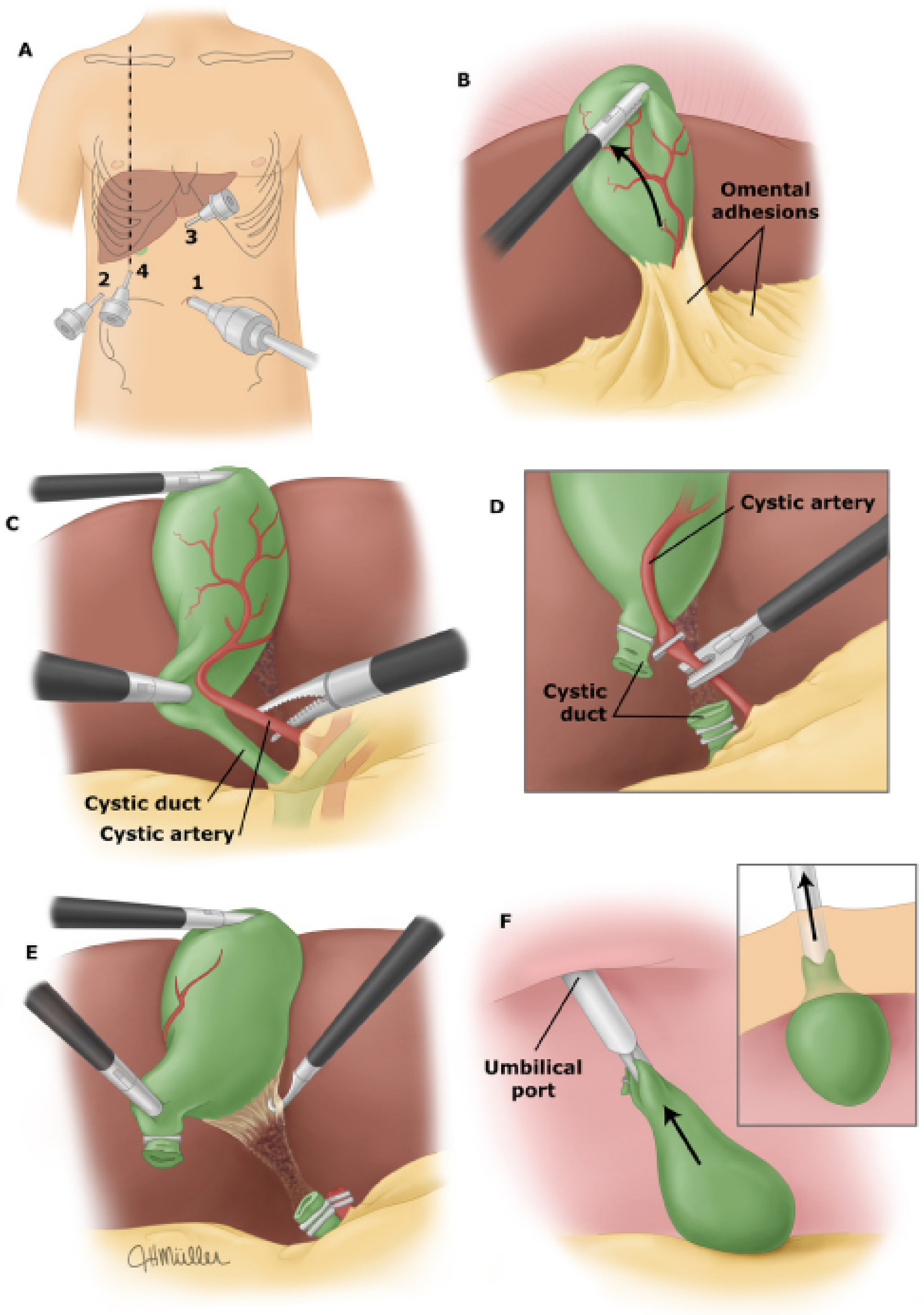
** In addition to mechanical bowel preparation, the following oral antibiotic regimen is administered: neomycin (1 g) plus erythromycin base (1 g) OR neomycin (1 g) plus metronidazole (1 g). The oral regimen should be given as 3 doses over approximately 10 hours the afternoon and evening before the operation. 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 37.0

Laparoscopic cholecystectomy



(A) Port placement.

(B) Initial retraction of gallbladder.

(C) Critical view of safety.

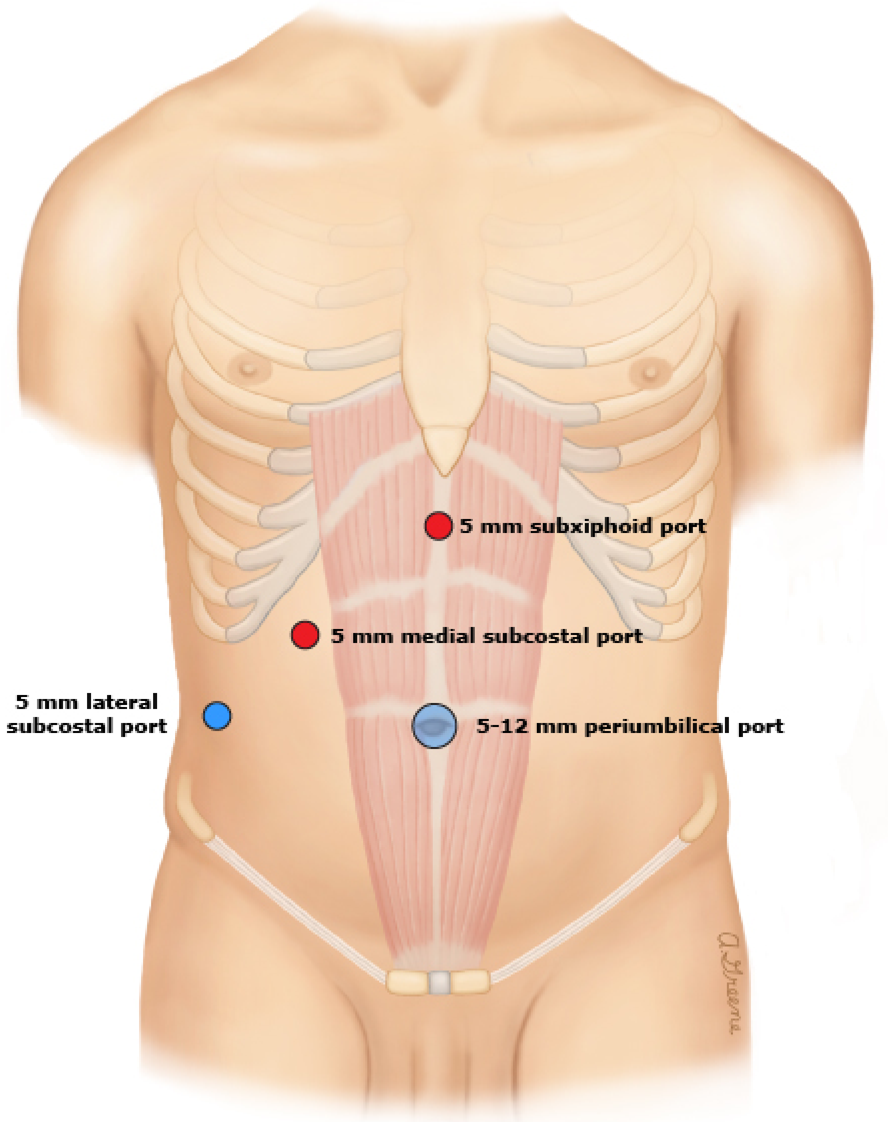
(D) Clipping and division of cystic artery and duct.

(E) Dissection of gallbladder from liver bed.

(F) Extraction of gallbladder.

Graphic 52727 Version 3.0

Port placement for laparoscopic cholecystectomy*



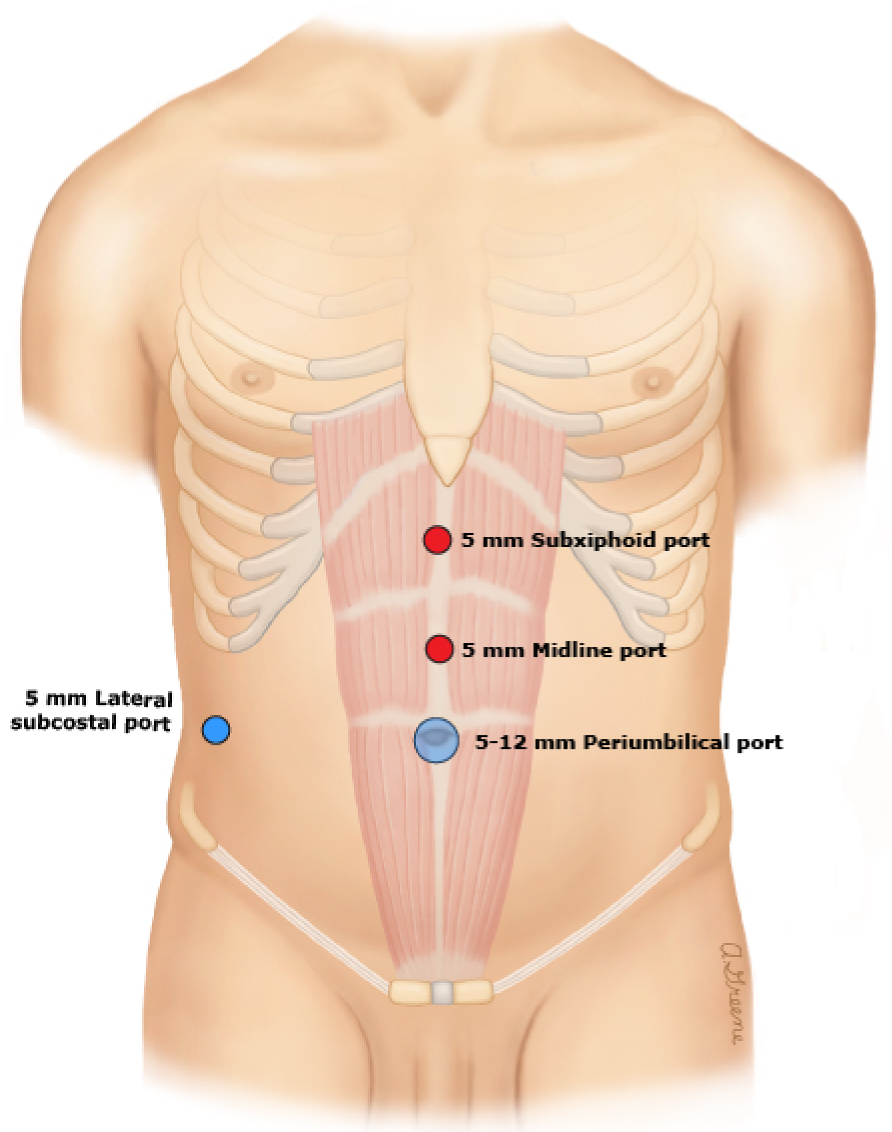
An open (Hasson) technique is used to enter the peritoneal cavity and place a 5 to 12 mm Hasson trocar at the umbilicus. The laparoscope is introduced through this port, and three additional 5 mm ports are placed under direct vision 1 to 2 cm inferior to the right subcostal margin. The surgeon operates 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

Alternative port placement for cholecystectomy



An alternative port placement for cholecystectomy places a 5 mm port halfway between the xiphoid and umbilical ports. The surgeon retracts the infundibulum of the gallbladder through the midline port and uses the dissector through the subxiphoid port (shown in red). The assistant retracts the fundus of the gallbladder through the right lateral port and operates the laparoscope via the periumbilical port. The gallbladder is removed through the umbilical port.

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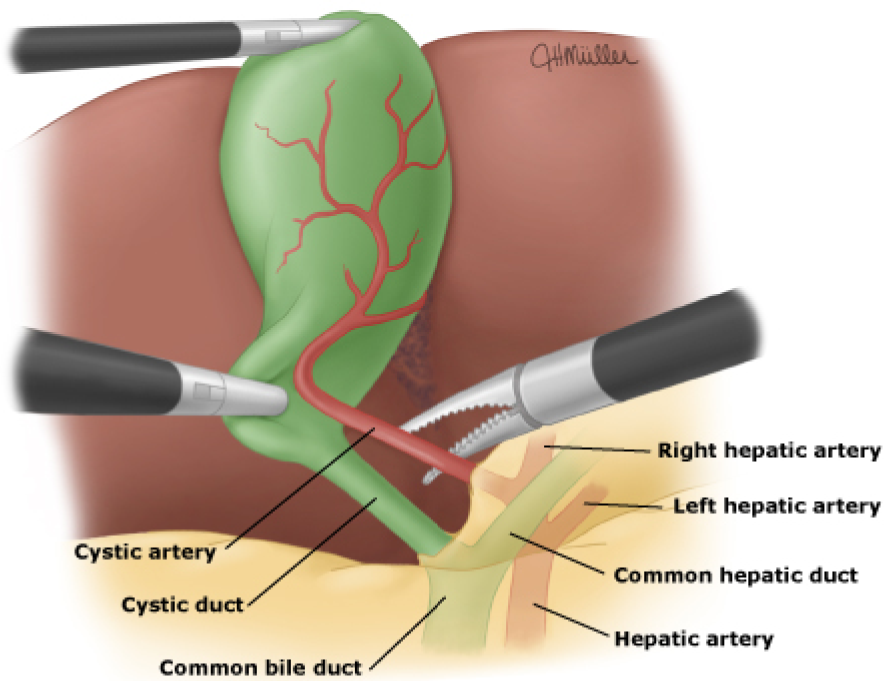
* Port placement and technique may vary amongst laparoscopic surgeons.

Graphic 65844 Version 5.0

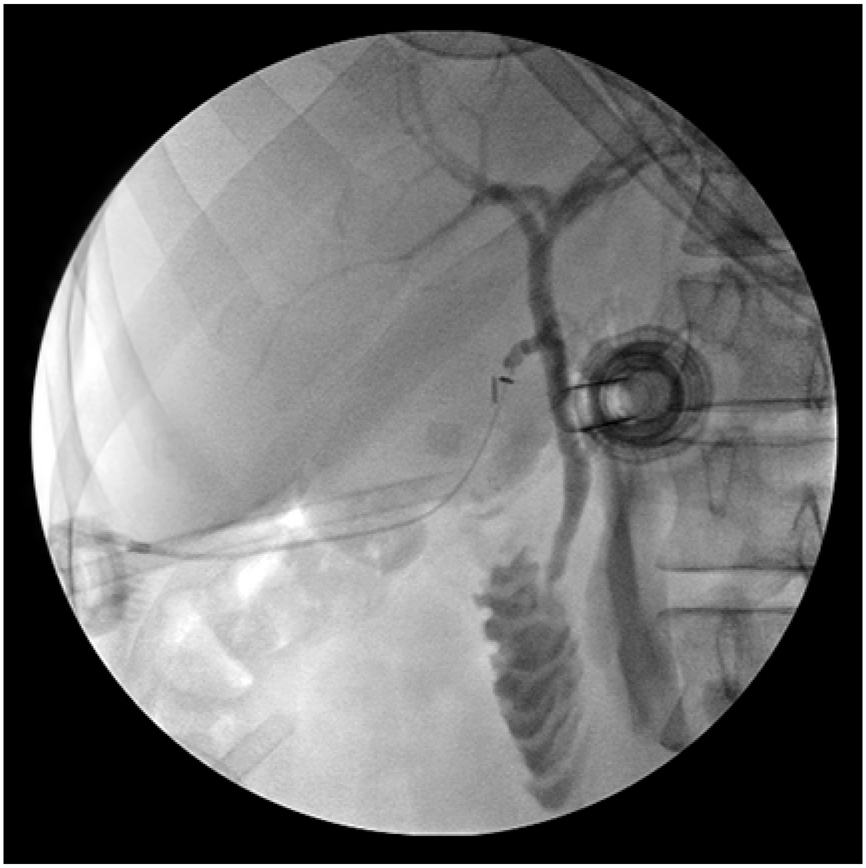
Critical view of safety in laparoscopic cholecystectomy



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

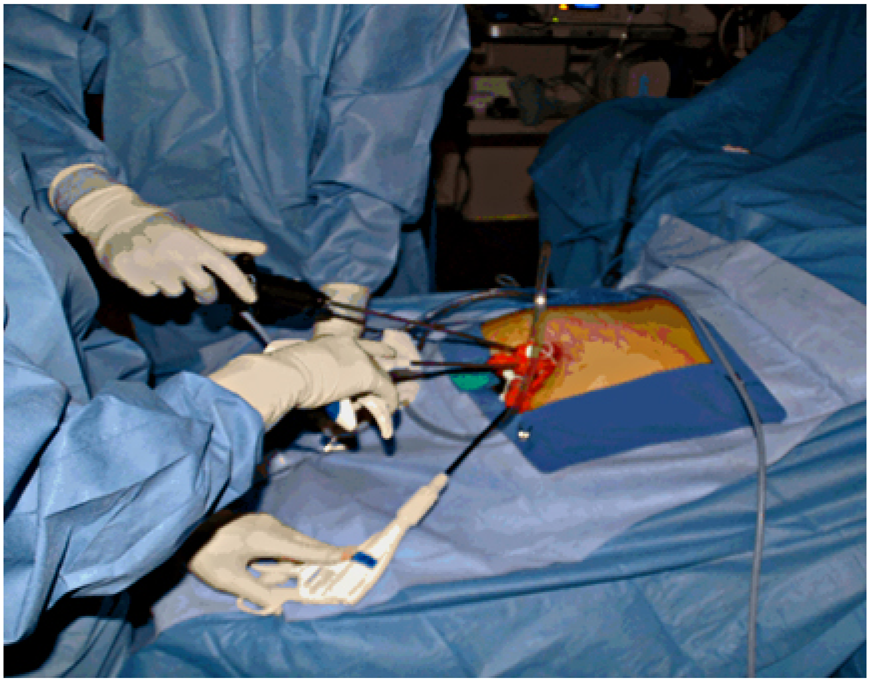
Normal intraoperative cholangiogram after cholecystectomy



Courtesy of Nathaniel J Soper, MD, FACS.

Graphic 59179 Version 4.0

Single incision laparoscopic surgery



Three instruments have been introduced through a single umbilical port.

Courtesy of Dr. Aurora Pryor.

Graphic 64522 Version 1.0

Contributor Disclosures

Nathaniel J Soper, MD, FACS Equity Ownership/Stock Options: Mesh Suture [Laparoscopic surgery]. Consultant/Advisory Boards: FlexDex [Laparoscopic surgery]; Mesh Suture [Laparoscopic surgery]; Miret Surgical [Laparoscopic surgery]. All of the relevant financial relationships listed have been mitigated. **Preeti Malladi, MD** No relevant financial relationship(s) with ineligible companies to disclose. **Stanley W Ashley, MD** No relevant financial relationship(s) with ineligible companies to disclose. **Wenliang Chen, MD, PhD** No relevant financial relationship(s) with ineligible companies to disclose.

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