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Laparoscopic Cholecystectomy

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Abstract
Laparoscopic cholecystectomy (LC) is recognized as the gold standard for cholecystectomy for most gallbladder pathology. There are numerous advantages to laparoscopy, including wound healing, cosmesis, decreased postoperative pain, quicker return to work, and daily activities. LC has become a relatively safe and tolerable procedure performed in the outpatient setting and, unquestionably, it has become the new gold standard for biliary disease requiring cholecystectomy in both the elective and acute setting. It has been shown to be safe and effective with decreased rates of bile duct injury after the initial learning curve. Shifts in the training paradigm for today's surgical trainees lead to greater skill and comfort with laparoscopy. Appropriate patient selection, judicious use of intraoperative cholangiography, and "bail-out" techniques, this paper suggests, allow for laparoscopic management of GB pathology with minimal advantage to a conversion to open technique.
Keywords: Laparoscopic cholecystectomy, abdominal entry, gallbladder exposure and dissection of Hepatocystic Triangle, removal of the gallbladder

Biliary disease with gallbladder pathology is one of the most common surgical diseases encountered in the United States. Cholelithiasis and its associated complications constitute a significant proportion of biliary and gallbladder pathology. In the United States, 10-15% of the adult population (20-25 million Americans) is affected by gallstone disease (1). Surgical management of biliary tract disease with cholecystectomy has significantly evolved within the past 3 decades. Laparoscopic cholecystectomy (LC) was first performed in the late 1980s and its use became more widespread by the mid-1990s. It was initially met with skepticism and concern for higher rates of complications, namely, injury to the common bile duct. Early on, a steep learning curve for laparoscopy and its use for biliary pathology took place. Common bile duct injuries were reported as high as 1 in 100 cases during this initial learning curve (2-3). A large population-based study of Medicare beneficiaries undergoing LC from 1992-1999 shows that common bile duct injury was much more likely to occur within the surgeon's first 20 cases (4). Since the early 1990s, we have seen a significant enhancement of laparoscopic technology

and a shift in the surgical training paradigm to incorporate significant exposure to laparoscopy. With experience, it appears that the risk of common bile duct injury is currently similar to that of open cholecystectomy (5). Thus, it does not seem that laparoscopy inherently increases the risk of common bile duct injury. This has led to a shift from traditional open cholecystectomy (OC) toward a laparoscopic approach. The indications for LC include symptomatic cholelithiasis, biliary colic, acute and chronic cholecystitis, gallstone pancreatitis, choledocholithiasis, biliary dyskinesia, and complications of acute and chronic gallbladder disease. After the advent of LC, the number of cholecystectomies performed (both open and laparoscopic) increased drastically between 1988 and 1992, despite the fact that there were no changes in indications for surgery (6). This was driven by increased patient demand and the perception of lower-risk surgery with a minimally invasive approach. There are numerous advantages to laparoscopy, including wound healing, cosmesis, decreased postoperative pain, quicker return to work and daily activities. LC has become a relatively safe and tolerable procedure performed in the outpatient setting and, unquestionably, it has become the new gold standard for biliary disease requiring cholecystectomy in both the elective and acute setting (7-10).

While LC can be performed in a relatively straightforward manner, it is important for the surgeon to be mindful of the complexity, often seen within the biliary system. Aberrant biliary anatomy, significant inflammation or fibrosis, underlying hepatic disease, and other variations can lead to significant morbidity and mortality. While traditionally a conversion to OC during a technically difficult cholecystectomy is prudent, the shift in the training paradigm towards laparoscopy, and away from open surgery, has led to a generation of newly minted surgeons with less experience of open operation. Given the degree of technical difficulty encountered, which can be inferred by the decision to convert to open surgery, the advantage for such conversion by more recently trained surgeons who have limited experience with open cholecystectomy may be minimal. It is important, therefore, for the surgeon to rely on the principles of safe laparoscopic cholecystectomy when performing a more technically challenging LC. Judicious use of intraoperative cholangiography (IOC) is an important adjunct to safe cholecystectomy. It can highlight difficult-to-discern anatomical variations. Laparoscopic IOC is a technical skill that should be in the armamentarium of all surgeons seeking to perform LC. There are several "bail-out" options to be considered during a technically difficult or complex LC. Laparoscopic placement of a cholecystostomy tube can be safely performed relatively easily and it can reduce the risk of bile duct injury while allowing the initial septic process to resolve. These patients will often benefit from interval cholecystectomy once the inflammatory process has subsided (11). Patient selection is also an important consideration with regard to performing safe LC. While cholecystectomy is the ideal definitive management of patients presenting with acute cholecystitis (AC), patients who are critically ill and medically complex may benefit from less invasive measures, such as percutaneous cholecystostomy as a temporizing measure prior to interval cholecystectomy (12).

Laparoscopic Cholecystectomy: Conduct of Operation

The operative approach for LC is similar in both the elective and the acute settings. There are several technical nuances regarding the surgical approach to AC discussed in this paper. Preoperative planning is essential, regardless of the indication for surgery. Often preoperative right-upper-quadrant ultrasound will have been performed. It provides key information including gallbladder size, GB wall thickness, presence and size of gallstones, and size of the common bile duct. A careful review of symptomatology, imaging, and laboratory workup can provide the surgeon with an appropriate expectation of the degree of inflammation, the possible presence of choledocholithiasis, potential anomalous biliary or arterial anatomy, and allow for appropriate preoperative expectations and planning.

Abdominal Entry

The laparoscope will be positioned at or slightly above the umbilicus. Abdominal entry can be performed by Hasson cut-down technique or via Veress' needle entry. This depends on both patient factors (prior surgical history) and the surgeon's preference. If there is a concern for abdominal scarring around the umbilicus, an alternative method would be the following: Veress' needle insertion in the RUQ and placement of laparoscope at the pararectus muscle in the right upper quadrant with visualization

of the degree of intra-abdominal adhesions will guide the placement of additional trocars. Regardless of modality, an inspection of underlying structures after initial trocar entrance into the abdomen is mandatory due to the risk of injury to the viscera.

Trocar Placement and Diagnostic Laparoscopy

After confirming no sign of secondary injury to abdominal entry, the surgeon performs diagnostic laparoscopy in order to rule out any liver abnormality, evaluate the status of the gallbladder, and identify any intra-abdominal adhesions or other pathology. Next, subsequent 5 mm ports will be placed as depicted in Fig 1. Generally, a high epigastric port is placed at the level of the edge of the right lobe of the liver, between the xiphoid and the costal margin on the patient's right. The midclavicular port is then placed lateral to the gallbladder in a trajectory towards the fundus of the gallbladder. Finally, a lateral port should be placed in the subcostal margin at the anterior axillary line, which will be used to grasp the fundus of the gallbladder.

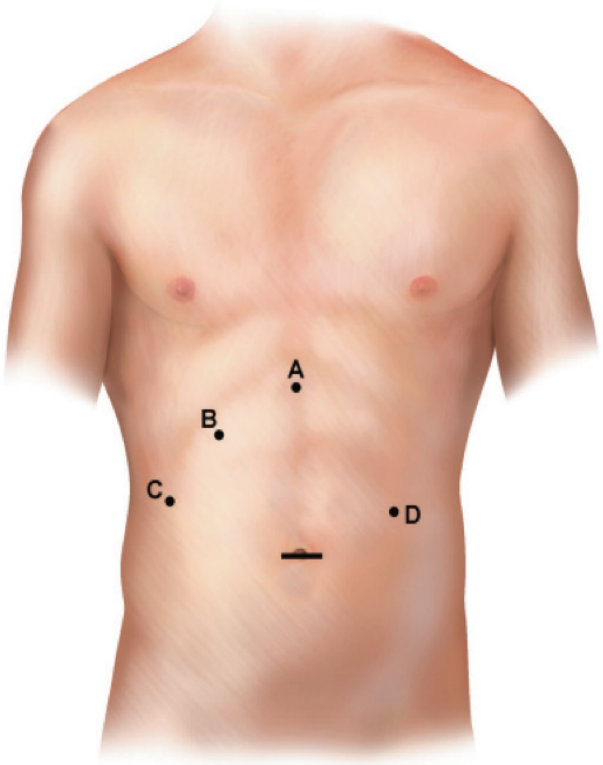

Fig. 1. Placement of ports for laparoscopic cholecystectomy. Port A should be placed high in the epigastrium adjacent to the liver edge. Port B should be placed approximately in the midclavicular line just lateral to the position of the fundus of the gallbladder. Port C is the lateral port used for the insertion of a fundus grasper and should be placed in the approximate anterior axillary line below the liver edge. Port D is an optional 5mm left midrectus port that can be used for downward retraction of the duodenum or transverse colon. (Sneider, B.B., Cahan, MA., Litwin, D.E "Acute Cholecystitis." I Gagner, M ed. Atlas of Hepatopancreatobiliary Surgery, Woodbury, CT: Cine-Med. Inc., (2015) Pp 88-109.)

Gallbladder Exposure and Dissection of Hepatocystic Triangle

Once ports are successfully placed, the gallbladder will be retracted superiorly and towards the patient's right shoulder, being sure to pull the gallbladder up and over the liver edge. Often, in cases of acute or chronic cholecystitis, there will be inflammatory omental adhesions, which must be lysed prior to retraction of the gallbladder in order to prevent injury to surrounding structures, including the liver capsule. Once clear of adhesions, it is important to grab the most redundant portion of the dome of the fundus with an atraumatic grasper in order to adequately open the hepatocystic triangle (triangle of Calot). Significant thickening of the gallbladder wall may preclude adequate grasping and retraction. In this situation, gallbladder decompression can be performed by using electrocautery to create a hole in the fundus followed by the use of suction to empty the gallbladder of its contents. The gallbladder can then be grasped by placing one jaw of the grasper into the gallbladder lumen to allow for adequate tissue purchase and retraction (Fig. 2).

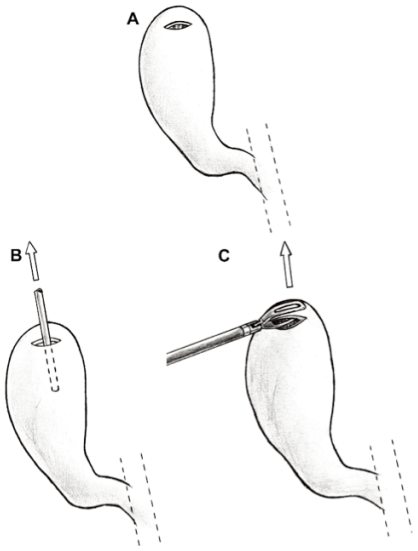

Fig. 2. *Retraction strategy for AC. (A) Opening of the GB. (B) Aspiration of infected GB contents. (C) Grasping cut margin to elevate the GB.*

The gallbladder must next be retracted laterally by grasping the gallbladder body just proximal to the infundibulum. This will create a right angle to the CBD. Appropriate lateral retraction is imperative to splay open a suitable window for dissection. The anterior and posterior peritoneum overlying the hepatocystic triangle is incised with electrocautery, typically with the L-hook. The space is then teased open bluntly in a lateral to medial fashion by gently pulling the peritoneum and fatty tissue off the gallbladder. In cases of severe inflammation, the overlying peritoneum is often rigid and edematous, and blunt dissection with a suction/irrigation apparatus tip can be very effective in this blunt dissection. This can be paired with hydrodissection by gently irrigating and washing away any oozing of blood to maintain visualization of key structures. A blunt dissecting instrument may be used to spread parallel to the cystic duct and artery. After blunt dissection, there are thin strands of tissue and inflammatory bands, which can be easily divided with an L-hook with electrocautery. Any thin band after blunt dissection is likely fibrous tissue, lymphatics or small blood vessels, which do not represent major structures. Large masses of tissue should not be divided or clipped; rather, each strand should be visualized and dissected individually to avoid inadvertent transection of a major duct or vessel. By using the above-stated technique, the entire hepatocystic triangle will be exposed and the entire window of dissection will be opened. Appropriate retraction and counter-retraction is essential for safe LC. Commonly, the gallbladder is either grasped in the wrong place or too much tissue by the infundibulum is grasped. This can inadvertently "crimp" the tissues and limit the exposure by making the dissection more difficult. A useful strategy, once a window has been created, is to use the grasper as a fan retractor by holding the jaws open and retracting the gallbladder laterally. This will broaden the dissection window and make structures easier to visualize. Further dissection along the cystic plate will provide the "Critical View of Safety" (CVS) as proposed by SAGES Safe cholecystectomy program (13). The CVS is defined by the following three criteria: (1) the hepatocystic triangle is cleared of fat and fibrous tissue, (2) the lower third of the gallbladder is separated from the liver to expose the cystic plate, and (3) two and only two structures (cystic duct and cystic artery) should be seen entering the gallbladder (see Fig. 4). (Litwin, DE, Cahan MA, Laparoscopic Cholecystectomy. Surgical Clinics of North America 2008 Dec; 88 (6): 1295-313.)

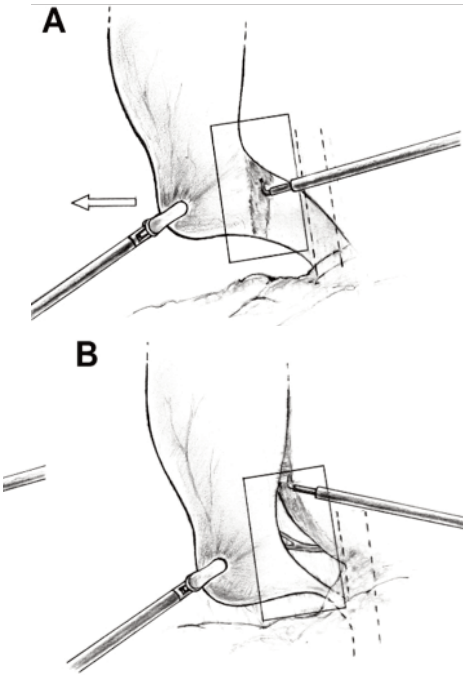

Fig. 3. The window of dissection. (*A*) Appropriate traction to patients right exactly as depicted. Dissection begins in the triangle of Calot taking small bands and strands of tissue. (*B*) The open window. All tissue is divided except for the and cystic artery, and the lower part of the GB is completely separated from the liver, allowing for confirmation that no duct or vessel re-enters the liver.

Extent of Dissection

Once the critical view has been established, it is important to confirm that the dissection of the cystic duct is adequate. Dissection must lead to the identification of the normal tapering of gallbladder, to infundibulum, and to cystic duct described as a "funnel." Further dissection allows for a clear identification of a tubular structure distally, such that when the lowest clip is placed on the cystic duct, there is a tubular structure seen below it. This verification helps to minimize the misidentification and inadvertent clipping of a tented CBD or CBD/cystic duct junction. Once this has been confirmed the cystic duct and the cystic artery can be doubly clipped and divided. (Litwin, DE, Cahan MA, Laparoscopic Cholecystectomy. Surgical Clinics of North America 2008 Dec; 88 (6): 1295-313.)

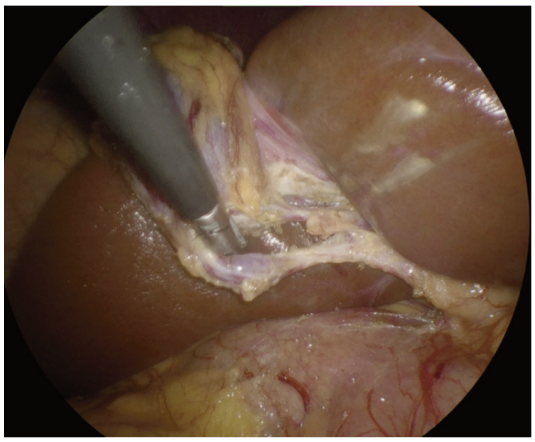

Fig. 4. Critical View of Safety during laparoscopic cholecystectomy

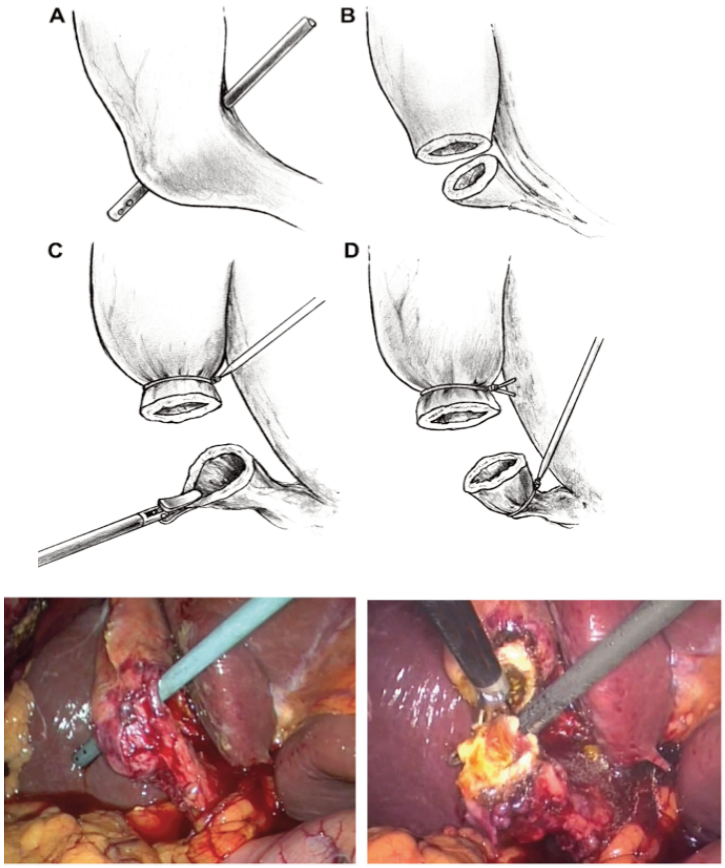

Fig. 5. (Left) Schematic of retrograde dissection technique. (*A*) Lower portion of GB separated from liver. (*B*) Transection of the GB above junction; Endoloop upper GB cuff to avoid stone spill. (*C*) Caudad retraction of remnant with retrograde dissection (top-down) along GB wall toward the cystic artery and cystic duct. (*D*) Dissect to the cystic duct, GB junction. An Endoloop is then placed around the remnant cuff. (Right) Intraoperative representation. (Litwin, DE, Cahan MA, Laparoscopic Cholecystectomy. Surgical Clinics of North America 2008 Dec; 88 (6): 1295-313. Sneider, B.B., Cahan, MA., Litwin, D.E "Acute Cholecystitis." I Gagner, M ed. Atlas of Hepatopancreatobiliary Surgery, Woodbury, CT: Cine-Med. Inc., (2015) Pp 88-109.

Removal of the Gallbladder

Upon division of the cystic duct and cystic artery, after the dissection we have described, the gallbladder will have attachments only to the liver bed. Removal of the gallbladder from the liver bed is facilitated by retraction of the gallbladder, both medially and laterally, to provide tension and easy identification of the plane between the gallbladder wall and the liver bed. The adherent peritoneum can be taken first, followed by gentle blunt dissection and electrocautery to accentuate and divide the tissue along this plane. Alternating from medial to lateral retraction in a to-and-fro pattern is helpful for visualization and prompt removal. Once the gallbladder has been freed of its attachments to the liver bed, it is retrieved through the umbilical port. Care must be taken to avoid spillage. If the gallbladder wall were violated during dissection or is particularly friable, an endocatch bag may be used to avoid bile leakage or stone spillage.

Intraoperative Cholangiography

The use of intraoperative cholangiography (IOC) during LC remains a controversial topic (14-15). Routine use of IOC has been argued to reduce the incidence and severity of common bile duct injury. While there is no consensus with regard to selective versus routine IOC use during LC, it is imperative that all surgeons who intend to perform LC have the capacity and technical skill to perform an IOC when needed. IOC is a useful adjunct to LC in cases when there is significant inflammation, unclear or aberrant anatomy. It should be used liberally in these situations to help identify structures and minimize any potential biliary injuries. The cholangiogram catheter should enter the abdomen between the lateral two ports. A clip should be placed above the infundibulum/cystic duct junction and a small nick is created in the cystic

duct. The operating surgeon will then grasp the catheter at a 100-120-degree angle and insert the catheter into this hole in the cystic duct. Once the tip of the catheter is inserted, the instrument should be rotated clockwise to help facilitate the catheter's passage into the cystic duct. Lateral retraction of the gallbladder can assist in making the angle of insertion more amenable to catheter placement. The catheter is then clipped to the cystic duct to hold in position. Contrast is then injected through the catheter and fluoroscopy is used to identify biliary anatomy and the presence of gallstones. An alternative technique during difficult dissection is to insert the cholangiocatheter into the GB remnant/cuff and use a locking clamp to hold it into place while injecting contrast under fluoroscopy as seen in Fig 6.

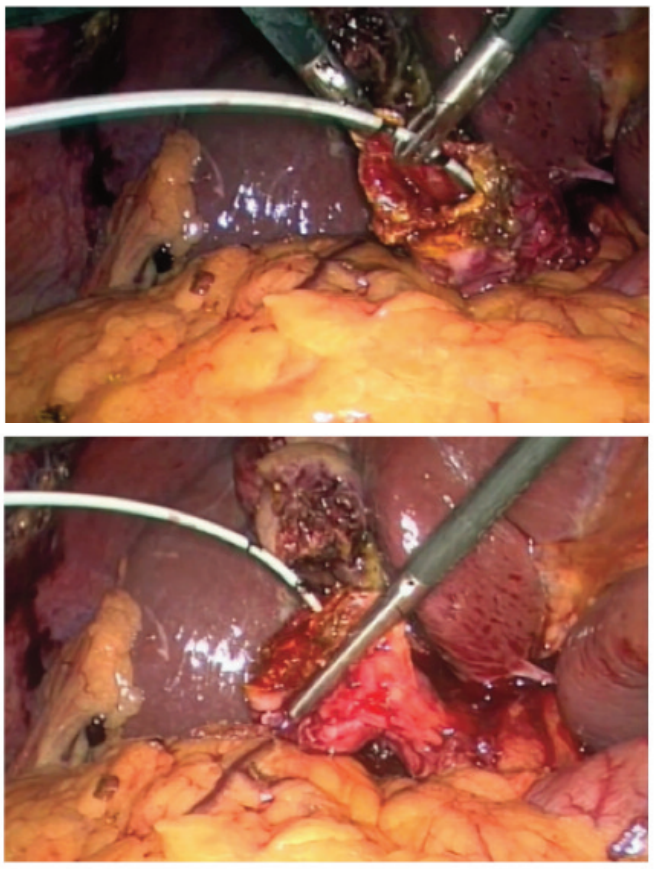

Fig. 6. Cholangiocatheter is placed in the GB cuff/remnant, with locking clamp to secure during cholangiography. (Sneider, B.B., Cahan, MA., Litwin, D.E "Acute Cholecystitis." I Gagner, M ed. Atlas of Hepatopancreatobiliary Surgery, Woodbury, CT: Cine-Med. Inc., (2015) Pp 88-109.)

Acute Cholecystitis and "Bail-out" Measures

The degree of difficulty of LC increases over time in the setting of AC. Many of the above-described techniques for safe cholecystectomy become technically challenging or impossible to be performed safely especially after >72h of symptoms. Tissues are often more friable and native planes of dissection are more difficult to identify and separate. This often leads to more obscurative bleeding and difficulty in identifying major structures. In preoperative evaluation, it is important to identify the duration of symptoms and to identify indicators of complex or complicated cholecystitis which may make LC more difficult and with increased risk of injury. If a patient with AC is deemed critically ill or at significant risk of morbidity and mortality with general anesthesia, percutaneous cholecystostomy (PC) is a viable option. PC is a less invasive radiologic procedure that allows for decompression and drainage of an acutely inflamed gallbladder. It can be used as a definitive treatment or as a transient means to decrease inflammation until recovery from critical illness. Often patients are able to undergo interval LC with minimal inflammation and low risk of complications (12). The ability to identify those patients who should not be brought to the operating room for AC is an important means of decreasing the risk of serious biliary injury.

Once the decision has been made to operate for AC, one must have options for exiting from a difficult situation safely. Laparoscopic placement of a cholecystostomy tube can be a useful "bail-out' measure in the setting of severe cholecystitis or gallbladder necrosis. The gallbladder wall can be opened with electrocautery at the level of the fundus, large enough to insert the suction/irrigator tip. The gallbladder contents can then be suctioned clear. A large-bore tube such as a Malecot can be positioned into the gallbladder. The tube exits through a port site and is secured to the skin. Occasionally, the gallbladder wall may need to be sutured around the tube in a purse-string fashion in order to secure it in place. A closed suction drain should always be placed in Morrison's pouch in this situation. Similar to percutaneous placement, laparoscopic cholecystostomy tubes allow for sepsis control and acute inflammation to subside. Most patients may then safely undergo interval LC in 6-8 weeks with minimal residual inflammation or adhesions.

Summary

LC is recognized as the gold standard for cholecystectomy for most gallbladder pathology. It has been shown to be safe and effective with decreased rates of bile duct injury after the initial learning curve. Shifts in the training paradigm for today's surgical trainees lead to greater skill and comfort with laparoscopy. Appropriate patient selection, judicious use of intraoperative cholangiography, and "bail-out" techniques allow for laparoscopic management of GB pathology with minimal advantage to a conversion to open technique.

Conflict of Interest Disclose Statement

The author has no conflict of interest to disclose.

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