The difficult cholecystectomy: What you need to know

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ABSTRACT: This review discusses the grading of cholecystitis, the optimal timing of cholecystectomy, adopting a culture of safe cholecystectomy, understanding the common error traps that can lead to intraoperative complications, and how to avoid them.[1–28] The Tokyo Guidelines, American Association for the Surgery of Trauma, Nassar, and Parkland scoring systems are discussed. The patient factors, physiologic status, and operative findings that predict a difficult cholecystectomy or conversion from laparoscopic to open cholecystectomy are reviewed. With laparoscopic expertise and patient conditions that are not prohibitive, early laparoscopic cholecystectomy is recommended. This is ideally within 72 hours of admission but supported up to the seventh hospital day. The majority of bile duct injuries are due to misidentification of normal anatomy. Strasberg's four error traps and the zones of danger to avoid during a cholecystectomy are described. The review emphasizes the importance of a true critical view of safety for identification of the anatomy. In up to 15% of operations for acute cholecystitis, a critical view of safety cannot be achieved safely. Recognizing these conditions and changing your operative strategy are mandatory to avoid harm. The principles to follow for a safe cholecystectomy are discussed in detail. The cardinal message of this review is, "under challenging conditions, bile duct injuries can be minimized via either a subtotal cholecystectomy or top-down cholecystectomy if dissection in the hepatocystic triangle is avoided". [21] The most severe biliary/vascular injuries usually occur after conversion from laparoscopic cholecystectomy. Indications and techniques for bailout procedures including the fenestrating and reconstituting subtotal cholecystectomy are presented. Seven percent to 10% of cholecystectomies for acute cholecystitis currently result in subtotal cholecystectomy. Level of evidence: III (*J Trauma Acute Care Surg.* 2024;97: 325–336. Copyright © 2024 Wolters Kluwer Health, Inc. All rights reserved.)

KEY WORDS: Acute cholecystitis; cholecystectomy; difficult cholecystectomy; error traps.

Cholecystectomy is one of the most commonly performed operations in the United States, more than 1.2 million documented yearly.[1] However, the incidence of bile duct injury remains 0.2% to 0.4%, even for experienced surgeons. This review discusses the grading of cholecystitis, the optimal timing of cholecystectomy, adopting a culture of safe cholecystectomy, understanding the common error traps that can lead to intraoperative complications, and how to avoid them. This article will also review intraoperative adjuncts that can assist with anatomical clarity and bailout procedures for the most challenging cases.

Definitions and Grading

Several grading systems have been established to help characterize the severity of cholecystitis either preoperatively or intraoperatively, to better prognosticate outcomes for patients. Here, we will review the Tokyo Guidelines, the Parkland grading scale, the American Association for the Surgery of Trauma (AAST) grading system, and the Nassar operative difficulty scale.

Tokyo Guidelines were originally written in 2007 and subsequently revised in 2013 and 2018 and have demonstrated high sensitivity and specificity.[2] These guidelines include diagnostic criteria for acute cholecystitis and criteria to grade the severity of acute cholecystitis as mild, moderate, or severe. Grade I is mild acute cholecystitis. Grade 2 (moderate) has imaging findings of marked inflammation, white blood cell count >18,000/mm^3, or symptoms >72 hours. Grade III (severe) has associated organ dysfunction (cardiovascular, respiratory, renal, hepatic, or hematologic). These criteria help guide treatment of the patient with acute cholecystitis based on their disease severity and patient comorbidities.

The Parkland grading scale, published in 2018, grades the severity of cholecystitis based on intraoperative findings.[3] The scale ranges from Grade 1 to Grade 5, with the visual characteristics ranging from completely normal gallbladder to perforation, necrosis, or inability to visualize the gallbladder due to adhesions. In a validation study, Madni et al.[4] found that the difficulty of surgery, subtotal cholecystectomy (STC) rate, conversion to open, length of operation, and presence of postoperative bile leak rose with increasing Parkland grade of severity. While this scale relies on intraoperative findings and therefore by definition cannot be used to determine appropriateness for the patient to undergo surgery, it allows potential recognition of cases requiring more advanced techniques in the moment and assists with postoperative prognostication and vigilance for those patients with more severe cholecystitis.

The AAST originally published a grading system for cholecystitis in 2016, which uses a combination of clinical criteria, imaging criteria, operative criteria, or pathologic criteria to grade cholecystitis from Grades I to V.[5] In a 2020 study, Schuster et al.[6] compared the performance of the Tokyo Guidelines, the Parkland grading scale, and the AAST grading system as to their association of higher grades to higher frequencies of poor patient outcomes. This multicenter prospective study found that the Parkland grading scale outperformed both the AAST and Tokyo Guidelines grading systems, with the inferior two being comparable with each other. Therefore, the AAST grading system was revised in 2021 with improvement in distribution across grades and predictive improvements.[7] However, the Parkland grading scale continued to outperform the AAST grading scale, suggesting that degree of surgical difficulty is a predominant predictor of patient outcome.[7]

The Nassar operative difficulty grading scale is based on three operative criteria, assessing degree of inflammation of the gallbladder, cystic pedicle, and adhesions.[8] The grades increase from minimal inflammation to severe, Grades 1 to 5. Grade 5 is defined as Mirizzi type 2 or higher or cholecysto-cutaneous, cholecysto-duodenal, or cholecysto-colic fistula. Recognition of Mirizzi's syndrome, if not diagnosed preoperatively, is critical, as it can require the assistance of a hepatobiliary surgeon for safe management. The Nassar scale has been validated as a significant predictor of operative duration, conversion to open surgery, and complications.[9]

Several groups have independently studied risk factors that increase the difficulty of cholecystectomy, with higher likelihood of conversion from laparoscopic to open cholecystectomy, as listed hereinafter.[9–14] Increasing numbers of these

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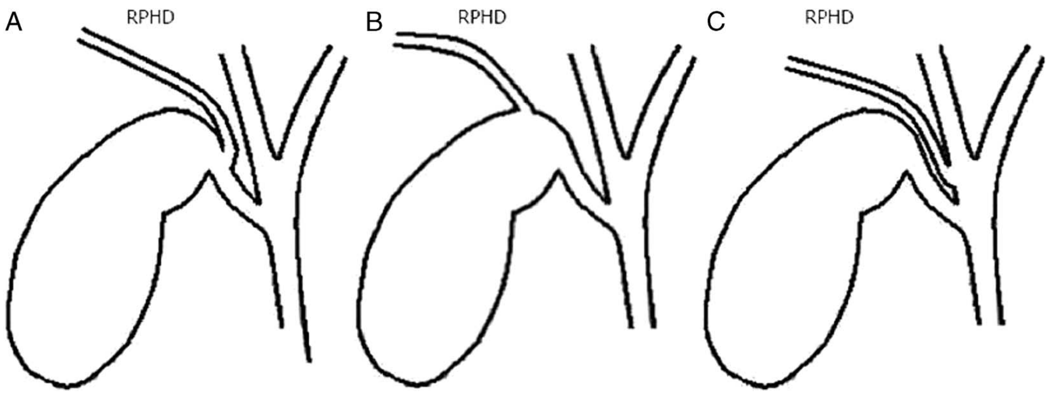

Figure 1. Common anomalies of the posterior right hepatic duct (reproduced with permission from Wojcicki M, Patkowski W, Chmurowicz T, et al. Isolated right posterior bile duct injury following cholecystectomy: report of two cases. *World J Gastroenterol.* 2013;19:6118–6121. Baishideng Publishing Group Co., open access).

factors in a given patient will increase the likelihood of conversion or difficult cholecystectomy.

Patient factors

- Male sex
- Elderly patient
- Higher ASA classification
- Charlson Comorbidity Index >6
- Previous abdominal surgery
- Diabetes mellitus

Physiologic factors

- Prior sphincterotomy
- Cholecystectomy delayed >2 weeks
- Diagnosis of acute cholecystitis or choledocholithiasis
- Thickened gallbladder wall (≥3 mm)
- Common bile duct (CBD) dilation (>6 mm)
- Nonelective operation
- Previous percutaneous cholecystotomy

Timing of Cholecystectomy

Numerous studies have addressed the optimal timing for operative intervention for acute cholecystitis but with variable definitions of an "early" cholecystectomy versus a "late" operation. In a large retrospective cohort study of 14,220 propensity matched patients, de Mestral et al.[15] found that early cholecystectomy (defined as within 1 week of admission) was associated with a lower risk of bile duct injury or death, with a logical shorter hospital length of stay. A multicenter randomized controlled trial, the ACDC study, compared cholecystectomy within 24 hours of admission to delayed cholecystectomy, 7 to 45 days

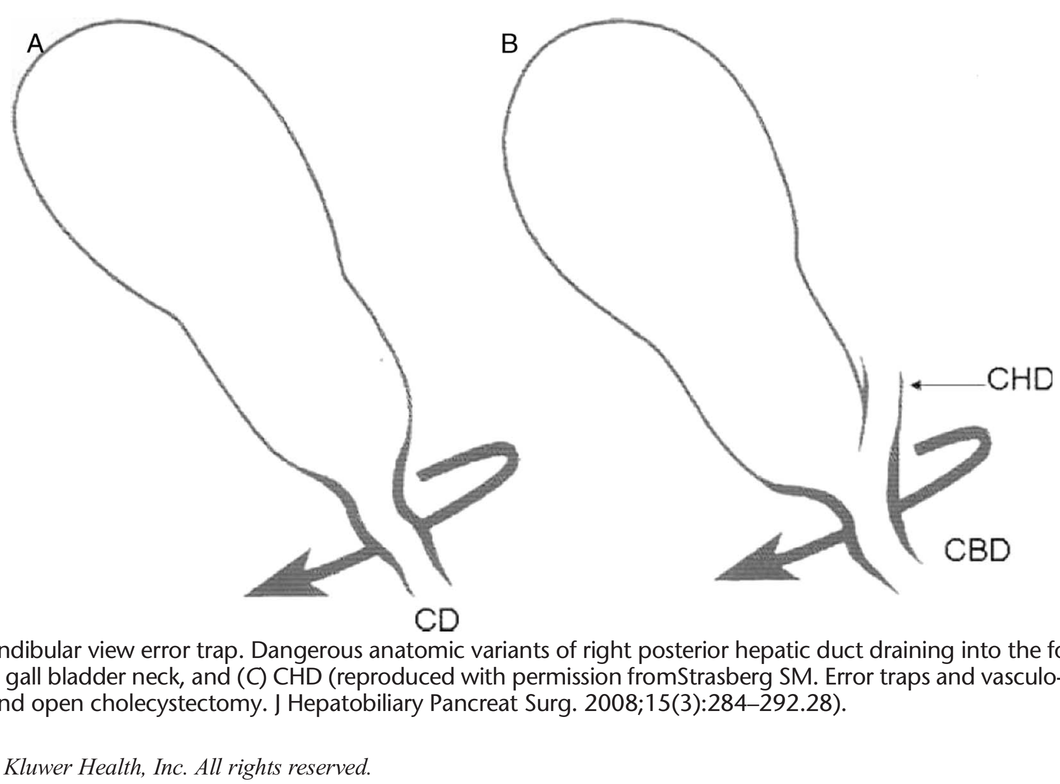

Figure 2. Infundibular view error trap. Dangerous anatomic variants of right posterior hepatic duct draining into the following: (*A*) cystic duct, (*B*) gall bladder neck, and (*C*) CHD (reproduced with permission fromStrasberg SM. Error traps and vasculo-biliary injury in laparoscopic and open cholecystectomy. J Hepatobiliary Pancreat Surg. 2008;15(3):284–292.28).

after admission. Morbidity was significantly lower in the early cholecystectomy group (11.8% vs. 34.4%) without difference in conversion rate.[16] Another randomized controlled trial performed in 2016 evaluated early (defined as the earliest daytime operative time possible) versus delayed cholecystectomy in patients who presented with >72 hours of symptoms on admission.[17] Overall morbidity was decreased in the early cholecystectomy group (14% vs. 39%), defined as a composite outcome of failure of initial antibiotic therapy requiring emergency cholecystectomy, unplanned hospital readmission or emergency consultation while awaiting cholecystectomy, and any postoperative complication within 30 days of surgery.[17]

Defining the optimal time point for early laparoscopic cholecystectomy (ELC) was evaluated in a population-based analysis of 4113 patients undergoing emergency laparoscopic cholecystectomy (LC) from the Swiss Association of Laparoscopic and Thoracoscopic Surgery. Outcomes were reported for LC at days 0, 1, 2, 3, 4/5, and ≥6. Conversion rates (12% vs. 28%), postoperative complications (5.7% vs. 13.0%), and need for reoperation (0.9% vs. 3.0%) were significantly higher for cholecystectomies performed ≥6 days versus day 0.[18]

Using the national surgical quality improvement program database, Brooks et al.[19] reported timing of cholecystectomy for 5,268 patients. The primary variable was preoperative hospital length of stay. Outcomes were reported for LC at days 0, 1, 2, 4, or 4 to 7. The inflection point for increasing rate of conversion (16.3% vs. 28.9%) and operative time (82 minutes vs. 89 minutes) was day 2 (both, $p < 0.05$). By days 4 to 7, conversion was noted in 37.0% with operative time increasing to 98 minutes.[19] A meta-analysis performed in 2018 compared ELC with delayed laparoscopic cholecystectomy (DLC) but further subcategorized ELC into surgery within 3, 4, and 7 days of symptom presentation.[20] This meta-analysis found that, while operative time was longer in the 7 day ELC group versus the DLC group, there was no difference between the ELC and DLC groups in bile duct injury, bile leakage, wound infection, conversion to open, or total complications. As expected, hospital stay was shorter in the ELC group.

Based on these data, several societies have published guidelines that recommend ELC, as it provides significant benefit to patients in all three Tokyo grades as compared with DLC in the prevention of readmission or recurrent biliary disease in

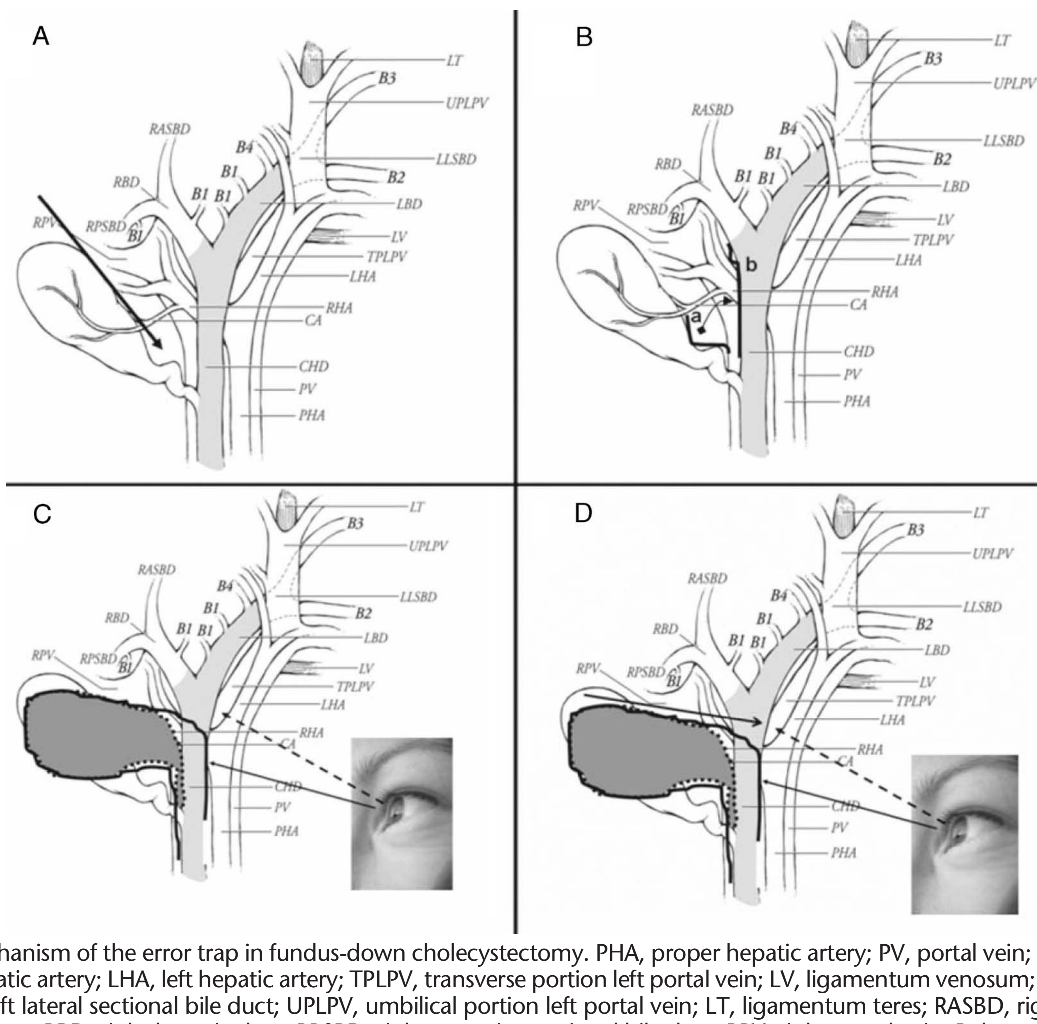

Figure 3. Mechanism of the error trap in fundus-down cholecystectomy. PHA, proper hepatic artery; PV, portal vein; CA, cystic artery; RHA, right hepatic artery; LHA, left hepatic artery; TPLPV, transverse portion left portal vein; LV, ligamentum venosum; LBD, left hepatic duct; LLSBD, left lateral sectional bile duct; UPLPV, umbilical portion left portal vein; LT, ligamentum teres; RASBD, right anterior sectional bile duct; RBD, right hepatic duct; RPSBD, right posterior sectional bile duct; RPV, right portal vein; B, branch. See text for explanation of outlined areas and arrows and of "a" and "b" in B (reproduced with permission from Strasberg SM. Error traps and vasculo-biliary injury in laparoscopic and open cholecystectomy. J Hepatobiliary Pancreat Surg. 2008;15(3):284–292. 28).

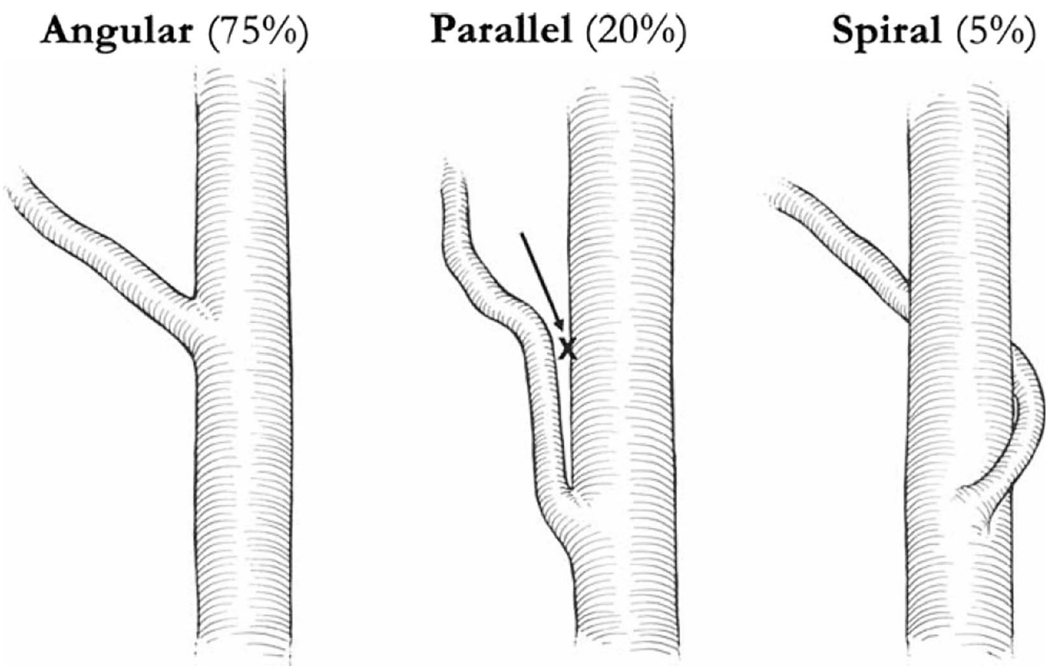

Figure 4. The three types of cystic duct/CHD confluence. The parallel union confluence is shown in the middle. Dissection of this type of cystic duct (arrow) may lead to injury to the side of the CHD (cross). During LC, this is often a cautery injury (reproduced with permission from Strasberg SM. Error traps and vasculo-biliary injury in laparoscopic and open cholecystectomy. J Hepatobiliary Pancreat Surg. 2008;15(3):284–292. 28).

the time preceding surgery, assuming laparoscopic expertise and that the patient does not have prohibitive operative risk.[21–23] Ideally, ELC should be performed on the index admission within 72 hours of symptom onset. That being said, the operation is not emergent and should be performed during the day when senior help is readily available. Early LC after 72 hours of symptom onset can be expected to be more difficult, with increased conversion rates, emphasizing the importance of laparoscopic expertise. Review of the literature suggests that ELC should be performed during the first 7 days of hospitalization.[22,23] Avoid cholecystectomy between 8 and 42 days of the patient's documented course of acute cholecystitis.

Epidemiology of Bile Duct Injuries

The most common cause of bile duct injury (BDI) is not in fact abnormal anatomy but the misinterpretation of normal anatomy by the surgeon.[24,25] This makes appropriate dissection technique and identification of anatomy critical for the safety of this procedure. The hepatocystic triangle is a vital landmark for interpretation of correct anatomy and is formed by the cystic duct inferiorly, the surface of the liver superiorly, and the common hepatic duct (CHD) medially.[26]

As mentioned, patient factors can contribute to misinterpretation of anatomy, including acute inflammation and chronic scarring, with severity of cholecystitis leading to an increase in the risk of BDI.[27] This inflammation can distort the anatomy. Importantly, the most severe biliary/vascular injuries occur after conversion from laparoscopic to open cholecystectomy. The difficult dissection with the laparoscope is still challenging during open cholecystectomy. Significant inflammation and aberrant anatomy can lead to error traps for the surgeon.

Error Traps

An error trap is an operative approach that works well in most situations but is prone to fail under certain circumstances. Because the technique is usually effective, the surgeon develops confidence in it and fails to recognize when dangerous circumstances are present. Four error traps are present in a cholecystectomy.

The first trap is the failure to recognize an aberrant posterior right hepatic duct either in the operative field or on a cholangiogram. This aberrant anatomy exists in up to 25% of patients and can drain into the cystic duct, the gallbladder neck, or the CHD[28] (Fig. 1). The posterior right hepatic duct, which drains into the infundibulum or proximal cystic duct, will not be seen on cholangiography, as the cholangiocatheter is inserted lower, into the cystic duct (Fig. 1*A* and *B*). Division of a posterior right hepatic duct will generally require drainage via a Roux-en-Y or liver resection.

The second trap occurs with the infundibular view (Fig. 2). With significant inflammation, the hepatocystic triangle can be obliterated, and the CHD is adherent to the gallbladder, appearing a part of the gallbladder wall.[28] In this setting, the CBD is mistaken for the cystic duct. If not recognized, this can result in resection of a portion of both the CBD and CHD with the gallbladder.

The fundus-down error trap occurs during a top-down dissection, where the gallbladder is densely adherent to the cystic plate. In this situation, there may not be an immediately discernible plane between the back of the gallbladder and the CHD, which can lead to transection of the CHD or injury to other portal structures. The error is believing that you are dissecting in a safe normal plane (Fig. 3*A* and *B*). However, that plane is obliterated, and the dissection in actuality is outside the inflammatory

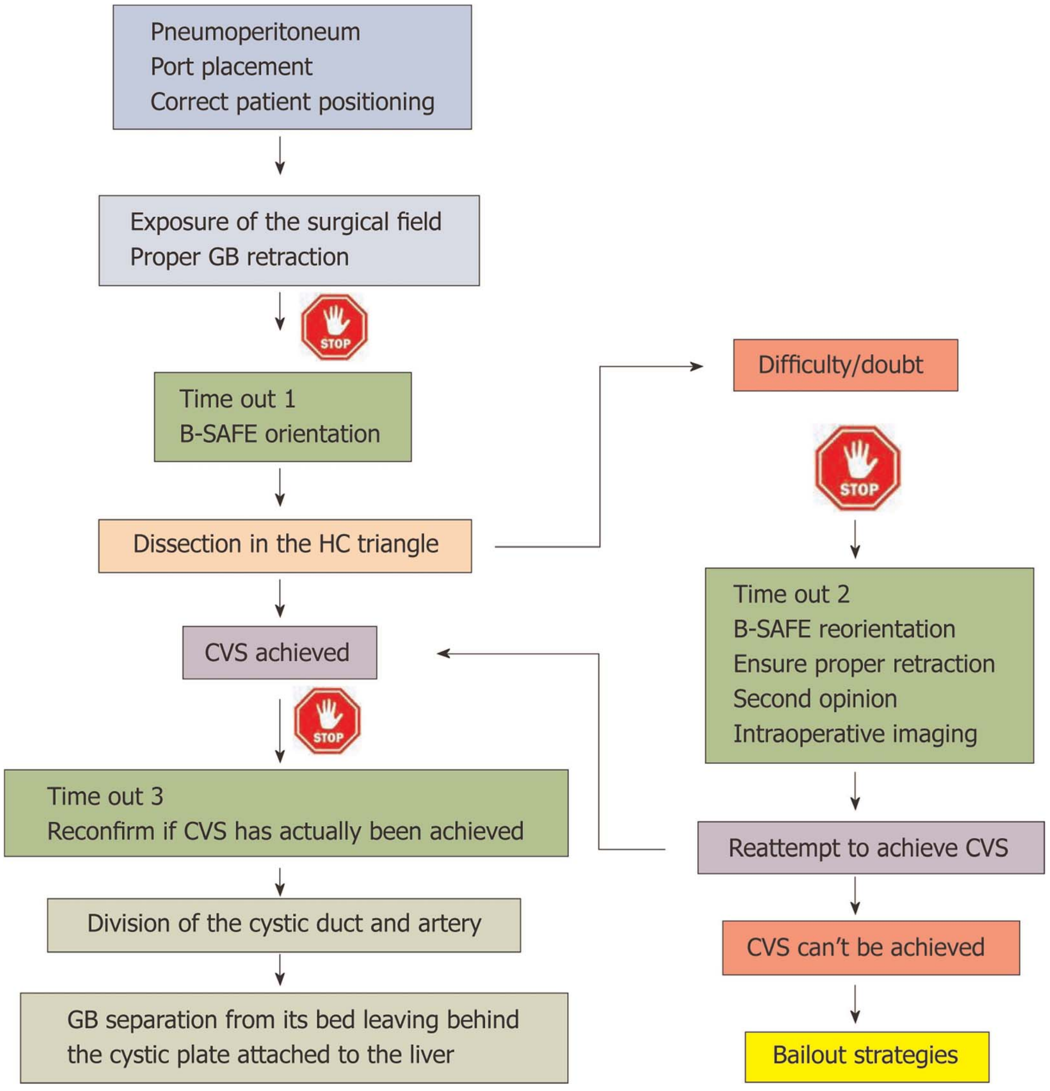

Figure 5. Algorithm for LC applying the culture of safety. GB, gallbladder; B-SAFE, surgical landmarks; HC triangle, hepatocystic triangle (reproduced with permission from Gupta V, Jain G. Safe laparoscopic cholecystectomy: adoption of universal culture of safety in cholecystectomy. World J Gastrointest Surg. 2019;11(2):62–8435, Baishideng Publishing Group, open access).

tissues, in areas of danger (Fig. 3*C* and *D*). This injury is typically associated with vascular injuries and commonly occurs after conversion to open cholecystectomy, which emphasizes that open cholecystectomy does not obviate the risks of BDI.[28]

The fourth error trap is that of parallel union of the cystic duct. In 20% of cases, the cystic duct will run parallel to the CHD, and in 5% of cases, the cystic duct will spiral around the CHD.[28] Therefore, during dissection of the cystic duct, the CBD or CHD can be misidentified as the cystic duct (Fig. 4).

Danger Zones

While the initial goal of any cholecystectomy is a total cholecystectomy, it is important to recognize that there are times when anatomy or inflammation will not allow this to be accomplished. In 10% to 15% of operations for acute cholecystitis, the critical view of safety (CVS) cannot be achieved. Recognition of these circumstances is critical. In the setting of severe inflammation, an inflammatory wall of tissue eponymously called "McElmoyle's shield" covers the hepatocystic plate.[29,30] This shield of tissue should not be violated, as dissection deep to this could lead to injury of the porta hepatis. More specifically, it is important for the surgeon to recognize zones of danger in which dissection should be avoided. First, dissection should take place along the gallbladder wall. By drifting off of the gallbladder wall, there is an increased risk for vascular or biliary injury. Second, dissection should not be carried out posterior to Rouviere's sulcus, a 2- to 5-cm sulcus that is present to the right of the liver hilum anterior to the caudate process.[31] This sulcus is present in 78% to 82% of patients and indicates the plane of the CBD.[31,32] Therefore, by remaining anterior to this clearly visible landmark, the risk of BDI is decreased. Third, deep dissection into the cystic plate must be avoided because this could lead to injury of the middle hepatic vein and catastrophic bleeding.[33] If performing any of these dissections is required for completion of a total cholecystectomy, that endeavor should be aborted and a bailout procedure should be performed, as described hereinafter.

CHOLECYSTECTOMY: HOW TO DO IT SAFELY

B-SAFE Orientation

Sutherland and Dixon[34] published a mnemonic to assist with surgeon cognitive mapping during LC, called "B-SAFE." The components of the B-SAFE landmarks include visualization of the bile duct at the duodenum or hilum (B), the sulcus of Rouviere on the undersurface of the right liver (S), the hepatic artery to the left of the porta hepatis (A), the umbilical fissure to the left (F), and the enteric stomach or duodenum to orient vertically (E). The authors state that identification of these landmarks allows the surgeon to confirm spatial orientation and better identify safe areas for dissection.

The Safe Cholecystectomy

In 2019, Gupta and Jain[35] published regarding the adoption of a "universal culture of safety" in cholecystectomy, which is an expansion of the SAGES "culture of safety" recommendations (Fig. 5).

The principles of a safe cholecystectomy are as follows[35]:

- Thorough knowledge of anatomy, landmarks, and anomalies
- Use of intraoperative imaging to define anatomy
- Understanding mechanisms of biliary injury (misidentification)
- Knowledge of preoperative and intraoperative predictors of the difficult cholecystectomy
- Proper gallbladder retraction
- Safe use of energy devices
- Understanding the CVS
- Knowledge of the error traps
- Use of bailout strategies
- Use of timeouts

Included in these steps is the important concept of "time-outs." In this model, during a cholecystectomy, the surgeon should pause to reorient themselves (time-out 1), bring back the camera to have a panoramic view of the field if laparoscopic, and identify the landmarks of the B-SAFE orientation. This time-out should occur immediately after entry into the abdomen, prior to any dissection. Time-out 2 should occur when dissection/exposure has been difficult or with any doubt of the structures in the operative field. Invoke time-out 2 before dissection of the hepatocystic triangle, when faced with ambiguous or anomalous anatomy, and before the cystic duct and artery are clipped and divided. Call for help before you are in trouble, not after an injury has resulted. Time-out 3 is to reconfirm that a CVS is indeed achieved, by all surgeons in the room, ideally by a second partner. By performing these time-outs in every case, the surgeon can ensure that they and their entire surgical team are accustomed to constantly reevaluating the field and properly delineating the anatomy. This allows the entire team to recognize when something is different and a change in strategy is necessary to avoid BDI.

Dissection Techniques

As a general principle, dissection during a cholecystectomy for acute cholecystitis should preferentially be with blunt technique. Use of energy devices should be minimized and used only with certainty of a safe area, clearly away from the hepatocystic triangle. It is important to understand that the technique for dissection during a cholecystectomy and how the anatomy is safely identified are related but different concepts. Dissection techniques include the infundibulum-first, top-down (dome first), and semi–top-down (middle first) cholecystectomy.

The infundibular technique involves the identification of the junction of the infundibulum and cystic duct, which is then circumferentially dissected and divided, followed by retrograde dissection of the gallbladder from the liver bed. This can lead to duct misidentification when the cystic duct is fused with the CBD, when the cystic duct is very short, or when the hepatocystic triangle is not adequately exposed. This approach can lead to misidentification of the CBD as the cystic duct, leading to CBD transection.[28]

The top-down approach involves initial dissection of the fundus of the gallbladder, with subsequent separation of the gallbladder from the cystic plate down toward the hepatocystic triangle. When there is severe inflammation or variant anatomy, this can result in visual distortion that can lead to misidentification of biliary structures. While this was a common approach in open cholecystectomy, in LC, the dome-down technique can lead to difficulty in retraction leading to poor visualization of anatomy.[28,36] The operation is facilitated by leaving a 1-cm cuff of peritoneum on the liver as the top-down dissection begins. This allows easy retraction of the liver. On occasion, another port and liver retractor are needed for adequate exposure and visualization. In addition, dissection is from known to unknown, toward the porta hepatis. Failure to recognize proximity to this zone of danger and halting further dissection lead to severe biliary/vascular injury. While this approach is safe when dissection is kept directly on the gallbladder and remains above Rouviere's sulcus, it can lead to distortion of the typical view of the anatomy and requires careful evaluation and potential intraoperative adjuncts to ensure that the anatomy is as it appears.

The semi–top-down or middle first LC combines the advantages of both approaches and minimizes the disadvantages. Dissection is started higher on the gallbladder, above the infundibulum of the gallbladder. The peritoneum is scored, lateral side first, coming across the peritoneum over the infundibulum of the gallbladder and then opening the peritoneum coming up the medial side of the gallbladder. Dissection continues, rolling the gallbladder back and forth. This largely detaches the gallbladder from the liver, leaving only the fundus attached to provide easy retraction. With this wide exposure and mobilization of the middle two thirds of the gallbladder off the cystic plate, the infundibulum and its junction with the cystic duct are then approached, generating a top-down approach to the cystic duct and cystic artery. When proceeding with the semi–top-down approach, taking only tissues that you see through clearly, any structures that may be encountered such as an aberrant duct, right hepatic artery, or posterior cystic artery can be seen and avoided. At this point in the operation, an exaggerated CVS has been created. The cystic artery and cystic duct are clearly exposed, with the critical approach to the infundibulum-cystic duct junction performed in essentially a top-down dissection.

Ductal Identification Strategies

Several options for ductal identification during LC have been developed to help avoid BDI. These include the CVS, intraoperative cholangiography (IOC), intraoperative ultrasound, and fluorescent cholangiography. The CVS is currently the most accepted technique for appropriate identification of anatomy in LC.[24,37,38]

The CVS, developed by Strasberg and Brunt,[39] requires three factors to be present prior to division of any structures: clearance of all tissue from the hepatocystic triangle, visualization of two and only two tubular structures entering the gallbladder, and mobilization of the lower third of the gallbladder off of the cystic plate. This view should be visible completely circumferentially.[40] The use of this technique has been demonstrated to be the most effective method of avoiding BDI. However, many surgeons who perform LC do not routinely obtain the CVS. Furthermore, despite reporting that a CVS was obtained in the operation, all three criteria have been met in only 50% of cases. Mobilization of the lower third of the gallbladder from the cystic plate is most often lacking. For this reason, the SAGES Safe Cholecystectomy Program strongly recommends obtaining the true CVS for safe anatomic identification.[41]

Intraoperative cholangiography is a well-established technique to assist with the ascertainment of biliary anatomy, in which contrast is directly injected into the cystic duct with intraoperative radiography to determine the anatomy of the CHD, the right and left hepatic ducts, and the CBD entering into the duodenum. This can both be useful in the evaluation of the biliary tree with the goal of either preventing or detecting BDI as well as identifying common duct stones.[42] In one large survey study from 2008, 27% of general surgeons defined themselves as routine IOC users, with use in more than 75% of LCs performed.[43] While several retrospective studies have demonstrated reduced rates of BDI when IOC is routinely used,[44–48] randomized controlled trials have not demonstrated a clear difference in BDI when IOC is routinely used.[49–51] There are also technical limitations to IOC, including short or fibrotic cystic ducts precluding catheter placement and that it adds time to the procedure.[50] Furthermore, IOC is only valuable if it is correctly interpreted, which requires appropriate training and experience.[50] That being said, it is certainly a useful adjunct when appropriately interpreted when the biliary anatomy is unclear intraoperatively and

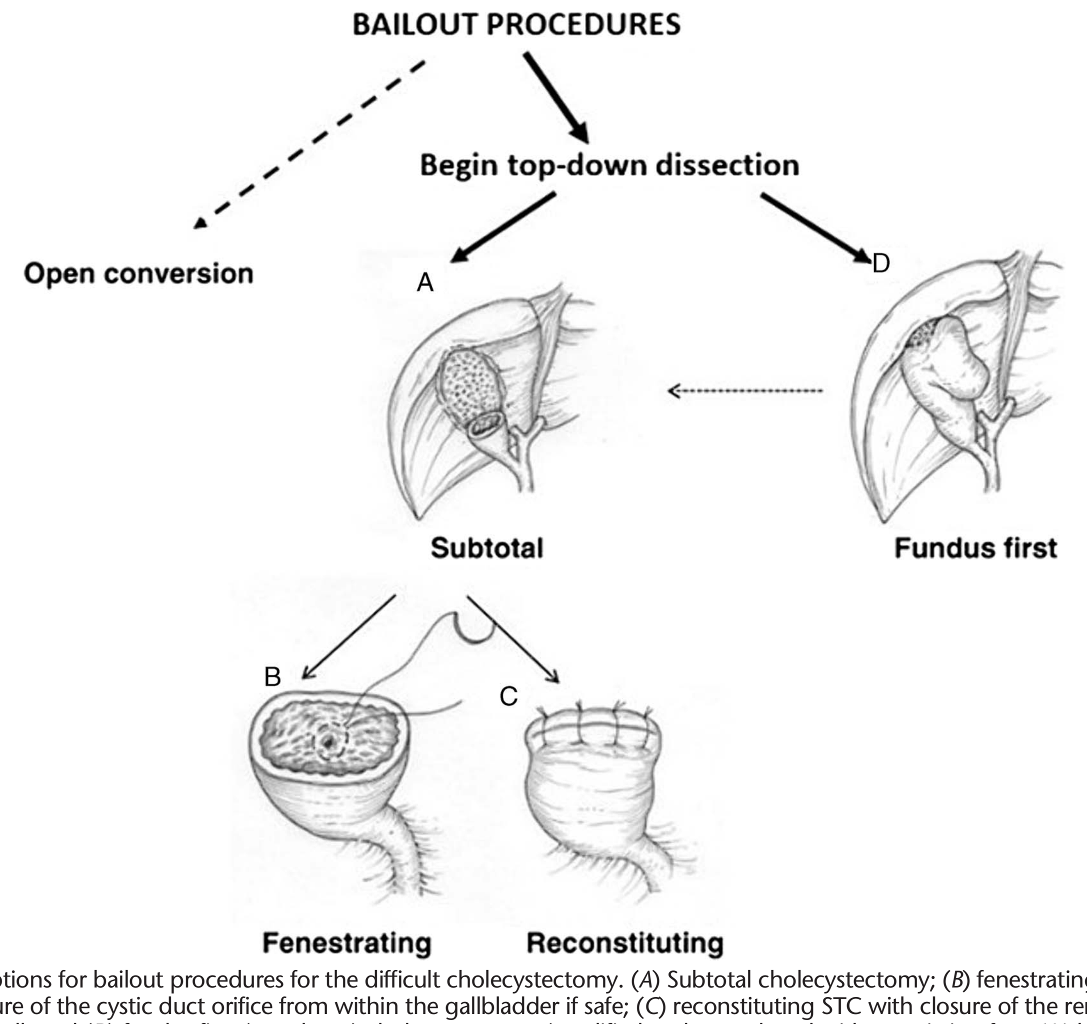

Figure 6. Options for bailout procedures for the difficult cholecystectomy. (*A*) Subtotal cholecystectomy; (*B*) fenestrating STC with possible closure of the cystic duct orifice from within the gallbladder if safe; (*C*) reconstituting STC with closure of the remnant gallbladder wall; and (*D*) fundus first (top-down) cholecystectomy (modified and reproduced with permission from Wakabayashi G, Iwashita Y. Hibi T, et al. Tokyo Guidelines 2018: surgical management of acute cholecystitis: safe steps in laparoscopic cholecystectomy for acute cholecystitis. *J Hepaticobiliary Pancreat Sci*. 2018;25:73–76).

provides significant benefit in the detection of BDI. Early detection of BDI and immediate operative management result in significantly improved survival as compared with those patients whose BDI detection is delayed.[47]

Indocyanine green (ICG) is a water-soluble dye that is strongly fluorescent in the near-infrared range of wavelengths. It is exclusively cleared by the liver with an intravascular half-life of approximately 3 minutes, allowing preoperative administration for intraoperative definition of biliary anatomy when using laparoscopic towers with fluorescent capabilities.[52] The use of ICG does not add time to the procedure and is not precluded by those factors that could cause technical limitations to IOC.[52–54] Also, as the fluorescence can emit through >1 cm of overlying tissue, ICG can be used from the beginning of the dissection to better understand biliary anatomy.[52,55] However, in patients with acute inflammation and an occluded cystic duct, its filling of the cystic duct and gallbladder may be impeded and therefore its usefulness may be limited. Furthermore, in one retrospective study looking specifically at the acute care surgery population, ICG did not decrease the need for a bail-out operation as compared with use of white light alone.[56] However, because the medication is safe with a minimal adverse effect profile, giving routine ICG preoperatively when the technical capabilities to use it are available is a reasonable approach to assist with biliary anatomy definition when allowed by the pathology.[57–59] Furthermore, because robotic cholecystectomy is adopted more widely, the in-built capability to use ICG may make this approach more appealing.[60] Of note, while there are theoretical advantages of robotics for cholecystectomy, the current literature is mixed as to its use based on patient outcomes and cost, particularly in the acute setting.[61,62]

Laparoscopic ultrasound is another adjunct that can be used to help delineate both biliary and vascular anatomy. Similar to ICG, it does not require dissection prior to its use, it does not add significant time to the operation as compared with IOC, and Doppler can also be used to specifically better define vascular structures, which cannot be done by either ICG or IOC.[63,64] Furthermore, it is a useful technique for identifying common duct stones.[65] However, its use is limited by both the availability of the technology and surgeon comfort both in technically performing and in interpreting the ultrasound.[66] For this reason, it has not been widely adopted, and large multicenter prospective studies have not yet been performed on this adjunct.

Bailout Procedures

A critical point during attempted cholecystectomy must occur with the realization that the circumstances are different; the operation is not a straightforward cholecystectomy. Findings that indicate a need for a change in operative plan include the following: there is significant inflammation, there is uncertainty that a CVS can be safely achieved, the anatomy appears confusing, the dissection is not progressing, there is bleeding or bile leakage in the field, and too many or too large a clip is required for a structure. These circumstances must be recognized and result in a change in operative strategy. The cardinal principle is, "under challenging conditions, BDI can be minimized via either a subtotal cholecystectomy or top-down cholecystectomy if dissection in the hepatocystic triangle is avoided."[21] Should the anatomy as described previously be encountered once a cholecystectomy is started, there are several options for bailout procedures. The first step that should be initiated is to call for help, as having experienced assistance will help prevent BDI. Intraoperative imaging to help define the anatomy is also important at this juncture.

Options for a bailout procedure include laparoscopic top-down approach, which can result in STC or completed cholecystectomy, or conversion from LC to open cholecystectomy (Fig. 6). The top-down approach and the STC are not mutually exclusive but rather exist along a continuum of dissection. Should a top-down approach not lead to appropriate visualization and delineation of the critical anatomy, this can be converted to a laparoscopic STC as a safe bailout procedure. It is important to recognize that the procedure remains challenging after conversion; in one retrospective study, conversion to open resulted in completion cholecystectomy in only 66% of cases.[67] Despite open surgery being considered a bailout procedure, the most severe BDI occurs after laparoscopic conversion to open, in the setting of persistence in attempting to perform a total cholecystectomy. It is also notable that, since the advent and widespread adoption of LC, younger and less experienced surgeons may be less familiar with the technical aspects of open cholecystectomy, for which reason we emphasize calling for experienced help once bailout procedures are being contemplated. Seven percent to 10% of operations for acute cholecystitis currently result in STC.[68] Laparoscopic STC is preferable to open STC because of the more rapid recovery after the laparoscopic procedure.[69] Either laparoscopic or open STC is always preferable to injury to the biliary system.

The laparoscopic top-down cholecystectomy requires dissection of the fundus of the gallbladder first off of the liver, which allows the surgeon to stay away from the hepatocystic triangle if it is hostile. The technique has been described earlier.

The STC can be performed, either laparoscopically or open. An essential component of the operation is extraction of all gallstones from the gallbladder. The two subtypes of STC are fenestrated and reconstituting, with fenestrated leaving an open remnant gallbladder and reconstituting leaving a closed remnant gallbladder.[70] There are several risk factors for the need for STC, including male sex, older age, acute or acute on chronic cholecystitis, previous cholecystostomy, and time from onset of symptoms to surgery.[13,71] Laparoscopic STC is associated with a lower risk of subhepatic collections, wound infection, and mortality but has a higher risk of bile leak than open STC.[72] There is risk of bile leak, ranging from 4% to 18%, after subtotal fenestrating or reconstituting cholecystectomy, generally higher after fenestrating cholecystectomy.[69,72] A drain should always be left to control a potential bile leak after STC, and minimally invasive techniques such as endoscopic retrograde cholangiopancreatography) or Percutaneous transhepatic cholangiography (PTC) can be used should a bile leak occur. While a subtotal reconstituting cholecystectomy has a lower risk of bile leak, it can lead to recurrent remnant cholecystitis, which is highly challenging to manage, particularly considering the reoperative field.[73] More residual infundibulum remains after reconstituting than fenestrating STC, especially if a stapling device is used for closure. It is suggested that the risk of remnant cholecystitis increases with a more remaining infundibulum. As we see more cases of remnant cholecystitis, our preference is fenestrating STC.

Management of BDI

Early recognition of BDI is critical to optimizing patient outcome. If bile is visualized in the field, have significant suspicion for BDI.[74] If expertise for repair is not available locally, do no further harm. Place drains and refer the patient to a center with hepatobiliary surgeons. Conversion to open surgery solely to confirm diagnosis or stage the injury is not advised.[22] When suspicion for BDI exists with hepatobiliary expertise available locally, the next step is to definitively determine the presence or absence of BDI, which may require conversion to open and/or use of IOC or endoscopic retrograde cholangiopancreatography.[75] Early detection and management are critical because it significantly reduces patient morbidity and mortality;[75] however, only 25% to 46% of injuries are recognized during the index operation and are more likely to be discovered if IOC is performed.[76,77] While small bile duct leaks can be potentially managed minimally invasively, a hepatobiliary specialist should be consulted to evaluate the patient and perform biliary reconstruction should it be required.[78] If no appropriate hepatobiliary specialist is available at the institution where the procedure is occurring, the patient should be transferred immediately to a facility that has this capability.[76]

If BDI is suspected in a delayed fashion, imaging techniques such as ultrasound, computed tomography, and magnetic resonance cholangiopancreatography are important to define biliary anatomy.[79] Once it is diagnosed, principles of management are similar; the patient should be referred to a hepatobiliary specialist and should be transferred to another center should that be required to obtain this expertise.[79]

AUTHORSHIP

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DISCLOSURE

Conflicts of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/D717).

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