Acute cholecystitis: When to operate and how to do it safely

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I would like to thank the AAST and President Cioffi for the great honor to present this Master Surgeon Lecture. On this date, I must acknowledge that it is September 11, and we need to take a moment of silence for our fallen colleagues and countrymen on that day.

My topic today is, "Acute Cholecystitis: When to Operate and How to Do It Safely." The obvious question is why did I select such a mundane topic? It is estimated that 30% to 49% of surgeons will produce a bile duct injury during their careers. This event is difficult both for the patient and the surgeon. The premise of my talk is that nearly all bile duct injuries during cholecystectomy are avoidable. Approximately 700,000 cholecystectomies are performed per year in the United States, with an estimated incidence of bile duct injury in 0.5% (3,500 patients). When laparoscopic cholecystectomy was initially introduced, bile duct injury was four times more frequent than for open cholecystectomy. Current estimate is that the incidence of bile duct injury remains twice as frequent with laparoscopic versus open cholecystectomy.[1–29] A population-based study from Sweden, reviewing 153,000 cholecystectomies from 1987 through 2002, showed a slight increase in the incidence of bile duct injury despite decades of experience with laparoscopic cholecystectomy (0.32–0.47%).[26] Similarly, the incidence of bile duct injury in Japan is unchanged from 1990 to 2009 (0.66–0.62%).[29] Thus, laparoscopic cholecystectomy is clearly an operation that we have not perfected, despite how often it is performed.

The goals in today's talk are as follows:

- Discuss the timing of operation for cholecystitis
- Discuss factors that predict the difficult cholecystectomy
- Discuss the role of percutaneous cholecystostomy in the management of acute cholecystitis
- Discuss how to minimize the risk of bile duct or vascular injury during cholecystectomy
- Discuss techniques and tricks for the difficult cholecystectomy, both open and laparoscopic
- Discuss what to do once an injury has been recognized.

Timing of Operation for Acute Cholecystitis

Indications listed by SAGES [Society of American Gastrointestinal and Endoscopic Surgeons] for laparoscopic cholecystectomy include symptomatic cholelithiasis, biliary dyskinesia, acute cholecystitis, and biliary pancreatitis.[28] Twenty percent of cholecystectomies are performed for acute cholecystitis. The Tokyo guidelines for the diagnosis of acute cholecystitis are shown in Table 1.[29–41] Asymptomatic gallstones are generally not considered an indication for laparoscopic cholecystectomy. The first question to address is whether cholecystectomy should be performed during the index hospitalization for acute cholecystitis or the patient treated with antibiotics and discharged for delayed cholecystectomy, usually 6 weeks to 12 weeks after the hospitalization. A series using the national Medicare sample claims data on 29,818 patients older than 65 years hospitalized for acute cholecystitis from 1996 to 2005 demonstrated that 75% of patients underwent cholecystectomy during that admission.[42] Median time to operation was 1 day, with conversion from laparoscopic to open cholecystectomy in 29% of patients. Percutaneous cholecystostomy was applied in only 0.5% of patients. Thus, 25% of patients did not undergo

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TABLE 1. Tokyo Guidelines (TG13) Diagnostic Criteria for Acute Cholecystitis[29–41]

A. Local signs of inflammation, etc.
(1) Murphy's sign, (2) RUQ mass/pain/tenderness
B. Systemic signs of inflammation, etc.
(1) Fever, (2) elevated CRP, (3) elevated WBC count
C. Imaging findings
Imaging findings characteristic of acute cholecystitis
Suspected diagnosis: one item in A + one item in B
Definite diagnosis: one item in A + one item in B + C

Acute hepatitis, other acute abdominal diseases, and chronic cholecystitis should be excluded.

CRP, C-reactive protein; RUQ, right upper abdominal quadrant; WBC, white blood cell.

cholecystectomy at the initial admission. The lack of cholecystectomy resulted in 38% gallstone-related admissions during the next 2 years (occurred in only 4% of the patients who had undergone cholecystectomy). Thus, it was concluded that laparoscopic/open cholecystectomy for acute cholecystitis in elderly patients should be performed during initial hospitalization.

In a population-based study from Ontario, 25,397 adult patients admitted from 2004 to 2011 with the first episode of acute cholecystitis were reviewed.[7,13] Median follow-up was 3.4 years. Fifty-nine percent of patients underwent cholecystectomy during the index admission; 41% (10,304 patients) were discharged without cholecystectomy. Of the patients discharged without cholecystectomy, the incidence of gallstone-related event after discharge was 14% at 6 weeks, 19% at 12 weeks, and 29% at 1 year. Importantly, of these events, 30% were for biliary tract obstruction or pancreatitis, significant complications of cholelithiasis. Interestingly, these events were more frequent in patients aged 18 years to 34 years. At 1 year, the incidence of recurrent biliary tract disease was 42% in patients 18 years to 34 years, 32% in patients age 50 years to 64 years, 27% in patients age 65 years to79 years, and 24% in patients older than 80 years. The authors concluded that increased risk in younger patients with recurrent gallstone disease reinforced the value of early cholecystectomy.

The Cochrane review published in 2013 reviewed six trials with 488 patients.[43] Early cholecystectomy was defined as within 7 days of clinical presentation. Delayed cholecystectomy was defined as greater than 6 weeks. The authors concluded that there was no significant difference in the incidence of bile duct injury, similar rate of conversion from laparoscopic to open cholecystectomy, and obviously shorter stay in patients who underwent early cholecystectomy. However, this Cochrane review is underpowered to evaluate significant difference in bile duct injury. It is estimated to document a 50% difference (statistically significant, appropriately powered) in incidence of bile duct injury that 30,000 patients would need to be included. In addition, the authors concluded that "all trials were at high risk of bias and might have overestimated the benefits or underestimated the harms of either early laparoscopic cholecystectomy or delayed laparoscopic cholecystectomy. However, trials with high risk of bias indicate that early laparoscopic cholecystectomy during acute cholecystitis seems safe and may shorten total hospital stay."

KEY CONCEPT: Cholecystectomy should be performed during the index hospitalization for acute cholecystitis, unless the patient is deemed a prohibitive operative risk.

The next issue to be addressed is at what time point during the initial hospitalization cholecystectomy should be performed. In an article presented at the AAST, using the American College of Surgeons' National Surgical Quality Improvement Program files from 2005 to 2010, emergency cholecystectomy for acute cholecystitis in 5,268 patients was evaluated.[44] The primary predictor variable was preoperative hospital length of stay, reported as 0, 1, 2, 3, or 4 to 7 days. In this study, 83% of the patients underwent cholecystectomy at Day 0 or 1. As shown in Table 2, morbidity and mortality increased significantly from Days 0 to 2 through Days 4 to 7. This was probably more a factor of the patient's comorbid disease than the operation itself. If we specifically look at the impact of early operation, the conversion rate significantly increased by 2 days (nearly doubled) and continued to increase daily. The operative time increased significantly with delay to cholecystectomy. Obviously, the length of stay was increased as the operation was delayed. The authors concluded that "patients hospitalized for 2 or more days preoperatively had longer operative times and were significantly more likely to undergo conversion to open cholecystectomy. Any delay in operation beyond the day of admission resulted in a significantly longer length of stay."

A population-based study from the SALTS [Swiss Association of Laparoscopic and Thoracoscopic Surgery] reported 4,100 patients undergoing emergency laparoscopic cholecystectomy from 1995 to 2006.[45] They were grouped by day of admission defined as Days 0, 1, 2, 3, 4 or 5, or 6 or later. The median age in this study was 60 years. Conversion rate from laparoscopic to open cholecystectomy was 12% at Day 0 and increased to 28% at Day 6 or later. Postoperative complications increased from 5.7% to 13%, from Day 0 to Day 6. Need for reoperation tripled from Day 0 to Day 6, from 0.9% to 3%. Thus, the authors showed that delaying laparoscopic cholecystectomy for acute cholecystitis resulted in significantly higher conversion rates and complications. The authors stated that "this investigation provides compelling evidence that acute cholecystitis merits surgery within 48 hours of admission."

In the study presented at the American Surgical Association recently, 35 centers from Germany and Slovenia reported a randomized prospective study evaluating early versus delayed cholecystectomy.[46] Early cholecystectomy was within 24 hours

TABLE 2. Analysis of the Timing of Cholecystectomy During Admission for Acute Cholecystitis[44]

Time to cholecystectomy, d					
Outcome variable, d	0 d	1 day	2 d	3 d	4–7 d
30-d mortality, %	0.8	0.9	1.8*	2.0	5.3
30-d morbidity, %	6.0	7.6	12.7*	15.2	19.1
Conversion to open cholecystectomy, %	16.3	21.3	28.9*	30.9	37.0
Operative time, mean, min	82	87	89*	91	98
Total length of stay, median, d	1	3	4*	6	9

*Significantly different from Day 0.

TABLE 3. Tokyo Guidelines 2013 (TG13) Severity Grading for Acute Cholecystitis[29–41]

Grade I (Mild) Acute Cholecystitis	
Grade I is acute cholecystitis in a healthy patient with no organ dysfunction and mild inflammatory changes in the gallbladder, making cholecystectomy a safe and low-risk operative procedure.	
Grade II (Moderate) Acute Cholecystitis	
Associated with any one of the following conditions:	
1. Elevated white blood cell count (>18,000/μL)	
2. Palpable tender mass in the right upper abdominal quadrant	
3. Duration of complaints of >72 h	
4. Marked local inflammation (gangrenous cholecystitis, pericholecystic abscess, hepatic abscess, biliary peritonitis, emphysematous cholecystitis)	
Grade III (Severe) Acute Cholecystitis	
Associated with dysfunction of any one of the following organs/systems:	
1. Cardiovascular dysfunction	Hypotension requiring treatment with dopamine ≥ 5 μg/kg/min or any dose of norepinephrine
2. Neurologic dysfunction	Decreased level of consciousness
3. Respiratory dysfunction	PaO_2/FIO_2 ratio < 300
4. Renal dysfunction	Oliguria, creatinine > 2.0 mg/dL
5. Hepatic dysfunction	Prothrombin time/international normalized ratio > 1.5
6. Hematologic dysfunction	Platelet count < 100,000/μL

of admission, and late cholecystectomy was defined as Days 7 to 45. Six hundred eighteen adult patients were randomized. Morbidity was significantly different, 12% in early cholecystectomy versus 34% in late cholecystectomy. They noted no difference in conversion rate, 10% versus 12%. Hospital length of stay was significantly increased in those who underwent delayed cholecystectomy. The authors concluded that "immediate laparoscopic cholecystectomy should be the therapy of choice for acute cholecystitis in operable patients."

An interesting study by Catani showed correlation between duration of symptoms, rather than hospitalization, and length of operative time.[47] They reported a linear relationship between timing of surgery relative to duration of symptoms and operative time. There was an inflection point at 60 hours. At this point, each hour delay in cholecystectomy doubled the time added to the operation compared with operation earlier than 60 hours.

Another population-based study from Ontario, looked at 22,202 patients admitted with acute cholecystitis and undergoing cholecystectomy from 2004 to 2011.[7,13] Early cholecystectomy was within 7 days of admission and compared with delayed cholecystectomy. The primary goal of the study was determination of the incidence of bile duct injury. They reported a doubling of the incidence of bile duct injury in delayed versus early cholecystectomy, 0.53% versus 0.28%, respectively ($p = 0.025$). The relative risk ratio with an advantage to early cholecystectomy was 0.53 (95% confidence interval, 0.31–0.90). As stated by the authors, this is the first study with significant power to detect a difference in bile duct injury, showing a clear advantage to early surgery for acute cholecystitis.

KEY CONCEPT: For acute cholecystitis, laparoscopic cholecystectomy should be performed on the day of admission or Day 1, unless there are clear contraindications.

I do think it is important that this not be performed at 2:00 AM or 3:00 AM, when the surgical team may be distracted by other issues or incoming patients. The patient admitted late at night or early in the morning should be on the operating room schedule as the first case, when the team is fresh and ready to deal with a difficult cholecystectomy.

Next, we need to discuss the Tokyo guidelines. These are important contributions generated by two dozen international experts on cholecystitis and biliary tract disease.[29–41] An entire issue of the *Journal of Hepato-Biliary-Pancreatic Surgery* was devoted to this in 2007. These guidelines have been updated with other articles in 2013 and 2014 (Table 3). The Tokyo guidelines stratified acute cholecystitis into mild cholecystitis (Grade 1), moderate cholecystitis (Grade 2), and severe cholecystitis (Grade 3). *Mild cholecystitis (Grade 1)* is defined as cholecystitis in a healthy patient with no organ dysfunction and only mild inflammatory changes in the gallbladder. *Moderate cholecystitis (Grade 2)* has evidence of local inflammatory response or complaints for more than 72 hours. *Severe cholecystitis (Grade 3)* is acute cholecystitis accompanied by any evidence of organ dysfunction. As shown in the flow chart, defining the grade of acute cholecystitis determines management (Fig. 1). The patient with mild cholecystitis, that is, without complicating factors, should undergo early laparoscopic cholecystectomy. Severe, Grade 3 acute cholecystitis is best served by urgent gallbladder drainage, usually percutaneously. Less well defined is the ideal treatment for patients with moderate acute cholecystitis, where either percutaneous

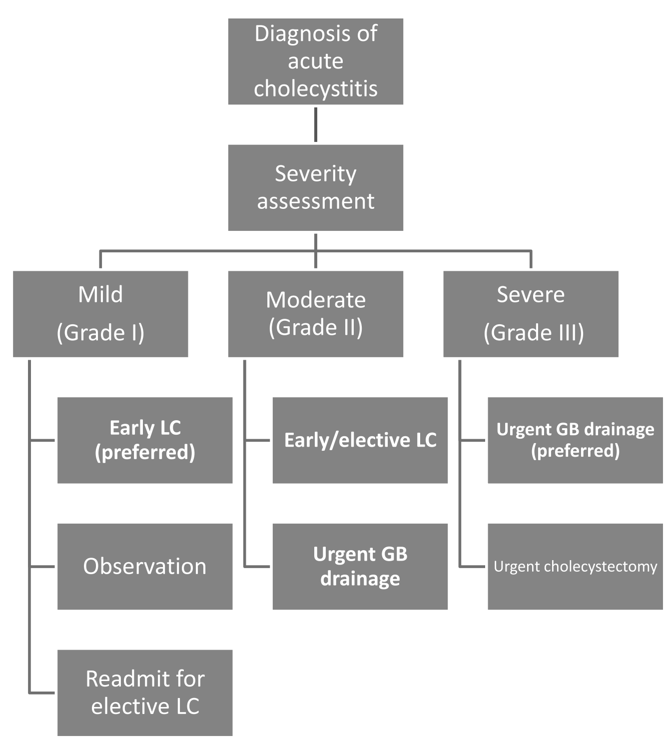

Figure 1. Tokyo guidelines for management of acute cholecystitis. (Source: Miura et al.[34] Reproduced with permission from John Wiley and Sons.)

drainage or laparoscopic cholecystectomy is appropriate based on a combination of factors. In patients with an elevated white blood cell count, palpable mass in the right upper quadrant, or signs of significant local inflammation, percutaneous drainage as an acute treatment followed by delayed cholecystectomy may be the safest option. The management of a patient who is classified as Grade 2 solely based on the duration of complaints for more than 72 hours is a more difficult decision. Often, cholecystectomy in such a patient is straightforward. At other times, acute inflammation and scarring are encountered, and the operation is difficult. This is an issue where we do not have a clear answer. Several authors have recommended that during the index hospitalization, unless there are clear reasons otherwise, any patient with acute cholecystitis should undergo operation, despite the duration of symptoms.[43,48,49] However, they do concede that the surgeon must accept a longer and more difficult operation, and the skill set of the surgeon must be considered as well.

Antibiotics in Acute Cholecystitis

There is a relative paucity of high-quality studies examining the use of antibiotics in acute cholecystitis. Positive bile cultures, however, correlate with progression of cholecystitis to a more severe form,[50–52] so the decision to begin antibiotics should be made shortly after the diagnosis has been established. According to the Tokyo guidelines, antibiotics are not necessary in patients with minimal abdominal pain and mild inflammatory findings.[31,37] In these patients, who may be experiencing biliary colic as opposed to true acute cholecystitis, nonsteroidals may prevent progression to acute cholecystitis and may improve gallbladder function.[53] For the vast majority of patients, however, antibiotics should be started promptly. According to the Surgical Infection Society and Infectious Diseases Society of America guidelines,[54] mild cases of acute cholecystitis can be adequately treated with a first- (cefazolin), second- (cefuroxime), or third- (ceftriaxone) generation cephalosporin. Antibiotics should be discontinued 24 hours after cholecystectomy unless infection has spread outside the gallbladder wall.[31,54,55] For complicated Grade II (pericholecystic abscess or perforated gallbladder) or Grade III cholecystitis, antibiotics should be continued until the patient is afebrile, has normalized white blood cell count, and is free of abdominal findings.[31]

For more severe cases or in those of advanced age or who are immunosuppressed, coverage should be broadened to include enterococci by using either an extended-spectrum penicillin or cephalosporin, a carbapenem, or a quinolone in combination with metronidazole. The Tokyo guidelines[31,37] are similar except that they recommend a penicillin/β-lactamase inhibitor in even mild (Grade 1) cases because of the likelihood of β-lactamase production by intestinal organisms. Furthermore, these authors suggest that cultures of bile and the gallbladder wall "should be performed at all available opportunities, especially in severe cases" and that antibiotic coverage should be tailored depending on sensitivity results. Antibiotics should not be selected on the basis of biliary penetration because bile penetration by the antibiotic in the setting of obstruction (acute cholecystitis) essentially stops.[56]

Percutaneous Cholecystostomy

The indications for percutaneous cholecystostomy are still not well defined.[57–59] For the less common cases of Grade 3 acute cholecystitis, cholecystostomy insertion is recommended by the Tokyo guidelines.[24,33,34] In addition, cholecystostomy is a safe option in patients with less severe cholecystitis who are considered poor surgical candidates or when a difficult dissection is encountered. Predictors of failure of antibiotic treatment alone and thus consideration for cholecystostomy tube include being older than 70 years, history of diabetes, and persistent leukocytosis of more than 15,000/μL at 48 hours.[60] Continued drainage must be established because aspiration alone is not as effective.[61] Success rates of more than 80% are similar whether the procedure is performed for calculous or acalculous cholecystitis,[62–65] and clinical improvement is generally seen within 72 hours.[62,66,67] Mortality following the procedure is high (5–40%) but generally is related to the severity of the underlying disease process.[62–65] As stated in a recent systematic review of percutaneous cholecystostomy, "there is no doubt that percutaneous cholecystostomy together with antibiotics can convert a septic cholecystitis into a non-septic condition."[68] However, specific indications and criteria are still not well defined.[58,69]

Of the patients who undergo percutaneous cholecystostomy and those whose tubes are removed, the need for delayed cholecystectomy remains controversial, with reports ranging from 0% to 87%.[58,69–74] de Mestral et al.[69] reported in their population based study that approximately 40% will have recurrent biliary tract disease within 1 year following cholecystostomy. In their review of 47 articles and 1,724 patients, Winbladh et al.[68] observed that more than 40% of patients eventually underwent cholecystectomy. A prospective randomized trial (the CHOCOLATE Trial) in the Netherlands is underway, comparing early cholecystectomy with percutaneous cholecystostomy.[75]

Factors Predicting the Difficult Cholecystectomy

Conversion from laparoscopic to open cholecystectomy should not be viewed as a failure. With a difficult cholecystectomy, it is critical to operate under the premise that bile duct injury is never an acceptable outcome and thus, if necessary, conversion is the safest option. Preoperative factors predict the patient for whom difficult cholecystectomy or need for a conversion can be expected. These include male patients, age greater than 70 years, inflammation, duration of symptoms for the acute episode, chronicity and duration of symptoms with recurrent disease, an impacted stone, gallbladder wall thickness, pericholecystic fluid, elevated white blood cell count, previous upper abdominal surgery, repeated bouts of cholecystitis, or a contracted gallbladder on imaging.[24,27,49,60,76–84]

Why Do Bile Duct Injuries Still Occur?

KEY CONCEPT: We would agree that we each want bile duct injury to be on the list of complications that we never have.

So, why do bile duct injuries still occur? Common factors include anatomic variation, acute inflammation, chronic scarring, misperception, and error traps. Misperception by the surgeon of what he or she is seeing in the operative field is a

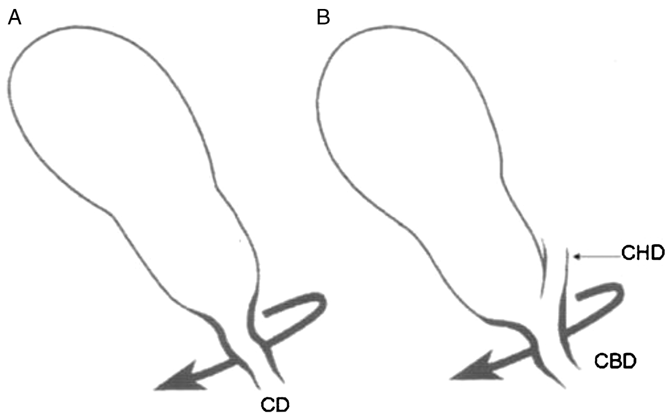

Figure 2. Infundibular view error trap. Dangerous anatomic variants of right posterior hepatic duct draining into the following: *A*, cystic duct; *B*, gall bladder neck; and *C*, common hepatic duct. (Source: Strasberg et al.[19] Reproduced with permission from Elsevier, Inc.)

major factor in generating bile duct injury.[6,8,17–22,80] In short, the surgeon sees what he or she believes and does not believe what he or she sees, and thus, the injury occurs.[6,80] Along the same lines, Strasberg and colleagues[17–22] discuss error traps. As noted by several authors, during the past two decades of laparoscopic cholecystectomy, the bile duct injuries seen may be less common but more severe.[17–22,85] Strasberg and colleagues[17–22] define an error trap as an operative approach that works well in most circumstances but is prone to fail under certain circumstances. Similar to the misperception issues, with an error trap, because the technique usually works, the surgeon develops confidence in it and fails to recognize when dangerous circumstances are present. The error traps that Strasberg and colleagues described are as follows:[17–22]

1. The "infundibular view" error trap
2. Fundus down cholecystectomy in the face of severe inflammation
3. Failure to perceive the absence of an aberrant right hepatic duct on cholangiography (IOC). (I would add failure to recognize an aberrant right hepatic duct or posterior right hepatic duct intraoperatively as well.)
4. Injury to the common bile duct in the case of a "parallel union" cystic duct.

The usual approach to the gallbladder is starting from the infundibulum and then working toward the fundus. It is taught that the taper between infundibulum and cystic duct identifies cystic duct. In a single view, this can be misleading, especially with any inflammation, and the common duct can be mistakenly divided, believing it is the cystic duct ("infundibular view error trap") (Fig. 2). This produces the classic injury with resection of a portion of the common bile duct.

The error trap with an open, top-down cholecystectomy again is caused by what is normally safe, applied in a dangerous situation. Strasberg states that the worst injuries occur in those patients who undergo conversion from laparoscopic to open cholecystectomy, performed top-down because of marked inflammation and difficult dissection. This initially seems counterintuitive but will make sense as we explain it. The perceived, safe operative plane coming down the medial wall of the gallbladder is now obliterated by an inflammatory reaction, which incorporates the right-sided porta hepatis and the common bile duct. Thus, this injury is commonly associated with major biliary and vascular injury, at times requiring liver resection for the ischemic injury.

The variability of the right posterior hepatic duct includes drainage into the cystic duct, gallbladder neck, or common hepatic duct (Fig. 3).[25,86,87] With the infundibular approach to the gallbladder, injury to such an aberrant posterior right hepatic duct is nearly unavoidable. However, with a top-down approach on the gallbladder, the aberrant right posterior hepatic duct can generally be seen and protected; leave a rim of infundibulum to protect the duct. In addition, this aberrant posterior right hepatic duct will often not be seen on an IOC because the cholangiocatheter is introduced into the cystic duct below insertion of the aberrant duct.

If a posterior right hepatic duct is transected and not recognized, the clinical presentation is uncommon but classical. Generally, a clip is on the proximal duct, but the liver side of the duct is draining freely (Fig. 4). This case shows an IOC

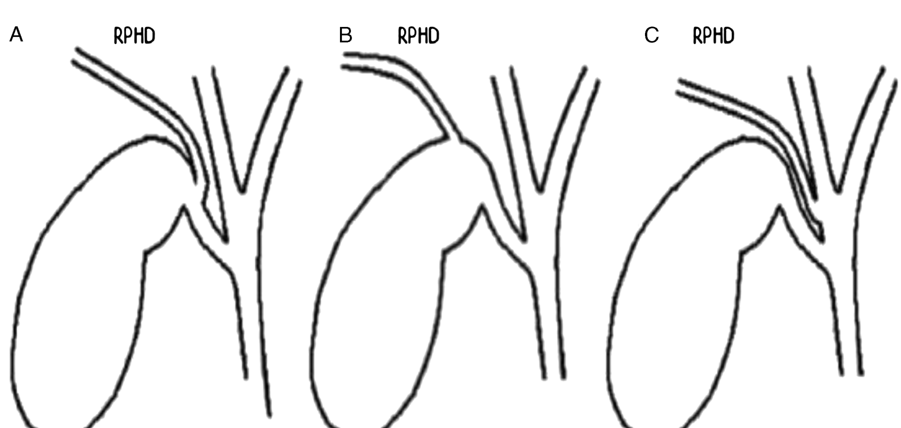

Figure 3. Common anomalies of the posterior right hepatic duct. (Source: Wojcicki et al.[86] Reproduced with permission from Baishideng Publishing Group Co.)

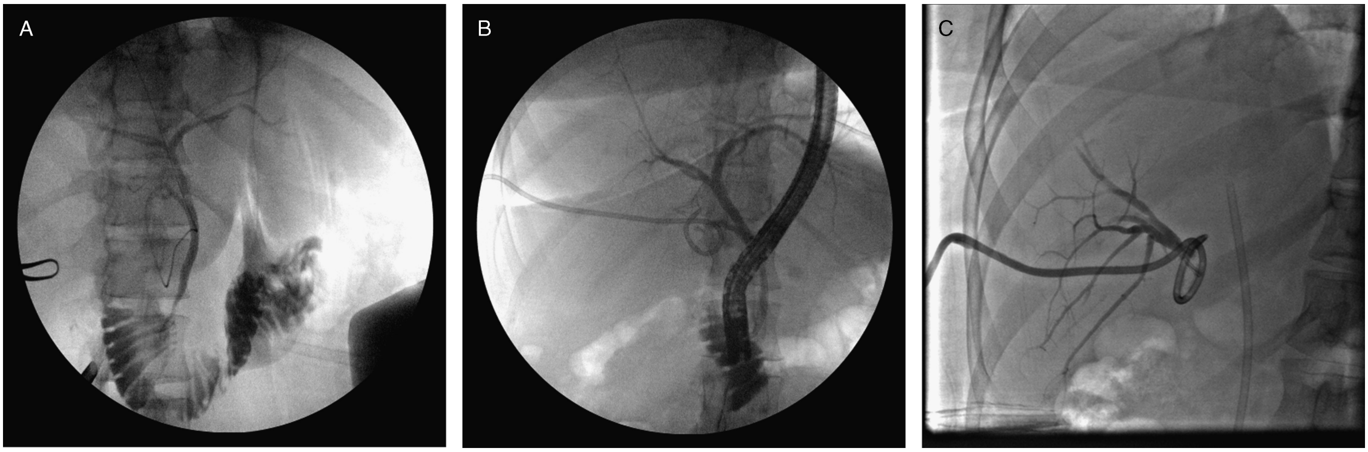

Figure 4. Studies from a patient with a transected posterior right hepatic duct. *A*, An IOC interpreted as normal. *B*, An ERCP a week postoperatively interpreted as normal. *C*, A sinogram showing filling of the posterior right lobe.

and endoscopic retrograde cholangiopancreatography (ERCP) a week later (for a bile leak), which are both interpreted as normal. Sometimes, what you do not see is as important as what you do see on these studies. Absent on both the IOC and ERCP is filling of the posterior right lobe. When contrast is injected through the drain as a sinogram, the transected right posterior sectoral duct fills (Fig. 4*C*). This requires either Roux-en-Y to the duct remnant or liver resection (as was performed in this case).

The most common configuration of the cystic duct joining the common duct is angular (75%). However, the parallel union occurs in 20%. Especially with any degree of inflammation, this fused cystic duct and common duct generate a situation where injury is more likely. Similarly, a spiral union between cystic duct and common duct can be misinterpreted.

Chronic scarring from recurrent or neglected bouts of cholecystitis is as dangerous as acute inflammation. This contracts all of the portal structures from the inflammatory response, thus obliterating the usual safe planes. This can be predicted based on preoperative history and imaging that shows a shrunken, contracted gallbladder. Cholecystectomy in these circumstances can be particularly difficult.

Cholecystectomy: How to Do It Safely

The essentials for safe laparoscopic cholecystectomy begin with a 30-degree or 45-degree high-definition laparoscope. Take full advantage of the angled scope, visualizing from different angles continuously as the operation proceeds. Hunter[88] describes many of these key principles nicely in his 1991 article. The assistant grasps the fundus cephalad and retracts this toward the patient's right shoulder. This reduces redundancy in the infundibulum and exposes the cystic duct. A second grasper retracts the infundibulum laterally to make the cystic duct perpendicular to the common bile duct and again separate the gallbladder from the common bile duct (Fig. 5). The key principles for safe laparoscopic cholecystectomy include the following:[17–22,88]

- 30-degree or 45-degree high-definition laparoscope
- Cephalad traction on the dome of the gallbladder
- Lateral traction on the infundibulum
- Finding the gallbladder wall and staying on it
- Dissecting from above down to the neck
- Widely opening the hepatocystic triangle
- Moving the infundibulum back and forth (wave the flag), repeatedly looking at both sides of the gallbladder
- Critical view of safety
- Dividing the cystic duct as close to the gallbladder as possible
- Never dividing the cystic duct with any cauterizing instrument—if it turns out to be the common bile duct, the resulting ischemic injury will only lessen the chances for a good repair

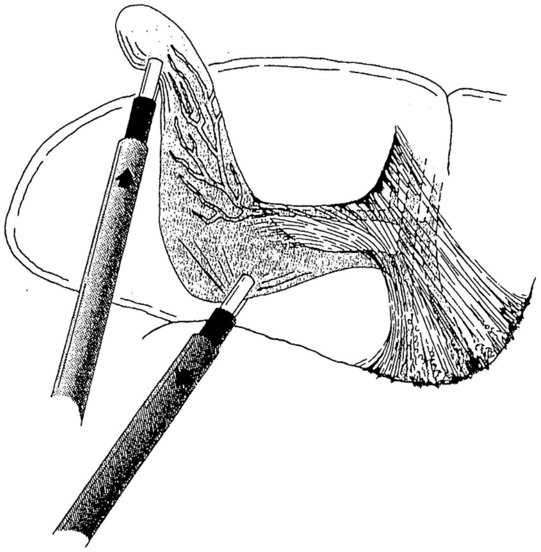

Figure 5. The assistant grasps the fundus cephalad and retracts this toward the patient's right shoulder. This reduces redundancy in the infundibulum and exposes the cystic duct. A second grasper retracts the infundibulum laterally to make the cystic duct perpendicular to the common bile duct, and again separate the gallbladder from the common bile duct. (Source: Hunter.[88] Reproduced with permission from Elsevier, Inc.)

KEY CONCEPT: Operative dissection technique versus method to identify anatomy.

Related but different principles include how we dissect the gallbladder and how we safely identify the anatomy. Dissection techniques include the *infundibular technique*, which is most commonly used; the *fundus first (top-down)*; and what we call the *semi–top-down technique*. The *infundibular technique* is how most of us have learned. As mentioned, this is a technique that works majority of the time but will fail in predictable circumstances, specifically anatomic variation or inflammation.

KEY CONCEPT: What is safest and best for an open procedure is safest and best for a laparoscopic procedure.

With infundibulum-first cholecystectomy, we violate this principle. Thus, it should not be a surprise at times that this generates problems. The fundus first (top-down) has been well described, mimicking what we do for open cholecystectomy.[89–92] Certainly, with acute inflammation, this is the preferred approach. However, this can be awkward because of the floppiness of the gallbladder when it is fully detached from the liver. Gently retracting the liver surface will generally stabilize this. On occasion, a liver retractor may be necessary.

The semi–top-down technique of laparoscopic cholecystectomy combines the advantages of both approaches and minimizes the disadvantages. Dissection is started higher on the gallbladder, above the infundibulum of the gallbladder (Fig. 6*A–E*). The peritoneum is scored circumferentially, lateral side first, coming across the peritoneum over the infundibulum of the gallbladder, then opening the peritoneum coming up the medial side of the gallbladder, being careful not to enter the cystic artery as you do so. Then, by rolling the gallbladder back and forth, the gallbladder can be largely detached from the liver, leaving only the fundus attached to again provide easy retraction. At this point and only at this point is the infundibulum and its junction with the cystic duct approached, thus generating a top-down approach to the cystic duct and cystic artery. When proceeding with the semi–top-down taking only tissues that you see through clearly, any structures that may be encountered such as an aberrant duct, right hepatic

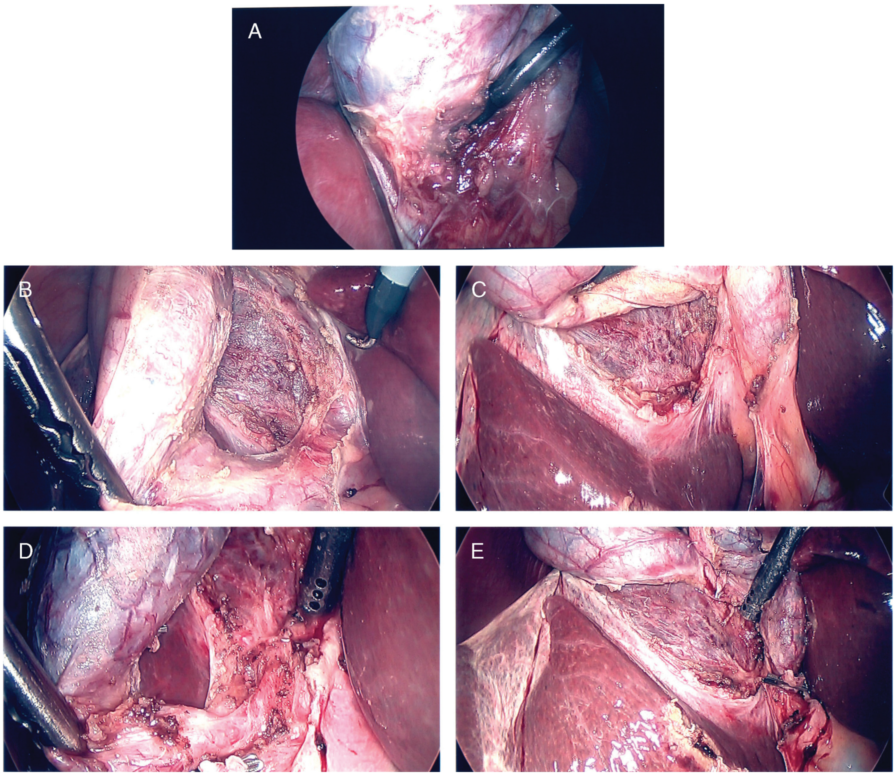

Figure 6. Technique of semi–top-down laparoscopic cholecystectomy. *A,* Dissection is started on the gallbladder, above the infundibulum of the gallbladder. The peritoneum is scored circumferentially, lateral side first, coming across the peritoneum over the infundibulum of the gallbladder, then opening the peritoneum coming up the medial side of the gallbladder, being careful not to enter the cystic artery as you do so. Dissection of the gallbladder off the liver is being completed here on the lateral aspect of the gallbladder. *B* and *C,* Then by rolling the gallbladder from one side to the other, the gallbladder can be fully detached from the liver, leaving only the fundus attached, to provide full exposure. *D,* At this point and only at this point is the infundibulum and its junction with the cystic duct approached, thus generating a top-down approach to the infundibulum, cystic duct, and cystic artery. When proceeding with the semi–top-down 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. *E,* An exaggerated critical view of safety has resulted. The cystic artery has been divided, and the cystic duct is clearly defined and ready for clipping and dividing.

artery, or posterior cystic artery can be seen and avoided. As you proceed with this dissection, often, the cystic artery widely separates from the gallbladder. At this point in the operation, what you have generated is an exaggerated critical view of safety. It is now clear which structures are cystic artery and cystic duct, having proceeded in essentially a top-down dissection.

KEY CONCEPT: The safest plane for dissection in a cholecystectomy, open or laparoscopically, is on the wall of the gallbladder. Dissection away from the wall of the gallbladder will lead to trouble.

Operative Tricks and Tips

Operating on an acutely inflamed gallbladder for acute cholecystitis or hydrops is challenging and difficult. When placing the laparoscope and seeing this, you must stop and ask the following questions. How sick is my patient? Will he or she tolerate an open cholecystectomy? Will he or she tolerate a long operation? How do I protect the structures in the porta hepatis? Maybe most critical, can I protect the structures in the porta hepatis? If it is clear that the patient is too ill or the anatomy is hazardous from the inflammation, then cholecystostomy is the appropriate option. If it is decided that cholecystectomy can be performed safely, then the gallbladder generally must be decompressed.

Importantly, performing a cholecystectomy on an acutely inflamed, hydroptic gallbladder involves a paradigm shift in operative strategy as compared with the straightforward cholecystectomy. Now, the strategy for the protection of the portal structures is to find and stay only on the wall of the gallbladder (at times submucosa) and know where not to be. The surgeon must know that attempts or persistence in obtaining the classical critical view of safety will lead to biliary or vascular injury. One of the difficulties in this operation is finding the wall and staying on the wall of the gallbladder. In my mind's eye, what I see when I encounter a hydroptic, acutely inflamed gallbladder is analogous to an onion—with multiple peels of inflammatory tissue. Carefully dissect through these layers to safely get onto the wall of the gallbladder, often the submucosa, and complete the dissection in this plane. Again, emphasizing the fact that the safest plane for dissection, open or laparoscopic, is on the wall of the gallbladder.

Partial Cholecystectomy

KEY CONCEPT: At times, the safest plane is viewing the anatomy from within the gallbladder itself.

Partial cholecystectomy has been documented by several authors as a safe and durable option in treating acute cholecystitis.[93–100] Lateral, medial, and anterior walls of the gallbladder are excised using electrocautery. The densely adherent posterior wall is left on the liver. The mucosa is fully cauterized. As you proceed proximally, you are now within the infundibulum of the gallbladder and visualizing infundibulum and cystic duct from within the gallbladder. Be certain that all stones are extracted. The mucosa is then oversewn with a purse string suture, being certain not to get deeply enough such that portal structures are at risk. Another option in the setting of acute inflammation if the gallbladder can be safely taken off the liver but the infundibulum is markedly inflamed is amputation of the gallbladder at the infundibulum.[100] The anatomy can again be identified from within the gallbladder; determine the junction of cystic duct and infundibulum. Dissection can often be continued in a safe plane, circumcising the inflamed peritoneum off the gallbladder wall and continuing the dissection. As applied earlier, oversewing the cystic duct from within may be the safest option in this setting. If you cannot safely close the cystic duct from within, in uncommon circumstances where it is not clear that a stitch can be placed safely, a drain is left.

As mentioned, identification methods and technique of dissection are related but different. We will discuss three methods to identify the anatomy during cholecystectomy: the critical view of safety, IOC, and intraoperative ultrasonography. The critical view of safety, espoused by Strasberg for two decades, has been confirmed in multiple studies to be an effective method.[9,17,22,101–103]

KEY CONCEPT: There are three essential components of the critical view of safety as follows:

1. **At least one third of the gallbladder must be dissected from the liver bed**
2. **The Triangle of Calot must be widely cleared**
3. **Only cystic artery and cystic duct remain as the two structures between the gallbladder and the hepatic ligament**

In an interesting study, adequacy of the critical view of safety was reviewed in photos from 100 cases.[103] All three criteria were met in only half, with inadequate dissection of the gallbladder off the liver plate as the most common deficiency. Thus, in application of the critical view of safety, all three criteria are required to safely identify anatomy.

Intraoperative Cholangiography

IOC has also been applied as a method for the identification of structures.[1,3–5,8,10,14,15,23,104] The purposes of IOC include the following: to prevent retained common bile duct stones, to define the biliary anatomy, and to prevent or identify

Figure 7. Computed tomography of a 61-year-old woman, hypotensive and tachycardic on presentation, which shows a liver abscess contiguous to marked cholecystitis. She was taken to the operation room for cholecystectomy and drainage of the liver abscess. The patient died of bleeding from the middle hepatic vein.

bile duct injury. For those who perform cholangiography selectively, which is our approach, the indications include history suggestive of common duct stones including pancreatitis or jaundice or any question of the biliary anatomy during cholecystectomy. Multiple studies have evaluated routine IOC as a means to make laparoscopic cholecystectomy safer;[1,3–5,8,10,14,15,23,104] the data are conflicting. Several observational cohort studies suggest that routine a use of IOC can reduce the risk of common bile duct injury by 50%.[10,15] In a large meta-analysis by Ludwig et al.[10] of more than 300,000 laparoscopic cholecystectomies, which included 405 major bile duct injuries, the incidence of major bile duct injury was 0.21% in the group where routine cholangiography was used as compared with 0.43% in the selective cholangiography group, representing a statistically significant reduction. Furthermore, 87% of the injuries were diagnosed at the time of surgery in the routine group, compared with only 45% in the selective group. Proponents of routine cholangiography cite this reduction in incidence, earlier recognition of the injury, and perhaps, more successful repair and outcomes as the major reasons to use cholangiography routinely.[3,10,15] Opponents, however, claim that routine cholangiography is not cost-effective, adds unnecessary time to the operative procedure, and is not always effective at preventing or identifying injury.[80] A recent editorial in support of routine cholangiography asked, "why are we still debating?"[3]In contrast, in a systematic review of IOC published recently, eight randomized trials with 1,715 patients were evaluated.[1] There were only two cases of bile duct injury, confirming that it was underpowered. The authors concluded that "there is no robust evidence to support or abandon the use of IOC to prevent retained stones or bile duct injury." Another recent review of 92,392 Medicare patients with matched cohorts reported that 40% of patients underwent IOC and 60% did not. The authors concluded that, when confounders were controlled, "intraoperative cholangiography is not effective as a preventive strategy against common bile duct injury during cholecystectomy."[14]

The IOC is dependent on correct interpretation by the surgeon, such as, the transected posterior right hepatic duct described previously. In addition, failure of IOC to prevent bile duct injuries is predictable and relates to (*a*) filling the CBD only to the bifurcation and not completely filling the liver and, perhaps more importantly, (b) the lack of experience of the general surgeon in reading cholangiograms, particularly the concept of what you do not see is often more important than what you do see. In contrast, bile duct injury found early on IOC leading to prompt diagnosis and treatment improves outcome from injury to the bile duct.

Intraoperative Ultrasonography

Laparoscopic ultrasonography (LUS) is an alternative to IOC for intraoperative assessment of biliary anatomy.[5,28,105–111] LUS can delineate the common bile duct; cystic duct–common bile duct junction; hepatic artery; portal vein; anomalous anatomy, particularly vascular; and choledocholithiasis. A definite learning curve is associated with LUS, estimated to be 30 to 50 cases. Visualization of the distal common bile duct is more difficult with LUS, and IOC also has the advantage of confirming free flow of bile (contrast) into the duodenum. Once proficiency with LUS is attained, it is less time consuming than IOC, without radiation exposure, and can be repeated during the operation. Biffl et al.[107] reported 842 cholecystectomies, with their practice initially split regarding routine LUS. They reported LUS to be associated with fewer bile duct complications (bile duct injury, retained stones, cystic duct leaks) than without LUS. In their meta-analysis assessing accuracy of LUS in the detection of choledocholithiasis, Aziz et al.[105] reported sensitivity of 0.87 and specificity of 1.00, nearly identical to IOC (sensitivity, 0.87; specificity, 0.99). Machi et al. have drawn similar conclusions.[105–111] The SAGES guidelines[28] determined that the literature provided Level II, Grade B data for both LUS and IOC as means to delineate biliary anatomy and prevent bile duct injury. Other technologies to delineate biliary anatomy and avoid bile duct injury include passive infrared cholangiography, light cholangiography, near-infrared fluorescence cholangiography, and hyperspectral cholangiography.

KEY CONCEPT: Beware of the middle hepatic vein.

The middle hepatic vein bisects right and left lobes and normally runs within millimeters of the gallbladder fossa. In 20% of patients, a branch of the middle hepatic vein is essentially in the gallbladder plate.[112] Particularly when performing cholecystectomy for acute cholecystitis, drifting off the wall of the gallbladder may result in life-threatening hemorrhage with injury to the middle hepatic vein (Fig. 7).

What to Do When a Bile Duct Injury Occurs

If recognized intraoperatively, one must assess his or her ability to repair the injury. The best result comes from an early repair, and the first repair has the best outcome. Except in the most unusual of circumstances, avoid a duct-to-duct anastomosis; do a tension-free Roux-Y. If the surgeon is inexperienced with such a repair, leave the bile duct alone and simply place a drain immediately next to the duct and transfer the patient. The expertise of the surgeon dealing with this complication will impact long-term outcome. If the hepatic artery has also been injured, it is probably best not to repair the bile duct immediately, but wait several months until collaterals have

KEY CONCEPTS

- Perform the cholecystectomy during the index hospitalization for acute cholecystitis.
- Perform the cholecystectomy within 24–48 h of admission.
- Know the error traps; avoid them.
- Semi–top-down technique
- Critical view of safety
- ±IOC
- ±Intraoperative ultrasonography
- The safest plane for dissection—open or laparoscopic—is on the wall of the gallbladder.
- Sometimes, the safest plane is viewing things from within the gallbladder.
- Avoid the use of cautery near the common bile duct or previously placed clips.
- Know when cholecystostomy is the right operation—know when *not* to operate.

developed. The liver parenchyma can easily survive on the portal vein alone as approximately 70% to 75% of the parenchymal blood flow comes from the portal vein; however, the biliary system is heavily dependent on arterial blood flow.

If the injury is recognized after surgery, place a drain percutaneously and transfer the patient. The ideal treatment if a delayed repair is required is to place a percutaneous transhepatic cholangiocatheter (PTC) (which is difficult because of decompressed ducts) and an intra-abdominal drain (percutaneously if possible) to limit/drain the bile peritonitis. The common hepatic duct will scar down around the PTC and, the abdominal drain will cease draining bile. The abdominal drain can then be removed, and the bile duct can be repaired months later. Obviously, the PTC cannot be clamped but must remain connected to external drainage.

DISCLOSURE

The authors declare no conflicts of interest.

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