Notable Grand Rounds
of the
Michael & Marian Ilitch
Department of Surgery

Wayne State University
School of Medicine

Detroit, Michigan, USA

Anastasya Chuchulo, MD

PATHOLOGY OF THE BILIARY TRACT

March 20, 2024

About Notable Grand Rounds

These assembled papers are edited transcripts of didactic lectures given by mainly senior residents, but also some distinguished attending and guests, at the Grand Rounds of the Michael and Marian Ilitch Department of Surgery at the Wayne State University School of Medicine.

Every week, approximately 50 faculty attending surgeons and surgical residents meet to conduct postmortems on cases that did not go well. That "Mortality and Morbidity" conference is followed immediately by Grand Rounds.

This collection is not intended as a scholarly journal, but in a significant way it is a peer reviewed publication by virtue of the fact that every presentation is examined in great detail by those 50 or so surgeons.

It serves to honor the presenters for their effort, to potentially serve as first draft for an article for submission to a medical journal, to let residents and potential residents see the high standard achieved by their peers and expected of them, and by no means least, to contribute to better patient care.

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Pathology of the Biliary Tract

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March 20, 2024

This paper has been adapted from an oral presentation.

Note: Anatomical drawings are reproduced from Shackelford & Yeo (2019[1]).

Introduction

The management of biliary tract diseases has undergone significant advancements over the past few decades, with laparoscopic techniques becoming the standard of care for conditions such as cholecystitis and choledocholithiasis. This paper aims to review these advancements, focusing on the prevention of bile duct injuries, the management of difficult gallbladders, and the treatment of choledocholithiasis in patients with Roux-en-Y gastric bypass.

Biliary procedures, including cholecystectomies, are among the most commonly performed abdominal operations in the US, affecting 20 to 25 million Americans. The estimated total cost is $6.2 billion annually, making this a significant topic. It is the second most expensive digestive tract disease, only surpassed by GERD. With an increasing global population and growing life expectancy, biliary disease poses a substantial problem in both developed and developing nations.

Laparoscopic cholecystectomy has now become the standard of care for biliary colic and acute cholecystitis nationally. Patient procedures have shifted towards more outpatient and ambulatory procedures, as have many other procedures. From 2005 to 2019, inpatient cholecystectomy rates decreased by 30% for laparoscopic cases and 60% for open procedures. As of 2019,

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[1] Shackelford, RT., Yeo, CJ (2019). Shackelford's surgery of the alimentary tract. Eighth edition. Philadelphia, PA: Elsevier.

600,000 of these procedures were performed on an ambulatory basis laparoscopically.[2]

Fig. 1. Abraham Vater
Source: Wikipedia.

History

The earliest documentation of gallstone disease dates back to Egyptian mummies around 2000 BCE. Many years later, Francis Glisson described the common capsule enclosing the hepatic artery, portal vein, and bile ducts. He was also the first to describe a sphincter mechanism around the opening of the common bile duct. In 1720, Abraham Vater (**Fig. 1**) described the elevation of mucosa in the duodenum and detailed the first case of an ampulla with two orifices.

In 1687, Stalpert von der Wiel opened a right upper quadrant abdominal abscess in a patient with chronic abdominal pain and documented gallstones. Jean Louis Petit, considered the founder of gallbladder surgery, suggested in 1733 that when an area of reddening abdominal skin occurred, symptomatic of biliary colic, it should be incised, the gallstones removed, and a gall fistula should remain. He performed such a procedure the following year.

John Bobbs, in 1867, operated on a female with an ovarian cyst and found an inflamed, adherent sac containing, “much to his surprise, several solid biliary bodies about the size of ordinary rifle bullets.” He closed the colostomy incision after removing the stones. Marion Sims in 1878 performed the first cholecystostomy, removing stones and sewing the gallbladder wall to the corner of the abdominal incision.

While these operations provided temporary pain relief, they had high rates of fistula, morbidity, and often, the symptoms recurred.

While earlier physicians focused on relieving acute infections, Dr. Carl Langenbuch (**Fig. 2**) in 1882 performed the first successful cholecystectomy. Before this, the gallbladder was considered an essential organ, and attempts to remove it were not undertaken. He honed his technique on cadavers for years before performing the first operation on a 43-year-old man who had suffered from biliary colic for 16 years. Remarkably, the patient was reported to be afebrile, smoking a cigar, and was discharged from the hospital after six weeks. He gained weight and remained free of pain.

Fig. 2. Carl Langenbuch
Source: Felekouras, Evangelos & Kaparelos, D. & Papalambros, E.. (2010). The history of liver surgery, hepatectomy and haemostasis. Hellenic Journal of Surgery. 82. 280-296. 10.1007/s13126-010-0046-2.

Jean-François Calot, in 1890, described the anatomy and technique of cholecystectomy in great detail, including the triangle formed by the common hepatic duct, cystic duct, and cystic artery, known today as Calot's triangle (**Fig. 3**).

Theodor Kocher (1841–1915 (**Fig. 4**, next page)) further advanced the field by advocating for a subcostal incision, now known as the Kocher incision, and published procedures for sphincteroplasty. In 1903, he standardized the technique for duodenal mobilization, known as Kocher's maneuver.

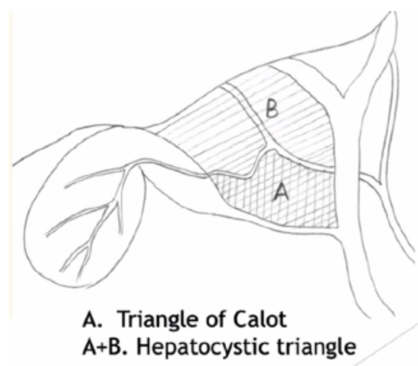

Fig. 3. Triangle of Calot
Source: Kumar, Sunil & Joshi, Mohit. (2014). Calot’s Triangle: Proposal to Rename it as Calot’s Region and the Concept of ‘Ducto-Arterial Plane’. Indian Journal of Surgery. 77. 10.1007/s12262-014-1057-y.

Ludwig Courvoisier (1843–1918 (**Fig. 5**)) was the first to describe the removal of a stone

[2] Unalp-Arida, A., CE Ruhl (2024). The Burden of Gallstone Disease in the United States Population. Preprint. medRxiv 2022.07.08.22277386; doi: https://doi.org/10.1101/2022.07.08.22277386

from the common bile duct, addressing different types of ductal obstructions and establishing Courvoisier's law from a review of 187 cases, indicating that a painless, enlarged gallbladder with mild jaundice was more likely related to neoplastic processes than to gallstone disease.

Ruggero Oddi (1864–1913 (**Fig. 6**)) was pivotal, by measuring the resistance of the sphincter, in demonstrating that gallbladder removal causes ductal dilation.

Laparoscopy

The early 20th century saw the beginnings of laparoscopy. In 1910, Hans Christian Jacobaeus coined the term “laparoscopy.” An internist, he used the technique to examine the cavities of patients with cirrhosis, draining significant amounts of ascites (up to 23 liters) in the process. He cautioned about the risks of bowel injury, emphasizing the protective nature of ascites for safe abdominal entry. His trocar design (**Fig. 7**) has evolved into those used today.

Fig. 4. Theodor Kocher
Source: Wikipedia

Fig. 5. Ludwig Courvoisier
Source: Wellcome Collection. https://wellcomecollection.org/works/ywne2adq

Fig. 6. Ruggero Oddi
Source: Attributed to National Library of Medicine—see https://www.clinicalanatomy.com/mtd/383-ruggero-oddi

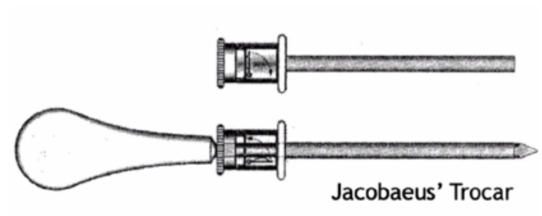

Fig. 7. Jacobaeus' Trocar
Source: Litynski, G.S. (1997). Laparoscopy - The Early Attempts: Spotlighting Georg Kelling and Hans Christian Jacobaeus. JSLS : Journal of the Society of Laparoendoscopic Surgeons, 1, 83 - 85.

At the same time, Georg Kelling developed a technique to increase abdominal compartment pressure to treat intraperitoneal hemorrhage, noting the rapid decompensation in patients with intra-abdominal hemorrhage when the abdomen was opened.[3]

A quote attributed to Jacobaeus underscores the preference for laparoscopy over exploratory laparotomy among surgeons familiar with the former technique:

> "What plays the largest role at this time is which method one is accustomed to. Naturally a surgeon always performs an exploratory laparotomy while an internist with some experience in laparoscopy will prefer the latter operation.”

Cholecystography

Evarts Graham and Warren Cole developed the first cholecystography using an oral contrast medium, followed by X-rays to visualize the gallbladder (see example at **Fig. 8**). This was the precursor to operative cholangiography, with Pablo Mirizzi (**Fig. 9**, next page) coining the “Mirizzi syndrome” in 1948, marking a significant advancement in diagnosing biliary tract diseases.

Fig. 8. Galbladder X-ray (following a fatty meal)
Source: https://gallbladder.thecommonvein.net/small-gallbladder/

[3] Litynski G. S. (1997). Laparoscopy--the early attempts: spotlighting Georg Kelling and Hans Christian Jacobaeus. *JSLS : Journal of the Society of Laparoendoscopic Surgeons*, *1*(1), 83–85.

ERCP

In 1968 McCune, Shorb, and Moscovitz documented the first clinical application of Endoscopic Retrograde Cholangiopancreatography (ERCP (**Fig. 10**, next page)). Initially developed for the early diagnosis of pancreatic neoplasms, its use has since expanded significantly.

Fig. 9. Pablo Mirizzi
Source: http://ishrad.org/historical-archive/gallery-of-innovators/early-days/pioneers-in-south-and-central-america

Laparoscopic Cholecystectomy

The landscape of surgery began to shift dramatically when, in 1985, Erich Mühe (**Fig. 11**) performed the first laparoscopic cholecystectomy. This procedure, lasting two hours, utilized a monocular laparoscopic lens held in the left hand, alongside grip instruments very similar to those in use today. (**Fig. 12**) Interestingly, the OBGYN field had already developed a clip applicator for tubal ligations, which Mühe adapted to ligate the cystic duct, making the first procedure feasible. This pioneering operation was essentially a one-man job, as only the surgeon could view the laparoscopic images, leaving assistants unable to assist visually.

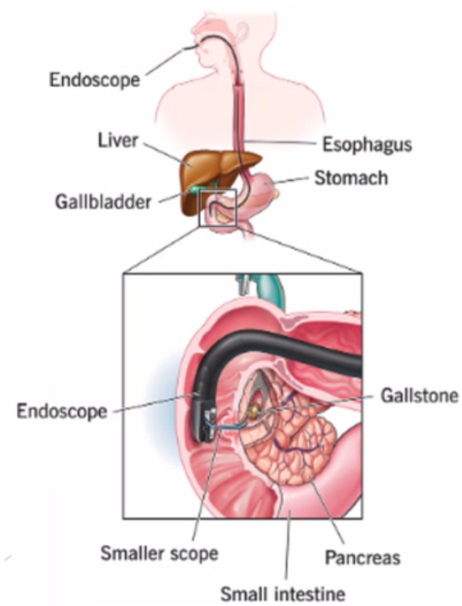

Fig. 10. Endoscopic Retrograde Cholangiopancreatography (ERCP)
Source: Shackelford (2019) (see footnote 1)

Mühe's technique, offering all the advantages of minimally invasive surgery we take for granted today (the abdominal muscles are not cut, there is little postoperative pain, short immobilization, short postoperative hospitalization, and rapid return to the workplace) was initially met with skepticism and ridicule by surgical societies, with criticisms such as "small brain, small surgery." However, patient demand drove the adoption of laparoscopic cholecystectomy. News of this less invasive procedure spread quickly among patients, leading to a significant preference for it over traditional methods. This patient-driven demand led to a rapid increase in the technique's adoption. Initially, setting up randomized controlled trials to compare the efficacy and safety of laparoscopic cholecystectomy with traditional open cholecystectomy was challenging, as patients often refused the open procedure. Remarkably, by 1992, just seven years after its introduction, an estimated 80% of cholecystectomies were performed laparoscopically, making it the standard of care for acute cholecystitis with a mortality rate of 0.25%.

Fig. 11. Erich Mühe
Source: Reynolds, Walker. (2001). The first laparoscopic cholecystectomy. JSLS 5:89-94.

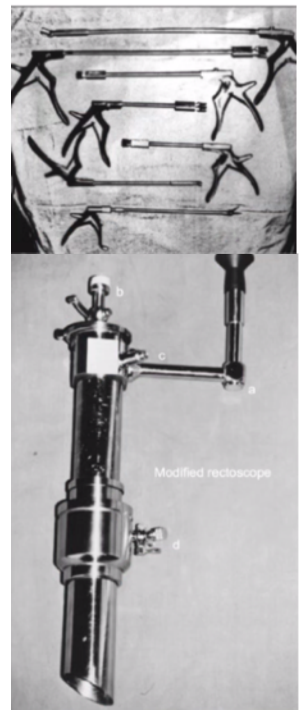

Fig. 12. (Top): Laparoscopy instruments (top) used by and (bottom) invented by Erich Mühe.
Source: Lee, Sang-Mok. (2019). I Am Number 3 or 4?: Presidential Lecture at KSELS 2019. JMIS 22:51-54. 10.7602/jmis.2019.22.2.51.

Furthermore, the first robotic cholecystectomy was performed in 1997, marking another significant milestone in the evolution of biliary surgery (De, 2023).[4]

Biliary Anatomy

The Portal Triad

In the normal biliary anatomy, the portal triad consists of the portal vein situated posteriorly, the hepatic artery running anteromedial to the bile duct, with the bile duct positioned laterally (**Fig. 13**). Generally, the cystic artery originates from the right hepatic artery, which runs posterior to the bile ducts. The blood supply to the bile ducts is derived from multiple sources, with approximately 40% coming from superior sources. This includes a network of vessels around the surface, primarily supplied by two vessels located on the lateral and medial sides at the three o'clock and nine o'clock positions. The remaining 60% of the blood supply is sourced inferiorly from the gastroduodenal artery and other contributing arteries.

Ductal Anatomy Variations

The normal' anatomy, where the cystic duct inserts onto the bile duct in the middle third laterally, is only present in 17 to 50% of individuals, according to case series and studies. This means that at least half the time, anatomic variations are present. It's important to recognize that the cystic duct can insert onto the bile duct anteriorly, posteriorly, or even spiral around it. Variations (**Fig. 14**, next page) include a long cystic duct with a low fusion point with the common hepatic duct, which, if fibrotic and subjected to excessive traction, can inadvertently pull and injure the common hepatic and bile ducts. Conversely, an abnormally high fusion with the common hepatic duct can pose a risk of injury higher up. There may also be an accessory hepatic duct draining into the cystic duct or directly into the gallblad-

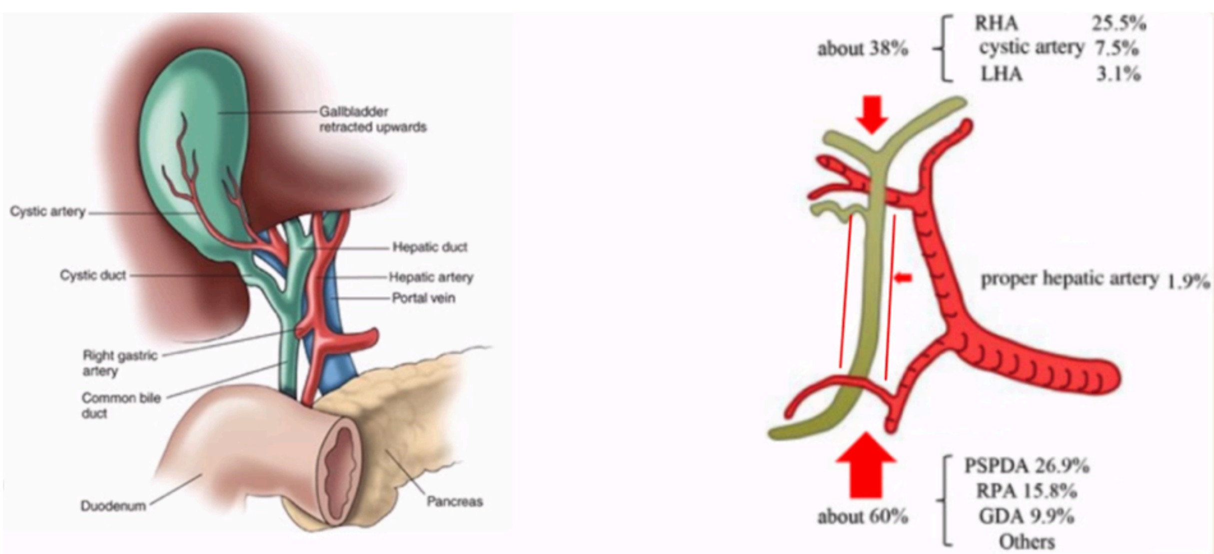

Fig. 13. Normal Biliary Anatomy
Source: (L:) Fig. 10-3 in Resa E. Lewiss RE & DL Theodoro (ND). Hepatobiliary. Web page on Radiology Key. https://radiologykey.com/hepatobiliary/; (R:) Shackelford 2019 (see footnote 1).

[4] De, Anushtup (2023). 6 Historical Milestones in Gall Bladder Surgery. Self-published essay accessible at https://www.linkedin.com/pulse/6-historical-milestones-gall-bladder-surgery-anushtup-de/ (accessed 3/31/24 without Linked-In subscription).

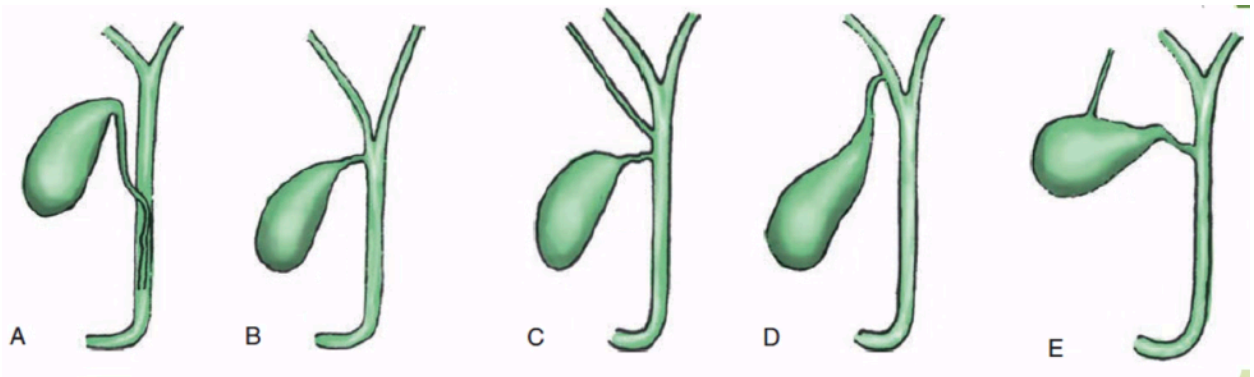

Fig. 14. **A**: Long cystic duct with low fusion with common hepatic duct; **B**: Abnormally high fusion with common hepatic duct (trifurcation); **C**: Accessory hepatic duct; **D**: Cystic duct entering right hepatic duct; **E**: Cholecystohepatic duct
Source: Shackelford 2019 (see footnote 1)

der, and the cystic duct can drain into the right hepatic duct.

The gallbladder itself also varies in shape and size. Variations include a Phrygian cap (**Fig. 15**), which can appear on imaging as a thickened portion of the gallbladder potentially concerning for cancer. Hartmann's pouch might present in the infundibulum, potentially causing Mirizzi syndrome. Other variations include a bilobed gallbladder, resembling an hourglass; a gallbladder with a diverticulum; septations within the gallbladder; duplications of the gallbladder; and gallbladders located on the left side of the liver. (**Fig. 16**)

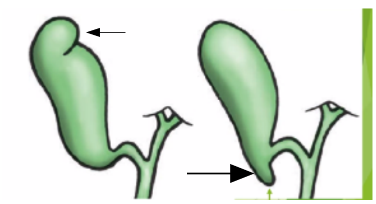

Fig. 15. Phrygian Cap (left, at top); Hartmann Pouch (right, at bottom)
Source: Shackelford 2019 (see footnote 1)

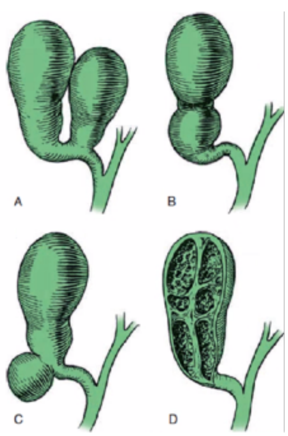

Fig. 16. Some gallbladder variations
Source: Shackelford 2019 (see footnote 1)

The gallbladder can be suspended by mesentery, attaching either at the actual body or the cystic duct, making it crucial to be cautious of the cystic artery within that mesentery. Additionally, there are instances where the gallbladder is entirely embedded within the liver parenchyma. In patients with such gallbladders who develop cirrhosis, imaging might only show a sliver of stones within the liver parenchyma itself.

The cystic artery also exhibits variations, which are vital to recognize to avoid injury to the hepatic arterial system. In 80 to 90% of cases, it originates from the right hepatic artery and can course behind or anterior to the bile ducts. Variations can include duplication of the cystic artery or the presence of an accessory cystic artery.

Imaging for Gallbladder Pathology

Ultrasonography

Fig. 17. Ultrasonography
Source: Shackelford 2019 (see footnote 1)

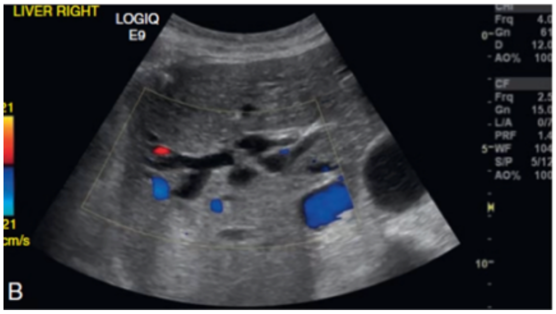

Fig. 18. Ultrasonography
Source: Shackelford 2019 (see footnote 1)

Ultrasonography is the preferred initial choice due to its affordability, safety, speed, and effectiveness, especially with pediatric and pregnant patients. Examples are shown at **Fig. 17** and **Fig. 18**. Key indicators include gallbladder wall thickness, which should generally be less than 4mm. Primary causes for thickening include cholecystitis and, although less common, adenomyomatosis and cancer. Secondary causes unrelated to cholecystitis may include AIDS cholangiopathy, biliary obstruction from infectious strictures, sclerosing cholangitis, hepatitis, pancreatitis, heart failure, hypoalbuminemia, cirrhosis, portal hypertension, and lymphatic obstruction.

The normal range for the diameter of extrahepatic bile ducts is 4 to 8mm, with diameters of 6mm or greater requiring further investigation under the appropriate clinical context. Post-cholecystectomy, the upper limit of normal for these ducts extends to 10mm. Intrahepatic bile ducts should measure 2mm or less, or less than 40% of the accompanying portal vein's diameter.

Doppler ultrasonography can differentiate between vascular and ductal structures. The “parallel channel sign”—simultaneous imaging of dilated hepatic ducts with the adjacent main portal vein of the same size—indicates intrahepatic ductal dilation. (See **Fig. 19**.)

CT

CT imaging provides a more comprehensive visualization of the biliary tree and is more adept at identifying other causes of biliary obstruction. Its sensitivity for detecting choledocholithiasis

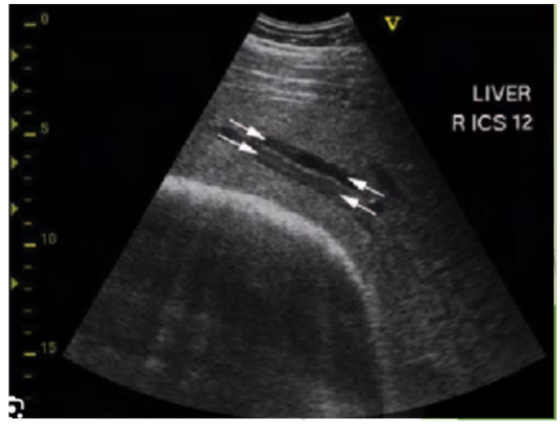

Fig. 19. Doppler ultrasonography showing the parallel channel sign indicating intrahepatic dilation

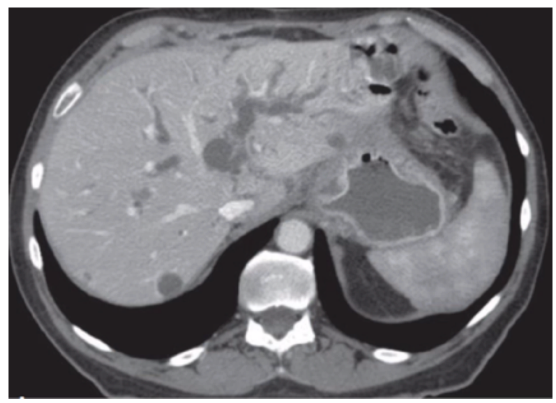

Fig. 20. CT
Source: Shackelford 2019 (see footnote 1)

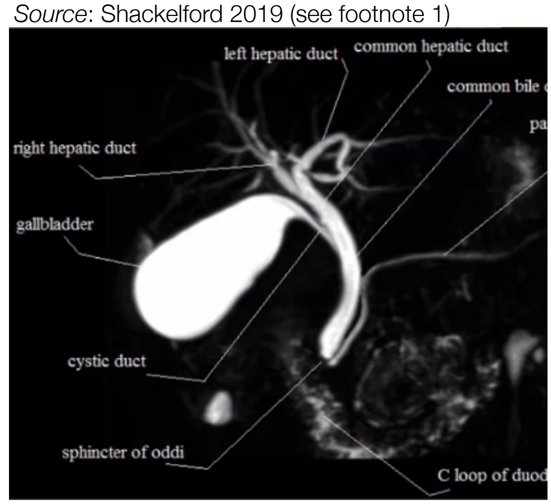

Fig. 21. MRI
Source: https://quizlet.com/cdn-cgi/image/f=auto,fit=cover,h=200,onerror=redirect,w=240/https://o.quizlet.com/0qeTB2ox-Yz8VX4Hsnf2DUQ.png

ranges from 72 to 88% and is invaluable for guiding percutaneous interventions. (See example at **Fig 20**.)

MRI

MRI offers high sensitivity and specificity for biliary tract pathology, capable of detecting stones as small as 2mm and is instrumental in visualizing structural anomalies and leaks. (See example at **Fig. 21**, previous page.)

Hepatobiliary Iminodiacetic Acid (HIDA) Scan

HIDA is considered the gold standard for diagnosing acute cholecystitis. It is highly sensitive and reliable; however, in cases where imaging results are negative but there is a strong clinical suspicion of biliary disease, the next step should involve an ERCP investigation. (See example at **Fig. 22**.)

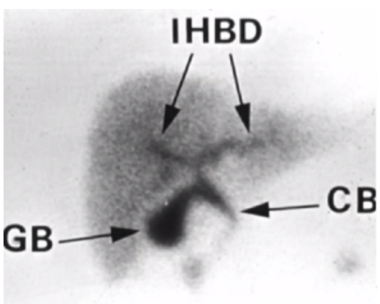

Fig. 22. HIDA
Source: https://www.meddean.luc.edu/lumen/meded/radio/curriculum/procedures/hida_scan1.htm

Biliary Dyskinesia

Biliary dyskinesia is characterized by typical symptoms of biliary colic, such as pain, but without the presence of stones or sludge on imaging. A HIDA scan revealing a decreased ejection fraction of less than 35% is diagnostic. Patients typically undergo cholecystectomy, which results in symptom resolution in 90% of cases.

Sphincter of Oddi Dysfunction

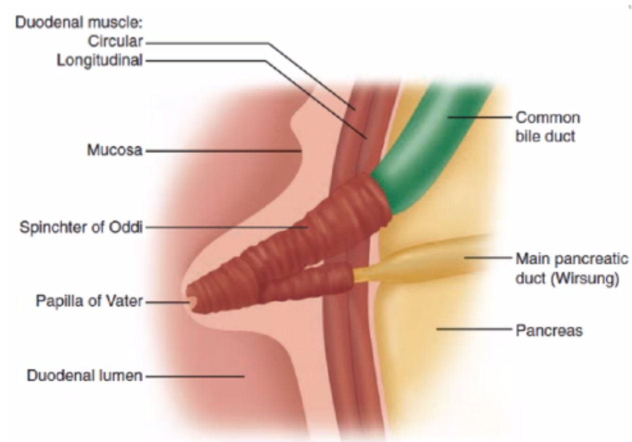

Fig. 23. Sphincter of Oddi
Source: Shackelford 2019 (see footnote 1)

The Sphincter of Oddi (**Fig. 23**) plays a crucial role in regulating the flow of bile and pancreatic juices, preventing the regurgitation of digestive juices from the duodenum and diverting bile into the gallbladder. It measures approximately 4 to 6 millimeters in length, with a resting pressure of 10 millimeters of mercury. Its spontaneous activity is regulated by the interstitial cells of Cajal, with relaxation influenced by hormonal factors such as cholecystokinin (CCK), glucagon, and secretin.

Sphincter of Oddi dysfunction is a relatively rare condition, often diagnosed by exclusion, and is typically encountered post-cholecystectomy (see Zackria & Lopez 2023[5] for a general discussion of post-cholecystectomy syndrome (PCS)). The etiology remains largely unknown, with spasms, strictures, and inappropriate relaxation being considered potential causes. It can lead to significant, debilitating abdominal pain, affecting quality of life and potentially resulting in chronic narcotic use. Risk factors include prior cholecystectomy, gallbladder agenesis, choledochal cysts, prior gallstone lithotripsy, liver transplantation, alcohol use disorder, hypothyroidism, and irritable bowel syndrome (IBS). The condition can cause transaminitis and pancreatitis without an-

[5] Zackria R, Lopez RA (2023). Postcholecystectomy Syndrome. [Updated 2023 Aug 28]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available at: https://www.ncbi.nlm.nih.gov/books/NBK539902/

other identifiable cause, and in severe cases, lead to obstructive jaundice and chronic pancreatitis. In patients with idiopathic chronic pancreatitis, the prevalence of Sphincter of Oddi dysfunction can be as high as 72%.

The Milwaukee classification system identifies three types of Sphincter of Oddi dysfunction:

- Type I includes abdominal pain, abnormal hepatic or pancreatic enzymes on at least two occasions, and dilated common bile duct or pancreatic duct.
- Type II encompasses patients with pain and either enzyme abnormalities or imaging findings.
- Type III involves patients with pain alone.

This classification is crucial for guiding the management and diagnosis of sphincter of Oddi dysfunction.

The gold standard for diagnosing Sphincter of Oddi Dysfunction is ERCP with manometry, where a basal sphincter pressure of greater than 35 millimeters of mercury is diagnostic. (See example at **Fig. 24**.) However, not all centers offer this due to its invasiveness. An alternative is the Nardi test, a morphine-prostigmine provocation test, where 10 milligrams of morphine and 1 milligram of prostigmine are administered. The test is considered positive if the patient experiences reproduction of pain along with a fourfold increase in amylase or lipase levels. However, this test is limited by low specificity and sensitivity. Another diagnostic method is a quantitative HIDA scan, which measures the rate of bile flow to indirectly assess the patency of the Sphincter of Oddi.

Treatment generally involves endoscopic sphincterotomy, particularly beneficial in Type I and Type II dysfunctions. For Type III dysfunction, a Botox trial might be conducted as a diagnostic and therapeutic measure before considering sphincterotomy, provided other diagnoses have been excluded. (See treatment algorithm at **Fig. 25**.)

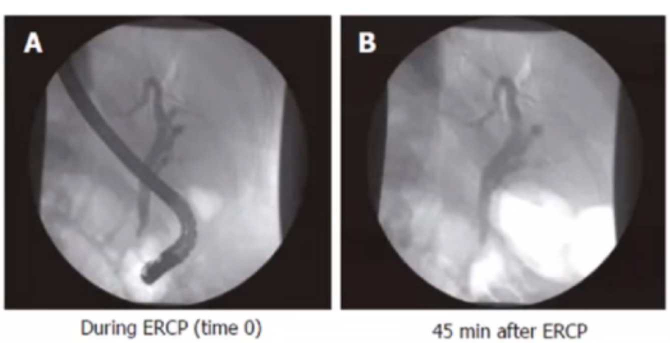

Fig. 24. Sphincter of Oddi dysfunction
Source: Funch-Jensen P, Drewes AM, Madácsy L. Evaluation of the biliary tract in patients with functional biliary symptoms. World J Gastroenterol 2006; 12(18): 2839-2845 [PMID: 16718807 DOI: 10.3748/wjg.v12.i18.2839]

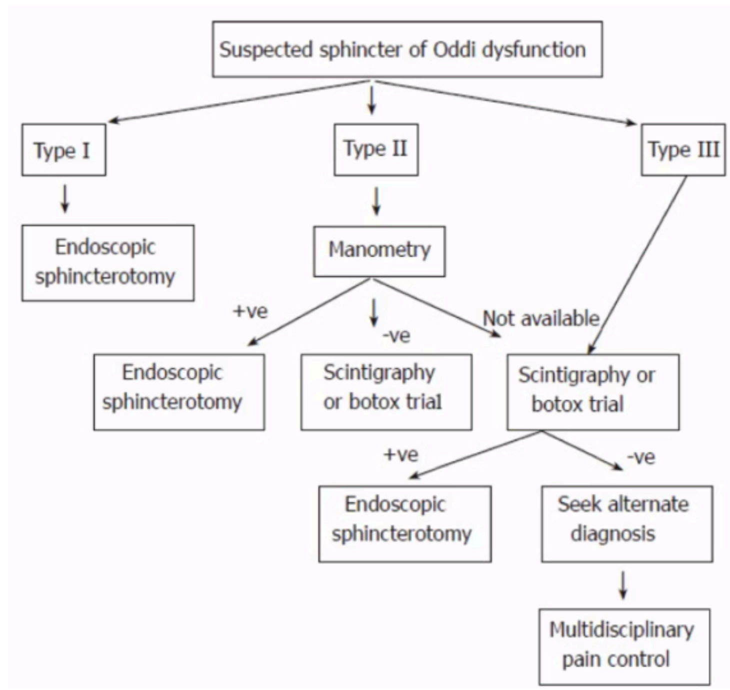

Fig. 25. Sphincter of Oddi: Treatment algorithm
Source: Bistritz L, Bain VG. Sphincter of Oddi dysfunction: managing the patient with chronic biliary pain. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4087924/

Bile Duct Injuries

Though rare, bile duct injuries represent a significant source of morbidity and litigation, especially in the context of cholecystectomy. Initially, when cholecystectomy was performed openly, mortality rates were around 20%. Currently, mortality rates have decreased to 0.2-2.5%, though morbidity remains significant. Bile duct injuries occur at a rate of 0.3-0.7%, predominantly iatrogenic, resulting from trauma (penetrating or blunt) or altered anatomy, with the most common cause being misidentification of the anatomy.

Early identification of these injuries is crucial. Routine intraoperative cholangiography does not decrease the incidence of bile duct injury but is recommended following suspected injury to delineate anatomy. The most common type of injury involves mistaking the common bile duct for the cystic duct, leading to its transection.

Patients with undetected intraoperative injuries might present postoperatively with bile leakage, fever, pain, nausea, elevated liver enzymes, intolerance to oral intake, jaundice, peritonitis, or sepsis. Up to 30% of these cases may present more than two months post-injury, potentially leading to biliary cirrhosis and cholangitis.

If a bile duct injury is identified intraoperatively, the recommended approach is to delineate the anatomy with cholangiography if expertise and support are available on-site. If not, it's advisable to halt further dissection, avoid converting to open surgery, and transfer the patient to a tertiary care center for specialized treatment. If feasible, it's advisable to leave a cholangiogram catheter in place. This allows the receiving team to perform a detailed diagnostic cholangiogram for planning further care and managing postoperative issues.

Following a bile duct injury, investigations are necessary to determine the nature of the injury, such as leaks, fistulas, transections, and their specific characteristics.

Bile duct injuries are categorized according to the Strasberg-Bismuth classification (**Table 1** and **Fig. 26**). This classification includes:

- Leakage from the cystic duct or small accessory ducts, often referred to as the Ducts of Luschka.

Bile duct injury	Bismuth	Strasberg
Cystic duct leak or leaks from small ducts in liver bed	–	A
Occlusion of an aberrant right hepatic duct	–	B
Leak from an aberrant right hepatic duct	–	C
Lateral injury to the common bile duct (<50% of the circumference)	–	D
Common hepatic duct stricture, stump >2 cm	Type I	E1
Common hepatic duct stricture, stump <2 cm	Type II	E2
Hilar stricture with preserved biliary confluence	Type III	E3
Hilar stricture with involvement of confluence	Type IV	E4
Stricture to an aberrant right hepatic duct and to common hepatic duct	Type V	E5

Table 1. Strasberg-Bismuth classification
Source: Table 1 in Pesce A, Palmucci S, La Greca G, Puleo S. Iatrogenic bile duct injury: impact and management challenges. *Clin Exp Gastroenterol*. 2019;12:121-128

- Occlusion or leakage from an aberrant right hepatic duct.
- Lateral injuries to the common bile duct.

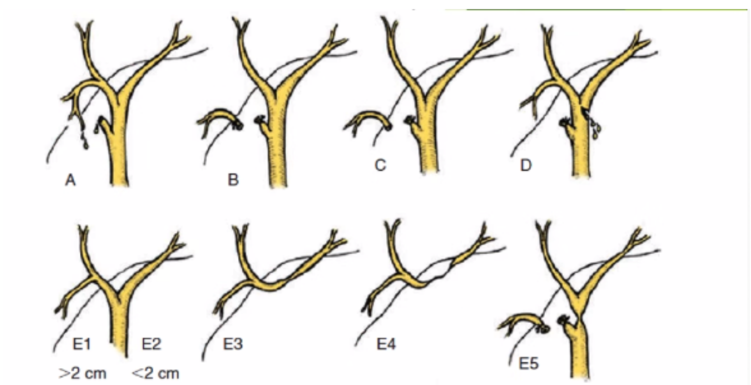

Fig. 26. Strasberg-Bismuth classification
Source: Strasberg, S. M., Hertl, M., & Soper, N. J. (1995). An analysis of the problem of biliary injury during laparoscopic cholecystectomy. Journal of the American College of Surgeons, 180(1), 101–125.

- Various injuries affecting the hilum.

In the event of a major bile duct injury during a laparoscopic cholecystectomy, if repair on-site is possible, several options exist:

- End-to-End Repair: If the ends of the bile duct can be approximated without tension, an end-to-end repair is feasible. This is often performed over a T-tube, where an additional choledochotomy is made to insert the T-tube, and the repair is completed over the tube.

- Hepaticojejunostomy: In cases where there is too much tension for a direct repair, or due to concerns about blood supply and the risk of stricture, a hepaticojejunostomy is preferred over a choledochojejunostomy. This involves rerouting bile flow from the liver to the intestine via a segment of the jejunum.

If the patient is transferred to a tertiary center, imaging should be performed to drain any fluid collections and a percutaneous transhepatic drain may be placed to decompress the biliary system. Typically, a waiting period of four to six weeks is recommended before attempting a definitive repair with hepaticojejunostomy to allow for inflammation to subside and to plan the surgery more effectively.

Preventing bile duct injuries is paramount in gallbladder surgery. The most universally accepted method for prevention is achieving a meticulous critical view of safety. This involves clearing the hepatocystic triangle of fatty tissue to ensure visibility of only two structures entering the gallbladder, exposing the lower third of the cystic plate, and obtaining the "doublet view" (**Fig. 27**) — confirming the critical view of safety from both medial and lateral perspectives.

Surgeons may adopt a practice of taking "time-outs" at critical moments during the procedure:

- Initial Placement of Trocars: To confirm correct anatomical landmarks before starting any dissection.
- Encountering Challenges: If difficulties arise, it's advisable to consider calling in another experienced surgeon for a second opinion.
- Achieving Critical View of Safety: To pause and verify correct identification of structures before ligating anything.

While intraoperative adjuncts like cholangiography, ICG fluorescence, and ultrasound can be beneficial, it is crucial to note that none have been conclusively shown to prevent injuries on their own and should not replace meticulous dissection techniques. Preoperative imaging review is also vital for identifying anatomical variations.

Documenting the critical view of safety through intraoperative photography can be useful, particularly for litigation purposes, and surgeons should be cautious of blind clipping, especially near major ducts, to avoid inadvertent damage.

Cholangiography versus ICG fluorescence

- *Intraoperative Cholangiography (IOC)* has not been shown to significantly reduce bile duct injuries, whether used routinely or selectively, and its utilization often depends on surgeon preference.

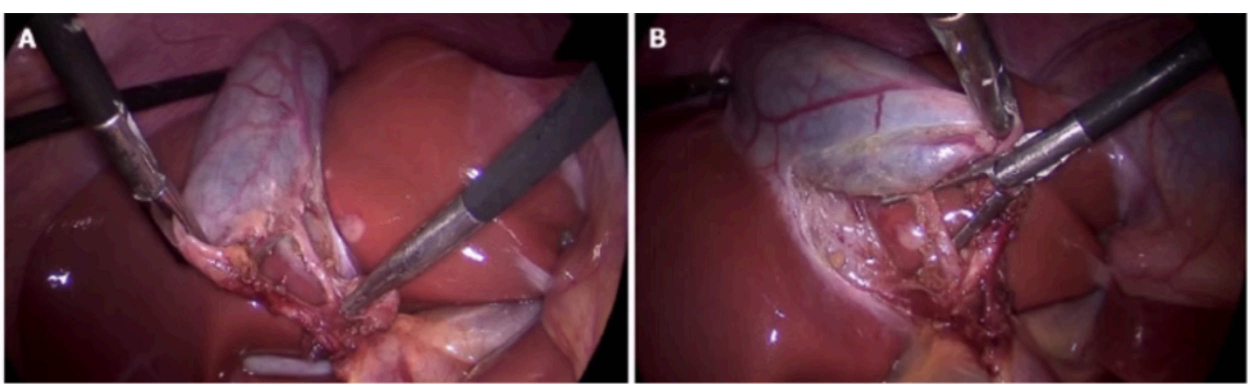

Fig. 27. Doublet view
Source: Gupta V, Jain G. Safe laparoscopic cholecystectomy: Adoption of universal culture of safety in cholecystectomy. World J Gastrointest Surg 2019; 11(2): 62-84 URL: https://www.wjgnet.com/1948-9366/full/v11/i2/62.htm DOI: https://dx.doi.org/10.4240/wjgs.v11.i2.62

- *Indocyanine Green (ICG) Fluorescence* is a newer technique still under investigation. Although no studies have conclusively shown its effectiveness in preventing bile duct injuries, ICG offers advantages such as ease of use, no need for radiation exposure or specialized technical expertise, and the ability to delineate anatomy even before dissection begins. This can be particularly helpful for residents or surgeons in training, providing a visual roadmap to guide early dissection.

The FALCON 2023 international multicenter RCT trial[6] (n=294) indicated that ICG administration allowed surgeons to detect the cystic duct, common hepatic duct, and achieve the critical view of safety nearly twice as fast compared to traditional laparoscopy, without impacting hospital stay or postoperative complications.

In situations with a challenging gallbladder, several intraoperative decisions may be considered:

- Seeking Assistance: An initial step can be to call for help, bringing in another surgeon for a second opinion and assistance, which can be invaluable.
- Evaluating Surgical Necessity: In cases where the gallbladder is severely inflamed and the patient's condition is critical, it's important to assess whether surgery is necessary or if an alternative approach like cholecystostomy might be preferable.
- Considering Conversion to Open Surgery: While laparoscopic skills are emphasized in current surgical training, there might be instances where converting to an open procedure is considered. However, the decision should be based on whether it offers a safer alternative for the patient, not just on the ease of operation.
- Altering the Approach: Changing the dissection technique, such as adopting a top-down approach or dissecting from a different angle, can sometimes offer a safer pathway to achieving the critical view of safety.
- Gallbladder Amputation: In some cases, amputating the gallbladder and working from within can be an effective strategy. Additional intraoperative imaging may aid in this process.
- Recognizing Danger Zones: It's crucial to avoid drifting from the gallbladder wall or into areas that could jeopardize patient safety, such as the Rouviere's sulcus or near the cystic plate, which is close to the middle hepatic vein.

For extremely difficult cases characterized by an “inflammatory frozen hepaticocystic plate” (McElmoyle's shield), attempting to achieve a critical view of safety is discouraged due to the risk of injury. Alternatives include:

- Subtotal Cholecystectomy: This can be fenestrating (opening the gallbladder, ligating the cystic duct from the inside, and possibly leaving a portion of the gallbladder on the liver bed) or reconstituting (closing the gallbladder's neck). Any remaining gallbladder remnants should be ablated to prevent complications.
- Cholecystostomy: Placement of a cholecystostomy tube, either during surgery or in an emergency setting, is another option.

Choledocholithiasis Management:

About 20% of patients undergoing cholecystectomy will have choledocholithiasis. While ERCP is commonly used for treatment, laparoscopic common bile duct exploration (LCBDE) is an alternative that's gaining popularity in the U.S. LCBDE has shown to be as safe as ERCP, with comparable stone extraction rates, reduced costs, shorter hospital stays, and less exposure to anesthesia for patients.

In addressing choledocholithiasis, surgeons have several intraoperative options:

[6] van den Bos, J. et al. (2023). Near-infrared fluorescence cholangiography assisted laparoscopic cholecystectomy (FALCON): an international multicentre randomized controlled trial. Surgical endoscopy, 37(6), 4574–4584. https://doi.org/10.1007/s00464-023-09935-6

- Transcystic or Transcholedochal Common Bile Duct Exploration: This can be augmented with lithotripsy for large or difficult-to-remove stones. A wire basket or balloon under fluoroscopy or direct visualization can facilitate stone extraction. (**Fig. 28**)
- Balloon Sphincteroplasty of the Sphincter of Oddi: This technique can enhance the removal of stones by dilating the bile duct's outlet.

For a transcystic approach:

- The cystic duct is clipped and incised (choledochotomy).
- A guidewire is introduced, followed by a choledochoscope with a working channel.
- A wire basket can be used to retrieve stones.
- If necessary, the incision can be extended to the common bile duct to accommodate stone removal.

Criteria for a transcystic exploration include a cystic duct width of at least 4 millimeters, stone size smaller than 8 millimeters, and fewer than six stones.

A transcholedochal approach involves an incision on the common bile duct itself, bearing higher risks of bile leaks and being suitable only if the common bile duct is at least 8 millimeters wide to minimize stricture risks. This method requires more advanced laparoscopic suturing skills.

Laparoscopic Reverse Cholangiopancreatography is another described technique for accessing and clearing the bile ducts, mirroring procedures typically done percutaneously:

A balloon catheter is inserted into the common bile duct.

The Sphincter of Oddi is dilated and maintained in dilation for at least five minutes. Caution is advised to avoid using a balloon larger than the bile duct to prevent damage.

Post-dilation, the balloon is deflated, repositioned, and inflated again to flush or push stones into the duodenum.

A cholangiogram is performed post-procedure to ensure all stones have been cleared and none have moved up into the proximal biliary tree.

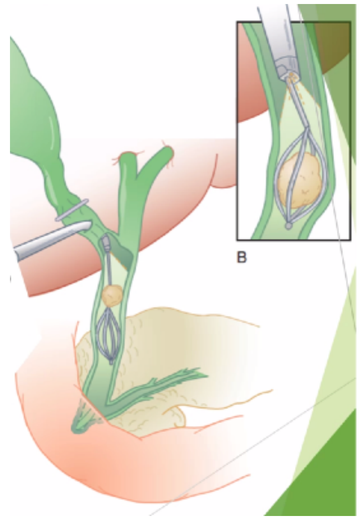

Fig. 28. Transcystic or Transcholedochal Common Bile Duct Exploration
Source: Schwab, B., E. S. Hungness, N. J. Soper (2019): Chapter 109 - 'Management of Common Bile Duct Stones" - in Yeo, C.J. (Ed): *Shackelford's Surgery of the Alimentary Tract*, 2 Volume Set (Eighth Edition), Elsevier, 2019, pp 1286-1293, https://doi.org/10.1016/B978-0-323-40232-3.00109-6.

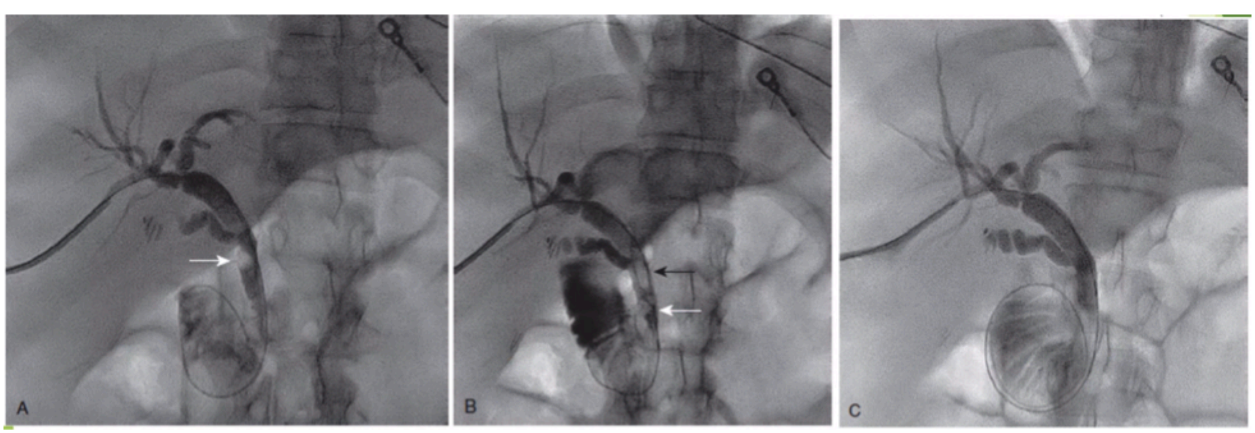

Fig. 29. Laparoscopic Reverse Cholangiopancreatography
Source: Shackelford 2019 (see footnote 1)

This technique, often utilizing a Fogarty catheter, is termed "reverse" because it achieves similar outcomes to ERCP and sphincterotomy but from a different, more proximal approach in the biliary tract. **Fig. 29** (previous page) shows an example.

In cases where patients are critically ill and not candidates for surgery, or when a palliative procedure is required for decompression, several options are available:

- Cholecystostomy: Direct drainage of the gallbladder can alleviate symptoms.
- External Biliary Drains: These can be used to manage biliary obstructions.
- Endoscopic retrograde cholangiopancreatography-guided transpapillary gallbladder drainage (ERGD): This involves transpapillary drainage with the placement of double pigtail stents in both the common bile duct and the gallbladder, facilitating decompression.
- Percutaneous cholecystolithotomy with Lumen-Apposing Metal Stents (LAMS): Interventional endoscopy can deploy these stents to create a fistula between the duodenum and gallbladder, aiding in decompression. However, this method may have high recurrence rates and typically requires multiple procedures, making it less definitive than surgery. See **Figs. 30** and **31**.

For patients with altered digestive anatomy, such as those who have undergone Roux-en-Y procedures, and develop bile duct stones:

- Surgical Removal: If the gallbladder is present, it can be surgically removed, followed by laparoscopic bile duct exploration or laparoscopic-assisted ERCP.
- Device-Assisted ERCP: For patients without a gallbladder or when surgery is not indicated, a double balloon ERCP can access the pancreatico-biliary limb, though it has a moderate success rate and potential complications such as GI bleeding, pancreatitis, or perforation.
- Laparoscopic-Assisted ERCP: Offers a higher therapeutic success rate. In cases of failure, a G-tube may be placed for later attempts using a pediatric gastroscope.

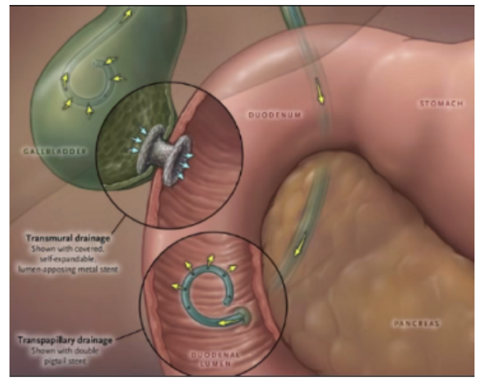

Fig. 30. Lumen-Apposing Metal Stents (LAMS)
Source: Shackelford 2019 (see footnote 1)

- Rendezvous Technique: Involves accessing the cystic duct, leaving a guidewire into the duodenum for the endoscopist to perform ERCP via a snare method.

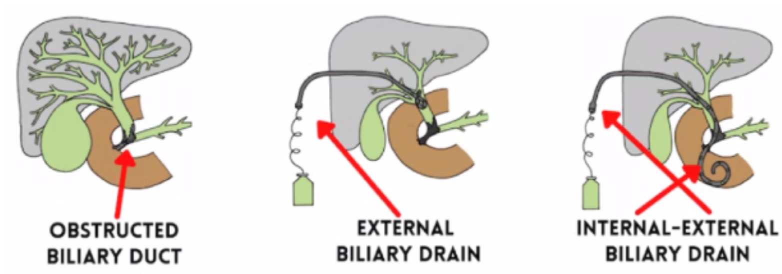

Fig. 31. Percutaneous cholecystolithotomy with LAMS
Source: Shackelford 2019 (see footnote 1)

Each technique has its specific indications, success rates, and potential complications. The choice of procedure depends on the patient's condition, anatomical considerations, and the expertise available at the treating institution. See **Fig. 32** (next page) for the algorithm.

EDGE

An intriguing investigational technique that has caught attention is the EDGE (Endoscopic Ultrasound Guided Transgastric ERCP) procedure (Fig. 33). This approach is designed for patients with altered gastrointestinal anatomy, such as post-Roux-en-Y gastric bypass. The procedure involves creating a fistula between the gastric pouch and the gastric remnant or jejunal loops, resulting in either a gastro-gastro (GG) or jejuno-jejunal (JJ) fistula. Through this newly created pathway, lumen-apposing metal stents are placed to facilitate the performance of ERCP.

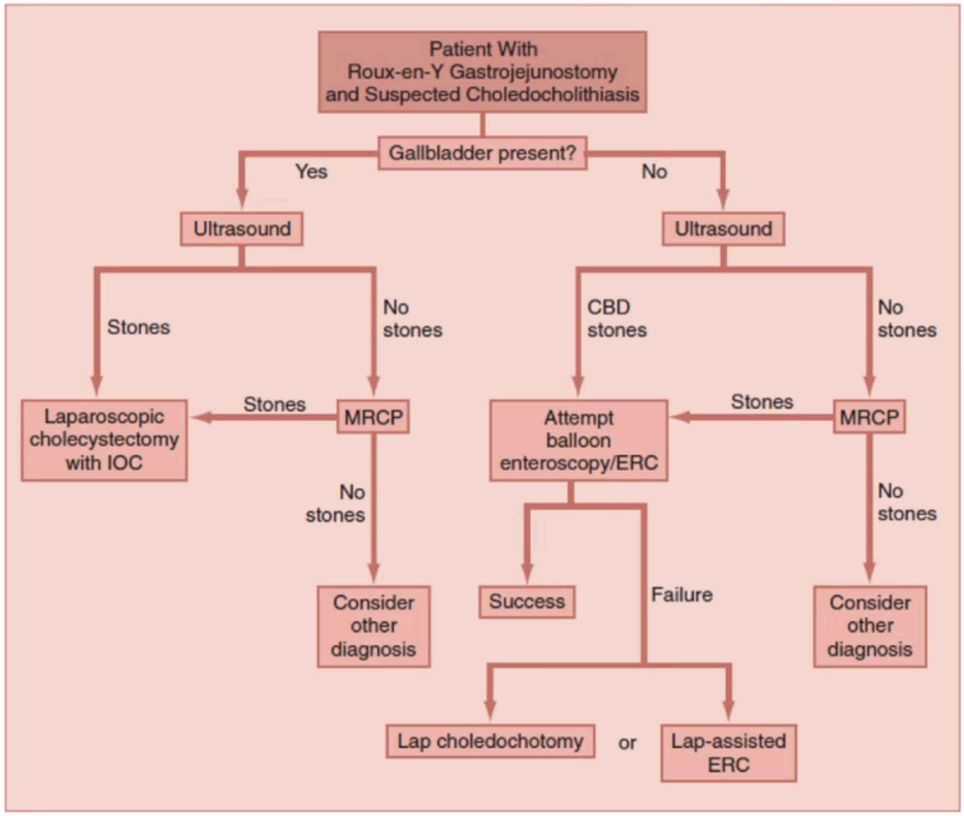

Fig. 32. Procedural algorithm
Source: Shackelford 2019 (see footnote 1)

While the EDGE procedure boasts a technical success rate of approximately 90%, it's not without significant risks. Complications can be substantial, including the potential for persistent fistulas even after stent removal, which should ideally close on their own but may not always do so. Other reported complications include stent migration, persistent or recurrent fistulas, perforations, and ulcer formations, culminating in a complication rate of up to 28%.

Given these considerations, the EDGE procedure is generally viewed as a last-resort option for patients with a 'hostile abdomen', where conventional approaches have failed or are not feasible due to complex anatomical changes or extensive adhesions.

Conclusions

This paper has reviewed current practices, investigational techniques, and decision-making processes in the management of biliary tract diseases, particularly focusing on laparoscopic cholecystectomy, bile duct exploration, and interventions for choledocholithiasis in patients with altered anatomy. The goal has been to provide insights into the evolving landscape of biliary surgery.

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Bibliography

Bistritz L, Bain VG. Sphincter of Oddi dysfunction: managing the patient with chronic biliary pain. World J Gastroenterol. 2006;12(24):3793-3802. doi:10.3748/wjg.v12.i24.3793

Funch-Jensen P, Drewes AM, Madácsy L. Evaluation of the biliary tract in patients with functional biliary symptoms. World J Gastroenterol 2006; 12(18): 2839-2845 [PMID: 16718807 DOI: 10.3748/wjg.v12.i18.2839]

Garg S, Dutta U, Chaluvashetty SB, Kumar KH, Kalra N, Sahni D, Aggarwal A. The anatomy of the cystic duct and its association with cholelithiasis: MR cholangiopancreatographic study. Clin Anat. 2022 Oct;35(7):847-854. doi: 10.1002/ca.23856. Epub 2022 Apr 7. PMID: 35316537.

Li ZZ, Guan LJ, Ouyang R, Chen ZX, Ouyang GQ, Jiang HX. Global, regional, and national burden of gallbladder and biliary diseases from 1990 to 2019. World J Gastrointest Surg. 2023;15(11):2564-2578. doi:10.4240/wjgs.v15.i11.2564

Litynski GS. Laparoscopy--the early attempts: spotlighting Georg Kelling and Hans Christian Jacobaeus. JSLS. 1997;1(1):83-85.

Polychronidis A, Laftsidis P, Bounovas A, Simopoulos C. Twenty years of laparoscopic cholecystectomy: Philippe Mouret--March 17, 1987. JSLS. 2008;12(1):109-111.

Sarawagi R, Sundar S, Gupta SK, Raghuwanshi S. Anatomical Variations of Cystic Ducts in Magnetic Resonance Cholangiopancreatography and Clinical Implications. Radiol Res Pract. 2016;2016:3021484. doi:10.1155/2016/3021484

van den Bos J, Schols RM, Boni L, Cassinotti E, Carus T, Luyer MD, Vahrmeijer AL, Mieog JSD, Warnaar N, Berrevoet F, van de Graaf F, Lange JF, Van Kuijk SMJ, Bouvy ND, Stassen LPS. Near-infrared fluorescence cholangiography assisted laparoscopic cholecystectomy (FALCON): an international multicentre randomized controlled trial. Surg Endosc. 2023 Jun;37(6):4574-4584. doi: 10.1007/s00464-023-09935-6. Epub 2023 Feb 27. PMID: 36849564.

Zaman JA, Singh TP. The emerging role for robotics in cholecystectomy: the dawn of a new era?. Hepatobiliary Surg Nutr. 2018;7(1):21-28. doi:10.21037/hbsn.2017.03.01