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Difficult choledocholithiasis. Literature review

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The incidence of stones in the common bile duct in patients with symptomatic gallstone disease varies significantly and depends on age, ranging from 5 % to 33 %. In 85—90 % of cases, choledocholithiasis is effectively treated with endoscopic papillotomy (EPT) and lithoextraction, which is currently considered the standard method for managing this pathology. However, in 10—15 % of cases, choledocholithiasis is technically challenging for endoscopic treatment, requiring alternative methods and specialized equipment. This research examines the epidemiological aspects related to the increasing detection rate of choledocholithiasis, which is attributed to advancements in modern diagnostic techniques. Particular emphasis is placed on etiological factors such as genetics, obesity, and dietary habits that enhance bile lithogenicity. The pathogenesis section elucidates the mechanisms underlying primary and secondary stone formation in the bile ducts and their physiological impacts, including such complications as acute cholangitis, biliary sepsis, cholestatic hepatitis, and biliary cirrhosis of the liver. Distinct focus is placed on the criteria for difficult choledocholithiasis, encompassing stone characteristics, location, altered biliary anatomy, and the patient's general condition. Diagnostic techniques include laboratory and instrumental investigations, particularly ultrasound, magnetic resonance cholangiopancreatography, endoscopic retrograde cholangiopancreatography, and endoscopic ultrasound. The treatment section emphasizes the importance of timely stone removal to prevent complications. Modern treatment options are discussed, including both conservative and surgical methods such as endoscopic procedures and laparoscopic surgeries. The significance of an interdisciplinary approach to the diagnosis and treatment of choledocholithiasis and its many manifestations is emphasized.

Difficult choledocholithiasis remains a relevant issue in hepatobiliary surgery, and its effective treatment requires an individualized and multidisciplinary approach, involving endoscopic and laparoscopic technologies.

Keywords
difficult choledocholithiasis, choledochoscopy, choledocholithoextraction, mechanical jaundice, endoscopic retrograde cholangiopancreatography.

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Choledocholithiasis is a complication of gallstone disease, characterized by the formation of stones in the common bile duct (CBD) or their migration from the gallbladder. Most publications classify choledocholithiasis as difficult when it cannot be managed by primary endoscopic techniques due to specific criteria and signs (Table 1) [58, 67, 69, 79].

Some sources also consider the qualification and experience of the endoscopist as a criterion for difficult choledocholithiasis [78].

Etiology, epidemiology and pathogenesis of choledocholithiasis

In the early 1960s, choledocholithiasis was diagnosed in about 6—7 % of patients with gallstone disease. However, in the past two decades, the incidence has increased to 20—30 % [66, 70]. At present, choledocholithiasis develops in 5—33 % of patients with gallstone disease, and in 10—15 % of these cases, it presents challenges. This pertains to the advancement and accessibility of screening and non-invasive diagnostic techniques, in addition to nutritional influences [60].

Choledocholithiasis represents a significant issue in contemporary hepatobiliary surgery, as it accounts for 40 % of cases with obstructive jaundice [18, 45].

Common bile duct (CBD) stones may result in cholestasis and mechanical jaundice syndrome. If these conditions are not diagnosed promptly, they can progress to severe complications such as acute cholangitis and biliary sepsis [26, 33, 35].

Table 1. **Criteria for difficult choledocholithiasis** [12, 24, 35, 58, 79]

Category	Condition	Basis
Characteristics of bile duct stones	Large stone (> 15 mm) Multiple choledocholithiasis (> 3 stones, size > 10 mm) Atypical form of bile duct stones (barrel-shaped)	Indication for lithotripsy Impossibility of stone extraction with the Dormia basket
Location of bile duct stones	Intrahepatic ducts Bile duct stones above the stricture of the duct Mirizzi syndrome	Difficulty in reaching bile duct stones
Altered anatomy	Stenosis of the esophagus, stomach, or duodenum Condition after gastrectomy and Billroth II gastric resection Parapapillary diverticulum Vitreous edema of the duodenum Tubular stenosis of the distal common bile duct in chronic pancreatitis	Difficulty in reaching the major duodenal papilla
Patient condition	Various terminal states Significant coagulation disorders	High risk of fatal complications

Numerous publications identify genetics, excessive body weight, and poor nutrition as the primary etiological factors contributing to cholelithiasis, as they increase the risk of bile lithogenicity and stone formation [57, 70]. Gallstones and choledocholithiasis are associated with the patient's age, hypothyroidism, chronic cholangitis, and parasite infestation of the bile ducts [61].

The primary pathogenetic cause of choledocholithiasis is the presence of stones in the common bile duct, leading to obstructed bile flow and the subsequent onset of cholestasis and mechanical jaundice of varying severity [24, 33].

Based on the formation process of bile duct stones, primary stones are identified as those formed directly inside the bile ducts, whereas secondary stones originate from the gallbladder or cystically dilated intrahepatic bile ducts [68, 70]. Primary formation of stones in the bile duct occurs in about 1.0—5.7 % of patients with gallstone disease. This is typically linked to disrupted pigment metabolism, alterations in bile composition, inflammation of the bile ducts, and bile stasis [24, 33].

Primary bile duct stones, which are not associated with the gallbladder, are more common in Southeast Asian countries. The incidence of intrahepatic lithiasis varies significantly, ranging from 0.38 to 18 % (up to 50 % in Taiwan) [14, 60, 70]. Secondary bile duct stones are prevalent in most Western countries [70].

The passage of stones from the gallbladder to the bile duct is facilitated by its dilation or the formation of a cholecystocholedochal fistula (Mirizzi syndrome). The incidence of residual choledocholithiasis ranges from 2 to 10 %, whereas the recurrence rate varies from 1 to 7 % [4, 30, 37].

Solitary CBD stones are observed in 30 % of patients, whereas numerous stones are seen in 70 % of patients. Stones are detected in the common bile duct in 60—70 % of patients, in the intrahepatic bile ducts in 5—10 %, and in the major duodenal papilla (ampulla of Vater) in 15—25 %. Approximately one-third of choledocholithiasis patients, particularly those with stones in the distal segment of the CBD, are asymptomatic, whereas stones located in the terminal segment of the CBD are often impacted and result in significant clinical manifestations of mechanical jaundice [40, 78].

Diagnosis of difficult choledocholithiasis

The primary objective in managing both uncomplicated and complicated choledocholithiasis is prompt diagnosis, which minimizes the incidence of unnecessary invasive diagnostic interventions. ESGE (European Society of Gastrointestinal Endoscopy, 2019) and ASGE (American Society for Gastrointestinal Endoscopy, 2019) guidelines advocate for choledocholith extraction in all patients with either symptomatic or asymptomatic choledocholithiasis [29, 33, 70].

Due to the complexity of hepatopancreatobiliary surgery, a series of procedures are necessary to establish an accurate diagnosis and select the appropriate treatment technique. The process begins with the collection of anamnestic data and laboratory assessments, which include a total blood count (leukocytosis, left shift in the leukocyte formula, elevated erythrocyte sedimentation rate), a biochemistry blood test (total and direct bilirubin, total protein, glucose, potassium, sodium, calcium, creatinine, urea, amylase, liver transaminases, -glutamyl transpeptidase,

alkaline phosphatase), a coagulogram, procalcitonin, and other inflammatory markers, along with a general urinalysis. These procedures facilitate the assessment of primary liver functions and the identification of pathological syndromes requiring correction. Literature indicates that normal liver test readings suggest the absence of hepatic stones. Biochemical markers, namely total and direct bilirubin levels, γ-glutamyl transpeptidase, and alkaline phosphatase, serve as significant indications of mechanical jaundice, cytolysis, and choledocholithiasis [23, 67, 69].

Clinically, choledocholithiasis may present as pain in the right subcostal region (a symptom of acute cholecystitis), symptoms of mechanical jaundice (dark urine and acholic stool), often without pruritus, and occasionally as Charcot's triad (fever, jaundice, and biliary colic) [38].

Instrumental examination methods, particularly routine ultrasonography (US), are employed to diagnose choledocholithiasis due to their availability, non-invasiveness, cost-effectiveness, and relevance in assessing liver diseases [11, 54, 60]. A high sensitivity of ultrasound for detecting gallstones has been established (about 96 %), which is explained by the proximity of the gallbladder to the abdominal wall and the absence of gases between the sensor and the wall of the organ [22, 77]. The effectiveness of ultrasound in detecting CBD stones is about 50 %. The presence of stones predominantly in the distal and terminal segments of the common bile duct, which are inadequately visible by ultrasound, accounts for this, along with the physician's proficiency in transabdominal ultrasound diagnostics [11, 60]. Choledocholithiasis can be inferred from indirect ultrasound indicators: dilation of the bile ducts, indicative of biliary hypertension, and the presence of numerous small gallstones that frequently migrate into the common bile duct. Clinical and laboratory data, together with ultrasound diagnostic results, serve as primary diagnostic criteria for identifying signs of choledocholithiasis, as confirmed by the ESGE guidelines [9, 39, 67, 79]. Three risk groups for choledocholithiasis were established based on these findings (Table 2) [9, 66].

Computed tomography (CT) is widely used in abdominal surgery and serves as a secondary diagnostic method for choledocholithiasis. However, its effectiveness without contrast is only marginally superior to ultrasound and considerably less effective than magnetic resonance imaging [55]. Consequently, CT diagnostics for suspected choledocholithiasis is conducted using contrast, markedly enhancing its effectiveness and specificity. Literature indicates that CT with contrast is helpful in 69—96 % of choledocholithiasis cases. However, its sensitivity diminishes with small biliary stones (< 5 mm) in patients of older age groups and with a low calcium concentration in the stones [41, 47, 57].

A few decades ago, endoscopic retrograde cholangiopancreatography (ERCP) was extensively employed for diagnostic purposes and was regarded as the gold standard in diagnosing biliary tract pathologies [25, 54]. ERCP, when combined with endoscopic papillosphincterotomy, is an exceptionally successful diagnostic and treatment method for biliary tract disease [1, 73, 75]. The technique is used to detect gallstones, CBD stones, and CBD strictures. This procedure enables the examination of the gastric and duodenal mucosa, the bile duct, and the collection of a pure bile or pancreatic juice sample for microbiological (culture), cytological, and biochemical study [66]. An increasing number of studies emphasize the necessity for clear indications for such a procedure [54, 57]. A clear indication for ERCP is the presence of jaundice and bile duct stones detected during ultrasound. Some authors consider acute pancreatitis, acute cholecystitis, and purulent cholangitis with septic complications as contraindications to ERCP.

ERCP is generally regarded as an effective and safe diagnostic and therapeutic procedure. However, such complications as pancreatitis, bleeding from a papillotomy site, duodenal perforation, and cholangitis may arise, occurring at a frequency of 8—12 %, even when conducted by a highly skilled endoscopist. Under the ESGE and ASGE guidelines, ERCP should be performed only in cases of morphological confirmation of choledocholithiasis and in patients exhibiting clinical signs of cholangitis [21, 25, 79].

Currently, magnetic resonance cholangiopancreatography (MRCP) and endoscopic ultrasound diagnostics (endo-US) are the most accurate methods for detecting bile duct stones and are recommended for patients at «high» and «moderate» risk of

Table 2. **Predictors of choledocholithiasis**
(American Society of Gastrointestinal Endoscopy, 2019)

Predictors	Description
Very strong	Common bile duct stone on ultrasound Clinical manifestations of cholangitis Elevated total bilirubin level > 4 mg/dL
Strong	Dilated common bile duct on ultrasound (> 6мм) Elevated total bilirubin level (1.8—4.0 mg/dL)
Moderate	Elevated LFTs (ALT, AST Age > 55 years Clinical manifestations of biliary pancreatitis

choledocholithiasis [57]. MRCP is regarded as the most accurate non-invasive (non-endoscopic) method to detect bile duct stones, with high sensitivity (85—92 %) and specificity (93—97 %) [41, 60].

The research indicates that both methods are highly specific and informative but have a number of disadvantages. MRCP is contraindicated in patients with pacemakers, other metallic implants, obesity, and claustrophobia. Endo-ultrasound is marked by limited prevalence, high equipment costs, minimal invasiveness, and considerable challenges associated with altered gastrointestinal structure [70].

Invasive diagnostic techniques include intraoperative cholangiography and percutaneous transhepatic cholangiography, whose specificity is comparable to that of ERCP and MRCP. Nonetheless, they have some disadvantages. Research indicates that the incidence of bile duct stone detection during routine intraoperative cholangiography in patients with gallstone disease is 10—12 %. However, this technique has not gained popularity due to the greater availability of non-invasive diagnostic methods, which are continually improving in accuracy [21, 23].

Consequently, in diagnosing choledocholithiasis and difficult choledocholithiasis, it is essential to employ all available diagnostic methods and their combinations, contingent upon the particular clinical case and cost viability.

Treatment of difficult choledocholithiasis

Endoscopic methods of treatment are more often used in patients with choledocholithiasis. According to the literature, ERCP is one of the most complex endoscopic procedures. It was first performed in 1968 as an invasive diagnostic manipulation [39]. It is important that ERCP can easily transform from a diagnostic procedure into a therapeutic one. Such invasions include endoscopic papillosphincterotomy (EPST), endoscopic mechanical lithoextraction, and endoprosthesis of the bile ducts (bouginage and stenting), which are most often performed together and used in complex treatment [79]. Endoscopic papillosphincterotomy was first independently described in 1974 in Germany and Japan. Initially, it was used to remove residual or recurrent CBD stones after cholecystectomy with or without choledochotomy. Choledocholithiasis is the most common indication for conducting EPST. In patients with acute purulent cholangitis, usually caused by a stone, the method of choice is urgent endoscopic retrograde cholangiography with EPST [35]. When ERCP and EPST are introduced into clinical practice for the diagnosis and treatment of patients with the appropriate profile, it significantly improves the results of treating this pathology, particularly in patients with severe concomitant pathology [51, 66, 79]. According to various sources, the efficiency of papillosphincterotomy reaches 90 % depending on the experience of the endoscopist, the clinical case, and the presence of signs of difficult choledocholithiasis [66, 79]. Complex cannulations, such as parapapillary diverticula and altered anatomy of the upper parts of the digestive tract, typically lead to difficulties in performing EPST. Although this operation is considered quite safe, the complication rate is 5.0—9.8 % [7, 75]. According to the classification of complications after endoscopic transpapillary interventions (P. B. Cotton, C. B. Williams, 1996), the following complications are most common: bleeding (0.3—2 %), perforation of the duodenum (0.1—1.1 %), post-papillotomy pancreatitis (1.3—6.7 %), and mortality, which is 16—18 % [10]. In cases of difficult choledocholithiasis, ERCP and EPST are usually not enough; mechanical, balloon lithoextraction, electrohydraulic and laser lithotripsy, and extracorporeal shock wave therapy (EUHL) are used instead [12, 50].

Endoscopic papillary balloon dilation (EPBD), also known as papillosphincteroclasy, is a procedure for the extraction of CBD stones, introduced in the 1980s as a substitute or adjunct to EPST, particularly for difficult choledocholithiasis. Staritz et al. [63] reported that during EPBD, the sphincter of Oddi was dilated to 15 mm, facilitating the extraction of biliary stones. Nonetheless, about 40 % of patients required either EPST or mechanical lithoextraction. In 2003, Ersoz et al. [19] began to use larger-diameter balloons to dilate the sphincter of Oddi to 20 mm, which markedly enhanced the outcomes of lithoextraction in difficult choledocholithiasis, particularly with large stones, without employing lithotripsy techniques. The primary benefit of this technique is that it maintains the integrity of the sphincter of the major duodenal papilla. Furthermore, EPBD can be used in patients with considerable coagulopathy and abnormal anatomy of the upper digestive tract. Nevertheless, its implementation has been limited due to a substantial incidence of postoperative acute pancreatitis [17].

To enhance the outcomes of choledocholithoextraction, the majority of researchers use a combination of EPBD and minimal EPST, thereby mitigating the risks of perforation, severe hemorrhage, and cholangitis. ESGE and ASGE guidelines indicate that the principal technique for lithoextraction in difficult choledocholithiasis is partial EPST alongside EPBD [37].

Mechanical lithotripsy is the predominant technique for the fragmentation and choledocholithoextraction of stones. Riemann et al. first described it in 1982 [52]. In cases of difficult choledocholithiasis, where lithoextraction using Dormia baskets or balloons has proven ineffective, this procedure typically takes place after EPST. The research indicates that choledocholithoextraction is successful in 90 % of patients, particularly for large stones (> 20 mm) and is associated with a low complication rate [72]. The indications for this treatment method include solitary stones > 10—15 mm in diameter, < 10 mm stones in the presence of a constricted terminal segment of the common bile duct, numerous stones that occlude the hepatic choledochus and are in close proximity to one another, and the preservation of the sphincter apparatus of the major duodenal papilla in young patients with choledocholithiasis [78]. Mechanical lithotripsy is contraindicated in cases with dense, immovable stones that are firmly attached to the duct walls, particularly when accompanied by jaundice, purulent cholangitis, intrahepatic lithiasis, or considerable dilation of the intrahepatic ducts. Mechanical lithotripsy can be performed in a single session or several phases, contingent upon the size and number of stones and the technical specifications of the procedure [74]. Mechanical lithotripsy is employed alongside balloon dilation of the sphincter of Oddi in patients with large stones [48]. The dimensions of the stones designated for destruction vary significantly, ranging from 6 to 40 mm. The effectiveness of mechanical lithotripsy for stones measuring < 20 mm in diameter is 85—100 %, but for stones > 20 mm, it is 55—68 % [39, 48]. A retrospective study conducted by Lee et al. revealed that stones lodged in the ampulla of Vater, stones > 30 mm in diameter, and variations in the diameters of the common bile duct and the stone are risk factors for unsuccessful mechanical choledocholithoextraction, thereby requiring supplementary lithoextraction techniques [32]. 209 patients with CBD stones underwent mechanical lithotripsy [6, 57]. Numerous stones were discovered in 50 % of the patients. The stones varied in size from 4 to 8 mm, with the majority being between 10 and 19 mm in diameter. About one-third of patients presented with stone diameters of ≥ 20 mm. The success rate of lithotripsy was 87.6 %. Stones with a diameter of ≥ 20 mm were fragmented in 79.1 % of cases, whereas for stones with a diameter of ≥ 25 mm, mechanical lithotripsy achieved success in 67.6 % of cases. Despite the relative simplicity and availability of this procedure, there are a number of contraindications: 1) Acute myocardial infarction; 2) acute disruption of cerebral blood circulation; 3) diseases and conditions in which endoscopic manipulation is contraindicated; 4) presence of acute destructive pancreatitis of non-biliary etiology; 5) peritonitis; 6) inflammation of the bile ducts with septic complications; 7) significant coagulation disorders [57].

Technical issues during the procedure, such as damage to the lithotriptor basket or traction string or the entrapment of the lithotriptor basket with a stone in the distal segment of the CBD, typically cause complications following manipulation. This is because the lithotriptor's insufficient destructive power prevents the extraction of the stone. Numerous studies indicate that the overall complication rate ranges from 3 % to 34 % [27, 37, 57]. Currently, the preferred method for treating difficult choledocholithiasis is mechanical lithotripsy, especially when standard choledocholithoextraction proves inadequate and requires a specialized approach [32, 57].

Cholangioscopy-guided lithotripsy is conducted using two primary techniques: electrohydraulic and laser, originally introduced in 1977 and 1986, respectively, and subsequently employed without cholangioscopy [27, 32, 76]. Endoscopic cholangioscopy is an efficacious diagnostic technique and an integral part of surgical strategies for managing difficult choledocholithiasis [57].

There are three main types of peroral cholangioscopy (POC):

1) Two-operator peroral cholangioscopy («Mother-baby»), which requires a duodenoscope and a cholangioscope operated by two endoscopist surgeons. The cholangioscope is inserted into the working channel of the duodenoscope, and the bile ducts are examined. Nowadays, this technique is rarely used due to the high cost of the equipment, its poor durability, and the need for two experienced operators [41].

2) Single-operator peroral cholangioscopy (SpyGlass Direct Visualization System) was developed by Boston Scientific Corp. in 2005. Currently, the third generation of these systems is available. This cholangioscope provides a clear picture, a 30° angle of view in any direction, two irrigation channels, and a working channel with a diameter of 1.2 mm, which ensures lithotripsy and other manipulations. The main advantages are the ability to control the duodenoscope and cholangioscope at the same time, greater flexibility, and significantly greater functionality compared to the two-operator system [41].

3) Direct peroral. This system is an ultra-thin endoscope. Initially, it was used in pediatrics and during transnasal operations. The main advantages are maneuverability, multifunctionality, and the presence of one operator. Difficulties may arise in the

cannulation of the major duodenal papilla, which requires the use of conductors, balloon catheters, guide probes, etc. to stabilize the endoscope. Another drawback of this method is the 5—6 mm diameter of these endoscopes, which typically necessitates EPST or balloon dilation of the sphincter of Oddi. This, in turn, lengthens the intervention duration and increases the risk of complications [39].

Therefore, the development and availability of endoscopic cholangioscopy have led to the increased use of electrohydraulic and laser lithotripsy for difficult choledocholithiasis, since visualization is crucial for successful choledocholithoextraction [2, 5, 11]. The ESGE guideline recommends cholangioscopic lithotripsy (laser or electrohydraulic) as an effective and safe treatment for difficult choledocholithiasis [37].

Electrohydraulic lithotripsy (EHL) fundamentally involves the generation of high-frequency hydraulic pressure waves, which are absorbed by the stone, leading to its disintegration [17, 50]. Electrohydraulic lithotripsy was formerly conducted under fluoroscopic guidance. However, direct cholangioscopic visualization is now favoured, markedly decreasing the risk of biliary perforation [17, 47, 50].

Laser lithotripsy (LL) involves directing a laser beam of a certain wavelength onto the stone's surface, resulting in wave-like fragmentation comparable to laser ablation of tumours [20, 39]. Similar to electrohydraulic methods, laser lithotripsy can be conducted under fluoroscopic guidance. However, cholangioscopic visualization is preferred.

McCarty et al.'s meta-analysis [39] indicates that in patients with difficult choledocholithiasis, the success rate of intraductal stone fragmentation under cholangioscopic guidance was 91.6 %, the bile duct clearance rate in a single session was 76.9 %, and the complication rate was 8.9 % [39]. McCarty et al. [39] determined that there is no statistically significant difference in the incidence of successful intraductal fragmentation between EHL and LL (90.1 % vs. 92.9 %, $p = 0.360$). LL has a superior success rate in conducting lithotripsy in a single session compared to EHL (83 % vs. 70.9 %, $p = 0.021$) and a reduced treatment duration (75.7 min vs. 54.3 min, $p < 0.001$) [38].

Buxbaum et al. [9] state that in cases of difficult choledocholithiasis (large stones), cholangioscopic laser lithotripsy demonstrates significant advantages over mechanical lithotripsy or balloon papillary dilation, particularly regarding the efficacy of biliary stone clearance (93 % vs. 67 %, $p = 0.009$).

In another randomized study, Franzini et al. [21] compared cholangioscopic EHL and EPBD, revealing no significant differences in biliary stone clearance rates (77.1 % vs. 72 %, $p > 0.05$) or complication rates (4.2 % vs. 12 %, $p > 0.05$). However, in instances requiring an additional session, the biliary clearance rate was markedly superior for EHL compared to EPBD.

The primary drawback of cholangioscopic LL or EHL is the higher cost and prolonged duration of the surgical procedure; however, the considerate and competent application of these techniques in difficult cases of choledocholithiasis eliminates these disadvantages, aligning with the guidelines of ESGE and ASGE [37, 80]. Cholangioscopic lithotripsy techniques are used when mechanical lithoextraction or EPBD fails, serving as a viable alternative to open or laparoscopic choledochoscopy [17, 80].

Another method for treating gallstones is ESWL, which uses generated shock waves under the control of fluoroscopy to target the gallstone locations. In 1986, doctors first used it to manage choledocholithiasis, and they continued to use it for difficult cases or failures after ERCP [16]. The average rate of biliary tract stone removal is 84.4—90.2 %, necessitating a minimum of three sessions and the administration of either epidural or general anesthesia [3, 63, 66]. The incidence of complications after ESWL, as reported by many authors, varies between 9.1 % and 15.9 % [3, 66]. Most endoscopic associations recommend this treatment only in cases where traditional lithoextraction techniques fail or when cholangioscopic methods are unavailable [33].

Endoscopic sonography has led to an increasing use of choledochyloextraction methods under endo-US control, particularly in cases of unsuccessful or complicated ERCP [64]. There are two main methods of biliary interventions: endo-US rendezvous (EUR) technique and endo-US antegrade (EUA) technique. EUR is useful in cases of failed cannulation and difficulties with access to the major duodenal papilla. It is similar to conventional ERCP. Access to the extrahepatic bile ducts is provided through the stomach or small intestine. This technique's main drawback is its limited access to the left hepatic bile duct, making it technically challenging in cases of minor biliary hypertension [3, 66].

Surgical methods of treatment of choledocholithiasis include open and laparoscopic choledocholithoextraction. Open choledocholithoextraction has been used since the end of the 19th century and was the main method of CBD stone extraction until the 1970s. However, in some cases of difficult choledocholithiasis, it is still the method of choice [1, 34, 36]. However, open operations on the CBD in cases of perivesical infiltration or non-dilated ducts were technically challenging and frequently resulted

in serious postoperative complications, both in the short and long term [65—67]. Additionally, cases of recurrent choledocholithiasis, which could be caused by stenosis of the hepatic artery, foreign bodies in the hepatobiliary system, such as ligatures (ligature choledocholithiasis), or fragments of drain, were also observed after such interventions.

The introduction of minimally invasive technologies, in particular laparoscopic choledocholithoextraction, caused a review of approaches to the treatment of patients with choledocholithiasis. Now, minimally traumatic methods can be used to achieve optimal results during surgery [1, 34, 36].

Laparoscopic procedures are a viable alternative to endoscopic methods of lithoextraction for people with difficult choledocholithiasis and are often the best way to treat this condition [10, 71]. An important aspect of laparoscopic technology for the treatment of choledocholithiasis is the choice of access to the bile duct (through the cystic duct, choledochotomy), as well as the method of revision of the bile ducts (intraoperative cholangiography, ultrasound, choledochoscopy). Although intraoperative cholangiography and ultrasound have high specificity and sensitivity (63—99 %), in cases of difficult choledocholithiasis, laparoscopic choledochoscopy provides visualization of the bile ducts and complete lithoextraction [9, 69].

Laparoscopic choledochoscopy and choledocholithoextraction through the cystic duct are less traumatic, have fewer complications than choledochotomy, and hence result in a shorter stay in the hospital. Rhodes et al. [51] and DePaula et al. [15] found that choledocholithoextraction through the cystic duct was 96 % and 84 % efficient, respectively. However, this procedure has many limitations for use: the size of the stone is < 6 mm, the diameter of the stone must be the same or smaller than the diameter of the cystic duct, the number of stones is < 5, and there is a scar-infiltrative process in the area of the hepatoduodenal ligament. Furthermore, conditions such as proximal choledocholithiasis, common bile duct strictures, an acute angle between the cystic and common hepatic ducts, and difficult choledocholithiasis limit the use of choledochoscopy and cholelithoextraction through the cystic duct [77].

In the presence of preoperative contraindications (signs of difficult choledocholithiasis) or complications during peribladder lithoextraction, the majority of authors advocate for choledochoscopy and choledocholithoextraction using choledocholithotomy. This approach provides easy access to stones, allowing choledochoscopy in both distal and proximal directions and hence enhancing choledocholithoextraction. Choledocholithotomy facilitates the use of larger-diameter fibrocholedochoscopes, which have a larger instrument channel, thereby markedly improving visualization and choledocholithoextraction. The assessment of the bile ducts via choledocholithotomy is warranted under the following conditions during the initial choledochoscopy: 1) A large CBD stone (i 15 mm) is anticipated; 2) an intrahepatic bile duct stone is detected; 3) pre-existing bile duct strictures (regardless of etiology); 4) an impacted stone is present in the distal segment of the CBD; 5) multiple choledocholithiasis is observed > 3 stones, size > 10 mm) [65].

The main disadvantage of choledocholithotomy is possible complications related to the drainage of the bile duct, or remote complications such biliary tract strictures [65]. Rhodes et al. [51] indicate that bile inflow via the drain-catcher during choledochotomy is slightly more than through transcystic access (11.0 % vs 1.7 %, $p < 0.05$), which is consistent with the data of other authors (4.5—16.7 %) [65]. Regarding the efficacy of bile duct stone removal, there is no significant difference between the two methods [28, 51, 81]. The vast majority of authors recommend using laparoscopic choledocholithoextraction and choledochoscopy via the transcystic route, which offers benefits for reduced hospital stay and a lower rate of complications. However, in cases of difficult choledocholithiasis, it is necessary to perform choledocholitotomy with choledocholithoextraction and choledochoscopy [65]. The ESGE guidelines confirm that choledochoscopy is an effective and safe technique for choledocholithoextraction in patients undergoing transcystic or transductal cholecystectomy, particularly in cases with difficult choledocholithiasis. This management strategy should be chosen based on the availability of suitable resources and expertise in using this technology [37].

Notwithstanding the continuous advancements in laparoscopic and endoscopic technology and treatment techniques for patients with difficult choledocholithiasis, optimal management protocols using minimally invasive interventions on the bile ducts remain elusive.

Consequently, the chosen research direction is relevant and has substantial practical significance.

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All authors contributed equally to this work.

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Складний холедохолітіаз. Огляд літератури

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Частота утворення каменів у загальній жовчній протоці в пацієнтів із симптоматичною жовчнокам'яною хворобою значно варіює та залежно від віку становить від 5 до 33 %. У 85—90 % випадків холедохолітіаз ефективно лікують ендоскопічною папілосфінктеротомією та літоекстракцією. Нині це стандартний метод лікування зазначеної патології. Однак у 10—15 % випадків холедохолітіаз є технічно складним для ендоскопічного лікування, що потребує застосування інших методик та спеціалізованого обладнання. Розглянуто епідеміологічні аспекти, які вказують на зростання частоти виявлення холедохолітіазу завдяки використанню сучасних методів обстеження. Особливу увагу приділено етіологічним чинникам, зокрема спадковості, ожирінню та харчовим звичкам, що призводять до підвищення літогенності жовчі. Наведено механізм утворення первинних і вторинних каменів у жовчних шляхах, а також їхній вплив на організм, зокрема спричинені ними ускладнення, такі як гострий холангіт, біліарний сепсис, холестатичний гепатит і біліарний цироз печінки. Висвітлено критерії складного холедохолітіазу (характеристики каменів, їхня локалізація, змінена анатомія жовчних шляхів) і загальний стан пацієнта. Розглянуто діагностичні методи — як лабораторні, так і інструментальні (ультразвукове дослідження, ендоскопічна ретроградна холангіопанкреатографія, магнітно-резонансна холангіопанкреатографія, ендоскопічна ультрасонографія. Наголошено на важливості своєчасного видалення каменів для запобігання ускладненням. Наведено сучасні підходи до лікування (як консервативні, так і хірургічні методи, зокрема ендоскопічні процедури та лапароскопічні операції). Наголошено на важливості міждисциплінарного підходу до діагностики та лікування холедохолітіазу та його складних форм.

Складний холедохолітіаз залишається актуальною проблемою гепатобіліарної хірургії. Його ефективне лікування потребує індивідуального та міждисциплінарного підходу з використанням ендоскопічних і лапароскопічних технологій.

Ключові слова: складний холедохолітіаз, холедохоскопія, холедохолітоекстракція, механічна жовтяниця, ендоскопічна ретроградна холангіопанкреатографія.

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