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Original Article

Ultrasound-guided percutaneous transhepatic cholan gioscopicelectrohydraulic lithotripsy for difficult bile duct stones

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Abstract: Objective: The aim of this study was to evaluate the feasibility and efficacy of ultrasound-guided percutaneous transhepatic cholangioscopic electrohydraulic lithotripsy (PTCEHL) as a method of removing resistant extrahepatic and intrahepatic bile duct stones. Methods: Clinical data of 42 patients who underwent ultrasound-guided PTCEHL were analyzed. Results: All patients were treated with ultrasound-guided PTCEHL successfully. After the first round of therapy, complete stone clearance was achieved in 36 patients, with few residual stones in the left or right hepatic duct found in six patients. The stone clearance rate was up to 85.71%. All calculi were completely removed after the second round of therapy. The average operative time was 63±24.6 minutes, the intraoperative blood loss amount was 15±12 mL, the average episode of stone removal was 4.2±1.3 times, the time to recovery was 12±3.7 hours, food intake began 23±6.5 hours after operation, and the average length of hospital stay was 5±2 days. No severe complications, such as hemobilia or bile duct injuries, occurred. After 1-24 months of follow-up, there were no serious postoperative complications of residual calculi or calculus recurrence and no biliary strictures. Conclusion: Ultrasound- guided PTCEHL is a simple, safe, and effective treatment method for patients with resistant bile duct stones. It has the advantages of minimal invasion, fewer complications, and quick patient recovery.

Keywords: Bile duct stones, choledochoscopy, electrohydraulic lithotripsy, ultrasound-guide

Introduction

Gallstone diseases remain one of the most common medical problems leading to operative interventions. The goal of treatment is to remove obstructing biliary calculi using the minimum number of procedures with the lowest risk of morbidity [1]. Currently, traditional laparotomy has been challenged by minimally invasive operations. Most stones can be removed by operative exploration of the bile ducts and endoscopic retrograde cholangiopancreatography (ERCP) [2]. However, some patients present with stones that are difficult to remove using-conventional endoscopic methods. Percutaneous transhepatic cholangioscopic lithotripsy (PTCSL) can be an alternative method for this condition, but is not yet well established [3].

Percutaneous transhepatic cholangio-drainage (PTCD) is an effective procedure for decompressing an obstructed biliary system, and preoperative PTCD for acute cholecystitis remains a frequent first-choice therapy. PTCD for patients with bile duct stones as well as acute biliary tract infection and a second PTCSL through the PTCD tube sinus tract are a safe method [4]. Calculi can be fragmented by hydraulic shock waves generated by an electrical discharge across the tip of a coaxial electrode [5]. We began using ultrasound-guided percutaneous transhepatic cholangioscopic electrohydraulic lithotripsy (PTCEHL) for such patients between 2012 and 2016, achieving satisfactory results, which are reported in this study.

Material and methods

Clinical data

A total of 42 patients, including 19 men and 23 women aged 29-85 years (mean age, 57±8.63

Table 1. Baseline characteristics of 42 patients with difficult bile duct stones (n=42)

Characteristic	Value
Male/Female	19/23
Mean age in years (range)	57±8.63 (29-85)
Past history	
Hypertension	8
Diabetes	15
Biliary tract infection	9
Biliary stenosis	16
Biliary cirrhosis	8
Biliary tract ascariasis	3
General surgery history	
Abdomen	21
Cholecystectomy	17
Exploratory choledochotomy	10
Hepatic resection	6
Roux-en-Y anastomosis	3
ASA grade	
I	7
II	17
III	13
IV	5
Child-Pugh grade	
A	18
B	24

ASA = American Society of Anesthesiologists

years), were diagnosed with complex bile duct calculus. All diagnoses were confirmed via ultrasound, computed tomography (ct), and magnetic resonance cholangiopancreatography before operation. all of them had lengthy histories of chronic abdominal pain, and some presented with acute exacerbations accompanied with fever and jaundice. Of all patients, eight were diagnosed with stones in the left bile duct, 14 with stones in the right bile duct, 12 with stones in both the left and right bile ducts, and eight with stones in both the left and right bile ducts and common bile duct. Twelve patients also had stones in the gallbladder. Prior to referral, the patients had already undergone multiple treatments for an attempt to render them stone-free, including 17 patients who underwent laparoscopic or open cholecystectomies, 12 with at least one ercp with or without papillotomy, and 13 with open operative attempts at stone retrieval, such as common bile duct exploration or hepatic resection. The average number of prior treatments for the entire cohort was 0-5 (1.9±1.3). The patients' demographic characteristics are presented in **Table 1**.

The inclusion criteria were as follows: age of 18-90 years; diagnosis of complicated extrahepatic and/or intrahepatic bile duct stones; stable state of consciousness without restlessness; and signed informed consent for participation in this study (from the patients' families).

The exclusion criteria were as follows: heart, liver, lung, or renal dysfunction; severe hypertension, diabetes, or digestive tract diseases; non-complicated hepatolith; liver function classified under Child-Pugh class C; atrophied or fibrotic liver segment or lobe; condition combined with cholangiocarcinoma; and refusal to undergo operative treatment.

This study was approved by the Ethics Committee of our hospital.

Treatment

Forty-two patients underwent ultrasound-guided PTCSL and PTCEHL. All of them had underwent cholangioscopic exploration of the common bile duct, and six underwent a second operation through the tube sinus tract.

Equipment

1. Olympus electronic choledochoscope (A10-T2, Japan); 2. Chinese domestically made electrohydraulic lithotripsy equipment; 3. Optical fiber.

Procedure

The operation was conducted by employing two procedures. The first procedure was to create a tract between the skin and the intrahepatic duct via PTCD and dilatation of the tract for passage of a cholangioscope. The second procedure was to insert a cholangioscope to facilitate the fragmentation and removal of bile duct stones. After puncture using an ultrasound-guided needle and the introduction of a guidewire to the bile duct through the puncture needle, the PTCD tube was inserted through the guidewire. Two weeks after PTCD, the tract was dilated, except in patients with persistent cholangitis. After final dilatation, a choledocho-

Table 2. Results of PTCEHL in patients with difficult bile duct stones

Variable	Value
Stone size	18.6 (5-32) mm
Large impacted stone size	21.9 (17-32) mm
No. of stones	2.8 (1-9)
Complete stone removal rate	100%
Duration of operation (range)	63±24.6 (46-98) minutes
Intraoperative blood loss	(15±12) ml
Times of lithotomy	(4.2±1.3) times
Time to recovery activity	(12±3.7) hours
Time to food-intake	(23±6.5) hours
Hospital stay	(5±2) days
Stone location	
Common bile duct	8
Left bile duct	28
Right bile duct	34
Gallbladder	12
Minor complications	
Fever or chilling	1
Biliary hemorrhage	2

scope was inserted, and the biliary tree was explored to determine the location, size, and number of stones, as well as variations in the intrahepatic bile duct anatomy, such as abnormal branching and stenosis. In simple cases, stones were removed using a retrieval basket under choledochoscopic view. When we encountered large stones or when intrahepatic and extrahepatic stones were difficult to remove, these were fragmented and extracted through the tract via choledochoscopic electrohydraulic lithotripsy. A laser guidewire was introduced through the working channel of the choledochoscope and extended beyond the end of the scope for 15 mm. Under direct visualization with the choledochoscope, the guidewire was placed in contact with the stones to fragment them. The stones were fragmented repeatedly until they could be safely removed using the basket. Smaller stones (2-3 mm) could generally be flushed out or passed spontaneously. the PTCD tube was maintained for 1 to 2 weeks in the patients with residual stones and ~3 months in those with biliary stenosis at the end of the procedure.

If repeated treatment was required, PTCSL was performed at 2- or 3-week intervals after the first round of therapy through the PTCD tube. When no additional symptoms occurred during the 3-day period of PTCD tube clamping after complete stone removal, the PTCD tube was removed.

Results

The mean operation time ranged from 46 to 98 minutes (mean, 63±24.6 minutes) and the intraoperative blood loss amount was 15±12 mL. The average episode of stone removal was 4.2±1.3 times and the time to recovery was 12±3.7 hours. Food intake began 23±6.5 hours after operation and the average length of hospital stay was 5±2 days. In an attempt to render the patients stone-free, electrohydraulic lithotripsy was performed to fragment large stones. Stone baskets were used to extract calculi whenever possible. when large stones were encountered, these were fragmented and extracted through the tract using a rigid endoscope. External drainage tubes were placed in all patients at the end of the procedure (**Table 2**).

There were no serious intraoperative complications, such as bile duct injury or bleeding, and no patients required blood transfusions. However, a small amount of biliary bleeding- occurred in three patients and all of them werecured with conservative treatment. Postoperative abdominal ct showed that 36 patients achieved complete clearance, and six patients had only a few residual stones in the left or right hepatic bile duct. These six patients underwent a second electrohydraulic lithotripsy through a PTCD tube, achieving complete clearance. All patients were followed up for 1-24-months (mean, 12±2.6 months), reporting no abdominal pain, fever, or jaundice. Postoperative ultrasound and follow-up ct revealed no residual calculi and calculus recurrence and no biliary stenosis as shown in **Figure 1**.

Discussion

Cholelithiasis includes choledocholithiasis, extra- and intrahepatic bile duct stones, and gallbladder stones and is one of the most prevalent and costly biliary tract diseases worldwide [6]. It has been well demonstrated that the presence of gallstones increases with age. An estimated 20% of adults aged over 40 years and 30% of those aged over 70 years have biliary calculi [3, 6]. During the reproductive years,

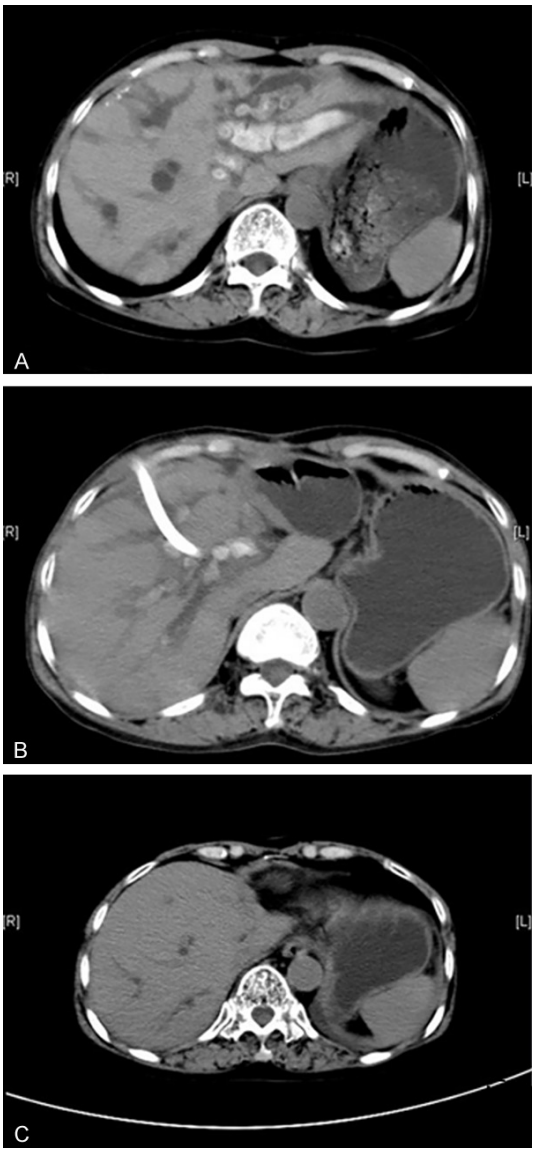

Figure 1. Case 1 (A) showing a large number of stones in intrahepatic bile duct before operation (arrow). (B) Showing that the left liver had been removed and recurrentstones after operation, and a PTCD tube were placed in intrahepatic bile duct before PTCEHL (arrow). (C) Showing that the right intrahepatic bile duct stones were basically removed after operation.

the female-to-male sex ratio is approximately 4:1, with the sex discrepancy narrowing in older populations to near equality [6]. During the last two decades, the general principles of gallstone management have not notably changed [6, 7]. However, treatment methods have been dramatically altered. Currently, cholelithiasis is treated mainly with laparoscopic cholecystectomy, whereas common bile duct stones are treated with ercp [2, 6]. In China, most hospitals perform liver resection for hepatic stones. In recent years, surgeons have realized that ERCP can damage the duodenal papilla, thus leading to postoperative biliary reflux, cholangitis, recurrence of gallstones, etc. [2]. In addition, the use of hepatectomy has been limited because it is a highly invasive high-risk procedure that often leaves behind residual stones and may be followed by postoperative complications [8].

In recognition of the revolutionary advances in the treatment of cholelithiasis, it is the purpose of this collective review to describe recent information on the following topics: types of gallstones, asymptomatic gallstones, symptomatic gallstones, chronic cholecystitis, acute cholecystitis, and other complications of gallstones [6, 7]. Gross and compositional analyses of gallstones allow them to be classified as cholesterol, mixed, and pigment gallstones [6]. Only approximately 30% of patients with asymptomatic cholelithiasis will warrant operation during their lifetime, suggesting that cholelithiasis can be a relatively benign condition in some patients [7]. Intraoperative laparoscopic ultrasonography has recently replaced cholangiography as the method of choice for detecting common bile duct stones [7]. It is important to remember that gallstones can lead to a variety of other complications, including choledocholithiasis, gallstone ileus, and acute gallstone pancreatitis [6].

Electrohydraulic lithotripsy is used for bile duct stones not amenable to removal with standard endoscopic techniques [9, 10] since it yields complete ductal clearance of stones in 85-98% of cases, with complications occurring in 2-9% of patients, including mild hemobilia, cholangitis, and pancreatitis [11, 12]. advanced endoscopic skills, in addition to proper equipment, are necessary as the procedure may take a long period and can be complicated, but can ultimately be successful. In addition, because water absorbs a great amount of energy, electrohydraulic shockwaves only minimally damage the surrounding tissues while fragmenting the stones [13]. Use of the choledochoscope to guide the electrohydraulic shockwave in finding the stones to crush and remove them not only utilizes the intuitive and minimally invasive characteristics of cholangioscopy but also takes advantage of the quick, safe, and effective

features of electrohydraulic lithotripsy [14]. In short, the combined use of electrohydraulic lithotripsy and cholangioscopy in treating resistant intra- and extrahepatic stones has the advantages of implementing accurate fragmentation, causing less injury, ensuring safety and effectiveness, and promising a quick recovery [12-16]. On follow-up, none of our patients were found to have had any serious complications, such as postoperative bile duct injury or hemobilia. After the first round of therapy, complete stone clearance was achieved in 36 patients. only a few residual stones in the left or right hepatic duct were found in six patients. The stone clearance rate was up to 85.71%. The overall residual rate was 14.3%, which is slightly higher than the rate of 11.2-78% following liver resection reported in the literature [17]. All calculi were completely removed after the second round of therapy. All patients were followed up for 1-24 months and there was no recurrence, which is lower than the reported recurrence rate of 33% after liver resection [18, 19]. However, the follow-up periods tendedto beshort, and three patients were only followed up within 3 months. thus, a more in-depth research is needed.

Taking into account a review of the literature [9-11, 14-16] and our own experience, we believe that choledochoscopic electrohydraulic lithotripsy is especially effective in the following situations: multiple intrahepatic bile duct stones within ducts of grades II and III or above and stones that could not be removed by other methods, such as ERCP. In this study, some advantages of choledochoscopic electrohydraulic lithotripsy were found. First, it allowed high-efficiency pulverization for cholesterol gallstones, bile pigment stones, and mixed stones regardless of size. Second, safety with minimal risks of injury was observed, and it could be used repeatedly if necessary with no additional risk. furthermore, it could be applied at all levels of the bile duct and was especially effective in higher-level bile ducts of grades II, III, or above, wherein the procedure should be conducted within the field of view to avoid blind maneuvering and equipment damage [20, 21].

This study has limitations. The number of patients included in this study is relatively small, and we did not compare electrohydraulic lithotripsy with other methods, such as choledochoscopic holmium laser lithotripsy. For a more precise conclusion, the clinical effects of ultrasound-guided PTCEHL in patients with difficult bile duct stones need to be further studied clinically.

Conclusion

Electrohydraulic lithotripsy improves the technology of cholangioscopy, which greatly reduces the difficulty of stone removal, achieves maximal stone clearance in a single treatment session, and has the advantages of yielding minimal injury and quick recovery and being an easy procedure. Thus, choledochoscopic electrohydraulic lithotripsy provides an efficient and safe option for patients with extra- and intrahepatic bile duct stones and is worthy of clinical promotion and application.

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Disclosure of conflict of interest

None.

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