How Should Biliary Stones be Managed?

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Minimally invasive therapy is currently invaluable for the treatment of biliary stones. Clinicians should be familiar with the various endoscopic modalities that have been evolving. I reviewed the treatment of biliary stones from the common practice to pioneering procedures, and here I also briefly summarize the results of many related studies. Lithotripsy involves procedures that fragment large stones, and they can be roughly classified into two groups: intracorporeal modalities and extracorporeal shock-wave lithotripsy (ESWL). Intracorporeal modalities are further divided into mechanical lithotripsy (ML), electrohydraulic lithotripsy, and laser lithotripsy. ESWL can break stones by focusing high-pressure shock-wave energy at a designated target point. Balloon dilation after minimal endoscopic sphincterotomy (EST) is effective for retrieving large biliary stones without the use of ML. Peroral cholangioscopy provides direct visualization of the bile duct and permits diagnostic procedures or therapeutic interventions. Biliary stenting below an impacted stone is sometimes worth considering as an alternative treatment in elderly patients. This article focuses on specialized issues such as lithotripsy rather than simple EST with stone removal in order to provide important information on state-of-the-art procedures. (*Gut Liver* 2010;4:161-172)

Key Words: Biliary stone; Lithotripsy; Endoscopic papillary balloon dilation; Cholangioscopy; Biliary stenting

INTRODUCTION

The choice of therapeutic modalities for the biliary stones mainly depends on both the stone-related charac-

teristics such as location, size, and number, and the conditions of biliary tract including shape, diameter, presence of stricture, and associated morbidity. Besides these factors, the condition of patient and social background can exert an effect on the decision. Needless to say, the treatment of choice in a patient should be determined after due consideration about these factors. Since the introduction of endoscopic sphincterotomy (EST) in 1974, a variety of complementary methods have been developed for the management of biliary stones. Recent technological advances have led to breakthroughs in the endoscopic management of difficult stones, enabling endoscopists to successfully fragment and remove nearly 100% of bile duct stones. The following consists of four subjects including various modalities of lithotripsy, the stone removal by endoscopic papillary balloon dilation (EPBD), the utilization of direct cholangioscopy, and biliary stent placement as an alternative procedure.

1. Lithotripsy

Lithotripsy, a procedure that fragments stones, is used to reduce the size of large or difficult-to-remove stones to facilitate their removal or passage via the biliary or to dislodge impacted stones. Lithotripsy may be performed using intracorporeal modalities or extracorporeal shock-wave lithotripsy (ESWL).

1) Intracorporeal modalities

Intracorporeal modalities include mechanical lithotripsy (ML), electrohydraulic lithotripsy (EHL), or laser lithotripsy (LL) at the time of peroral (via endoscopic retrograde cholangiopancreatography, ERCP) or percutaneous (via percutaneous transhepatic cholangioscopy) access.

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(1) **ML:** Approximately 80% of common bile duct stones can be removed endoscopically using standard basket or balloon extraction techniques. The addition of ML has improved success rates by another 10%.

① **Equipment:** ML is the simplest and typically the most cost-effective method of fragmenting stones in the bile duct. A mechanical lithotripter consists of a wire basket, a metal sheath, and a handle, which provides me-

chanical retraction of the basket into the metal sheath, directing a crushing force to the stone. Two types of mechanical lithotriptors are used, depending on whether lithotripsy is performed on an emergency or elective basis.

② **Technique:** The system can be applied through the scope in anticipation of lithotripsy for large common duct stones or intrahepatic stones above a strictured/stenosed

Fig. 1. Cholangiographic views of an mechanical lithotripsy (ML). (A) A large stone has been captured in the lithotripter basket. (B) The metal sheath is advanced up to the level of the stone. (C) ML is performed by pulling the stone against the metal sleeve using a cranking device. (D) The large stone is fragmented into multiple small pieces. (E) Endoscopic view showing the evacuation of multiple fragmented stones with a Dormia basket.

Fig. 2. Radiological views of an emergency lithotripsy. (A) A large stone has been engaged in an mechanical lithotripsy Dormia basket, but stone extraction has failed. (B) The duodenoscope is removed, and the metal sheath of a Soehendra lithotripter is inserted over the traction wire to the level of the stone. (C) The fragmented stones are completely extracted.

bile duct, and then no need exists to remove the duodenoscope. Once the stone is properly trapped within the basket, the metal sheath is advanced up to the level of the stone by adjusting the controls on the shaft of the lithotripsy basket. Tension is then applied to the wires by turning the control knob to crush the stone. The metal sheath is retracted within the channel of the duodenoscope so that only the Teflon catheter and basket are used to cannulate the bile duct. Then, the Teflon catheter is pulled back using the opened basket to engage the stone (Fig. 1). However, trapping of the stone may be difficult, as a large stone may not leave sufficient space within the bile duct for basket manipulation. Shaking the basket often does not work. If necessary, the metal sheath is railroaded up the Teflon catheter to provide stiffness for manipulation of the basket. Gentle twisting of the scope will transmit a rotational force to the basket to facilitate movement of the basket wires around the stone for stone engagement. Advancing the scope farther into the second part of the duodenum is sometimes helpful in straightening the axis of the basket and the bile duct to facilitate stone engagement. On the other hand, salvage devices, consisting of just the metal sheath and the handle, are used when a basket containing a stone becomes impacted in the duct during attempted stone extraction. Since their advent, Soehendra lithotripter has been used to crush stones captured within an impacted basket or to break the wires of the Dormia basket for release of the trapped basket.¹ Salvage devices are designed to be applied over a variety of stone-removal baskets, but not all baskets are lithotripter-compatible. For the preparedness to fail in stone removal, basket design must allow basket removal from around the stone and the duct when an application of maximum force fails to achieve stone fragmentation. When lithotripsy with salvage devices is required, the basket handle is cut off, the metal lithotripter sheath is passed over the plastic sheath and the wires of the impacted basket, and the lithotripsy handle is attached to the metal sheath and the basket wires. Under fluoroscopic guidance, rotation of the handle retracts the basket and the stone against the sheath, breaks the stone or the basket, and allows the basket to be removed (Fig. 2).

③ Results: ML leads to complete bile duct clearance in about 80-90% of patients, but 20-30% require more than one procedure.²⁻⁶ Moreover, ML is less likely to be successful with larger and impacted stones. Nakajima *et al.*⁷ were able to achieve a stone-free rate of 93%, independently of the diameter of the stones, in patients with choledocholithiasis in whom access to the papilla was obtained using only balloon dilation. Cipolletta and

colleagues⁴ found that the size of the stone was the only factor important in the failure of bile duct clearance using ML. They found that bile duct clearance rates were 90% for stones with a diameter less than 10 mm compared to 68% for those greater than 28 mm in diameter. Subsequently, a prospective study by Garg and colleagues³ identified only impaction of common duct stones in the bile duct as a factor in the failure of ML.

④ Complications: Basket impaction or rupture of the basket traction wire are potential complications unique to ML. A study collected from expert centers reported that the rate of complications associated with ML was 3.6% (23/643).⁸ Complications included trapped/broken basket,⁹ traction wire fracture,¹⁰ broken handle,¹¹ and perforation/duct injury.¹² The majority of complications related to intracorporeal lithotripsy were associated with (the process of) gaining pancreaticobiliary access (e.g., ERCP or percutaneous transhepatic access) and included pancreatitis, hemorrhage, perforation, and sepsis.¹³

⑤ How to manage trapped baskets during ML (Second Lithotripsy): The impaction of Dormia baskets with captured stones or rupture of the basket traction wire during ML are rare complications (0.8-5.9%) of the endoscopic treatment of choledocholithiasis.^{6,14} Traditionally the treatment approach to these complications has been surgical. But, recently, various nonsurgical methods were developed to deal with these problems, including extension of sphincterotomy, awaiting spontaneous passage of the impacted basket and stone after successful stent placement, application of a second lithotripsy, such as ESWL,¹⁵ LL,¹⁶ EHL,^{17,18} and transhepatic lithotripsy.¹⁹ Sauter *et al.*²⁰ reported that 12 consecutive patients underwent ESWL in an attempt to remove trapped baskets by nonsurgical means. According to their result, after fragmentation of the bile duct stones by ESWL, it was possible to remove the impacted Dormia baskets with fragmented stones, either by traction of the basket wire or by endoscopic extraction.²⁰ When the entrapped stone resists ML, all four branches of the basket can be stressed, which can result in fracture of the traction wire in up to 5% of cases (Fig. 3).²⁰ Fracture of the traction cable is a more severe complication of ML, which usually requires additional procedures, such as ESWL or surgery. When this occurs with the wire fracture outside the mouth, exchanging the initial 80-cm metal sheath for a shorter ones (70, 60, 50 cm) may allow immediate continuation of lithotripsy in most cases, making this technique time-saving, less expensive, and more successful, avoiding other unnecessary procedures such as ESWL or surgery.

Fig. 3. Peroral cholangioscopic electrohydraulic lithotripsy (EHL) as a secondary lithotripsy. (A) The common bile duct stone is not fragmented by mechanical lithotripsy. (B) The stone is not fragmented by an emergency lithotripter due to the traction wire fracture. (C) After removing the metal sheath of the emergency lithotripter, a nasobiliary catheter is inserted. (D) Peroral cholangioscopic EHL is performed. (E) The stones fragmented by EHL and the trapped basket are completely evacuated.

(2) EHL

① **Equipment:** An electrohydraulic shock-wave generator (Lithotron EL-27; Olympus Medical Systems Co., Tokyo, Japan) set at an output of 2,000 V can be used to generate shock waves of increasing frequency (intensity up to 500 mJ), which are applied as a continuous sequence of discharges. The 4.5 Fr caliber probe, which can fully pass through the working channel of the babyscope, is usually used in conjunction with a nasobiliary catheter for saline irrigation. In the absence of a nasobiliary catheter, using the 3 Fr probe is necessary to be able to irrigate alongside the probe. When a charge is transmitted across the electrodes at the tip of the probe, a spark is created. This induces expansion of the surrounding fluid and an oscillating spherical shock wave of a pressure sufficient to fragment the stone. Continuous saline irrigation

is required to provide a media for shock-wave energy transmission to ensure visualization and to flush away debris.

② **Technique:** The procedure is usually performed under direct choledochoscopic guidance to avoid errant application of shock waves that can cause ductal trauma and perforation. The probe is aimed directly at the stone and is optimally positioned ≥ 5 mm from the tip of the endoscope and 1-2 mm from the stone.¹⁰ When direct cholangioscopic control is not available or is limited, EHL with a balloon catheter may be an alternative.¹⁰ A balloon catheter can be used to center the EHL probe on the stone and to avoid contact with the bile duct wall (Fig. 4). The lumen of a standard extraction balloon catheter (Wilson-Cook Medical Inc., Winston-Salem, NC, USA), with an 18 mm diameter balloon, is expanded to accommodate the 3 Fr EHL probe. The catheter is 6.8 Fr in di-

Fig. 4. Radiographic views showing electrohydraulic lithotripsy (EHL) using the balloon catheter. (A) Image of a bile-duct stone and balloon catheter with an EHL probe. (B) Cholangiogram showing a stone impacted in the bile duct with the metal tip of the EHL probe (arrow) in contact with stone. The balloon (arrowhead) at the end of the balloon catheter has been expanded to position the probe properly. (C) Cholangiogram obtained during EHL showing multiple stone fragments. (D) Cholangiogram showing the complete clearance of stones from the bile duct.

ameter and 2 m in length. The 3-m-long EHL probe, with a 3 Fr radiopaque tip (Olympus Medical Systems Co.), is passed through the lumen of the modified balloon catheter. Then, the balloon catheter is inserted through the 3.2-mm-diameter accessory channel of a standard duodenoscope (JF-240; Olympus Medical Systems Co.). The balloon catheter with EHL probe then is introduced into the bile duct. The tip of the balloon catheter is positioned near the stone, and the balloon is expanded. The tip of the EHL probe is advanced a few millimeters beyond the radiopaque tip of the balloon catheter under fluoroscopic guidance to ensure that the EHL probe is positioned on the stone surface. Fluoroscopy is used to target the stone and to monitor fragmentation. Because of the risk of serious complications, however, balloon catheter EHL should be limited to cases not amenable to conventional endoscopic methods.

③ **Results:** Peroral cholangioscopy-directed EHL has been shown to be highly successful in treating difficult extrahepatic bile duct stones.^{21,22} The largest reported study with EHL is that of Binmoeller; EHL was successfully used to fragment stones in 63 of 64 patients, all of whom had failed previous attempts at ML.²³ Arya and colleagues²² published a retrospective series of 94 patients who had failed stone extraction by standard techniques before peroral cholangioscopy. Overall, the stone clearance rate was 90%, with 90% requiring one or two EHL sessions, and the rest requiring three or more. The complication rate was 17%. In the setting of recurrent pyogenic cholangiohepatitis, intrahepatic bile duct (IHBD) stones pose a special challenge, generally requiring a more intensive and predominantly percutaneous approach; downstream strictures and acute angulations are more dif-

ficult to overcome with a retrograde approach. Our study²⁴ with 114 consecutive patients with hepatolithiasis treated with percutaneous choledochoscopy directed EHL showed that despite a mean of 4.8 (1 to 16) choledochoscopy sessions, ductal clearance was achieved in 90.6%. Both EHL and LL have an overall complication rate of 7-9%, the most common being hemobilia, cholangitis, and less commonly, ductal perforation.^{21,25,26} No complications have been reported from holmium:YAG or FREDDY lasers. However, the published experience is limited and biliary epithelial damage has been noted in vitro with the holmium:YAG device.^{27,28}

(3) LL

① **Equipment:** Since the first report of successful retrograde laser-induced shock-wave lithotripsy of bile duct stones in 1986,⁹ various solid-state laser and pulsed dye laser systems have been developed and introduced for bile duct stone lithotripsy.²⁹ The combination of a rhodamine 6G-dye laser with a stone/tissue detection system, which minimizes the risk of bile duct injury, allows the safe disintegration of bile duct stones without cholangioscopic guidance.^{8,30} However, this system is expensive, bulky, requires a highvoltage supply,⁸ and has limited fragmentation power. Recently, a new solid-state laser lithotripter, the frequency-doubled double-pulse neodymium YAG laser ('FREDDY') system, was developed in Germany.^{26,31} This system promises to combine the advantages of dye and solid-state lasers, such as reliability, effectiveness, and low price.^{26,32} The FREDDY laser system uses wavelengths of 532 (20%) and 1,064 nm (80%). The green light ignites a plasma at the stone surface, while the infrared laser energy boosts this plasma to form a rapidly

collapsing bubble, which produces a strong shock wave that fragments the stones (Fig. 5).³¹ The laser-pulse duration is 1.2 ms at 160 mJ, with single or dual pulse at adjustable rates of 1, 3, 5, or 10 Hz with standard 110 volt AC electricity, or 15 or 20 Hz with 220 volt electricity.³³ We use the following laser parameters for all patients: energy output, 120 mJ/pulse; pulse rate, 10 Hz; and maximum number of pulses per laser session, 3,000. The laser beam is transmitted via a 0.73-mm-diameter laser fiber. These fibers can be inserted through the ports of most choledochoscopes.

② **Technique:** The FREDDY laser causes minimal or no ductal injury and has been used through the guidewire port of a stone-extraction balloon to maintain it in the center of the duct. To avoid injury to the working channel of the endoscope by the sharp laser fiber, the laser fiber was passed through the lumen of a standard balloon-tipped catheter (Escort II®/Tri-Ex®; Wilson-Cook Medical Inc.). The correct apposition of the laser tip on the stone was judged radiographically, and the transmission of the shock wave was monitored by listening to the typical 'tick, tick' percussion sound using a stethoscope taped to the patient's upper abdomen. FREDDY lithotripsy under percutaneous transhepatic choledoscopy guidance appears to be the most effective treatment for intrahepatic bile duct stones (Fig. 6). It is less likely to cause mucosal damage than EHL or ultrasound lithotripsy

because of its stone/tissue discrimination system. The fragmentation of stones under saline irrigation allows

Table 1. Advantages and Disadvantages of Laser Lithotripsy

Advantages	<ul style="list-style-type: none"> - It is less likely to cause mucosal damage because of its stone-tissue discrimination system (STDS) than electrohydraulic lithotripsy (EHL). - Fragmentation of stones under saline irrigation allows their spontaneous evacuation without tedious manipulation of basket forceps. - The STDS further increases the safety when the tip of the fiber is difficult to visualize endoscopically during fragmentation caused by the presence of biliary sludge or location inside of the stone.
Disadvantages	<ul style="list-style-type: none"> - Difficult and time-consuming to target stones by fluoroscopy because the position of the radiolucent laser fiber inserted through a catheter is not visible--The tip of laser fiber is not visible on the fluoroscopy. - The laser fiber is so fragile and may be inadvertently broken during the procedures. - The hemobilia may develop due to direct mechanical trauma of bile duct mucosa with sharp laser fiber tip.

Fig. 5. Radiographic views showing laser (FREDDY) lithotripsy under fluoroscopy guidance with a balloon catheter. (A) Cholangiogram revealing multiple large common bile duct stones. This patient undergoes two sessions of laser lithotripsy (LL) under fluoroscopy guidance with a balloon catheter (arrow). (B) After one session of LL, the large stones are fragmented into smaller stones. (C) The cholangiogram reveals complete clearance of the bile duct.

their spontaneous evacuation, without the tedious manipulation of baskets.³⁴ In our experience, however, when the stones are located above an acutely angulated bile duct, overcoming the angulation with the laser fiber was difficult because the tip of the laser fiber is not flexible (Table 1).

③ **Results:** Neuhaus reported a 97% success rate, after a mean of 1.3 sessions in 38 patients; 18 were treated perorally and 20 by the percutaneous transhepatic route. In this study, both cholangioscopy and fluoroscopy were used to monitor intraductal lithotripsy, without complications.³⁵ In the largest series to date, Hochberger *et al.*³⁶ reported an 80% clearance rate of common duct stones in 50 patients, with an 8% morbidity rate. Recently, Maiss *et al.*³⁷ reported the first clinical data on LL of common bile duct (CBD) stones with a new FREDDY laser system in 22 patients. At the end of treatment, 20 of 22 patients (91%) were free of biliary stones (5 patients had additional ML, 1 patient underwent ESWL). Regarding complications, mild pancreatitis was noted in two patients

(9%). Experience with LL has been limited to a few centers and most of the published reports on its use involve small numbers of patients in nonrandomized studies. Despite these limitations, the success rate of duct clearance for retained bile duct stones using LL in these studies is between 64 and 97%.¹⁷⁻³⁷ The results of this study were consistent with ours.³⁸ In our series, of the 52 patients treated using transpapillary routes, complete stone removal was achieved in 48 patients (92.3%). The complete removal of stones required a mean of 1.4 (range, 1 to 2) endoscopic sessions. The rate of complications related to laser lithotripsy was 23.0% (acute pancreatitis, 3 cases; transient hemobilia, 8 cases; acute cholangitis, 1 case).³⁸

2) ESWL

The reasons for the failure of conventional endoscopic therapy include impacted or extremely large stones, stones located intrahepatically or proximal to a bile duct stenosis, or prior operations preventing endoscopic ac-

Fig. 6. Radiographic views of percutaneous laser (FREDDY) lithotripsy of intrahepatic duct stones. (A) Endoscopic retrograde cholangiopancreatography shows multiple stones in both intrahepatic ducts. (B) Percutaneous laser lithotripsy (LL) allows the intrahepatic duct stones to be removed under percutaneous cholangioscopic guidance. (C) The final cholangiogram obtained after the sixth percutaneous transhepatic cholangioscopy LL shows complete clearance of intrahepatic bile duct stones. (D) Flushing of the biliary laser with normal saline achieves clearance of the fine particles of fragmented stone.

cess to the major papilla such as a Billroth-II gastrojejunostomy.

(1) Technique: ESWL focuses high-pressure shock-wave energy at a designated target point, while minimizing energy exposure to adjacent tissues. Shock waves can be generated by underwater spark gap (electrohydraulic), piezoelectric crystals, or electromagnetic membrane technologies. This energy can be focused by elliptical reflectors, fixation of piezoelectric crystals to an elliptical dish, or by acoustic lenses, respectively. Spark-gap lithotripters are more powerful and may induce better stone clearance rates. When shock waves traverse the stone, cavitation occurs at the surface, and the changes in acoustic impedance release compressive and tensile forces, resulting in fragmentation. When stones are located in the bile duct, a nasobiliary catheter is usually needed for contrast administration. The major drawback of ESWL is the time-consuming process which requires one or more sessions of treatment the insertion of a nasobiliary catheter in the interval, and repeated endoscopic retrograde cholangiography (ERC) for fragment extraction. Localization of common duct stones amenable to ESWL is performed under fluoroscopy or ultrasound.

(2) Results: Complete clearance rate of common duct stones following ESWL ranges between 83% and 93%.³⁹⁻⁴² The majority of patients will require endoscopic extraction of the bile duct stone fragments following ESWL, although approximately 10% of stones may subsequently pass spontaneously following treatment.^{40,43} Following ESWL, patients subsequently undergo ERC in which residual stone fragments are extracted using baskets. ESWL was effective in the clearance of stones in 80-90% in a series of 310 patients, with only rare complications (cholangitis, hematoma).⁴⁰

(3) Complications: Complications are observed in 30-40% of patients. Biliary colic is the most common complication among them, biliary obstruction or pancreatitis is developed in about 5% of patients.^{44,45} ESWL for choledocholithiasis is associated with short-term morbidity in about 14% of patients, including pain, hemobilia, cholangitis, sepsis, hematomas, pancreatitis, hematuria, ileus, and anesthesia problems.

2. Practical application of EPBD

1) EPBD

EPBD was first initiated for the purpose of extracting common bile duct stones while minimizing damage to the sphincter of Oddi. For patients with stones less than 10 mm in diameter, both EPBD and EST approaches ultimately achieve similar success rates and need similar numbers of

treatment sessions regardless of the stone size. EPBD with slow dilation of the papilla to large diameter can provide a large opening than a large EST and prevents perforation and bleeding. This method of stone retrieval is easy to perform and can effectively treat large or multiple bile duct stones.

2) Balloon dilation of the papilla with minimal EST

For patients with stones over 10 mm in diameter, EPBD requires a significantly greater mean number of treatment sessions than EST. To overcome the limitations of conventional EPBD, "large balloon dilation after minimal biliary sphincterotomy" has been devised. Balloon dilation after minimal EST is effective for retrieving large biliary stones without the use of mechanical lithotripsy.

(1) Technique: Using a therapeutic duodenoscope (JF 240; Olympus Medical System), the endoscope is advanced to the duodenum. It is important to use a duodenoscope with a large working channel (4.2 mm in diameter), for easier passage of large balloons. The difference from conventional EPBD is that EST is performed before the balloon catheter is inserted. EST with a small incision up to the pancreatic orifice is performed over a guidewire. In most cases, a major EST is not required and a minimal EST is sufficient. This is because the purpose of EST is not to dilate the sphincter of Oddi (SO), but to direct the direction of SO dilation. When using a large balloon catheter to dilate the SO without EST, it is difficult to predict the direction of SO dilation. Therefore, by performing a minimal EST before balloon inflation, the direction of papilla dilation can be predicted. Another reason for minimal EST is to prevent postprocedure pancreatitis by minimizing the peri-papillary edema after dilating the papilla. After minimal EST, a guidewire is inserted into the bile duct and a balloon catheter is guided over the wire. The diameter of the balloon should be 15-20 mm when it is inflated. A balloon catheter that was initially developed for dilation in pyloric stenosis (Wire-guided CRETM balloon; Boston Scientific, Natick, MA, USA) can be useful. The diameter of the balloon catheter is determined by the size of the bile duct stone and the size of the bile duct proximal to the tapered segment. Endoscopic papillary dilation is performed slowly with a large balloon (a maximum of 20 mm in diameter) to match the size of the bile duct. Approximately 1 minute of balloon dilation time is sufficient.

(2) Results: In 19 of 24 patients, the extrahepatic bile duct (EHD) stones were removed without mechanical lithotripsy (EML) after dilating the ampulla.⁴⁶ Stone retrieval was successful in all cases without the need to crush large stones up to 14±3 mm.⁴⁷ Standard EST is the

classical treatment modality for EHD stones. However, for large bile duct stones (usually >15 mm in diameter), EML is used to break the large stones into small fragments. However, multiple large bile duct stones are present, repeated EML is needed to remove all the EHD stones. In this situation, if the ampulla can be dilated widely enough by balloon dilation after minimal EST, such large stones can be removed without the use of EML. Also, patients in whom bile duct stones can not be cleared because of a tapered distal bile duct and patients with large, square, or barrel-shaped stones can benefit from this procedure.

(3) Complications: The most common complications of this procedure are mild cholangitis, pancreatitis, bleeding, and perforation. Complications occurred in 15.5% of patients in one study,³ with most (10.3%) being mild and self-limiting. Moderate to severe bleeding developed in three patients (5.2%), which were attributed to EST, and all recovered without the need for surgery. Perforation did not occur in any patient who underwent dilation with a large diameter balloon.⁴⁸ Mild pancreatitis developed in two patients (3.4%). Theoretically, the risk of pancreatitis by large balloon dilation after minor sphincterotomy is less than balloon dilation alone. It is probable that after EST, the force exerted by balloon dilation is directed more toward the common bile duct than the pancreatic orifice. Minor EST before a large balloon dilation might decrease the risk of pancreatitis as compared to dilation alone. Bleeding occurs in 2-5% of the patients undergoing EST to remove bile duct stones.^{49,50} In contrast, no significant bleeding has been observed after endoscopic balloon dilation.^{51,52} The bleeding rate (9%) reported by Ersoz *et al.* was higher than the rate reported for standard EST and EPBD.³ Therefore, bleeding is a potentially important complication, particularly in patients with a tapered distal bile duct. Studies of larger series of patients are warranted to determine the frequency of this complication.

3. Novel application of direct cholangioscopy

Peroral cholangioscopy provides direct visualization of the bile duct and permits diagnostic procedures or therapeutic interventions. An endoscopic sphincterotomy or papillary balloon dilation with large balloon is necessary before introducing the ultraslim endoscope. Currently, the available "mother-baby" scope system is not widely used because of several limitations. However, direct cholangioscopy using an ultraslim upper endoscope with a guidewire was reported to be an easy way to make a direct visual examination of the biliary tree. In addition to using a guidewire, direct peroral cholangioscopy (direct POC) is

also possible either by the means of ultraslim endoscope with an overtube balloon or intraductal balloon to maintain access.^{53,54} When using the overtube, the overtube (TS-13140; Fujinon Co., Saitama, Japan) using a double-balloon enteroscope was equipped with an ultraslim upper endoscope (GIF-260N; Olympus Medical Systems Co.). After advancing the endoscope with the overtube into the duodenal bulb, the overtube was fixed by ballooning. Then, the slim endoscope was advanced directly into the bile duct through the ampulla of Vater. When using a balloon catheter to maintain access, an ultraslim upper endoscope (GIF-260N or GIF-XP260N; Olympus Medical Systems Co.) was advanced over the balloon catheter directly into the bile duct through the ampulla of Vater.

Wire-guided direct POC was performed successfully in 5 of 10 patients (50%). The success rate of intraductal balloon-guided direct POC was 93.3% (14/15 patients; $p < 0.05$). Overtube balloon-assisted direct POC was performed successfully in 9 of 11 patients (81.8%). As a forcep biopsy and therapeutic interventions including laser lithotripsy or EHL could also be performed successfully under direct visualization of the intraductal lesions.⁵⁵ Intraductal balloon-guided direct peroral cholangioscopy seems to be a promising new procedure for the direct visual examination of bile ducts (Fig. 7).

4. Biliary stent placement as an alternative procedure

Biliary stenting deserves consideration as a quick alternative treatment in the elderly and/or frail patients who are unlikely to tolerate prolonged endoscopic attempts at stone extraction. For the treatment of refractory bile duct stones, stent placement has an important role in immediate and subsequent definitive stone treatment. Biliary stent placement may be required on a temporary basis for difficult-to-retrieve common duct stones. Studies have shown that the majority of common duct stones decrease in size following stenting.⁵⁶ A potential advantage of pig-tail stents over straight stents exists in that the duodenal portion of the stent comes out at an angle and may keep the biliary orifice open more effectively. If the stent becomes occluded after several months, it still has the potential to keep common duct stones from impacting. The stent probably functions as a wick around which the bile can drain, rather than as a conduit for bile. Some recent evidence has suggested that long-term stenting may not be necessary and that adding oral ursodeoxycholic acid may dissolve stones. In one report, 9 of 10 patients who underwent stenting combined with orally administered ursodeoxycholic acid became stone-free compared with none

Fig. 7. Radiographic and endoscopic views showing electrohydraulic lithotripsy (EHL) by means of intraductal balloon-guided direct peroral cholangioscopy. (A) Retained common bile duct (CBD) stones are seen. (B) Using a balloon catheter (arrow) to maintain access, an ultra-slim endoscope is advanced into the bile duct and lithotripsy is performed. (C) The EHL probe (arrow) is seen near the CBD stone. (D) Endoscopic view shows the fragmentation of stones.

of 40 patients with stents alone. Several studies have investigated the role of stent insertion as the sole treatment of common duct stones that could not be removed via ERC. In the study by Bergman and colleagues,⁵⁷ 58 of 117 patients had permanent biliary stent insertion as their treatment for common duct stones (i.e., expectant management and stent exchange only if complications occurred). Sixty percent of these patients were alive at 2 years of follow-up and of these 70% were symptom-free. However, overall, the complication rate was 40% and the mortality rate related to complications of the biliary stent was 16%. Cholangitis and jaundice were felt to be the causes of death of these patients, and occurred after a median time of 42 months. Jain and colleagues⁵⁸ carried out a prospective study on 20 patients with difficult-to-extract common duct stones. In each case, a pig-tail stent (7 Fr) was inserted and ERC was repeated at 6 months. In 20% of patients, the stones had fragmented and allowed balloon clearance of the duct, and in 35% of patients, the duct had cleared spontaneously.

CONCLUSIONS

Lithotripsy is a relatively safe and effective treatment for selected difficult bile duct stones. Treatment of difficult biliary stones is generally accomplished using a multimodal approach, with mechanical and/or shock-wave lithotripsy (EHL and LL or ESWL). The presence of large stones, impacted stones, small ducts, ductal strictures, or difficult anatomy including periampullary diverticula, Billroth-II anastomosis, Roux-en-Y anastomosis, and intrahepatic stones can make removal of biliary stones very

challenging. Most difficult biliary stones can be removed with ML. Stones that fail basket extraction are candidates for endoscopic intraductal shock-wave lithotripsy. For now, EHL seems to provide the best combination of technical success, low cost, and practicality. Published experience with holmium:YAG laser and FREDDY lithotripsy is limited. EHL and LL usually require direct visualization, which is technically difficult. Recent advances in the development of ultrathin cholangioscopes that fit through the working channel of a standard therapeutic duodenoscope and a pulsed laser with an automatic stone recognition system may enable routine lithotripsy under fluoroscopic guidance in the future. Minor EST and large balloon dilation can reduce the sessions of EML and shorten the procedure time, and thus serve as an effective treatment modality for multiple large extrahepatic bile duct stones. In addition, peroral or percutaneous cholangioscopic lithotripsy offer a highly effective and safe alternative to surgery in patients with difficult extrahepatic and intrahepatic ductal stones that are not amenable to routine endoscopic procedures.

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