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A Review of Lithotripsy Applications in Gastroenterology

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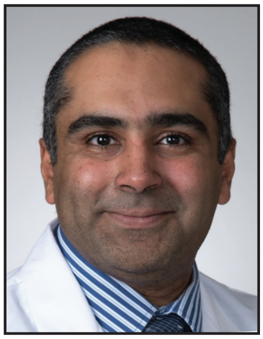

Moamen Gabr

Lithotripsy has been a principle technique in the field of urology for four decades but was not implemented in the field of gastroenterology until the mid-1980s. Large in vivo stones are often challenging to extract so lithotripsy is performed to assist in fragmenting or removing stones. Lithotripsy is used for various gastrointestinal conditions like common bile duct stones, pancreatic duct stones, gallstone ileus, Bouveret's Syndrome, and in the management of some cases of calcified, impacted or occluded stents. Mechanical lithotripsy, laser lithotripsy, electrohydraulic lithotripsy, and extracorporeal shockwave lithotripsy are some of the commonly used lithotripsy methods in gastroenterology.

INTRODUCTION

Lithotripsy is being increasingly used in gastroenterology for fragmentation of stones prior to extraction as large stone removal is technically difficult and failure is associated with increased risk of complications including infection and stone impaction.[1] Surgical techniques are invasive and often associated with significant morbidity and mortality compared to endoscopic procedures. Most stones can be successfully removed by conventional endoscopic techniques alone, however larger stone size, impaction, the location of stone and presence of stricture can limit endoscopic success.[2,3] Lithotripsy in conjunction with conventional endoscopic techniques increases the rate of successful stone removal.

Mechanical lithotripsy for common bile duct (CBD) stones was first described in 1982 by Riemann et al.[4] and is one of the most commonly used techniques for fragmentation of large CBD stones. Other types of lithotripsy techniques have been developed and used as an alternative to mechanical lithotripsy in patients with refractory stones which include electrohydraulic lithotripsy, laser lithotripsy, and extracorporeal shockwave lithotripsy. In addition to large

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gallstone management, lithotripsy is employed in other gastrointestinal conditions including chronic calcific pancreatitis caused by pancreatic duct calculi obstructing the main pancreatic duct, gallstone ileus with large stones impacting the duodenum or ileocecal valve, and calcified or occluded pancreatic duct stents.[5-7]

This review focuses on endoscopic lithotripsy techniques and their applications in various gastrointestinal conditions.

Lithotripsy Techniques

Mechanical Lithotripsy (ML)

First introduced in 1982, it is one of the most commonly used lithotripsy methods due to cost, simplicity, and availability; and is the initial modality of lithotripsy used for almost all GI lithiasis. ML uses a large, strong basket to capture the stone, and a crank handle (Figure 1.A) to apply tension to the basket wires to crush the stone. ML baskets are of two types: through the scope and a second type called the salvage device. The first uses a 3-piece pre-assembled basket (Figure 1.B) fitted through an inner plastic and outer metal sheath. This apparatus is inserted through the accessory port of the endoscope, and the stone is trapped using the basket and plastic sheath. The metal sheath is then advanced over it and tension is applied to crush the stone using a crank handle (wheel or a caulk gun design). The latter salvage design (LithoCrushV - Olympus America Inc.) is generally used for the emergent treatment of an unexpected broken basket or stone impaction. Hard stones can sometimes break the basket and wires resulting in impaction. A study by Thomas M et al.[8] with 712 ML cases showed the incidence of trapped/broken basket (N = 18), wire fracture (N = 12), and broken handles (N = 12) for overall biliary and pancreatic procedures. The salvage procedure is performed by removing the endoscope as well as the crank handle from the patient, and then a spiral metal sheath is glided over the bare basket wires with fluoroscopic assistance. The crank handle (Figure 1.C) is then connected, and the stone is crushed. Later both the broken basket and stone are retrieved. Newer techniques now allow passing a smaller sheath through the scope without having to remove the duodenoscope.[9] A

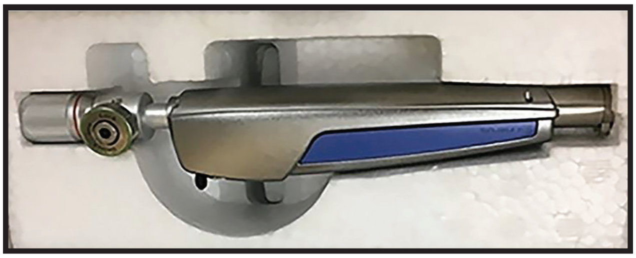

Figure 1.A. A Crank Handle. This device helps crush the stone by applying tension to the basket wires.

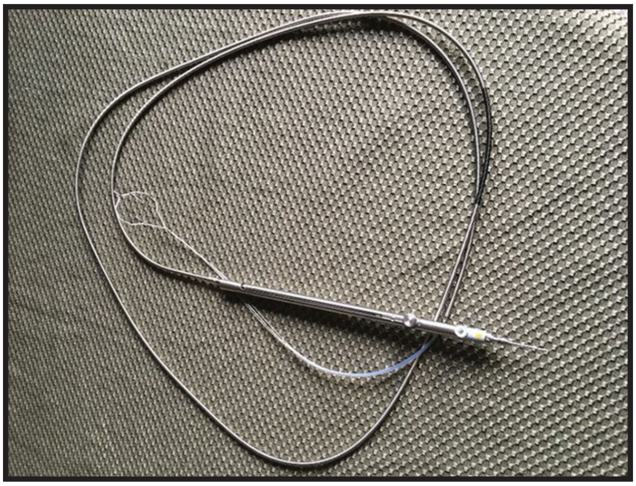

Figure 1.B. Mechanical Lithotripsy Basket. A 3-piece system with outer metal, inner plastic sheath and basket. The stone is captured via the basket and is crushed against the metal sheath

Figure 1.C. Mechanical Lithotripter - Salvage Device. Used for emergent removal of impacted baskets.

success rate of up to 90% has been reported with this technique.[10] However, this is influenced by several factors including stone composition, size, shape, number, the diameter and tortuosity of the bile duct with or without the presence of stricture, broken lithotripter baskets, stone engagement by lithotripter and impaction.[11-13] Complications like basket impaction, broken handle, bile duct perforation, and pancreatic duct leak are seen with approximately 4% of ML procedures.[8] ML is also an acceptable modality of endoscopic treatment for pancreatic duct stones with favorable outcomes.[14] However, rates of complications are three-fold higher than in biliary applications.[8]

Electrohydraulic Lithotripsy (EHL)

After successful animal and corpse experiments, this industrial mining tool was introduced in the late 1970's by Koch for the management of large bile duct stones in humans.[15] EHL (Northgate Technologies, Inc, Elgin, IL, USA) uses a mother-baby endoscopy system, and a cholangioscope (Figure 2.A) is inserted through the instrument port of a larger duodenoscope. Under direct visualization or fluoroscopic guidance, a bipolar probe connected to a generator (Figure 2.B) is deployed through the instrument channel of the cholangioscope close to the stone, and continuous irrigation is performed to create an aqueous medium. The bipolar probe then creates high-frequency hydraulic pressure waves leading to stone fragmentation.[16] Traditionally, two endoscopists were required to perform this procedure, one to maneuver the duodenoscope and a second to operate the cholangioscope. In addition, older systems had other technical limitations such as fragile scopes and reduced steerability. In 2015, a single-operator cholangiopancreatoscopy system - SpyGlass DS (Legacy and DS; Boston Scientific, Boston, Mass) was introduced with improved operating characteristics and higher image resolution thus overcoming the limitations of older systems.[17,18] EHL has been shown to have a stone fragmentation rate of 96% and final clearance of 90% for gallstones and 83% fragmentation rates for pancreatic duct calculi. Complications are seen in 7-9% of patients with the most common being cholangitis and ductal perforation.[17] A study by Arya N et al.[19] with 111 patients showed complications such as cholangitis (13 patients), hemobilia (1 patient), post-ERCP pancreatitis (1 patient) and biliary leak (1 patient) post-EHL. A multi-center retrospective study of 224 patients by Alder DG et al.[20] undergoing a single operator cholangiopancreatoscopy reported adverse events including post ERCP pancreatitis, cholangitis, bleeding and perforation in 3.9%, 1.4%, 1% and 0.7% of cases respectively.

Laser Lithotripsy (LL)

In 1986, endoscopic retrograde laser lithotripsy was used for the first time in the treatment of problematic large bile duct stones.[21] Numerous types of laser technologies are employed, such as pulsed dye laser lithotripsy, a rhodamine-6G dye laser with an integrated stone-tissue detection system, holmium laser lithotripsy, and Double Pulse Nd: YAG (FREDDY) laser.[22-25] LL (Lumenis Ltd. Israel) (Figure 3.) is performed by direct visualization using a cholangioscope, or under fluoroscopic guidance. A tissue-stone recognition system developed in 1993 identifies gallstones, and the tip of the probe is placed on the surface of the stone using the helium-aiming beam. Laser light initiates plasma formation at the stone surface, and a short, very high-intensity pulse heats the plasma which causes expansion and contraction of the stone leading to fragmentation. Fragments are later extracted with a dormie basket or balloon catheter.[24] Alternatively, the stone can first be captured using a double lumen basket, with LL performed subsequently.[26] LL is also used for pancreatic duct calculi when conventional methods fail. EUS-guided pancreaticogastrostomy with a self-expanding stent is used to access the main pancreatic duct, and LL is performed on pancreatic duct stones.[25] Stone fragmentation rates of 80-90% with a ductal clearance of 64-97% are reported. Adverse events like pancreatitis, hemobilia, and cholangitis have been observed in a trivial number of patients.[24]

Extracorporeal Shockwave Lithotripsy (ESWL)

This well-established treatment technique for urolithiasis has been extrapolated for the management of gallstones and pancreatic duct stones. It was first used in 1985 to treat difficult gallstones using a kidney lithotripter.[27] Stones are targeted with fluoroscopy after injection of contrast medium via nasobiliary catheter or ultrasound guidance, and shock waves are generated by an electromagnetic lithotripter (Delta Compact, Dornier Medtech, Wessling, Germany). These high-pressure shock waves through liquid or tissue medium are then fixated on to a target by elliptical transducers. First generation ESWL required immersion of patients in water and obligated use of general anesthesia. Newer machines do not require immersion and can be used with sedation only.[28,29] Stone clearance rates were as high as 90% for gallstones and 71% for pancreatic duct stones. Complications are seen in about 10-15% of patients, with patients experiencing cardiac arrhythmia, hemobilia, cholangitis, pancreatitis, and hematuria. A prospective study involving 283 patients by Tandan M et al.[30] showed complications such as mild hemobilia (12% cases), cholangitis (3.8% cases), and post-ERCP pancreatitis (3.5% cases). Other rare incidents reported include bowel perforation and splenic rupture.[28,31] ESWL is successful and well tolerated by patients, and the equipment is easily available at most institutes as they are the same ones used for renal stones. However, LL has been shown to have better outcomes compared to ESWL in terms of stone-free rates (97% vs. 73%) and number of sessions needed for stone clearance (1.2 vs. 3 respectively).[32]

Lithotripsy Applications

Common Bile Duct Stones

Approximately 10% of the US population is diagnosed with gallstones, and 10-20% of these patients develop choledocholithiasis. 35% of patients with gallstones will ultimately become symptomatic and will require cholecystectomy. Of these, 3-10% of patients are found to have CBD stones.[33] CBD stones can vary in size from 1-2 mm to as large as 3 cm or more. CBD stones up to 1.5 cm can be treated with conventional techniques like endoscopic retrograde cholangiopancreatography (ERCP) with endoscopic sphincterotomy and basket or balloon extraction. However, conventional endoscopic techniques fail in 10-15% of patients, because the stones are too large or impacted, or due to challenging bile duct access or intrahepatic stones.[12] In such cases, stone fragmentation is required prior to extraction using techniques like lithotripsy. ML technique is very effective in the management of large bile duct stones, but in frail patients or in select high-risk groups, peroral cholangioscopy guided laser or electrohydraulic lithotripsy is safer for fragmentation and ductal clearance.[29] EHL has also provided treatment for symptomatic cholelithiasis for high-risk surgical candidates such as patients with end-stage liver disease.[34]

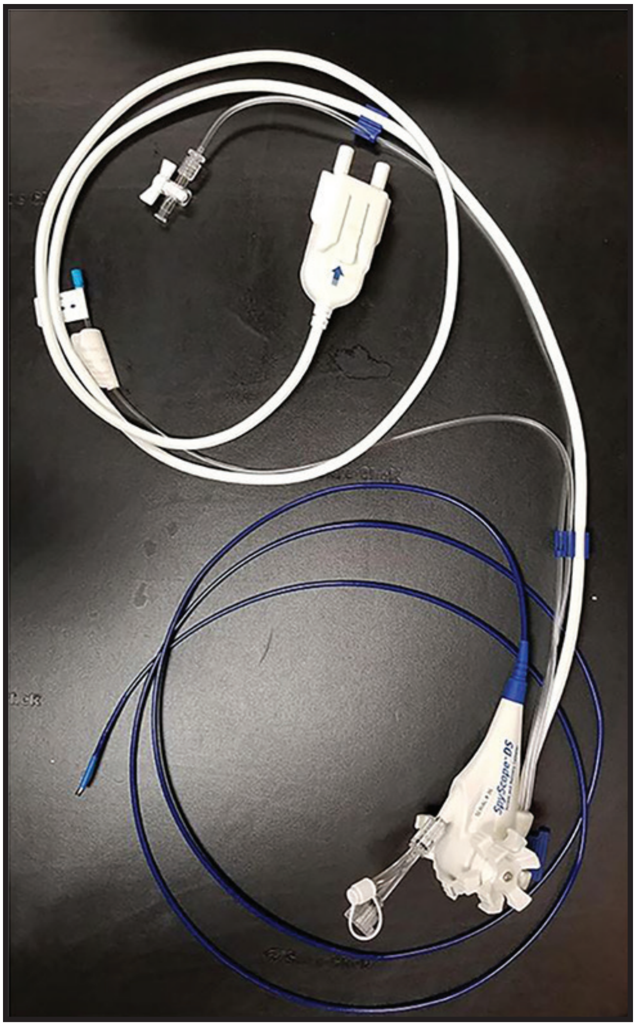

Figure 2.A. Cholangioscope. The system is introduced through a larger duodenoscope and through its channel an EHL probe is inserted with its tip over the stone which aids in fragmentation by shock wave propagation

Chronic Calcific Pancreatitis

Pain in chronic pancreatitis is caused by a wide variety of factors, but the main pancreatic duct obstruction due to stones or strictures resulting

Figure 2.B. Electrohydraulic Lithotripsy Generator. EHL probe is connected to the generator and shockwaves are generated by an electric spark (50-90 W).

Figure 3. Laser Lithotripsy

in increased duct pressure and pain is well established.[35] Stones are observed in as many as 90% of patients with chronic alcoholic pancreatitis. ERCP with sphincterotomy and balloon or basket stone removal after mechanical lithotripsy have been validated with reasonable outcomes. The success of these procedures is limited when the size of the pancreatic duct stone is > 5mm, or in the setting of strictures or impaction. Surgery carries a risk of 5% mortality and has not been shown to achieve long-term pain relief.[31] Bekkali et al.[17] described ductal clearance for pancreatic duct stone when using SpyGlass-assisted pancreatography with EHL which obviated the need for surgery; similar results have been reproduced by other groups.[36] ESWL has been shown to be effective in patients who failed conservative pain management in several retrospective and prospective studies. A study by Tandan et al. showed 84% pain relief at 6 months follow up post ESWL. In a subsequent study, 68.7% of patients at 24-60 months and 60.3% at > 60 months showed the absence of pain after ESWL and ERCP.[30,35] A meta-analysis of 27 studies on ESWL showed 52.7% pain relief, quality of life improvement in 88.2% and ductal stone clearance in 70.7% of patients.[31] Alternative therapies with LL or EHL for patients who failed ESWL or with hereditary pancreatitis are also available, but experience with these techniques is limited.[37]

Gallstone Ileus and Bouveret's Syndrome

Large gallstones can rarely migrate through a cholecystoduodenal or choledochoduodenal fistula and cause obstruction of the gastric outlet, duodenum or ileum.[38] Endoscopic treatment with or without lithotripsy is now the first line management for this disorder. A comprehensive review of 61 cases by Dumonceau showed successful treatment by mechanical lithotripsy (40% of cases), EHL (21% of cases), LL (15% of cases), and ESWL (4% of cases).[39]

Calcified or Occluded Pancreatic Stents

One of the main indications for pancreatic duct stent placement is pain secondary to obstruction from strictures or stones. Several studies have shown a success rate of 75-100% pain relief after stent placement.[40,41] However, the benefit is only short term due to a common phenomenon of stent clogging at 9-12 weeks making regular stent exchange inevitable. ESWL is used effectively to cleanse clogged stents with success in as many as 80% of cases thus increasing exchange intervals.[7] Stent exchanges can be complicated by calcified stents making them difficult to retrieve by snares or forceps during ERCP; ESWL has been used in such cases where lithotripsy is performed prior to ERCP making stent exchange successful.[42]

CONCLUSION

In conclusion, given high rates of morbidity and mortality associated with surgical methods, endoscopy with lithotripsy has become the primary modality of treatment in the past few years for difficult to treat gastrointestinal lithiasis. Recent advances in endoscopy techniques with newer ultrathin endoscopes, and single operator cholangioscopes have made these procedures safer and more reliable. In addition, patients prefer alternative non-surgical approaches. Future studies should focus on quality, safety, efficacy and best modalities of lithotripsy for a specific gastrointestinal condition. ■

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