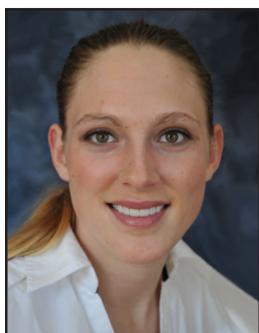


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Endoscopic Management of Pancreatic Duct Stones via ERCP



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INTRODUCTION AND OVERVIEW OF PANCREATIC DUCT STONES

Calcium carbonate deposition combined with inadequate pancreatic ductal drainage and/or pancreatic duct strictures in the setting of chronic pancreatitis can lead to the formation of pancreatic duct stones. (Figure 1) The formation of such stones can result in inflammation and/or obstruction of the pancreatic duct and promulgate a vicious cycle whereby stones lead to inflammation and obstruction, and ongoing obstruction can further promote the formation of pancreatic duct stones. Pancreatic stones can lead to increased intraductal pressure, enhancing the symptoms of pancreatitis, most notably pancreatic-type pain.¹ If pancreatic stones develop they can sometimes be asymptomatic. If stones cause obstruction of the

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pancreatic duct, pain is most often the first symptom. Pain from chronic pancreatitis is often epigastric but can often manifest anywhere in the upper abdomen, and can often radiate to the back.

In addition to pain, pancreatic duct stones can be the cause of other symptoms such as pancreatic duct obstruction and severe acute pancreatitis.² Surgical or endoscopic measures are often used in the management and treatment of pancreatic duct stones. The primary goal of these procedures is to remove the stone(s) in order to relieve pain and restore the patency of the pancreatic duct.³

Endoscopic sphincterotomy (ES) has allowed the development of interventional endoscopic procedures to remove pancreatic duct stones. These endoscopic approaches were less invasive than previously developed surgical measures to treat pancreatic duct stones and rapidly gained widespread acceptance. Other endoscopic procedures such as electrohydraulic lithotripsy, extracorporeal shock wave lithotripsy, and laser lithotripsy can be used in the removal of pancreatic duct stones.

This manuscript will review the current state of the art with regards to endoscopic management of pancreatic duct stones.

Sphincterotomy and Balloon Extraction

In order to facilitate the removal of pancreatic duct stones, a pancreatic sphincterotomy is typically the first therapeutic maneuver performed after pancreatic cannulation and deep guidewire access to the main pancreatic duct have been obtained. (Figure 2) This procedure can be done using a needle-knife sphincterotome (usually over a pancreatic duct stent) or with a standard sphincterotome passed over a guidewire. Both are equally effective and safe. A standard sphincterotome is most commonly used. In a study performed of 1,000 patients by Choi and Lehman, complications in patients who underwent pancreatic sphincterotomy procedures included acute pancreatitis (2-7%), bleeding (0-2%), perforation (< 1%), and delayed stenosis of the pancreatic sphincter orifice (up to 10%) were reported, arguing for the overall safety of the procedure.²

Following pancreatic sphincterotomy, the most common first step when attempting to remove pancreatic duct stones is simple balloon extraction in a manner analogous to that used during ERCP to remove common bile duct stones. (Figure 3) An occlusion balloon is inserted into the duct until it reaches an optimal location proximal to the stone. The balloon is then inflated to an appropriate size and used to sweep the pancreatic duct, dragging stones and debris through the duct, out the sphincterotomy, and into the duodenal lumen.

Compared to other stone extraction techniques such as basket extraction and lithotripsy, balloon extraction is considered to be the safest and easiest to perform. Unlike basket extraction, an extraction balloon has little to no chance of becoming impacted in the pancreatic duct because it can be deflated. Removal of pancreatic duct stones with occlusion balloons usually works best in patients with small stones and/or pancreatic duct debris. Balloons may fail clinically if they are popped or torn on the sharp or jagged edges of pancreatic duct stones and may be of limited value in patients whose stones are above difficult pancreatic duct strictures.²

Concomitant Pancreatic Duct Stricture Therapy

The successful removal of pancreatic duct stones is often predicated on the absence of significant ductal strictures. Other key factors include the size and number of stones, the absence of impacted stones, and the location of the stones within the pancreatic duct.⁴ If ductal strictures interfere with stone extraction, endoscopic balloon dilation (EBD) of the stricture itself can be performed.



Figure 1. CT image of a large pancreatic ducts stone in the pancreatic head.

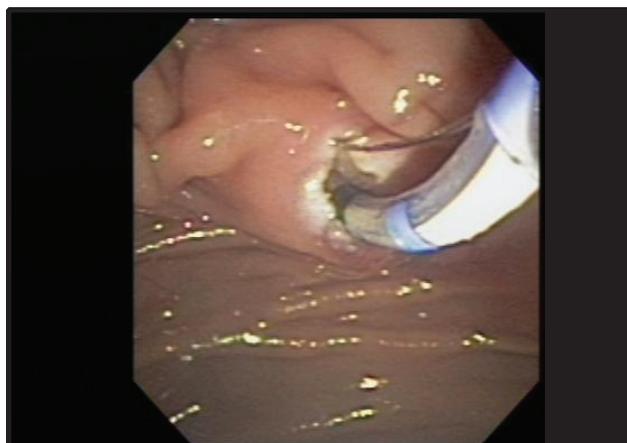


Figure 2. Endoscopic image of a pancreatic sphincterotomy, performed prior to pancreatic duct stone removal. Note that the sphincterotomy is directed to the 1 O'clock position.

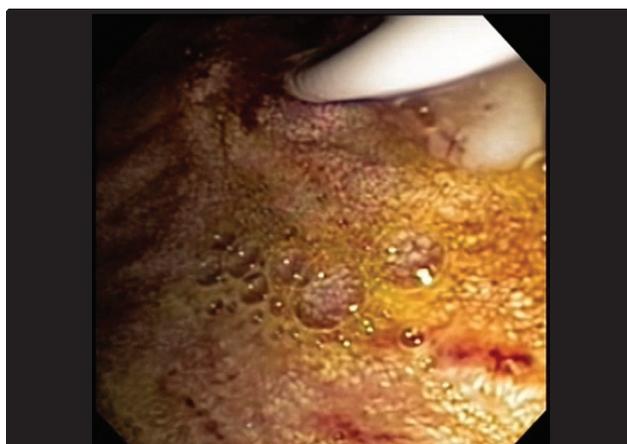


Figure 3. Endoscopic image of a pancreatic duct stone being removed via a balloon sweep.

Dilation of the pancreatic duct (either by balloon or passage dilators) followed by stone extraction can be performed in a single session in many patients.⁵

Endoscopic balloon dilation requires guidewire passage across the stricture, which can be difficult (or impossible) in very tight strictures.⁶ In addition, endoscopic catheters may not always be able to traverse pancreatic duct strictures, especially if they are highly angulated.⁷ In a study by Brand et al., the use of the 7-Fr Soehendra Stent Retriever used as a dilator when conventional endoscopic balloon dilation was unsuccessful was evaluated. Successful dilation of the tight strictures was accomplished in all of the patients.⁸ If a pancreatic duct stricture is intractable, proximal stones may not be able to be removed endoscopically.

Basket Extraction

In addition to balloon extraction, basket extraction is a standard method for removal of pancreatic duct stones. A basket catheter or Dormia basket is commonly used, although a variety of baskets are available from multiple vendors. No single basket has been identified as being ideal. A basket catheter is typically made of nitinol wires. A wide range of sizes is available, with basket diameters of 1-3cm being most commonly employed. A wire connecting the tip of the basket to the handle of the device allows the basket to be opened and closed. Modern stone extraction catheters are typically double lumen, one lumen to extract the stone, and the second to accommodate a guidewire, although some single lumen devices are still available.⁹

Baskets may be designed to simply trap stones or may also be considered lithotripters i.e. baskets that are able to both capture and crush stones in the duct itself prior to attempts at removal. Lithotripter baskets typically have braided wires for additional tensile strength and to reduce the risk of wire breakage during lithotripsy.

Non-lithotripter baskets can be used to trap and drag stones through the pancreatic duct and out to the duodenal lumen through the pancreatic sphincterotomy. (Figure 4) In practice, non-lithotripter baskets are uncommonly used for pancreatic duct stone removal given the risk of basket entrapment (either above a stricture, after stone capture, or both). After the stone has been trapped inside the basket, a metal coil (which may be advanced over a Teflon sheath or may simply serve as the sheath itself) is advanced to the base of the basket and the basket/stone complex is withdrawn into

the sheath, crushing the stone and releasing the stone fragments from the basket into the duct as the lumen of the basket functionally disappears.¹⁰ The basket can then be reopened to capture and/or crush more stones and stone fragments as needed.

In a retrospective review of 69 patients by Thomaset al., endoscopic clearance of pancreatic ductal stones was successful in 90-97% of patients when basket extraction and mechanical lithotripsy were combined with pancreatic sphincterotomy. Of those 69 patients, there was a complication rate of 11.6% (8/69 patients). Of the eight patients that experienced complications, 37.5% had single stones, while 62.5% had multiple stones, suggesting that more involved duct clearance procedures were associated with a higher rate of pancreatitis. Seven patients experienced complications concerning a trapped or broken basket. Wire fracture of the basket occurred during mechanical lithotripsy in four patients. One patient experienced a pancreatic duct leak following the procedure. Complications were successfully treated with endoscopic measures including electrohydraulic lithotripsy, stenting, per-oral Soehendra lithotripsy, and extracorporeal lithotripsy.¹⁰

In a study by Hintze and Adler, 60 patients had pancreatic ductal stones large enough to require mechanical lithotripsy before removal. Three patients experienced traction wire fracture during the procedure. In 2 patients the use of a shorter metal sheath allowed for immediate resolution and continuation of the procedure. Extracorporeal shock wave lithotripsy was performed on 1 patient in order to successfully remove the stone.¹¹ In a retrospective study of 53 patients by Smitset et al., pancreatic ductal stones were fragmented using mechanical lithotripsy in 4 patients. Eight patients underwent extracorporeal shock wave lithotripsy. A pancreatic stent was placed in 28 patients. Small stones were removed with a balloon-tipped catheter. Dormia-type baskets were used to extract larger stones. If balloon and/or basket extraction techniques were unsuccessful, a nasopancreatic drain or pancreatic stent was inserted beyond the stone to allow for sufficient drainage. After a mean follow-up of 33 months, stone removal was successful in 79% of patients.¹²

In a study by Farnbacher et al., 125 patients with pancreatic ductal stones were retrospectively analyzed. Successful removal of ductal stones was achieved in 85% of patients. Eleven patients (8.8%) underwent mechanical lithotripsy procedures to fragment the stones

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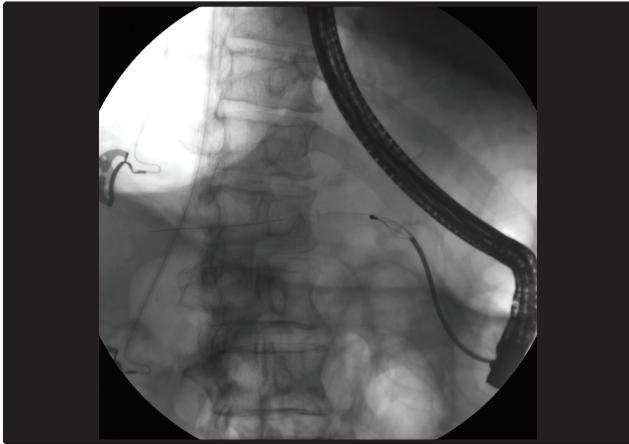


Figure 4a. Fluoroscopic image of a lithotripter basket open in the main pancreatic duct. Note the small stone seen in the basket.



Figure 4b. Endoscopic image of a pancreatic duct stone in the duodenum after removal via a lithotripter basket.

before subsequent removal. There were no significant complications experienced in lithotripsy procedures. Patients that experienced stones larger than 12 mm, stones in the tail of the pancreas, or multiple stones (2 or more) required more extensive therapeutic measures before removal could be accomplished.¹³

Pancreatoscopy, while not used directly during mechanical lithotripsy of pancreatic duct stones, can be used to identify the specific locations of pancreatic duct stones prior to inserting a basket into the pancreatic duct if the location of the stones is unclear on pancreatography.¹⁴ Pancreatoscopy can also be used to confirm duct clearance after stone extraction. (Figure 5)

Unlike extraction balloons, which can almost always be removed from the duct without difficulty (whether the balloon is working or has failed), stone retrieval baskets can become impacted within the pancreatic duct. Basket impaction can occur via several mechanisms, the most common of which is if the stone/basket complex cannot fit through the duct and be withdrawn to the duodenum. This situation is common if the pancreatic duct contains strictures, especially fibrotic strictures. Furthermore, if the ductal stones are too dense to be crushed, traction wires can fracture during attempted mechanical lithotripsy, creating a non-functioning basket with part or all of a stone still inside. Fractured traction wires can make the basket impossible to close and/or remove by pulling it back through the duct.¹⁵ In a multi-center study cited by Hlaing, a complication rate of 11.6% was associated with mechanical lithotripsy of pancreatic duct stones,

often due to basket failure and/or impaction.¹⁶

Basket impaction in the pancreatic duct can be treated by the use of a Soehendra lithotripter cable (to destroy the stone/basket complex and allow basket removal) or via EHL or laser lithotripsy to try to break up the stone in the basket (theoretically allowing the empty basket to then be removed from the pancreatic duct), although the latter two devices may be very difficult to use in this situation. The actual incidence of basket impaction in the pancreatic duct is unknown as these events are likely underreported in the literature.

In a study by Sasahira et al., basket extractions in 10 patients with main pancreatic duct stones of 5 mm or less were observed. There was one case of temporal basket impaction. The basket was easily removed after the stone was released from the basket. A sphincterotomy extension was performed and the stone was successfully extracted after a second attempt. In 5 patients a nitinol basket catheter was successfully used to remove ductal stones. A basket catheter was used to initially extract stones in the remaining 5 patients. A balloon catheter sweep was performed to remove any residual stones. A pancreatic stent was temporarily placed in all 10 patients.⁹ In a study by Thomas et al., 69 patients with pancreatic stones underwent endoscopic intervention. A complication rate of 0.8-5.9% associated with mechanical lithotripsy was reported. Extraction baskets broke in 7 patients, traction wires fractured in 4 patients, and basket handles broke in 5 patients. The basket impactions were successfully resolved using EHL and extracorporeal shock wave lithotripsy

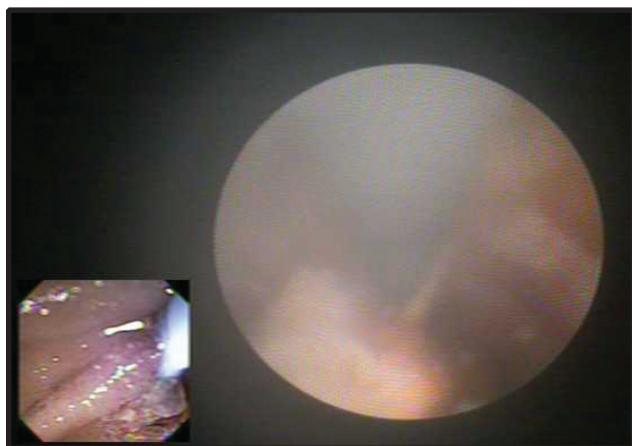


Figure 5a. Pancreatic duct stone in main pancreatic duct identified on pancreatoscopy.

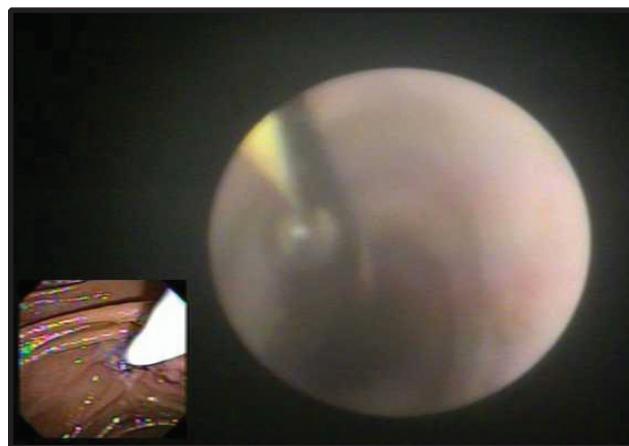


Figure 5b. Clear pancreatic duct as seen on pancreatoscopy following pancreatic duct stone extraction.

(ESWL).¹⁰

Electrohydraulic Lithotripsy

Electrohydraulic Lithotripsy (EHL) can be applied to pancreatic ductal stones in order to facilitate endoscopic removal. EHL applies high-energy shock waves to small areas.¹⁷ The technique uses a wire to generate a spark in a fluid filled duct. The spark generates a shock wave that propagates through the fluid and can fracture stones. EHL requires pancreatoscopy to perform, both to access and visualize the stones in question. EHL is directly applicable to pancreatic duct stone extraction as this procedure can be used to fragment stones that are too dense to be successfully fragmented using mechanical lithotripsy or that have failed attempts at balloon extraction.

Thomas et al. reported retrospective results in 69 patients with pancreatic stones. Two patients with large stones that proved difficult to remove underwent EHL. Stone clearance was successful in both procedures without any complications of pancreatitis associated.¹⁰ Attwell et al. performed a study of 46 patients undergoing various methods of endoscopic stone removal. EHL was performed in 85% of patients. Stone clearance and reduction of pain was successfully obtained in 74%.¹⁸

Craigie et al. reported on 10 patients with stones in the head of the pancreas underwent EHL. Intraductal stones were fragmented and successfully removed in all patients. There were no reported complications associated with EHL or stone extraction procedures.¹⁹

Studies on EHL have generally been small, single center, and retrospective in nature. In a study by Howell et al., 6 patients underwent EHL to fragment pancreatic duct stones. EHL was used as initial therapy in 1 patient. In 5 patients, EHL was used after other endoscopic clearance procedures were unsuccessful. Of note, balloon dilation of pancreatic duct strictures was performed in the same procedure to facilitate the entire procedure. After EHL was completed, balloon catheters and baskets were used to remove the stone fragments. Ductal clearance was successfully achieved in 50% of patients. Improved drainage and symptom relief was obtained in 100% of patients. No complications associated with EHL were observed.²⁰

In a small series by Tanaka et al., two patients with large pancreatic ductal stones lodged in the head of the pancreas underwent EHL. The stones were successfully fragmented and optimal ductal flow was restored.²¹

In a case study by Papachristou et al., a patient with a pancreatic stone measuring 15.5x11.1x6.4 mm underwent various endoscopic procedures. EHL was performed after failed attempts of balloon extraction, balloon dilation, and mechanical lithotripsy. Using EHL, the stone was successfully fragmented and removed using balloon and basket extraction devices.¹⁷

Laser Lithotripsy

Laser lithotripsy procedures can be used to facilitate removal of difficult pancreatic stones, although there is relatively little clinical data on the efficacy of this

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technique. Laser lithotripsy, like EHL, requires a pancreatoscope to both directly identify stones and to serve as a conduit for a laser fiber. In laser lithotripsy, a laser pulse is used to pulverize the stone making extraction measures more successful. GI lasers or lasers designed for urology can be used for laser lithotripsy. Stones fragmented by laser lithotripsy can then be removed from the pancreatic duct via baskets and/or balloons.

In a study by Alatawi et al., five patients with pancreatic stones were treated with laser lithotripsy using a holmium YAG (yttrium aluminum garnet) laser. All patients had previously undergone unsuccessful ERCP treatments. After stone fragmentation, stone retrieval was performed using a dormia basket or balloon catheter. Stone extraction was successful in all five patients. No complications associated with laser lithotripsy procedures were reported.²²

In a small prospective study by Maydeo et al., 4 patients with pancreatic stones underwent laser lithotripsy when removal by basket or balloon catheters failed. Pancreatic stones were fragmented in 100% of patients followed by complete clearance via ERCP. No complications associated with laser lithotripsy or ERCP were reported.²³

In a case report Hlaing et al., laser lithotripsy was used to assist in removing a basket that had become impacted in the pancreatic duct after entrapment of a pancreatic duct stone. During a mechanical lithotripsy procedure, the basket wires fractured and the basket became entrapped in the pancreatic duct. The pancreatic stone was fractured via laser lithotripsy. The basket and stone fragments could be successfully removed after laser lithotripsy.²⁴

Extracorporeal Shock Wave Lithotripsy

Extracorporeal shock wave lithotripsy (ESWL) is a non-invasive treatment for pancreatic duct stones. ESWL can be used to fragment stones using an externally applied shock wave pulse. A water filled cushion can be placed externally adjacent to the target area, or ESWL can be administered to a patient that is partially immersed in water. Sedation, epidural anesthesia, or general anesthesia can be used in patients undergoing ESWL depending on local institutional protocols. ESWL is generally used if the patient has many stones or if previous endoscopic measures have failed.

In a study performed by Ong et al., 250 patients

underwent ESWL after chronic pancreatitis was confirmed via ERCP, conventional ultrasound, endoscopic ultrasound, or computed tomography scans. Multiple stones were reported in 87% of patients. Only 13% of patients had single stones. Stones in the head of the pancreas were seen in 98% of patients with multiple stones. After the stones were fragmented with ESWL, the pieces were removed with a dormia basket and/or balloon extraction via ERCP. Complete clearance of associated stones was achieved in 60% of patients and partial clearance occurred in 24% of patients, illustrating how even the most aggressive treatments can sometimes fail to allow duct clearance. Complications associated with ESWL occurred in 6% of patients. Pain during ESWL was the most common complication reported. Mild bleeding during ERCP occurred in three patients. No complications of acute pancreatitis associated with ESWL or stone extraction procedures were reported.²⁵

Farnbacher et al. retrospectively analyzed 125 patients with pancreatic duct stones. Eighty-two patients had multiple stones. Successful stone clearance was achieved in 85% of patients. Stone clearance was achieved in 11 patients by mechanical lithotripsy and 114 patients by ESWL followed by ERCP. ESWL was performed in patients in whom stone clearance was unsuccessful via ERCP.²⁶

In a retrospective study by Hiromu et al., 80 patients with pancreatic stones underwent ESWL. Forty-five patients underwent pancreatic stenting prior to ESWL treatment. Stone fragmentation was achieved in 91% of patients who underwent stenting prior to ESWL therapy and in 80% of patients who did not undergo stenting prior to ESWL therapy. Stone fragmentation was successful in 89% of patients while symptom relief was observed in 88% of patients regardless of stent placement. A complication rate of 7% was seen in patients who had pancreatic stents and 17% in patients who had no pancreatic stent. Complications included rare pancreatitis and cholangitis.²⁷

CONCLUSIONS

A variety of endoscopic treatments are available for pancreatic duct stones. For small pancreatic duct stones and/or debris, balloon catheters and basket extraction devices can be used to extract stones. For larger or difficult pancreatic duct stones, a combined approach of basket/balloon extraction with more extensive measures such as electrohydraulic lithotripsy, laser lithotripsy, and/or extracorporeal shockwave lithotripsy can be

used. Some patients will fail all endoscopic techniques; in these patients, surgery is still an option. Endoscopic approaches to treating pancreatic duct stones has an acceptable rate of adverse events and is now considered first line therapy. ■

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