Pancreatic Stones and Extracorporeal Shockwave Lithotripsy:
A Review of the Literature

by Landon K. Brown, James Gnecco, Hussein Abidali, Shreyas Saligram, Laura Rosenkranz, Sandeep Patel, Oleh Haluszka, Umesha Boregowda, Hari Sayana

Background & Aims:
Pancreatic stones are a sequelae of chronic pancreatitis which can result in poor quality of life, frequent hospitalizations, and large economic burden to an individual and to the U.S. as a whole. Extracorporeal shock wave lithotripsy (ESWL) is a treatment modality currently available to treat pancreatic stones that is less invasive when compared to other methods. Our aim in this review article was to discuss the treatment of pancreatic stones by extracorporeal shockwave lithotripsy (ESWL). We will also briefly discuss other modalities and how these differ to ESWL.

Methods:
Databases were searched electronically on articles discussing treatment of pancreatic ductal stones by ESWL or multiple modalities. Articles discussing or comparing treatment success rates were preferentially included. An inductive approach was used to identify articles related to the treatment of pancreatic stones with ESWL throughout the review process.

Conclusion:
While there are multiple modalities available for the treatment of pancreatic stones, ESWL should be considered as a viable method for the relatively safe management of pancreatic stones. Although laser lithotripsy (LL) and electrohydraulic lithotripsy (EHL) appear to have higher success rates, the potential for ESWL to affect clinical outcomes is substantial, especially in individuals where a more invasive procedure would be of higher risk. The decision to perform ESWL, as well as the other modalities, should be performed if the result will substantially alter clinical management and undertaken by an experienced provider.

INTRODUCTION
Chronic pancreatitis is a syndrome involving inflammation, fibrosis, and loss of acinar and islet cells that manifests as abdominal pain, malnutrition, and exocrine and endocrine insufficiency.1 Multiple etiologies have been identified to cause chronic pancreatitis including alcoholic/toxic, idiopathic, genetic, and autoimmune etiologies.1,2 Chronic pancreatitis leads to poor quality of life, frequent hospitalizations, and an estimated individual cost of $22,502 per year.3,4 A sequelae of chronic pancreatitis is intraductal pancreatic stone formation, which can lead to significant patient morbidity. It has been suggested that the presence of stones in the pancreatic duct leads to obstruction and increased intraductal pressure subsequently resulting in pain, a cardinal symptom in chronic pancreatitis.5-7 Length of disease duration appears to cause increased prevalence of pancreatic stone formation with estimated prevalence of stone formation in 50%
Pancreatic stones are suspected to be formed by a pancreatic stone protein (PSP). Through multiple factors, PSP causes increased calcium carbonate concentrations in pancreatic secretion resulting in deposition of calcium carbonate over a nidus causing stone formation over time. Pancreatic stones are mainly composed of calcium carbonate stones resulting in an increase in microhardness when compared to common bile duct stones. Variation in a stone’s presentation appears to vary individually. Pancreatic stones can present as: radio opaque vs. radiolucent, single vs. multiple stones, or present in the main pancreatic duct, side branches, or calcification in the pancreatic parenchyma.

Large pancreatic ductal calculi development is seen at the end stage of chronic pancreatitis in a majority of patients. Usually clearance of these stones is a therapeutic goal for pain relief. Although smaller intraductal stones may be retrieved endoscopically, pancreatic stones greater than 5 mm and/or irregularly shaped stones are often impacted and may require fragmentation for successful retrieval and outcomes. Fragmentation can be performed by lithotripsy, a procedure for fragmentation of stones to facilitate their removal/passage from the pancreatic ducts. In this review, we will focus on the principles of extracorporeal shockwave lithotripsy with comparison to new endoscopic treatment modalities such as EHL and Spyglass.

Extracorporeal Shock Wave Lithotripsy

ESWL was first introduced in the 1980s for fragmentation of renal and urethral calculi and later utilized in the treatment of biliary and pancreatic calculi. In 1989, the first case series of biliary stone clearance achieved with ESWL was reported. Lithotripsy mechanism involves concentrating focused shock waves on biliary/pancreatic calculi with the goal of disrupting the stone into smaller fragments. Third-generation lithotripters utilize an electromagnetic coil to produce desired shock waves that are focused in a conical shape using an acoustic lens or reflector to target the calculi, which is localized using either fluoroscopy or ultrasound techniques. These shock waves generate compressive stress on the calculi surface eventually overcoming the tensile strength of the calculi causing fragmentation.

It has been suggested that for treatment of pancreatic stones a maximum of 5,000-6,000 shocks are delivered per session with an intensity of 15-16 kV at a frequency of 90 shocks per minute on successive days until desired fragmentation is achieved. Another study looking at ESWL followed by ERCP treatment in patients with chronic pancreatitis showed mean ESWL shocks needed for pancreatic clearance was 7.903.33 +/- 4.830. Approximately 57% of individuals needed 2,000-7,000 shocks, 24% needed 7,001-12,000 shocks, 14.2% needed 12,001-15,000, and 4% needed more than 15,000 shocks. In a case series with high success in fragmentation, the mean number of ESWL sessions was 2.2 and 8% required 4 or more treatments, but a large series showed up to 8 sessions were needed for adequate fragmentation. However, more shock waves are likely required for larger stones, multiple stones, or stones associated with a pancreatic stricture. Interestingly, pancreatic stenting prior to ESWL seems to decrease the number of shockwaves and sessions required for adequate stone fragmentation.

There are currently multiple 3rd generation commercial lithotripters available on the market used for stone fragmentation/clearance. However, depending on the device, it could affect treatment protocols. A study published in 2015 compared two models of lithotripters for the treatment of difficult to treat biliary stones: Lithostar Plus vs. Modulith SLX-F2. The study showed that both lithotripters allowed for clearance of difficult biliary stones at the same rate but the newer lithotripter (Modulith SLX-F2) had a significantly lower number of ESWL sessions and total shock waves along with fewer adverse events. Although these studies focused on biliary stones, they suggest that the type and the configuration of settings can affect treatment protocols/outcomes along with duration of treatment with regards to treatment of pancreatic stones, although the role of the type of lithotripter has been controversial.
When to Use ESWL
ESWL is recommended in patients with chronic pancreatitis where proceeding with other forms of stone extraction would be harmful to the patient or not amenable due to location or stone characteristics. Ideal targets are calculi in the head and body. Furthermore, ESWL should be avoided in patients with extensive calculi throughout the pancreas or isolated pancreatic tail calculi due to concerns of splenic injury/damage. The European Society of Gastrointestinal Endoscopy recommends ESWL for the clearance of radiopaque obstructive main pancreatic stones larger than 5 mm located in the head/body of the pancreas.

Success of ESWL for Pancreatic Duct Stones
A large recent single center study had evaluated the overall success rate of ESWL for pancreatic stones. This study performed ESWL on 5,124 patients and were followed for a period of six months. It was stated that complete stone clearance rate was 72.6%. However, the study focused on larger pancreatic stones (> 5 mm in diameter) and excluded smaller stones; as well as stones in the tail of the pancreas to avoid collateral damage to the spleen. Most patients (86%) required 3 sessions of ESWL and about 4% required between 5-8 sessions for stone clearance. This large single center study appeared similar to clearance rates of other studies. A large meta-analysis looking at ESWL treatment for pancreatic stones showed a complete clearance rate of approximately 71% with a partial ductal clearance of approximately 22%, but often these were combined with ERCP. However, other researches have reported higher clearance rates. A group studying 2,800 patients reported a complete clearance of 80% and incomplete clearance in 13.8% of patients. The recurrence rate for pancreatic stones ranges from 18-22%.

Table 1. Studies that have Evaluated Endoscopic Lithotripsy

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>Study Design</th>
<th>Technical Success</th>
<th>Clinical Success</th>
<th>Single Session Duct Clearance</th>
<th>Adverse Events</th>
<th>Post-ERCP Pancreatitis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Studies That Have Evaluated Electrohydraulic Lithotripsy</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Howell et al. 1999</td>
<td>United States</td>
<td>Retrospective single center</td>
<td>100% (6/6)</td>
<td>83.3 (5/6)</td>
<td>50% (3/6)</td>
<td>16% (1/6)</td>
<td>0% (0/6)</td>
</tr>
<tr>
<td>Fishman et al. 2009</td>
<td>United States</td>
<td>Retrospective multicenter</td>
<td>100% (6/6)</td>
<td>50% (3/6)</td>
<td>50% (3/6)</td>
<td>0% (0/6)</td>
<td>0% (0/6)</td>
</tr>
<tr>
<td>Ito et al. 2014</td>
<td>Japan</td>
<td>Retrospective single center</td>
<td>37.5% (3/8)</td>
<td>37.5% (3/8)</td>
<td>25% 92/8)</td>
<td>12.5% (1/8)</td>
<td></td>
</tr>
<tr>
<td>Ogura et al. 2019</td>
<td>Japan</td>
<td>Retrospective single center</td>
<td>95% (19/21)</td>
<td>85.7% (18/21)</td>
<td>5% (1/21)</td>
<td>4.7% (1/21)</td>
<td></td>
</tr>
<tr>
<td><strong>Studies That Have Evaluated Laser Lithotripsy</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Alatawi et al. 2013</td>
<td>France</td>
<td>Retrospective single center</td>
<td>100% (5/5)</td>
<td>100% (5/5)</td>
<td>80% (4/5)</td>
<td>0% (0/5)</td>
<td>0% (0/5)</td>
</tr>
<tr>
<td>Navaneethan et al. 2016</td>
<td>United States</td>
<td>Retrospective multicenter</td>
<td>100% (5/5)</td>
<td>80% (4/5)</td>
<td>80% (4/5)</td>
<td>0% (0/5)</td>
<td>0% (0/5)</td>
</tr>
<tr>
<td><strong>Combination of Electrohydraulic lithotripsy and Laser Lithotripsy</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Attwell et al. 2015</td>
<td>United States</td>
<td>Retrospective multicenter</td>
<td>89.3% (25/28)</td>
<td>89.3% (25/28)</td>
<td>60.7% (17/28)</td>
<td>28.5% (8/28)</td>
<td>3.5% (1/28)</td>
</tr>
<tr>
<td>Brewer Gutierrez et al. 2019</td>
<td>United States and Europe</td>
<td>Retrospective multicenter</td>
<td>92.7% (101/109)</td>
<td>90% (98/109)</td>
<td>66% (72/109)</td>
<td>10% (11/109)</td>
<td>4.5% (5/109)</td>
</tr>
<tr>
<td>Gerges et al. 2019</td>
<td>Germany/Netherlands</td>
<td>Retrospective multicenter</td>
<td>100% (20/20)</td>
<td>95% (19/20)</td>
<td>95% (19/20)</td>
<td>30.4% (7/23)</td>
<td>26% (6/23)</td>
</tr>
<tr>
<td>Han et al. 2019</td>
<td>United States</td>
<td>Retrospective single center</td>
<td>99.2% (124/125)</td>
<td>99% (124/125)</td>
<td>20% (25/125)</td>
<td>6.4% (8/125)</td>
<td></td>
</tr>
</tbody>
</table>

(Table 1. continued on page 32)
(continued from page 30)

# A SPECIAL ARTICLE

Pancreatic Stones and Extracorporeal Shockwave Lithotripsy: A Review of the Literature

## Table 1. (continued from page 30) Studies that have Evaluated Endoscopic Lithotripsy

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Country</th>
<th>Study Design</th>
<th>N (M/F)</th>
<th>Complete Stone Fragmentation</th>
<th>Successful Post-ESWL ERCP</th>
<th>Complete Ductal Clearance, n/N (%)</th>
<th>Pain Relief, complete + partial</th>
<th>Complications ESWL/ERCP</th>
<th>Follow up, Months</th>
<th>ESWL Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromagnetic Lithotripsy</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Wang et al.¹⁴ 2018</td>
<td>China</td>
<td>P</td>
<td>50 (36/14)</td>
<td>NR 28%</td>
<td>89.8% (75.5+14.3)</td>
<td>7%/NR</td>
<td>2.4 (1-4.5)</td>
<td>3EML (Compact Delta II)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hu et al.¹⁵ 2016</td>
<td>China</td>
<td>P</td>
<td>214 (156/58)</td>
<td>100%</td>
<td>96.7% 72.4%</td>
<td>95.4% (71.3+24)</td>
<td>4.23%/2.9%</td>
<td>18.5 ± 3.3</td>
<td>3EML (Compact Delta II)</td>
<td></td>
</tr>
<tr>
<td>Vaysse et al.¹⁶ 2016</td>
<td>France</td>
<td>P</td>
<td>146 (96/50)</td>
<td>NR 91/132 (69%)</td>
<td>75/13 (56.8%)</td>
<td>NR 4%/NR</td>
<td>23 (6-90)</td>
<td>3EML (Compact Delta II)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tandan et al.¹⁷ 2013</td>
<td>India</td>
<td>R</td>
<td>636 (414/222)</td>
<td>NR 100%</td>
<td>76.9%</td>
<td>95% (65+30)</td>
<td>NR/NR</td>
<td>96</td>
<td>3EML (Compact Delta II)</td>
<td></td>
</tr>
<tr>
<td>Li et al.²² 2016</td>
<td>China</td>
<td>R</td>
<td>With PPC 59 (51/8)</td>
<td>100%</td>
<td>98%</td>
<td>67.2%</td>
<td>89.1% (63.6+25.5)</td>
<td>11.9%/NR</td>
<td>21.9 (12.0–45)</td>
<td>3EML (Compact Delta II)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Without PPC 790 (552/238)</td>
<td>NR</td>
<td>NR</td>
<td>83.2%</td>
<td>NR</td>
<td>12.4%/NR</td>
<td>12</td>
<td>3EML (Compact Delta II)</td>
</tr>
<tr>
<td>Korpela et al.²³ 2016</td>
<td>Finland</td>
<td>R</td>
<td>83 (59/24)</td>
<td>NR 100%</td>
<td>83.1%</td>
<td>89.2% (NR)</td>
<td>NR/NR</td>
<td>12 (1–36)</td>
<td>EML-FL ; Storz Modulith SLX Modulith SLX-F2</td>
<td></td>
</tr>
<tr>
<td>Brand et al.²⁴ 2000</td>
<td>Germany</td>
<td>P</td>
<td>48 (35/13)</td>
<td>60.4%</td>
<td>100%</td>
<td>43.8%</td>
<td>82% (45+37)</td>
<td>NR/NR</td>
<td>7 (5–9)</td>
<td>2 (n =38)</td>
</tr>
<tr>
<td>Parsi et al.²⁵ 2010</td>
<td>USA</td>
<td>P</td>
<td>10 (3/7)</td>
<td>NR 100%</td>
<td>70.0%</td>
<td>100%</td>
<td>NR</td>
<td>20 (12–36) (n =10)</td>
<td>Transportable ESWL Modulith SLX-2</td>
<td></td>
</tr>
<tr>
<td>Delhaye et al.²⁶ 2004</td>
<td>Belgium</td>
<td>R</td>
<td>56 (46/10)</td>
<td>NR 100%</td>
<td>48%</td>
<td>NR</td>
<td>25%</td>
<td>14.4 ± 0.6 years</td>
<td>Siemens Lithostar</td>
<td></td>
</tr>
<tr>
<td>Milovic et al.²⁷ 2011</td>
<td>Germany</td>
<td>P</td>
<td>32 (24/8)</td>
<td>NR 100%</td>
<td>40.6%</td>
<td>87.5% (53.1+34.4)</td>
<td>0%/40%</td>
<td>NR</td>
<td>Minilith SL</td>
<td></td>
</tr>
<tr>
<td>Piezoelectric Lithotripsy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lapp et al.²⁸ 2016</td>
<td>U.S.A.</td>
<td>R</td>
<td>37 (21/16)</td>
<td>60%</td>
<td>97.3%</td>
<td>81%</td>
<td>89%</td>
<td>0%</td>
<td>NR</td>
<td>Piezolith 3000</td>
</tr>
<tr>
<td>Tadenuma et al.²¹ 2005</td>
<td>Japan</td>
<td>R</td>
<td>117 (85/32)</td>
<td>96.6%</td>
<td>56%</td>
<td>55.6%</td>
<td>68.2%</td>
<td>4.7%/7.7%</td>
<td>77.5 ±30.9</td>
<td>Piezoelectric lithotripter (LT-01, 02) Piezolith 2500</td>
</tr>
<tr>
<td>Farnbacher et al.²² 2002</td>
<td>Germany</td>
<td>R</td>
<td>114 (NR)</td>
<td>82.5%</td>
<td>NR</td>
<td>34.2%</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>Piezolith 2300, 2500, 2501-economy</td>
</tr>
<tr>
<td>Karasawa et al.²³ 2002</td>
<td>Japan</td>
<td>R</td>
<td>24 (19/5)</td>
<td>12.5%</td>
<td>58.3%</td>
<td>54.2%</td>
<td>95.0%</td>
<td>0%</td>
<td>NR</td>
<td>Piezolith 2500</td>
</tr>
</tbody>
</table>

(Table 1. continued on page 33)
Pancreatic Stones and Extracorporeal Shockwave Lithotripsy: A Review of the Literature

Table 1. (continued from page 32) Studies that have Evaluated Endoscopic Lithotripsy

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Type</th>
<th>Patients</th>
<th>Success</th>
<th>Failures</th>
<th>Failure Rate</th>
<th>Success Rate</th>
<th>Duration</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kozarek et al.</td>
<td>USA</td>
<td>R</td>
<td>40 (21/19)</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>NR</td>
<td>20%</td>
<td>2.4±0.6 years</td>
</tr>
<tr>
<td>Maruyama et al.</td>
<td>Japan</td>
<td>R</td>
<td>100 (84/16)</td>
<td>NR</td>
<td>72%</td>
<td>76.0%</td>
<td>NR</td>
<td>NR</td>
<td>68 (36-180)</td>
</tr>
<tr>
<td>Ohyama et al.</td>
<td>Japan</td>
<td>P</td>
<td>128 (99/29)</td>
<td>NR</td>
<td>100%</td>
<td>51.6%</td>
<td>89.9%</td>
<td>NR</td>
<td>42.4±35.8</td>
</tr>
<tr>
<td>Suzuki et al.</td>
<td>Japan</td>
<td>R</td>
<td>479 (NR)</td>
<td>92.1%</td>
<td>53.2%</td>
<td>74.3%</td>
<td>90.8%</td>
<td>NR</td>
<td>31.4 (1-83)</td>
</tr>
<tr>
<td>Merrill et al.</td>
<td>USA</td>
<td>R</td>
<td>30 (20/10)</td>
<td>NR</td>
<td>100%</td>
<td>90.0%</td>
<td>NR</td>
<td>0%/16%</td>
<td>NR</td>
</tr>
<tr>
<td>Inui et al.</td>
<td>Japan</td>
<td>R</td>
<td>555 (465/90)</td>
<td>92.4%</td>
<td>42.7%</td>
<td>72.6%</td>
<td>91.1%</td>
<td>NR</td>
<td>44.3 (3-141)</td>
</tr>
<tr>
<td>Rubenstein et al.</td>
<td>USA</td>
<td>P</td>
<td>23 (11/12)</td>
<td>100%</td>
<td>100%</td>
<td>82.6%</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Ito et al.</td>
<td>Japan</td>
<td>R</td>
<td>98 (78/20)</td>
<td>100%</td>
<td>100%</td>
<td>74.5%</td>
<td>91.0%</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

R: Retrospective; P: Prospective; M: Male; F: Female; NR: Not reported; PPC: Pnacretic pseudocyst; 3LS: 3-point Likert scale; 5LS: 5-point Likert scale; VAS: VAS score; 3EML: P-ESWL, electromagnetic lithotripter (Compact Delta II; Dornier Med Tech, Wessling, Germany; Modulith SLX; Storz Modulith SLX, Medical AG, Tägerwilen, Switzerland; Piezolith 3000: Piezolith 3000 (Knittlingen, Germany)
Piezolith 2500: Piezolith 2500 lithotripter (Piezoelectric effect technique; Richard Wolf GmbH, Knittlingen, Germany)
ESL: Electromagnetic Siemens Lithoskop
LITHOSTAR Multiline: LITHOSTAR Multiline (Electromagnetic generation technique; Siemens GmbH, Munich, Germany)
Piezoelectric lithotripters (LT-01, 02 [EDAP International Inc, Paris, France])
ESWG: transportable cylindrical electromagnetic shock wave generator device
Modulith SLZ; Storz Medical AG, Kreuzlingen, Switzerland
EML: Electromagnetic Siemens Lithoskop (Siemens AG, Munich, Germany)
EMS: Electromagnetic system
EHSG system: Electrohydraulic spark gap system
PEG: Piezoelectric generator
Dornier HM3: Dornier HM3 (Medizintechnik GmbH, Germering, Germany)
Minilith SL: Modified mini-lithotripter (Minilith SL 1, Storz, Switzerland)
EM: Electromagnetic system
Modified Lithostar prototype: Siemens, Erlangen, Germany

The smaller diameter of the pancreatic stones appears lower than CBD stones as common duct stones clearance following ESWL ranges from 83–93%.21-25 This difference in success rate is possibly attributable to the different sizes and composition of pancreatic stones when compared to biliary stones. The mean diameter of biliary stones in one study was found to be 23.4 mm (range 15.0-40.0 mm), whereas the mean diameter of pancreatic stones was 5.6 mm (range 5.0-6.0 mm).26
stones likely makes lithotripsy more difficult because greater precision is likely required for stone fragmentation. Furthermore, the chemical composition differs between the two categories of stones. As previously mentioned, pancreatic stones are mainly composed of calcium carbonate while biliary stones are mainly composed of cholesterol. Calcium carbonate stones’ microhardness likely contributes to decreased success rate of treatment of pancreatic stones with ESWL. Wang et al. found that stones with densities >900 Hounsfield units (HU) had a greater possibility of ESWL failure.27 Furthermore, Liu et al. showed that mean stone density was an independent indicator for predicting ESWL outcome, and patients with a mean stone density value <375.4 HU tended to have a better stone clearance rate, which provide accurate guidance in the preoperative assessment of PDS patients.28 Thus, accurate radiographic imaging and evaluation by radiologist could help predict which patients would benefit from treatment with ESWL.

Interestingly, Khan et al. showed no statistically significant correlation between pancreatic duct clearance and age, gender, pancreatic duct diameter, stone size, stone number, number of ESWL shocks, and number of ESWL sessions when looking at treatment of pancreatic stones with ESWL followed by ERCP.14 However, other predictors of successful stone clearance using ESWL include stone in the head/body, solitary stones, secretin injection during the procedure, and pre-ESWL pancreatic stent placement.8

Endoscopic Modalities
Pancreatic stones can also be extracted by endoscopic means in place of or in conjunction with ESWL. One modality is ERCP, which has been used for many years and is usually the primary modality to remove stones and has been used to retrieve stone fragments after initial ESWL sessions. ERCP has a higher success rate for treatment of PD stones measuring < 5 mm which are more proximally located and not impacted. However, complicated cases or stones > 5 mm are more difficult to retrieve and require ESWL. Stone removal and clearance with solely ERCP is usually achieved in a very small percent of patients (9–14%).29-31 Risk factors for failure include downstream strictures, size > 10 mm, and impacted stones.32

ESWL in combination with ERCP has been shown to have significant clinical impact. Studies have indicated that ESWL treatment of pancreatic stones have shown complete pain relief in 71.4-84% of patients and partial pain relief in 12.3-16.7% of patients.11,14,33 However, the addition of ERCP is not necessarily needed to achieve significant pain relief. An observational study evaluating analgesics and opioids use before and after intervention showed no significant difference between patients using ESWL and those receiving ESWL and concurrent ERCP.5 Additionally, two comparative studies looking at ESWL alone to ESWL with ERCP showed no differences between pain scores or number of painful events between the two groups.34-35 Dumonceau et al. reported similar decreased in pancreatic duct diameter and in number of pain episodes per year when comparing individuals being treated with ESWL alone vs. ESWL combined with endoscopic therapy. Furthermore, the combined ESWL with endoscopic therapy group appeared to have longer hospital stay and increased treatment costs.34 Vaysse et al. found no difference in pain resolution at 6 months after treatment when comparing patients receiving ESWL alone versus combination of ESWL and endoscopic therapy.35

The above contrasts to Spyglass, which allows for endoscopists to visualize the biliary system and closely related structures under direct vision. Within the Spyglass system, operators have the ability to use two chief principal methods to fragment stones, which include Electrohydraulic Lithotripsy (EHL) or Laser Lithotripsy (LL). EHL uses the generation of electric shock wave in a liquid medium to propagate into stones and result in fragmentation. LL uses a Holmium YAG laser to apply shock waves in direct contact with the stone resulting in fragmentation.

Many studies have shown a very high success rate in using Spyglass for pancreatic stone extraction. A recent meta-analysis showed that the overall technical success rate of EHL was 85.92% (95% CI 66.35 to 94.97), with clinical success being 76.16% (95% CI 55.61 to 89.07).36 Adverse event rates were shown to be 10.24% (95% CI 4.60 to 21.26). When compared to EHL, LL on average seemed to perform better with technical success being 97.74% (95% CI 92.42 to 99.35),
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clinical success 96.32% (95% CI 82.88 to 99.30) and adverse event rates 7.09% (95% CI 3.59 to 13.54).36

In some cases, Spyglass is also used in conjunction with ESWL in order to remove the fragmented stones or alleviate strictures to allow for increased passage of stones.37 Although Spyglass appears to have greater success rates than ESWL, there is little randomized data comparing ESWL with other modalities of lithotripsy (EHL or LL) in pancreatic stones. Two RCT studies have compared ESWL to laser lithotripsy in the late 90s for biliary stones. In trial one, complete stone clearance occurred in 52.4% of patients undergoing ESWL compared to 82.4% undergoing laser lithotripsy.38 In the other trial, stone clearance rate was 73% in patients treated with ESWL compared to 97% in patients treated with laser lithotripsy.39 However, these stones were evaluating biliary stones and not pancreatic duct stones. Despite this increase in success rate, Spyglass is more invasive and has the potential to pose greater risks to patients including cholangitis (1.4%), bleeding (1.1%), and perforation (0.7%).40

Complications / Safety of ESWL
A variety of complications ranging in severity from mild to severe have been reported using ESWL for pancreatic stone fragmentation in 5-10% of patients suggesting a morbidity of 5.8% with a single mortality of 0.05%.16 While another study has shown an overall complication rate of 6.7%.41 The most common adverse event in the treatment of pancreatic stones appear to be pancreatitis occurring in 4.2% of patients2 which appears to be similar to pancreatitis rates in the use of Spyglass, which occurs in 4-6.6% of patients.36,42

Interestingly, 20-40% of individuals with chronic pancreatitis develop pancreatic pseudocysts during the course of their disease. Despite this common occurrence of cysts, ESWL has been shown to be safe for the assistance in treating pancreatic ductal stones. A prospective study looking at outcomes of using ESWL prior to ERCP in patients with pancreatic pseudocysts showed no significant difference in the number of adverse events or in rates of adverse events when using ESWL in patients with pancreatic pseudocysts versus controls.43

Contraindications to ESWL include non-correcatable coagulation disorders, pregnancy, and the presence of bone, calcified vessels or lung tissue in the shockwave path.16,44 Furthermore, certain precautions need to be taken for patients with pacemakers and implantable defibrillators.16,45

Despite the seemingly less invasive nature of ESWL procedure, it does pose possible serious events which include bowel perforation, splenic rupture, necrotizing pancreatitis, bleeding and sepsis.11,15,41 However, these are rare events.11 Reduced patient movement and accurate targeting could minimize possible complications as a result of diminishing possible exposure of shock waves to nearby organ systems.

CONCLUSION
ESWL is an effective and safe treatment for the treatment of pancreatic duct stones and has been shown to be an optimal treatment option for patients with chronic pancreatitis. Advantages of ESWL include relatively high efficacy of stone clearance, minimal complication rates, non-invasiveness, and pain relief. ESWL should be considered as a viable method for the treatment of pancreatic stones alone or in conjunction with endoscopic techniques.■

References
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