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ERCP Stone Extraction: Simple

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INTRODUCTION

Endoscopic retrograde cholangiopancreatography (ERCP) was initially developed as a diagnostic procedure for visualizing the pancreatic and biliary ducts. However, it has evolved over the years into a predominantly therapeutic tool. The most common indication for undergoing ERCP is biliary stone disease. Choledocholithiasis refers to the presence of gallstones in the common bile duct (CBD). (Figures 1-3) Stones in the CBD can cause stasis and obstruction leading to bacterial translocation and cholangitis. The clinical presentation varies

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Figure 1. Endoscopic image showing multiple common bile duct stones in the second part of the duodenum

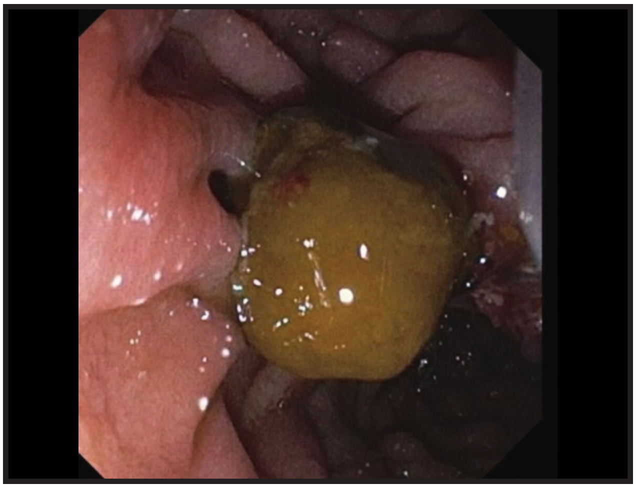

Figure 2. Endoscopic image showing large common bile duct stone in the second part of the duodenum

from biliary colic, cholangitis, and can also include biliary pancreatitis. Therefore, ERCP plays a vital role in managing choledocholithiasis and preventing and treating complications. ERCP is used to identify the stones often seen as a filling defect. The modalities used to identify stones are the injection of undiluted contrast, diluted contrast, and regular and occlusion cholangiograms.[1]

Diagnostic ERCP is commonly performed with undiluted water-soluble contrast. The initial fluoroscopic images can reveal bile duct stones that manifest as a filling defect (an area where dye cannot go), often with a "meniscus sign," or an arc of contrast at the level of the stone. Diluted contrast can be used if the bile duct is dilated, as the undiluted contrast can mask the small stones, although in practice the use of diluted or undiluted contrast during ERCP varies widely. An occlusion cholangiogram, whereby the bile duct is filled with contrast over an inflated occlusion balloon attached to an ERCP catheter, is performed in patients with suspected intrahepatic stones or stones proximal to a stricture or to prove duct clearance after stone removal. Bile duct stones will manifest as intraluminal filling defects, but other lesions can present as filling defects as well, including air bubbles, blood clots, parasites, mucus, tumors and neoplasms of the duct, and other etiologies. The patient's clinical picture should be considered to make a definitive diagnosis.

Of utmost importance for stone extraction is for the operator to properly gauge the size of the exit passage. The size of the stone should be measured relative to the size of any intended or performed biliary sphincterotomy and the diameter of the bile duct. The sphincterotomy site should be adequate to allow for the stone to pass. Different methods can be used to measure the size of the ampullary orifice. One of the methods is by pulling a stone extraction balloon, inflated to the approximate size of the stone, through the sphincterotomy and the distal bile duct. The stone extraction should, in theory, be easily accomplished if the balloon passes easily and without resistance or deformation. However, stone extraction may prove to be difficult if there is resistance during the passage or the balloon becomes deformed during its transit through the distal CBD and the ampullary orifice-this suggests that the sphincterotomy itself may be inadequate and may need to be extended or completed. Another way of measuring sphincterotomy size is by pulling a fully bowed sphincterotome through the papilla. A bowed sphincterotome should be able to pass easily through the sphincterotomy, and with no resistance. If the sphincterotomy size is deemed inadequate even after what is felt to be a complete sphincterotomy has been performed, additional therapies such as balloon dilatation of the sphincterotomy and distal bile duct may be required for stone extraction.[2]

Balloon dilation of the bile duct itself is occasionally needed in patients harboring benign

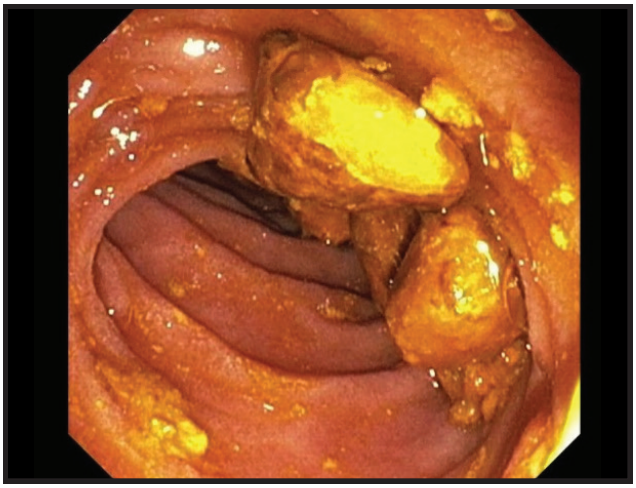

Figure 3. Endoscopic image showing multiple stones in the Common Bile duct

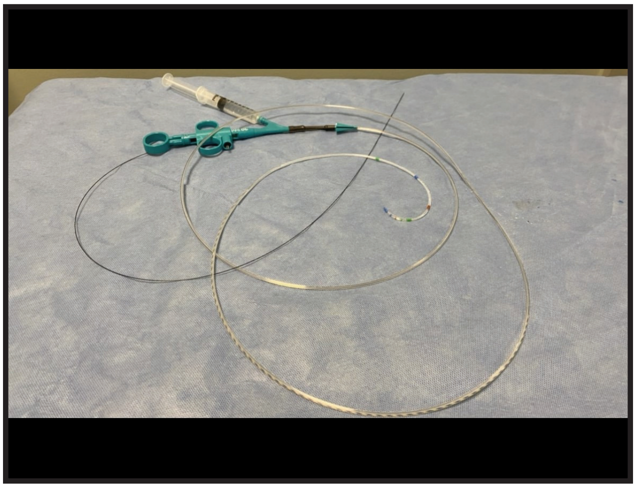

Figure 4. Image showing the RX 39 sphincterotome 30 mm cut wire. 0.025" x 260 cm

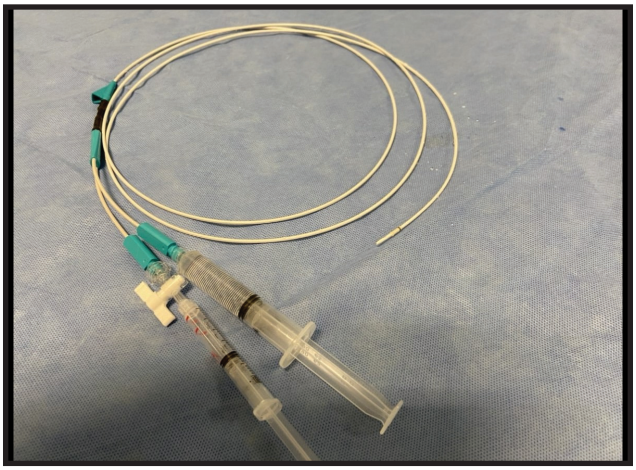

Figure 5. Image showing variable diameter stone extraction balloon

biliary strictures when the stone is proximal to the stricture or cases of intrahepatic stones. Biliary dilation balloons are used for dilation. These are low-profile balloons ranging from 4 to 10 mm in diameter and 2 to 4 cm in length that can be inflated to a single, fixed diameter (unlike esophageal dilation balloons, for example, which can often be inflated to several distinct sizes). Biliary dilation balloons can be placed over a guidewire across the biliary stricture in question and inflated using saline or dye to achieve effacement of the underlying stricture. A radio-opaque marker (or markers, depending on the vendor) placed at the end and/or in the middle of the balloon helps with proper positioning of the balloon across the stricture. The choice of balloon size is based upon the diameter of the bile duct. The balloon is visualized under fluoroscopy during inflation to provide an additional margin of safety. The disappearance of the waist (full effacement) during inflation would determine the effectiveness of the dilation and typically demonstrates if the dilation was successful. If there is distortion during inflation, it would suggest inadequate dilation or a recalcitrant stricture. Additional therapies, including stone fragmentation, may be warranted before attempting stone removal when the calculus itself is located above an incompletely dilated stricture. Alternatively, indwelling stents can be placed to allow biliary decompression, avoid cholangitis, and to prevent other complications until the stricture is adequately treated.[3]

Indications

(i) Common bile duct stones

(ii) Intrahepatic duct stones

Contraindications

(i) Medical conditions preventing the use of sedation in the patient

(ii) Anatomical - Gastric outlet obstruction that prevents the access to major papilla

Patient Preparation

Patients undergoing ERCP should be evaluated for their general fitness for the procedure itself as well as the sedation required to perform the procedure. In the United States, most ERCP procedures are performed under General Anesthesia or Monitored

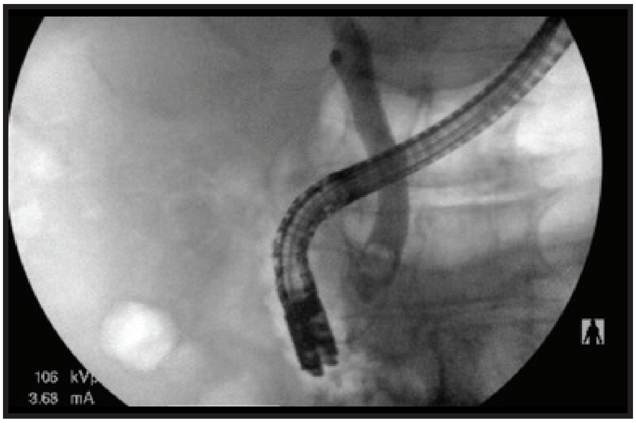

Figure 6. Fluoroscopy image with occlusion cholangiogram showing dilated common bile duct with distal CBD stone

Figure 7. Fluoroscopy image with occlusion cholangiogram showing dilated CBD with multiple stones

Anesthesia Care. Endotracheal intubation is preferred in patients with sepsis with unstable hemodynamics.[4] Most patients can safely undergo ERCP, including young and old patients, cirrhotic and non-cirrhotic patients, children, and pregnant patients, depending on the circumstance.[5]

Positioning

There are several position options for patients undergoing ERCP: prone, supine, left lateral decubitus, or oblique. The positioning is determined by operator experience and preference as well as patient-related factors such as body habitus, neck mobility, or the presence of abdominal drains. The other factors that play a role in choice of patient position are anesthesia and airway considerations. The left lateral and oblique positions are sufficient for cases involving extrahepatic bile duct but can be less than ideal inadequate for patients requiring pancreatic duct or intrahepatic duct imaging.[6] In these cases, either a prone or supine position is preferred. There have been studies that have compared prone and supine positioning during ERCP. A large randomized controlled trial at a tertiary center found no difference in cannulation rate or adverse events between the prone and supine groups, irrespective of operator skill.[7] In addition, a retrospective study was performed with 649 patients undergoing ERCP: prone (n = 506) and supine (n = 143) with a mix of moderate and generalized anesthesia administered. The study found no difference between cannulation rate or adverse events between the prone and supine groups.[8] In general, ERCP is usually performed in the prone position in the United States.

Antithrombotics

Many patients who need to undergo ERCP require antithrombotic or anticoagulant medications to treat other underlying illnesses, and practitioners of ERCP often must make decisions regarding if and when to stop and restart these medications so that the procedure can be performed. The decision to proceed with ERCP and whether to start or stop antithrombotic agents should be, in general, individualized and based on clinical urgency, the bleeding risk of the specific ERCP that needs to be completed, and the cardiovascular risk of holding the antithrombotics. For example, the active use of anticoagulants should not defer an ERCP procedure in cases of sepsis that require urgent ERCP i.e., a decompressive biliary stent can be quickly and safely placed in a patient on any anticoagulant and with any international normalized ratio (INR). This approach can save time in a critically ill patient but leaves for a later day the decision on how to manage anticoagulants so that the offending stone can be safely removed. One study has shown a threefold increase in organ failure in patients with cholangitis who waited for ERCP for > 48 hrs, further arguing for early intervention.[9]

Endoscopic sphincterotomy (ES), which is nearly universally practiced to facilitate the

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removal of bile duct stones in the United States, always carries a risk of causing acute or delayed bleeding, although the absolute risk of bleeding is low. Endoscopic papillary balloon dilatation (EPBD) without ES is a low-risk bleeding procedure, but carries an increased risk of causing pancreatitis, which can be severe. In non-urgent cases, antithrombotics and anticoagulants can be held prior to performing ES, whereas they can be continued in patients undergoing EPBD. In urgent cases, a plastic biliary stent can be placed for drainage without the need for ES to decrease the risk of bleeding. For patients with low cardiovascular risk who require ES, anticoagulation can frequently be held, whereas "bridging" with heparin can be considered in higher cardiovascular risk patients, although in practice bridging is rarely performed.

The 2016 ASGE guideline on the role of blood thinners in endoscopy provides a thorough review of this topic.[10] The key concern generally involves weighing the risk of bleeding against the risk of a thromboembolic event. The primary risk factor for bleeding during ERCP is endoscopic sphincterotomy.[11] Therefore, it is unnecessary to discontinue antithrombotics if ERCP without ES is planned.

Antibiotics

The guidelines recommend using preprocedural antibiotics for immunocompromised patients, liver transplant patients, cholangitis and patients with biliary obstruction in whom incomplete drainage is anticipated (multiple stones or complex strictures).[12] The use of pre- and/or post-procedural antibiotics has shown lower rates of post-ERCP cholangitis in cases of biliary obstruction without cholangitis and anticipating complete drainage after ERCP.[13] In many centers antibiotic prophylaxis is widely used for patients undergoing ERCP regardless of indication given the low cost and significant potential benefits.

Stone Extraction: Devices and Techniques

The choice of stone extraction device depends upon the number, size, and type of stones and the structure of the bile duct relative to the stone(s). The size of the stone and duct diameter can be estimated by comparing to the width of the duodenoscope, which is generally around 12mm.

ERCP Guidewires

Guidewires are the mainstay of ERCP. They are critical for duct cannulation, maintaining access to a desired duct, exchanging devices, guiding devices, dilating strictures, and placing stents; all of these maneuvers are employed during stone extraction cases. There are a variety of guidewires that are commercially available, and these differ widely in terms of materials, length, diameter, mechanical properties, and design.[14]

Broadly speaking, there are three general classes of guidewires available for ERCP: (1) Monofilament wires with stainless steel cores that are designed for rigidity. (2) Coiled wires are made of inner monofilament core and outer spiral core of

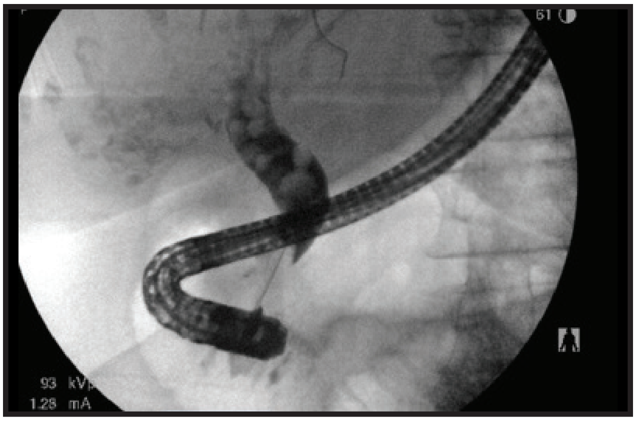

Figure 8. Fluoroscopy image showing occlusion cholangiogram with the dilated CBD, multiple CBD stones with distal CBD stricture

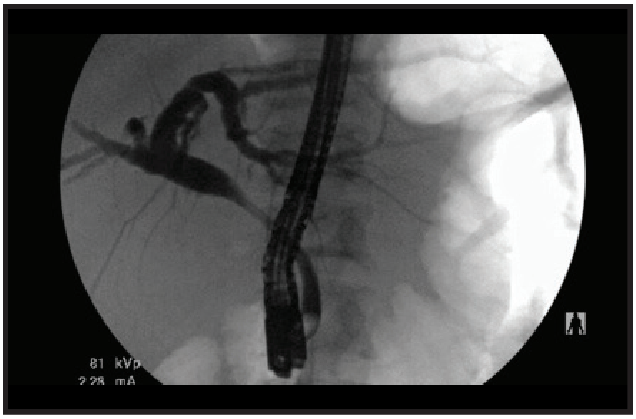

Figure 9. Fluoroscopic image with occlusion cholangiogram showing balloon sweep for stone retrieval

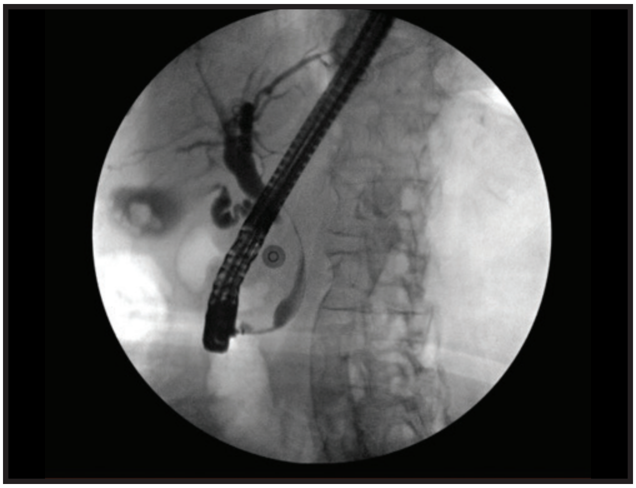

Figure 10. Fluoroscopic image with occlusion cholangiogram showing multiple gallbladder stones

Figure 11. Fluoroscopic image showing stone engaged in a Dormia basket

stainless steel. The inner core provides stiffness, and the outer core provides flexibility. (3) Coated or sheathed wires made of stainless steel or nitinol monofilament cores with an outer sheath of Teflon, polyurethane, or other materials. Guidewires are advanced into the desired duct through a sphincterotome or a balloon catheter under endoscopic and fluoroscopic guidance. Most wires come with external markers of some type printed on their outer coatings to illustrate movement and measure depth of entry. Guidewire locking devices, that fit externally onto a duodenoscope, can be used to fix the proximal end of the guidewire (outside the patient) and reduce the risk of wire dislodgement.[15] A summary of currently available guidewire types is listed in Table 1.

Sphincterotomy – Devices and Techniques

Biliary Sphincterotomy

Endoscopic sphincterotomy (ES) of the biliary sphincter is indicated for many biliary interventions and is critical for stone extraction. The sphincterotome itself helps in achieving deep bile duct cannulation and is then used to perform the sphincterotomy itself. Advantages of using sphincterotomes include the following: 1. When it is anticipated that a sphincterotomy will be needed, exchange to a sphincterotome from a straight biliary catheter is avoided. 2. A sphincterotome allows for the variable deflection of the catheter tip to facilitate biliary access during cannulation. Studies have shown a higher cannulation rate with sphincterotomes than with standard straight biliary catheters, with no difference in adverse effects.[16,17] A recent meta-analysis showed an increased cannulation rate and decreased risk of post-ERCP pancreatitis for guidewire-assisted cannulation compared with contrast-assisted cannulation, both of which are generally performed with sphincterotomes in the modern era.[18,19]

Sphincterotomes (Figure 4) vary in the diameter and length of the tip, size, characteristics of the cutting wire, and shaft stiffness.[20] Tapered devices can be easily inserted into the papilla but also come with a potentially higher incidence of tissue trauma when compared to blunt tip devices. Modern sphincterotomes are considered to be “triple lumen devices” with one channel for contrast injection, one for guidewire access, and the third lumen in the catheter being the one that contains the cutting wire itself. As such, most sphincterotomes have a lumen for the guidewire and an integrated hub for contrast injection, thus allowing contrast injection without guidewire removal (as was required in the past with so called “double lumen devices”).

Sphincterotomy Procedure for Biliary Stone Extraction

The papilla is approached with the sphincterotome from a distance so that the pre-curved distal part can be seen exiting the endoscope. The tip of

Table 1. Guidewires Available for ERCP Applications

Wire Type/Name (Manufacturer)	Diameter (in)	Length (cm)	Core Material	Sheath Material	Tip Material
Monofilament					
Axcess 21 (CE)	0.021	480	Nitinol	None	Platinum
Amplatz (BS)	0.038	260	SS	None	Platinum
Coiled					
Standard Wires (CE)	0.018, 0.021, 0.025	480	SS		Stainless tapered core coil
Coated					
Tracer Metro Direct (CE)	0.021, 0.025, 0.035	260, 480	Nitinol	Teflon	Platinum, hydrophilic
Delta (CE)	0.025, 0.035	260	Nitinol	Polyurethane	Hydrophilic
Acrobat (CE)	0.025, 0.035	260, 450	Nitinol	Polytetrafluoroethylene	Hydrophilic
Tracer Metro (CE)	0.035, 0.035	260, 480	Nitinol	Teflon	Platinum, hydrophilic
Roadrunner (CE)	0.018	480	Nitinol	Teflon	Platinum
Jagwire (BS)	0.038, 0.035, 0.025	260, 450	Nitinol	Teflon	Tungsten, hydrophilic
Hydra Jagwire (BS)	0.035	260, 450	Nitinol	Endoglide coating	Tungsten, hydrophilic
NovaGold (BS)	0.018	260, 480	Triton alloy	Hydrophilic	Straight, shapable
NaviPro (BS)	0.018, 0.025, 0.035	260	Nitinol	Polyurethane	Platinum, hydrophilic coating on entire length
Pathfinder (BS)	0.018	450	Nitinol	Endoglide	Platinum, hydrophilic
VisiGlide (O)	0.025	450, 270	Superelastic alloy	Fluorine	Hydrophilic
LinearGuideV (O)	0.035	270, 450	Nitinol	Polytetrafluoroethylene	Hydrophilic
X wire (CM)	0.035, 0.025	260, 450	Nitinol	Hydrophilic	Nitinol

BS, Boston Scientific, Marlborough, MA; ***CE,*** Cook Endoscopy, Winston-Salem, NC; ***CM,*** ConMed, Utica, NY; ***O,*** Olympus America Inc., Lehigh Valley, PA; ***SS,*** stainless steel.

the sphincterotome is inserted into the papillary opening, and the device is maintained by the short, straight position of the duodenoscope. The subsequent bowing of the tip allows the insertion into the common bile duct opening. The S-shaped distal part of the common bile duct is overcome by straightening the tip and gently withdrawing the endoscope. The guidewire is passed into the bile duct under endoscopy and fluoroscopy guidance

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without contrast injection. A soft hydrophilic guidewire is preferred to reduce the risk of ductal injury. The unbowed sphincterotome can then be advanced to attain deep cannulation. The guidewire is then moved into the proximal biliary system to secure ductal access for maneuvers and the exchange of accessories.

Precut Sphincterotomy for Biliary Cannulation

Selective biliary cannulation (SBC) is the mainstay of therapeutic ERCP.[21] Despite significant advancements in imaging techniques and newer designs of guidewires and sphincterotomes, the success rate for biliary cannulation has been around 85% using standard cannulation techniques for average providers.[22] Precut sphincterotomy, which refers to cutting into the ampulla before deep biliary access has been obtained, is performed when biliary cannulation is not attained using standard techniques. Difficult SBC has been defined variously but can be considered to apply when the cannulation requires ≥10 attempts and/or takes more than 10 minutes to achieve cannulation.[23] Precut sphincterotomy increases the cannulation rate to approximately 98%.[24] A ‘precut’ is defined as an incision made into the CBD or the ampulla of Vater before attaining SBC during ERCP.[25]

Endoscopic Papillary Balloon Dilatation

Endoscopic papillary balloon dilatation (Figure 5) is used to facilitate stone extraction with or without preceding endoscopic sphincterotomy. This technique is specifically helpful in achieving adequate opening (i.e., exit passage) to allow retrieval of stones, in cases of complicated anatomy (e.g., diverticulum), in cases of prior failed stone extraction, and in circumstances that prohibit sphincterotomy (e.g., coagulopathy) or extension of sphincterotomy. The dilation balloons (< 10 mm) include the Fusion dilation balloon (Cook Endoscopy, Winston Salem NC) and the Hurricane balloon (Boston Scientific, Natick MA). The balloon should not be dilated greater than the diameter of the proximal bile duct to avoid perforation. In addition, the dilation should be performed slowly and under fluoroscopy to evaluate for the disappearance of the “waist.” The balloon should be kept dilated for about 30 to 60 seconds after the disappearance of the waist according to some, but no hard and fast guidelines exist. However, a longer duration should be considered, as this may reduce the risk of pancreatitis (mainly when sphincterotomy is not performed). Balloon dilation with endoscopic sphincterotomy has comparable outcomes in terms of stone clearance. However, there is an advantage of overall lower risk of adverse events and pancreatitis than sphincterotomy alone.[26]

Balloon Extraction

Stone extraction balloons are available in multiple sizes. The size varies from 8 to 20 mm depending upon the amount of air in the balloon. The exit site is gauged by inflating the balloon to the maximum diameter of the bile duct below the stone and pulled out to check for resistance or change in the diameter or any significant deformity of the balloon under the fluoroscopy. The shape can be distorted and become “sausage-shaped” in cases of chronic pancreatitis due to inflammation. Triple lumen catheters allow the catheter to pass over the guidewire. This provides an advantage as it maintains access to the biliary system while allowing for the injection of the contrast. The disadvantage is that the triple-lumen balloon shafts are stiffer than the double-lumen shafts.

Prior to introducing the balloon catheter into the endoscope, the tip of the catheter should be slightly bent or curved to allow for easier cannulation of the bile duct. (Figures 6-10) The catheter is passed into the bile duct, and the images are obtained under fluoroscopy. The catheter is passed proximal to the stone, and the balloon is inflated. It is gently pulled back until the stone reaches the level of the papilla. Once at the papilla, the axis of traction is adjusted by aligning the scope with the axis of the bile duct. This has a mechanical advantage and also reduces damage to the duct. The tip of the endoscope is angled upwards against the sphincterotomy. While continuing the slow pulling of the catheter, the scope is angled downward, leading to the expulsion of the stone from the ampulla. If the removal of the stone is unsuccessful at the first attempt, the scope should be angled upward, and gentle traction should be applied along with the repetition of a similar downward movement of the scope. It is necessary to maintain the traction as the stone is getting expelled from the bile duct. More traction can be applied if required by bending the scope downward and rotating it to the right to expel the stone.

Occasionally, the inflated balloon can also cause resistance, and it is essential to deflate the balloon to the size of the bile duct or the sphincterotomy. This can be done by adjusting the flow inside the balloon by the stopcock. In the case of multiple stones, the most distal stones are removed first and then the proximal ones. This will avoid the impaction of the stone or rupturing of the balloon. The balloon should be adjusted according to the size of the bile duct. The other thing to be careful about is not to dislodge the wire. The balloon goes over the wire, and excessive movement can dislodge the wire. The balloon should be pulled gently, and excessive movement should be avoided to prevent dislodgement of the wire. However, if the guidewire access is lost, the balloon should be withdrawn, and the bile duct should be re-cannulated with the guidewire. There are multiple advantages (Table 2) and disadvantages (Table 3) of using the stone extraction balloon.

Basket Extraction

Wire baskets are commonly used for stone extraction. The baskets are available in different shapes and sizes and allow stone extraction for sizes ranging from 5 mm to 3 cm. A variety of baskets currently available (Table 4) are listed with their characteristics, advantages and disadvantages. However, stones that are larger than 2 cm require fragmentation before extraction. The most commonly used basket is the four-wire Dormia basket. It is made of braided steel and is hexagonal in shape. The stone is captured between the basket wires when it is closed. The stone is then removed by continuous gentle traction during basket withdrawal.[27] Smaller stones are difficult to capture due to the large spacing between the wires. Newer baskets with a modified design help in capturing smaller stones. So called "flower baskets" are divided into eight wires, with narrow space between the wires, allowing for better engagement of smaller stones. The eight-wired basket allows for better engagement of small stones than the four-wired basket. There are spiral baskets that are used for relatively small stones. The wires wind closely around the stone when the basket is opened. These spiral baskets are not designed for mechanical lithotripsy. The baskets for lithotripsy have stronger wires and metal sheets that provide support to crush the stone. The tension can be applied manually or using a crank handle to crush the stones.

Dilute contrast is injected during the procedure, and the images are obtained to outline the stones in the bile duct. Care should be taken to avoid injecting excessive contrast due to the risk of displacing the stones proximally into the intrahepatic ducts or interfering with proper visualization. The single-lumen basket allows for the free flow of dilute contrast when it is opened. A double-lumen basket has different channels for injection of contrast and passage of a guidewire. The basket can also be advanced over an already positioned guidewire. This is mainly useful for removing stones in the intrahepatic duct or those that could have migrated to the intrahepatic ducts. The traditional guidewires run through the entire length of the basket catheter. Modern baskets are typically designed for short-wire systems. These involve only a part of the basket going over the guidewire. The wire is locked in position, and then the manipulation is done. A newer modification is the "ropeway" basket. It is a single lumen system and has a catheter attached

Table 2. Advantages of Balloon Extraction

Advantages of Balloon Extraction
• Complete occlusion of the bile duct by the inflated balloon leading to the removal of small stones and debris
• The balloon catheter is inserted over a guidewire and can be passed into the intrahepatic ducts, facilitating removal of intrahepatic stones
• An occlusion cholangiogram can be done at the same time to ensure complete clearance of the bile duct
• There is no possibility of impaction of balloon catheter in the duct which can occur with basket

Table 3. Disadvantages of Balloon Extraction

Disadvantages of Balloon Extraction
• The possibility of impacting the stone in the distal duct during retrieval
• The inability to completely clear the bile duct as the balloons can conform around the stone in the distal duct during traction through the papilla, leading to a false impression of clearance

to the tip of the basket, which allows only the tip (instead of the shaft) of the basket to go over the wire. The contrast is injected, and images are obtained to specify the location of the stone. (Figure 11) The stone can also be visualized on the cholangiogram. The basket in a closed position is inserted into the bile duct and is advanced proximal to the stone. Once the basket is in the duct, it is opened slowly above the stone. An alternative is to go all the way to the intrahepatic duct and then open the basket and pull back gently to capture the stone. Caution should be taken to avoid opening the basket below the stone as this can push the stone proximally into the intrahepatic duct, thus making extraction difficult. The basket is pulled back and manipulated along the stone to engage it. Once the stone is captured, the basket is partially closed to avoid losing the stone. The endoscope is pushed further into the duodenum to help align the basket's axis with the bile duct. Continuous gentle traction is applied to the basket catheter until it reaches the distal bile duct or the level of sphincterotomy. The endoscope tip is angled upward to the sphincterotomy, and the traction is applied. Once the stone is at the papilla, the tip of the scope is turned down, and traction is applied to remove the stone. If the stone is not extracted, the same motion can be repeated with the steady traction of the basket. Furthermore, the scope tip should be turned down and rotated to the right once it has reached the tip, helping to extract the stone out of the bile duct. The basket is closed gently during extraction instead of the fully open basket. The closed basket allows all the wires to come together, and the overall force is transmitted along with the wire basket and along the distal bile duct. However, if the basket is withdrawn in a fully opened position, the loose wires tend to cut across the sphincterotomy rather than the axis of the common bile duct. This leads to bruising and submucosal tissue damage. In addition, caution should be taken to avoid closing the basket tightly around the stone. This can lead to embedding the wires to the stone's surface, resulting in the impaction of the stone, especially in cases of large stones. In some instances, the wires cannot be freed from the stone, thus leading to the impaction of the basket.

Another technique that can be applied to capture stones in a dilated bile duct is an aspiration. The basket is opened above the bile duct, and the aspiration of the contrast or bile is done as the basket is withdrawn. This creates a negative suction force and helps trap the stones within the basket wires. The same technique can be applied to smaller stones that are difficult to capture. The basket can be placed at the level of the papilla to keep the open sphincter. Suction is applied from the duodenum that helps in the movement and capturing of the stones in the basket. This can also be used for small stones in the hepatic duct. The basket can be placed at the bifurcation of the duct, and the suction is applied. This leads the stones to descend in the hepatic duct and into the basket placed in the bile duct, from where the stones are eventually removed.

There are numerous advantages of the extraction basket. These include more effective traction and help remove medium to large stones. However, there are some disadvantages of extraction baskets. Smaller stones or fragments are difficult to engage in the wires. The stones in the intrahepatic ducts may be difficult to capture because of the narrow diameter and less flexibility of the capture baskets. There is also a constraint in opening the basket in the narrow intrahepatic ducts. Thus, in these scenarios, extraction balloons are perhaps a better choice. The recent trials comparing the extraction balloons to extraction baskets have favored balloons for smaller (10 to 11 mm) stones.[28,29] However, the choice for smaller stone removal depends upon personal preference.

Table 4. Currently Available Baskets for ERCP Applications

	Dormia Basket	Flower Basket	Spiral Basket
Shape and Characteristics	Hexagonal in shape and made of braided steel or nitinol wires	Modified design with the top of the basket divided into eight wires giving more narrow mesh spacing for improved stone engagement when the basket is closed	Helical configuration with wires springing closely around the stone as the basket is pushed open
Advantages and Disadvantages	Small stones may be difficult to capture with standard baskets that have large gaps between wires	Small stones are thus more easily trapped than with the regular four-wire basket	Used to remove relatively small stones Not designed for mechanical lithotripsy

Table 5. Summary of the included studies in meta-analysis conducted by Gbreel et al.

Study	Ekmektzoglou et al.	Takeshita et al.	Ishiwatari et al.	Ozawa et al.
Study design	RCT	Retrospective cohort	RCT	RCT
Study arms, sample, and doses	Balloon catheter (90) Basket catheter (90)	Balloon catheter (104) Basket catheter (88)	Balloon catheter (86) Basket catheter (86)	Balloon catheter (93) Basket catheter (91)
Primary outcomes	The rate of complete bile duct clearance for each method	Post-ERCP pancreatitis rate	The rate of complete clearance of the duct by the assigned catheter	The rate of complete removals of stones within 10 min
Secondary outcomes	Time completed and amount of radiation dose recorded in each ERCP session, as well as any reported adverse events	Occurrence of other complications and the total number of complications	The rate and time to complete clearance of the duct in a single endoscopic session and adverse events	The rate of procedure-related complications
Conclusion	The balloon was noninferior to basket stone extraction	The choice of device did not affect PEP occurrence. The sub-analysis showed that the retrieval balloon could be a better first choice for completing stone extraction in one session	For extraction of BDSs≤10 mm, complete endoscopic treatment with a single catheter is more likely when choosing a balloon catheter over a basket catheter	Basket and balloon catheters showed similar efficacies for endoscopic biliary stone extraction when stone size is 11 mm or smaller

Comparing Balloon and Basket Extraction

Basket and balloon catheters are used for stone extraction. Nearly 85-90% of stones are easily retrieved by these methods following endoscopic sphincterotomy (EST), whereas difficulty is encountered in 10-15% of cases. The balloon catheter can capture small stones by obstructing the lumen. However, it cannot prevent small stones from slipping and impaction in the corner pocket at the distal third of the bile duct during stone extraction. Thus, the basket catheter has a better traction power than the balloon catheter.[30] The European guidelines recommend using either technique as there is minimal difference between overall outcomes with basket or balloon catheters. However, the American guidelines recommend balloon catheters over baskets due to the risk of adverse effects related to basket impaction.[31,32]

Ishiwatari et al. performed a randomized control trial in Japan that primarily investigated the clearance rates between the basket or balloon catheters.[33] The complete clearance rates were 92.3% (72/78) in the balloon group and 80.0% (64/80) in the basket group. The difference in the rates between the two groups was 12.3 percentage points, indicating noninferiority of the balloon method (noninferiority limit −10%; P< 0.001 for noninferiority).

Ozawa et al. conducted another randomized control trial in Japan.[34] It was designed as a noninferiority study and compared basket extraction with balloon extraction. The study involved 184 patients over six institutions with bile duct stones < 11 mm in diameter. The primary aim of the study was the rate of complete stone extraction within 10 minutes. The rate of successful extraction within 10 minutes was 81.3% (74/91) in the basket group and 83.9% (78/93) in the balloon group (p = 0.7000). The complication rate was 6.6% in the basket group as compared to 11.8% in the balloon group (p = 0.3092). The complications included bleeding, pancreatitis, and cholangitis.

Ekmektzoglou et al. reported a randomized control trial from Greece.[35] It was a noninferiority study with 180 patients randomized into balloon and basket groups. The study primarily looked at the complete bile duct clearance rate with each method. 69 out of 82 patients (84.1%) achieved complete clearance in the basket catheter group compared to 79 out of 84 patients (94%) in the balloon catheter group (p = 0.047). The time required for clearance was shorter in the balloon group than the basket group. The study concluded that the balloon extraction was noninferior to basket stone extraction (OR 3.35, 95% CI [1.12, 10.05], P = 0.031).

Takeshita et al. conducted a retrospective cohort study that primarily investigated the rates of post-ERCP pancreatitis.[36] 244 cases were divided into the group that used a retrieval balloon as the first choice (n =107) and a group that used a basket catheter as the first choice (n = 137). The groups were further subdivided into one device group and a multiple-device group. 104 cases achieved complete stone removal by only using a balloon, and 88 cases had complete stone removal by only using a basket catheter. 5/104 had pancreatitis in the balloon only group compared with 3/88 in the basket only group (4.8% vs. 3.4%; P = 0.73). The sub-analysis revealed that the use of additional extraction balloon was significantly higher than that of a basket catheter, suggesting that the complete stone retrieval rate using a single device was higher with an extraction balloon than the basket catheters. The study concluded that the choice of the device did not affect PEP occurrence.

Gbreel et al. conducted a meta-analysis comparing balloon extraction and basket extraction.[37] The primary outcomes were divided into efficacy, including time to complete clearance, complete clearance, and clearance according to

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the number of stones. The secondary outcomes included pancreatitis, bleeding, perforation, and cholangitis. The analysis comprised 728 patients over four studies. The results revealed that the balloon catheter was better than the basket catheter in terms of incomplete bile duct clearance (RR = 0.91, 95% CI [0.85, 0.98], P = 0.01). It also found that the balloon catheter was better than basket for clearance of less than four stones (RR = 0.91, 95% CI [0.85, 0.99], P = 0.02) with no significant difference noted for more than four stones (RR = 0.77, 95% CI [0.48, 1.24], P = 0.29). The analysis concluded that a balloon catheter is better than a basket catheter for complete clearance with no significant difference in safety outcomes. A summary of all the included studies is shown in Table 5.

Adverse Effects

Extraction Balloons

Multiple adverse events can happen when using the extraction balloons. The most common is balloon rupture if pushed hard against the stone, although this is unlikely to cause actual patient injury. The other common complication is the impaction of the stone. The inflated balloon can get deformed alongside the stone and can slip out, leaving the stone impacted at the lower end of the common bile duct or the level of the papilla. The stone should be pushed proximally using accessories like forceps or the balloon itself to free the impacted stone. Alternatively, the sphincterotome can be used to extend the sphincterotomy, potentially liberating the stone. Another method is to use the needle knife to cut the bulging portion in the duodenum to free the stone from the bile duct. However, the balloon can be used if the stone is impacted at the distal bile duct but not the papilla. The inflated balloon is placed below the impacted stone, and the contrast is injected under pressure to push the stone proximally. Once the stone is freed, other therapies can be pursued to help in extraction. If the stone cannot be liberated, stenting should be done to provide adequate bile drainage to prevent cholangitis. The indwelling guidewire can be used to operate the balloon to maintain biliary access in case of failed extraction to ensure adequate drainage.

Extraction Basket

The most common adverse event while using the extraction basket is the migration of stones into the intrahepatic ducts. The stones in the bile duct can migrate proximally into the intrahepatic ducts. Therefore, capturing the stone from the intrahepatic duct can be challenging. Once this happens, balloon extraction should be used instead. A guidewire is used, and the required segment is cannulated. The wire is advanced into the intrahepatic duct, and the balloon is advanced over it. The balloon is then inflated proximal to the stone and pulled gently to bring the stone into the common hepatic duct or bile duct.

Further attempts can be made by balloon extraction or basket extraction to remove the stone. Although the basket can be used over the guidewire, the manipulation is difficult within the bile duct because of the basket's stiffness and narrow diameter of the bile duct. In cases where it is difficult to extract the stone from the basket, care should be taken to avoid impaction. In this scenario, the basket is advanced proximally into the bifurcation zone of the duct and opened to free the stone as the wires open up. Once the stone is disengaged from the basket, the basket is closed gently and pulled back to avoid engaging the stone again. Once it is closed, it can be pulled out. However, the stone extraction would need further intervention with balloon extraction or lithotripsy.

The other complication of the basket extraction is the impaction of the stone in the bile duct or at the level of the papilla. This could occur due to large size of the stone, small exit passage (inadequate sphincterotomy), or inability to enlarge the sphincterotomy. In rare cases, the stone and basket impaction can happen at the level of the head of the pancreas. This occurs because of the narrow distal common duct. This would need emergent intervention involving lithotripsy to prevent complications. Emergent mechanical lithotripsy may be done using Soehendra lithotripter to either crush the stone or break the wires of the basket to allow its release.

CONCLUSION

Bile duct stones should be removed, even if asymptomatic, due to the high risk of obstruction, cholangitis, and pancreatitis. The biliary system is accessed via the sphincterotomy and sphincteroplasty. Basket and balloon catheters help remove most stones up to 1.5 cm in diameter. The use of guidance wire allows for proper access to the intrahepatic system, thus facilitating the removal of intrahepatic stones or migrated stones. Stones above a biliary stricture require balloon dilation of the stricture before successful removal. Mechanical lithotripsy is employed to break large stones and stones above a stricture to facilitate removal. ■

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