Techniques in Vascular and Interventional Radiology

Percutaneous Biliary Endoscopy for Stones

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Intraductal biliary stones can result in significant acute and long-term complications. When patients' anatomy precludes more traditional management, the interventional radiologist may be called upon to provide well-established techniques for percutaneous biliary drainage and stone removal. This can be particularly challenging when the patient has excessively mobile, impacted, large or multiple stones. Percutaneous biliary endoscopy with adjunct interventional techniques can successfully treat these patients avoiding the patient dreaded "tube for life" scenario. Direct percutaneous visualization of the biliary tree can also diagnose and provide symptomatic relief for stone-mimicking pathologic conditions such as biliary tumors. This article will review the role, technique, and considerations for percutaneous biliary endoscopy and adjunct interventions in patients with isolated and complex, biliary stone disease and stone-mimicking pathologies.
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Introduction

Intraductal biliary stones can result in significant acute and long-term complications with only 5.2%-12% of these stones being considered asymptomatic.[1,2] Acute symptoms and signs of these stones include biliary colic, jaundice, pancreatitis, and cholangitis.[2,3] Long term, patients with intraductal biliary stones have an increased risk of developing ductal strictures, recurrent cholangitis, liver abscess, secondary biliary cirrhosis, and cholangiocarcinoma.[3,4] Similarly, stone-like biliary casts can occur in patients after they experience liver ischemia or biliary infection, as well as postliver transplant or biliary drainage catheter placement. In liver transplant patients, biliary casts occur in 2.5%-18% of patients and are associated with increased rates of graft failure, need for re-transplantation, and mortality.[5,6] Difficult-to-diagnose biliary tumors can mimic the clinical presentation of a ductal stone whereby diagnosis and initiation of appropriate treatment can be accomplished through direct visualization. Given the long-term sequelae of stones and stone-like presenting conditions, an overwhelming majority of clinicians recommend some form of treatment for those afflicted.

In modern practice, peroral endoscopic sphincterotomy and stone removal using a Dormia-type basket or balloon catheter to perform a "sweep" of the duct has become the most frequently used treatment, successfully removing the stone(s) in 68%-98% of patients with relatively low morbidity and mortality.[2,7,8] This standard procedure, however, is not possible when peroral access to the biliary tree cannot be obtained. In this situation, the interventional radiologist has historically been called upon to use the well-established techniques for percutaneous access and stone removal using baskets, graspers, or balloons.[9-11] These techniques, however, can be of little benefit when stones are excessively mobile, impacted, large, or multiple. In these situations, direct visualization with percutaneous endoscopy can facilitate treatment while also differentiating biliary stone symptom mimickers such as biliary tumors.

Abbreviations: GU, genitourinary

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Indications, Contraindications, and Patient Selection

Indications and contraindications for percutaneous biliary endoscopy have been well-elaborated in prior articles.[12,13] Biliary endoscopy continues to be most commonly intended to treat biliary tract calculi that are excessively mobile, impacted, large or multiple following failure of more traditional techniques. Because of the direct-vision capabilities of the technique, ambiguous filling defects appearing in the biliary tree on standard imaging modalities, such as stones/casts, blood clots, mucus balls and polypoid tumors, can be precisely differentiated. Biopsy can be facilitated for intraductal tumors which can mimic the clinical presentation of a stone (Fig. 1). In addition, stone disease can result in, or be a result of, ductal strictures. The use of biliary endoscopy can help assess, cross, and potentially treat difficult-to-negotiate strictures when this cannot be accomplished by traditional fluoroscopic guidance, reducing the likelihood of stone recurrence. The biliary-enteric anastomosis can also be more completely evaluated and intervened upon through direct visualization since suture material can act as a nidus for stone formation at this location. This can be difficult to appreciate by standard imaging yet contributes significantly to biliary obstructive symptoms. Intraductal anastomotic suture material can be resected through the endoscope using clam-shell biopsy forceps or with Holmium-YAG laser energy applied via a fiber used through the scope's working channel thereby decreasing the likelihood of future stone formation. By employing diagnostic biliary endoscopy and its associated therapeutic options which are well within most interventional radiologists' technical capabilities, meaningful contributions can be made to the care of the patient with complex biliary pathology. This facilitates treatments not otherwise possible and further avoids the patient dreaded "tube for life" scenario.

Contraindications to percutaneous biliary endoscopy are limited to acute cholangitis, sepsis, and uncorrectable coagulopathy. With respect to coagulopathy, a dry tract is necessary to facilitate optimal visualization of the biliary tree through the scope, particularly when the percutaneous tract is transhepatic. Biliary endoscopy requires fluid to be administered through the scope with the inherent risk of intravasation. Therefore, a "less is more" philosophy in the acutely ill patient should be adhered to with drainage being the primary objective. Percutaneous biliary endoscopy should be performed electively after the patient has completely defervesced following drainage and medical management.

Preparation of the Patient and Special Considerations for Biliary Endoscopy

There are unique considerations an interventional radiologist must be aware of when considering the use of biliary endoscopy as part of a patient's treatment regimen. The fact that biliary endoscopy is a multi-part procedure beginning with percutaneous drainage, or pre-existing access through a T-tube tract, and often occurring over several weeks needs to be well communicated to and understood by the patient. At each stage, from biliary drainage to endoscopy, preprocedural antibiotics are administered intravenously within 1 hour of the procedure. Typical antibiotics include piperacillin and tazobactam (Zosyn, Pfizer, New York, NY) or levofloxacin (Levaquin, Johnson & Johnson, New Brunswick, NJ). Percutaneous tract(s) should be mature at the time of endoscopy to limit bleeding because this can hamper visualization through the endoscope. A peel-away sheath creates a smooth, friction-free pathway for the endoscope while excluding and tamponading potential sources of bleeding, the specifics of which will be discussed later in this article. Diagnostic biliary endoscopy, including the adjunctive use of graspers and baskets, can be performed readily under conscious sedation. Laser lithotripsy for stones, in our practice, is performed under general anesthesia since stone cleavage

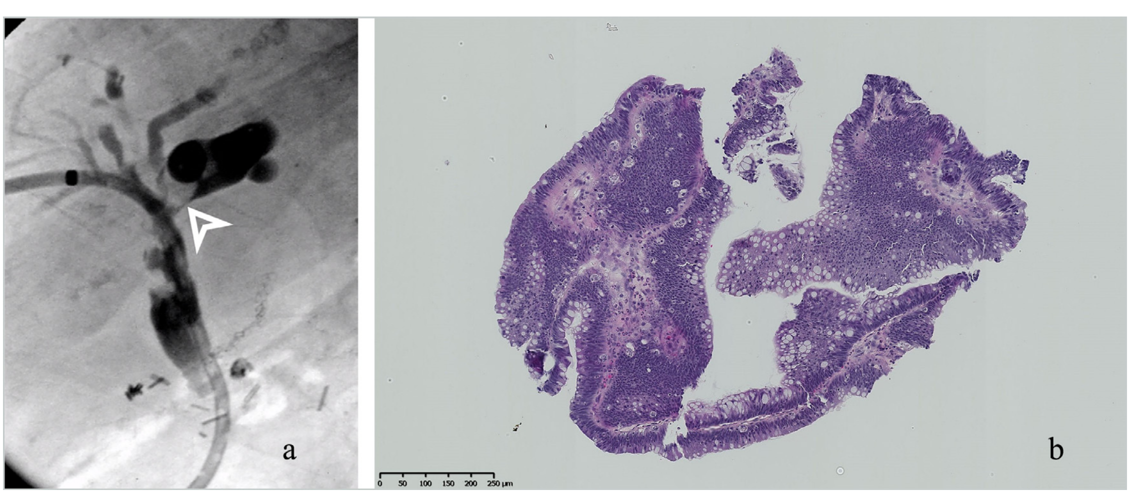

Figure 1 (a) Cholangiogram of patient with recurring cholangitis and intermittent obstructive symptoms. Arrow points to an Intraductal Papillary Neoplasm surrounded by mucous diagnosed on endoscopic biopsy but thought initially to represent stones. Rounded filling defects in the common hepatic and common bile ducts are mucous balls. (b) The tissue from (a) obtained using a 3 French Piranha Biopsy Forceps (Boston Scientific, Marlborough, MA).

can be painful. In addition, sudden patient movement can result in errant laser energy applied to the duct wall with the potential for perforation and intraperitoneal bile leak. Internal—external biliary drains are preferable and are upsized to 12 French during the waiting period prior to endoscopy, since this is the size peel-away sheath used during endoscopy with a 7.5-9 French ureteroscope. Be mindful that significantly upsizing the peel-away sheath larger than the indwelling drain can be a potential cause of bleeding, which can hamper visualization and result in pain for a sedated patient.

In our practice, endoscopy of the biliary tree performed through a T-tube tract is typically undertaken 6 weeks postsurgery. This is because the tract passes directly through the peritoneal space with slightly less time passing from drainage to transhepatic endoscopy, usually around 3-4 weeks. Yamakawa et al described the creation of a fibrous tract around a T-tube as early as 3 weeks postsurgery. Of interest, Yamakawa et al reported that choledocoscopy through a T-tube tract at 2 weeks postsurgery resulted in a subphrenic bile collection requiring surgical drainage.[14,15]

Standard biliary drainage techniques and precautions should be entertained with the duct of entry for the drain(s) meticulously chosen based on preprocedural imaging since flexible endoscopes can be used most successfully when not excessively flexed. Specifically, equipment used through the working channel of an endoscope may not be able to exit the endoscope if the distal tip requires excessive deflection. With the presence of multiple biliary stones, such as extrahepatic stone(s) coupled with intrahepatic stone(s), site and laterality of percutaneous access should be carefully planned to maximize a straight-line approach to the stone(s) as much as possible. Bilateral or multiple biliary access may be required. Peripheral access of the selected biliary duct is vastly preferred for patients who may undergo percutaneous endoscopy because bleeding, which is more often associated with the larger central hepatic vascular structures, can significantly hamper visualization. This is considerably more important if considering using a 15-16.5 French choledocoscope compared with a 7.5-9 French ureteroscope. The major advantage of the choledocoscope is better intraprocedural visualization with a larger field of view and a larger working channel for equipment passage. In our practice, we have not used a choledocoscope to perform biliary endoscopy for stones in many years since modern ureteroscopes demonstrate excellent intraprocedural visualization and equipment used through the working channel of the scope have gotten smaller in diameter while continuing to improve on usability. Rigid endoscopes, in our opinion, have no advantage over flexible endoscopes in the biliary tree due to the inherent curved nature of biliary ducts. Highly flexible modern laser fibers for lithotripsy function well through the smaller working channel of ureteroscopes, cleaving a typically soft biliary stone and even converting it to dust. Torqueing a rigid scope through a curved duct may hamper the procedure since this torqueing may result in bleeding from a torn duct extending into the liver parenchyma, limiting visualization through the scope, and complicating the procedure.

Fortunately, biliary endoscopy can be viewed as an extension of catheter and guidewire techniques that all interventional radiologists know with the added benefit of being able to directly visualize the biliary ductal system. When an experienced interventional radiologist new to percutaneous endoscopy cannot satisfactorily control the scope, he or she can consider the scope as just another catheter and use a wire through the working channel, contrast and fluoroscopy to accomplish the task at hand.

The Technique of Biliary Endoscopy for Stones

Percutaneous biliary endoscopy with various forms of direct visualization lithotripsy and basket extraction of stone fragments has been well described in small studies.[12,13,16–21] These papers can mostly be found in nonradiologic literature and should be reviewed for the techniques described. We will restrict our discussion of equipment and technique to that typically available in most hospitals based primarily on modern endourologic practice, which forms the basis for much of biliary endoscopy today. For the interventional radiologist, a majority of the techniques used to perform these procedures are within our standard repertoire except for the use of the endoscope and laser. A fair amount of specialized equipment, not used routinely by the interventional radiologist, is required to be able to perform these procedures in the suites. Hence, the cost of purchase can be an issue. Disposable ureteroscopes have recently become available which include the 9.5-French LithoVue (Boston Scientific, Marlborough, MA) and Neo-flex (Neoscope Inc, Silicon Valley, CA). The advantage of disposable ureteroscopes over reusable ones is that there is no need for sterilization and the added expense of maintenance, which can be substantial, is avoided. These disposable ureteroscope manufacturers are selling relatively low-cost PC monitors to process and view the digital CMOS-acquired endoscopic images so the cost of the endoscopic camera and associated equipment can be avoided. Having the disposable endoscope packaged for what is typically occasional use makes sense for how an interventional radiologist would use this equipment. In our practice, the mobile urologic endoscopy cart (Fig. 2) is readily available to us so our experience with the disposable scopes is limited. However, having used the Boston Scientific LithoVue ureteroscope in the genitourinary (GU) system, we can say that this device provides adequate visualization and ability to perform intervention through the working channel similar to that of a reusable ureteroscope. Since most hospitals have a mobile urologic endoscopy cart, we encourage communication with your urologic colleagues as you foray into percutaneous endoscopy.

Typically, the biliary endoscopy is performed with the patient supine. The indwelling biliary drain(s) and surrounding skin is prepped in a sterile manner and a small hole is cut in an Ioban Incise Drape (3M, Maplewood, MN,) to fit over the biliary drain(s) and stick to the skin. A small hole is then made in a neurosurgical drape's clear window to again fit over the drain(s) sticking to the Ioban Incise Drape. The neurosurgical drape contains a pouch below the clear window to catch fluid. In our practice, we have found this draping

Figure 2 Mobile urologic endoscopy cart includes all equipment needed to perform the procedure. Mobile stand to the right holds a viewing screen and various light sources depending on the particular scope to be used.

method provides the driest set-up for the operators. Ureteroscopes, most recently being the Storz 7.5F ureteroscope (Karl Storz, Tuttlingen, Germany), have been used exclusively. Fluoroscopy is always used for catheter manipulation and to assist in locating the endoscope within the biliary tree to ensure complete visual interrogation. This limits the likelihood of missing significant pathology. Similar to GU endoscopy, biliary endoscopy is performed using a low-pressure technique since saline is required to provide visualization and mild duct distention. A cholangiogram is performed immediately prior to the endoscopy as stone(s) position can easily change. The biliary drainage catheter is exchanged over a guide wire for a 25-cm vascular sheath so that a safety guide wire can be advanced into the duodenum. The safety guide wire is then isolated external to a 12-French peel-away sheath so that the initial guide wire can be removed. This facilitates smooth, friction-free endoscope passage while allowing egress of saline, which is the hallmark of low-pressure endoscopy (Fig. 3a, b and c). The use of the 12 French peel-away sheath provides adequate distention without excessive pressurization of the biliary tree, which can result in pain, nausea, and potentially sepsis. If using a choledocoscope, an 18-French biliary drain is preferred to allow tract maturation to that size. An upsized peel-away sheath at the time of endoscopy can be considered. With a mature percutaneous tract, passage of the choledocoscope over a wire can be achieved which benefits sedated patients since more extensive dilation can result in pain.

A Single Hand Action Pump Syringe (Boston Scientific, Marlborough, MA) is used to administer saline through the 3.6-French working channel of the Storz ureteroscope. Alternatively, a saline line with a pressure bag can be used if an assistant is not available. Care should be taken to not overpressurize the biliary tree which can occur more easily if not monitored using this set up. A Check-Flo Adapter (Cook Medical, Bloomington, IN) is used on the working channel of the endoscope which has a leak-proof diaphragm for passage of equipment into the working channel and a side-port, in the

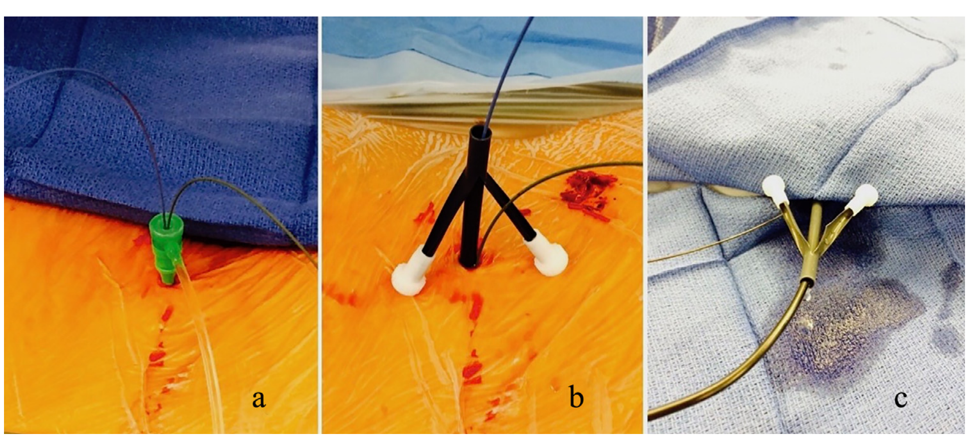

Figure 3 (a) 6F, 25-cm sheath through percutaneous tract to place safety wire. (b) 12F Peel-away sheath inserted. (c) Egress of saline between 7.5F ureteroscope and 12F peel-away sheath.

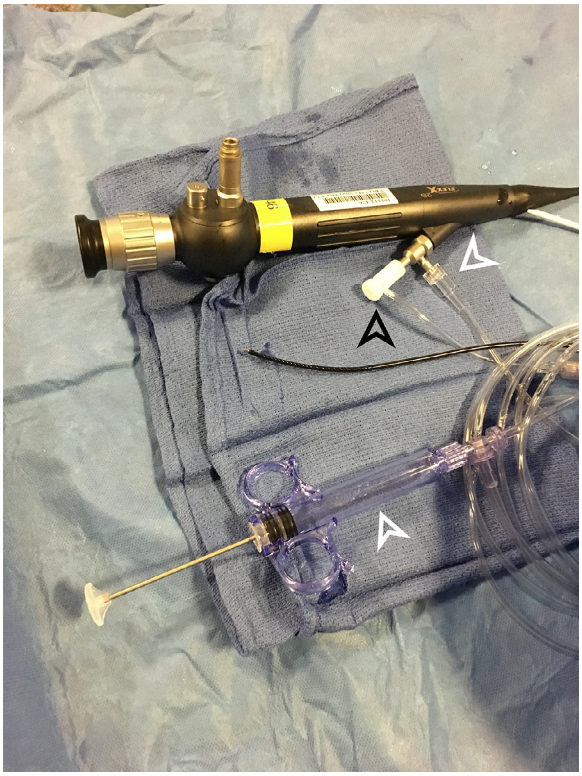

Figure 4 Demonstrates our typical set up for the ureteroscope with the working channel covered by the Check-Flo Adapter (black arrow) and the pump syringe attached (white arrows).

same manner as a vascular sheath (Fig. 4). In our practice, saline via the pump syringe is connected directly to the side-port of the working channel because if connected to the side-port of the Check-Flo Adapter, pressure can overcome the diaphragm and spray the operator. Care should be taken in the patient with biliary obstruction to pump or flush less saline through the endoscope to not over-pressurize the biliary tree. Manipulation of the ureteroscope within the biliary tree is accomplished by using up-and-down distal tip deflection (Fig. 5). Side-to-side tip deflection requires physical rotation of the endoscope 90 degrees. Of importance to the interventional radiologist, the small diameter ureteroscope tracks well over a hydrophilic guide wire and can be used as a catheter/guide wire system under fluoroscopic guidance when direct visualization alone is not adequate for manipulation. Once localization of the stone(s) is accomplished, direct visual assessment of the stone's size is performed to determine if the stone requires cleavage with the laser prior to removal of fragments with a stone basket. In our practice, this has been accomplished most recently with a 1.9 French Zero Tip Basket (Boston Scientific, Marlborough, MA) (Fig. 6). We have not found either the Tricep (Boston Scientific, Marlborough, MA,) or the Captura (Cook, Bloomington, IN) 3 prong graspers to be of benefit. Of note, biliary stones are often associated with soft debris, particularly in the case of prior biliary-enteric anastomosis, which can be washed out under direct visualization. The biliary-enteric anastomosis can be a site where suture material extends intraluminal, forming a nidus for stone formation which can be difficult to appreciate without direct visualization yet result in significant obstructive symptoms.

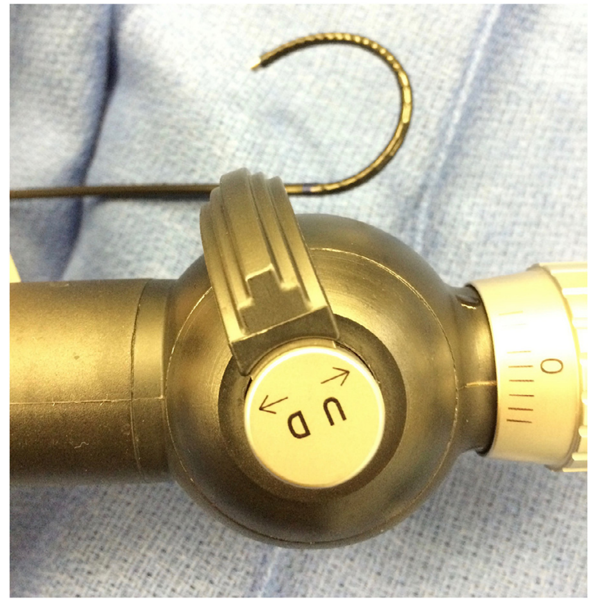

Figure 5 Storz ureteroscope up-and-down distal tip deflection.

These stones can be cleaved with the laser and/or retrieved with a basket revealing the underlying suture. The suture can then be trimmed using a 3 French Piranha Biopsy Forceps (Boston Scientific, Marlborough, MA) through the endoscope under direct vision to limit reformation of stone at the anastomosis. Alternatively, the suture can be trimmed using the Holium-YAG laser by applying energy under direct vision using a glass fiber in the same manner as below.

If the stone(s) is felt to be too large for removal through the sheath, it is cleaved with the Holmium-YAG laser (Lumenis Surgical, Yokneam, Israel) with special emphasis on minimizing the number of fragments so as to not make excessive debris that may lengthen the procedure time. These residual stone fragments are retrieved using the Zero Tip Basket under direct vision being withdrawn through

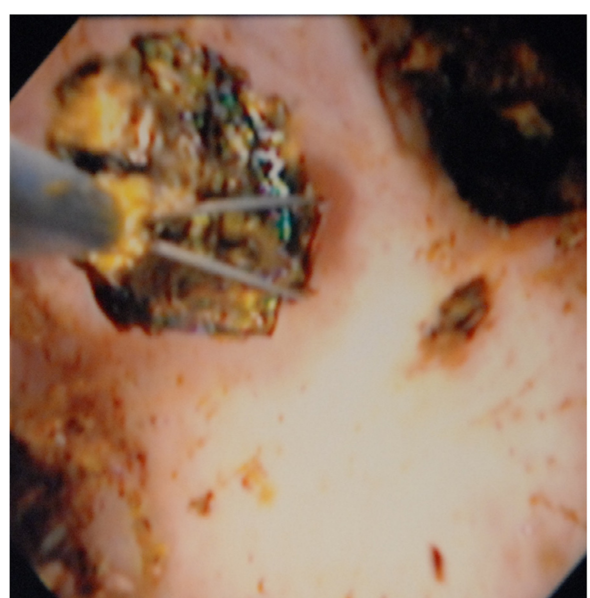

Figure 6 Basket removing biliary stone.

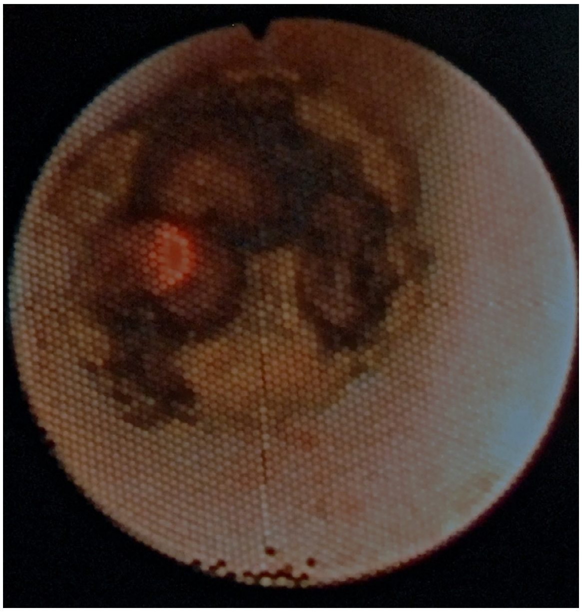

Figure 7 Laser fiber at 9 o'clock position with red aiming laser tip about to cleave a biliary stone (Color version of figure is available online).

the sheath. Additionally, an occlusion balloon can be advanced over a guide wire to "sweep" stone debris into the bowel. Laser settings are typically 0.5-1.0 J with repetition rate of 8-10 Hz. A 200-micron laser fiber (Microvasive, Boston Scientific, Marlborough, MA), rather than the thicker and more rigid 365-micron laser fiber that can straighten the scope, is used when excessive endoscope tip deflection is required to limit loss of visualization of the stone which would preclude laser use (Fig. 7). Of note, cleavage of the stone requires physically touching the laser fiber to its surface to achieve the necessary energy transfer. Calcium bilirubinate-dominant stones tended to be harder than cholesterol-dominant stones, requiring more energy to achieve cleavage. A substantial portion of a cholesterol-dominant stone may actually vaporize when laser energy is applied.

The above techniques allow an overwhelming majority of our patients to be cleared of large or multiple stones in a single endoscopy session (Figs. 8 and 9). Prior to completion of the procedure and placement of a 12F internal/external biliary drainage catheter over the safety wire, the entire biliary tree is interrogated with endoscopy to ensure that no additional stone(s), or other pathology, is present. Intraductal biliary tumors (Fig. 1) can be biopsied under direct visualization using the 3-French Piranha Biopsy Forceps through the endoscope. Larger forceps which can be accommodated through the working channel of a choledocoscope can resect a good portion of these tumors to provide symptomatic relief. Of note, a 2-French Fulgurating Electrode (Gyrus ACMI, Southborough, MA) attached through a Bugbee cord to a cautery can arrest bleeding and facilitate tumor resection. The Fulgurating Electrode can be used safely in a saline environment.

When all sizeable stone fragments have been removed and the biliary tree is satisfactorily interrogated, a 12-French internal/external biliary drainage catheter is reinserted and placed to external drainage for 1 week to allow debris to exit. Postprocedure, all patients are observed overnight in the hospital. Our practice is to not routinely administer antibiotics postprocedure, and no patient in our series developed acute cholangitis after diagnostic or therapeutic biliary endoscopy.[12] A follow-up outpatient cholangiogram is performed 1 week after the procedure to ensure that no stone is missed and to begin the catheter removal process.

Figure 8 Pre (a) and post (b) percutaneous biliary endoscopy and laser lithotripsy for a large 2.8 × 1.2 cm common bile duct stone.

Figure 9 Numerous predominantly calcium bilirubinate stones removed by endoscopic direct visualization basket retrieval from the left hepatic duct peripheral to a stricture.

Complications of Biliary Endoscopy

Our experience has been that biliary endoscopy, when used as either a diagnostic adjunct with conscious sedation or as a therapeutic technique under general anesthesia, is quite well-tolerated, particularly when using an ureteroscope. When care is taken to not overdistend the biliary tree with saline during the procedure, complications of biliary endoscopy are seen rarely and are typically mild. Intraprocedurally, mild vasovagal reactions have been reported which are typically treated with fluids and, if needed, atropine.[12] This has not been encountered in our series but can result from excessive biliary distention and can be reduced by monitoring the saline infused through the endoscope. Acute cholangitis is a known complication of biliary drainage/intervention and was encountered in only 1 of our stone patients' postbiliary drainage; this patient was successfully treated with antibiotics. This same patient went on to have an uneventful elective biliary endoscopy to treat their stone disease. Lastly, we recommend that T-tube tracts be treated gently since they can be disrupted with manipulation. Use of the small diameter ureteroscope and a sheath to protect the tract will limit this from occurring. Aborting the endoscopy with replacement of the drainage catheter over the safety wire should be considered in this instance.

Additional Thoughts on Percutaneous Biliary Endoscopy

In current medical practice, most biliary stones are treated with techniques commonly performed via peroral endoscopy. A significant number of patients, however, are unable to have their stones removed in this manner because the stones are either too large, multiple, impacted or inaccessible by prior bowel-diverting surgery. Standard percutaneous interventional techniques are often employed as a second-line treatment for many of these patients, who pointedly look to the interventional radiologist to completely solve their complex problem, not simply provide symptomatic relief with a "tube for life." Unfortunately, biliary drainage followed by standard fluoroscopic-guided stone removal techniques utilizing baskets, graspers, and balloons only can treat a subset of these more complicated patients. Biliary endoscopy with direct visualization holmium-YAG laser lithotripsy and direct visualization basket retrieval of stone fragments, alone or in combination with the standard fluoroscopic stone removal techniques, can significantly enhance the interventional radiologist's ability to provide complete treatment to these patients.

Endoscopy is not something that most interventional radiologists have in their armamentarium from both an equipment and skill competency standpoint. We highly encourage working with a urologist to begin treating these patients, since both specialists benefit from each other's unique skill sets. The small endoscope, such as the 7.5-French ureteroscope, can be manipulated much like a catheter, which should increase the comfort level for most interventional radiologists. It cannot be overstressed that cholangiograms performed during the endoscopy significantly aid in locating smaller stones, making the interventional radiologist indispensable during this procedure. Using a basket through the endoscope, under direct visualization, is significantly easier than trying to retrieve a stone under fluoroscopic guidance. In addition, the skills of an experienced endoscopist can maximize the ability of interventional radiology to treat these patients.

The urologic, surgical, and to a lesser extent interventional radiology literature does contain small retrospective series of biliary stone patients treated using these techniques.[16–18,20,21] However, no single specialty has traditionally provided the complete breadth of procedures required to treat the complex biliary stone patient. In our experience, an interventional radiologist and endourologist combining their respective skill sets achieved complete stone removal in nearly all patients, almost always utilizing just a single endoscopy session.

Conclusion

Percutaneous biliary endoscopy supplemented with direct visualization Holmium-YAG laser lithotripsy and/or direct visualization basket retrieval, is a safe and effective technique to extend the interventional radiologist's ability to provide treatment for complex excessively mobile, impacted, large or multiple intraductal biliary stones. Direct vision techniques also allow for diagnosis and treatment for symptomatic relief of stone-mimicking pathologies such as intraductal tumors.

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