Interventional Radiology-Operated Endoscopy: Indications, Implementation, and Innovation

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Interventional radiologists perform a variety of image-guided procedures utilizing a variety of tools to create minimally invasive access into the biliary, gastrointestinal, and genitourinary systems, as well as other structures. Endoscopy has been utilized by other specialists, namely gastroenterology and urology, to treat similar pathologies, but interventional radiology-operated endoscopy has only been implemented at a few academic centers to date.

The learning curve for an interventional radiologist to become proficient at endoscopic interventions is tempered by the technical dexterity and hand–eye coordination already required for other image-guided procedures. Moreover, the relative safety of endoscopy evidenced by the routine performance of laryngoscopy, bronchoscopy, esophagogastroduodenoscopy, colonoscopy, and cystoscopy at the bedside or in outpatient clinics supports its implementation by interventional radiologists.

This article discusses the application of interventional radiology-operated endoscopy in the biliary, gastrointestinal, and genitourinary systems (► Fig. 1).

Preparation and Equipment

Procedural Preparation

Procedures may be performed using moderate sedation with intravenous midazolam and fentanyl, although general anesthesia is favored. Peri-procedural antibiotics are administered according to the Society of Interventional Radiology guidelines. Orogastric and rectal tubes may be placed in patients during procedures expected to be longer than 1 hour to control fluid loads and help maintain body temperatures. Body warmers are also used in all patients to maintain core temperatures.

Preprocedural discussion with the referring medical or surgical subspecialties should be performed to ensure all clinicians are in agreement regarding the planned procedure. Initial access into the area of interest is gained using standard techniques for cholangiography, cholecystostomy, gastrostomy, or nephrostomy. Percutaneous access into the area of interest may be obtained in the same session as endoscopy. A mature tract, however, may decrease leakage and pain, especially when using larger endoscopes. Laboratory evaluation with particular attention to coagulation parameters should be performed, especially if same-day endoscopy is being considered. International normalized ratio greater than 1.5 and platelet count less than 50,000/ μ L are relative contraindications to percutaneous access procedures.

Endoscopes

Endoscopy may be performed with a 7-Fr flexible reusable 9.5-Fr flexible disposable, 9-Fr flexible reusable, 16.5-Fr flexible reusable (Olympus America), or 22.5-Fr rigid reusable endoscope (Olympus America), depending on the indication, access route, operator preference, and the availability of the endoscope. ► Fig. 2 demonstrates the types of endoscopes.

The endoscopes are connected to a large continuous saline flush bag system with a UroLok adapter and three-way stopcock. Light sources and suction devices are connected to the endoscopes.

Prior to endoscopy, a steel reinforced support wire is placed, followed by a second steel reinforced support wire that serves as a safety wire. For larger endoscopes, namely the 22.5-Fr rigid reusable endoscope, the tract is dilated using a high-pressure 8-mm $\times$ 15-cm X-Force balloon. Once the tract is dilated, a sheath is placed over one of the

Fig. 1 Schematic illustration demonstrating various interventional radiology-operated endoscopic procedures. A sheath and endoscope are positioned within the gallbladder (a), kidney (b), stomach (c), and small bowel (d) for direct visualization.

Fig. 2 Types of endoscopes. A variety of endoscopes are available including a 9.5-Fr flexible disposable endoscope (a), a 16.5-Fr flexible reusable endoscope (b, c), as well as a 22.5-Fr rigid endoscope (d). C demonstrates the connection points for video (solid white arrow) and the light source (dashed white arrow) and the 5.5-Fr working channel (white arrowhead) on the 16.5-Fr flexible endoscope.

Table 1 Endoscope types and compatible devices

Endoscope size (Fr)	Required sheath size (Fr)	Type	Channel diameter		
			Form factor	(Fr)	Compatible devices
7	12	Reusable	Flexible	3.6	Microcatheters, small snares, nitinol baskets, and forceps, ^a lasers, ^b EHL ^c
9.5	14	Disposable	Flexible	3.6	Microcatheters, small snares, nitinol baskets and forceps, lasers
16.5	20	Reusable	Flexible	5.5	5.5-Fr biopsy forceps, ^d brush biopsy sets, ^e EHL, PTD ^f
22.5	24	Reusable	Rigid	12	Stone baskets, ^g large biopsy forceps, ^h ultrasonic lithotripter, ⁱ 3-mm forceps ^j

Abbreviations: EHL, endoscopic hydraulic lithotripter; PTD, percutaneous thrombectomy device.

Note: EHL probes are not compatible with the flexible disposable scope, as it causes interference with the digital video signal; larger endoscopes will also accept devices listed for the smaller endoscopes.

^aNitinol baskets include the Zero Tip Nitinol Basket and Grasp-It Nitinol Forceps.

^bHolmium laser.

^cEndoscopic hydraulic lithotripter.

^d5.5-Fr biopsy forceps.

^e5-Fr Ureteral Brush Biopsy Set.

^fArrow-Trerotola Percutaneous Thrombectomy Device.

^gStone baskets for the rigid scope include the Perc NCircle and NGage Nitinol Tipless Stone Extractor.

^h7-Fr Biopsy Forceps.

ⁱUltrasonic lithotripter.

^j3-mm forceps.

guidewires. A peel-away sheath is typically used to allow for external drainage of excess fluid during endoscopy. The appropriate sheath size varies according to the endoscope, and should be large enough to accommodate both the endoscope and at least one wire while allowing for easy removal of the endoscope (►Table 1). Devices for stone fragmentation or foreign body removal may be inserted through the endoscope's working channel (►Table 1).

Interventional Radiology-Operated Biliary Endoscopy

Indications

The most common indication for biliary endoscopy is stone disease within the biliary system.^{1,2} Gallbladder stones affect 1.4% of the general population annually with progression to symptomatic disease in 1 to 4%.^{1,2} The efficacy of cholecystostomy tubes is well established in high-risk surgical patients, but such patients may require life-long percutaneous drainage unless endoscopic stone extraction is performed.^{3,4} Endoscopic treatment for biliary colic or obstruction usually begins with endoscopic retrograde cholangiopancreatography. Failure of endoscopic retrograde cholangiopancreatography, such as in the setting of altered bowel or biliary anatomy, obstructing mass, or benign strictures, may necessitate percutaneous transhepatic cholangiography with biliary drainage. Bariatric patients who have undergone Roux-en-Y gastric bypass, for instance, are at high risk for developing biliary calculi and colic.⁵ Additionally, benign hepaticojejunostomy strictures may occur in up to 12.5% of anastomoses.⁶ In these situations, endoscopic retrograde cholangiopancreatography is often not feasible secondary to the postsurgical anatomy rendering percutaneous biliary drainage necessary.⁵ In liver transplant recipients, up to 18% of patients develop biliary cast syndrome, and often require biliary drainage due to peripheral duct involvement (Figs. 3–5).⁷

Considerations

When performing interventional radiology-operated cholecystoscopy (gallbladder endoscopy) and cholecystolithotripsy, the ideal approach is along the long axis of the gallbladder from the fundus to the cystic duct which may be achieved by either transhepatic or transperitoneal access. This allows for thorough examination of the gallbladder and in-line extraction or antegrade sweeping of fragmented calculi through the cystic duct. Initial 7- to 10-Fr access catheters are placed with staged upsizing of the tract to 12- to 24-Fr for cholecystoscopy. Single-session cholecystostomy access and cholecystoscopy may be performed in some patients, although this is generally less optimal due to the potential risk of intraperitoneal leakage without tract maturity.

General anesthesia may be needed for patient comfort, given procedure times commonly exceed 2 hours. Additionally, significant intraprocedural pain may occur with balloon dilatation of biliary ducts as well as transhepatic and transperitoneal tracts. The anesthesiologist should be aware that the procedure will involve the use of high-flow and high-volume irrigation into the biliary and gastrointestinal system which may cause electrolyte disturbances and fluctuations in body temperature. As such, cranial draping may prevent additional heat loss by the patient. A commercial available drainage system may be utilized to decrease spillage of fluid onto the floor minimizing hazard for interventional radiology staff. Orogastric and rectal tubes may be placed for containment of gastrointestinal output and monitoring of patient fluid and electrolyte status.

Techniques

Following preprocedural preparation, cholecystostomy tubes are first removed over a guidewire, a steel reinforced support wire is placed as a safety wire into the gallbladder.

Over a second stiff wire, the tract is dilated with a high-pressure 8 mm × 15 cm X-Force balloon, to facilitate placement of the 22.5-Fr rigid endoscope. Electrohydraulic, laser, and ultrasonic lithotripsy devices may be used to fragment stones that are too large to be extracted through the endoscope introducer or pushed through the cystic duct. Mechanical Zero Tip nitinol stone retrieval baskets may be used to retrieve or sweep obstructing stones or debris. The Arrow-Trerotola thrombectomy device may also be used to liquefy thick debris to allow for easier sweeping of stones into the cystic duct. Repeat cholecystogram and endoscopy should be performed until adequate clearance of debris and stones is achieved.

Upon completion of the procedure, a transcystic internal/external drainage catheter as well as replacement of the cholecystostomy drainage catheter should be performed. Catheter size is dependent on operator preference and the final tract size (e.g., a 10-Fr internal/external and 14-Fr external drain for a 24-Fr tract). Patients are admitted overnight for observation with a second dose of intravenous antibiotics the following morning. Upon discharge, patients are prescribed an oral antibiotic, amoxicillin/clavulanate 875 mg/125 mg, or other equivalent antibiotic, twice daily for 7 to 10 days. Some operators may choose to discharge patients with ursodeoxycholic acid 300 mg twice daily to prevent gallstone recurrence.

Reevaluation is performed in 2 weeks, with removal of the internal/external drainage catheter if a patient's cystic duct is patent via sheath cholecystogram. Depending on the size of the cholecystocutaneous tract, cholecystostomy tubes may be removed or downsized appropriately with plan for eventual removal.

Reports of cholecystoscopy with cholecystolithotripsy have been described with overall positive outcomes.⁸⁻¹⁰ Through staged procedures, the use of cholecystoscopy increases the rate of complete calculus removal through direct visualization, as compared to fluoroscopic-guided percutaneous cholecystolithotripsy alone.¹¹ Most patients should be drain free within 2 to 4 weeks with a low rate of recurrent disease.

Similar considerations apply to intrahepatic or extrahepatic biliary pathology. Once acute decompression is achieved with biliary drainage and the active infection resolved, 7- to 10-Fr drainage catheters are upsized through the mature tract to 12- to 14-Fr drainage catheters following 4 to 6 weeks to allow for tract maturation.

The techniques for interventional radiology-operated choledochoscopy (endoscopy of the biliary tree) and interventions in the biliary tree are similar to those described earlier for cholecystoscopy. Depending on the suspected location of the targeted lesion, both small bore and large bore rigid and flexible endoscopes may be utilized. Choledochoscopy may be performed for the treatment of biliary sludge, choledocholithiasis, and biliary casts utilizing the same devices listed in ▶Table 1. Additionally, filling defects or strictures shown by cholangiography may be further characterized, biopsied, and treated under endoscopic guidance.

Postprocedure management following choledochoscopy also requires placement of internal/external percutaneous biliary drainage catheters, overnight observation, repeat intravenous antibiotic dosing the following morning, and 7 to 10 days of oral antibiotics. Reevaluation in 2 weeks is also required to demonstrate adequate bilioenteric drainage via sheath cholangiogram and removal or downsize of indwelling drainage catheter if appropriate.

See ▶Figs. 3 and 4 for examples of interventional radiology-operated cholecystoscopy and choledochoscopy.

Interventional Radiology-Operated Genitourinary Endoscopy

Indications

Percutaneous nephrostomy is the mainstay of treating acute obstructing uropathy when a retrograde approach fails. Antegrade percutaneous nephrolithotripsy has become a mainstay of urologic practice providing definitive management of obstructing calculi, but often requiring a multidisciplinary approach.¹² Minimally invasive techniques of ureteral balloon dilatation and nephroureteral stenting are performed after stricture traversal. When fluoroscopic-guided recanalization cannot be achieved, interventional radiology-operated genitourinary endoscopy may lead to success.¹³ Placement of an internal/external drainage catheter allows patients to drain internally, thereby improving quality of life. This may facilitate eventual internalization, with no residual external component. Interventional radiology-operated ureteroscopy (endoscopy of the ureter) may also be used to aid in foreign body retrieval including retained instruments or stent fragments which may serve as a nidus for infection. Though rare, migrated renal embolization coils have also been retrieved.¹⁴⁻¹⁷ The removal of migrated coils has a high risk of causing significant bleeding and interventional radiologists may be prepared to treat such complications with simultaneous prone transradial arterial access.¹⁸

Considerations

Generally, percutaneous nephrostomy should be placed through Brodel's line to avoid vascular structures, but interventional radiology-operated nephroscopy (endoscopy of the kidney) or ureteroscopy for stone or foreign body removal should have percutaneous access that is ideal for the intervention. In patients with urinary obstruction and ongoing urinary tract infection, appropriate drainage and antibiotic course should be completed prior to any invasive procedures including tract dilation and ureteroscopy. If no active infection is present, percutaneous access, tract dilation, and ureteroscopy may be performed in single session.

Techniques

After placement of a steel reinforced support wire securely into the renal pelvis or proximal ureter, serial dilation is performed to accommodate the appropriate sheath size and corresponding endoscope (▶Table 1). In general, the 22.5-Fr rigid endoscope may be utilized for upper tract

Fig. 3 Interventional cholecystoscopy. (a) Cholecystogram showing a distended gallbladder containing innumerable gallstones (solid white arrows). (b) An 8-mm $\times$ 15-cm X-Force balloon (solid white arrow) is used for tract dilation prior to placement of the endoscope. (c) The 22.5-Fr rigid endoscope (solid white arrow) with ultrasonic lithotripsy device (dashed white arrow) was placed. (d) Endoscopic evaluation showing multiple gallstones (solid white arrows). (e) More than 50 gallstones were removed. (f) Completion image showing the cholecystostomy (solid white arrow) and transcystic (dashed white arrow) drains.

disease with more flexible and smaller caliber endoscopes for distal disease. Rigid endoscopes may require dilation of the tract using a high-pressure 8 to 10 mm $\times$ 15 cm X-Force balloon.

In cases of ureteral obstruction in which fluoroscopic guidance alone has failed, flexible endoscopes provide direct visualization to aid in crossing these strictures. They contain working channels for guidewires and catheters to allow for access into the distal collecting system. Conversion of percutaneous nephrostomy drainage catheters to nephroureteral stents and double J antegrade ureteral stents has been described.¹³ In addition, when there is concern for recurrent malignancies or strictures, endoscopic guidance may be utilized for accurately directed biopsies. In these settings, the smallest caliber endoscope to allow for the planned intervention based on the size of the inner working channel should be chosen to limit complications and leakage after the procedure.

Interventional Radiology-Operated Gastrointestinal Endoscopy

Indications

Percutaneous gastric access is routinely performed for venting or feeding. For upper gastrointestinal surveillance endoscopy in patients with altered surgical anatomy, a combined approach by interventional radiology and gastroenterology

is feasible. Interventional radiology-operated gastrointestinal endoscopy, however, may be performed for single-session upper gastrointestinal intervention. Interventional radiology-operated gastrointestinal endoscopy may be used for placement complex feeding tubes or for foreign body retrieval including fragmented plastic or metallic stents as well as eroded embolization coils. In the latter setting, simultaneous arterial access to prepare for potential bleeding complications may also be performed (**► Figs. 5 and 6**).

Similarly, interventional radiology-operated endoscopy of the lower gastrointestinal tract for surveillance should be performed by trained gastroenterologists. The combined use of fluoroscopy and endoscopy, however, makes interventional radiology-operated endoscopy optimal for lower gastrointestinal interventions. Complete or partial obstruction of the colon may occur in up to 29% of patients with colorectal cancer.¹⁹ While the standard management of a significant malignant bowel obstruction requires prompt decompression, an abdominal operation for diverting ostomy in an unprepared colon carries a high morbidity and mortality compared to elective operations.²⁰ Within the subset of inoperable patients with malignant bowel obstruction, interventional radiology-operated gastrointestinal endoscopy may provide benefit. Patients with benign strictures due to prior adhesions or radiation are often considered poor surgical candidates. In these patients, interventional radiologists are often consulted for venting gastrostomy tubes. Further interventions, however, may be

Fig. 4 Interventional choledochoscopy. (a) Cholangiogram demonstrating intrahepatic ductal dilation with abrupt termination of the distal common bile duct (solid white arrow) consistent with known pancreatic head mass. (b) During attempted access for biliary drainage, an AccuStick Introducer System was inadvertently fractured. Transhepatic choledochoscopy using the 9.5-Fr flexible disposable endoscope (solid white arrow) was performed. (c) Endoscopic evaluation demonstrating a normal biliary tree. (d) The fractured AccuStick Introducer System (solid white arrow) is visualized. (e and f) The fractured AccuStick Introducer System was retrieved under direct visualization using the endoscope and a snare.

utilized to treat the primary cause. Previous reports of fluoroscopic- and endoscopic-guided colonic dilatation and colonic stenting have been described by interventional radiologists as a bridge to operative management or simply as a palliative procedure with success rates up to 92%.^{21,22}

Considerations

In gastric or upper gastrointestinal interventions, percutaneous transperitoneal gastrostomy access is required. While the traditional access for placement of a gastrostomy tube is toward the pylorus, the access route may be altered to target the area of interest. If there are plans to dilate the tract up to 24- or 30-Fr, T-fasteners should be placed to ensure safe tract dilation and maturation.

If percutaneous access, dilation, and intervention are all performed in a single session, general anesthesia is recommended, as the procedure may be prolonged and percutaneous tract dilation may cause significant intraprocedural pain. In addition, high-flow and high-volume irrigation into the gastrointestinal system may be utilized similar to biliary interventions, and the anesthesiologist should be made aware. Orogastric or nasogastric tubes allow for insufflation and decompression as needed, and rectal tubes provide containment of gastrointestinal output.

Techniques

Once percutaneous access into the stomach has been achieved and secured with T-fasteners, a steel reinforced support wire should be advanced into the proximal duodenum or coiled in the stomach. A safety wire should also be placed in a similar fashion. Depending on the indication, the tract may be dilated using an appropriately sized high-pressure balloon over which the corresponding sheath may be inserted.

Utilization of interventional radiology-operated gastroscopy (endoscopy of the stomach) enables direct visualization of lesions, or radiolucent foreign bodies, with assistance of injectable contrast media under fluoroscopy to detect perforation and determine positioning. If a percutaneous approach is performed, an appropriately sized gastrostomy tube must remain in place for 6 weeks following the procedure to allow for tract maturation, after which the tube may be removed if no longer indicated.

Patients who have undergone incomplete colonoscopy due to obstructions may be further evaluated by interventional radiology-operated colonoscopy (endoscopy of the colon) beyond the obstruction with possible biopsy or stenting of the lesion. If the patient is obstructed and a palliative operation is feasible, oral bowel preparation should be avoided until the obstruction is relieved.

Fig. 5 Interventional gastroscopy. (a) A 22.5-Fr rigid endoscope (dashed white arrows) and endobronchial forceps are seen grasping the eroded coils (solid white arrow). A Coda balloon catheter was inflated within the midesophagus (white arrowhead) to prevent reflux of saline into the esophagus. A catheter is seen within the left gastric artery. (b) Endoscopic image demonstrating the eroded coils from the base of a gastric ulcer. (c) Endobronchial forceps successfully grasping the coils under direct endoscopic visualization prior to extraction.

Fig. 6 Interventional colonoscopy. (a) Fluoroscopic image after instillation of rectal contrast demonstrating an abrupt termination (solid white arrows) of contrast consistent with known rectal carcinoma. (b and c) Under direct endoscopic visualization (solid white arrow), multiple colonic and rectal stents (solid white arrow) were deployed. (d) Completion image after the placement of multiple colonic and rectal stents (solid white arrows) showing good flow of contrast throughout from the colon to rectum.

Fig. 7 Interventional endoscopy-assisted enterocutaneous fistula closure. (a) Advancement of the catheter into the enterocutaneous fistula with injection showing a large enterocutaneous fistula (solid white arrow) and communication with small bowel. (b) The 9.5-Fr flexible disposable endoscope (solid white arrow) was used to determine the exact location of enterocutaneous fistula tract entry into small bowel. (c and d) Under direct endoscopic visualization, the enterocutaneous fistula was closed using the Delta NeverTouch 810-nm laser diode catheter.

Endoscopic and fluoroscopic colonic interventions may be performed under moderate intravenous sedation or general anesthesia for prolonged procedures. Depending on the distance of the segment of interest from the anus, a traditional colonoscope may be substituted with a flexible or rigid endoscope. Around the endoscope or through the working channel, a guidewire may be placed to traverse obstructions. Once a stiff Lunderquist or Amplatz guidewire is secured proximal to the obstruction, a long sheath may be used to straighten tortuous colon and allow instrumentation and endoscopy across the obstruction.

Specific considerations and techniques in regard to colonic stenting have been described.^{21,22} In patients with malignant obstruction, rates of restenosis due to tumor ingrowth have been reported as high as 12%.²³ Therefore, in palliative patients, cecostomy tubes may be placed once a definitive operation has been performed.

See ►Figs. 5 and 6 for examples of interventional radiology-operated gastroscopy and colonoscopy.

Discussion

The feasibility and appropriateness for interventional radiologists to perform endoscopic procedures mentioned in this review may be contested.²⁴ As this review suggests, however, interventional radiologists are in a position to implement routine interventional radiology-operated endoscopy and are poised to develop new and associated techniques. Just as ultrasound and fluoroscopy have been utilized to facilitate surgical and medical procedures, endoscopy should be an adjunctive tool for interventional radiologists in the era of image-guided therapy. Over the past several decades, general surgery societies and training programs have promoted endoscopic training. Laparoscopic surgery has similarly become a major component of both urologic and gynecologic training. As other medical and surgical subspecialties have borrowed from one another to improve their therapies, interventional radiologists should be equally opportunistic with interventional radiology-operated endoscopy.

Collaboration with other specialties is key in maintaining an integrated approach to the comprehensive care of patients. Turf wars have been a common topic since the advent of interventional radiology. Interventional radiology-operated endoscopy may be questioned by colleagues, but patient selection and treatment coordination are key. Multidisciplinary approaches with two or more subspecialties in the endoscopy, fluoroscopy, or operating suite may be required. Implementation of interventional radiology-operated endoscopy will likely be embraced by colleagues when used appropriately.

Because endoscopic procedures come with risk, interventional radiologists must have admitting privileges and coordinate with colleagues in case of complications. Such a relationship already exists between gastroenterology and surgery for upper gastrointestinal endoscopy and colonoscopies complicated by perforation. The modern interventional radiologist must also know when to request help when unforeseen complications arise which may require evaluation and treatment by a different specialist.

Modern diagnostic and interventional radiology trainees have no or little exposure to interventional radiology-operated endoscopy throughout their training. The process for interested trainees is not well established in the United States, though other countries have established guidelines for obtaining endoscopy training, including the British Society of Gastrointestinal and Abdominal Radiology.²⁵ The use of endoscopy in interventional radiology is a supplemental tool, with minimal setup and small learning curves. Interventional radiology-operated endoscopy, however, has the potential to revolutionize the care of patients with pathology of the biliary (Figs. 3–5), genitourinary, and gastrointestinal (►Figs. 5 and 6) systems and beyond (►Fig. 7).

Conclusion

Endoscopy has advanced over the past decades. The resources needed for endoscopy are minimal and interventional radiologists are well poised to incorporate such imaging modalities into their clinical practices. The indications,

considerations, and techniques discussed earlier are some of the ways interventional radiology-operated endoscopy may help provide better and more comprehensive care for select patients. With appropriate patient selection, adequate resources, and integration into modern training paradigms, interventional radiology-operated endoscopy may prove to be an invaluable tool to deliver exquisite patient care.

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