An Overview of the Evolution of Direct Cholangioscopy Techniques for Diagnosis and Therapy

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Abstract: Direct examination of the biliary tree with endoscopes has been a challenge since endoscopists began performing endoscopic retrograde cholangiopancreatography (ERCP) in the late 1960s. Previously, surgeons had used rigid instruments intraoperatively, which made examination difficult. The first direct cholangioscopy performed by an endoscopist was likely unintentionally done in a patient with postsurgical anatomy. Indirect imaging, ERCP, and percutaneous transhepatic cholangiography are helpful modalities for examining the biliary tree, but they are limited procedures, particularly with regard to the evaluation and treatment of strictures and bile duct stones. This article reviews the history and evolution of direct cholangioscopy since the advent of flexible endoscopes. Additionally, the article describes a new single-operator cholangioscopy technique for direct visualization of the biliary tree for diagnosis and intervention. There remains opportunity for innovation as endoscopists strive for safe and less-invasive methods for the identification and treatment of biliary pathology.

The first direct endoscopic view of the biliary tree most likely occurred unintentionally when an endoscopist was examining the duodenum of a patient who had previously undergone choledochoduodenostomy. This occurrence, along with the understanding of postsurgical anatomy, subsequently led to the management of sump syndrome,[1,2] whereby endoscopists could directly evacuate stones from both the proximal and distal limbs of a side-by-side enterostomy, dilate a stenotic enterostomy stoma, and perform a sphincterotomy, all while avoiding additional surgical intervention.

Since then, endoscopists have devised many techniques for visualization of the biliary tree. Much focus has been placed specifically on the evaluation of biliary strictures, as they raise concern for malignancy, although their diagnosis remains challenging.[3,4] Currently, the initial evaluation of biliary strictures involves endoscopic retrograde cholangiopancreatography (ERCP), a method of indirect visualization.[3] Diagnosis is first attempted via brush cytology and/or intraductal biopsy, but these methods have poor sensitivity and specificity.[5] Thus, many strictures remain indeterminate, necessitating the development of other cholangioscopy-based techniques. This article reviews the evolution of direct cholangioscopy and describes

a new technique for direct visualization of the biliary tree for diagnosis and intervention.

Mother-Daughter Systems

In the 1980s, mother-daughter systems were introduced as a way to directly examine the biliary tree.[6-8] These systems are comprised of a large-channel duodenoscope ("the mother") through which a smaller cholangiopancreatoscope ("the daughter") can be inserted just as any other accessory. By the nature of this design, mother-daughter systems require 2 endoscopists. The first operator passes the larger endoscope into the duodenum and manipulates the smaller endoscope to cannulate the bile duct while the second operator controls the smaller endoscope within the bile duct. The smaller endoscope has its own light source, accessories, and biopsy channel for therapeutic procedures. Although such intervention is labor-intensive, the outcomes have proven to be worthwhile.[9,10]

However, the original mother-daughter systems were fiberoptic, and the bundles were fragile and prone to breakage. Newer systems have been updated with high-resolution digital video systems, although the outer sheath remains prone to damage by the elevator. While these newer systems have improved visualization of structures and are somewhat more durable, they are also more costly and still require 2 endoscopists.

Percutaneous Endoscopic Extraction of Retained Stones

Another early technique used by endoscopists to directly visualize the bile duct is percutaneous endoscopic extraction of retained stones (PEERS).[11,12] The PEERS procedure is performed by introducing a thin-caliber endoscope percutaneously through a mature T-tube tract into the biliary tree.[13,14] Endoscopists first used small bronchoscopes and, later, flexible fiberoptic choledochoscopes.[15] This procedure allows for direct examination of the biliary tree and extraction of common bile duct stones. Other possible interventions include performing sphincteroplasty via dilating balloons, directing a second endoscopist while performing a retrograde sphincterotomy, or even performing an antegrade sphincterotomy using a small-caliber endoscope.[16,17] A major limitation of PEERS and related techniques is the amount of time required for the T-tube to mature, usually 6 weeks, before the intervention can be performed.

Skinny-Needle Percutaneous Transhepatic Cholangiogram

Performed by interventional radiologists, the skinny-needle percutaneous transhepatic cholangiogram (PTC) is another method for accessing the biliary tree.[18-20] Similar to ERCP, this procedure provides indirect visualization of bile ducts while allowing the radiologist to drain the biliary system, obtain brush cytology, and even remove stones.[21-25] This technique was modified in 1978 by Yamakawa, who gained direct access into the bile duct by performing a PTC, followed by progressive dilation of the percutaneous tract until a thin-caliber fiberoptic endoscope could be introduced to directly examine the biliary tree.[26,27] While efficacious, this approach is very uncomfortable for patients. Additional burdens of this technique include the need for percutaneous drains while the tract matures and the risk of hepatic bleeding and/or bile leakage from the puncture site.

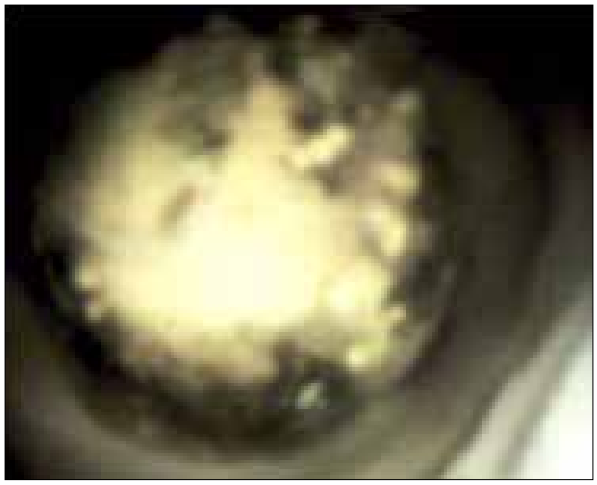

Figure 1. Direct visualization of a bile duct stone using a single-operator cholangioscopy system.

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Catheter-Based Systems

Innovation in direct peroral cholangioscopy led to the recent development of single-operator cholangioscopy (SOC) systems (SpyGlass Direct Visualization System from Boston Scientific and the PolyScope system from PolyDiagnost, which is not available in the United States). The SpyGlass catheter-based system attaches to an ERCP endoscope and is preferred over previous iterations due to its improved visualization and durability, in addition to being a single-operator system.[28-30] As an extension of ERCP, the SpyGlass SOC system enables high-resolution direct imaging, biopsy targeting, and stone fragmentation (Figures 1 and 2). A systematic review suggested that biopsies obtained using this SOC system have moderate sensitivity for the diagnosis of malignant biliary strictures.[31] A recent multicenter study reported high sensitivity and specificity of SOC visual impression and guided biopsies of biliary strictures for the diagnosis of malignancy. The

Figure 2. Direct visualization and biopsy of a biliary stricture with a single-operator cholangioscopy system.

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study also reported high rates of complete ductal clearance of bile duct stones using SOC.[32] Although the current system is versatile and widely adopted, it could be further improved with a larger field of view and a larger working channel in the catheter/endoscopes.

Ductal Anchoring Device

Another promising single-operator peroral innovation was the ductal anchoring device (Cholangioscopy Access Balloon, Cook Endoscopy).[33] During ERCP, this device was introduced over a guidewire into the proximal biliary tree and inflated with air. Once anchored, the balloon could be disengaged from the endoscope, after which a forward-viewing endoscope could be advanced over the balloon into the biliary tree. However, this device was associated with fatal air emboli and removed from the market.

Newest Approaches

Postsurgical Anatomy

Cholangioscopy in patients with postsurgical anatomy, such as after a Whipple procedure or certain bariatric surgeries, is complicated and labor-intensive. Endoscopists have described different techniques for performing cholangioscopy in such settings.[34-37] Often, endoscopists advance long forward-viewing endoscopes through the enteroenterostomies of the small bowel under fluoroscopic guidance. Following characterization of the anatomy and identification of the implanted bile duct orifice, endoscopists are able to intervene. As an example,

Figure 3. A fluoroscopic image of a colonoscope intubating a bile duct of a patient who had previously undergone a Whipple procedure.

following dilation of the stenotic orifice, we have been able to use a colonoscope for therapeutic cholangioscopy by applying electrohydraulic lithotripsy (EHL) to fragment common bile duct stones in post–Whipple procedure patients with bile duct stones (Figure 3).

Native Anatomy

There are various ways to directly enter the biliary tree using forward-viewing endoscopes.[38-40] Endoscopists have described performing direct peroral cholangioscopy using an upper endoscope guided by an intraductal balloon catheter.[38] A modified balloon catheter is inserted and fixed within a branch of the intrahepatic duct to facilitate advancement of the endoscope. Alternatively, endoscopists have also described overtube balloon-assisted direct peroral cholangioscopy.[39] The device is generally adapted from the overtube of either a single- or double-balloon enteroscope. Using an overtube helps secure the endoscope and prevent loop formation. Both techniques use an ultraslim upper endoscope.

Our own current approach to direct cholangioscopy is as follows: Initially, an ERCP is performed using a duodenoscope. The bile duct is cannulated and contrast injected to opacify the biliary tree for measurement. A sphincterotomy is performed, or if one was previously done, then the sphincterotomy is dilated to the size of the common bile duct using various types of dilating balloons. The duodenoscope is then withdrawn. An endoscope appropriate for the size of the bile duct is used to enter the second portion of the duodenum. The ampulla is visualized tangentially, and the endoscope is advanced beyond it. The endoscope is then turned to the direction of the ampulla and slowly reduced, orientating the endoscope in the direction of the ampulla. The sphincterotomy can then be directly entered. An occlusion balloon catheter

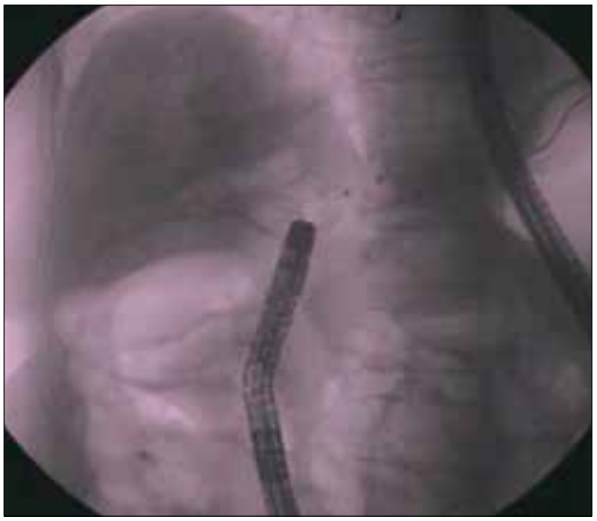

Figure 4. A fluoroscopic image of a bile duct intubated with a forward-viewing endoscope.

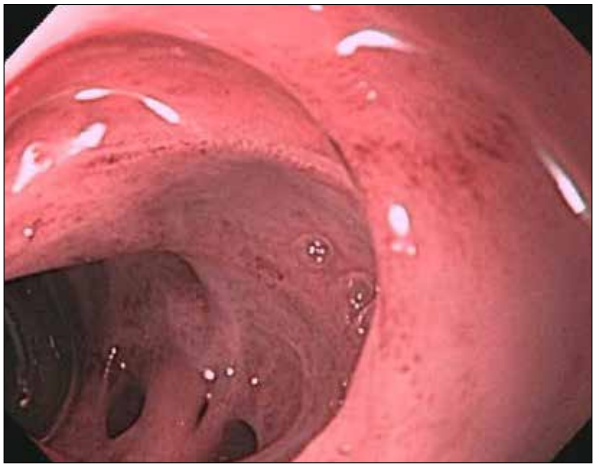

Figure 5. Narrow-band imaging of a stricture in an intrahepatic bile duct using a forward-viewing endoscope.

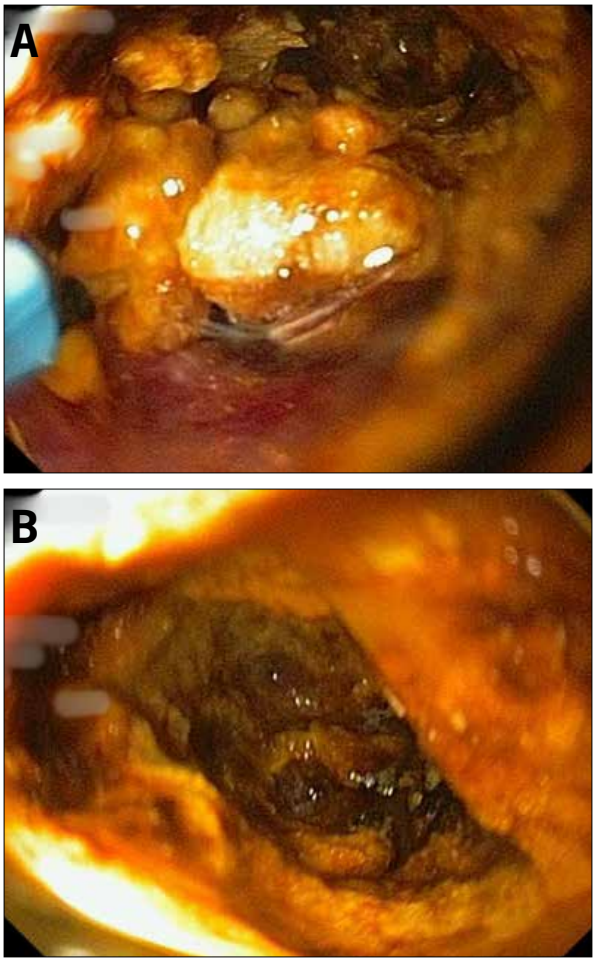

Figure 6. Electrohydraulic lithotripsy of bile duct stones under direct visualization with a forward-viewing endoscope (**A**). The bile duct after electrohydraulic lithotripsy with a forward-viewing endoscope (**B**).

can be placed deeply into the proximal bile duct or intrahepatic system. The balloon can be inflated to anchor the endoscope. The endoscope is then reduced and tension is applied to the balloon, facilitating the advancement of the endoscope deeper into the proximal bile duct. With the endoscope in place, the balloon is deflated and removed, allowing for direct visualization of the biliary tree and facilitating diagnostic and therapeutic options (Figure 4).

In addition to a larger field of view, the use of a regular endoscope allows for the use of several advanced modalities that cannot be performed with a "daughter" endoscope or current SpyGlass SOC system. In addition to cytology brushings and normal-sized biopsies, suspicious strictures can also be evaluated using narrow-band imaging, intraductal ultrasonography, and probe-based confocal laser endomicroscopy[9,41-43] (Figure 5). Bile duct stones can be treated with EHL under direct visualization (Figures 6A, with accompanying video online, and 6B). Stone fragments may be removed directly using a basket or occlusion balloon. Alternatively, the forward-viewing endoscope may be withdrawn, and a duodenoscope reinserted for clearance of the stone fragments and placement of stents, if needed.

Summary

Indirect visualization of the biliary tree is imperfect, and current methods for the evaluation of biliary strictures are limited in their sensitivity. This article reviewed the evolution of direct cholangioscopy—including mother-daughter systems, PEERS, skinny-needle PTC, catheter-based SOC systems, a ductal anchoring device, and novel techniques for direct peroral cholangioscopy—and

described a new technique for direct visualization of the biliary tree for diagnosis and intervention. There remains opportunity for innovation as endoscopists strive for safe and less-invasive methods for the identification and treatment of biliary pathology.

The authors have no relevant conflicts of interest to disclose.

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