12 Cholangioscopy Systems: State of the Art

Raffaele Manta and Michel Kahaleh

12.1 Introduction

Peroral cholangioscopy (POC) permits direct visualization of the biliary tree for diagnostic procedures and provides endoscopic guidance for therapeutic interventions.

POC is traditionally conducted using a mother-baby scope system. However, POC using this system is cumbersome, labor intensive, and difficult. A small caliber baby scope can be broken easily, is expensive, and is difficult to handle with limited irrigation and suction, and it has a small working channel of 1.2 mm diameter. The mother-baby scope system is also operated by two skilled endoscopists using two endoscopic systems. Therefore, routine clinical application of this system has been given up or limited to few endosocpic centers [1]. A single-operator cholangioscopic system has been developed as a new type of POC system, and nowadays POC can be performed by using a dedicated cholangioscope that is advanced through the accessory channel of a duodenoscope or by direct insertion of a small-diameter endoscope (ultraslim upper endoscope) directly into the bile duct for visualization of the biliary mucosa and lumen.

R. Manta, MD (✉)
U.O.C. Gastroenterologia ed Endoscopia Digestiva, Nuovo Ospedale Civile S.Agostino-Estense, Viale Giardini 1355, Baggiovara-Modena, Italy
e-mail: r.manta@libero.it; r.manta@ausl.mo.it

M. Kahaleh, MD, AGAF, FACG, FASGE
Professor of Medicine Chief, Endoscopy, Medical Director Pancreas Program, Division of Gastroenterology and Hepatology, Department of Medicine, Weill Cornell Medical College, 1305 York Avenue, 4th Floor, New York,10021 NY, Italy

R. Conigliaro, M. Frazzoni (eds.), *Diagnosis and Endoscopic Management of Digestive Diseases*, DOI 10.1007/978-3-319-42358-6_12

12.2 Direct Cholangioscopy

Compared to ductoscopy using a dedicated cholangioscope, the direct approach has several advantages and disadvantages. Three major advantages compared with other POC systems should be underlined: Direct POC provides high-quality endoscopic imaging with the ease of performance of enhanced endoscopy using narrow band imaging (NBI) and enables detection of smaller and more obscure lesions. A large, 2-mm-diameter working channel can be extended for interventional procedures, including for tissue sampling, and permits 5-Fr instruments. The direct POC system uses a conventional endoscope with a standard endoscopic setup by a single operator and avoids problems associated with simultaneous operation of multiple endoscopes such as the need of human resources, coordination of movements, and costs [2].

According to disadvantages ultraslim endoscopes present larger outer diameters, generally 5–6 mm; therefore, they can be used only after a large endoscopic sphincterotomy and/or sphincteroplasty and in patients with dilated bile ducts (>8 mm). The most profound disadvantage of direct peroral cholangioscopy is the difficulty associated with traversing the biliary sphincter to gain access to the bile duct. The current ultraslim scope is not designed for use as a cholangioscope, as it is too flexible, and it is easy to make a loop in the gastric fundus or third portion of the duodenum. There are therefore multiple published reports in the endoscopic literature with innovative suggestions on how to achieve this task. Some of the suggestions of endoscope introduction are over a guide wire, through a regular overtube, or with the help of a double-balloon overtube. However, despite use of these accessories, failure rate still remains high [3].

Another disadvantage of direct cholangioscopy is the instability of the ultraslim upper endoscope once it is inside the bile duct. All accessories supporting the scope, such as an intraductal balloon catheter, including the guide wire should be removed from the working channel of the scope to use interventional instruments. This can cause instability in the scope position. The distal tip of the scope can easily dislocate on the distal CBD or fall into the duodenum. This instability makes it difficult to perform diagnostic or therapeutic procedures such as obtaining biopsies of lesions or lithotripsy of difficult to remove biliary stones [4].

Moreover an air embolism is a rare complication of direct POC but can be a fatal problem. Cholangitis can also occur during or after the procedure. The use of a CO_2 system instead of room air during the POC procedure and administration of antibiotics before and after the procedure are strongly recommended [5].

Finally new accessories or specialized scopes must be developed to overcome the technical disadvantages of current direct POC in order to facilitate the diagnostic and therapeutic roles of direct POC.

12.3 Dedicated Cholangioscopy (or Indirect Cholangioscopy)

Regarding POC that can be performed using a dedicated cholangioscope advanced through the accessory channel of a duodenoscope, SpyGlass (Boston Scientific, Natick, MA, USA) is the most frequently used and widely diffused probe. Similar to the SpyGlass scope is the Polyscope® (Polyscope system; Polydiagnost, Pfaffenhofen, Germany), which consists of a detachable flexible endoscope system available in 8 Fr (185 cm length) with separate optical, working/irrigation (1.2 mm), illumination, and steering channels. Although there are few differences between the two systems from technical aspects, as summarized in Table 12.1, Spyglass is preferred to polyscope, and it represents the best known tool for the management of a selected group of biliary diseases.

12.4 SpyGlass System

The first single-operator cholangioscopy (SOC) system was presented, in 2005, by Boston Scientific (Natick, MA, USA) with the name of SpyGlass Direct Visualization System (SGDVS) [6]. It was an endoscopic advanced method, based on an image acquisition system mediated by optical fibers, which significantly facilitates the diagnosis of biliary-pancreatic diseases by a single operator. It made possible the direct macroscopic visualization of lesions, allowing their microscopic characterization through targeted biopsies, and eventual treatment.

A study performed in 2007 showed that the cholangioscopy using SpyGlass (SOC-S) was superior to that of a videocholangioscope (CHF BP-30, Olympus) in terms of visualization of the four lumen quadrants and in carrying out biopsies

Table 12.1 Comparison of different systems for indirect peroral cholangioscopy

Characteristics	SpyGlass	Polyscope
Optics resolution	6000 pixels	10,000 pixels
Working channel	1.2 mm	1.2 mm
Viewing angle	70°	70°
Outer diameter	10 Fr	8 Fr
Reusable	Yes	Yes
Optical channel	No	Yes
Hermetically close		(The optical fiber doesn't need to be sterilized; this prolongs its life cycle)
Steerability	Four way	One-way (With locking of the bending and rotating of the tip)
Compatibility with existing endoscopy tower	No (You have to buy a complete endoscopy tower system)	Yes (You can use, through adapters, an existing endoscopy tower in the hospital)

(95 % CI OR, from 1.7 to 2.94; P <0.001). Indeed, the SpyGlass system allows to deflect the tip in the four directions [7].

In 2015 a new SOC was launched by Boston Scientific (Natick, MA, USA): SpyGlass DS (Digital Simple) Direct Visualization System. Built on the technology of the original SGDVS, the new SpyGlass DS System was designed to optimize procedural efficiency and productivity with improved ease of setup, ease of use, and image quality.

12.4.1 Equipment

The SpyGlass DS Direct Visualization System is a sterile and disposable device composed of a flexible catheter useable in a normal duodenoscope with a working channel. Compared to the previous version, an integrated digital sensor provides superior imaging, far greater resolution, and a 60 % wider field of view. The controller is an endoscopic video imaging system that combines the functionality of a camera and a LED light source. The controller receives video signals from the catheter, processes the video signals, and outputs video images to an attached monitor. It also generates and controls the illumination transmitted to the distal end of the catheter. The catheter comprises a control section, an insertion tube, and a connection cable. The control section is provided with a handle with two knobs that allow the orientation of the distal end of catheter in the four directions, with a minimum inclination of 30° in the presence of all accessories. Moreover, it owns a locking lever and a urethane band under the operator channel, which lock the system at the duodenoscope. The flexible catheter (SpyScope) consists of a Teflon device of 3.3 mm (10 Fr). It contains one working channel (1.2 mm) that allows the passage of dedicated biopsy forceps, probes for lithotripsy, or laser and guide wires, two channels (0.6 mm) for irrigation, two optical fibers to transmit illumination from the controller, and wiring to transmit video signals to the controller. The catheter is introduced through a duodenoscope that has an operating channel of at least 4.2 mm^2 (Figs. 12.1 and 12.2).

The biopsy forceps (SpyBite) are sterile and disposable accessories for sampling intraductal biopsy. They have an external diameter of 1 mm and a length of 286 cm, with an opening of 4.1 mm. The irrigation system consists of a sterile tube set connected to an irrigation pump, activated with a pedal.

12.4.2 Clinical Applications

There are different indications for SOC-S use. It can be used for diagnostic and therapeutic procedures. Among common uses, there are difficult biliary stones and macroscopic and histological typing of indeterminate biliary strictures. Less common uses are the selective guide wire placement in a bile duct, the evaluation of either stenosis after a liver transplant or filling defects of the bile ducts not characterized by other methods (MRI, ERCP, EUS), as well as resolution of multiple lithiasis. The rare uses comprise staging or endoscopic ablation of tumors, the trans-papillary gallbladder drainage, and evaluation of hemobilia.

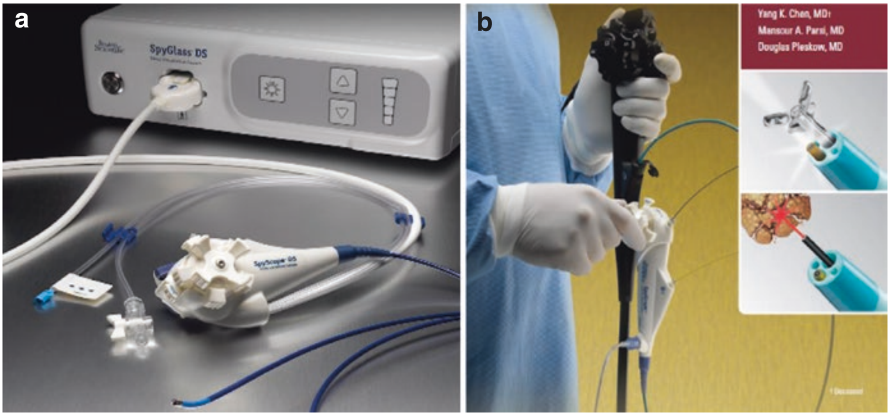

Fig. 12.1 SpyGlass DS equipments. Controller (**a**), and a flexible catheter (**b**) useable in a normal duodenoscope with a working channel

12.4.3 Treatment of Difficult Biliary Stones

Intraductal lithotripsy is the main therapeutic application of SOC-S when conventional procedures fail. The failure rate in the treatment of choledocholithiasis following standard endoscopic retrograde cholangiopancreatography (ERCP) is ranging between 8 and 16 % [8, 9]. A partial bile duct clearance depends on stones' characteristics (number, size, shape, texture, seat), the bile duct structure (shape, size, low insertion of the cystic duct), and the presence of a juxtapapillary diverticulum. Common bile duct and Wirsung lithiasis can be treated with laser (LL) or electrohydraulic lithotripsy (EHL). In such a field, the SOC-S has two important advantages. The first is to allow a direct visualization of the lumen and the stones position, avoiding duct damage. The second is to consent the correct functioning of the EHL device through the irrigation of bile ducts with the saline solution. In fact, the 1.9 Fr nitinol catheter of the EHL presents two insulated coaxial electrodes in the tip that produce sparks generating high-amplitude hydraulic pressure waves able to fragment the stones [10, 11]. The LL fragments stones using a laser beam that is delivered by means of a quartz flexible fiber introduced in the SOC-S operator channel. The pulsed application of the beam generates ion formations and free electrons at high energy with consequent spherical mechanical waves which fragment the stones [12]. A complete common bile duct drainage was achieved in 92 % of 26 patients with difficult cholelithiasis who failed three ERCP sessions with standard mechanical lithotripsy [13]. Similarly, following a mean of 1.2 sessions, a 100 % common bile duct clearance was reported by using Holmium laser lithotripsy in 60 patients with mechanical lithotripsy failure (stones average size of 23 mm), or with other conditions, such as the Mirizzi syndrome or stone impacted [14]. In a recent retrospective single-center study, a 77 % technical success in removing gallstones from the bile duct was reported [15].

The SOC-S has been used in 13 patients with cystic duct stones, including four with Mirizzi syndrome type 1, achieving complete clearance of both cystic duct and

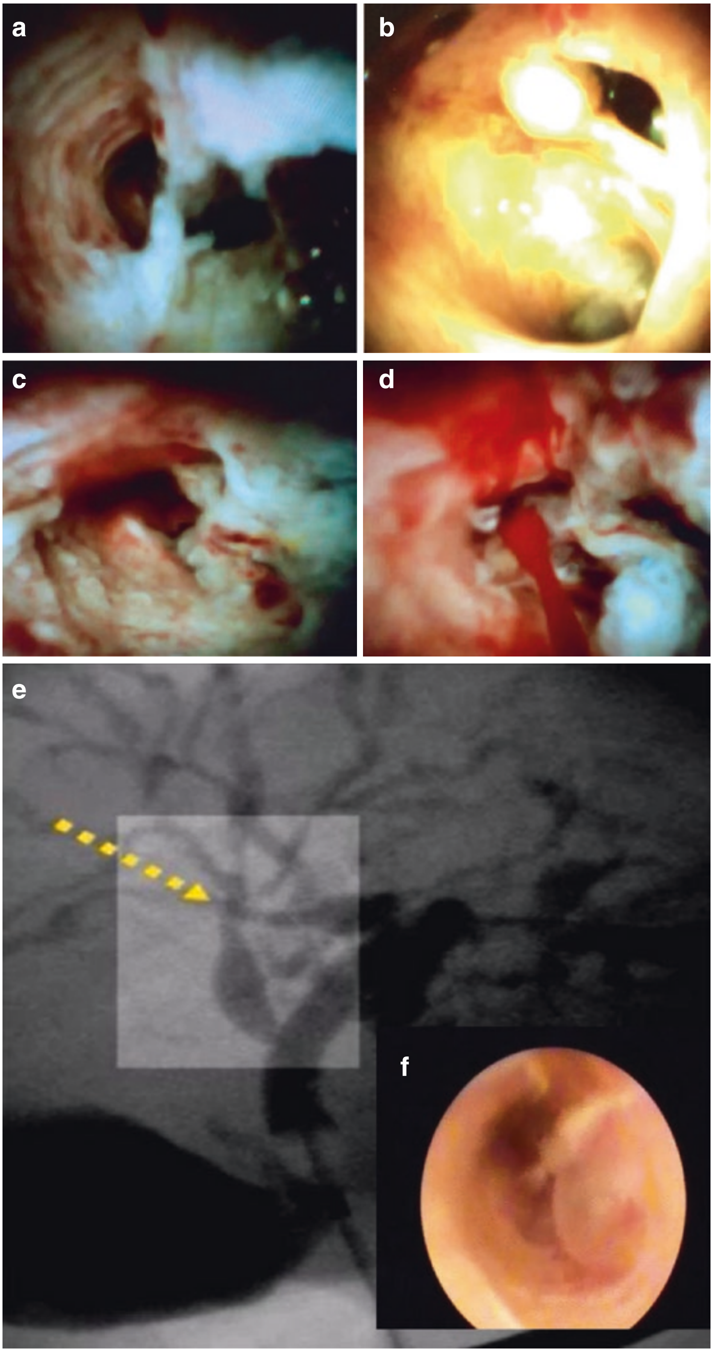

Fig. 12.2 SpyGlass DS images. (**a**) Cholangiocarcinoma of common bile duct; (**b**) a rare case of biliary cystoadenocarcinoma involving the intrahepatic left duct; (**c**, **d**) bleeding and stenotic neoplastic lesion located at hepatic hilum. A rare case of intrahepatic varices. (**e**) Stenosis of intrahepatic duct; (**f**) varices in intrahepatic duct

common bile duct in 77 % of cases [16]. In a prospective, multicenter study, 66 patients with difficult biliary stones (stones average size of 19 mm) underwent EHL (50 cases) or LL (16 cases). A complete bile ducts' clearance was achieved in all cases, with two sessions being needed in only 29 % of cases [17]. A case report showed a successful biliary lithiasis treatment with SOC-S and EHL by using an operator colonoscope in a patient with hepatic jejunostomy with Roux-en-Y reconstruction [18]. Of note, the use of SOC-S in pregnant women with gallstones allows to prevent radiological exposure [19]. Finally, a percentage of missed stones ranging between 8 and 30 % should be also taken into account, including those small stones not visible after contrast medium or masked by larger stones. These could be diagnosed and successfully treated by using the SOC-S [20, 21].

12.4.4 Treatment of Pancreatic Lithiasis

Pancreatic lithiasis is a demanding challenge for the endoscopist. Although there are only preliminary data, pancreatic lithiasis represents another promising therapeutic application of SOC-S. The efficacy of peroral pancreatoscopy with endoscope and that of SOC has been compared in series of 45 patients with main pancreatic duct (MPD) lithiasis [22]. A complete or partial clearance was obtained in 57 % and 100 % of case, respectively, without a difference between the two tools. In three patients (12 %) treated with SpyGlass, minor complications related to pancreatoscopy occurred. In a US multicenter, retrospective study on the efficacy of SOC-S in the treatment of the MPD lithiasis in 28 patients undergoing pancreatoscopy with LL was described [23]. The average size of stones was 15 mm (range: 4–32 mm). The stone removal was successful in 79 % of cases, with a partial clearance in further three (11 %) patients. Moreover, there was a good clinical outcome in 89 % of cases at 1 year follow-up, in terms of pain reduction, use of narcotics, and hospitalization. Recently, the use of SpyGlass-guided EHL was found to be a valid alternative for pancreatic lithiasis treatment in 98 patients following a failure of combined endoscopic lithotomy and extracorporeal shock wave lithotripsy (ESWL) [24].

12.4.5 Assessment of the Indeterminate Strictures of the Bile Duct

The ability to discriminate between benign and malignant biliary strictures is obviously of crucial importance in patient care management. The current radiologic methods (CT, MRI) do not provide adequate sensitive and specific diagnostic performance for all biliary-pancreatic lesions. The cytological sampling by brushing during ERCP or fine-needle aspiration (FNA) during endoscopic ultrasonography showed high specificity but modest sensitivity [25, 26]. Disappointing results were achieved even by using more performing brushes, dilation of stenosis before brushing, or gene analysis of the collected tissue [27]. Several cohort series on the use of

SOC-S in this field showed encouraging results [7]. However, the macroscopic characteristics of malignant biliary lesions are not completely standardized. Some studies on cholangioscopy with endoscope or SOC have defined highly suggestive criteria. They include the presence of dilated and tortuous vessels ("tumor vessel sign" or "capillary signs"), ulceration, nodules, exophytic or papillary excrescences, friability, and irregular surface [9, 28, 29]. On the other hand, mucosal alterations with a smooth surface or finely granular without neovascularization or intraductal masses suggest a benign condition [30]. A 61 % sensitivity and a 100 % specificity, with a 100 % interobserver agreement, for tumor vessel sign were found in a study [31]. On the contrary, another study found a good interobserver agreement with SOC only for tumoral masses, strictures, ulceration, and hyperplasia, stressing the need of validating the cholangioscopic criteria for biliary lesions [32]. When a suspected lesion is encountered, biopsies with SOC-S can be obtained by following two procedures: (1) cholangioscopy-direct biopsy obtained with the dedicated mini-forceps (SpyBite, Boston Scientific) and (2) cholangioscopy-assisted biopsy, which consists in identifying fluoroscopically the stricture area, to withdraw the cholangioscope, and to insert a standard forceps, until the stenosis under fluoroscopic guide [28]. Of note, by using the SpyBite, an adequate quantity of tissue was obtained in more than 95 % of cases [9, 13]. A prospective study involving 26 patients with indeterminate biliary strictures found that sensitivity, specificity, and accuracy of biopsies obtained with SpyBite were significantly higher as compared to either cytology or standard biopsy under fluoroscopic guidance [33]. In our experience, sampling performed with SpyBite was adequate in 97.5 % of 45 patients, with a sensitivity, specificity, and positive and negative predictive values of 93 %, 88 %, 87 %, and 94 %, respectively [34]. Another study found a 92.3 % and 74.4 % technical and clinical success, respectively, on 39 patients with indeterminate biliary strictures, and PPV and NPV as high as 100 % and 95.8 % [15].

A major challenge for the physicians is the early detection of cholangiocarcinoma in patients with primary sclerosing cholangitis (PSC). In a recent prospective observational Finnish study, the performance of the SOC-S with biopsy, brushing, and flow cytometry, in the diagnosis of indeterminate strictures in 11 patients with PSC, was evaluated. In all cases it was possible to obtain the direct biopsy sampling and cytology, with an adequate sampling in 82 % for cytology and 91 % for biopsy [35]. Similarly, the diagnostic yield of biopsies obtained by using the SpyBite was higher as compared to that of cytology in 19 patients with PSC [36].

As expected, the direct visualization with SpyGlass showed a sensitivity of 62 % for the extrinsic bile duct strictures [17], while biopsies achieved a very low (8 %) diagnostic yield [8].

In a prospective study enrolling 36 patients with indeterminate stricture of common bile duct, an adequate histological sampling was achieved in 82 % of cases, despite several hilar stenoses being present in 58 % of cases [8]. By using macroscopic evaluation, a 84 % sensitivity in diagnosing malignant lesions was observed [13].

In our study, concerning the data of our Endoscopic Unit, in Modena-Baggiovara Hospital, the direct visualization of lesions allowed to exclude seven patients with non-organic stenosis, including varices of the common bile duct or piled microcalculi [34].

In a retrospective study of 30 patients with extrahepatic cholangiocarcinoma in whom the diagnosis failed with cytology during ERCP or during EUS with FNA [37], the diagnostic accuracy of macroscopic observation with SOC-S was 77 %. Encouraging results were also reported in a recent retrospective study of 36 patients with indeterminate biliary strictures in whom the sensitivity, specificity, and diagnostic accuracy for malignant lesions using direct visualization with SOC-S and biopsy with SpyBite were 100 % and 64.2 %, 90 % and 100 %, and 96.7 % and 73.6 %, respectively [38].

A multicenter study enrolled 226 patients with indeterminate biliary strictures who underwent ERCP with SOC-S, and 140 received biopsy with SpyBite (adequacy of the sample 88 %, 20 % hilar stenosis). The sensitivity and specificity in detecting malignant stenosis was 51 % and 54 % by using only cholangiographic visualization, 78 % and 82 % for macroscopic visualization with SpyGlass, 49 % and 98 % for direct sampling of lesions with SpyBite [17].

Finally, a recent meta-analysis of eight studies on the SOC-S use for the indeterminate biliary strictures diagnosis showed that a direct visualization achieved a sensitivity of 90 % and a specificity of 87 % for malignant lesions, while the histological diagnosis following SpyBite biopsies achieved 69 % sensitivity and a 98 % specificity [39]. These data would suggest that the best use of SOC-S could be to identify macroscopically a suspicious lesion, by using macroscopic malignancy criteria, and then proceed to targeted biopsies under direct vision (cholangioscopy-direct biopsy) or indirect vision (cholangioscopy-assisted biopsy).

12.4.6 Complications

The studies on SOC-S reported an adverse event rate – especially cholangitis and pancreatitis – oscillating between 5 and 13 % (9, 10, 29, 4). It has been found that the cholangiopancreatoscopy is associated to an overall (7 % vs 2.9 %) increased procedure-related adverse event rate as compared to the simple ERCP [5]. In detail, pancreatitis, perforation, and bleeding (4.2 % vs 2.2 %) and, particularly, post-procedural cholangitis (1.0 % vs 0.2 %) were significantly higher. An overall complication rate of 7.5 %, mainly cholangitis, was also reported in another study. All adverse events resolved without sequelae. This highlights the need to offer aggressive biliary or pancreatic drainage post cholangiopancreatoscopy.

Conclusions

The cholangioscopy single operator using the digital SpyGlass system seems to be a promising and highly advantageous tool for both diagnosis and therapy of different biliary tract diseases. In detail, very interesting results have been obtained for treatment of difficult biliary stones. Moreover, the possibility of characterizing stenosis following a failure of other investigations, both macroscopically and with targeted biopsies, is of paramount importance. Further studies are required on pancreatic diseases. Research and technological development of this method, and its spread in biliopancreatic endoscopy, is expected to improve management of patients with difficult biliary and pancreatic diseases.

References

1. Moon JH, Terheggen G, Choi HJ, Neuhaus H. Peroral cholangioscopy: diagnostic and therapeutic applications. Gastroenterology. 2013;144:276–82.
2. Overhiser AJ, Sharma P. Advances in endoscopic imaging: narrow band imaging. Rev Gastroenterol Disord. 2008;8:186–93.
3. Terheggen G, Neuhaus H. New options of cholangioscopy. Gastroenterol Clin North Am. 2010;39:827–44.
4. Moon JH, Choi HJ. The role of direct peroral cholangioscopy using an ultraslim endoscope for biliary lesions: indications, limitations, and complications. Clin Endosc. 2013;46:537–9.
5. Sethi A, Chen YK, Austin GL, et al. ERCP with cholangiopancreatoscopy may be associated with higher rates of complications than ERCP alone: a single-center experience. Gastrointest Endosc. 2011;73:251–6.
6. Parsi MA. Peroral cholangioscopy in the new millennium. World J Gastroenterol. 2011;17:1–6.
7. Chen YK. Preclinical characterization of the Spyglass peroral cholangiopancreatoscopy system for direct access, visualization, and biopsy. Gastrointest Endosc. 2007;65:303–11.
8. Ramchandani M, et al. Role of single-operator peroral cholangioscopy in the diagnosis of indeterminate biliary lesions: a single-center, prospective study. Gastrointest Endosc. 2011;74:511–9.
9. Chen YK, Pleskow DK. SpyGlass single-operator peroral cholangiopancreatoscopy system for the diagnosis and therapy of bile-duct disorders: a clinical feasibility study (with video). Gastrointest Endosc. 2007;65:832–41.
10. Sievert CE, Silvis SE. Evaluation of electrohydraulic lithotripsy as a means of gallstone fragmentation in a canine model. Gastrointest Endosc. 1987;33:233–5.
11. Shah RJ, Chen YK. Techniques of peroral and percutaneous choledochoscopy for evaluation and treatment of biliary stones and strictures. Tech Gastrointest Endosc. 2007;9:161–8.
12. Hochberger J, et al. Lithotripsy of gallstones by means of a quality-switched giant-pulse neodymium:yttrium-aluminum-garnet laser. Basic in vitro studies using a highly flexible fiber system. Gastroenterology. 1991;101:1391–8.
13. Draganov PV, et al. Prospective evaluation of the clinical utility of ERCP-guided cholangiopancreatoscopy with a new direct visualization system. Gastrointest Endosc. 2011;73:971–9.
14. Maydeo A, Kwek BEA, Bhandari S, Bapat M, Dhir V. Single-operator cholangioscopy-guided laser lithotripsy in patients with difficult biliary and pancreatic ductal stones (with videos). Gastrointest Endosc. 2011;74:1308–14.
15. Tieu AH, et al. Diagnostic and therapeutic utility of SpyGlass(®) peroral cholangioscopy in intraductal biliary disease: single-center, retrospective, cohort study. Dig Endosc. 2015;27:479–85.
16. Sepe PS, et al. Single-operator cholangioscopy for the extraction of cystic duct stones (with video). Gastrointest Endosc. 2012;75:206–10.
17. Chen YK, et al. Single-operator cholangioscopy in patients requiring evaluation of bile duct disease or therapy of biliary stones (with videos). Gastrointest Endosc. 2011;74:805–14.
18. Baron TH, Saleem A. Intraductal electrohydraulic lithotripsy by using SpyGlass cholangioscopy through a colonoscope in a patient with Roux-en-Y hepaticojejunostomy. Gastrointest Endosc. 2010;71:650–1.
19. Uradomo L, Pandolfe F, Aragon G, Borum ML. SpyGlass cholangioscopy for management of choledocholithiasis during pregnancy. Hepatobiliary Pancreat Dis Int. 2011;10:107.
20. Fishman DS, Tarnasky PR, Patel SN, Raijman I. Management of pancreaticobiliary disease using a new intra-ductal endoscope: the Texas experience. World J Gastroenterol. 2009;15:1353–8.
21. Awadallah NS, Chen YK, Piraka C, Antillon MR, Shah RJ. Is there a role for cholangioscopy in patients with primary sclerosing cholangitis? Am J Gastroenterol. 2006;101:284–91.
22. Attwell AR, et al. 296 ERCP with per oral pancreatoscopy for calcific chronic pancreatitis using endoscope and catheter-based pancreatoscopes: a 10-year single center experience. Gastrointest Endosc. 2011;73:AB121–2.

23. Attwell AR, et al. ERCP with per-oral pancreatoscopy-guided laser lithotripsy for calcific chronic pancreatitis: a multicenter U.S. experience. Gastrointest Endosc. 2015;82:311–8.
24. Ito K, et al. Efficacy of combined endoscopic lithotomy and extracorporeal shock wave lithotripsy, and additional electrohydraulic lithotripsy using the SpyGlass direct visualization system or X-ray guided EHL as needed, for pancreatic lithiasis. Biomed Res Int. 2014;2014:732781.
25. Mansfield JC, Griffin SM, Wadehra V, Matthewson K. A prospective evaluation of cytology from biliary strictures. Gut. 1997;40:671–7.
26. Moreno Luna LE, et al. Advanced cytologic techniques for the detection of malignant pancreatobiliary strictures. Gastroenterology. 2006;131:1064–72.
27. Ornellas LC, Santos Gda C, Nakao FS, Ferrari AP. Comparison between endoscopic brush cytology performed before and after biliary stricture dilation for cancer detection. Arq Gastroenterol. 2006;43:20–3.
28. Shah RJ, Langer DA, Antillon MR, Chen YK. Cholangioscopy and cholangioscopic forceps biopsy in patients with indeterminate pancreaticobiliary pathology. Clin Gastroenterol Hepatol. 2006;4:219–25.
29. Fukuda Y, Tsuyuguchi T, Sakai Y, Tsuchiya S, Saisyo H. Diagnostic utility of peroral cholangioscopy for various bile-duct lesions. Gastrointest Endosc. 2005;62:374–82.
30. Shim CS, Neuhaus H, Tamada K. Direct cholangioscopy. Endoscopy. 2003;35:752–8.
31. Kim HJ, et al. Tumor vessel: a valuable cholangioscopic clue of malignant biliary stricture. Gastrointest Endosc. 2000;52:635–8.
32. Sethi A, et al. Interobserver agreement for evaluation of imaging with single operator choledochoscopy: what are we looking at? Dig Liver Dis. 2014;46:518–22.
33. Draganov PV, et al. Diagnostic accuracy of conventional and cholangioscopy-guided sampling of indeterminate biliary lesions at the time of ERCP: a prospective, long-term follow-up study. Gastrointest Endosc. 2012;75:347–53.
34. Manta R, et al. SpyGlass single-operator peroral cholangioscopy in the evaluation of indeterminate biliary lesions: a single-center, prospective, cohort study. Surg Endosc. 2013;27:1569–72.
35. Siiki A, et al. Spyglass single-operator peroral cholangioscopy seems promising in the evaluation of primary sclerosing cholangitis-related biliary strictures. Scand J Gastroenterol. 2014;49:1385–90.
36. Rey JW, et al. Efficacy of SpyGlass(TM)-directed biopsy compared to brush cytology in obtaining adequate tissue for diagnosis in patients with biliary strictures. World J Gastrointest Endosc. 2014;6:137–43.
37. Siddiqui AA, et al. Identification of cholangiocarcinoma by using the Spyglass Spyscope system for peroral cholangioscopy and biopsy collection. Clin Gastroenterol Hepatol. 2012;10:466–71; quiz e48.
38. Woo YS, et al. Role of SpyGlass peroral cholangioscopy in the evaluation of indeterminate biliary lesions. Dig Dis Sci. 2014;59:2565–70.
39. Sun X, et al. Is single-operator peroral cholangioscopy a useful tool for the diagnosis of indeterminate biliary lesion? A systematic review and meta-analysis. Gastrointest Endosc. 2015;82:79–87.