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REVIEW/STATE OF THE ART

Percutaneous Removal of Biliary Calculi

Adam Hatzidakis · Miltos Krokidis · Nicholas Gourtsoyiannis

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Introduction

Nowadays diagnostic noninvasive approach of the biliary tree for detection of lithiasis is performed very well with ultrasound (US) and magnetic resonance cholangiopancreatography (MRCP) [1–4]. In cases where these modalities are inconclusive, more invasive procedures like endoscopic retrograde cholangiopancreatography (ERCP) or percutaneous transhepatic cholangiography (PTC) can reveal the diagnosis and may also lead to therapeutic solutions [5, 6]. ERCP is usually chosen first, and only in the case of contraindication or failure are percutaneous radiological methods advisable [6].

Under percutaneous interventional radiology of the biliary system we understand diagnostic transhepatic cholangiography with or without external/internal drainage of bile [7, 8]. Diagnostic procedures also include percutaneous guided intraluminal biopsy. Therapeutic procedures include percutaneous drainage-decompression of the biliary tree or gallbladder, dilation of a bile duct stenosis or surgical anastomosis, application of intraluminal plastic or metallic stents, dissolution and removal of gallstones, and, finally, percutaneous intraluminal radiotherapy of biliary tumors [9–14]. Percutaneous cholangioscopy is a distinct method which can contribute to diagnosis as well as treatment by aiding other techniques, such as lithotripsy [15, 16].

In this review article, we analyze the indications for, techniques for, and complications of percutaneous treatment of intra- and extrahepatic biliary stones, with a discussion of the literature.

A. Hatzidakis (✉) · M. Krokidis · N. Gourtsoyiannis
Department of Radiology, Medical School of Heraklion,
Em. Kastrinaki 7, 71306 Heraklion, Crete, Greece
e-mail: adamhatz@med.uoc.gr; adamhatz@hotmail.com

Etiology and Clinical Presentation of Biliary Lithiasis

Intra- or extrahepatic biliary stones can be the result of various conditions [6]. The most common cause is the passage of small gallbladder stones through the cystic into the common bile duct (CBD). Another cause is the presence of a biliary stricture somewhere in the biliary tree, due to primary or secondary cholangitis, with subsequent inadequate bile drainage from that part of the biliary system, so that small stones tend to get formed above the strictures. In other patients, an intrahepatic biliary stone can be formed without an obvious cause, just because of slow or impaired bile drainage through the papilla of Vater. Benign strictures of the papilla can play a role here, so that if these relatively small stones do not pass the papilla, they can grow and cause biliary obstruction symptoms, such as cholangitis and jaundice.

A common cause for extrahepatic stricture is direct iatrogenic CBD injury during laparoscopic or open cholecystectomy [17–19]. Multiple biliary duct confluence strictures are usually the result of indirect injury, due to thermal injury of the CBD wall's vasa vasorum. Postoperative stenosis of a biliodigestive anastomosis, along with other inflammatory causes, follow in frequency [9, 20]. Such stenosis is usually present at long-term follow-up and can lead to cholangitis and jaundice with or without formation of calculi.

Sometimes biliary stones originating from the gallbladder can be blocked in a smaller intrahepatic biliary duct, causing obstruction followed by cholangitis. In all these cases, the cholangitis process causes stricture formation, new strictures cause new cholangitis, and so on. Such small stones can be detected after surgery if a t-tube catheter (Kehr) is left in place. Transcatheter cholangiography can reveal the problem and the stone can be removed before the tube is taken out.

Cholangitis usually presents with local pain, fever, jaundice, and hepatic enzyme elevation. Two factors are necessary for the onset of clinical symptoms: the presence of a significant number of bacteria and an elevated intraductal pressure that causes the passage of endotoxins and bacteria into the blood.

Indications for a Radiological Approach

For many decades ERCP has been the primary interventional imaging method for the diagnosis and treatment of biliary calculus disease. In recent years MRCP, in connection with the continuously improving technological capacities of MRI, has become an important noninvasive, noninterventional diagnostic tool for detection of benign and malignant biliary disease [3, 4]. So ERCP is reserved more for therapeutic intervention and less for diagnostic needs.

However, when endoscopic access to the biliary system is impossible, diagnostically inadequate, or insufficient, percutaneous transhepatic approach and lithotripsy are indicated [21–26]. Percutaneous lithotripsy is a therapeutic method that allows performance of biliary stone removal through the transhepatic route, without the help of endoscopy or open surgery. The necessary equipment is used through special sheaths, also used for endovascular procedures. Fluoroscopic guidance, with or without the additional help of intraluminal biliary endoscopy, is required. This can occur particularly if there is a shortage of specialized medical staff or ERCP equipment (rare nowadays); if there has been a previous operation and the anatomy of the area has changed, thus making catheterization of the biliary tree impossible; and also if there is extensive benign or malignant stenosis of the gastrointestinal tract at any point prior to the papilla of Vater or if a duodenal diverticulum is present [22]. In special cases, when intrahepatic stones exist, these stones can either be multiple, impacted, or located in isolated branches or above a stenosis, so that the endoscopist cannot reach the problem [27].

In more detail, the algorithm of the therapeutic approach of biliary lithiasis can be summarized as follows [27].

1. In cases of a normal biliary tree, without the presence of a stricture, the stones can usually be endoscopically removed through the intestine. The percutaneous approach can be attempted only after unsuccessful endoscopic attempts. If catheterization is difficult for the endoscopist, a combined percutaneous and endoscopic procedure is indicated (rendezvous technique) [28].
2. In cases of a biliary tree with benign or malignant underlying strictures and cholelithiasis above them, percutaneous lithotripsy should also be performed after endoscopic failure.

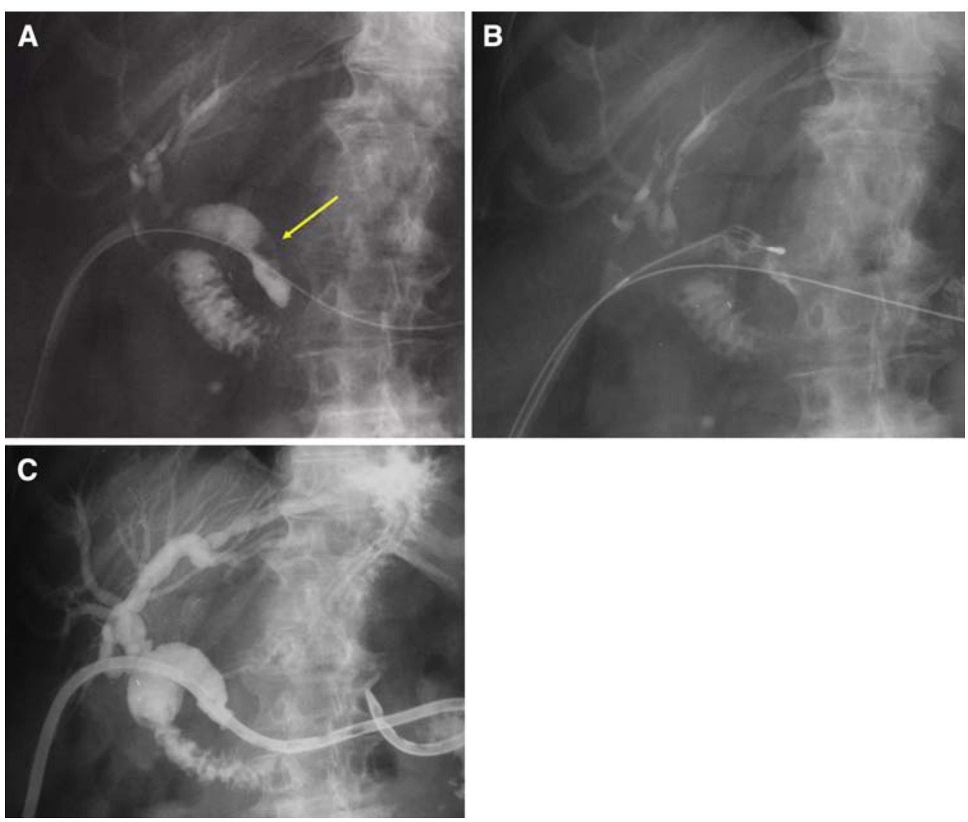

Fig. 1 **A** Patient with a t-tube catheter after open cholecystectomy and CBD exploration revealed a small retained stone in the CBD (*arrow*). Catheterization of the papilla with a guidewire is performed. **B** The stone is caught by a Dormia basket inserted through a 12-Fr peel-away sheath. **C** Basket and stone are removed through the t-tube tract and a 12-Fr internal drainage catheter is placed. No further filling defects are seen

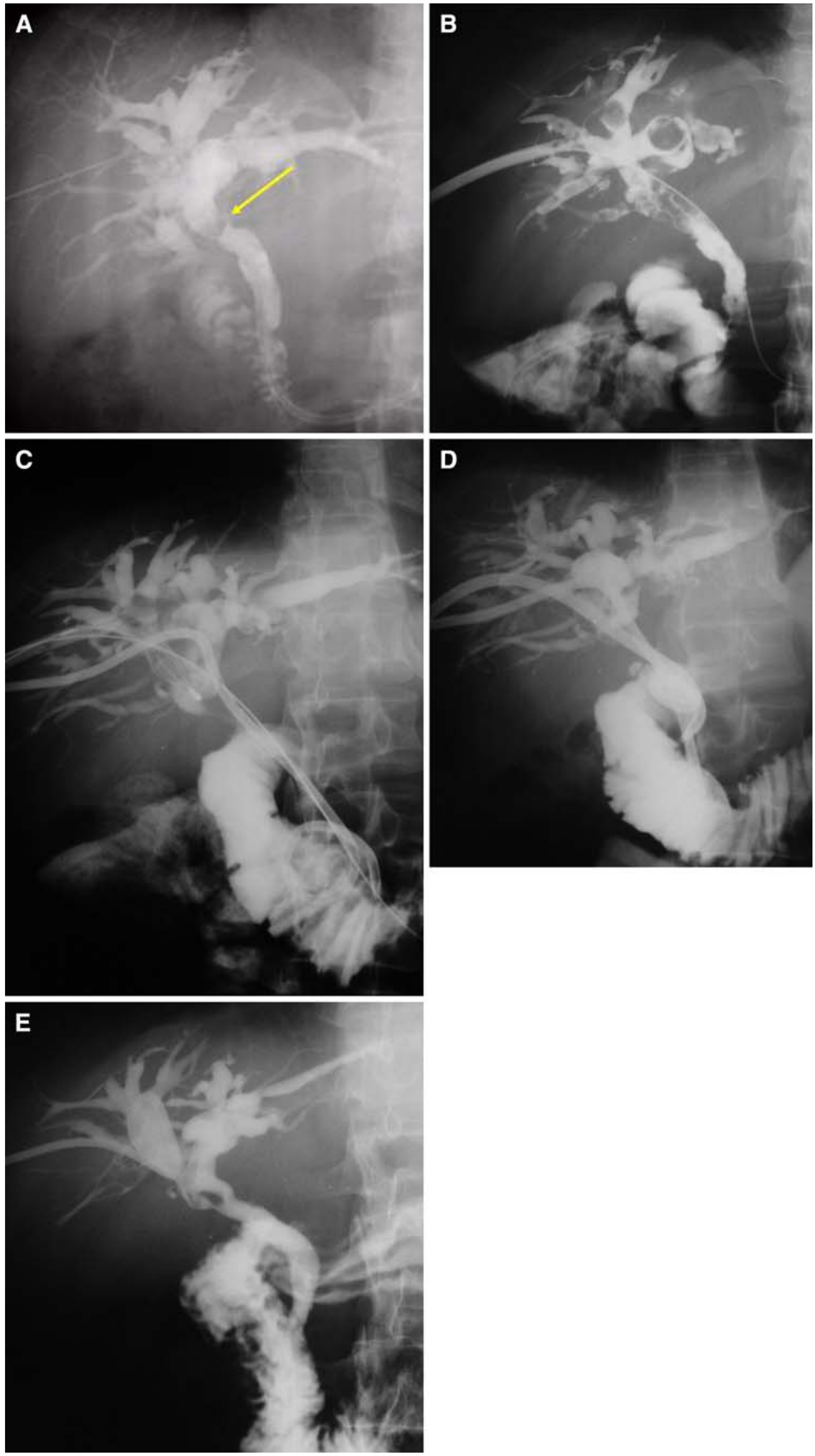

Fig. 2 **A** Patient with open cholecystectomy and retained intrahepatic stones, treated with plastic stent insertion. Eighteen months later he presented with recurrent episodes of cholangitis, jaundice, and sepsis. PTC revealed stenosis in the middle of the CBD (*arrow*), with the endoscopic stent migrated beneath the stenosis. **B** Dilatation of the stricture followed by percutaneous removal of the stent was performed. Multiple intrahepatic impacted stones of various sizes are seen. **C** A second transhepatic access was needed in order to get next to the largest stone, obstructing the sixth segment duct, which drains through the left main biliary duct. After fragmentation with electrohydraulic lithotripsy, removal of all fragments with the help of Dormia baskets was achieved. **D** After completion of stone removal, one 10-Fr and one 12-Fr catheter placed through the two different transhepatic accesses were left parallel to each other for 5 months. **E** Five months later, the result was satisfactory and the catheters were removed. A closed external drainage catheter was left in place for another month. The patient did well, so the catheter was removed, and there had been no recurrence at 9 years

3. In cases of impacted intrahepatic lithiasis, percutaneous treatment should be the first choice, especially in the presence of underlying biliary strictures [29, 30].
4. After CBD exploration, stones can be detected during t-tube cholangiography and lithotripsy can be performed percutaneously through the catheter tract [31].
5. Above a biliodigestive anastomosis, cholelithiasis can be the result of intraoperatively undetected intrahepatic lithiasis or postinflammatory formation due to anastomotic stricture [28, 32]. Inability of endoscopic treatment usually leads the patient to percutaneous therapy as the first choice. A percutaneous transenteric approach could be possible if the surgeon has made a bowel loop fixation on the anterior abdominal wall.

Methods of Biliary Lithotripsy

Percutaneous treatment is initiated with the performance of transhepatic fine-needle cholangiography, which is a

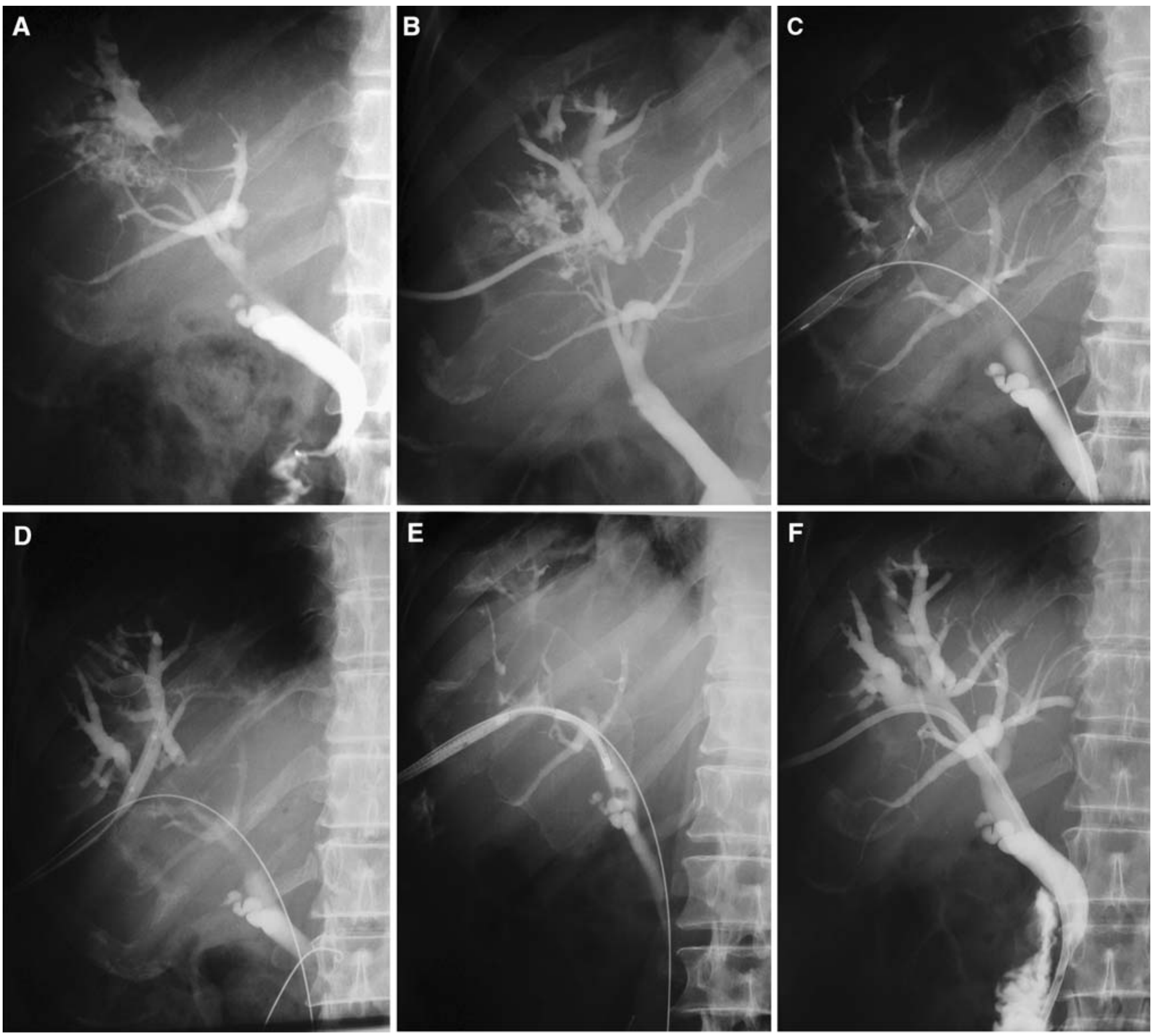

Fig. 3 **A** Patient with Crohn's disease and recurrent cholangitis presented for PTC after unsuccessful ERCP. Transhepatic cholangiography revealed dilated biliary ducts in the seventh–eighth liver segments, full of small filling defects, due to impacted stones. **B** A percutaneous external drainage of 8 Fr was initially placed in the region of interest, through an access allowing future interventions. The tract was dilated in subsequent weeks up to 12 Fr. **C** Mechanical lithotripsy with special Dormia baskets was performed. **D** Dilatation of intrahepatic strictures allowed passage of small fragments to the lower CBD. **E** Cholangioscopy helped with recognition of small fragments and pushed them through the Papilla into the duodenum. **F** The final result was satisfactory and the patient remained asymptomatic at 10 years

widely accepted and applicable interventional diagnostic procedure with a low risk rate. Its technical success rate reaches up to 98% in patients with dilated, and up to 70% in patients with nondilated, biliary tree branches [5]. Absolute or relative contraindications of the method include serious blood coagulation disorders, extensive ascites, polycystic or extensive malignant liver disease, and, less frequently, bowel loop interposition.

Percutaneous transhepatic drainage of the dilated biliary tree is the second step. The puncture point where the catheter will be inserted is of great importance. This point should be chosen according to the localization of each potential problem. A wrong choice can lead to subsequent therapeutic failure or to the need for a new transhepatic puncture. In each case, this leads to time loss and an increase in complications and patient discomfort, factors which should always be taken under serious consideration.

Transhepatic drainage can be performed through the right or the left liver lobe. Before further treatment, formation of a biliocutaneous fistula, which requires at least 12 weeks to develop, is necessary. This lapse in time often assists the patient's recovery, with gradual improvement of the cholestatic and hepatic enzyme values. It also assists in the treatment of often accompanying cholangitis, due to the percutaneous decompression of infectious bile.

Outcome of Biliary Lithotripsy

Lithotripsy for stones above an anastomotic stricture is reported to have a very high success rate, even 100% [32]. Nevertheless, the 3-year success rate following balloon dilatation of strictures is less encouraging, ranging from 42% for stenoses due to sclerotic cholangitis, to 67% for postoperative stenoses of biliodigestive anastomoses, to 76% for stenoses following iatrogenic injuries [9].

Complications of biliary lithotripsy

Complications of percutaneous transhepatic drainage, other than those of cholangiography, can be minor or major [7]. Mild to moderate complications include mild to moderate

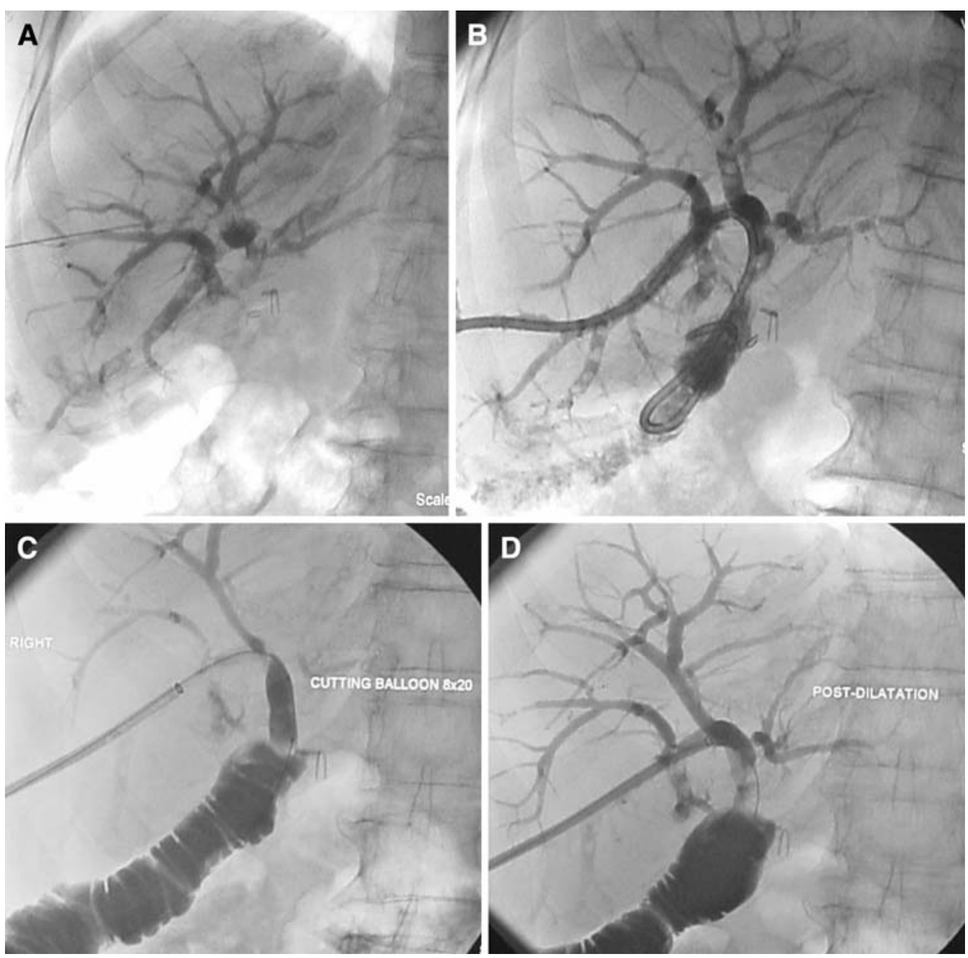

Fig. 4 **A** Patient with biliodigestive anastomosis presenting with cholangitis and jaundice. PTC reveals obstruction at the anastomosis level and multiple intrahepatic filling defects representing stones. **B** Percutaneous internal drainage was placed until the patient recovered from cholangitis. **C** Dilatation of the anastomosis with an 8 × 20-mm cutting balloon was performed and the calculi were pushed toward the small bowel loop. **D** The final result was considered satisfactory

pain, catheter-related problems like obstruction, migration or, misplacement, vagotony, and cholangitis. Subcapsular hematoma, injury of the hepatic artery with consequent hemorrhage or development of pseudoaneurysm, biliary leakage and peritonitis, infection, bacteremia, abscess, injury of the pleura or diaphragm, and pneumothorax are more serious complications [5, 33]. The most feared event is hemorrhage, which can be subcapsular, intraperitonal, or intrathoracic, as well as bacteremia followed by septicemia. The majority of these complications can usually be treated by other percutaneous interventional methods, such as drainage and embolization. The success rate of the percutaneous technique ranges from 93% to 98%, with a complication rate of about 10% and a procedure-related mortality rate lower than 2% [8].

Access for Stone Removal

The transhepatic approach is not always necessary, as in cases where a fistula already exists, due to a surgically placed t-tube catheter within the CBD. The first successful stone extraction was performed by Mazzariello, who used a specially designed, low-profile curved forceps inserted through a predilated t-tube tract [34]. In this manner he was able to break and remove a retained biliary stone. The same technique can be assisted by special Dormia baskets, also used by the endoscopists (Fig. 1A–C).

It is also possible that during a previous operation, where a biliodigestive anastomosis was formed, the surgeon had deliberately fixed a small bowel loop to the anterior abdominal wall. This was done to allow a percutaneous approach to the biliary tract through this loop in the future, if necessary. In such cases we do not need to perform a transhepatic puncture and biliary approach can be performed through the enteric loop.

After gaining the appropriate biliary access, the interventional radiologist should create a specific plan for complete lithotripsy, checking whether the access is adequate for reaching all the stones with the available instruments. If not, a second access should be established (Fig. 2A–E).

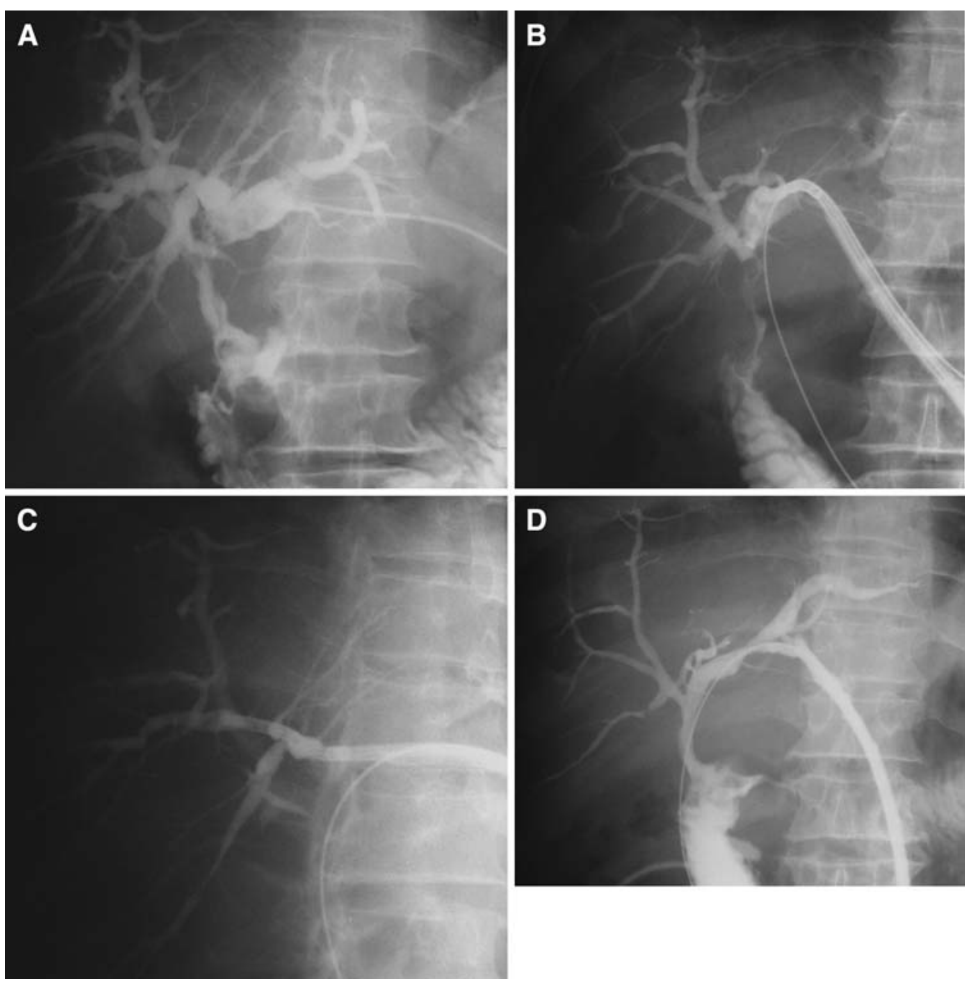

Fig. 5 **A** Patient with a stenosed biliodigestive anastomosis, presenting with cholangitis and jaundice due to intrahepatic lithiasis. A left-side approach was chosen in order to have access next to the stones. **B** Dilatation of the anastomosis was performed, followed by electrohydraulic lithotripsy through a 9.9-Fr cholangioscope for fragmentation of the largest stones. After lithotripsy the fragments were pushed through the anastomosis. **C** A small impacted stone was suspected in a small left lobe duct. Direct cholangioscopy confirmed the diagnosis. The stone was broken and removed. **D** The final result was satisfactory and the patient remained asymptomatic at 8 years

Balloon Angioplasty of Biliary Strictures

Before starting lithotripsy, the presence of intra- or extra-hepatic strictures should be determined, and if they are found, balloon dilatation should be performed first, followed by intraluminal lithotripsy (Fig. 3A–F). For dilatation of CBD strictures, simple angioplasty balloons 8–12 mm wide and 2 cm long can be used, or special high-pressure balloons of the same size if strictures are very tight. For intrahepatic biliary duct strictures, smaller balloons, of 4–7 mm, are required. Especially for patients with iatrogenic benign biliary strictures of the bile duct or the biliodigestive anastomosis, dilatation with 10- to 14-mm-wide high-pressure balloons (up to 20 atm) or special cutting balloons can be attempted prior to mechanical lithotripsy, followed by long-term internal drainage with large-bore catheters, 12–16 Fr [9] (Fig. 4A–D).

Tools Required for Biliary Stone Extraction and Fragmentation

Lithotripsy can be achieved by simple pushing of the stones through the papilla or the anastomosis [22, 23], use of occlusion or extraction balloons [22, 25], or special stone retrieval baskets (Dormia type) [27, 31], and special device-assisted lithotripsy, such as electrohydraulic [15, 24, 27], or laser induced [33, 35], (Fig. 5A–D).

It is advised that patients undergo endoscopic sphincterotomy prior to the above mention procedure. If the papilla is too tight, balloon-sphincteroplasty can follow in order to enlarge the lumen, using the same balloons mentioned above for stricture dilatation [22, 25, 36]. The technical success for percutaneous lithotripsy can reach initial rates of over 90% [10, 16, 24, 26], increasing to 93% on the second attempt [26]. Patient cooperation is essential

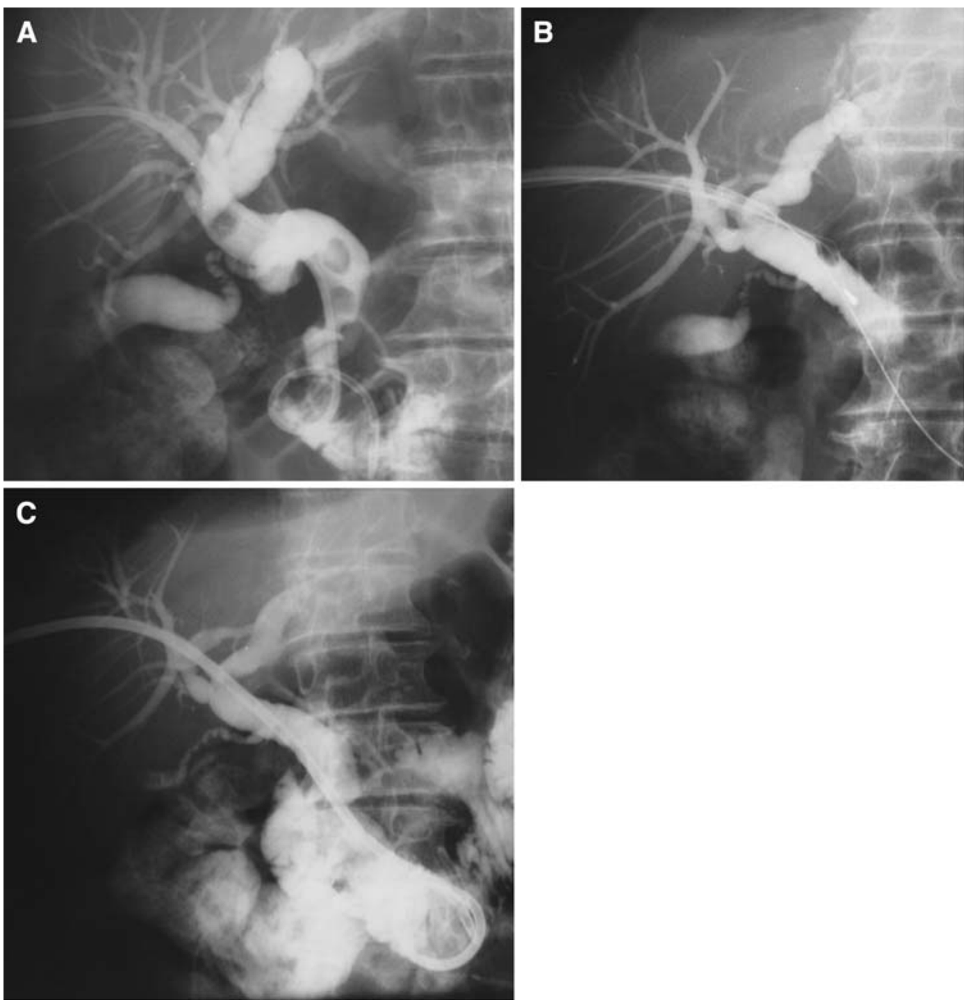

Fig. 6 **A** Patient with multiple CBD lithiasis and unsuccessful ERCP due to a diverticulum at the papilla of Vater. Percutaneous drainage was performed. **B** The stone is caught and removed by a Dormia basket inserted through a 10-Fr peel-away sheath. **C** The final result was considered satisfactory

for completion of such complicated and sometimes painful interventions, especially when a patient is obligated to tolerate a drainage catheter, which increases discomfort and definitely reduces quality of life.

Laser Lithotripsy

Laser-assisted lithotripsy is another sophisticated option for breaking calcified stones before removal of their fragments. Holmium:YAG laser devices can be helpful for this purpose using 200- or 365-µm fibers, generating 0.6–1.0 J at 6–15 Hz [34, 35]. An endoscope of small outer diameter, 7–15 Fr, and 70-cm length is usually used for percutaneous cholangioscopy. If a laser is not available, a special lithotripsy wire is guided through the endoscope's working channel to contact the stone and transfer the spark for electrohydraulic lithotripsy [15, 16, 28, 31, 32, 37]. Cholangioscopy can be quite helpful not only for assistance of stone arrest and guidance of lithotripsy, but also for differential diagnosis of stones from other noncalculus objects [15].

Special Problems

If transpapillary or transanastomotic stone extraction is not possible, stone or fragment removal can be performed through the transhepatic sheaths (Fig. 6A–C]. In less frequent cases, where patients are presenting with acute cholecystitis and jaundice, a percutaneous cholecystostomy might be placed. Following this, if stones are detected in the extrahepatic bile ducts, lithotripsy can be performed through the cystic duct, even with help of a cholangioscope [37].

If the cause of the initial stricture was primary or secondary cholangitis after obstruction of a biliodigestive anastomosis, the stenting results are quite discouraging [38].

In cases where the stones are very problematic and cannot be broken either mechanically or electrohydraulically, extracorporal lithotripsy can be attempted under the condition that the biliary tree is enhanced and the stones are fluoroscopically visible as filling defects [38, 39].

Conclusion

Based on international literature and our personal experience with more than 50 cases of calculus biliary disease, we believe that using percutaneous means such as electrohydraulic lithotripsy, aided either mechanically or endoscopically, is an extremely effective method in the hands of an experienced team. In combination with a qualified surgical and endoscopic department, this method constitutes the necessary supplement for providing complete therapeutic services in the sensitive area of benign biliary disease.

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