

Nonmechanical Treatment of Common Bile Duct Stones

Kenneth F. Binmoeller, MD

Approximately 80% of common bile duct stones can be removed endoscopically by using standard endoscopic basket or balloon extraction techniques. The addition of mechanical lithotripsy has improved success rates by another 10%. Intraductal lithotripsy with electrohydraulic or laser technology has enabled success rates to approach 100%. Endoscopic stent placement is a last resort measure that should be reserved for patients with difficult stones who cannot tolerate intraductal shock wave lithotripsy. High equipment costs for intraductal lithotripsy and the need for cholangioscopic guidance has restricted this technology to a few specialized centers around the world. The recent development of a pulsed laser with an automated stone recognition system eliminates the need for cholangioscopic guidance and has shown promising results in preliminary studies. However, lithotripsy performed under fluoroscopic guidance seems to be less effective than when performed under direct vision. Comparing the currently available modalities for cholangioscopic guided lithotripsy, electrohydraulic lithotripsy has advantages of being the most economical, practical (eg, small generator size, portable, no special outlets), and effective.

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Within a span of 21/2 decades, we have witnessed a remarkable progress in the endoscopic treatment of common bile duct (CBD) stones. Since the first biliary sphincterotomy and stone extraction described in 1974,¹ the development of simple accessories, such as a Dormia basket and a retrieval balloon catheter, allowed the removal of 70% to 80% of biliary stones. Demling et al³ described the first mechanical lithotripter in 1982, which enabled the fragmentation of difficult stones after successful capture in a Dormia basket. This improved the success rate for endoscopic removal of common bile duct stones to around 90%. Cholesterol solvents such as mono-octanoin and methyltertbutyl ether were used in the mid to late 1980s to dissolve bile duct stones,⁴ albeit with only mixed results. The first reports of cholangioscopy-guided intraductal shock wave lithotripsy emerged^{5,6,7} around 1990. With ultrathin endoscopes (babyscopes) inserted through a mother duodenoscope, shock waves could be applied under direct vision onto the stone surface to fragment the stone. This remarkable technology provided a critical breakthrough in the endoscopic management of difficult stones, enabling endoscopists to successfully fragment and remove nearly 100% of bile duct stones. The technique and results of nonmechanical

treatments for common bile duct stones are covered in this review.

Indication for Nonmechanical Treatment

Nonmechanical treatment should be reserved for stones that fail mechanical methods of lithotripsy. This may occur if the stone is too large to be captured in the basket or if the basket is unable to completely open or unfold around the stone. In other cases, stones lodged in the cystic duct at the juncture with the CBD (Mirizzi syndrome [Fig 1]) or intrahepatic stones that may be inaccessible to basket extraction for anatomic reasons.

Shock Wave Lithotripsy

Shock waves can be generated by using either electrohydraulic or laser technology, which create a plasma (gaseous collection of ions and electrons) that rapidly expands and collapses at the surface of the stone. Vaporizing fluid with high-voltage sparks across a pair of electrodes produces electrohydraulic lithotripsy (EHL) shock waves. With the laser, light is converted into thermal energy at the surface of the stones. The following three laser systems are currently available for endoscopic laser lithotripsy: the Q-switched Nd:YAG laser; the flashlamp pulsed dye laser; and, most recently, the flashlamp pulsed dye laser with an automatic stone recognition system. The Q-switched Nd:YAG laser has largely been abandoned because of poor results (tended to drill a hole into the stone rather than shatter it); high risk of thermal injury; and technical drawbacks, such as the need for a relatively large and stiff quartz fiber. The flashlamp pulsed dye laser is transmitted by a thin, flexible quartz fiber and is designed to deliver large power peaks in a fraction of a second. This minimizes the heat generated and transferred to surrounding tissue.

Use of Cholangioscopy

Intraductal shock wave lithotripsy without a stone-tissue recognition system can cause injury to the bile duct wall and should therefore be performed under cholangioscopic guidance (Fig 2). A mother-baby endoscope system is required for this (Fig 3). The babyscope (cholangioscope) is inserted through the working channel of the motherscope (duodenoscope). Dedicated motherscopes with a 5.5-mm working channel were previously required to enable the insertion of a babyscope with a 4.1-mm external diameter and 1.7-mm operating channel (Olympus TJF M 20 motherscope and CHF B 20 babyscope, Olympus, Tokyo, Japan). Newer ultrathin caliber cholangioscopes from Olympus Inc (CHF-BP 30, 3.4-mm external diameter and 1.2-mm operating channel), 5-Star Medical Inc (Hayward, CA) (3.2-mm external diameter

From the UCSD Medical Center, San Diego, CA.

Address reprint requests to Kenneth F. Binmoeller, MD, Division of Gastroenterology, UCSD Medical Center, 200 West Arbor Dr., San Diego, CA 92103-8413.

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Technique of Intraductal Lithotripsy

Cholangioscopic guided shock wave lithotripsy requires two experienced endoscopists to operate each of the endoscopes. The endoscopist operating the motherscope is responsible for guiding the babyscope into the bile duct and directing it to the stone, and the endoscopist operating the babyscope fine-tunes the position of the shock wave probe at the stone surface. Closely coordinated teamwork is mandatory to ensure the success and safety of the procedure and is facilitated by projecting the images of the motherscope and babyscope on side-by-side monitors. The endoscopist with the motherscope must monitor both images simultaneously to avoid slipping back into the stomach as the angle of entry of the babyscope is

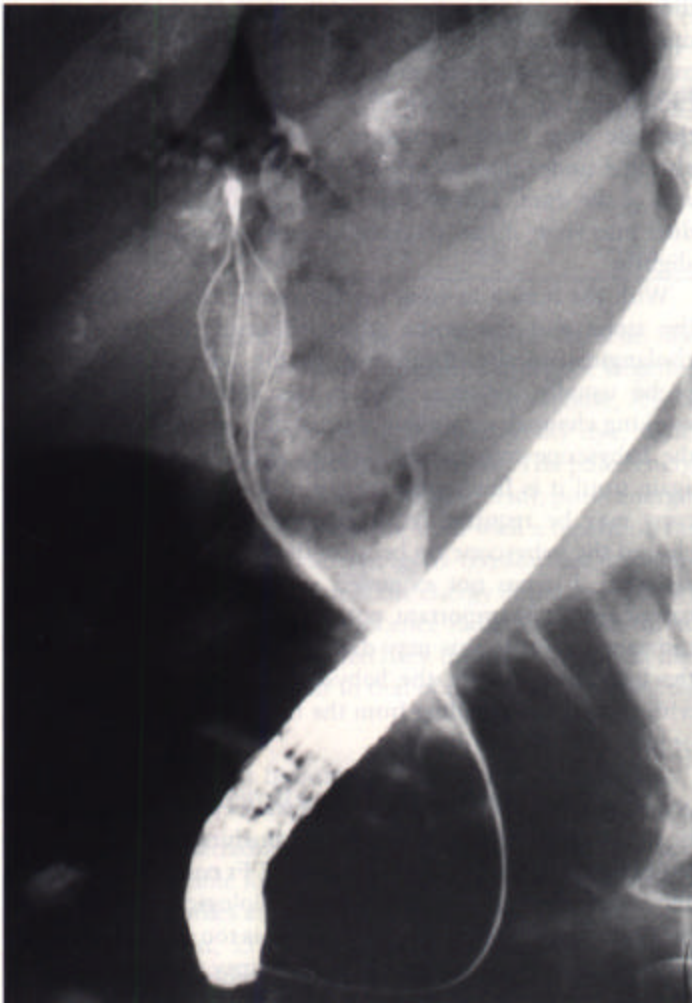


Fig 1. Radiological view of a large cystic duct stone impacted at the juncture with the CBD (Mirizzi syndrome). The basket enters the common hepatic duct and is unable to capture the stone.

and 1.35-mm channel), and Saratoga Medical Inc (3-mm external diameter and 1-mm channel) can be used with a standard 4.2-mm therapeutic duodenoscope. The babyscope has two-way (single plane) tip deflection. Currently available babyscopes are fiberoptic instruments that produce a relatively poor image when projected onto a screen with a camera adapter. Although a video cholangioscope developed by Olympus (XCHF-B200) produces an excellent wide-angle video image (Fig 4), it has an outer diameter of 4.5 mm and must be used with a dedicated large channel motherscope. To make things worse, the instrumentation channel is even smaller (1.2 mm) than that of a similar fiberoptic cholangioscope.

Automatic Stone Recognizing Laser System

A novel laser system with an automatic stone recognition system (Rhodamine 6G flashlamp pulsed dye laser, Lithognost, Telemit, Germany) enables lithotripsy to be performed safely only when using fluoroscopic guidance. The tip of the probe is equipped with sensors that read backscattered light and interrupt the laser pulses when readings indicate that the probe is aimed at tissue. The pulses are accompanied by an acoustic signal that indicates whether stone or tissue is targeted.



Fig 2. Mother-babyscope unit. (A) The cholangioscope is inserted through the mother duodenoscope. An EHL probe is inserted through the cholangioscope. (B) Tip of the cholangioscope showing the EHL probe (arrow) exiting from the working channel.

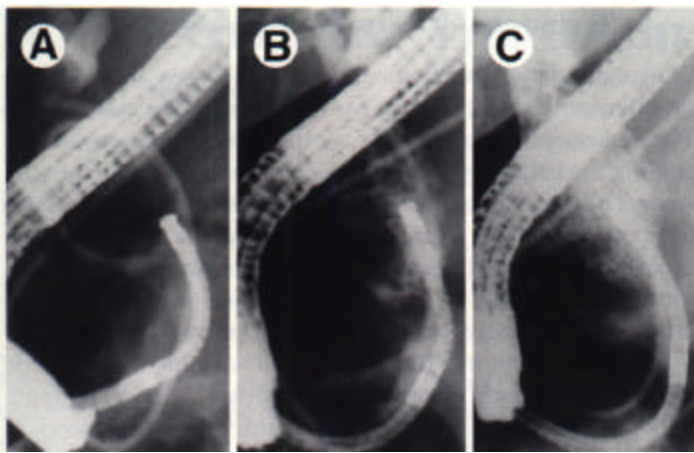


Fig 3. Radiological views of cholangioscopic shock wave lithotripsy of a giant CBD stone. (A) The cholangioscope is inserted into the common bile duct and positioned for EHL. (B) Initial fragmentation of the stone. (C) Complete fragmentation.

adjusted. Depressing a foot pedal fires the shock waves. I recommend that the endoscopist operating the mother scope command the firing and the endoscopist operating the baby scope depress on the foot pedal to smoothly coordinate the procedure.

I recommend loading the shock wave probe into the babyscope before inserting into the motherscope because advancing the probe through a straightened babyscope is significantly easier and less traumatic than doing it the other way around. The probe is advanced until it is flush with the tip of the babyscope. The babyscope is gently advanced through the operating channel of the duodenoscope after it is positioned opposite the papilla, taking care not to kink the shaft of the babyscope at the inlet port. Once the babyscope has exited the duodenoscope tip, it is flexed maximally upward in the

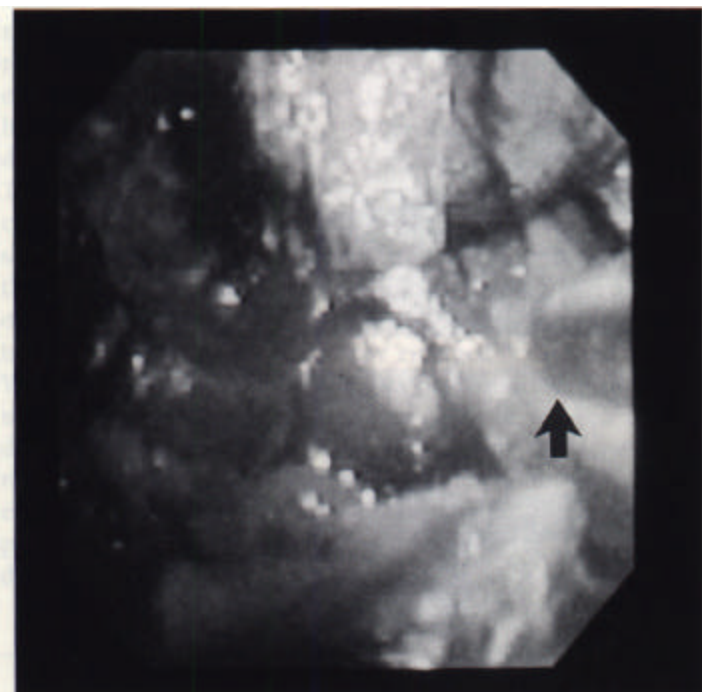


Fig 4. Cholangioscopic view of a large stone undergoing EHL using the Olympus XCHF-B200 video cholangioscope. The electrohydraulic probe exists from the cholangioscope at the right (arrow).

direction of the bile duct, positioned at the sphincterotomy opening, and gently negotiated into the bile duct. Usually the motherscope will need to be advanced a bit to increase the caudal-cranial orientation of the babyscope. Having entered the bile duct, the orientation of the babyscope should be checked under fluoroscopy and directed appropriately in the axis of the duct. This will usually bring the lumen of the bile duct into view; if not, the babyscope may need to be retracted slightly

With the lumen in view, the babyscope can be advanced to the stone and the probe advanced until the tip is visible cholangioscopically. Resistance to the advancement of the probe usually indicates that it has slipped back into the working channel; correcting this usually requires withdrawing the babyscope into the duodenum and advancing the probe again until it is flush with the tip of the babyscope. Fluoroscopy may be required to determine whether the probe has cleared the babyscope tip because the probe can be difficult to visualize if it has not extended enough or too far from the babyscope. It is important not to advance the probe against resistance because this may damage the operating channel of the babyscope. Lastly, the babyscope must not be advanced with the probe extending from the tip because this may injure or perforate the bile duct.

A fluid medium is required around the stone for effective generation and conduction of shock waves with electrohydraulic lithotripsy and is also helpful for flushing out stone debris after fragmentation. I prefer to insert a 7 Fr nasobiliary catheter above the stone for irrigation with physiological saline because the operating channel of the babyscope is too small to be useful for irrigation, especially with the lithotripsy probe in place.

Although fragmentation of a large impacted stone is relatively easy with shock wave lithotripsy, it is more difficult to crush individual fragments to a size less than 5 mm to enable extraction, especially with free floating stone debris.

Equipment

The EHL generator unit (Lithotron EL-23, Walz Electronics, Germany; Northgate SD 100, Northgate Technologists Inc, Arlington Heights, IL) is approximately the size of a standard diathermy unit. The cost of the generator is around \$10,000. The lithotripsy probes are available in 1.9, 3, and 4.5 Fr sizes and cost approximately \$150 each. I prefer to use the largest 4.5 Fr probe (which fills the working channel of the babyscope) in conjunction with a nasobiliary catheter for saline irrigation. In the absence of a nasobiliary catheter, it is necessary to use the 3 Fr probe to be able to irrigate alongside the probe. The 1.9 Fr probe is too fragile to be useful for endoscopic lithotripsy in my experience. The lifetime of one EHL probe constitutes a maximum of 1,601 impulses. When using the Walz Electronics unit, the generator is set to discharge 12 impulses per second in volleys of 3 impulses, and the energy is set at 0.46 J/min. A foot pedal serves to activate the discharge of impulses.

The Candela flashlamp pulsed dye laser (MDL 2000, Candela Laser Corporation, Wayland, MA) has been the most popular of the commercially available lasers for lithotripsy. The unit is about the size of a small refrigerator and considerably larger, heavier, and more expensive (\$200,000) compared with an EHL generator. Laser energy with a wavelength of 504 nm is transmitted through a 200-µm fiber that delivers up to 80 mJ of

TABLE 1. Results of Endoscopic Intraductal EHL

Author	n	Guidance	Clearance Rate (%)	Complications (%)	Mortality
Siegel ⁸	21	fluoroscopic	86%	5%	0
Hixson ⁹	5	cholangioscopic	100%	0	0
Binmoeller ^o	65	cholangioscopic	98%	1.5%	0
Adamek ⁿ	46	cholangioscopic	74%	9%	0
Bottari ¹²	9	cholangioscopic	100%	0	0
Alhalele ¹³	47	cholangioscopic	94%	3%	0

energy with a repetition frequency of 5 to 10 Hz. The fiber produces a red helium-neon aiming beam for precise targeting.

The Telemitt flashlamp pulsed dye laser (Lithognost, Telemitt Corp, Munich, Germany) uses a rhodamine-6G dye, which produces light with a wavelength of 594 nm. The pulse energy can be tuned from 40 to 120 mJ in steps of 5 mJ; pulse energies between 80 to 120 mJ per pulse are used with a repetition rate of 8 Hz for lithotripsy. Laser energy is transmitted through a 250-µm fiber. A small fraction of the energy of the laser pulse is used to induce a specific fluorescence radiation at the surface of the target, which is conducted back through the optical fiber and analyzed. Cost is similar to that of the standard pulsed dye laser.

Results of Lithotripsy

The results of intraductal shock wave lithotripsy have been uniformly favorable for both EHL and laser lithotripsy. Results of published studies are summarized in Tables 1 and 2.

In my opinion, EHL is preferable to the pulsed laser for intraductal lithotripsy for the following reasons. First, EHL can fragment stones with fewer firings; EHL literally explodes a stone whereas laser lithotripsy tends to drill into the stone eventually breaking the stone. On the other hand, EHL can cause greater injury to the bile duct wall than laser lithotripsy if misfired and thus must be used under cholangioscopic guidance. Second, the start-up and maintenance costs for EHL are significantly lower than that for laser lithotripsy. Third, the EHL unit is more compact and easier to transport.

We reported the largest experience with EHL in a group of 65 patients, all of whom had failed previous attempts at mechanical lithotripsy.¹⁰ EHL successfully fragmented the stones in 63 of 64 patients with the single failure resulting from a to a high-grade stricture that could not be passed with the babyscope. Stones were solitary in 35 patients and multiple in 29 patients. The median diameter of the stone was 2.6 cm; 23% measured less than 2 cm, 51% measured between 2 to 3 cm, and 26% measured greater than 3 cm. Narrowing of the bile duct was present in 19% of the patients. Complete fragmentation and removal of stones was achieved in a single session in 50 patients, two sessions in 13, and three sessions in one. We

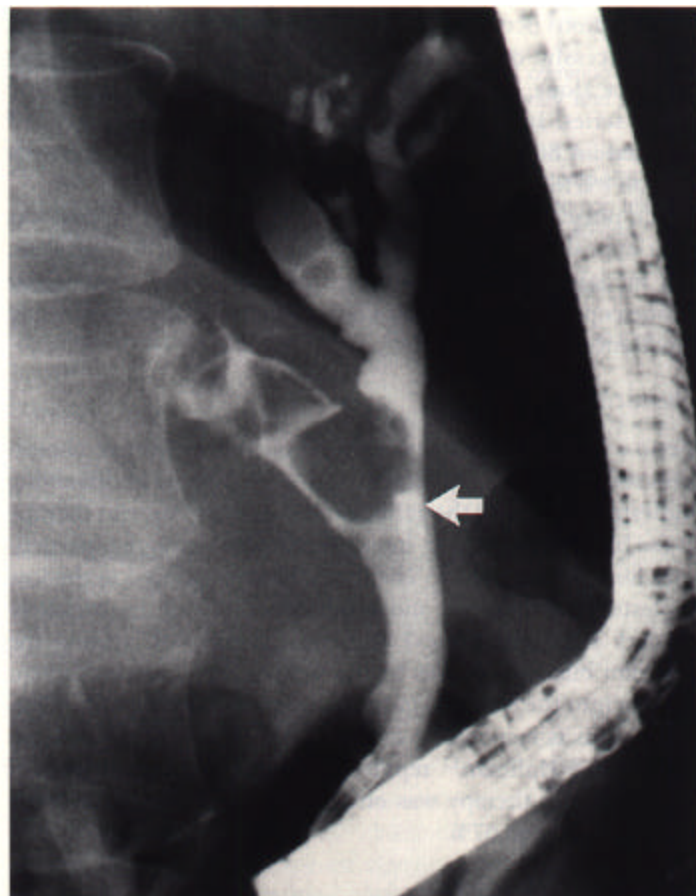


Fig 5. Radiological view of cholangioscopic shock wave lithotripsy of a cystic duct stone impacted at the juncture of the CBD (Mirizzi syndrome). Arrow shows the tip of the cholangioscope.

also successfully treated patients with Mirizzi's Syndrome by using EHL (Fig 5).¹⁹

Several studies have documented the efficacy and safety of the Telemitt pulsed dye laser with automatic stone recognition. Neuhaus¹⁶ reported a 97% success rate after a mean of 1.3 sessions in 38 patients; 18 were treated perorally and 20 by the percutaneous transhepatic route. In this study, both cholangioscopy and fluoroscopy were used to monitor the intraductal lithotripsy without any complications. E1114 reported an 89% successful clearance in 18 patients when using the same laser system under endoscopic (n = 9) and fluoroscopic (n = 9) controls. Patients treated under cholangioscopic control received significantly fewer laser pulses and had less misapplied pulses (7% v 18%), suggesting that cholangioscopic guidance is more effective. Schreiber et al¹⁷ used the laser on 16 patients with large CBD stones; 15 of whom had pulses applied under fluoroscopic guidance alone. Complete stone clearance was achieved in all patients after a mean of 1.7 sessions with minor

TABLE 2. Results of Endoscopic Intraductal Laser Lithotripsy

Author	n	Laser	Guidance	Clearance Rate (%)	Complications (%)	Mortality
Cotton ⁷	25	Pulsed dye laser	cholangioscopic	80%	0	0
E11 ¹⁴	18	YAG laser	fluorocholangioscopic	67%	6%	0
Prat ¹⁵	16	Pulsed dye	fluorocholangioscopic	88%	13%	0
Neuhaus ¹⁶	18	Pulsed dye/SRS	fluorocholangioscopic	89%	8%	0
Schreiber ¹⁷	16	Pulsed dye/SRS	fluoroscopic	88%	19%	0
Hochberger ¹⁸	50	Pulsed dye/SRS	fluorocholangioscopic	86%	8%	0

SRS, stone recognition system.

complications occurring in two patients. Swain et al²⁰ reported 90% successful duct clearance in 8 patients with fluoroscopic guidance alone. No major complications were reported in any of the series. In the largest series to date, Hochberger et al⁸ reported an 80% clearance rate of CBD stones in 50 patients with an 8% morbidity rate.

The pulsed dye laser with automatic stone recognition has great appeal because of the added safety profile. Nonetheless, this modality is significantly less effective when used under fluoroscopy compared with cholangioscopic guidance in my experience.

Chemical Dissolution

Mono-octanoin and methylterbutyl ether are effective cholesterol solvents and have been shown to be capable of dissolving cholesterol stones in the gallbladder. Results of solvent therapy in the bile duct, however, have been less encouraging, particularly for large stones.^{21,22} The limitations are related to the low cholesterol content of most bile duct stones (particularly primary bile duct stones) and the difficulty of bathing the common bile duct stones in the solvent. Most of the solvent escapes into the duodenum in a patient with a prior sphincterotomy; this is responsible for the high rate of adverse effects. Palmer and Hoffman²² reported that the dissolution rate of mono-octanoin therapy was only 26% and that the prevalence of side effects was 67%.

Biliary Stent Placement

Patients with acute cholangitis who are acutely ill may be best served by the placement of a stent or nasobiliary catheter to achieve initial ductal decompression followed by stone extraction on an elective basis after the acute disease resolves. Temporary stenting is also indicated if stone extraction fails or is incomplete. Stent placement should be always performed in patients who have evidence of delayed contrast emptying after ductal clearance, possibly because of inflammatory bile duct narrowing.

Biliary stenting deserves consideration as a quick alternative treatment in the elderly and/or frail patients who are unlikely to tolerate prolonged endoscopic attempts at stone extraction. The stent probably functions as a wick around which the bile can drain rather than as conduit for bile. Earlier reports have suggested that biliary stenting is a safe alternative to stone extraction,^{23,24,25,26} but a recent long-term (median follow-up period of 3 years) study by Bergman et al²⁷ showed that complication rates after stenting may have been underreported. Of 58 patients who were treated with permanent stents for endoscopically irretrievable stones, 40% developed a total of 34 complications that were primarily related to stent dysfunction. The overall complication rate was 16% at 1 year and 50% at 4 years.

There is some recent evidence that long-term stenting may not be necessary and that adding oral ursodeoxycholic acid may dissolve stones. In one report, 9 out of 10 patients who underwent stenting combined with orally administered ursodeoxycholic acid became stone free, compared with 0 of 40 patients with stents only²⁸

Conclusion

A CBD stone that can be captured with a Dormia basket can be usually extracted either by traction force alone or with

mechanical lithotripsy. Stones that fail basket extraction are candidates for endoscopic intraductal shock wave lithotripsy. Numerous studies have documented the efficacy and safety of this approach with either laser or electrohydraulic technology, but the need for two skilled endoscopists and the high equipment cost have restricted this procedure to a few specialized centers. Recent advances in the development of ultrathin cholangioscopes that fit through the working channel of a standard therapeutic duodenoscope and a pulsed laser with an automatic stone recognition system may enable routine lithotripsy under fluoroscopic guidance in the future. However, for now electrohydraulic lithotripsy seems to provide the best combination of technical success, low costs, and practicality.

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