Chapter 5
Lithotripsy Assisted Bile Duct Exploration by Laparoendoscopy (LABEL)

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In 2014, we introduced the LABEL technique [1] as "Laser Assisted Bile duct Exploration by Laparoendoscopy," aimed at decreasing failure of CBD clearance for large and/or impacted stones and increasing the transcystic rate of CBD exploration. Since other methods of lithotripsy can be used to achieve this purpose, we now refer to LABEL as "Lithotripsy Assisted Bile duct Exploration by Laparoendoscopy".

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Modes of Lithotripsy

Laser lithotripsy was first described by Orii et al. in 1981 when a Neodymium-doped yttrium aluminium garnet (Nd:YAG) laser was successfully used with a choledochoscope during open surgery to fragment stones in two patients [2]. However, the Nd:YAG laser was less effective on cholesterol stones, tending to drill rather than fragment, limiting its use to pigment stones. Safety issues surrounding the use of Nd:YAG within the bile duct causing thermal injury and damage to bile duct mucosa fuelled the search for alternative energy sources. The pulsed-dye laser converts light energy into acoustic energy, creating shock waves which results in fragmentation of CBD stones [3]. Of the pulsed-dye lasers, the 504-nm coumarin laser was utilised the most. However, there were still concerns over damage to the mucosa of the biliary tree with the possibility of subsequent perforation and bile leak [4]. Pulsed-dye laser lithotripsy has been used via multiple routes to the CBD: (1) T-tube choledochoscopy [5], (2) percutaneous transhepatic choledochoscopy [6, 7] and (3) cystic duct (transcystic) [8–10]. However, pulsed-dye laser fell from favour because of high costs and the limited range of applications, and subsequently laser lithotripsy appeared to fall from vogue altogether for the next decade or so.

Technical progresses have brought the holmium: YAG (Ho:YAG) laser to the forefront among the modalities of stone fragmentation to treat ureteric calculi. In the case of flexible percutaneous nephrolithotomy, the Ho: YAG laser has become the elective intracorporeal lithotripter, being the most efficient lithotripsy method for all types of stones, regardless of their location. Holmium laser lithotripsy (HLL) offered an alternative method to fragment the larger and more refractory biliary calculi with good success. HLL can deliver high energy to a distant target along flexible fibres of narrow diameter. The laser emits energy in pulses, which creates extreme temperatures at the fibre tip for a fraction of time. This converts material into gas (vaporisation) at high speed. Water expands explosively as a gas bubble, which is known as the cavitation effect [11]. There are multiple effects of HLL, and apart from vaporisation, causes rupture of cell membranes and coagulation in the immediate proximity of the cavitation when directed on cell tissue. When directed to solid material, such as biliary calculi, the effect is vaporisation. Furthermore, the resulting shockwave also causes erosion by shearing and contrecoup forces. The diameter of the cavitation is just 0.4 mm, which is ideal for the narrow confines of the bile duct, minimising the risk of damage to the surrounding mucosa and therefore avoiding subsequent scarring and stricture formation. The advantages of Ho: YAG laser when compared to pulsed-dye laser include its greater energy absorption by water, therefore reducing the risk of accidental damage. Moreover, it is less dependent on stone composition for its fragmentation rate, and the optical fibre is less likely to get damaged during handling and firing. The first use of HLL within the bile duct was via the percutaneous route (percutaneous transhepatic choledochoscopy) in 1998 followed by its use combined with T-tube tract choledochoscopy in 2001 [12, 13]. It was not until a few years later than HLL was combined with a laparoscopic approach during LBDE, and perhaps surprisingly, the first few reported cases were via the transcystic route [14–16].

There are studies that have shown that frequency-doubled double-pulsed neodymium:YAG (FREDDY) laser lithotripsy is efficacious and safe in the management of refractory biliary stones by ERCP and choledochoscopy [17–20]. In 2016, the first series of FREDDY laser lithotripsy combined with LBDE was published which included 24 patients from 2008–2015 [21]. In this series, over a third of patients with impacted CBD stones required laser lithotripsy, all using transductal access via choledochotomy. Compared to Ho: YAG lasers, the FREDDY laser functions through the generation of a plasma bubble. Upon bubble collapse, a mechanical shockwave is generated, causing stone fragmentation without adverse thermal effects [22]. Direct visualisation via choledochoscopy is therefore recommended to minimise the risk of tissue injury from the laser. Owing to increased uptake since 2016, with published studies to date coming exclusively from China, FREDDY laser lithotripsy during LBDE has become the modality with the highest number of reported cases published worldwide (>300 patients).

Electrohydraulic lithotripsy (EHL) was developed in the 1950s as an industrial technique for fragmenting rocks. EHL was first applied medically to the management of bladder stones in 1968, which then led to its widespread use for stones in the bladder, ureter and renal pelvis over the next decade. EHL of human gallstones was investigated using in vitro and animal studies in 1987 [23]. The technique was largely effective and power requirement correlated with mechanical strength of stones, but not with biochemical composition. A trend toward higher power requirement was recorded with larger stones and stones over 2 cm in diameter could not be fragmented. Safety studies indicated that electrohydraulic lithotripsy was safe, provided the probe tip was not in contact with the bile duct wall. The probe is made up of two coaxially insulated electrodes ending at the open tip which acts as a sparking chamber. Each spark lasts approximately 1 microsecond and when discharged in 0.9% saline, vaporises the fluid resulting in high amplitude hydraulic pressure waves of varying wavelength which fragment solid objects in their path. In the in vitro study, duct injury was only seen when the end of the probe was in direct contact with the duct wall, most likely due to thermal injury from the spark itself rather than any effect of the shockwave. EHL was the first lithotripsy modality to be used during LBDE, where two patients successfully underwent EHL via the transcystic route in 1992 [24]. Since then, 13 more studies have reported on the use of EHL during LBDE in over 170 patients.

Table 5.1 summarises the different types of lithotripsy that have been used during LBDE along with the pooled number of cases that have been reported from 1992–2020.

TABLE 5.1 Types of lithotripsy

Type of lithotripsy	**Number of cases reported in literature**
EHL	172
CPDL	23
HLL	141
Pneumatic	15
PSW	62
FREDDY	305

EHL electrohydraulic lithotripsy, *CPDL* Coumarin (504-nm) pulsed-dye laser, *HLL* holmium laser lithotripsy, *PSW* plasma shock wave, *FREDDY* frequency-doubled double-pulsed neodymium:YAG

What Is the Evidence for Lithotripsy during LBDE?

Between 1992 and 2020, 36 studies including 718 patients have reported the outcomes of lithotripsy during LBDE (Table 5.2) [8–10, 14–16, 21, 24–52]. The aforementioned studies have reported on patients from 13 countries across the world. Figure 5.1 demonstrates the trend of reported cases by year from the inaugural description in 1992. There appeared to be increasing interest within the first 5 years in the early 1990s, which then seemed to wane over the next two decades until more recently where larger case series have been published. Figure 5.2 shows a similar trend in reported cases, but categorised by lithotripsy modality. It is important to note that the usual indication for lithotripsy techniques during LBDE is for difficult (large and/or impacted and/or multiple) CBD stones. From the available data, lithotripsy via the transcystic route has been used in just over half the cases (53%). Furthermore, several studies have shown that lithotripsy increases the transcystic rate of LBDE [27, 41, 45, 50]. The

Table 5.2 Systematic review of Lithotripsy assisted bile duct exploration by laparoendoscopy: efficacy

Author	Year	Country	Lithotripsy	n	TC-LABEL	TD-LABEL	Clearance (%)
Arregui	1992	US	EHL	2	2	0	100
Birkett	1992	US	CPDL	1	1	0	100
Carroll	1993	US	CPDL	2	2	0	100
DePaula	1994	Brazil	EHL	5	5	0	100
Stoker	1995	US	CPDL	20	ND	ND	ND
Sheen-Chen	1995	Taiwan	EHL	10	0	10	100
Ido	1996	Japan	EHL	54	54	0	74.1
Gigot	1997	Belgium	EHL	3	ND	ND	100
Craigie	1998	US	EHL	2	2	0	100
Berthou	1998	France	EHL	2	0	2	100
Thompson	2002	UK	EHL	31	ND	ND	ND
Shamamian	2004	US	HLL	2	2	0	100
Lo Menzo	2005	US	EHL	1	0	1	100

Muzio	2008	Italy	HLL	1	1	0	100
Day	2009	UK	HLL	1	1	0	100
Varban	2010	US	HLL	4	4	0	75
Farooq	2010	India	Pneumatic	12	0	12	100
Kelly	2010	UK	EHL	8	0	8	75
Joshi	2010	Nepal	Pneumatic	3	0	3	100
Petersson	2015	Sweden	HLL	8	8	0	87.5
Zhu	2015	China	EHL	29	29	0	ND
Pu	2016	China	PSW	62	0	62	93.5
Jinfeng	2016	China	FREDDY	24	0	24	100
Liu	2016	China	FREDDY	89	89	0	100
Xia	2018	China	HLL	38	38	0	100
Gökçen	2017	Turkey	HLL	1	0	1	100
Quaresima	2017	Italy	EHL	15	5	10	ND

(continued)

Table 5.2 (continued)

Author	Year	Country	Lithotripsy	n	TC-LABEL	TD-LABEL	Clearance (%)
Ni	2018	China	HLL	10	0	10	100
Fang	2018	China	FREDDY	74	74	0	100
Nitta	2019	Japan	EHL	1	0	1	100
Zhan	2020	China	EHL	9	0	9	100
Yang, C	2019	China	HLL	35	0	35	94.3
Yang, T	2019	China	FREDDY	42	0	42	100
Jones	2019	UK	HLL	7	0	7	85.7
Li	2020	China	FREDDY	76	0	76	97.4
Navaratne	2020	UK	HLL	34	34	0	100
TOTAL				718	351/664 52.9%	313/664 47.1%	582/623 93.4%

EHL electrohydraulic lithotripsy, *CPDL* Coumarin (504-nm) pulsed-dye laser, *HLL* holmium laser lithotripsy, *PSW* plasma shock wave, *FREDDY* frequency-doubled double-pulsed neodymium:YAG, *ND* not determined

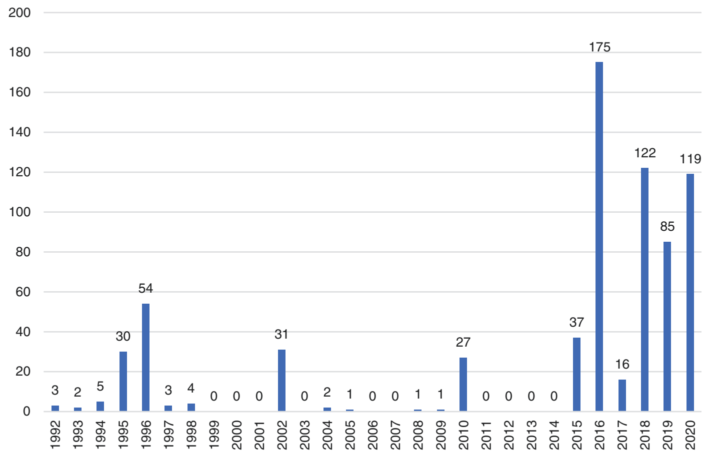

FIGURE 5.1 Total number of LABEL cases published in the literature from 1992 to 2020

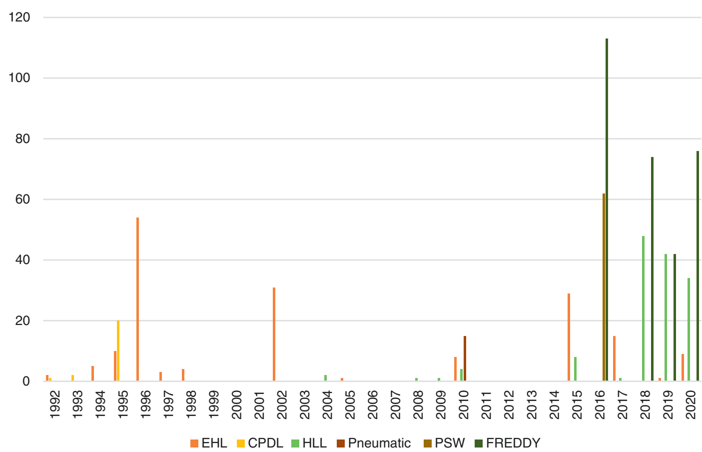

FIGURE 5.2 Total number of LABELS cases published in the literature from 1992 to 2020 categorised by lithotripsy modality

pooled stone clearance rate when lithotripsy has been used as an adjunct to LBDE was 93.4% (Table 5.2). Pooled safety data demonstrates that all modalities of lithotripsy was safe when used under direct vision with video choledochoscopy. The overall lithotripsy related complication rate from 621 patients was 1.1% (Table 5.3). These include haemobilia (n = 2 from EHL and n = 1 from plasma shock wave), retained stone fragments requiring post-operative endoscopic retrograde cholangiopancreatography (ERCP) (n = 2 from EHL and n = 1 from HLL), and pancreatitis from stone fragments (n = 1 from HLL). Within Europe and USA, the two most commonly used modalities to augment LBDE are

Table 5.3 Systematic review of Lithotripsy Assisted Bile duct Exploration by Laparoendoscopy: Safety

Author	Year	Lithotripsy	Lithotripsy related morbidity	Other morbidity
Arregui	1992	EHL	None	None
Birkett	1992	CPDL	None	None
Carroll	1993	CPDL	None	None
DePaula	1994	EHL	Haemobilia after EHL (n = 1; C-D 1–2)	None
Stoker	1995	CPDL	None	ND
Sheen-Chen	1995	EHL	Haemobilia after EHL (n = 1; C-D 1–2)	None
Ido	1996	EHL	None	Hyperamylasaemia (n = 3), hyperbilirubinaemia (n = 1)
Gigot	1997	EHL	ND	ND
Craigie	1998	EHL	None	None
Berthou	1998	EHL	None	ND

Table 5.3 (continued)

Author	Year	Lithotripsy	Lithotripsy related morbidity	Other morbidity
Thompson	2002	EHL	None	ND
Shamamian	2004	HLL	None	ND
Lo Menzo	2005	EHL	None	Pulmonary oedema (due to extended op time) (n = 1; C-D 2)
Muzio	2008	HLL	None	None
Day	2009	HLL	None	None
Varban	2010	HLL	Retained stone fragment requiring post-op ERCP (n = 1; C-D 3a)	None
Farooq	2010	Pneumatic	None	None
Kelly	2010	EHL	Retained stone fragments requiring post-op ERCP (n = 2; C-D 3a)	None
Joshi	2010	Pneumatic	ND	ND
Petersson	2015	HLL	None	None
Zhu	2015	EHL	ND	ND
Pu	2016	PSW	Haemobilia (n = 1)	Bile leak (n = 1), haemobilia (n = 1), cholangitis (n = 2), intra-abdominal collection (n = 4), worse hepatic insufficiency (n = 4), pleural effusion (n = 2)

(continued)

Table 5.3 (continued)

Author	Year	Lithotripsy	Lithotripsy related morbidity	Other morbidity
Jinfeng	2016	FREDDY	None	ND
Liu	2016	FREDDY	None	Post-op infection requiring antibiotics (n = 4; C-D 2)
Xia	2018	HLL	ND	ND
Gökçen	2017	HLL	None	None
Quaresima	2017	EHL	ND	ND
Ni	2018	HLL	Pancreatitis (n = 1; C-D 2)	Pancreatitis (n = 1; C-D 2)
Fang	2018	FREDDY	None	None
Nitta	2019	EHL	None	None
Zhan	2020	EHL	ND	ND
Yang, C	2019	HLL	None	Retained stones (n = 2; C-D 3a)
Yang, T	2019	FREDDY	None	Bile leak (n = 4; C-D 2-3a)
Jones	2019	HLL	None	Retained stone (n = 1; C-D 3a), bile leak (n = 1; C-D 3a), gastrointestinal bleed (n = 1; C-D 2), exacerbation of cardiac failure (n = 1; C-D 2)
Li	2020	FREDDY	None	Retained stone (n = 2; C-D 3a), bile leak (n = 2; C-D 3a), intra-abdominal collection (n = 1; C-D 3a), CBD stricture (n = 1; C-D 3a)

Table 5.3 (continued)

Author	Year	Lithotripsy	Lithotripsy related morbidity	Other morbidity
Navaratne	2020	HLL	None	Bile leak (n = 1; C-D 3b), minor complications (n = 4; C-D 1–2)
TOTAL			7/621 1.1%	45/542 8.3%

EHL electrohydraulic lithotripsy, *CPDL* Coumarin (504-nm) pulsed-dye laser, *HLL* holmium laser lithotripsy, *PSW* plasma shock wave, *FREDDY* frequency-doubled double-pulsed neodymium:YAG, *ND* not determined, *C-D* Clavien-Dindo

EHL and HLL. Table 5.4 summarises the main differences between EHL and HLL. Three studies reporting on EHL did not include efficacy data for patients that specifically required lithotripsy [31, 38, 43], however, from the remaining studies (97 patients) the pooled stone clearance rate of EHL was 84%. By comparison, HLL has a pooled stone clearance rate of 96%. Lithotripsy related morbidity were similar between the two modalities (3% and 2% respectively).

Which Patients Might Require LABEL?

In 2017, our group published the LABEL (Laser-Assisted Bile duct Exploration by Laparoendoscopy) technique for treating difficult common bile duct (CBD) stones and reducing technical failure [1]. Since then, we have demonstrated that use of lithotripsy techniques has increased our rate of successful transcystic LBDE from 67% to over 83% and only one reported failure of stone clearance in the last ~250 patients [50]. Therefore, without lithotripsy, we estimate that transcystic exploration is limited to around 60–70%, which is an opinion shared by other authors [53–55]. Since the LABEL technique is applicable to all forms of lithotripsy

Table 5.4 Electrohydraulic lithotripsy versus holmium laser lithotripsy

	EHL	HLL
Mechanism		
Fragmentation	Vaporises normal saline resulting in high amplitude hydraulic pressure waves of varying wavelength which fragment stones	The laser emits energy in pulses, which creates extreme temperatures at the fibre tip for a fraction of time. This converts material into gas (vaporisation) at high speed. Water expands explosively as a gas bubble, which is known as the cavitation effect
Equipment related		
Probe size	800 μm	200 μm
Price per unit	£350	£350
Number of shots	1500	Unlimited
Availability of generator	~3% of UK hospitals[a]	Most hospitals
Special license required	NO	YES
Special theatre required	NO	YES
Goggles required	NO	YES
Interference with video image	YES	NO
Target diode light	NO	YES

TABLE 5.4 (continued)

	EHL	HLL
Efficacy[b]		
Stone clearance	81/97 (84%)	136/141 (96%)
Safety[b]		
Lithotripsy related morbidity	4/116 (3%)	2/103 (2%)
Haemobilia	2/116 (2%)	
Retained stone fragments	2/116 (2%)	1/103 (1%)
Pancreatitis		1/103 (1%)

EHL electrohydraulic lithotripsy, *HLL* holmium laser lithotripsy
[a]Estimated in March 2021
[b]From pooled data

(not just laser), the term has been changed to Lithotripsy-Assisted Bile duct Exploration by Laparoendoscopy, and we recently published the ABCdE (age, bilirubin, CBD diameter, ERCP) score for PREdicting Lithotripsy Assistance during transcystic Bile duct Exploration by Laparoendoscopy (PRE-LABEL) [52]. We found that when using the transcystic approach to the bile duct, the chance of encountering difficult CBD stones (large and/or multiple and/or impacted) was nearly one-fifth of cases (18.1%). The addition of a lithotripsy procedure to standard retrieval techniques increases cost, operative time and requires additionally trained theatre staff. Furthermore, there are often operating room restrictions when using lasers. The ability to predict which patients might require lithotripsy in addition to standard retrieval techniques, by using standard pre-operative investigations, would therefore be useful in operative planning. The consequence of failing to clear the bile duct of stones using the transcystic route is to subject the patient to choledochotomy, with increased bile leak rate, other morbidity and length of hospital stay, and/or a post-operative endoscopic retrograde cholangiopancreatography (ERCP) [56]. Predicting the requirement for advanced extraction techniques, such as lithotripsy, identifies patients at risk of transcystic failure and prepares the surgical team for a complex procedure.

A simple scoring system for predicting CBD stones in patients with gallstones has been described [57]. Several other studies have evaluated various predictors of CBD stones prior to cholecystectomy [58–61]. In 2020, we published a scoring system for predicting the need for lithotripsy during transcystic LBDE (ABCdE Score) [52]. The primary aim of that study was to investigate clinical variables for PREdicting Lithotripsy Assistance during transcystic Bile duct Exploration by Laparoendoscopy (PRE-LABEL). The ABCdE score is composed of four independent predictors of requiring lithotripsy assistance during transcystic LBDE (Table 5.5). The hazard ratios of such factors allowed for weighting of the score: age ≤40 years (1 point), bilirubin > two-times upper limit of normal (1 point), CBD diameter ≥10 mm (1 point), ERCP (pre-operative) failed stone extraction (3 points). An ABCdE score ≥2 correlates with a sensitivity, specificity, and accuracy of 71%, 81% and 79% respectively for predicting lithotripsy assistance during transcystic LBDE (Table 5.6). We recommend using such a tool to identify complex choledocholithiasis, which can also be used

Table 5.5 ABCdE Score based on age, pre-operative bilirubin and CBD diameter and pre-operative ERCP (patient data from the UK)

	Clinical variable (predictor)	Score
A	Age ≤ 40 years	1
B	Bilirubin > two-times upper limit of normal	1
Cd	CBD diameter ≥ 10 mm	1
E	ERCP (pre-operative) failed stone extraction	3

CBD common bile duct, *ERCP* endoscopic retrograde cholangiopancreatography

TABLE 5.6 ABCdE Score as a screening tool for predicting lithotripsy assistance during bile duct exploration by laparoendoscopy (PRE-LABEL) from UK patient data

ABCdE Score	Sensitivity (%)	Specificity (%)	Accuracy (%)
≥ 1	94	36	46
≥ 2	71	81	79
≥ 3	38	92	82
≥ 4	18	96	82

to triage such patients to centres with high volume and experience in lithotripsy and advanced extraction techniques. We have proposed the concept of LATEST (Leveraging Access to Technology and Enhanced Surgical Technique) in LBDE [62]. Leveraging access to technology includes using thinner and more flexible choledochoscopes, often disposables, combined with fragmentation techniques such as laser or electrohydraulic lithotripsy. Enhanced surgical technique refers to full mobilisation of the gallbladder followed by complete dissection of the cystic duct to the cystic duct-common bile duct junction. The proximal cystic duct is then retracted by an Endoloop (Ethicon, New Brunswick, New Jersey, USA) to the abdominal wall using an Endo Close™ (Covidien, Mansfield, Massachusetts, USA) to create an optimal 90° cystic duct-common bile duct angle [56]. Enhanced surgical technique also refers to the trans-infundibular approach (TIA), which we have previously described, and is indicated when Calot's triangle cannot be safely dissected due to a 'frozen' hepatic hilum secondary to severe inflammation or fibrosis [63]. From the authors institutional data, we found that our transcystic exploration rate during the pre-LATEST era (n = 237) was 12% with a stone clearance rate of 97.9%, whereas during the LATEST era (n = 223), our transcystic rate had increased to 86% with a stone clearance rate of 99.3%. We believe that the concept of LATEST should be adopted by centres aiming to achieve high rates of transcystic LBDE.

Surgical Technique for LABEL

LABEL is a good example of *laparoendoscopy* where laparoscopic and endoscopic (choledochoscopy) techniques work together harmoniously, often also augmented by radiology (image intensifier and laparoscopic ultrasound). For LABEL, access to the lumen of the bile duct through the cystic duct is the preferred route, but sometimes that is not possible and it is necessary to perform a choledochotomy and use the transductal route (see Chap. 6). As previously mentioned, the main indications for LABEL are when CBD stone(s) are larger than the diameter of the cystic duct during transcystic LBDE, or when the stones are impacted and cannot be removed with standard extraction techniques during either transcystic or transductal LBDE. We outline three principles of the LABEL technique: (1) a clear view of the stone must be achieved, (2) the choledochoscope must be positioned to allow a perpendicular angle between the stone surface and the fibre (the newer 4-way steering choledochoscopes e.g., SpyGlass™ Discover from Boston Scientific makes this easier: Fig. 5.3) and (3) targeting must be under direct vision to avoid direct contact with the bile duct mucosa whilst firing.

Passing the Laser Probe Through the Working Channel of the Choledochoscope

Although the fibre used for laser lithotripsy (200 μm) is smaller than the probe used for EHL (800 μm), it is still very rigid and when passed through the working channel of the choledochoscope (~1 mm in diameter) may result in compromised deflection of the scope. This is more frequently experienced when the choledochoscope is directed towards the proximal ducts via the transcystic route which requires a high degree of deflection. Furthermore, there are situations which may require lithotripsy whilst the choledochoscope is in maximal or near maximal deflection. In this scenario, you may experience that the laser fibre doesn't move easily within

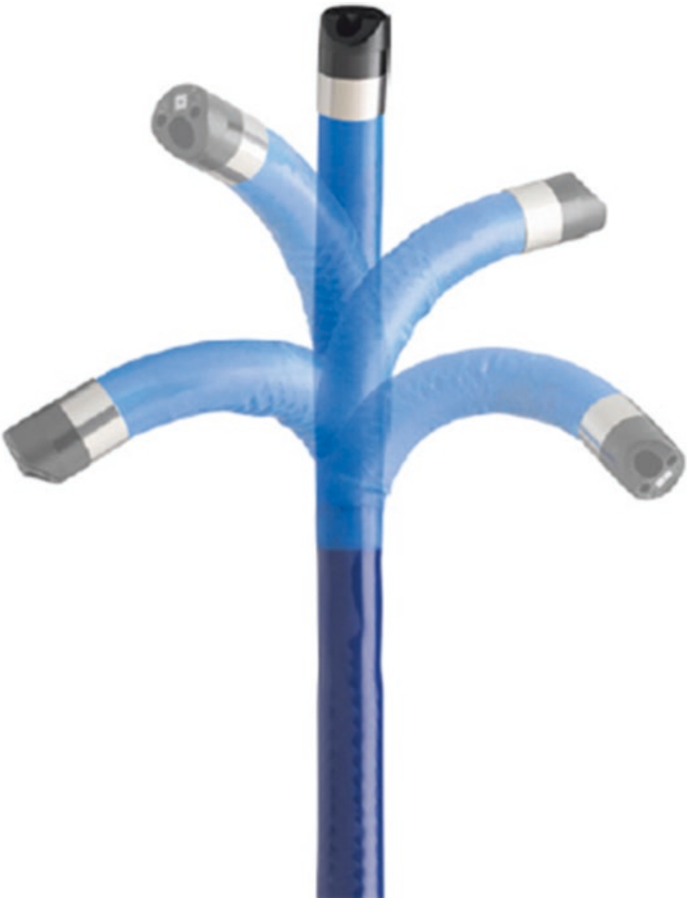

FIGURE 5.3 An example of a 4-way steering choledochoscope (SpyGlass™ Discover) (with permission from Boston Scientific, Marlborough, Massachusetts, USA)

the scope. The work around to this problem is to remove the choledochoscope and straighten the scope. Advance the laser fibre until it is just protruding from the tip of the choledochoscope, then withdraw the fibre so it is flush with the tip of the scope. Re-insert the choledochoscope and despite high degrees of defection, the laser fibre should be able to be advanced enough to be used safely and effectively. An additional reason to try this is because advancing a laser fibre all the way through the working channel whilst the choledochoscope is fully deflected can (rarely) cause the fibre to perforate through the shaft of a disposable scope.

Aiming at the Stone

At the authors institution, the Ho:YAG laser is preferred because the laser fibre has smaller diameter and a visible diode allows for safe targeting of the stone (Fig. 5.4). This may prevent collateral damage to the bile duct mucosa (Fig. 5.5) [64, 65]. As shown in Fig. 5.4, the targeting diode must be aimed at the stone perpendicular to the stone surface and separate to the bile duct mucosa to avoid iatrogenic injury.

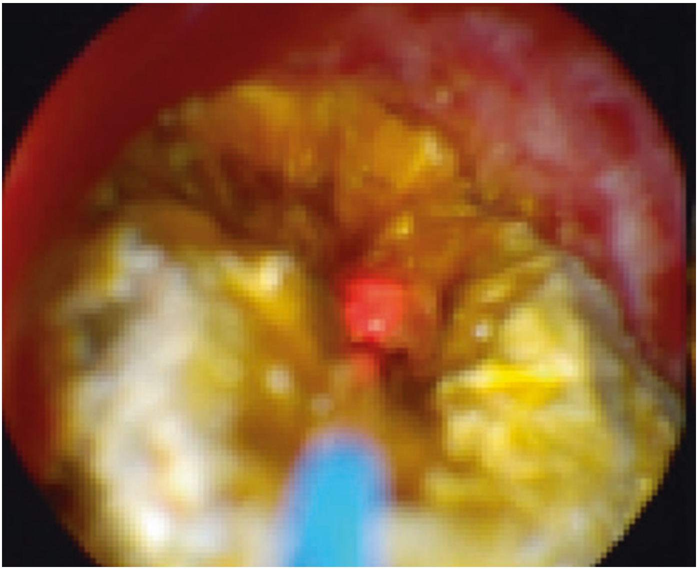

FIGURE 5.4 Holmium laser fibre with visible diode which allows safe targeting of the stone

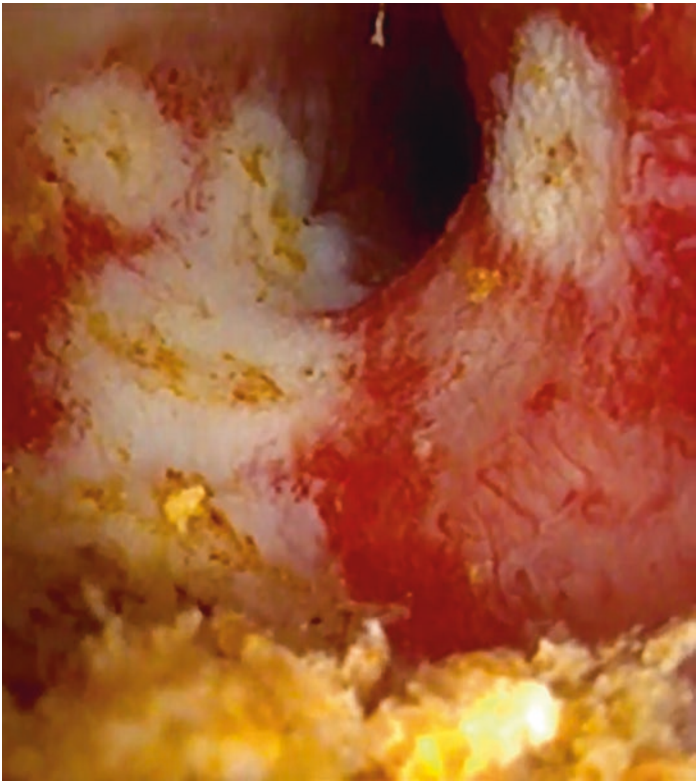

FIGURE 5.5 Collateral damage to the bile duct mucosa

Fragmentation vs Powderization

There are two main parameters determining the action of the laser: the pulse energy (PE) and the frequency (Fr). The PE is measured in Joules (J) and the frequency in Hertz (Hz). Power, in watts (W), is the product of energy and frequency:

$$\text{Power}(\text{W}) = \text{Energy}(\text{J}) \times \text{Frequency}(\text{Hz})$$

In general terms, increasing the Fr will increase the speed, and therefore also the power. The setting of PE will be influenced by certain factors, namely the stone density and the desired fragment size. The desired fragment size will depend on one of two scenarios: do you want to achieve fragmentation or powderization? Figure 5.6 and Table 5.7 outline these two scenarios. If your patient has had a failed pre-operative ERCP due to an impacted CBD stone, but a sphincterotomy

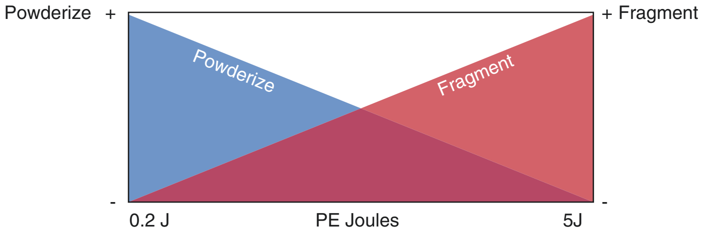

FIGURE 5.6 Fragmentation vs powderization. Increasing the PE will favour fragmentation whereas a lower PE will result in powderization. PE, pulse energy

TABLE 5.7 Fragmentation vs powderization

	Powderization	**Fragmentation**
Previous ERCP + ES	Yes	No
PE setting	Low (~0.2 J)	High (~1 J)
Fr setting	Can be increased to reduce lithotripsy time	Can be increased to reduce lithotripsy time
Clearance of fragments	Irrigation will wash small fragments through the papilla into the duodenum	Extraction with basket
Lithotripsy time	Longer	Shorter
Extraction time	Shorter (or none)	Longer

ERCP endoscopic retrograde cholangiopancreatography, *ES* endoscopic sphincterotomy, *PE* pulse energy, *Fr* frequency was performed, an appropriate strategy would be to powderize the stone and let the continuous irrigation wash the small fragments into the duodenum. This technique has been previously described as the dusting technique (Fig. 5.7) [66]. A

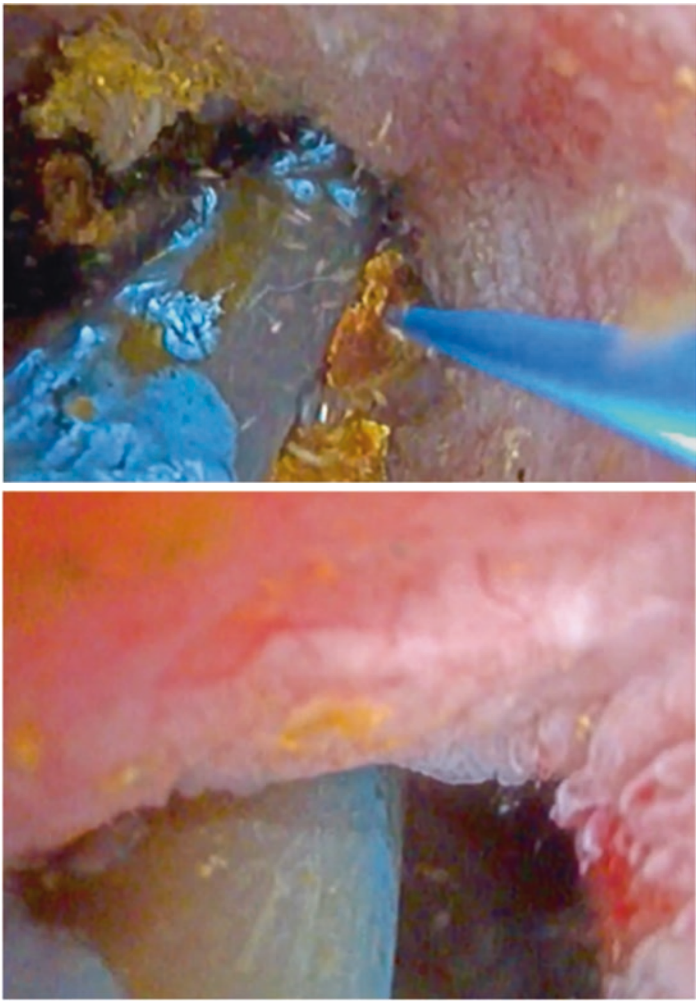

FIGURE 5.7 Dusting technique

lower PE setting of 0.2 J will be required for this approach and the frequency can be increased to increase the power and reduce the overall lithotripsy time. The other scenario is when your patient has not undergone a previous sphincterotomy and therefore passage of all fragments through the papilla is unlikely. The resulting fragments will need to be small enough for basket extraction through the cystic duct (in the majority of cases) or choledochotomy. For this, the PE should be increased to 1 J, which is considered a relatively high setting for lithotripsy and will cause fragmentation (Fig. 5.8). The dusting technique (powderization) takes longer in terms of lithotripsy time; however, it is important to remember that with fragmentation, the extraction time will be longer as individual fragments will need to be removed with a basket. Preoperative imaging allows measurement of the size and density of the stone, which can be used to predict lithotripsy time and difficulty. Figure 5.9 shows a very large stone with a high calcium content (bright white on CT) predicting a lengthy and difficult lithotripsy procedure.

Rate of Irrigation

The rate of irrigation is very important during choledochoscopy and needs to be adapted during the various phases of the procedure. During lithotripsy (mainly powderization) we should be keep a high flow to help with the passage of small fragments through the papilla. Similarly, for lithotripsy of intrahepatic fragments, a high irrigation flow rate should be maintained which will help to move stone fragments distally. When PE is set to fragmentation mode, the irrigation flow rate should be slowed down after lithotripsy to facilitate the capture of stone fragments with the basket. Newer choledochoscopes (e.g., Spy Discover DS Direct Visualisation System from Boston Scientific) have a working channel that can also be used for aspiration and therefore augment the dual dedicated irrigation channels to achieve a high flow rate (Fig. 5.10). We recommend the use of a foot pump for irrigation so the

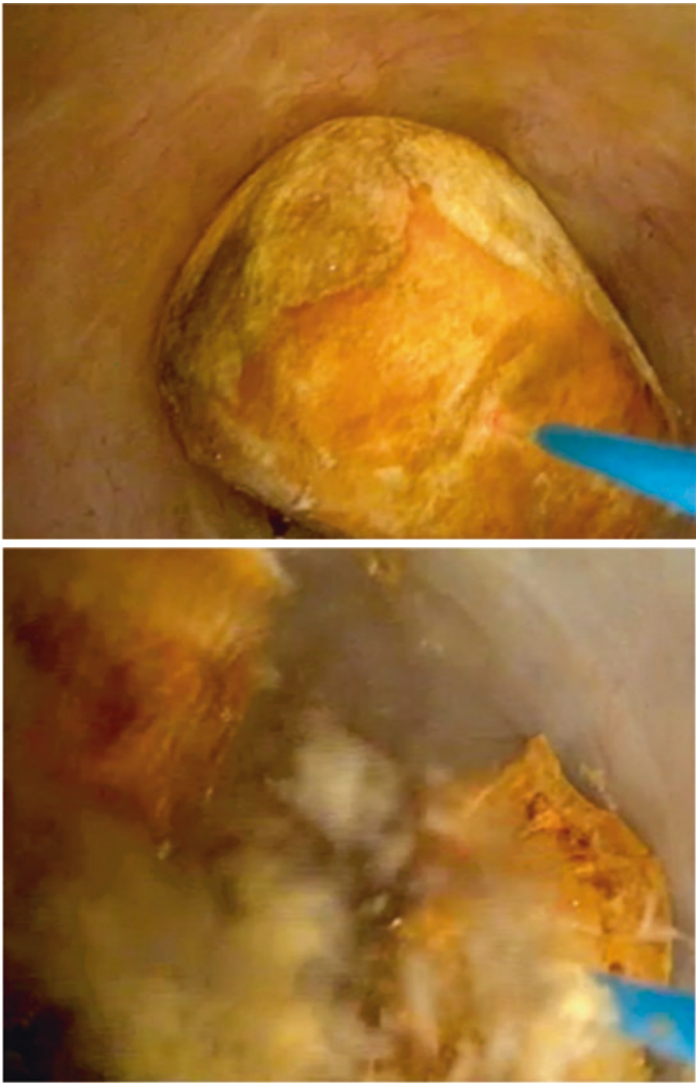

Figure 5.8 Fragmentation

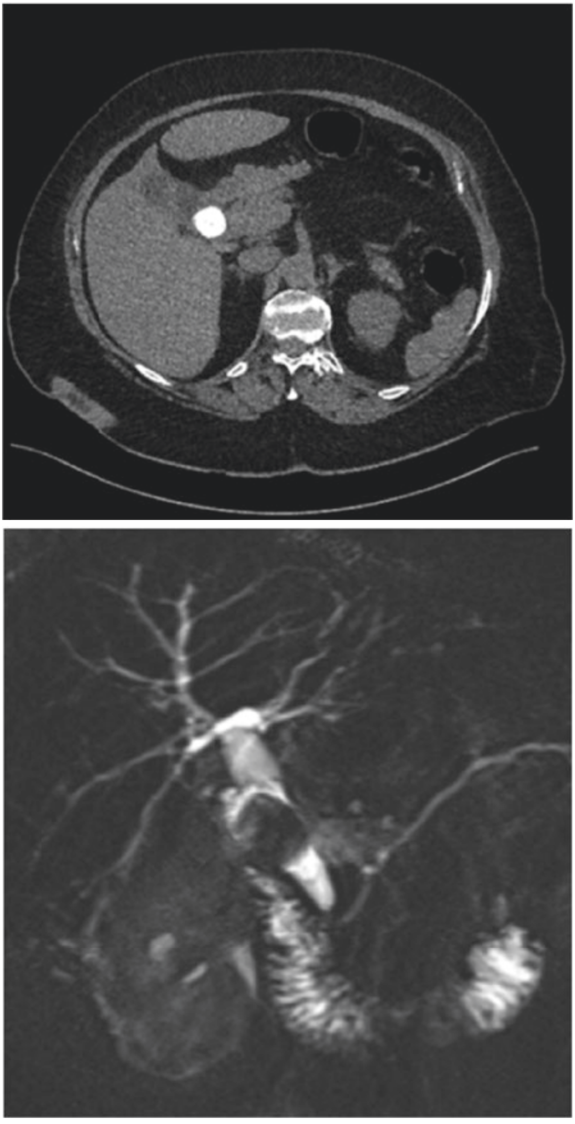

Figure 5.9 Pre-operative imaging allows measurement of the size and density of the stone, which can be used to predict lithotripsy time and difficulty

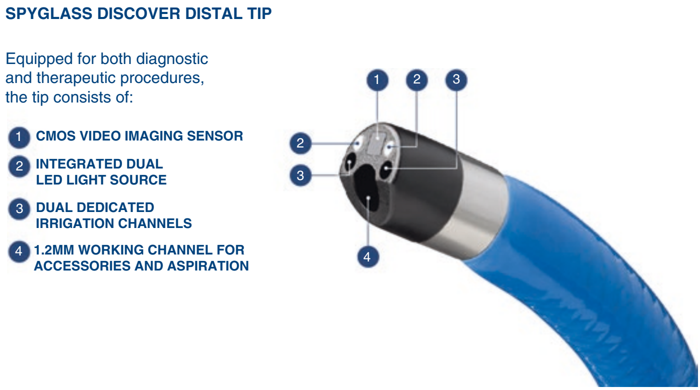

Figure 5.10 SpyGlass™ Discover with dual irrigation and 1.2 mm working channels by Boston Scientific (with permission from Boston Scientific, Marlborough, Massachusetts, USA)

operator can control the flow rate. Furthermore, the traditional use of saline bags is time consuming for the nursing staff and offers poor control of the irrigation flow rate. High flow irrigation will also help to prevent thermal injuries that may happen when the laser is used for long periods at high power settings (>40 W).

Damage to the Laser Fibre

During lengthy lithotripsies, the fibre tip may get damaged (fibre tip degradation) or bent. In such cases, after setting the laser device on standby and removing the laser fibre, it may be worth trying to cut the damaged tip with scissors and trying again prior to opening a new fibre. As a general rule, the higher PE used, the more likely that the fibre tip will degrade.

Iatrogenic Injury to the Bile Duct Mucosa

Perforation of the ureter is an uncommon but well-known complication experienced by urologists during lithotripsy due to the high volume of procedures that they perform. To date at the authors institution, there has not been a perforation of the bile duct, although superficial mucosal burns have been observed after lateral deflection of energy. In our experience, this has not required any treatment. If a ductal perforation does occur, the CBD should be drained, ideally with a transcystic drain or with a T-tube or anterograde stent if the lithotripsy was performed via the transductal route. Energy and frequency settings will determine the total power in watts (PE (J) × Fr (Hz) = Power (W)). High power settings will induce higher temperatures, which can be mitigated with intermittent laser firing and high irrigation rates, which will reduce the power to 20 W. In an experimental porcine model, 40 W were needed for 18 seconds in order to induce thermal injury [67]. From our experience, with the standard settings, it is difficult to achieve power readings as high as 40 W.

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