SECTION 1 General considerations for advanced laparoscopic hepatopancreatobiliary surgery

CHAPTER 1
The development of minimal access hepatopancreatobiliary surgery

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EDITOR COMMENT
This wonderful chapter, which may spark the interest of surgeons beyond the field of HPB surgery, is an account of the challenges faced by the pioneers of minimally invasive HPB surgery, challenges of a scientific but also a social nature. Some of these pioneers’ careers took an unfavorable turn because of their dedication to innovation. We owe these legends and also their families gratitude, not only for their ingenuity and the inquisitiveness from which the patients of minimally invasive HPB surgeons benefit in the operating room every day but also for taking on the societal challenge and risks to their career in order to drive innovation. The chapter also explores the available data on the development of modern laparoscopic and robotic liver, biliary, and pancreas surgery from its beginnings of limited resection to the advanced minimally invasive surgery that is practiced at many centers around the world today.

Keywords: advanced minimally invasive HPB surgery, history of minimally invasive HPB surgery

All truth passes through three stages:
• First it is ridiculed
• Second it is violently opposed
• Third it is accepted as self-evident

Arthur Schopenhauer

Hepatopancreatobiliary (HPB) operations are some of the most technically challenging procedures in surgery owing to the complex anatomy and proximity to vital structures. Over the years HPB procedures have excited, enthralled, and humbled surgeons all over the world. At the same time, the complexities of the disease processes have driven innovation not just in surgery but in medicine in general. The development of minimally invasive HPB surgery is synonymous with the development of laparoscopy and is perhaps the “holy grail” of laparoscopic surgery.

1.1 Beginnings

The term laparoscopy comes from “laparoskopie,” which is derived from two Greek words: laparo, meaning “flank,” and the verb skopos, meaning “to look or observe” [1]. The exploration of the human body through small or natural orifices dates back to the time of Hippocrates [2]. Hippocrates described the use of a primitive anoscope for the examination of hemorrhoids in 400 BC [2]. An Arab physician, Abulcasis, added a light source to the instrument for the
exploration of the cervix in AD 1000 [2,3]. Many centuries later, in 1585, Giulio Cesare Aranzi inspected the nasal cavity by reflecting a beam of light through water [2].

In 1805 Philipp Bozzini examined the urethra using an instrument that consisted of a wax candlelit chamber inside a tube which reflected light from a concave mirror [2,3]. Bozzini called it the “lichtleiter,” and it is considered the first real endoscope (Figure 1.1 and Figure 1.2) [2,3]. Using his lichtleiter, Bozzini managed to study the bladder directly, and his pioneering efforts laid the foundations of modern endoscopy.

Over the next century, Pierre Salomon Segalas and Antoine Jean Desormeaux from France refined Bozzini’s lichtleiter and took the first steps in developing the modern cystoscope [2,3]. Desormeaux presented his idea to the Academy of Medicine in Paris, and for his efforts he is considered the “father of cystoscopy” [3]. Around the same time, over in the United States, John Fischer in Boston was using a similar instrument to perform vaginoscopies, and in Dublin, Ireland, Francis Cruise was performing endoscopies on the rectum [2].

In 1877 a urologist from Berlin, Maximilian Nitze, created what is considered the first modern endoscope using a platinum wire heated by electricity and encased in

Figure 1.1 Self-portrait of a young Bozzini (ca. 1805). Source: Frankfurt town archives.

Figure 1.2 The lichtleiter (an original owned by the American College of Surgeons, Bush Collection). The 200th Anniversary of the First Endoscope: Phillip Bozzini (1773–1809). Source: Morgenstern 2005 [4]. Reproduced with permission of Sage Publications.

In 1877 a urologist from Berlin, Maximilian Nitze, created what is considered the first modern endoscope using a platinum wire heated by electricity and encased in

Figure 1.3 Maxmilian Nitze. Source: https://de.wikipedia.org/wiki/Datei:Max_Nitze_Urologe.jpg#file. Used under CC BY-SA 3.0 - http://creativecommons.org/licenses/by-sa/3.0/legalcode.
a metal tube (Figure 1.3 and Figure 1.4) [2,3]. A few years later, in 1880, Thomas Edison invented the light bulb, which revolutionized the way endoscopies were performed [3,6]. While these innovations all made advances in laparoscopy possible, little else occurred in the field until the beginning of the twentieth century.

1.2 Advent of laparoscopy

George Kelling from Germany is credited with exploring the abdominal cavity using a scope after creating pneumoperitoneum in 1901 (Figure 1.5). Kelling was a surgeon and first performed laparoscopies on dogs; he called the procedure “coelioskope” [2,3,6,7] (Box 1.1). The technique involved injecting the canine’s abdomen with oxygen filtered through sterile cotton and then using Nitze’s cystoscope to inspect the abdominal contents. Kelling performed this procedure in humans, but his findings were not published [3]. Around the same time, a Swedish internist called Hans Christian Jakobaeus popularized the procedure in humans by using a colposcope with a mirror to assess the abdomen of a pregnant woman [7]. In 1911 Jakobaeus presented his work Über Laparo- und Thorakoskopie and later continued his work in thoracoscopy (Figure 1.6) [3,6,7,8]. Jakobaeus used trocars very similar to the ones used today and is also credited with coining the term “laparoscopy” [3]. Not too far away in Petrograd (modern-day St Petersburg), Dimitri Ott performed the same procedure and called it “ventroscopy” [6,7]. The first to use the laparoscopic technique in the United States was Bertram M. Bernheim in 1911 [9]. Bernheim was a surgeon at the Johns Hopkins University, and he called this procedure “organoscopy” [2,3,6–8,11].

Box 1.1 Different terms used historically

Coelioskope: George Kelling, 1901 (Germany)
Ventroscopy: Dimitri Ott, 1901 (Petrograd/St Petersburg)
Organoscopy: Bertram Bernheim, 1911 (Johns Hopkins University)
Bernheim, like many others at the time, had not heard of the work of Kelling and Jakobaeus. Up to this point, all the procedures for exploring the abdominal cavity were performed with oxygen [3]. In 1924, Richard Zollikofer proposed that pneumoperitoneum be obtained using carbon dioxide. Carbon dioxide had two advantages: one was the rapid reabsorption of carbon dioxide by the peritoneal membrane and, unlike oxygen, it was noncombustible [3,6]. In 1929, Heinz Kalk, a German gastroenterologist, designed a new lens system with 135° vision and introduced the technique of “double trocar.” This invention eventually led to more refinements and the introduction of instruments into the cavities [2,3,6,7]. Between 1929 and 1959, Kalk submitted many articles on diagnostic laparoscopy; he is considered the “father of modern laparoscopy” [3].

The first therapeutic intervention was carried out by the German physician Fervers, who performed the lysis of abdominal adhesions and a liver biopsy [3,6]. Another significant advancement in laparoscopy is credited to the Hungarian physician Janos Veress. In 1938, he created a retractable needle to create pneumoperitoneum. We are all familiar with the Veress needle, but interestingly, it was initially used for the treatment of tuberculosis with pneumothorax in the preantibiotic era [2,3,6,7]. This technique was not accepted by all surgeons as it was considered unsafe. This led, in 1974, to Chicago-based gynecologist Harrith M. Hasson creating the open technique to access the abdominal cavity and achieve placement of the trocar that bears his name [2]. Raoul Palmer performed diagnostic laparoscopies in women and advised placing the patient in the Trendelenburg position for better visualization of the pelvis [2]. In addition, he was the first to control abdominal pressure during the procedure—two important aspects of modern laparoscopy [2].

In 1952, laparoscopic surgery underwent a revolution when French scientists M. Fourestier, A. Gladu, and J. Vulmiere created fiber-optics with cold light [3]. Two years later, scientists Lawrence Curtiss, Basil Hirschowitz, and Wilbur Peters did the same at the University of Michigan and brought cold light fiber-optics into practice in 1957. With improved visualization of the abdominal cavity, the advances in laparoscopy gained momentum [2].

Few surgeons have influenced the development of laparoscopic surgery more than the German gynecologist Kurt Semm. A pioneer in minimally invasive surgery, Semm developed a system of automatic insufflation in 1977. This consisted of a system of suction and irrigation, laparoscopic thermocoagulation, and the laparoscopic scissors as well as the “pelvitrainer” (Figure 1.7) used to teach laparoscopic techniques [2,3,6,7]. In 1981, Semm performed the first totally laparoscopic appendectomy [2,3,6,7]. The next significant milestone was the development of the high-resolution video camera in 1982 [2]. Since then the introduction of xenon/argon light sources and high-definition cameras has further improved visualization [2].

Despite the obvious potential advantages, skepticism regarding laparoscopic surgery remained prevalent because “big surgeons make big incisions” [3]. In 1985, the first Figure 1.7 Kurt Semm’s “pelvitrainer.” Surgical training system with a novel approach. Source: Semm 1986 [12]. Reproduced with permission of Thieme.
totally laparoscopic cholecystectomy using the Veress needle for access and the trocar called the “galloscope” was carried out by German surgeon Erich Mühe (Figure 1.8) during a two-hour-long intervention [5,11]. Mühe encountered significant criticism, and this great achievement was initially unrecognized [11]. Subsequently, in 1987, Philippe Mouret, a French gynecologist, performed the first laparoscopic cholecystectomy in France [2,3,6,13].

Over the years, continued refinements in techniques and instrumentation have enabled surgeons to push the envelope even further. In a short span of less than three decades, minimally invasive surgery has grown exponentially. What seemed like virtual reality in 1987 is now the new norm, and the laparoscopic approach has become the standard of care for many abdominal surgical procedures (Box 1.2).

**Box 1.2 Important historical events in minimally invasive HPB surgery**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>1901</td>
<td>Kelling examines the abdominal cavity of the dog with a cystoscope</td>
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<tr>
<td>1911</td>
<td>Jakobaeus – first laparoscopic series in a human</td>
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<td>1929</td>
<td>Kalk – oblique view, double trocar technique</td>
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<td>1938</td>
<td>Veress – abdominal puncture needle</td>
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<tr>
<td>1970</td>
<td>Semm – automatic insufflation</td>
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<tr>
<td>1974</td>
<td>Hasson – open laparoscopy trocar</td>
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<tr>
<td>1986</td>
<td>TV camera adapted to optics</td>
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<tr>
<td>1987</td>
<td>First laparoscopic cholecystectomy by Mouret</td>
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<tr>
<td>1992</td>
<td>First laparoscopic liver resection by Gagner</td>
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<tr>
<td>1994</td>
<td>First laparoscopic pancreaticoduodenectomy by Gagner and Pomp</td>
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In 1988, the first laparoscopic cholecystectomy was performed in the United States by John Barry McKernan, a surgeon, and William Saye, a gynecologist [6,14]. Eddie J. Reddick and Douglas Olsen in Nashville collaborated with McKernan and Saye and started performing laparoscopic cholecystectomies regularly [14]. In April 1989, Professor Jacques Perissat was not allowed to present a laparoscopic cholecystectomy at SAGES! Nevertheless, he carried out his video presentation at a cabin near the SAGES auditorium, close to the men’s restroom. Not surprisingly, this attracted a lot of attention [13]. This pivotal event marked the beginning of a revolution in laparoscopic surgery for general surgeons around the world [13]. Dubois subsequently published a series of 36 “celioscopic cholecystectomies” in *Annals of Surgery* [15]. The development and popularization of the technique of laparoscopic cholecystectomy practiced in the United States today are credited to Reddick and Olsen, who led the laparoscopic revolution in the continent [14].

It was quickly realized that the benefits of laparoscopic surgery centered on less postoperative pain, enabling better patient satisfaction and a quicker return to work. It seemed logical that the next set of innovations in laparoscopic surgery of the gallbladder be aimed at reducing the number and size of access points to the abdominal cavity.
et al. and Unger et al. evaluated patients who underwent laparoscopic cholecystectomy with 10 mm and 5 mm ports versus 5 mm and 2 mm ports. Both authors concluded that patients with smaller ports had less postoperative pain [16]. However, Bisgard found a significantly higher rate of conversion (38%) with mini-laparoscopy compared with standard laparoscopic trocars [17].

While the results of mini-laparoscopy were equivocal, in an effort to further reduce the number of ports, single-incision laparoscopic surgery (SILS) was born. This utilized a single 25 mm port with multiple trocars. The first SILS was performed in the late 1990s by Italian surgeon Fabrizio Bresadola and his team, who later published their experience after 100 cholecystectomies. They concluded that it is safe and feasible compared with traditional laparoscopic cholecystectomy but with better esthetic results [18]. Zehetner et al. and Pisanou et al. performed meta-analyses of studies comparing the single-port technique with the multiport laparoscopic technique and demonstrated that the only obvious advantage was improved cosmesis [19,20]. Further, reports of increased incidence of port site hernias with the single-port technique (1.2% versus 8.4%) have been published [21,22].

Another approach which had generated excitement was a NOTES (natural orifice transluminal endoscopic surgery) cholecystectomy performed transvaginally. Kalloo et al. were the first to describe the NOTES approach in 2004 [21]. The procedure can be cumbersome, and the main alleged advantage of this approach seems to be decreased postoperative pain. Even though feasible, the NOTES approach to laparoscopic cholecystectomy has failed to show definite advantage and has not gained widespread adoption. Introduction of the robotic platform in the 2000s further revolutionized laparoscopic surgery. Many surgeons now offer a robotic single-port cholecystectomy. Today, a distinct advantage of this approach is lacking, and it is safe to say that the conventional four-port cholecystectomy has stood the test of time and continues to be the gold standard.

Despite all the advantages demonstrated by laparoscopic cholecystectomy, an increased incidence of bile duct injury is still reported when compared with the incidence of the now historical open approach. Efforts to decrease that incidence are still evolving, and an important technical concept that has emerged is obtaining the “critical view of safety” prior to transecting the cystic duct (Figure 1.9). The premise behind this is that the cystic duct should be clearly identified, with the goal of avoiding injury to the common bile duct (CBD). This was originally proposed by Strasberg et al. in 1995 and is now accepted as the standard of care for the majority of cases [23]. Obtaining the critical view entails dissecting in Calot’s triangle till the cystic plate is clearly visible and ensuring that two, and only two, structures enter the gallbladder: the cystic duct and artery [21]. Occasionally, this may not be possible, in which case a cholangiogram, an intraoperative ultrasound or a top-down technique may be beneficial.

### 1.3.2 Bile duct surgery

The laparoscopic exploration of the common bile duct has become an accepted procedure for the treatment of choledocholithiasis associated with cholecystolithiasis.

![Figure 1.9](image-url)
first exploration of the common bile duct was carried out by Dr. Joseph Petelin [24] in 1989, and the first report of the exploration of the common bile duct was published in 1991 by Stoker et al. They described a series of five patients who underwent a laparoscopic exploration of the common bile duct with removal of gallstones and placement of a T-tube with satisfactory results [25]. In mid-1993 Petelin published his experience of the successful removal of gallstones in 83 of 86 patients who underwent exploration of the common bile duct [24]. Until then, the technique involved a laparoscopic choledochotomy and placement of a biliary drainage tube. Berci and Morgestern described the laparoscopic transcystic common bile duct exploration in 1994 [26].

In 2003 Petelin et al. published their 12 years of experience in common bile duct explorations with encouraging results [27]. Dorman et al. presented their experience with 148 patients who underwent laparoscopic common bile duct exploration; gallstones were removed successfully in 143 cases and endoscopic retrograde pancreatography (ERCP) was conducted in the rest [28]. By the late 1990s, it became evident that transcystic exploration of the common bile duct was technically feasible and ERCP could be used to treat residual lithiasis. As with many other minimally invasive procedures, traditional dogma was challenged when a laparoscopic common bile duct exploration was performed and the need for routine T-tube placement was questioned. Gurusamy et al. compared open bile drainage via a T-tube with primary closure and concluded that the use of a biliary T-tube prolonged both surgical time and hospital stay without any clear clinical benefit [29].

The laparoscopic approach has also been utilized for other biliary procedures including bilioenteric anastomoses, bile duct, and choledochal cyst excisions. The magnification afforded by the minimally invasive approach favors the complete excision of intrapancreatic choledochal cysts (Figure 1.10). Future interventions in surgery of the biliary tree will likely be centered around combined laparoendoscopic interventions in selected patients.

1.3.3 Pancreatic surgery

In Sanskrit, an ancient Indian language, the pancreas is called *agnyashay*, which is derived from *agni* meaning...
“fire.” It has been known since ancient times that the pancreas does not take too kindly to being disturbed. Anatomically, the pancreas is not easily accessible given its retroperitoneal location and proximity to vascular structures. Pancreatic resections have thus always been associated with significant morbidity and mortality. Initially, laparoscopy was utilized as a staging procedure in pancreatic malignant disease. However, with the evolution of new tools, refinements in technology, and increased surgeon experience, laparoscopic interventions on the pancreas seemed more plausible.

### 1.3.3.1 Laparoscopic pancreatic enucleation

So how do you approach an organ that does not like to be disturbed and makes most surgeons apprehensive? It seems intuitive that you do the least invasive surgery first. That is exactly what happened with the pancreas; enucleations of benign or malignant tumors were some of the first laparoscopic procedures performed. Gagner et al. and Tagaya et al. confirmed the feasibility and safety of this approach [30,31].

While feasible, the incidence of pancreatic fistula with a laparoscopic enucleation is high, as reported by Talamini et al. They found that the rate of pancreatic fistula in patients treated with laparoscopic pancreatic enucleation was 50% but only 12% in patients treated with laparoscopic pancreatectomy [32]. Fernandez Cruz et al., in a different study, demonstrated a pancreatic fistula rate of 35% [33]. At present, it is felt that laparoscopic enucleation of pancreatic tumors is a feasible and safe technique but requires the surgeon to be cautious when selecting appropriate patients.

### 1.3.3.2 Laparoscopic distal pancreatectomy

Laparoscopic distal pancreatectomy is considered an advanced and difficult procedure by some. Soper et al. first described laparoscopic distal pancreatectomy in a porcine model [34]. Laparoscopic distal pancreatectomy in humans was initially performed simultaneously by Sussman and Cuschieri in 1994 for benign pathologies and subsequently by Gagner et al. [35–37].

European multicenter experience of laparoscopic distal pancreatectomies published by Marbut et al. established its efficacy [38].

Our group has described the “clockwise technique,” with a 17.2% morbidity, 10.2% pancreatic fistula rate, and no mortality, confirming the benefit of a minimally invasive approach [39]. We subsequently published our experience of 172 patients; 90 patients underwent an open distal pancreatectomy and 82 underwent laparoscopy. We concluded that the benefits of laparoscopic surgery were based on less blood loss with less need for transfusions, shorter hospital stay, and less overall recovery time. The morbidity and mortality were similar in both groups, and oncologically there were no statistically significant differences [40].

While the laparoscopic approach proved to be efficacious for a variety of benign lesions, there was considerable debate regarding its role in the management of malignant disease. There were serious doubts related to the pancreatic margin, the retroperitoneal dissection, and the number of resected lymph nodes, as evidenced by the papers published by Merchant in 2009 [41] and Kubota [42]. However, Kooby et al. in 2010 published a multicenter study concluding that laparoscopic distal pancreatectomy compared with open resection has similar short- and long-term oncological outcomes [43]. Several meta-analyses confirmed that laparoscopic distal pancreatectomy had definite advantages over the open technique and presented no oncological compromise [44–46]. It is reasonable to conclude that, in experienced hands, the laparoscopic approach should be the procedure of choice for distal pancreatectomy even in patients with pancreatic cancer.

Another challenge in the development of laparoscopic distal pancreatectomy was the preservation of the spleen. Since Mallet et al. showed the important immunological role of the spleen in 1943, efforts to preserve it have intensified [47]. At present, there are two prevalent techniques. The first, described by Warshaw in 1997, requires division of the splenic artery and vein, leaving the spleen to be supplied by the gastroepiploic vessels and short gastric vessels [48]. The second technique, described by Kimura, allows the preservation of the splenic vessels joining the cross-collateral branches of both structures [49]. The Kimura technique demands greater laparoscopic skill and time in comparison to the Warshaw technique, which is faster but may increase the risk for the development of postoperative splenic abscesses and pain [48,59].

Robotic distal pancreatectomy has been developed over the last few years. The results compared with the laparoscopic approach appear to be mixed. Waters et al. showed that the robotic approach led to reduced hospital stay, lower cost, and a higher rate of splenic preservation with statistically significant differences [50]. Kang et al., on the other hand, found the robotic approach to be more
1.3.3.3 Laparoscopic pancreaticoduodenectomy

Open pancreaticoduodenectomy is considered one of the most difficult and challenging procedures. It is not surprising that the laparoscopic approach to a pancreaticoduodenectomy takes it to an even higher level of complexity. The first surgeons to perform a laparoscopic pancreaticoduodenectomy were Michel Gagner and Alfons Pomp in 1994 [52]. Gagner et al. in 1997 presented their initial series of 10 patients who underwent laparoscopic pancreaticoduodenectomy with a conversion rate of 40%. They reported significant morbidity for those completed laparoscopically with a mean hospital stay of 22.3 days. They concluded that laparoscopic pancreaticoduodenectomy did not offer any advantage over the open procedure and may increase morbidity.

However, other surgeons continued exploring this area [37]. Dulucq et al. presented their experience of 25 patients treated with laparoscopic pancreaticoduodenectomy where the mean hospital stay was 16.2 days, mortality rate 4.5%, morbidity 31.8%, and pancreatic fistula rate 4.5%. They concluded that laparoscopic pancreaticoduodenectomy is a difficult procedure to perform [53]. It was Palanivelu et al. who presented the first series which favored the laparoscopic approach. Forty-five patients underwent a laparoscopic pancreaticoduodenectomy with a mean hospital stay of 10.2 days, surgical time of 370 minutes, and an average of 13 lymph nodes harvested. There were no conversions, morbidity rate was 26.6%, mortality rate 2.2%, and median survival 49 months. They concluded that laparoscopic pancreaticoduodenectomy is safe and feasible in appropriately selected patients [54].

More recently, Nigri et al. published a meta-analysis comparing the minimally invasive versus the open approach to pancreaticoduodenectomy. They included 204 patients in the laparoscopic arm and 419 patients in the open arm. They reached the conclusion that there were no statistically significant differences in morbidity, mortality, pancreatic fistula, transfusion rate, oncological margin, resection of lymph nodes, reoperation rate, or infection rate. The laparoscopic approach, however, revealed a statistically significant reduction in hospital stay and blood loss [55].

Our group published a study comparing 215 patients treated with open pancreaticoduodenectomy and 53 patients treated laparoscopically. In terms of morbidity, mortality, pancreatic fistula, rate of reoperation, and oncological outcomes there were no statistically significant differences. On the other hand, patients treated laparoscopically had a shorter hospital stay (eight days), only 1.1 days in the intensive care unit, longer surgery time, less blood loss, and a greater number of lymph nodes harvested (average of 23.4 nodes). All these variables represented a statistically significant difference [56].

The robotic approach to pancreaticoduodenectomy has also been introduced with significant success in experienced hands and offers the advantages demonstrated by the laparoscopic approach. Furthermore, the technique may facilitate its adoption by shortening the learning curve. The associated disadvantages are the cost involved, the need for two experienced surgeons for all procedures, and the fact that there has been no objective data demonstrating a clear benefit over the laparoscopic approach.

1.3.3.4 Laparoscopic duodenectomy with pancreatic preservation

Laparoscopic duodenectomy with pancreas preservation is a technique of choice for a variety of premalignant and benign duodenal lesions that are not amenable to endoscopic excision. In our opinion, this procedure holds significant promise as it allows pancreas preservation and obviates complications associated with resection of the head. This laparoscopic approach was first described by us in 2010 and 2011 [57–61]. The procedure can consist of a total duodenectomy (Figure 1.11) when the lesion involves the ampulla of Vater or a partial duodenectomy if the ampulla can be preserved. We have published a small series of patients who underwent a laparoscopic total duodenectomy with pancreas preservation. The outcomes were similar to pancreaticoduodenectomy with potentially better long-term results. Our unpublished data on 20 partial duodenectomies for non-ampullary neoplasms showed an operative time of 259 minutes and acceptable morbidity of 15%. The partial procedure does not require reimplantation of the biliary and pancreatic ducts and therefore is much simpler than the total duodenectomy.
1.3.4 Laparoscopic liver surgery

Laparoscopy for management of liver lesions was first introduced in the early 1990s. Gagner et al. performed the first reported laparoscopic liver resection in 1992 [62]. They reported a series of two patients who underwent nonanatomical laparoscopic liver resections for focal nodular hyperplasia and metastasis from colorectal cancer. Azagra et al. performed the first anatomical resection that consisted of a left segmentectomy in 1993 [63]. While laparoscopy has been widely accepted in general surgery, it faced many obstacles in the field of hepatic surgery. Several advances provided the impetus for laparoscopic liver resections, including improvements in imaging, anesthesia, and postoperative management, as well as greater experience in laparoscopy. The first laparoscopic liver resections to gain widespread acceptance were mostly wedge-type resections for benign lesions.

The minimally invasive approach includes the following techniques: pure laparoscopy, hand-assisted laparoscopy, and the hybrid approach in which the surgery begins with laparoscopy for mobilization of the liver and initial dissection followed by a small incision to complete the liver transection. Towards the late 1990s and beginning of 2000, more evidence favoring laparoscopic liver resections emerged. These resections were not just nonanatomical or segmentectomies but initial steps towards the acceptance of major laparoscopic hepatectomies. O’Rourke and Fielding published a small series of 12 patients in 2004 [64]. In 2009, Dagher et al. conducted a large multicenter study of six high-volume hepatobiliary surgery centers and recruited 210 patients treated with major laparoscopic liver resections; 43% of these were totally laparoscopic resections and 57% were laparoscopic hand-assisted technique. Complete resection (R0) was achieved in 111 patients. Specific morbidity was 8.1%, all-cause morbidity was 13.8%, and mortality rate was 1%. These results proved that the laparoscopic approach for major liver resections was feasible and safe in appropriately selected patients [65]. In the same year, Ito et al. compared the laparoscopic approach with the open approach. They presented 130 patients, of whom 52 were treated with laparoscopic surgery and 65 with open surgery. The conversion rate was 12 patients (18%) excluded from the laparoscopic group. The mortality rate and oncological results did not demonstrate significant differences, but the laparoscopic approach had fewer transfused patients, shorter hospital stay, less pain, fewer days to begin oral feeding, less overall morbidity, and a

Figure 1.11 A laparoscopic pancreas-preserving total duodenectomy performed for a large ampullary adenoma in a patient with pancreas divisum. The duodenum has been completely separated for the pancreas except for the two ducts. Source: Horacio J. Asbun. Reproduced with permission.
lower rate of incisional hernias, and all these differences were statistically significant. These findings allayed fears regarding the oncological efficacy of laparoscopic liver resections. Additionally, it was reported that the patients who underwent laparoscopic liver resections had a faster recovery and less intraoperative blood loss [66].

More recently, in 2010, Reddy et al. published the results of a meta-analysis comparing major liver resections performed laparoscopically with an open approach. This study included 1146 operations with laparoscopic approach and 1327 patients with open technique. The results were similar to Ito’s [67]. In 2011, Machado et al. from Brazil published a new laparoscopic technique for major laparoscopic resections following the previously described open Glissonian approach. This technique was developed in 2008 for minor liver resections [68] and was subsequently described for a left hepatic lobectomy [69] and for a right hepatic lobectomy in 2011 [70].

Robot-assisted laparoscopic liver resections are being utilized to a greater degree. While the data are scarce at this time, there is some evidence supporting its use. Giulianotti et al. have published a small series of 24 patients who underwent a laparoscopic right hepatic lobectomy. The conversion rate was 4.2%, the mean surgery time was 337 minutes, and the average blood loss was 457 mL [71]. More recently, in 2013, Milone et al. published a meta-analysis of 72 patients who underwent robotic liver resections [72]. They concluded that the robotic approach is feasible albeit at a higher cost.

The most recent advances in liver resections include not just the surgical technique in itself; they involve improved planning of liver resections using computer-assisted 3D reconstructions. This was described in a recent publication by Mise et al. [73]. Using 3D technology, surgical planning includes the following steps: loading CT images into the software, reconstructing the liver anatomy (liver parenchyma, portal vein, hepatic veins, and tumors) in a 3D format, performing a virtual hepatectomy using the software (estimate the resection volume based on portal perfusion and venous congestion volume based on venous drainage), and finally, evaluating optimal procedures based on derived data. The practical application of navigation systems capable of transferring information for the preoperative planning of real-time surgeries could lead to safer and preplanned liver surgery. It is expected that in the near future there will be a major revolution in liver resection techniques with the improvement of 3D imaging, preoperative planning, and intraoperative imaging superimposition for augmented-reality surgery [73].

1.4 Laparoscopic ultrasound in liver and pancreatic surgery

The idea of applying ultrasound for diagnostic purposes during surgery evolved in the early 1960s. Schlegel et al. [74] used ultrasound for the first time to find kidney stones, and then Knight and Newell reported the use of the same technique applied to the intraoperative search for stones in the common bile duct [75]. Over time, laparoscopic transducers similar to standard linear transducers have been introduced.

The first to report the use of laparoscopic ultrasound was Fukuda et al., who in 1981 described diagnostic liver laparoscopies. With the rapid refinements in imaging technology such as computed tomography and magnetic resonance imaging, the use of ultrasound for the diagnosis of liver lesions has diminished [75]. However, the use of intraoperative ultrasound for locating liver and pancreatic lesions has gained popularity. It can be an invaluable tool in helping to localize lesions in the liver and pancreas and to define the anatomy of the hepatoduodenal ligament. For example, when a hepatoma is associated with liver cirrhosis, laparoscopic ultrasound helps in the detection of small lesions and in defining the relationship of large lesions to portal or hepatic vessels. This information may be crucial for operative planning [76]. Ultrasound is also useful to define the liver section in living donor heptectomies [76]. The use of laparoscopic ultrasound has become routine for the localization of endocrine tumors of the pancreas, especially in the evaluation of the relationship with the pancreatic duct. The sensitivity for the localization of insulinomas is 83–100%, allowing the detection of insulinomas 3–5 mm in diameter [76].

1.5 Conclusion

The past century has been one of innovation in every sphere of human life, including surgery. From Theodor Billroth and William Steward Halstead to Emil Theodor Kocher, the list of innovators is endless. Our lives have been changed because of these brilliant minds. Few innovations in the last century, however, have had a more lasting impact on human civilization than laparoscopy. From humble
The history of minimally invasive surgery in general and minimally invasive HPB surgery specifically is a history of scientific and social challenges. Laparoscopic pancreas, biliary, liver, and duodenal surgery has proved over time to be beneficial and oncologically sound for patients. HPB surgeons around the world are constantly pushing the envelope and challenging conventional wisdom and surgical dogma. We live in exciting times, and as far as HPB surgery is concerned, minimally invasive surgery is here to stay. It is becoming the standard of care for left-sided pancreatic resections as well as limited hepatic resections, and it is likely to become the standard of care for many other HPB procedures in the near future. However, caution and reassessment should be practiced on a regular basis when new advancements are introduced, keeping the interest of the patient at the forefront and as the guiding principle.

**KEY POINTS**

- The history of minimally invasive surgery in general and minimally invasive HPB surgery specifically is a history of scientific and social challenges.
- Laparoscopic pancreas, biliary, liver, and duodenal surgery has proved over time to be beneficial for patients.
- Significant future advances in the field of minimally invasive HPB surgery can be expected that include innovations in liver imaging, navigation-guided surgery, and augmented reality.

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