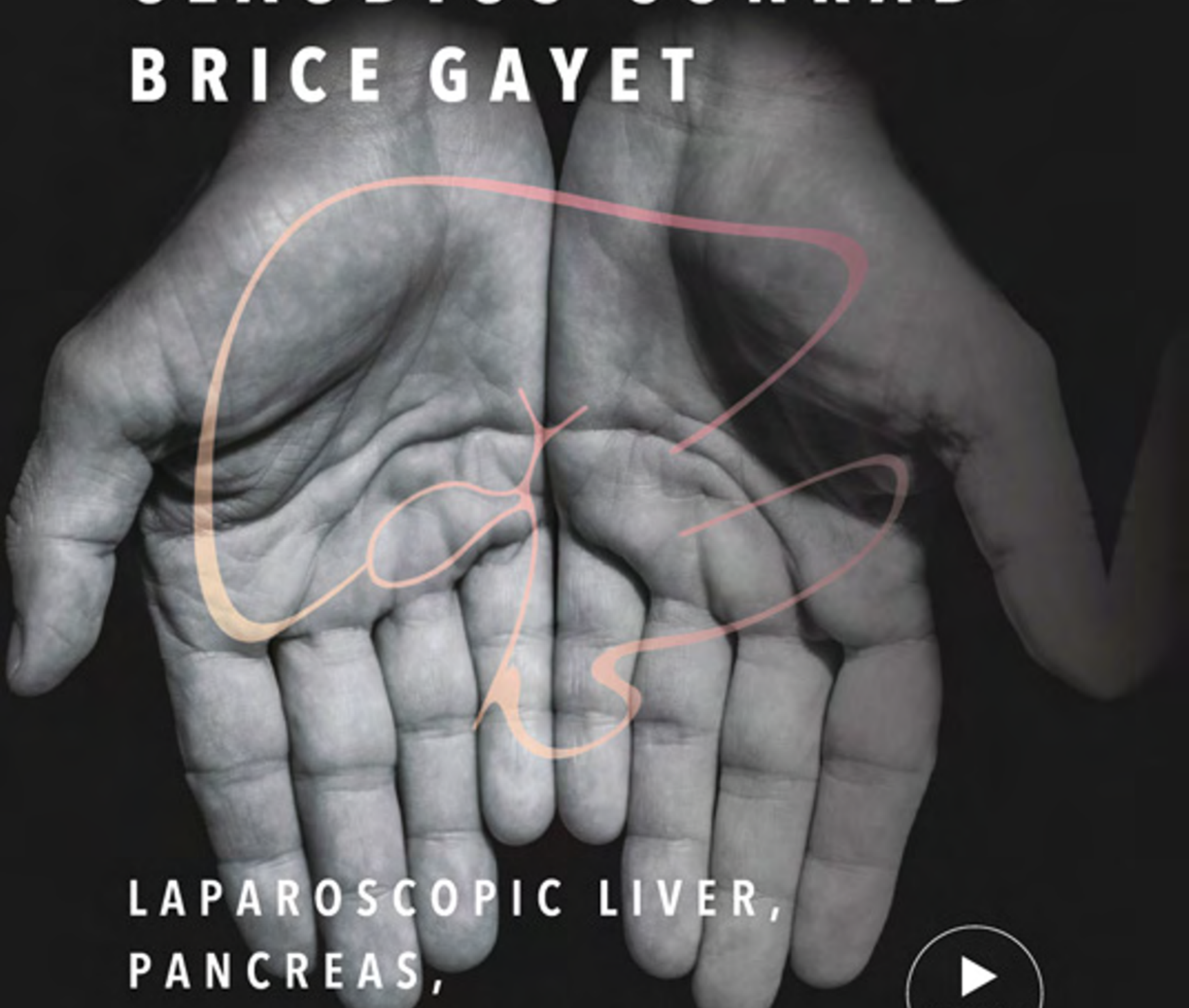
CLAUDIUS CONRAD
BRICE GAYET



# LAPAROSCOPIC LIVER, PANCREAS, AND BILIARY SURGERY

VIDEO ATLAS INCLUDED

WILEY

# Laparoscopic Liver, Pancreas, and Biliary Surgery

*Laparoscopic Liver, Pancreas, and Biliary Surgery* is an essential learning tool for all surgeons who manage patients considered for minimally invasive liver, pancreas, and biliary surgery.

Led by Claudius Conrad and Brice Gayet, pioneers in laparoscopic liver, pancreas, and biliary surgery, the authors have created a highly focused and multi-dimensional tool that takes the surgeon through the surgical procedures, one step at a time. Using a combination of text, illustrations, and high-definition videos, the authors explain and illustrate their excellence in surgical technique in a detailed and reproducible fashion.

The textbook contains contributions from world renowned experts and thought leaders in the field. They discuss key management concepts in the oncologic management of patients undergoing minimally invasive liver, pancreas, and biliary resections.

The accompanying comprehensive video atlas contains high-definition videos with a focus on true anatomic resections. The videos are supported by outstanding illustrations and 3D renderings of the relevant anatomy.

The authors expertly and logically demonstrate how to perform anatomic and non-anatomic liver, pancreas, and biliary resections. They cover patient and port positioning for laparoscopic and robotic approaches, detailed anatomy, and didactic breakdown of the operation. Including numerous surgical tips and tricks, and practical reviews for the management of patients with liver, pancreas, and biliary diseases before, during, and after operations the volume covers:

- Essential techniques (e.g. intraoperative ultrasound);
- Segmentectomies (I-VIII) and bisegmentectomies;
- Major hepatectomies, extended resections, and living donor liver transplantation;
- Pancreatectomies (e.g. Whipple) and Biliary resections;
- Advanced laparoscopic technologies and robotics.

This unparalleled resource will help a wide range of surgeons – including liver, pancreas, and biliary specialists, general surgeons, transplant surgeons, and surgical oncologists – to improve their surgical technique of both open and minimally invasive surgery.

# Laparoscopic Liver, Pancreas, and Biliary Surgery


EDITED BY

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# Foreword

It is with great pleasure that I write this foreword for the textbook and video atlas by Claudius Conrad and Brice Gayet on laparoscopic hepatopancreatobiliary (HPB) surgery. Claudius Conrad, who trained in my department at the Graduate School of Medicine, University of Tokyo, and Brice Gayet, who is a frequent guest-surgeon to Japan, have proved to me and the surgical community their excellent surgical skills in both open and laparoscopic surgery and their paramount concern for patient safety with their laparoscopic approach. Consequently, Claudius and Brice are very well equipped in creating this teaching material that promotes safe laparoscopic HPB surgery.

Today, almost all forms of hepatic resections have been performed via a laparoscopic approach, ranging from simple wedge resections to extended hepatectomies or resections with advanced vascular reconstruction. Brice Gayet and his team have certainly contributed significantly to its progress since its inception. Most studies that evaluate laparoscopic liver resection have shown comparable results to open resection in terms of operative blood loss, postoperative morbidity, and mortality. Many have demonstrated decreased postoperative pain, shorter hospital stays, and even lower costs. Preliminary oncological results, including resection margin status and long-term survival, are not inferior to open resection, although solid evidence proving equivalence is not available today as prospective and randomized studies are lacking. At least 40 studies (with more than 30 patients) on laparoscopic liver resection for malignancy have been reported although most of these were case series or case-control studies only. A larger series was first reported in 2002 while the majority of reports have been published since 2009. Therefore, reports on the long-term outcomes are not currently available.

As with open surgery, hepatocellular carcinoma and colorectal metastasis are the main indications for malignant tumor resection in laparoscopic surgery. However, in the earlier reports, a significant proportion of lesions resected laparoscopically were benign and this raises concerns as to whether these benign lesions were in fact resected because laparoscopy was readily available and not because their removal was deemed a necessity. It is important to recognize that laparoscopic surgery is merely a technique and its availability should not change the indication for resection. Further, the laparoscopic approach should not lead to shortcuts in terms of quality of oncological surgery provided.

Both Claudius and Brice have shown the importance of parenchyma-sparing liver surgery and how anatomical liver resection can indeed increase the safety of liver surgery. These important concepts can be successfully applied to laparoscopic surgery but do require a significant laparoscopic skill set. I am confident that this book and video atlas will allow a greater number of surgeons to successfully apply these concepts which will further the success of this field of laparoscopic surgery.

Progress in surgery is of the utmost importance and it is apparent to me that laparoscopic surgery will play a crucial role in HPB surgery in the near future. This informative textbook and atlas provides the community of HPB surgeons with what is laparoscopically feasible but it also clearly advocates the importance of operative and oncological safety. I am delighted to see this work by expert laparoscopic surgeons Claudius Conrad and Brice Gayet. I wholeheartedly endorse this book as a significant learning tool for surgeons who wish to attain valuable insights and to improve their laparoscopic skills in HPB surgery.

Congratulations on your great achievements, Claudius and Brice!

Professor Norihiro Kokudo
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# Foreword

As a "single-port, maximally invasive pancreatic surgeon," I have dreaded the day when laparoscopic pancreatic surgery would reach the point that these techniques would be available at all hospitals, provided by a wide variety of surgeons for every possible indication in almost every patient. I have been steadfast in my assumption that for these complex operations, especially with aggressive/invasive pancreatic malignancies, the wide exposure and an experienced surgeon using traditional open techniques would always be able to provide a "better" cancer operation, with superior short- and long-term outcomes, than "the new kids on the block" with either laparoscopic or robotic skills but limited experience in pancreatic surgery. I felt that even if high-volume centers with highly skilled surgical teams from around the world could report equivalent outcomes to open surgery, the rest of the surgical community would never catch up and I could play out the rest of my career as a "dinosaur" pancreatic surgeon with excellent outcomes but big incisions.

Then I met Brice Gayet and Claudius Conrad, and saw this well-written, this beautifully illustrated, this novel textbook and video atlas. I am realizing that the skills are now available in the surgical community and that there are teachers, such as Brice Gayet and Claudius Conrad, who can not only teach the techniques of minimally invasive pancreas surgery, but can build the confidence and determination of the next generation of pancreatic surgeons to push this field faster and further towards widespread application.

This textbook/atlas has clearly defined the laparoscopic technique for every common pancreatic surgical procedure and beautifully demonstrated the "tricks of the trade" in both the illustrations and video format. This book will be an essential for every institution developing a minimally invasive program in pancreatic surgery, as well as for those individuals training in surgical oncology, HPB surgery, and transplant surgery who hope to practice using the modern techniques for HPB surgery in the future.

In closing, it is likely too late for me, but for those early and midcareer pancreatic surgeons, be prepared, as it appears the "cows are out of the barn" with respect to minimally invasive pancreatic surgery and we are unlikely to corral the herd again with such a supportive and educational training tool such as this textbook/atlas.

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# Foreword

Recent decades have seen tremendous progress in the treatment of patients with liver and pancreas diseases. The overarching theme of this progress is that treatment is becoming more tailored: less invasive when possible and more radical when necessary. This progress has been made possible in part by multidisciplinary innovations that support the work of the surgeon. For example, understanding of the mutational profile of the primary tumor and metastases not only allows for accurate prognostication but also enables surgeons to accurately determine which patients would benefit from undergoing extensive liver resections. Further, portal vein embolization via an interventional radiology approach has made portal vein ligation almost obsolete and allowed patients requiring major resection to be treated safely with hepatectomy. This minimal-access procedure has therefore enabled surgeons to perform more radical resections.

The community of minimally invasive hepatopancreatobiliary surgeons has also made significant strides towards reduce the morbidity of the surgery itself. Minimally invasive surgery for liver and pancreas diseases has progressed from a purely diagnostic procedure and minor resections of liver and pancreas to advanced procedures that include extended liver resections, pancreaticoduodenectomy, and vascular reconstructions. While diagnostic laparoscopy and minor laparoscopic liver and pancreas resections are practiced at many centers, advanced resections are limited to a select group of surgeons and a few institutions. The reason is that advanced skills in both hepatopancreatobiliary surgery and minimally invasive surgery are required to safely perform these advanced procedures. Mastery of both skills requires significant time investments in observerships, practice of laparoscopic technical skills, and creation of an infrastructure.

Brice Gayet and Claudius Conrad have created this important study material to facilitate learning these advanced procedures. In the video atlas, basic and advanced anatomic resections of liver and pancreas, many of which are challenging to master even via an open approach, are demonstrated in a didactically well-structured fashion. Three-dimensional renderings of the relevant liver anatomy, port positioning, and critical phases of the operation are depicted in wonderfully detailed images. The textbook provides the foundation in hepatopancreatobiliary oncology and the current data on minimally invasive hepatopancreatobiliary surgery necessary to set the illustrated video atlas in a conceptual framework. In the descriptions and the videos themselves we recognize the didactic skills of Claudius Conrad and Brice Gayet. The in-depth knowledge and technical skills demonstrated by Brice Gayet are not only rooted in his professorship of surgery but also in that of anatomy for many years.

I strongly recommend that everyone aspiring to master these skills use this work as a study guide on a routine basis. Mastery of the important theoretical concepts and internalization of the operative approaches presented in this work are needed for optimal outcomes. In addition, the excellent didactic set-up and the high-quality and beautiful operations presented in the video atlas make this work an excellent study tool for surgeons performing surgery via an open approach.

Congratulations to Brice Gayet and Claudius Conrad on this important study material that will facilitate mastery of the art of advanced minimally invasive hepatopancreatobiliary surgery!

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MD Anderson Cancer Center
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# Preface

In the previous century, minimally invasive surgery was introduced to minimize trauma in gastrointestinal operations. After the first laparoscopic cholecystectomy, the indications for a laparoscopic approach increased significantly, particularly in colorectal surgery. Liver and pancreas surgery were initially thought to be unsuitable for laparoscopic techniques, due to the difficulties of safe mobilization and exposure. As a result, a significant number of experts in open hepaticopancreatobiliary surgery were reluctant to incorporate a laparoscopic approach into their practice and/or evaluate it in a randomized controlled trial.

Despite, and because of, significant advances in diagnostic, anesthesiological, and surgical technique that allowed for safer HPB surgery, these advances rarely became the bases for investigating how to make HPB surgery less invasive. This reluctance was rooted in the fear of losing the improvements the open HPB surgery community had achieved. Nevertheless, some expert centers reported on the feasibility and safety of laparoscopic HPB surgery and proved the benefits regarding reduced blood loss and pain, and improved recovery, compared to open liver surgery.

For open surgery, complete knowledge of HPB anatomy is essential. This is even more crucial when considering laparoscopic HPB surgery. For that reason, we have included two chapters on pancreas and liver anatomy by expert surgeons and anatomists from Japan, Drs Sakamoto and Takayama. These chapters will help to elucidate and safely reproduce the laparoscopic surgical techniques shown in the videos.

To date, two consensus conferences have been held on laparoscopic liver resections. One of the conclusions from the first consensus conference, held in 2009, was that laparoscopic resection of segments II and III should be considered the standard of care; the second conference in 2014 indicated that major resections were an innovative procedure, but still in an exploratory phase. An important conclusion by the consensus jury was that a "major focused effort is necessary to determine what laparoscopic skills are required by trainees and HPB surgeons to successfully perform major laparoscopic liver resections." Claudius Conrad and I hope very much that this textbook and video atlas will help initiate or ease this learning curve.

The development of laparoscopy has also proved to be beneficial in pancreatic surgery, and laparoscopic distal pancreatectomy currently represents the standard of care. Other procedures, such as advanced enucleations, middle pancreatectomy or pancreatoduodenectomy, remain investigational. However, recent series on these advanced pancreatic procedures suggest that laparoscopy offers significant potential in reducing morbidity.

This atlas of minimally invasive HPB surgery has been designed as a high-quality, comprehensive didactic tool. A work of this magnitude could only be achieved by the input of experts from around the world who have extensive experience in treating HPB diseases and are established educators who have successfully mentored many young surgeons. In this atlas, we attempt to elucidate and provide an update on the surgical and perioperative management of HPB disorders from a laparoscopic point of view. Claudius Conrad and I have prepared the didactic videos for both trainees and specialized HPB surgeons in a comprehensive manner with an attempt to present the topics in an easy and understandable format.

What does the future hold for us? A state-of-the-art advancement, stereoscopic vision (3D), is the latest innovation that, in our experience, can significantly reduce both bleeding and operative time. As computer-assisted surgery in the operating room is implemented that includes not only robotics (co-manipulation, so-called cobot) but also cognitics (automated cognition), we can expect to see further improvement and progress in the safety and patient outcomes related to minimally invasive HPB procedures. Already today, patients' imaging studies are used for virtual 3D modeling and visualization of anatomical or pathological structures. In the future, the synthesis of these advances will allow us to create an augmented reality during surgery. The next step is likely the development of true robotic interfaces to improve safety and reduce operative time and automation of algorithms for a better understanding of operative scenarios and treatments.

The creation of this atlas was undoubtedly dependent on the support and enthusiasm of an expert team. Claudius Conrad and I wish to thank all the authors who agreed to participate in this educational work and share their vast experience. Finally, I would like to thank our editor and Claudius' editorial team at the University of Texas MD Anderson Cancer Center, Houston, Texas, USA.

Brice Gayet
Paris

# Preface

> On résiste à l'invasion des armées; on ne résiste pas à l'invasion des idées . . .
>
> *Victor Hugo*

We live in exciting times. Hepato-pancreato-biliary (HPB) surgery is forging ahead into new territory. Those of us who aim to pioneer the field must be mindful of not only how novel its frontiers are but also, and more importantly, how valuable and how to extend ourselves to reach them. Surgeons are aiming to minimize the trauma of surgery, with the hopes of lowering morbidity, lessening time spent in hospital, potentially returning patients earlier to chemotherapy, or even improving long-term outcomes.

Because of the complexity of advanced HPB surgery, it was previously thought not to lend itself to minimally invasive surgery, but my coeditor, Brice Gayet, and others have shown us through their creativity and innovative work that the time for considering less invasive HPB surgery has come. I am delighted to be part of a community of surgeons aiming to advance the field of minimally invasive HPB surgery through reducing its morbidity and improving outcomes. My surgical mentors in Germany, the United States, Japan, and France have enabled me to make a meaningful contribution to this community, and I am very thankful to them for this.

With all of the excitement over the possibilities of laparoscopic HPB surgery, we must not forget its overarching goal, which is to obtain the best possible short- and long-term outcome for our patients. Since most patients undergo HPB surgery for cancer, it is paramount that oncological principles are observed if we are to ensure good outcomes. For that reason, it was important to me to ask international authorities in our field to contribute their expertise to this textbook and video atlas, since the best possible outcome can only be achieved if laparoscopic HPB surgery is put into the context of optimal oncological care. In addition to the contribution by these international experts, the camaraderie and the hard work of the international fellows at Institut Mutualiste Montsouris (IMM) were key in ensuring the success of this textbook and video atlas.

I hope very much that this textbook and video atlas will allow HPB surgeons to optimize outcome for their patients. I would like to thank Brice Gayet, our contributors, co-fellows at IMM, the editorial team, and, most importantly, my patients who have made this textbook and video atlas of laparoscopic hepato-pancreato-biliary surgery possible.

Claudius Conrad
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# About the companion website

This book is accompanied by a companion website:

www.wiley.com\go\conrad\liver-pancreas-biliary-laparoscopic-surgery

The website includes:

- videos, with transcription
- critical anatomy pictures
- port positioning
- important intraoperative pictures
- important points.

How to access the site:

Access to the website requires a password. There is a prompt on the website about how to obtain the password.

# PART I
# Textbook

**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

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Edited by Claudius Conrad and Brice Gayet.

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 Phillipp 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].

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

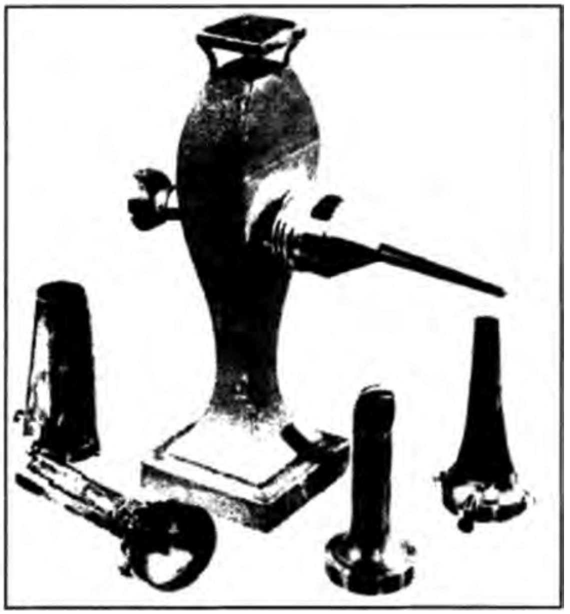

**Figure 1.2** The lichtleiter (an original owned by the American College of Surgeons, Bush Collection). The 200th Anniversary of the First Endoscope: Phillip Bozzini (1773–1809). Source: Morgenstern 2005 [4]. Reproduced with permission of Sage Publications.

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.

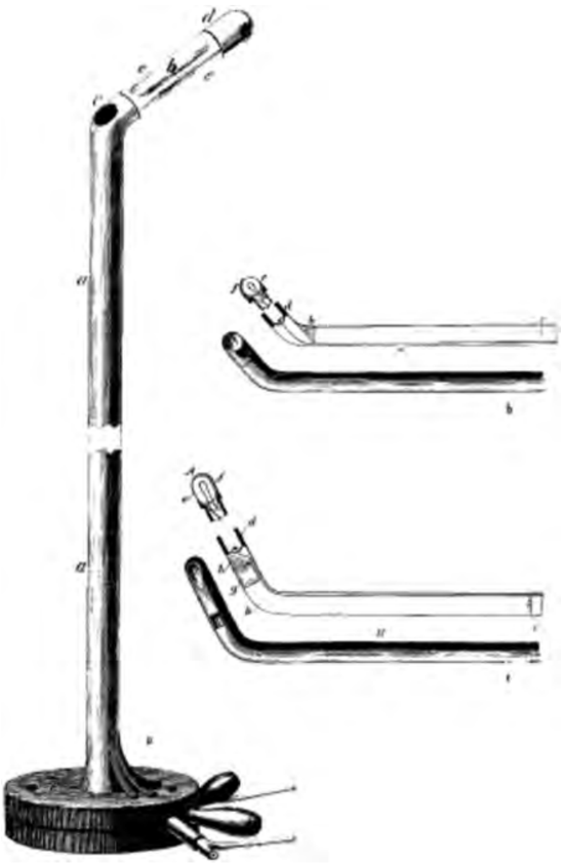

**Figure 1.4** Nitze cystoscope of 1877. Source: Mouton 1998 [5]. Reproduced with permission of Springer.

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

**Figure 1.5** George Kelling. Source: https://en.wikipedia.org/wiki/Georg_Kelling#/media/File:Portrait_georg_kelling.jpg. Used under CC BY-SA 3.0 de - http://creativecommons.org/licenses/by-sa/3.0/de/deed.en.

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

| |
|---|
| Coelioscope: George Kelling, 1901 (Germany) |
| Ventroscopy: Dimitri Ott, 1901 (Petrograd/St Petersburg) |
| Organoscopy: Bertram Berheim, 1911 (Johns Hopkins University) |

**Figure 1.6** Hans Christian Jakobaeus MD, performing a thoracoscopy. Source: Braimbridge 1993 [10]. Reproduced with permission of Elsevier.

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

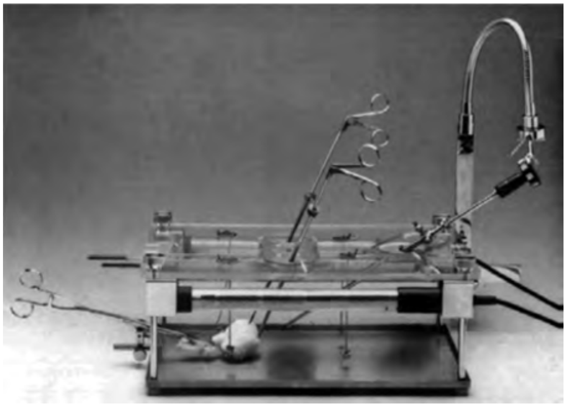

**Figure 1.7** Kurt Semm's "pelvitrainer." Surgical training system with a novel approach. Source: Semm 1986 [12]. Reproduced with permission of Thieme.

**Figure 1.8** Erich Mühe. Source: Society of Laparoendoscopic Surgeons.

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

- 1901: Kelling examines the abdominal cavity of the dog with a cystoscope
- 1911: Jakobaeus – first laparoscopic series in a human
- 1929: Kalk – oblique view, double trocar technique
- 1938: Veress – abdominal puncture needle
- 1970: Semm – automatic insufflation
- 1974: Hasson – open laparoscopy trocar
- 1986: TV camera adapted to optics
- 1987: First laparoscopic cholecystectomy by Mouret
- 1992: First laparoscopic liver resection by Gagner
- 1994: First laparoscopic pancreaticoduodenectomy by Gagner and Pomp

## 1.3 Laparoscopic hepatopancreatobiliary (HPB) surgery

### 1.3.1 Gallbladder surgery

As mentioned above, Mühe performed the first laparoscopic cholecystectomy in 1985 and was surprised by the patient's quick recovery [7,11]. He proclaimed "I can't believe it, the patient has bowel movements almost immediately after the surgery!" [11]. In 1986, Mühe presented his technique to the Congress of the German Surgical Society [11]. The audience was skeptical to say the least; Mühe's presentation received numerous negative comments, and his peers said that this was "Mickey Mouse surgery" or "small brains for small incisions" [11]. In 1988, Philippe Mouret from Lyon, France, presented a technique of laparoscopic cholecystectomy similar to that put forward by Mühe two years earlier [2,3,6,13]. Mouret also encountered criticism, this time from the French Surgical Society. This, however, inspired the French surgeons François Dubois (Paris) and Jacques Perissat (Bordeaux) to develop their technique for laparoscopic cholecystectomy independently in 1988 [13].

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. Schwenk *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. The

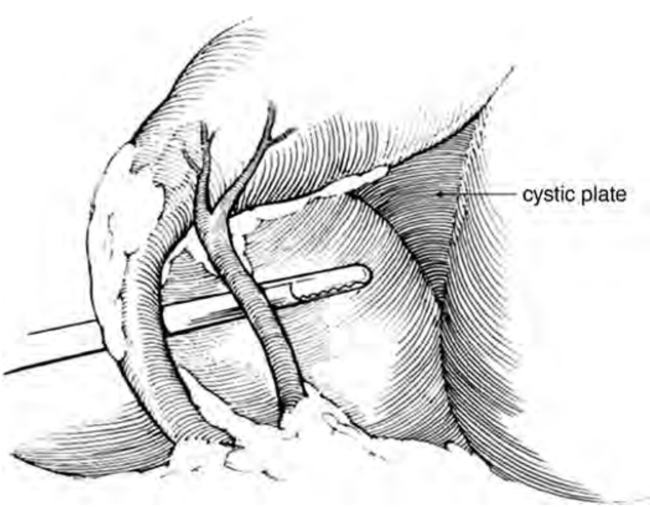


**Figure 1.9** The critical view of safety. The triangle of Calot has been dissected free of fat and fibrous tissue, but the common bile duct has not been displayed. The base of the gallbladder has been dissected off the cystic plate and the cystic plate can be clearly seen. Two, and only two, structures enter the gallbladder and these can be seen circumferentially. Source: Strasberg 2010 [23]. Reproduced with permissions of Elsevier.

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 Morgenstern 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

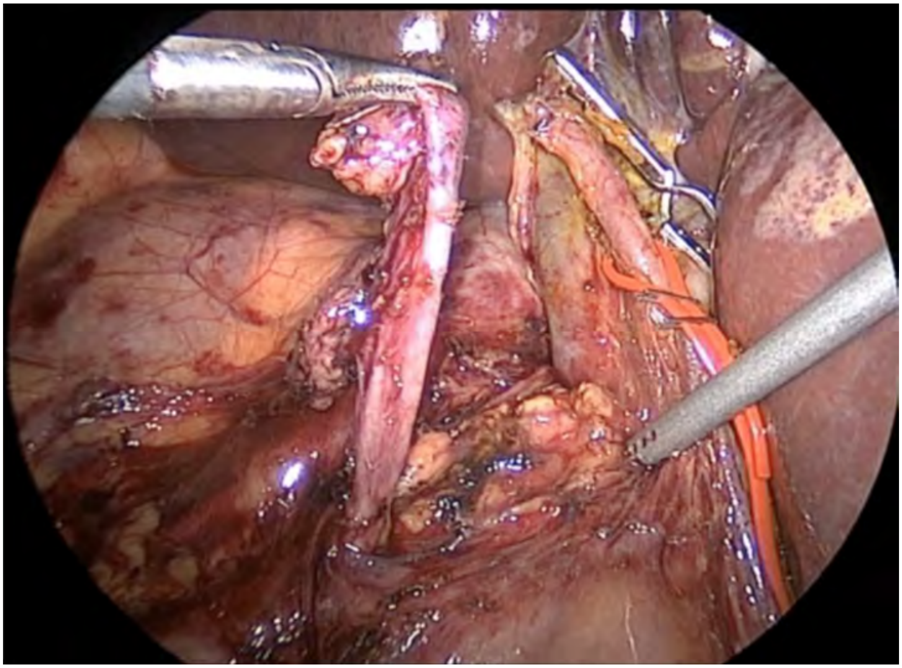

**Figure 1.10** Laparosopic intrapancreatic choledochal cyst excision. The cholecochal cyst has been excised from cephalad to caudad with complete intrapancreatic dissection. A bulldog clamp is noted at the level of the bifurcation; the hepatic artery is surrounded by a vessel loop. Source: Horacio J. Asbun. Reproduced with permission.

"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 expensive with longer operative time but to have a higher success rate for splenic preservation [51]. Ergonomically, the robotic platform seems to have a clear advantage over conventional laparoscopy. While tactile feedback is lacking, a greater range of motion of the robot can potentially circumvent some of those challenges. It is evident that cost is an important determinant of the utility of robotically assisted laparoscopic surgery.

#### 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.

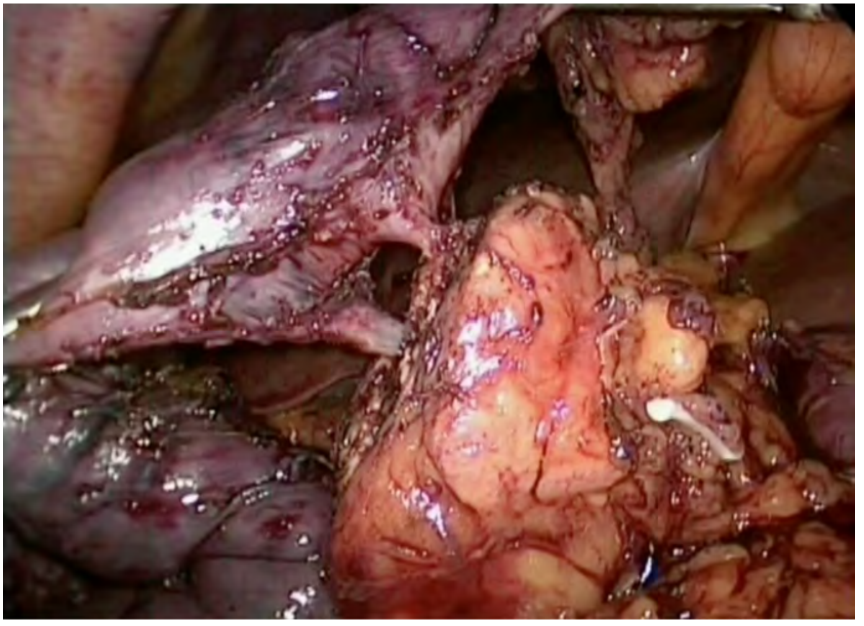

**Figure 1.11** A laparoscopic pancreas-preserving total duodenectomy performed for a large ampullary adenoma in a patient with pancreas divisum. The duodenum has been completely separated for the pancreas except for the two ducts. Source: Horacio J. Asbun. Reproduced with permission.

### 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 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 hepatectomies [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 beginnings, laparoscopy has spread globally and minimally invasive HPB surgery has been at the forefront of this revolution. We have proved beyond doubt that it is safe, effective, and oncologically sound and that for the majority of patients it leads to better outcomes. 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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Videos 1–26 will be of interest to readers of this chapter.

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## CHAPTER 2

# Acquisition of specific laparoscopic skills for laparoscopic hepatopancreatobiliary surgery

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### EDITOR COMMENT

In this important chapter on skill acquisition for advanced laparoscopic surgery, Drs Mees and Maddern highlight the important steps required to safely learn complex laparoscopic HPB surgeries. Recognizing that the acquisition of laparoscopic HPB surgery skills represents a time-consuming and challenging process, the authors suggest a thoughtful step-wise approach. In addition to simulator and nonsimulator-based skill acquisition, they propose a multistep process to develop not only the surgical skills required but also a well-trained team capable of efficient teamwork. The authors expand on ergonomics as an important factor for optimal application of learned laparoscopic HPB skills. Further, they describe how a surgical mentor allows for a safe transition from training to practice. Finally, we agree very much with the authors that advanced laparoscopic procedures require constant training and advancement to maintain the required skill level.

**Keywords:** ergonomics, laparoscopic skill acquisition, simulations, team training

## 2.1 Introduction

Laparoscopic surgery has risen in popularity in recent years, and laparoscopic training now represents an important factor in the surgical curriculum. Training in laparoscopic surgery is crucial, because insufficient training and limited experience are associated with an increase in the number of technical errors, can compromise patient safety, and may lead to poorer clinical outcomes [1]. This has been illustrated by the early experience with laparoscopic cholecystectomy. The incidence of adverse outcomes attributable to cautery injury was increased during early adoption of the technique and steadily diminished as surgeons became more experienced in the special requirements of laparoscopic surgery [2,3]. Crucial factors that limit the performance of surgical trainees in laparoscopic surgery are a lack of complete understanding of the operative steps, deficiency in synchronized movement of the nondominant hand, and fatigue [4].

The loss of depth perception because of the two-dimensional image, limited haptic feedback from tissue, usage of instruments with restricted range of motion, a small working field, and the fulcrum effect make laparoscopic techniques difficult to acquire for trainees. These challenges demand a comprehensive approach [5–7]. For laparoscopic surgery education, a variety of training options exists, including training in the operating room, synthetic (inanimate) models, box trainers, virtual reality trainers, animal models (ex vivo animal tissue models or in vivo animal models), and human cadaver models.

In the past, laparoscopic skill training was largely conducted via the mentored approach, consisting primarily of one-on-one teaching in the operating room. Though this approach is still widely used, it represents a suboptimal training option owing to current time and budget limitations. The restrictions on surgeons' work hours, from both a legislative and productivity perspective, have reduced the number of hours during which trainees are available for teaching. They have also reduced the time during

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which experienced surgeons are available to assist and teach trainees [8–10]. Additionally, the mentored approach of learning new skills on actual patients raises ethical and medico-legal concerns. These issues have resulted in the increasing use of simulations in the education of minimally invasive surgery.

Simulators have an advantage over in-theater training, in that they allow for repetitive practice without any time limitations. The training is performed in a safe environment and provides immediate performance feedback that facilitates learning. The use of simulators for teaching laparoscopic surgery skills has been shown to improve cognitive skills, technical knowledge, psychomotor skills, and surgical performance of the surgeons in the operating room, when compared with conventional mentored, in-theater, training [11,12]. A prospective, randomized, controlled trial evaluating laparoscopic trainers for basic laparoscopic skills acquisition showed that the combination of inanimate box training and virtual reality training results in better laparoscopic skill acquisition than either training method alone or no training at all [13]. These findings are supported by a prospective single-blinded, randomized trial showing that learning laparoscopic suturing on either a virtual reality simulator or a box trainer significantly decreased the learning curve. This study also indicates that, while virtual reality training is the more efficient training modality, box training is the more cost-effective option [14]. In a recently published randomized study using fresh cadaver models, positive learning results were also seen. Training using this model resulted in significantly improved basic laparoscopic skills with subsequent improved performance in virtual reality trainer tasks [15].

The maximum benefit of laparoscopic skills training will be achieved if a single task is practiced repeatedly, at least 30–35 times [13] rather than practicing a variety of skills at the same time [16]. Training over several days [17] with a systematic, interval training schedule has proven to be superior for laparoscopic skill acquisition, compared with training in a single day [18]. Considering the limitations on work hours, training can be offered outside regular work hours if trainees are seeking additional training [19]. In terms of maintaining the acquired skills, studies have shown that deterioration in skills occurs after several weeks without training. It is therefore recommended that training is ongoing and repetitive [20].

In spite of positive reports for simulators in surgical education, there are signficant limitations. These relate to the lack of realism, inability to simulate unusual anatomy, and lack of realistic operative stress in which the training occurs. Technical skills are only one aspect of successful surgery, and simulators rarely teach clinical judgment and acumen, skills which only develop with real experience.

In 2006, a systematic review evaluated the effectiveness of surgical simulation in comparison with other methods of surgical training [21]. The review showed that none of the methods of simulated training has yet been shown to be superior to other forms of surgical training. Thus, the main question remains unanswered: does simulator performance correlate with operative performance? Recent studies show evidence to support the increase in use of simulators as a core component in the training of a competent laparoscopic surgeon [6,11,22,23]. Further, evidence is now accumulating that simulation training can be transferred into the operating room itself [24]. Therefore, the acceptance of simulation-based training into surgical skill training programs is improving and plays an important role in many training programs for advanced laparoscopic procedures, such as liver or colorectal surgery [12,25].

## 2.2 What skills and/or requirements are needed for laparoscopic liver and pancreatic surgery?

### 2.2.1 Surgeon's requirements

Minimally invasive surgery confronts the surgeon with problems that do not exist in traditional/open surgery. In minimal invasive surgery, ergonomics plays an important role in optimal surgical performance in an extended operation. It deals especially with difficulties due to the field of view (2D view of 3D space), eye–hand coordination, limitation of surgeon movement because of port placement, and handling of (inadequate) laparoscopic instruments. Ergonomic factors that should be considered before a hepatopancreatobiliary (HPB) laparoscopic procedure include maximizing patient safety and chances for successful minimally invasive completion of the case, while minimizing physical strain on the operative team and increase in surgery time.

### 2.2.2 Ergonomic considerations

Laparoscopic HPB surgery requires the use of dedicated equipment, as well as the proper positioning of equipment, and also of the patient and the surgical staff to maximize ergonomics. Thus, one of the first steps before starting a laparoscopic procedure should be communication between the surgeon(s), the nurses, and the anesthetist, in order to clarify what procedure will be done and what equipment is needed. This discussion can prevent unnecessary and time-consuming measures, such as repositioning maneuvers or lack of instruments.

The positioning of the patient depends on surgeon preference. Thus, the surgeon responsible for the operation should position the patient himself or herself to ensure that he or she can carry out the operation in the most comfortable and most ergonomically efficient way to maximize patient safety. For this, not only has the port positioning to be considered but also the position of the patient may need to be modified to ensure that ports can be placed in the optimal positions.

It is most important that the equipment is placed and subsequently adjusted to be in the "optimal position"; the position of the equipment, instruments, and operating table should allow a physiological posture for the surgeon, including a straight head (without rotation or extension of the cervical spine), shoulders in a physiological position with arms alongside the body, elbows bent to 70–90°, forearms in an horizontal or slightly descending axis, and hands pronated [26]. The thoracic and lumbar spine and legs should be in a neutral position without rotation, anterior or lateral flexion. Noncompliance with these principles can cause cervical aches and pain to the shoulders, forearms, and fingers and can even cause paresthesia or hypoesthesia of the thumb [27,28]. The "optimal position" requires that the equipment – especially all cable-based items, such as scope, electrosurgical devices, or insufflation and light source – is easily accessible for the operative personnel.

Ergonomics of optics are very important in laparoscopic surgery and should be considered prior to every operation. The surgeon should face the target organ and be in line with the lens and monitor. The monitor must therefore be placed in the surgeon–organ–monitor line and be at or lower than eye level to minimize fatigue and cervical ache. The center of the monitor should be placed 20° lower than the eyes, because the position naturally adopted by the eyes is 15–20° towards the ground when the cervical spine is in a neutral position [29]. This position corresponds to the resting position of the oculomotor muscles, and differing from this position puts these muscles at strain. In longer operations, surgeons tend to overextend their cervical spine in order to return to this resting position. Therefore, the vertical position of the monitors should be adapted to each surgeon.

### 2.2.3 Port placement

Every procedure has its ideal port positioning, which may be changed according to patient anatomy, esthetic considerations or surgeon's preference. Therefore, it always constitutes a compromise, taking into account patient factors, target organ, and surgeon preference.

In HPB laparoscopic surgery, the optical port is often placed near the umbilicus, allowing for a favorable overview of the abdominal cavity. Nevertheless, this central and generally suitable position may be unsuitable for some patients. For example, the umbilicus of obese patients is more caudal, and positioning the port at the umbilicus will move the optic away from the operative target. Furthermore, patients with previous midline laparotomies usually have periumbilical adhesion and the port placement in midline or the umbilicus can be difficult and even dangerous. Some surgeons prefer optic ports and insert them off midline (e.g. Palmer's point, 3 cm below the left costal margin in the midclavicular line) to gain optimal access. Nevertheless, there are two important principles that should be adhered to in order to optimize the view and range of instruments: triangulation and sectoring.

The principle of triangulation means that (i) ports are positioned on an arc 20 cm from the target; (ii) the optical port centers the image and operating ports are located 5–7 cm on either side; and (iii) ports form an angle of 60–90° to the target [30,31]. Retracting ports are placed outside this triangulation zone, either laterally or at the superior portion of the arc, minimizing instrument conflict. This principle reproduces the set-up of open surgery, with a central visual field bordered on either side by the operative hands. However, the camera positioned between the hands of the surgeon may represent a potential conflict owing to instruments clashing with the camera.

The second principle is sectoring [31]. The optical port is placed laterally to the operating port. A minimal distance of 5–7 cm is necessary between two ports for the instruments to meet at such an angle that permits the performance of complex movements. The main advantage of sectoring is that it allows the surgeon to move freely, as the camera is away from the operative field and there is no physical contact between the surgeon and the camera holder.

In conclusion, both triangulation and sectoring are important principles, and the final position of the ports depends on the exact location of the target, which must be considered prior to port insertion, on patient anatomy, and ergonomics of the surgeon.

### 2.2.4 Institutional requirements

Laparoscopic HPB surgery is complex and requires advanced laparoscopic skills. In 2008, the Louisville Statement (International Position on Laparoscopic Liver Surgery) was published following a consensus conference of 45 experts in hepatobiliary surgery [32]. This consensus paper stated that liver surgeons "should be facile with laparoscopic suturing and other techniques of laparoscopic hemorrhage control, negating the need to convert. Additionally, major vascular injuries, although exceptional, may not allow time for conversion and require a surgeon with extensive laparoscopic training." The group of experts furthermore agreed that "laparoscopic liver surgery should be initiated only in centers in which the combined expertise in liver and laparoscopic surgery exists" in line with statements from other published work [33,34]. The recommendations of the Louisville Statement clarify that HPB surgery should be performed by experienced HPB surgeons in hospitals with experience in complex surgery. In our personal opinion, hospitals in which laparoscopic HPB surgery is performed need a 24-hour/7 days a week service of at least (i) an experienced HPB surgeon; (ii) an interventional radiologist (the latter two should be at least off-site on call and available for emergency interventions within 20 minutes); and (iii) an intensive care unit. In addition, team orientation and training, especially in the beginning of a HPB surgery program, are highly recommended for HPB surgery to optimize surgical results and patient safety [35].

### 2.2.5 Acquisition of skills

In the last decade, several studies have reported feasibility, safety, and favorable outcomes after laparoscopic liver [36–40] and pancreatic surgery [41–44]. Learning laparoscopic HPB surgery is feasible via the mentored approach in theater [45]; however, distinct learning curves have been demonstrated for these complex procedures [46–49], and the quantity of these procedures is generally limited because of a careful selection of adequate cases. Therefore, a systematic training program needs to be developed to enable surgical trainees to gain required laparoscopic HPB skills.

In general, surgeons who have already acquired advanced laparoscopic and traditional HPB skills might consider the pathway presented in Figure 2.1 as a practical guideline to start their training.

With progress in the field of simulation-based training, HPB-specific psychomotor skills can be gained on a surgical simulator [50]. For example, performing the Pringle's maneuver or a left lateral hepatectomy on a virtual reality trainer would represent appropriate exercises to start the training. Laparoscopic training on these simulators is highly recommended, but they are expensive and not universally available.

As a next step, surgeons should attend a laparoscopic training course to gain primary laparoscopic HPB skills. A multitude of courses are available worldwide, but they are of variable quality. A worthwhile course should provide lectures, debates, and discussions concerning anatomical variations and factors. Furthermore, the course should include in vivo training in an animal model to practice placement of ports, use of instruments, dissection/resection of organs, and how to deal with potential complications (Figure 2.2).

A training program for laparoscopic liver resections should include the following key steps.

1. Positioning of ports for the planned surgery.
2. Placement around the hepatoduodenal ligament for a safe Pringle's maneuver.
3. Dissection of hilar structures, portal vein, hepatic artery, and confluence of the hepatic ducts and common bile duct.
4. Left lobe procedures.
   - Left lobe mobilization.
   - Parenchymal transection devices:
     - i Electrosurgical devices (e.g. Harmonic, Thunderbeat, LigaSure, bipolar forceps)
     - ii Ultrasonic devices (e.g. cavitron ultrasonic surgical aspirator)
     - iii Stapling
     - iv Additional relevant techniques
5. Right lobe procedures.
   - Right lobe mobilization.
   - Right hepatectomy including dissection/stapling of hilar structures and right hepatic vein.

After attending a laparoscopic HPB training course, an observership in an institution with expertise in laparoscopic HPB surgery is highly recommended. Observing an experienced surgeon and his or her team performing this complex surgery gives excellent insights and provides a


**Figure 2.1** Pathway to acquiring laparoscopic HPB skills.

valuable opportunity to ask questions and evaluate differences in surgeon approach. The observer can follow the complete procedure, plan their own surgery in their mind, and discuss all major and minor issues around the laparoscopic surgery with the experienced team.

A recommended transition step between the observership and performing the first surgery on a patient is the consolidation of the acquired manual and theoretical skills in an animal model or human cadaver. The manual skills especially should be performed in a stress-free atmosphere with the opportunity to practice and perfect the surgical procedures. Additionally, learning to use high-energy devices such as diathermy, dissection or tissue handling, with the current simulators available, is still more efficient in an animal model compared with inanimate simulators.

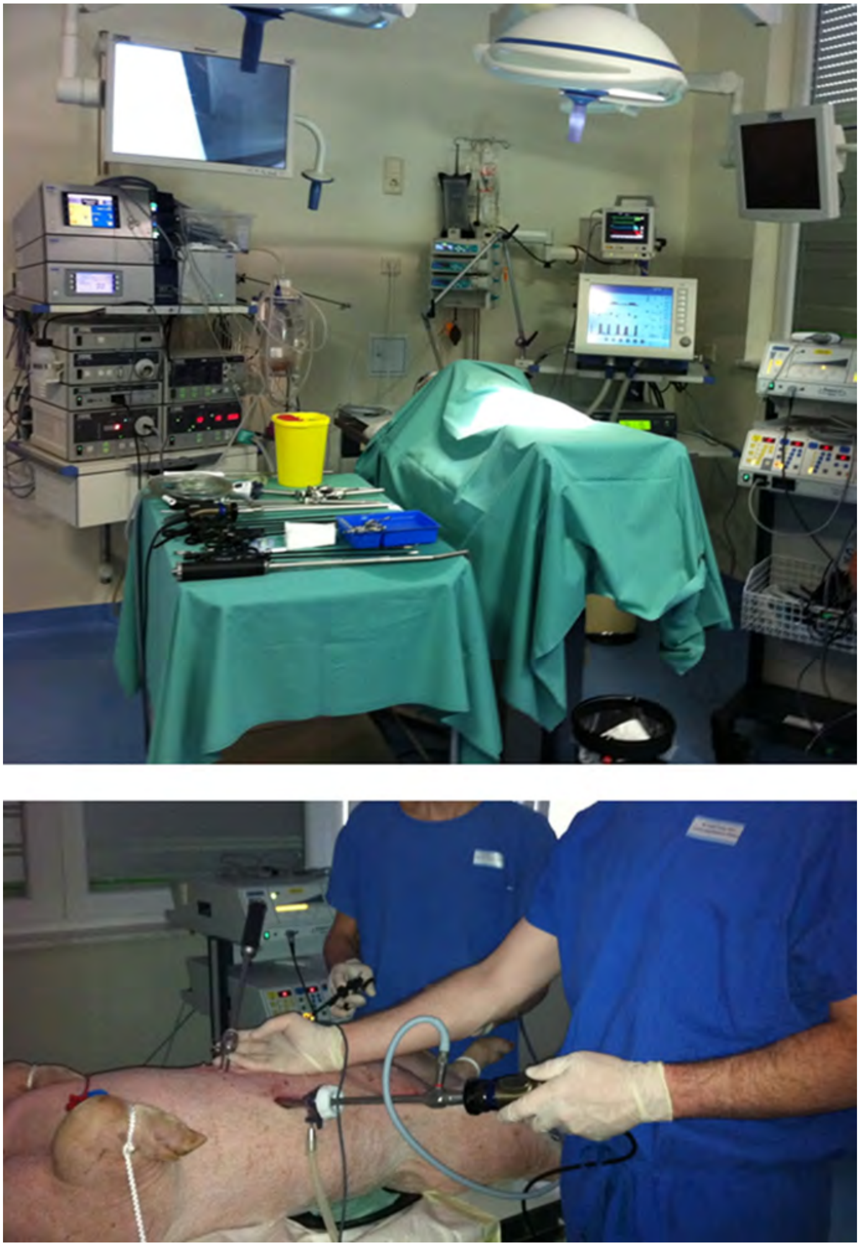

Figure 2.2 Exemplary presentation of an in vivo training set-up (pig model), including the use of modern electrosurgical devices and ultrasound dissector.

A number of different animal models have been widely used in laparoscopic training, but there are limitations to each of these models. In laparoscopic liver surgery, a variety of animal models have been described in the literature: rat [51] and canine [52,53] models have been advocated, but their major drawback is anatomical constraints, e.g. differences in size, number, and/or placement of liver lobes. Porcine models have been used extensively because of size and similar anatomy [54,55]. Sheep have also been used for liver resections because their anatomy is similar to humans [54,56]. For laparoscopic pancreas surgery, pancreaticoduodenectomies and distal pancreatectomies have been performed in porcine training models [57–59], although the porcine pancreas is less firm than the human pancreas.

Human cadavers have been used for many years to teach anatomy and are still considered a very effective approach for achieving important learning objectives in the field of anatomy [60–62]. In addition, cadaver training has been shown to be beneficial in the training program of general surgery [63,64], neurosurgery [65], vascular surgery [66], and trauma surgery residents [67].

Recently, frozen human cadavers have been used in laparoscopic skills training because of the close similarities to operative anatomical landmarks, consistency, handling of tissues, haptic feedback, and the use of gravity [68,69]. Additionally, patient positioning, port insertion, the use of instruments, and imitation of critical steps help to optimize the surgeon's training [70,71]. In this respect, hands-on training courses in colon, hernia, bariatric, and vascular surgery using Thiel human cadavers (a special method providing soft-fix embalmed cadavers) have been reported to be excellent models to teach advanced minimally invasive surgery [72]. For example, studies have demonstrated excellent learning results for laparoscopic nephrectomy using the Thiel human cadaver method [73] and have suggested that this training is superior to porcine models for urological laparoscopic training [74]. In terms of laparoscopic HPB surgery, cadavers have not been used for liver or pancreatic resection, but studies have shown evidence that in single-site laparoscopic cholecystectomy [75] and laparoscopic living donor procurement for liver transplantation such training is beneficial [76].

After training and consolidating surgical skills in an animal/cadaver model, it is advisable to perform the first laparoscopic HPB surgery on patients in the presence of a mentor or preceptor. The mentor, e.g. the surgeon from the observership, should be an experienced laparoscopic HPB surgeon who can supervise, support, and interact in this first laparoscopic case, if required. Mentorships have been shown to be helpful in medical training in general [77,78], and studies have demonstrated significant benefits in laparoscopic surgery training [79,80]. A mentored approach provides additional safety for the patient and protects the surgeon-in-training. It also represents an opportunity to recognize learner-specific challenges and optimize the set-up. In our opinion, an ideal mentorship plan for training in this system may include four mentor-supervised resections on two consecutive days (two operations per day).

It is recommended that the trained surgeon starts their laparoscopic HPB surgery independently with less complex cases, such as a left lateral sectionectomy, and advances gradually. It should always be borne in mind that advanced minimally invasive HPB surgery is complex and requires teamwork. The entire team, including anesthetists, theater nurses, and surgical trainees, needs to be trained and prepared for these kinds of procedures and proficient to deal with potential complications.

It is important to establish the safety and effectiveness of new surgical procedures, and they should be monitored after their introduction. An audit of indications and outcomes is recommended to evaluate the surgical morbidity and mortality. Ideally, the audit should be performed by an external, experienced HPB surgeon in order to achieve an objective and nonbiased assessment. Furthermore, internal processes for the reporting of any adverse events from new procedures should be developed and external processes considered, e.g. participation in multicenter audits [81].

The final step in the process of training in laparoscopic HPB skills is teaching. It is time-consuming and difficult to gain proficiency in minimally invasive HPB surgery, and it is an obligation to transfer the acquired skills to other surgeons for the benefit of our patients.

## 2.3 Conclusion

Acquisition of laparoscopic HPB surgery skills represents a time-consuming and challenging process. The skills will be acquired in a multistep process, and these complex procedures demand a well-trained team and efficient teamwork to achieve success. Having a surgical mentor who will supervise the team performing their first procedures is highly recommended. Finally, it should be mentioned that these advanced laparoscopic procedures require constant training and advancement; therefore, skill acquisition in laparoscopic HPB surgery will require continuous re-education and refreshing and updating of knowledge on an ongoing basis.

**KEY POINTS**

- Laparoscopic HPB skill acquisition is time consuming but necessary to ensure patient safety during advanced laparoscopic HPB procedures.
- Simulator-based and nonsimulator-based training methods are effective in acquiring the necessary skills.
- A thought-out, step-wise process from skill acquisition to clinical application that may incorporate a mentor may be an effective way of applying the learned skill set.
- Team training should be incorporated in the skill acquisition process.
- Continuous learning and skill maintenance is necessary to perform advanced laparoscopic HPB surgeries at the highest level of proficiency.

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