# Glissonean Pedicles Approach in Minimally Invasive Liver Surgery

Benedetto Ielpo
Edoardo Rosso
Alessandro Anselmo
*Editors*

*Foreword by*
Atsushi Sugioka

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# Foreword

This book covers liver surgery of the Glissonean pedicles, particularly in the context of minimally invasive liver resections (MILRs), its history, and the detailed surgical techniques. The editors are very experienced HPB surgeons from three prestigious European HPB centers and have the great merit to have put together some of the best experts worldwide that have covered all the aspects of this “new” approach to liver surgery. From history to anatomy, ending with detailed description of pedicle isolation for each type of hepatectomy, this work is a beautiful journey through the universe of anatomical liver resections.

The main concept behind this approach is that to standardize MILR, it is necessary to establish techniques to control the Glissonean pedicles that will enable not only to avoid complications, but also to remove the optimal amount of liver parenchyma. This technique is called “anatomic liver resection” and is fundamental for all types of liver resection and known to provide safe and favorable outcomes. However, many surgeons are not familiar with the Glissonean pedicle approach and anatomic liver resection in MILR at present. This very-well-written volume is the first one that is entirely focused on Glissonean pedicle approach and will be extremely useful for the current and the next generation of liver surgeons, helping them to handle with the Glissonean pedicles.

Couinaud proposed various approaches to the Glissonean pedicles, as follows: (1) intrafascial approach, (2) extrafascial approach, and (3) extrafascial and major fissural approach. The intrafascial approach means individual vascular dissection, whereas the extrafascial approach is Glissonean pedicle isolation in a broad sense. The extrafascial approach is further divided into two categories: one without liver parenchymal destruction, and the other with minor liver transection. The former is an extrahepatic Glissonean pedicle approach.

We have demonstrated the comprehensive and precise anatomy of the liver based on Laennec’s capsule that is a true membrane of the liver described by Laennec in 1802, which was ignored for more than 200 years. The technique of extrahepatic Glissonean pedicle isolation will come into practical use via “the gate theory.” This means that the gaps between Laennec’s capsule and the Glissonean pedicle can only be entered through the six gates defined by the four anatomical landmarks (the Arantius plate, umbilical plate, cystic plate, and pedicle of the caudate process (G1c)), and approach to the desired gate enables us to isolate any extrahepatic Glissonean pedicle at will.

The remaining issue of MILR is to establish a technique to control the hepatic vein. This is nearing completion owing to the fact that the Laennec's capsule also exists surrounding the hepatic vein and that is composed of two layers, as revealed by Monden and Kiguchi. All the aforementioned concepts are very well described and deepened throughout the pages of this book that will contribute to broadening of the knowledge of the Glissonean approach and to establishing of safe and curative MILR.

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# Preface

> Great is the fortune of he who possesses a good bottle, a good book, and a good friend—*(Molière)*.

As often happens, great ideas are conceived in a moment of relaxation, in company of sincere friends and in front of a good glass of wine.

Same for this book, which came to life from a common intuition, on a sunny day in June 2021.

Three friends, three hepatobiliary surgeons, meet in Barcelona, Spain, for surgical training in liver resections. They discover that for all this time, they have all been studying the same technique for hepatic resections coming from the East: “the Glissonean approach to hepatic pedicles.” They are passionate and thus was born the idea of sharing with the scientific community the latest notions on this fascinating and relatively new method (at least for the Western community) to perform anatomical liver resections in the context of minimally invasive surgery. Friends soon become many more. This volume is, in fact, the result of the work of some of the most talented Italian and European hepatobiliary surgeons, plus some from the well-known Japanese school. An experienced surgeon, like a young one, will find in this book some new concepts on Glissonean anatomy of the liver based on the Laennec’s capsule, precious notions of intraoperative ultrasound for the identification of biliovascular pedicles, details of minimally invasive surgery techniques, and numerous and valuable expert’s “tips and tricks” to be applied to each hepatic segment to be resected. A large set of surgical videos available online complete this work, which we invite you to savor slowly, just like sipping a good glass of wine.

Special thanks go to all the friends and authors who have given their valuable contribution, and our warm appreciation goes to Professor A. Sugioka, pioneer of this technique, who honored us with his enlightening foreword.

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| Rome, Italy | Alessandro Anselmo |
| Barcelona, Spain | Benedetto Ielpo |
| Luxembourg, Luxembourg | Edoardo Rosso |

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# About the Editors

**Benedetto Ielpo** is currently working as a senior surgeon at the HPB unit of the Hospital del Mar at Barcelona. From the beginning of his career, he has put in many long hours in both surgical and research activities, especially in minimally invasive procedures (including laparoscopy and robotics) and oncological surgeries. He is currently an Associate Professor at Pompeu Fabra University of Barcelona and Formal Secretary of the Spanish Chapter of the American College of Surgeons (ACS) and is certified by the European Board of Surgery in both hepatobiliopancreatic and oncological surgery. He is the president and founder of ACIE (Surgical Association of Italian Surgeons in Europe) and author of more than 140 publications in indexed journals.

**Edoardo Rosso** is the Head of the Department of General, Mini-invasive, and Robotic Surgery of the Centre Hôspitalier de Luxembourg. He is an expert of HPB surgery, particularly in the field of vascular resection and mini-invasive surgery. He is also a Fellow of the European Board of Surgery, Division of HPB. He has a huge experience in educational promotion in the HPB field. He is the author and co-author of more than 100 publications indexed in Web of Science and many surgical videos.

**Alessandro Anselmo** is a senior consultant surgeon at the Dept. of Surgery, HPB, and Transplant Surgery Unit, Policlinico Tor Vergata, Rome, Italy.

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He is a liver and kidney transplant surgeon with extensive experience and passion in oncologic HPB surgery. He has a strong interest in new technologies applied to minimally invasive liver and pancreatic surgery. He is also the author of 119 publications indexed in Web of Science and many surgical videos. He is an Aggregate Professor of Surgery at the Faculty of Medicine, Tor Vergata University of Rome. He is also an organizer, presenter, moderator, and faculty in many international and national meetings and courses.


Barcelona, June, 29, 2021
Alessandro Anselmo - Edoardo Rosso - Benedetto Ielpo


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# Part I

# Overview

# The History of Glissonean Approach: From Takasaki to PAM Consensus

# 1

Alessia Fassari, Vito de Blasi, and Edoardo Rosso

## 1.1 Historical Background of Surgical Anatomy

Anatomy, as Leriche writes, is unquestionably the oldest instrument of knowledge, and it remains the basis of all surgery. We can think that it has already said everything, but whenever surgery approaches a new field, the anatomy must be reviewed, and the experience shows that it provides details that were missing. We don't find something unknown, but the point of view changes. We look for details that a purely descriptive aspect had not preserved or whose interest we had not seen.

The vasculo-biliary sheath, containing the portal vein, the hepatic artery, and the bile duct, was first discovered in 1640 by Johannis Walaeus [1] and then described by the British anatomist Francis Glisson in 1642 [2]. In 1802, Rene T. H. Laennec [3] reported the existence of a proper membrane distinct from the serosa.

The plate system concept, a fibrous thickening part of the Glissonean sheath, was established by the French surgeon and anatomist Claude Maurice Couinaud in his text *Surgical Anatomy of the Liver Revisited* [4]. He proved the lack of continuity between the Glissonean pedicle and the Laennec's capsule. However, the importance of the latter was overlooked for two centuries. Only in 2008 the histological study on cadaveric livers published by Shogo Hayashi in Japan [5] proved the existence of Laennec's capsule enveloping the pedicles as a separate entity and revealed that the so-called Glissonean capsule derived from Laennec's capsule and not from the Glissonean sheath.

Subsequently, in 2017, Sugioka et al. from Fujita University [6] reported a comprehensive surgical anatomy of the liver based on Laennec's capsule giving a theoretical background to the extrahepatic Glissonean pedicle isolation. Sugioka describes the Laennec's capsule as a dense fibrous layer beneath the serosa surrounding the bare area, the Glissonean pedicle, the cystic fossa, and the outside of the hepatic vein. He recognized the existence of four anatomical landmarks (the Arantius plate, the umbilical plate, the cystic plate, and the caudate process pedicle) and six gates: (1) the caudal end of the Arantius plate, (2) the junction between the round ligament and the umbilical plate, (3) the right edge of the Glissonean pedicle root of the umbilical portion, (4) the left edge of the posterior extremity of the

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cystic plate or the anterior Glissonean pedicle, (5) the bifurcation of the right main Glissonean pedicle, and (6) the space between the posterior Glissonean pedicle and the caudate process pedicle. The six gates represent the entry/exit points to the plate system, the space between the Laennec capsule and the Glissonean pedicle enabling suprahilar, extrahepatic dissection without parenchymal injury.

These preliminary anatomical considerations are indispensable for understanding the Glissonean pedicle approach. According to Couinaud three main approaches to the inflow system at the hepatic hilus are described: the classical intrafascial, the extrafascial, and the extrafascial-transfissural approaches. The two latter techniques are considered the Glissonean approach.

## 1.2 The Extrafascial-Transfissural Approach

The extrafascial and transfissural approach was first introduced by Ton That Tung in Vietnam and Tien-Yu Lin in Taiwan around 1960. Ton That Tung is considered a pioneer of liver surgery. Between 1960 and 1977, Tung performed a total of 715 hepatic resections, 485 of which segmentectomies and sectorectomies, and described them in his text on liver anatomy and surgery, titled *Les Résections Majeures et Mineures du Foie* (Major and Minor Resections of the Liver) [7]. His solution to “bloodless” liver operations was a combination of the following techniques: hypothermia below 30°C, inflow occlusion, and intraparenchymal vessel ligation. He illustrated the anatomic basis, the targeted Glissonean pedicle, the operative approach, and potential pitfalls of each resection. Tung’s scientific contribution was obscured for many years due to the difficult political period experienced in Vietnam until the end of the Cold War. Only successively, in 1982, Bismuth recognized the Ton That Tung’s technique as the primary parenchymatous transection method [8].

Tung used the technique of parenchymal transection with the finger fracture method in order to expose vessels requiring ligation. This method, also called digitoclasia, was first described for extrafascial-transfissural approach by Tien-Yu Lin from the National Taiwan University in a report published in 1958 [9]. Even now digitoclasia remains a useful method of separating liver parenchyma. Successively, Henri Bismuth introduced a variant called Kellyclasie, consisting in the use of a clamp and crush technique instead of fingers [10].

In 1986, Okamoto in Japan realized a small variation of the extrafascial and transfissural approach, the so-termed unroofing method [11]. This technique consists of transection of the liver parenchyma at the segment IV above the hilar plate gaining access to the Glissonean pedicles.

## 1.3 The Extrafascial Approach

In 1985, Couinaud [12] reported a simple method for controlled left hepatectomy by performing ligation without interruption of the left pedicle at the hilum, providing immediate hemostasis of the left liver with an easy and bloodless resection.

However, the term “Glissonean pedicle transection method” was first used by Professor Takasaki in Japan in 1986 [13]. According to the surgical technique described by Takasaki, the liver is divided into three sections (left, middle, right) based on the ramification of the Glisson’s pedicle tree. The bifurcation of the pedicle tree is accessed through the detachment of the hilar plate from above the basis of segment 4b with subsequently extrafascial extrahepatic dissection of the main left or right pedicle, as well as both right sectional pedicles, without liver parenchyma injury.

Opposite to anterior transfissural approach, in 1989, Galperin [14] reported a new method for selective exposure of Glissonean pedicles developing through a superficial T-shaped incision of Glisson’s capsule in correspondence of pedicle projection on posterior liver surface and the successive use of surgeon’s forefinger into the hepatic parenchyma in order to hook the pedicle.

In 1992, Launois and Jamieson [15] described the peri-hilar posterior intrahepatic approach to the hepatic sheaths of the segments of the right liver through the dorsal fissure. Successively

Marcel A. Machado introduced small incisions of the hilar plate and strictly instrumental isolation of the pedicle in order to make the posterior approach safer [16].

Machado proved also the safety and feasibility of minimally invasive surgery applied to Glissonean approach resulting in a shorter operative time, lower blood loss, and low morbidity [17]. However accurate preoperative tumor localization, identification of potential anatomic pedicle variations, and surgeon expertise are mandatory for the success of laparoscopic technique.

Recently the study group of Precision Anatomy for Minimally Invasive Hepato-Biliary-Pancreatic (PAM-HBP) surgery investigated and confirmed the several advantages of the Glissonean approach compared to the conventional hilar approach. The PAM-HBP surgery project (that will be described in details in the next chapter) incorporates the opinions of international experts in hepatobiliary pancreatic surgery and the evidence from the previous literature. It also encouraged the use of endoscopic (laparoscopic and robotic) surgery that ensures higher resolution and magnification of anatomical structures which can be used as landmarks to establish the appropriate cutting lines during liver resections. However, as the PAM-HPB highlighted, the lack of a precise anatomical understanding has been the main impediment to the standardization of the surgical technique for the Glissonean pedicle approach [18].

As will be detailed in Chap. 3, a clear knowledge of liver anatomy, especially of Laennec's capsule anatomy, is the basis and represents the guide for any surgical procedure.

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# Glissonean Pedicles, Landmarks, and Gates

# 2

Alessandro Anselmo, Leandro Siragusa,
Bruno Sensi, and Giuseppe Tisone

## 2.1 The Definitions

The first step to achieve a safe extrahepatic Glissonean approach at the hilum, without any parenchymal disruption, is to properly understand the novel comprehensive surgical anatomy of the liver based on Laennec's capsule and therefore identify the landmarks and gates on the inferior surface of the liver according to Sugioka [1].

A "landmark" can be defined as an anatomical part of the liver that can help to identify the gates. A "gate" can be defined as a specific site at the hilum where the Laennec's capsule and Glissonean sheath can be mechanically separated with minimal or any parenchymal disruption. A physical space exists and can be enlarged at this level between the two membranes, allowing a safe totally extrahepatic pedicle isolation.

## 2.2 The Liver Envelopes: The Laennec's Capsule and the Glissonean Sheath

The "liver envelopes simulation model" (Fig. 2.1) illustrates the various layers that coat the liver surface in a "onion-like" fashion. The outer layer is the peritoneum (serosa) that covers all the liver and the hepato-duodenal ligament except the *bare areas*. The Laennec's capsule is the so-called proper membrane of the liver and covers the entire liver surface. The Glissonean sheath coats the liver pedicles and follows their "tree-like" distribution inside the liver parenchyma remaining in a tight contact with the Laennec's capsule except at the site of the "gates" at its inferior surface. A thickening of the Glissonean sheath at the liver hilum forms the plate systems that includes the Arantius, hilar, and cystic plates (Fig. 2.2).

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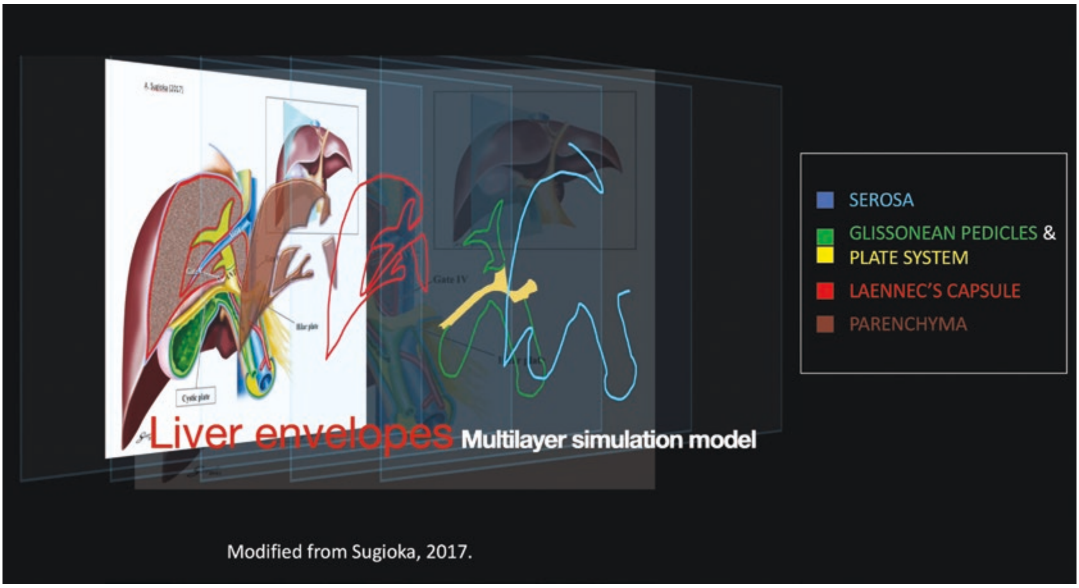


Modified from Sugioka, 2017.

**Fig. 2.1** Liver envelopes: Multilayer simulation model

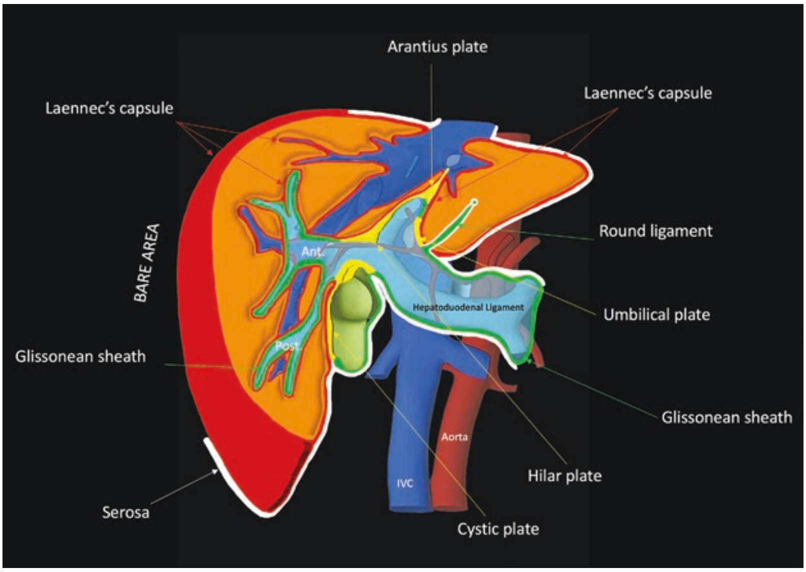


**Fig. 2.2** Liver envelopes: A schematic 3d drawing

To better explain the relationship between the Laennec's capsule and the Glissonean sheath, we have elaborated the "two gloves" model (Fig. 2.3a) in which the two anatomical structures are depicted as two gloves that cover the two hands representing the liver surface and the hilar structures. The classical surgical maneuver called detachment (or lowering) of the hilar plate is based on the existence of these two distinct membranes that cover the liver parenchyma and the hilar structures and that can be entered at the junction between the hilar plate and the base of segment IV (Fig. 2.3b).

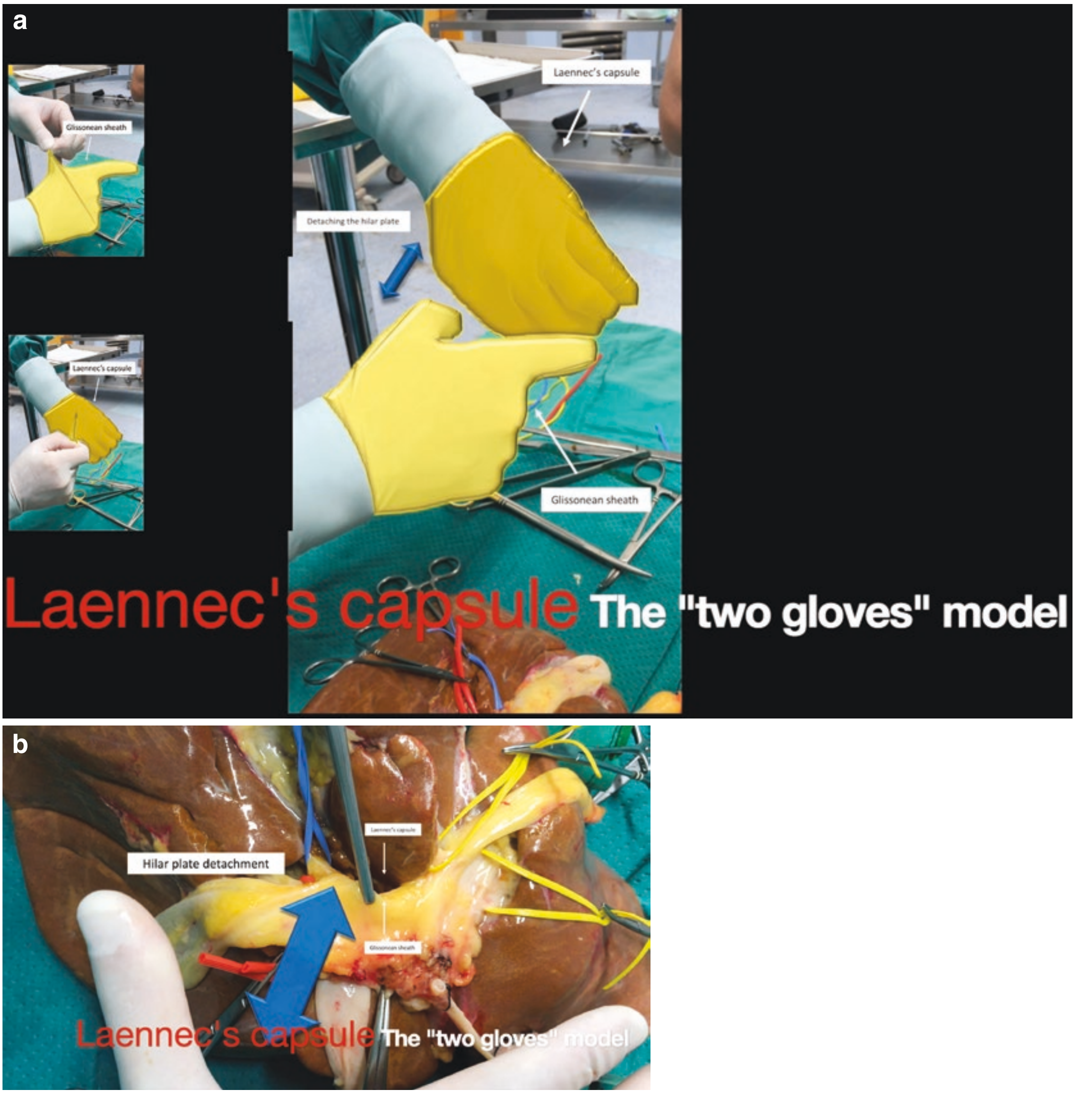


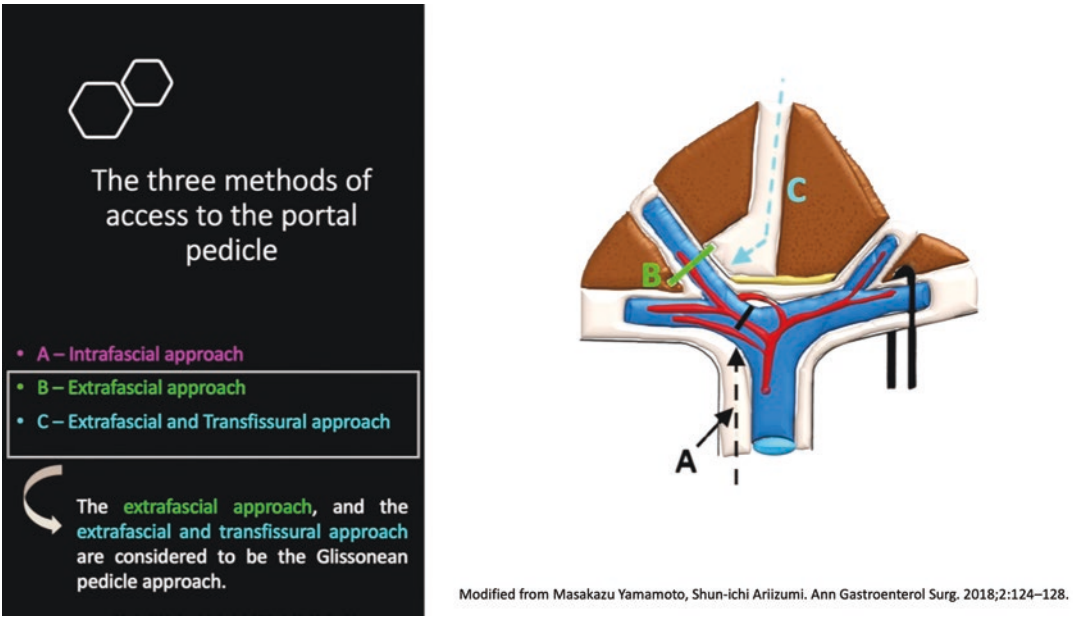
**Fig. 2.3** The “two gloves” model explains the relationship between Laennec’s capsule and Glissonean sheath and provides the anatomical background to better understand the surgical maneuver called *hilar plate detachment*

## 2.3 How to Recognize and Access the Gates

As described in Chapter 1, there are three main methods to access the portal pedicles according to Couinaud [2, 3] (Fig. 2.4). Identification of the four landmarks and six gates on the inferior surface of the liver is the key to perform the extrafascial approach without any major parenchymal disruption.

Four defined anatomical structures that can be visualized on the inferior aspect of the liver are the landmarks. Landmark number one is the Arantius plate; number two is the umbilical plate; number three is the cystic plate; number four is the caudate process Glissonean pedicle (Figs. 2.5, 2.6, 2.7, and 2.8).

This four landmarks allow to identify the six gates as follows:



The three methods of access to the portal pedicle

- A – Intrafascial approach
- B – Extrafascial approach
- C – Extrafascial and Transfissural approach

The extrafascial approach, and the extrafascial and transfissural approach are considered to be the Glissonean pedicle approach.

Modified from Masakazu Yamamoto, Shun-ichi Ariizumi. Ann Gastroenterol Surg. 2018;2:124–128.

**Fig. 2.4** The three methods of access to the portal pedicle. (A) Intrafascial, (B) Extrafascial, (C) Extrafascial and Transfissural

**Fig. 2.5** Landmark #1: Arantius Plate

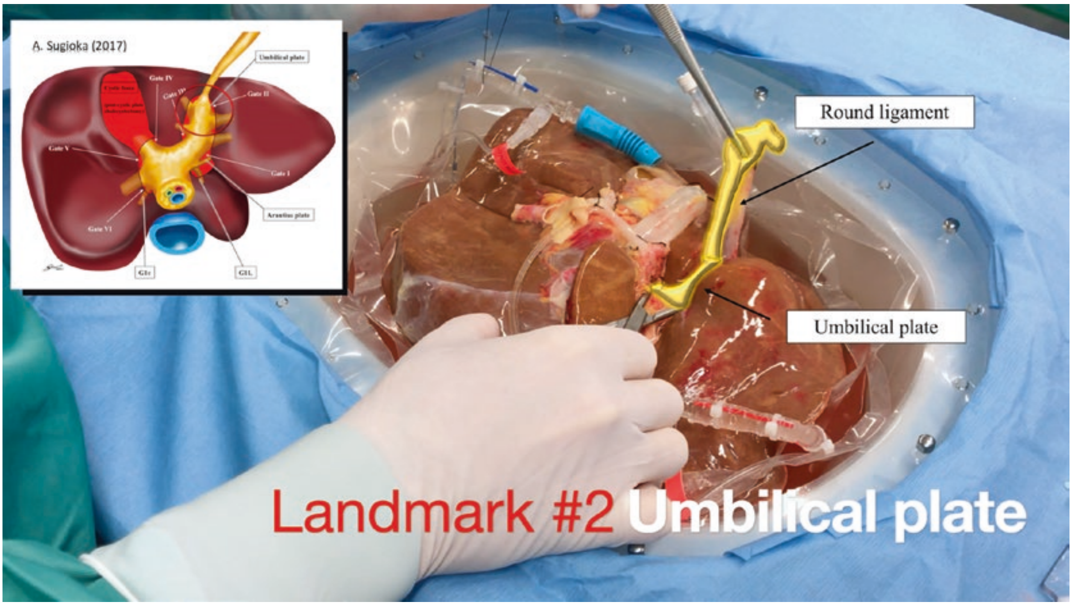


**Fig. 2.6** Landmark #2: Umbilical plate

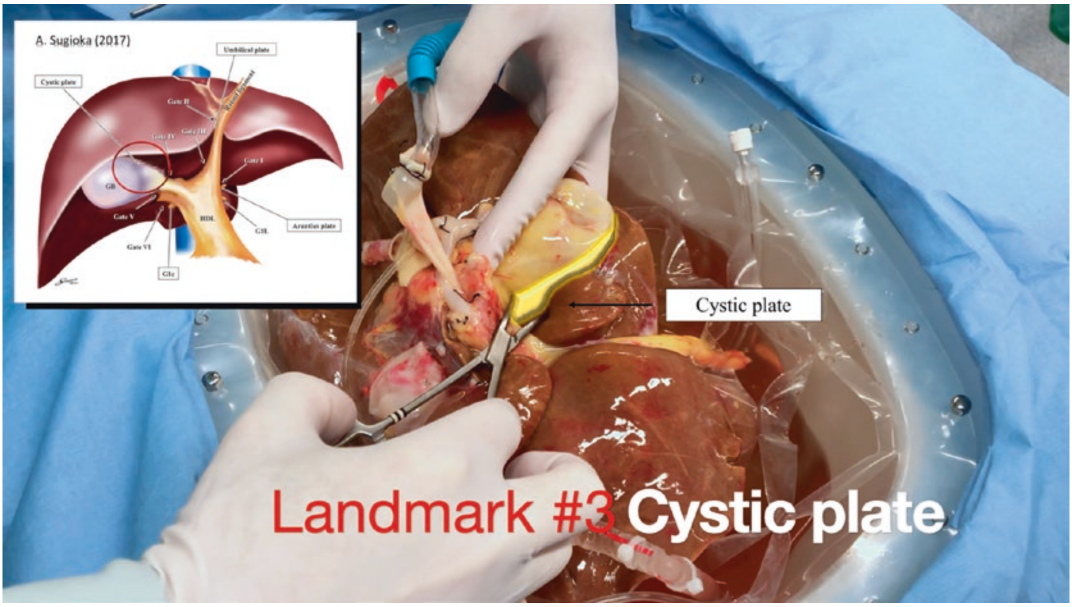


**Fig. 2.7** Landmark #3: Cystic plate

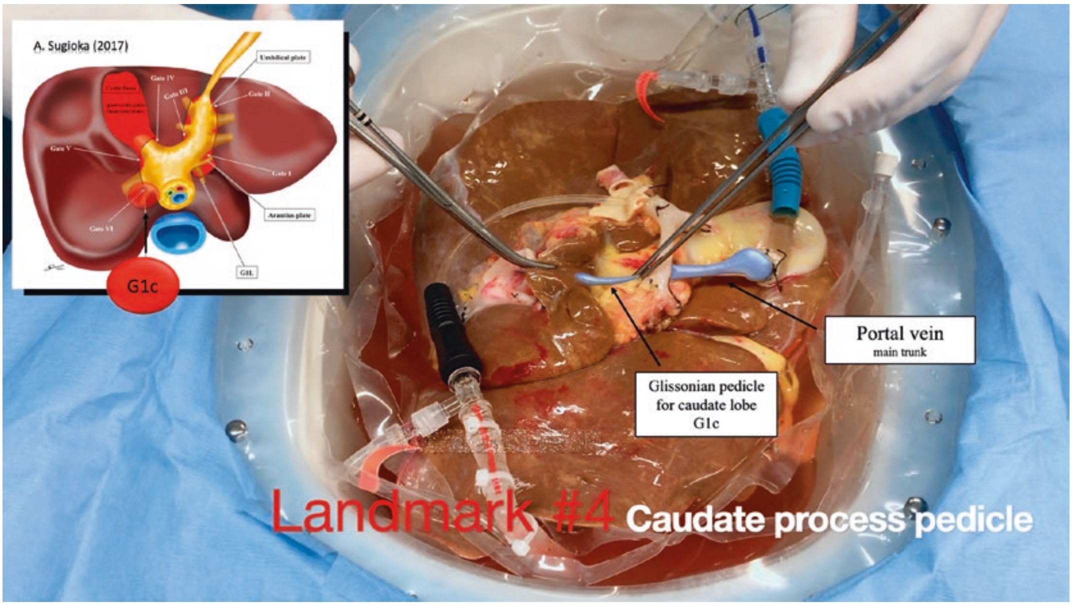


**Fig. 2.8** Landmark #4: Caudate process Glissonean pedicle

- Gate number one is located at the caudal end of the Arantius plate (Fig. 2.9).
- Gate number two is located at the junction between the round ligament and the umbilical plate (Fig. 2.10).
- Gate number three is located at the right edge of the Glissonean pedicle root of the umbilical portion (Fig. 2.11).

To properly identify gate four and five, the gallbladder should be removed performing a peculiar type of cholecystectomy made by cutting the cystic plate at the cystic neck (cystic plate cholecystectomy) as depicted in Fig. 2.12.

- Gate number four is located at the left edge of the posterior extremity of the cystic plate or the anterior Glissonean pedicle (Fig. 2.13).
- Gate number five is located at the bifurcation of the right main Glissonean pedicle (Fig. 2.14).
- Gate number six is located in the space between the right posterior Glissonean pedicle and the caudate process Glissonean pedicle (G1c) (Fig. 2.15).

An overview of all the landmarks and gates is provided in Figs. 2.16 and 2.17.

The extrahepatic isolation of the various Glissonean pedicles at the liver hilum, as shown above, permits the primary vascular control and the safe execution of the most common anatomical hepatic resections as depicted in Figs. 2.18, 2.19, 2.20, 2.21, 2.22, 2.23, and 2.24 [4, 5].

**Fig. 2.9** Gate #1: Caudal end of the Arantius plate

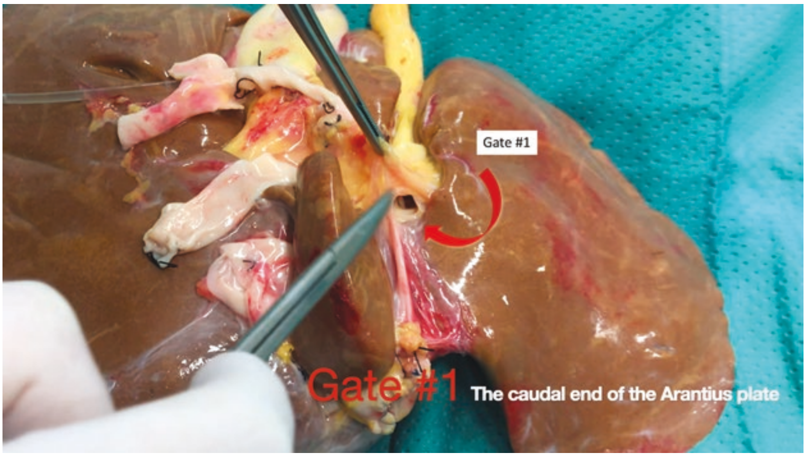


**Fig. 2.10** Gate #2: Junction between round ligament and umbilical plate

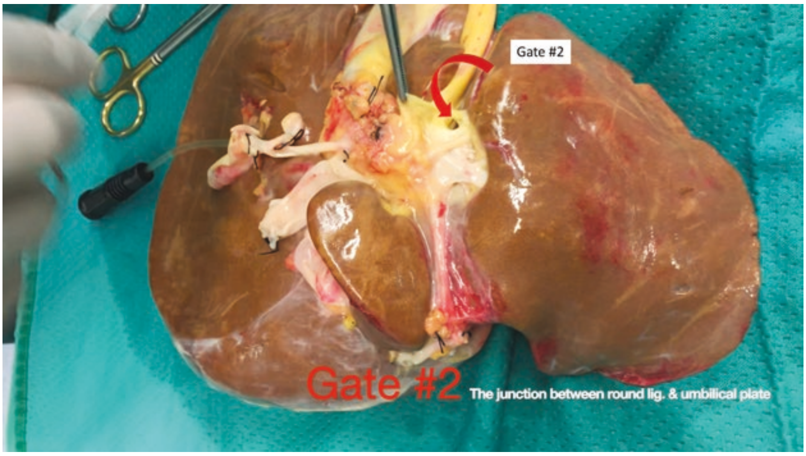
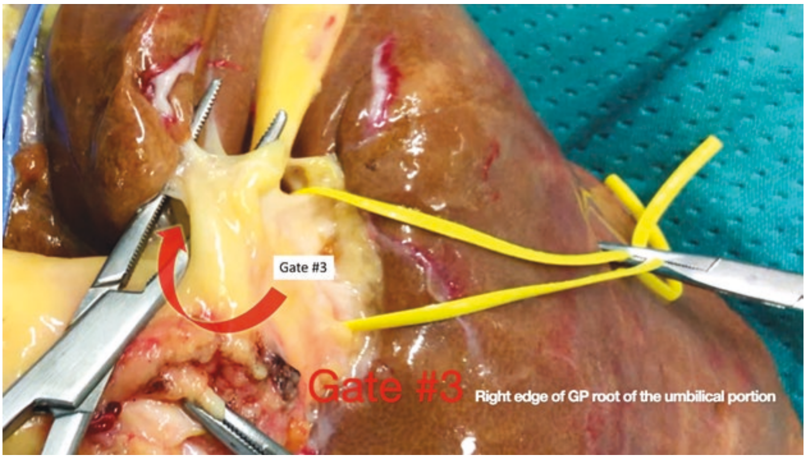


**Fig. 2.11** Gate #3: Right edge of Glissonean pedicle root of the umbilical portion



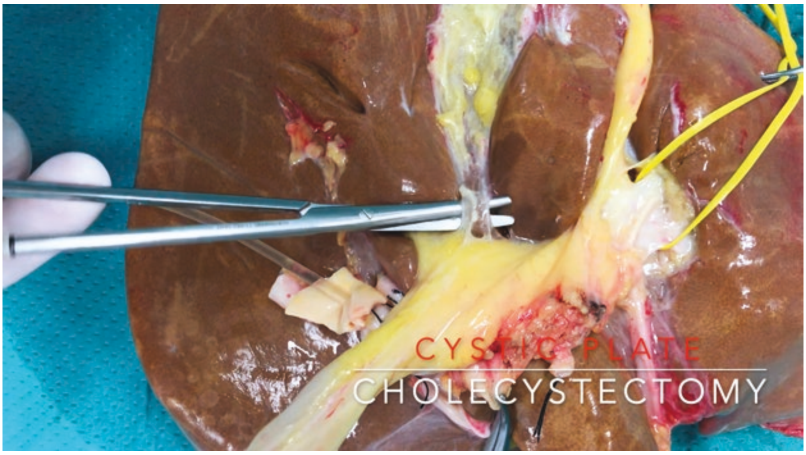


**Fig. 2.12** Cystic plate cholecystectomy

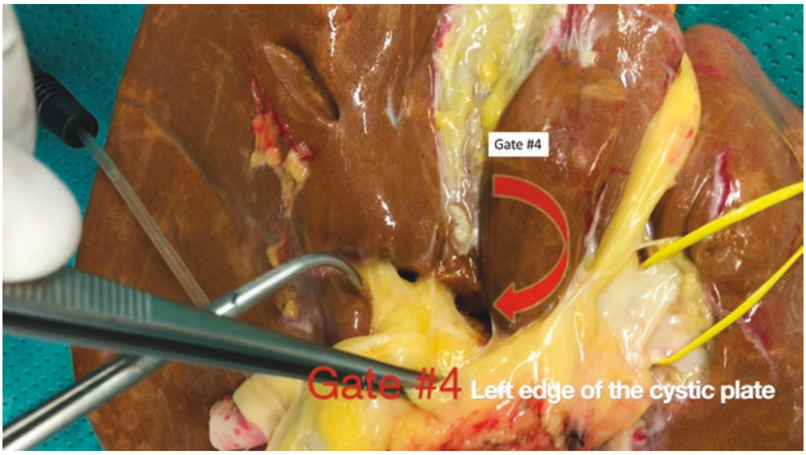


**Fig. 2.13** Gate #4: Left edge of the posterior extremity of the cystic plate or the anterior Glissonean pedicle

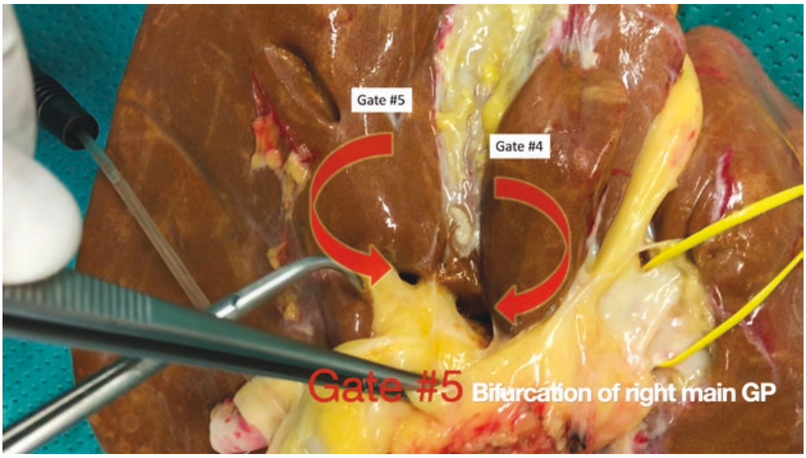


**Fig. 2.14** Gate #5: Bifurcation of the right main Glissonean pedicle

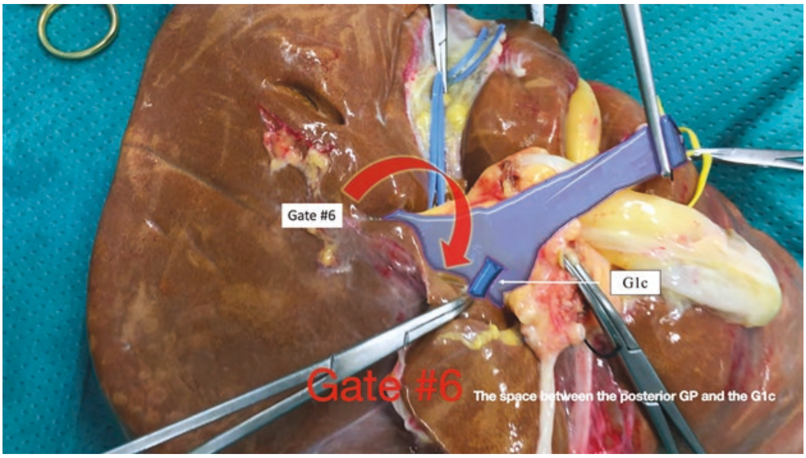


**Fig. 2.15** Gate #6: The space between the posterior right Glissonean pedicle and the caudate process Glissonean pedicle (G1c)

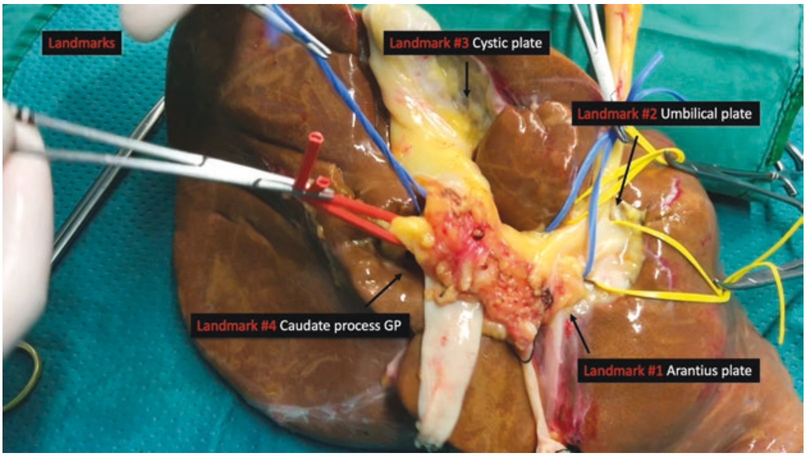


**Fig. 2.16** Overview of the landmarks

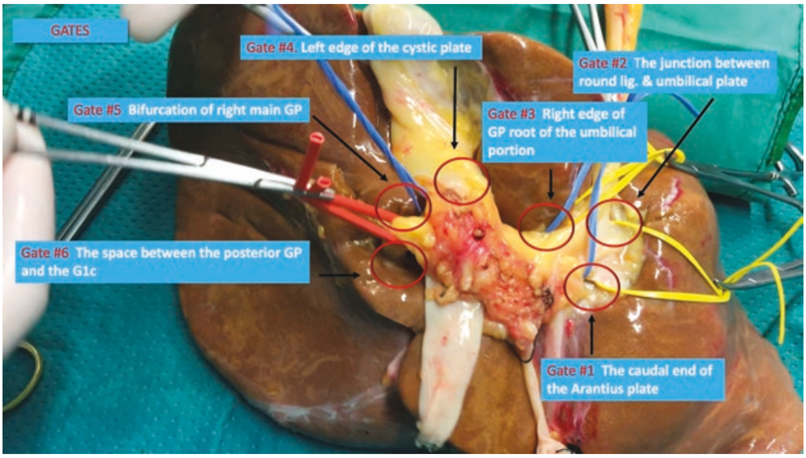
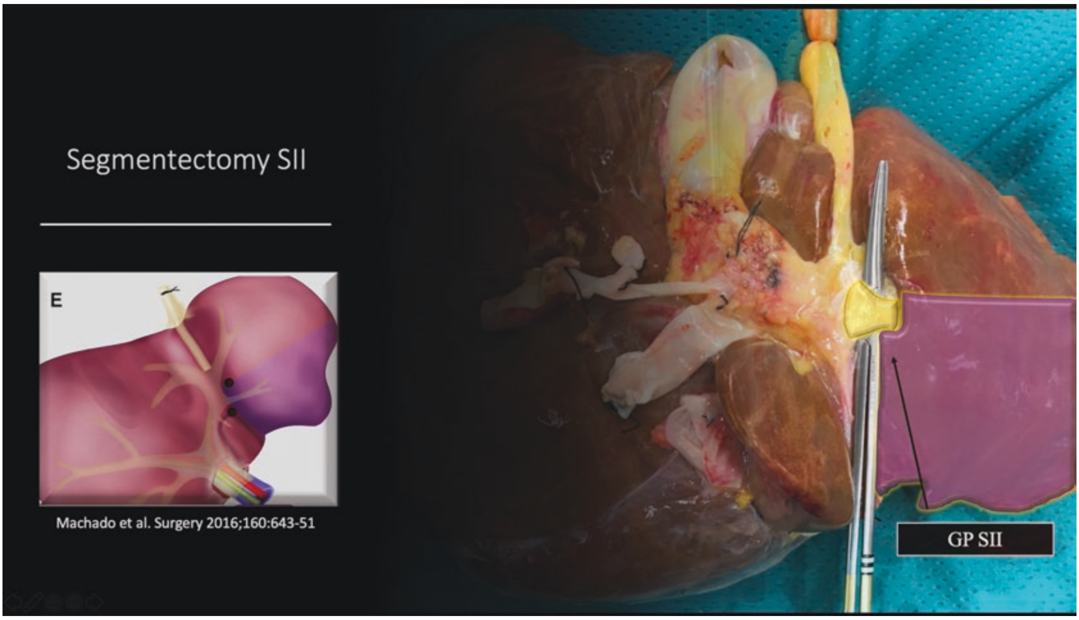


**Fig. 2.17** Overview of the gates



Segmentectomy SII

Machado et al. Surgery 2016;160:643-51

**Fig. 2.18** Extrahepatic Glissonean approach for SII segmentectomy

Segmentectomy SIII

Machado et al. Surgery 2016;160:643-51

**Fig. 2.19** Extrahepatic Glissonean approach for SIII segmentectomy

Left lateral sectionectomy

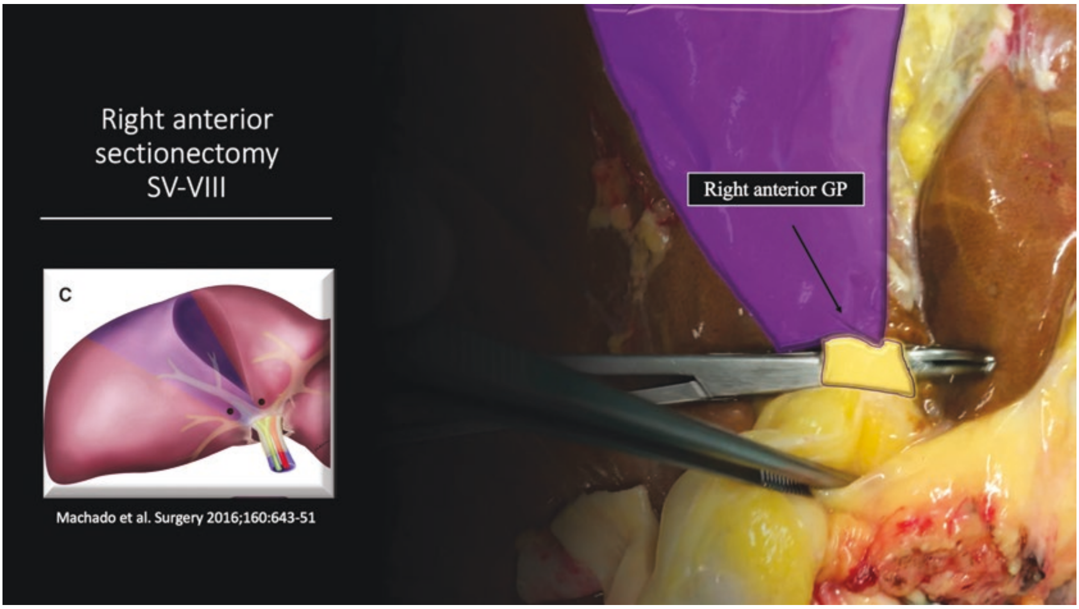
Machado et al. Surgery 2016;160:643-51

**Fig. 2.20** Extrahepatic Glissonean approach for SII-SIII left lateral sectionectomy

Left
Hemihepatectomy
S II-III-IV

Machado et al. Surgery 2016;160:643-51

**Fig. 2.21** Extrahepatic Glissonean approach for left hemihepatectomy



Right anterior
sectionectomy
SV-VIII

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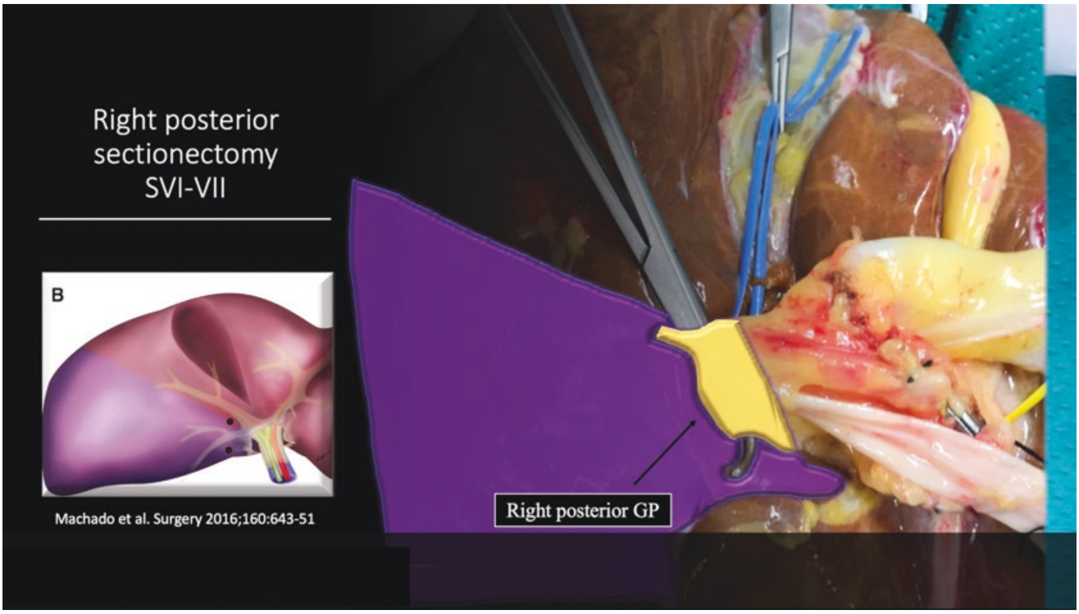
**Fig. 2.22** Extrahepatic Glissonean approach for right anterior sectionectomy



Right posterior
sectionectomy
SVI-VII

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**Fig. 2.23** Extrahepatic Glissonean approach for right posterior sectionectomy

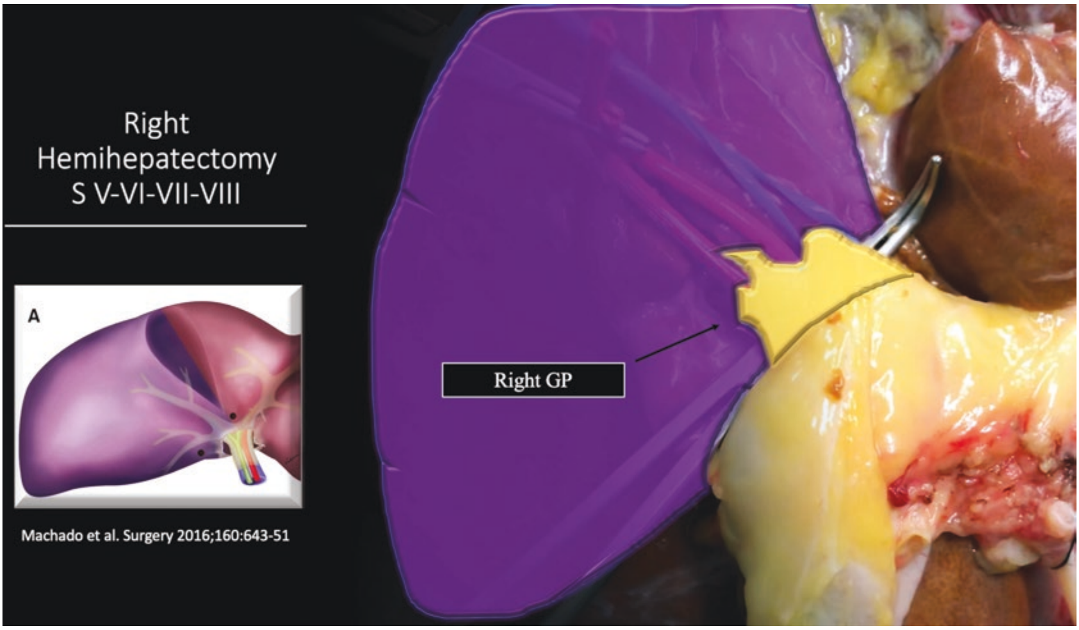

**Fig. 2.24** Extrahepatic Glissonean approach for right hemihepatectomy

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# 3 Intraoperative Ultrasound Pedicle Localization

Alessandro Ferrero, Roberto Lo Tesoriere, and Nadia Russolillo

## 3.1 Introduction

Liver resection is the treatment of choice for primitive and metastatic liver malignancies. Modern liver surgery still encompasses major hepatectomies but relies more and more on minor resections that can range from small atypical resections of peripheral lesions to segmentectomies and complex nonanatomical resections. A mandatory prerequisite for such resections is the identification of the proper Glissonean pedicle to be dissected and hepatic veins to be exposed on the cut surface [1, 2].

Intraoperative ultrasonography has long been reported as a useful tool for open liver surgery [3–5] with a valuable role for intraoperative diagnosis of liver lesions and for guidance to resection. In years its role has upgraded to a parenchyma navigation instrument, to meet the needs of modern liver surgery.

Laparoscopic liver surgery has reached a worldwide spread, and subsequent consensus conferences gave wide acceptance and progressive attempts of standardization [6–8]. Hepatobiliary surgeons demonstrated the possibility to perform most hepatectomies via a minimally invasive approach, with adequate oncological outcomes and better short-term results than open surgery [9].

As for any laparoscopic procedure, laparoscopic liver surgery is performed without tactile feedback along with a limited bidimensional field of view. For these reasons, laparoscopic intraoperative ultrasonography (LUS) could have the additional value to overcome laparoscopic limitations providing real-time feedback during all types of hepatectomy. At the same time, LUS is as reliable for staging liver tumors as open intraoperative ultrasound, with a similar performance in detecting new nodules [10].

The role of LUS in the planning of liver resections relies in its capacity to provide the ultimate staging of the disease and to provide the most accurate real-time anatomical study. The combination of this information enables LUS-guided laparoscopic liver resections [11] and allows to tailor the resection according to patient's specific anatomy and tumor localization.

In this chapter the technique of the LUS anatomical study will be described, focusing on the identification of the Glissonean pedicles.

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## 3.2 Main Indications and Contraindications

Intraoperative ultrasonography should be performed during every liver resection. A first ultrasound scan aimed exclusively at the study of liver anatomy is to be performed before any other maneuver and before the study of known lesions or the search for new ones. A systematic study of liver anatomy is also recommended to improve surgeon's skill and to be prepared to deal with complex anatomy or tumor anatomic relationships when they occur. Intraoperative identification of the Glissonean pedicles is indicated and necessary whenever an anatomical resection is required, whether it is a segmentectomy or subsegmentectomy. This may be the case when a Glissonean pedicle is directly affected by a tumor, and the whole segment must therefore be resected, when a segment or segments are congested for venous outflow impairment due to the resection of the tributary hepatic vein (LUS is a valuable tool to assess liver congestion too [12]) or for oncological reasons (i.e., hepatocellular carcinoma). Intraoperative ultrasound is the most reliable tool for intraoperative Glissonean pedicle identification.

## 3.3 Surgical Technique (Key Issues and Technique Details)

LUS can be performed trough 2, 12-mm ports, one for the 30° laparoscope and one for the laparoscopic probe. While acceptable that LUS can be performed with a two-way probe, a four-way probe should be preferred as lateral transducer movements can correct the sagittal orientation of the laparoscopic probe. An important feature that should be available is the intraoperative color Doppler mode or better a high-definition blood flow imaging mode with high spatial and temporal resolution. Such imaging modes are useful to display small, slow blood flow vessels such as peripheral Glissonean pedicles or branches of the hepatic veins as well as in the assessment of Glissonean pedicles after they have been clamped.

### 3.3.1 Patient Position

Patient position depends on the resection planned and surgeons' preferences. A complete LUS study can be performed through the first two trocar placed. It does not require any liver mobilization or the section of the round and falciform ligament. LUS can be repeated throughout the operation, using any 12-mm trocar. After the liver mobilization required by the planned resection, LUS helps to reassess anatomy and anatomical relationships that are modified by liver manipulation.

## 3.4 Exploration

The exploration is performed mainly with the probe inserted in the most right-sided trocar. The exploration begins by placing the probe on Sg4. This central position, directly above the portal bifurcation and the middle hepatic vein (MHV), represents an ideal starting point for the exploration, as well as a place where to return when in trouble. Specifically, if a convex probe is used, holding the probe in place and applying oscillatory movements along the probe's long (rocking) and short (tilting) axis allows for a good overview. The portal bifurcation is easily visualized. Small tilting movements allows to visualize the right and the left portal branches with the corresponding artery and bile duct, even when it is not dilated. Sliding the probe to the left, the left portal branch can be followed till the umbilical portion. Here, with the probe coming from the right, Sg4a Glissonean pedicles (G4a) can be longitudinally scanned (Fig. 3.1a). Sliding the probe toward the gallbladder Sg4b pedicles (G4b) are cross-scanned (Fig. 3.1b). Often the most cranial G4b arises very close to the origin of the most caudal G4a. The identification of the boundaries of Sg4a and Sg4b is a crucial point in Sg4 subsegmentectomies (i.e., Sg4b-5 bisegmentectomy for gallbladder cancer). On the left side of the umbilical portion of the left hepatic vein, the origin of Sg2 (G2) and Sg3 (G3) Glissonean pedicles can be seen (Fig. 3.2). G2 arises from the cranial part of the umbilical portion. It can be identified running

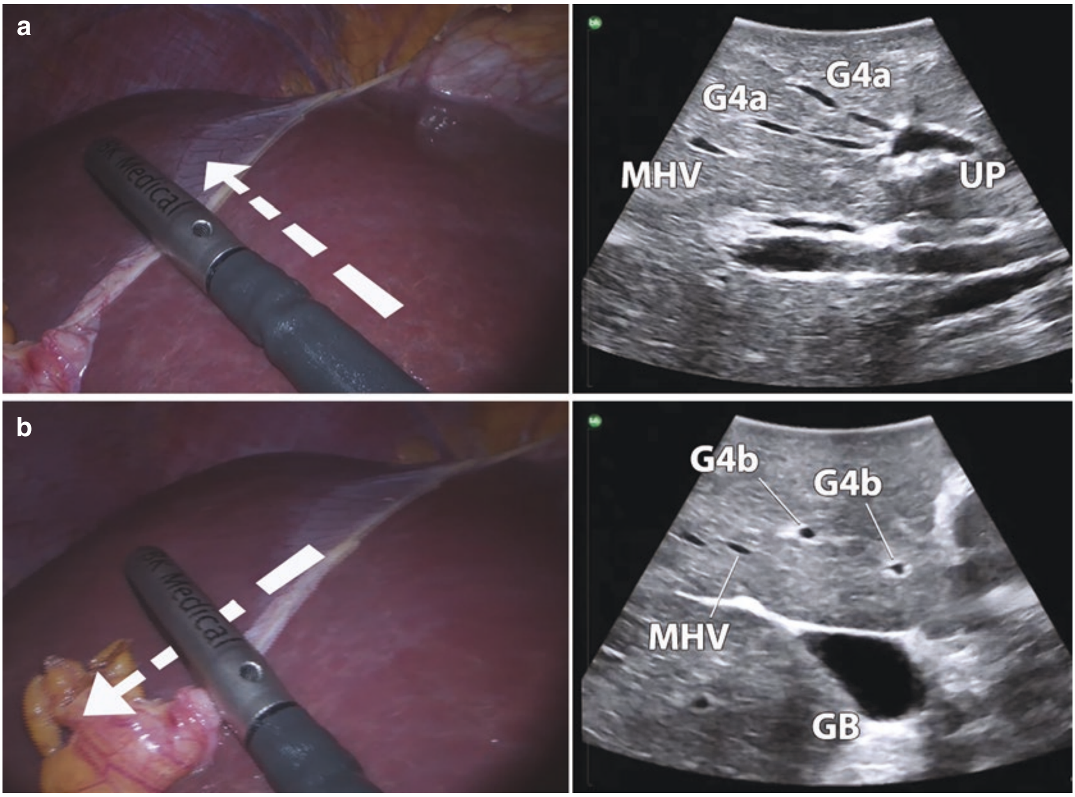

**Fig. 3.1** Sg4 Glissonean pedicles identification. (**a**) The probe slides longitudinally in the arrow direction that is parallel to Sg4a Glissonean pedicles (G4a). They are longitudinally scanned from the origin on the right side of the umbilical portion of the left portal branch (UP), heading toward the middle hepatic vein (MHV). (**b**) Sg4b Glissonean pedicles (G4b) are cross scanned sliding the probe laterally (arrow) toward the gallbladder (GB)

above Sg1 and the lesser omentum, below the left hepatic vein (LHV). With the aforementioned probe position, it is generally cross scanned. To scan it longitudinally, the probe must be properly angled using the lateral movements. Sliding the probe caudally, G3 pedicle is identified above the LHV that can be very close to the middle part of the pedicle. The left-to-right and bottom-to-top direction of the probe, with an axis similar to the G3 axis, allows it to be scanned longitudinally. Lateral probe correction allows a cross scan.

Placing again the probe on Sg4 the right Glissonean pedicle (RGP) is visualized. Slight tilting movements allows the visualization of the right anterior (G5–8) and posterior (G6–7) Glissonean pedicle, with the cross-scanned RHV running in between (Fig. 3.3). With the probe on G5–8 sliding toward the gallbladder, Sg5 Glissonean pedicles (G5) are visualized in a cross-section. Several G5 can be identified, sometimes arising also from Sg8 ventral pedicle. Back on G5–8, with a longitudinal cranial sliding, the origin of Sg8 dorsal (G8d) heading to the RHV and ventral (G8v) pedicle and heading to the MHV is seen (Fig. 3.4). Rather frequently a lateral (G8l) pedicle is present. It is identified as the earliest Sg8 pedicle rising from the right anterior pedicle, heading laterally above the RHV.

Back on Sg4, tilting the probe clockwise, the posterior (G7–8) pedicle can be seen behind the RHV. Sliding the probe laterally, Sg6 pedicle (G6) is cross scanned. Several pedicles (often superior and inferior) are visible. Sg7 pedicle (or pedicles) are easily scanned sliding longitudinally the probe cranially (Fig. 3.5a). G6–7 and its division branches, G6 and G7, lie deep in the liver parenchyma, close to the dorsal liver surface. After right liver mobilization, LUS can be per-

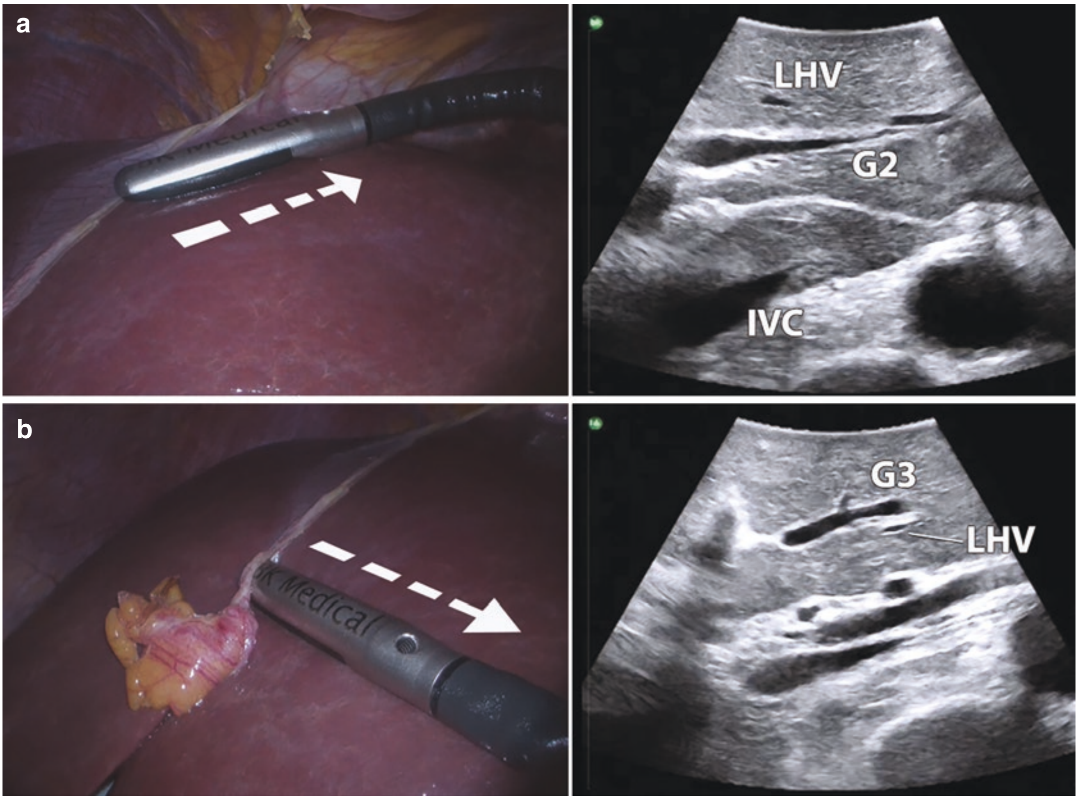

**Fig. 3.2** Sg2 and Sg3 Glissonean pedicles identification. (**a**) Sg2 Glissonean pedicle (G2) is longitudinally scanned, running below the left hepatic vein (LHV). The probe has been rotated left to match the G2 direction and slides longitudinally as indicated by the arrow. (**b**) The probe has been straightened to match G3 direction. Sg3 Glissonean pedicle (G3) is longitudinally scanned sliding the probe longitudinally (arrow). LHV is cross scanned. It lies below and very close to G3

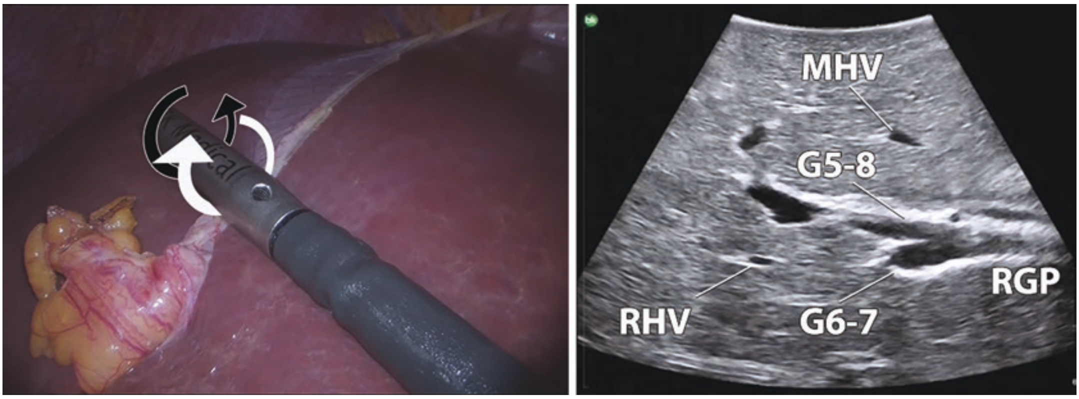

**Fig. 3.3** Right Glissonean pedicles identification. The probe is placed on Sg4, scanning the right Glissonean pedicle (RGP). With tilting counter-clockwise movements (black arrow), the right anterior (G5–8) Glissonean pedicles and the cross scanned middle hepatic vein (MHV) are visualized. Clockwise tilting movements (white arrow) allows to see the right posterior (G6–7) Glissonean pedicle. The cross-scanned right hepatic vein (RHV) runs in between

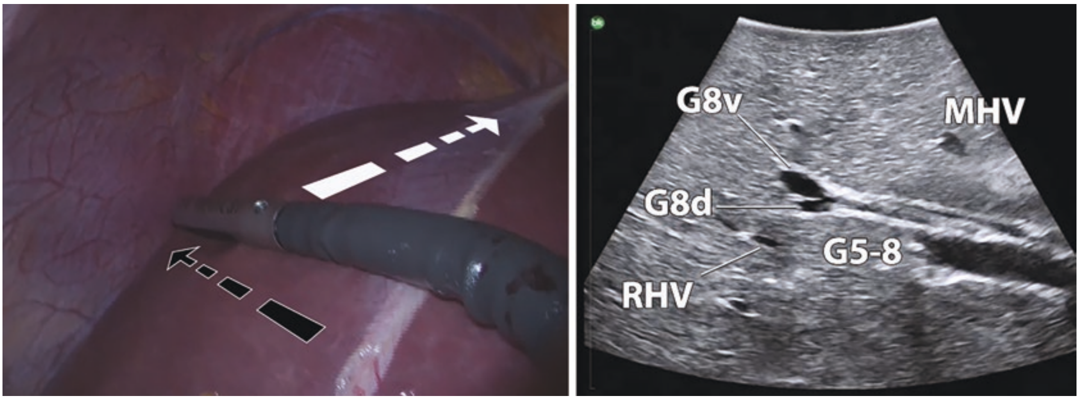

**Fig. 3.4** Sg8 Glissonean pedicles identification. The probe scans the right anterior Glissonean pedicle (G5–8). Sliding the probe longitudinally (black arrow), Sg8dorsal pedicle (G8d) heading to the right hepatic vein (RHV) will be longitudinally scanned. Sliding the probe laterally (white arrow) toward the middle hepatic vein (MHV), the Sg8 ventral Glissonean pedicle (G8v) will be cross scanned

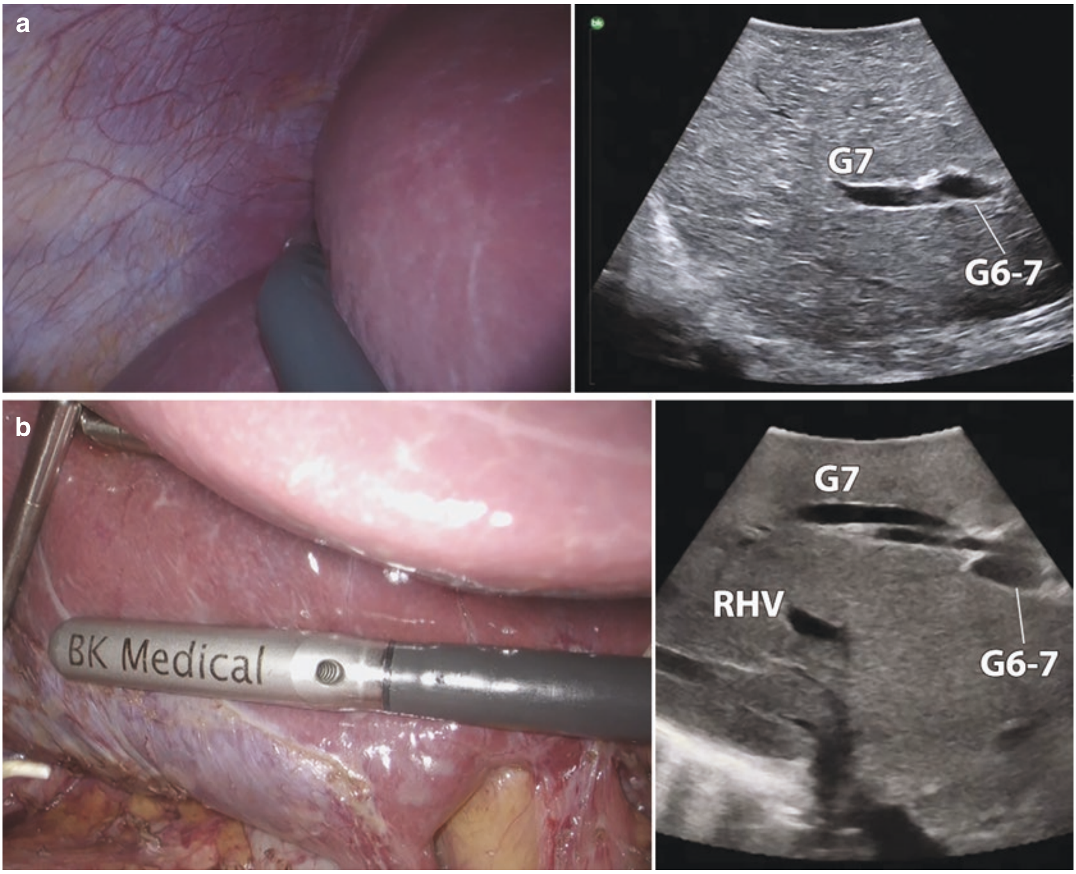

**Fig. 3.5** Sg7 Glissonean pedicle identification. (**a**) Sg7 Glissonean pedicle (G7) is scanned from the ventral side, arising from the right posterior Glissonean pedicle (G6–7). It lies deeply in the parenchyma. (**b**) After right liver mobilization, it is scanned from the dorsal side, running close to the dorsal liver surface, above the right hepatic vein (RHV)

formed directly on the dorsal liver side. With this probe setting, G6 and G7 can be longitudinally scanned and visualized as the most superficial structures, above the RHV (Fig. 3.5b). This peculiar anatomical situation allows for the Glissonean pedicle firs approach suitable for anatomical Sg6–7 segmentectomies or subsegmentectomies [13, 14].

## 3.5 Special Tricks and Tips

Generally, the Glissonean pedicle exploration is carried following the division of the pedicles from the first-order branches, in the second-order, and so on. When a pedicle is hard to identify this way, it can be useful to perform a LUS scan from the periphery to the center. For instance, if it is difficult to identify G5 from the origin on G5–8, where it can be mistaken for a G8l or its origin from G8v can be misleading, it is convenient to place the probe on the gallbladder bed, to identify the tiny peripheral G5 around the gallbladder and to follow them toward their origin.

After a Glissonean pedicle is identified and isolated, it is recommended to confirm the identification. The simplest tool is the intraoperative color Doppler assessment once the pedicle has been clamped. This method is more reliable than the ischemic demarcation of the liver surface that sometimes can be misleading for chronic hepatopathy and unlike the ICG negative staining can be repeated throughout the resection.

## 3.6 Main Key Points

Anatomical liver resections can be required for oncological reasons, for Glissonean pedicle tumor infiltration, hepatic vein infiltration, or because they allow parenchyma sparing resections. Nonetheless such resections are exposed to peculiar difficulties and require careful identification of the proper Glissonean pedicle to be dissected or to be spared. LUS is an essential tool for precise Glissonean pedicle identification and guidance to resection.

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# 4

# Main Instruments for Hepatic Transection and Minimally Invasive Pedicle Dissection

Fernando Burdio, Sofia Jaume-Bottcher,
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## 4.1 Introduction

Hemorrhage and blood loss have been one of the major complications of liver surgery since its beginnings. Before the 1980s, hepatic resection was associated with a high mortality rate, around 20%, largely due to intra- and postoperative hemorrhage [1]. Today, this procedure has become much safer with an operative mortality of 1%, intraoperative blood loss of <500 cc, and need for transfusion in <10–30% of patients [2].

Improvements in perioperative care and a better understanding of liver anatomy have led to a decrease in perioperative morbimortality (Fig. 4.1). Portal inflow compression to decrease liver bleeding (as described by Pringle in 1908), the use of subcostal incisions with retraction and the development of clamp-crushing, selective vascular control, parenchyma sparing surgery, laparoscopic approach, and finger fracture technique have also been fundamental to the advances in hepatic surgery [3].

Other implementations have been represented by the use of indocyanine green (ICG) to study hepatic vascularization intraoperatively, and the introduction of preoperative planning and navigation software. Additionally, over the past 20 years, the number of surgical devices to facilitate parenchymal transection, vascular control, and hemostasis in hepatic surgery have increased resulting in a rapid development of various techniques in liver resections [4]. The techniques range from simple tissue-fracturing techniques using the finger or a clamp to devices based on more advanced technologies, such as the water jet dissector, vascular stapler, harmonic scalpel, Ligasure™ device, or radiofrequency (RF)-assisted devices.

Numerous studies have been conducted comparing different liver transection techniques.

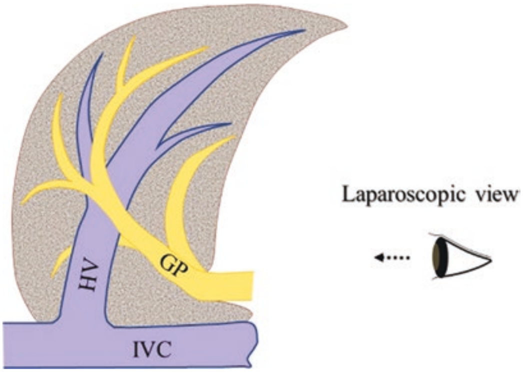

**Fig. 4.1** Introduction of laparoscopy allows for a caudodorsal approach. Another important progress has been the standardization of the systematic extrahepatic Glissonean pedicle isolation with recognition of the "four anatomical landmarks" and the "six gates (Gate I to Gate VI)" as described in Chap. 3

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However, there are few prospective randomized trials that disclose such comparisons, and those published have failed to demonstrate the superiority of one technique in comparison to the classic clamp-crushing method [5–6].

Therefore, the use of one device over another depends most of the time on the type of resection, the severity of liver injury, the length of the procedure, the cost, and personal preference of the surgical team. The aim of this chapter is to review and compare the most used instruments for hepatic transection and minimally invasive Glissonean pedicle dissection.

## 4.2 Vascular Staplers for Hepatic Transection

The use of vascular staplers has been broadened to include dividing hepatic parenchyma after initially being largely used for the division of major arteries [7]. However, there is concern about the risk of fracture and rupture with vascular staplers. For parenchymal transection, generally, these devices are combined with a clamp-crushing method, as described here: (1) The transectional line is marked and then the liver capsule is divided using diathermy. (2) The liver tissue is then shattered gradually with a clamp to prepare for the future dissection of the hepatic parenchyma; then the stapler crushes the dissection line. (3) The hepatic parenchyma can then be divided and transected sequentially using vascular staplers.

Compared to traditional crush clamping liver transection, vascular staplers seem to be more effective in small vessels and in narrow surgical fields, providing a better exposure of the surgical field by limiting the continuous hemorrhaging of these small vessels. Furthermore, vascular staplers are less time-consuming, which is why they also constitute a good option in emergency settings, such as blunt trauma [8–9].

However, in 2014, a randomized clinical trial by Rahbari et al. showed no difference in the amount of intraoperative blood loss between the stapler and clamp-crushing techniques. [10] Alternatively, as seen by Fritzman et al. in 2018, compared to the Ligasure™ device for parenchymal transection in elective partial hepatectomy, stapler hepatectomy was linked with less blood loss and a shorter operating time [11].

## 4.3 Vessel Sealing Devices in Hepatic Resection

The Ligasure™ device is a bipolar vessel-ligating system that uses pressure and electrothermal energy to fuse the collagen matrix in the vessel wall to permanently occlude blood vessels up to 7 mm in diameter. This tool may also include a built-in knife to enable quick and accurate division of the sealed vessels [12]. It has also the potential to reduce transection times since it simultaneously causes parenchymal division and vascular hemostasis. This device may break multiple partially sealed capillaries when it is applied directly to the liver tissue, causing leaking from the transection line. Therefore, some authors prefer the combined use of Kelly clamp dissection with the Ligasure™ sealing device to prevent this leakage from any ruptured vessel, as shown in Fig. 4.2.

In 2022, Muraki et al. published a propensity score matching comparing monopolar and bipolar sealing devices for hepatic parenchymal transection, concluding that monopolar cautery techniques had a significantly lower intraoperative blood loss and lower total operating time, whereas the bipolar group had a significantly lower incidence rate of ascites and intra-abdominal infections [13]. However, this is an observational single-center stud, and as such has its limitations in terms of applicability.

In another non-randomized study, by Liu et al. in 2018, compared the Ligasure™ device and the cavitron ultrasonic surgical aspirator (CUSA), concluding that neither intraoperative blood loss nor the need for blood transfusions increased with the use of Ligasure™. No statistical differences were found in relation to postoperative reperfusion injury, disease-free survival rate, or 2-year overall survival rate [14].

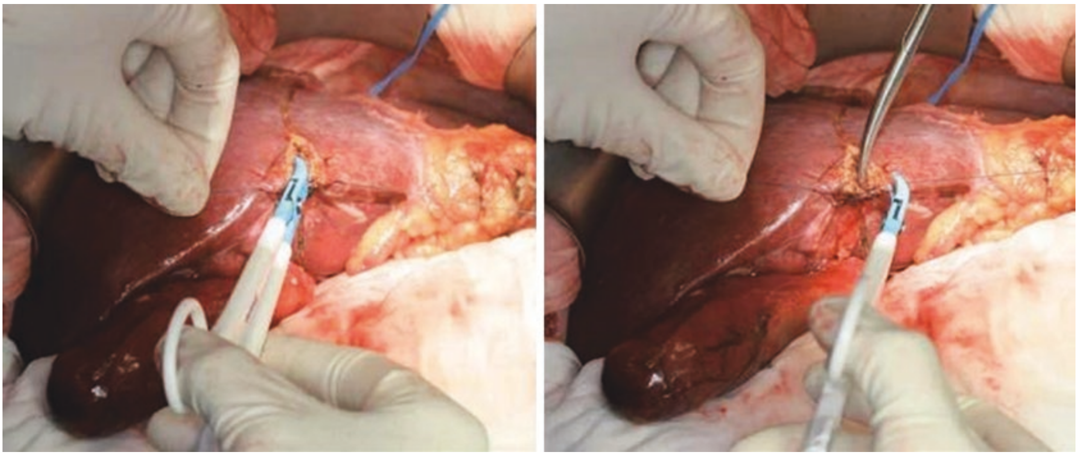

**Fig. 4.2** Combined use of Ligasure and clamp technique. Following the resection, the cut surface of the liver is examined for bile leaks, which, if found, are sutured

## 4.4 Ultrasonic Devices in Liver Resection

Ultrasonic devices are one of the most affordable instruments for hepatic transection. This method uses mechanical wave energy combined with aspiration to shatter the liver parenchyma tissue and expose biliary ducts over 2 mm and small hepatic vessels [15]. However, it is not able to coagulate or seal blood vessels, which provides the need to use titanium clips or other mechanical items to produce hemostasis. One advantage of CUSA is that it offers a well-defined transection plane and great pedicle identification, which is helpful when tumors are close to major blood vessels. Additionally, it can be utilized in both cirrhotic and non-cirrhotic livers [4].

An example of ultrasonic vessel-sealing device used for transection of liver parenchyma is the harmonic scalpel (Ethicon Endo-Surgery, Inc.; Cincinnati, OH), which uses harmonic energy to cut and seal vessels >3 mm using high-frequency vibration of the instruments (over 55,000 Hz/s), both in laparoscopy and open surgery. The basis of its functioning lies in protein denaturation, not heat. Several early nonrandomized studies linked the harmonic scalpel to a marked rise in the frequency of postoperative bile leakage when compared to the conventional clamp-crushing method [16]. In 2020, Kamarajah et al. published a meta-analysis comparing different types of parenchymal transection techniques during hepatectomy, observing that techniques with bipolar cautery appear to be the quickest and work best in minimizing blood loss. Harmonic scalpel, on the other hand, has a lower risk of overall and major complications [17].

Early randomized studies found no difference in intraoperative and total blood loss between an ultrasonic device and clamp crush technique, or even found clamp-crushing technique to be superior in terms of resection time, blood loss, and blood transfusions [18–19].

More recent studies however have found that ultrasonic devices are safe in terms of blood loss, transfusions, and postoperative complications, even when compared to other transection devices such as water jet dissection or TissueLink. Other prospective trials found that the harmonic scalpel was safer than the standard control utilizing suture material for small blood vessels (diameter ≤2 mm) and showed a tendency toward minimization of blood loss [20–21].

## 4.5 Radiofrequency-Assisted Devices in Liver Resection

With the use of RF electrodes, liver parenchyma is pre-thermocoagulated, causing a 0.1–1.5-cm-wide line of coagulative necrosis in a sphere of tissue surrounding the probe. As a result, the tissue becomes precoagulated and is ready to be transected with a scalpel. This method, pioneered by Weber et al., aims at a bloodless liver resection [22]. A recent meta-analysis by Jayant et al., comparing liver resection with one RF-based device (Habib™-4X) with the clamp-crush technique concluded that the use of the RF-based device was associated with lower blood loss and lower blood transfusion requirement [23].

Still, there are some studies which compare RF-assisted liver resection to crush-clamp techniques that have found a higher rate of intra-abdominal infections with RF-assisted resection [24].

This may be caused by the higher amount of tissue necrosis generated with RF in comparison with other techniques. Some early studies also proposed the possibility of heat injury to important biliary structures with RF, leading to an increase in bile leaks and bile stricture. However, later studies, such as Li et al., have not found a statistically significant association between RF-based devices and bile leak [25].

There are different devices that use RF energy, such as Habib 4X System, Cool-tip System (Radionics, and TissueLink. The system of application can also be classified according to the RF applicator in use as "needle" RF-assisted liver resection devices, "handheld instrument" RF-assisted devices, or combined ablation and resection (CARe) devices.

### 4.5.1 TissueLink™

The TissueLink™ radiofrequency-assisted devices uses low radiofrequency monopolar energy up to 3 mm of depth to generate heat that is transmitted through a metal probe and saline irrigation, achieving parenchymal dissection and hemostasis. Its drawback is an irregular transmission, and it's also slower and more expensive than other devices, such as the ultrasonic dissector or water dissector [26–27].

### 4.5.2 Aquamantys®

Aquamantys® is another saline-coupled bipolar technique for reducing intraoperative blood loss combining bipolar radiofrequency energy with continuously flowing saline at the electrode tip. Its difference with TissueLink™ resides in the use of bipolar energy, while TissueLink™ uses monopolar energy (Fig. 4.3) [28].

A study by Hammond et al. showed that Aquamantys® produced a wide band of coagulation adjacent to the line of transection, but this was not reflected in the necrotic band width, which was not significantly higher when compared to others such as Ligasure™ or CUSA [29]. However, this is an observational study undertaken in a non-perfused benchtop cadaveric model, and more randomized studies are needed.

### 4.5.3 Coolingbis®

The Coolingbis system (Vecmedical, Montcada I Reixac, Barcelona, Spain) is a type of handheld RF-assisted device, which consists of an internally refrigerated RF highly powered monopolar instrument equipped with a built-in knife that allows for hemostasis and deeper parenchymal ablation, while simultaneously performing precision cutting of the tissue that has been coagulated (Fig. 4.4).

The device consists of a closed hollow steel tube (length: 30 cm; diameter: 3.5 mm) with a 1.5-mm tube inside that uses a peristaltic pump to

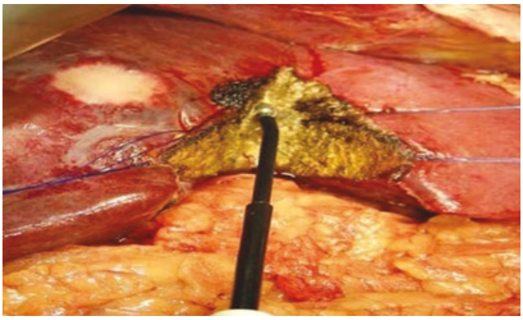

**Fig. 4.3** Liver parenchyma dissection using Aquamantys®

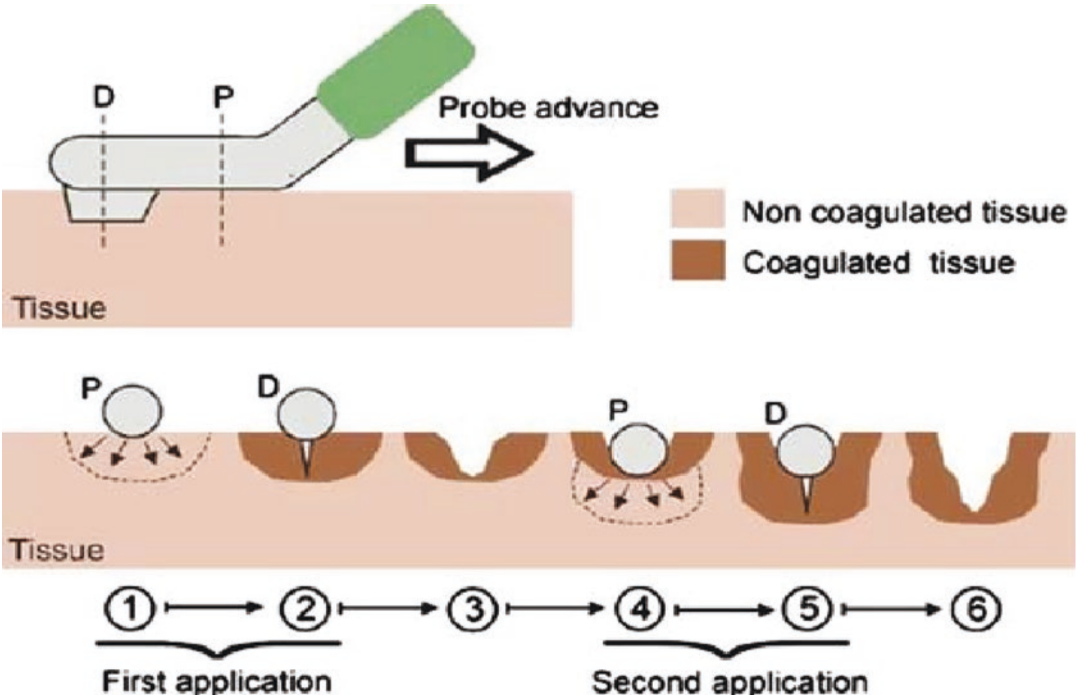

**Fig. 4.4** Top: Lateral view of the probe showing the distal section (D) with the attached sharp blade and the proximal section (P) as well as the advance direction. Bottom: Cross views of a tissue fragment showing two sequential applications, each consisting of two steps. First, the tissue is heated and coagulated by application of radiofrequency currents (arrows) using the proximal section (1 and 4). Second, the blade cuts the tissue previously coagulated (2 and 5)

deliver cold water (0°C) to the electrode's tip at a rate of about 130 mL/min. The outer tube, which is connected via an electric connection to a radiofrequency generator, returns the warmed solution to the outside collector. The device consists of two separate components in a single unit: a coagulation system with a blunt, non-insulated, cooled-tip that coagulates the liver surface just by coming into touch with it; and an optional cutting system with a 2-mm-wide blade attached distally to the tip that slices the precoagulated tissue. The tissue is first coagulated by the proximal blunt tip of the instrument as it is dragged backward and is then cut by the blade at the tip. Only the portion of previously coagulated tissue is transected (generally 2 mm). As a result, the tissue is only coagulated once, preventing overheating (Fig. 4.5) [30–31].

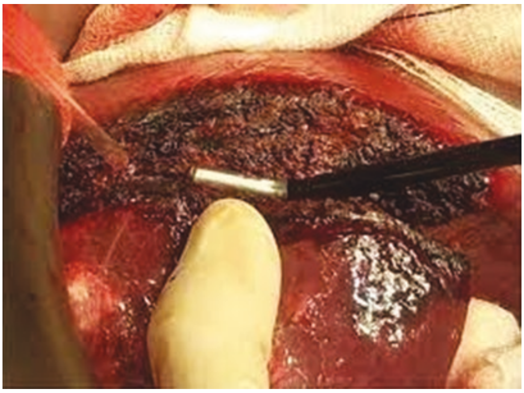

**Fig. 4.5** Parenchymal transection using Coolingbis

A recent retrospective study by Villamonte et al. studied 185 patients with a resection margin <10 mm and found that the use of Coolingbis on the resection surface during liver resection can also lower local hepatic recurrence in comparison to traditional hemostatic techniques. [32] More randomized studies are needed to support these findings.

## 4.6 Water Jet-Assisted Devices in Liver Resection

The water jet (WJ) technique uses a high-pressure water jet to break apart liver tissue and selectively isolate small vascular and biliary structures, thereby reducing blood loss. Afterward these ducts and vessels must be ligated individually in a second step, whereas other techniques allow for transection and hemostasis simultaneously [33].

There are also some concerns regarding vessels breaking with this technique. On the other hand, an advantage of using the WJ technique is the absence of any thermal damage in the surrounding tissue. A recent study by Hanaki et al. demonstrated this lower thermal damage to the detached liver section with WJ in comparison with CUSA. Still, it is a single-center retrospective study, and more randomized data is needed to support its efficacy [34].

## 4.7 "Clamp-Crush" Technique

This technique has been introduced more than 30 years ago, consisting in fracturing the liver parenchyma, preserving the main structures such as veins and pedicles. These structures are lately sectioned after ligation. This technique has been the gold standard procedure up until the introduction in the late 90s of the previously mentioned modern techniques. However, this technique is still a common procedure among liver surgeons, in combination with the use of the previous modern described devices. Several meta-analyses attempt to show the benefits of the energy devices in the liver transection compared with the classical "clamp-crush" technique. [17] However, none of them have been able to show relevant differences. Being most of the included studies retrospective and with heterogeneous populations, it is important to highlight that the evidence of the superiority of one technique above others is still low. With the widespread use of the liver laparoscopic resection, as the "clamp-crush" though laparoscopy is more difficult, its use apparently decreased in the last decade. However, currently, this technique is gaining popularity again thanks to the introduction of the robotic platform. In fact, the robotic system overcomes the movement limitations of the laparoscopic instruments, making the "clamp-crushing" of the liver parenchyma much easier, and for this reason, its popularity increased in the last years. In addition, the robotic forceps can be used with a double bipolar energy, enhancing the classical "clamp-crushing" technique.

## 4.8 Minimally Invasive Pedicle Dissection

As introduced before, a better understanding of hepatic anatomy is one of the most important aspects to minimize intraoperative blood loss in hepatic surgeries. In that context hepatic inflow and outflow control are essential.

### 4.8.1 Hepatic Inflow Control

Vascular staplers allow for intrahepatic pedicle ligation of the portal pedicles, permitting simultaneous ligation of the portal vein, hepatic artery, and bile ducts. These sheaths can be approached either anteriorly or posteriorly from behind the porta hepatis by performing several hepatotomies [35]. However, it should be noted that when a tumor is less than 2 cm from the hepatic hilus, an extrahepatic pedicle technique is preferable.

(a) *Left pedicle ligation*. The left portal pedicle can be isolated with a low risk of harming the hilus by lowering the hilar plate (Fig. 4.6, incision c) in the back of segment 4. Care must be made to ligate the left portal pedicle distal to the sources of the branches to the caudate lobe if the caudate lobe is to be preserved (Fig. 4.6, incision at sites c and e). If instead, the caudate lobe is to be preserved, these branches must be tied off (Fig. 4.6, incision at sites c and f). Constant traction is applied to the umbilical tape downward, and a vascular clamp is positioned on the portal pedicle's specimen side. After that, the left portal pedicle is severed.

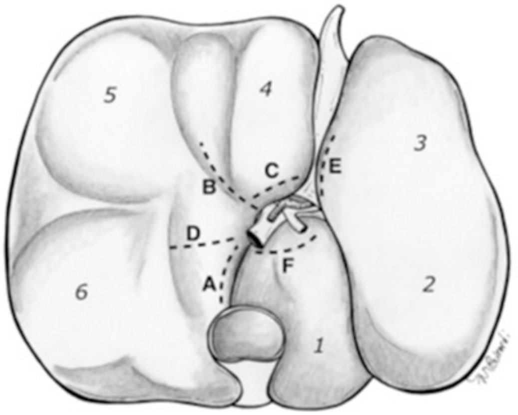

**Fig. 4.6** Sites for hepatotomy in portal pedicle ligation by a posterior intrahepatic approach. The undersurface of the liver is illustrated. Incisions at (**a**, **b**) allow isolation of the right main portal pedicle. Incision at (**c**) allows lowering of the hilar plate. Incisions at sites (**a**, **d**) allow isolation of the right posterior portal pedicle. Incisions at sites (**b**, **d**) allow isolation of the right anterior portal pedicle. Incisions at sites (**c**, **e**) allow isolation of the left main portal pedicle if the caudate process is to be preserved. Incisions at sites (**c**, **f**) allow isolation of the left main portal pedicle if the caudate process is to be removed

(b) *Right pedicle ligation*. First, the right lobe of the liver needs to be completely mobilized, the most inferior small hepatic veins or any major auxiliary right hepatic veins from the back of the liver to the vena cava must be split, and the gallbladder must be removed. Following that, a hepatotomy is made across the caudate process, often 1–2 cm deep. In the gallbladder bed, a second hepatotomy is performed. It is also crucial to lower the hilar plate in segment 4's back. A vascular clamp can be used to precisely delineate the segments that a particular sheath supplies. While applying steady traction to the umbilical tape to the left, the liver tissue on top the major right pedicle is transected by a vascular stapler. The umbilical tape's grip prevents unintentionally applying staples too closely to the hilus.

### 4.8.2 Hepatic Outflow Control

Post-sinusoid blood gathers in either the left, middle, or right hepatic vein before draining directly to the inferior vena cava (IVC) behind the liver, along with numerous other short retrohepatic veins that also drain to the IVC. That is why hepatic outflow control is mainly based on management of the IVC. The total hepatic vascular exclusion (THVE) technique was first described by Dr. Heaney and later modified by Dr. Huguet in 1978, and it was not until 1995 that Dr. Elias introduced selective hepatic vascular exclusion (SHVE), which allows control of the hepatic outflow with preservation of caval flow, resulting in a decrease in hemodynamic complications [36].

These procedures, however, are more technically challenging since they ask for individualizing of both the infra- and suprahepatic IVC.

Endo-GIA staplers (United States Surgical Corporation; Norwalk, CT) can make it much easier to ligate any of the major hepatic veins thanks to the application of staple lines on both sides of the vascular division, thereby sealing the stump on the IVC as well as the hepatic stump on the specimen side, where sewing is frequently challenging due to the orientation of the surgical specimen [37].

## 4.9 Instruments to Encircle the Hepatoduodenal Ligament

### 4.9.1 Endo Retract™ Maxi and Endo Mini-Retract ™

There are two laparoscopic devices from the same manufacturer that allow for laparoscopic encircling of the hepatoduodenal ligament as a tourniquet to obtain a complete interruption of blood inflow: Endo Retract™ Maxi (Covidien Japan, Tokyo, Japan) and Endo Mini-Retract ™ (Covidien Japan, Tokyo, Japan) [38]. However, the Endo Retract™ Maxi poses some difficulties because of a quite uncomfortable design of the device and the need for two handed handling.

On the other hand, Endo Mini-Retract™ solves these issues with the use of a more gently curved arm and a smaller, blunter shape of the retractor tip. However, it has the disadvantage of the absence of any hole at the tip of the arm that can be circumvented with the use of a shortened Nelaton catheter, improving both the ease and the safety of the procedure [39].

### 4.9.2 Goldfinger

The Goldfinger (GF) dissector is a device that was originally designed for retrogastric tunnel dissection. For that purpose, GF is used to perform 1–2-cm-deep transection of the liver parenchyma along the confluence of the caudate process and paracaval region anterior to the retrogastric tunnel. The GF is then put through the tunnel for blunt dissection, and the cad-retrogastric tunnel is established with careful articulation of its adaptable tip flexing between 30° and 45° (approximately one-third of the total retrogastric tunnel) [40].

Several studies have also found that the use of the Goldfinger dissector in cases of modified hanging maneuver for laparoscopic right and left hepatectomy is safe, reproducible, and can facilitate liver dissection during major hepatectomy [41].

## 4.10 Conclusions

There are few published randomized studies assessing liver transection techniques, and most of them have been unable to demonstrate any significant improvement over traditional techniques, particularly the clamp-crushing technique. In a recent Cochrane Systematic Review of 67 randomized clinical trials, which included 6197 patients, no evidence was found that using special equipment for liver resection is of any benefit in decreasing the mortality, morbidity, or blood transfusion requirements in liver surgery. Most of the trials included had a high risk of bias [42].

Most literature reviews conclude that the surgical device used in a laparoscopic approach should be the one the surgeon is most familiar with [43–44]. In 2021, the Expert Consensus Guidelines on Minimally Invasive Donor Hepatectomy for Living Donor Liver Transplantation concludes that parenchymal transection is left to the surgeon’s preferences. To prevent harm to larger structures, especially hepatic veins, it is advised against blindly using energy devices deeper than the superficial region of the liver [45].

The introduction of robotic surgery improves “dexterity” in vascular control, but the use of energy devices in these types of surgeries depends on the assistant which may be a limitation. Hawksworth et al. published an observational study of 20 patients undergoing robotic major hepatectomies and concluded that the use of CUSA may improve safety and reduce morbidity in these procedures. However due to the shortness of the current laparoscopic CUSA probe and the poor port placement for its introduction, there was a need for an assist port placement, which could limit the full range of the robotic arms. [46]

Currently there is no level 1 evidence to suggest that any robotic transection devices are superior to the simple clamp-crushing technique reported over 40 years ago. Therefore, nowadays there is no systematic review nor meta-analysis that supports solid evidence on the best technique for parenchymal resection in robotic surgery. However, the combination of surgical skills and technical development is well demonstrated and ever evolving.

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# 5

# Glissonean Pedicles for Liver-Sparing Parenchymal Resection Lesson Learned from Open Surgery

Fabio Procopio and Guido Torzilli

## 5.1 Introduction

Intraoperative ultrasound (IOUS) guidance is an indispensable tool for driving parenchyma sparing surgery. Indeed, IOUS allows an accurate three-dimensional estimation of the relationship between the tumor, Glissonean pedicles, and hepatic veins, by a precise definition of the integrity of the vessel wall. This enables to address the suitability or not of tumor-vessel detachment: the so-called R1 vascular (R1vasc) surgery. In the case of Glissonean pedicles, bile duct dilation, presence of tumor thrombus, and invasion of the vessel wall are signs suggesting undetachable conditions, which demand vessel amputation.

This approach was initially proposed for hepatocellular carcinoma (HCC) and subsequently for colorectal liver metastasis (CLM) and mass-forming cholangiocellular carcinoma (MFCCC), showing encouraging results in terms of local control [1–3]. These first experiences have been further confirmed in larger series of patients with CLM [4, 5] and HCC [6], strengthening the reliability of R1vasc for these tumors. Conversely, for MFCCC R1vasc showed a local recurrence rate similar to that of tumor exposure in contact with the liver parenchyma (R1par) [7].

IOUS guidance and R1vasc constitute the key factors for a novel policy. Indeed, the surgeon intentionally challenges the major vessels and their exposure and lets them drive the course of the liver resection: the so-called vessel-guided hepatectomy [8]. Sparing the main Glissonean pedicles and main hepatic veins allows to keep cleared from the tumors the core of the organ and getting toward the liver's core becomes something to be pursued. Technically this means searching for vessels, either Glissonean pedicles or hepatic veins, just a few millimeters below the liver surface, and then proceeding with the dissection being driven by them. Following the vessels from the surface to the deep parenchyma means in fact an anatomical approach, but with infinite trajectories according to the selected vessel, and consequently infinite solutions, maximizing the parenchyma sparing not just challenging the complexity of the liver, but being guided exactly by such complexity. The liver anatomy guides the surgeons with IOUS acting as interpreter before vessel exposure. In addition to that, IOUS recognition and tracing of peculiarities as accessory hepatic veins and/or communicating veins between adjacent hepatic veins further expand technical solutions in the case of unsuitability of R1vasc surgery. Therefore, an interaction with the liver anatomy, tumor, and surrounding structures results in a multitude of

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surgical options [9, 10], increasing the salvageability in the case of relapse [5, 11, 12].

## 5.2 Intraoperative Ultrasound Criteria and Surgical Policy for Tumor in Contact with a Glissonean Pedicle

The R1vasc policy according to the type of tumor is schematically represented in Fig. 5.1 [1]. A capsulated HCC is detached from the Glissonean pedicle in the case of integrity of the vessel wall at IOUS without any sign of bile duct dilation (Fig. 5.1a). Similarly, the pedicle can be spared when it is in contact with a CLM once IOUS has confirmed the integrity of the vessel wall, the absence of bile duct dilation, and the extent of contact is up to two-third of the pedicle circumference (Fig. 5.1a) [2]. In the case of bile duct dilation (Fig. 5.1b), invasion of the vessel wall (Fig. 5.1d), and, for CLM, contact wider than two-thirds of pedicle circumference (Fig. 5.1e), the Glissonean triad has to be divided. Similarly, the pedicle has to be also sacrificed in the case of a tumor thrombus (Figs. 5.1c, e). In these cases, extension of the hepatectomy is always considered.

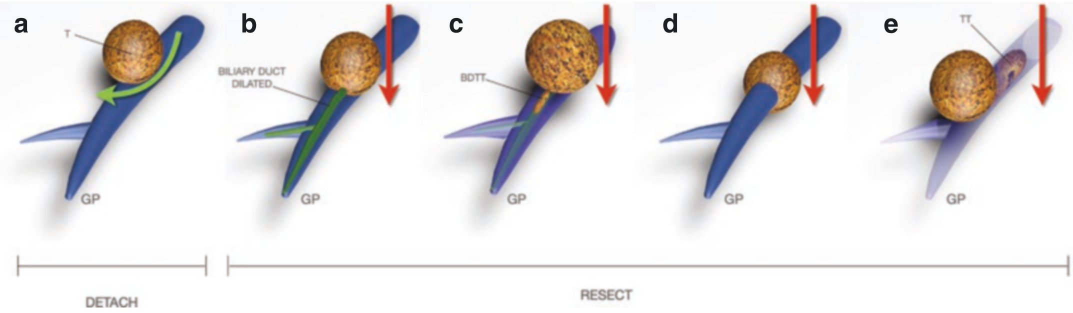

**Fig. 5.1** This schema visually emphasizes the oncologic suitability of R1 vascular policy. *T* tumor, *GP* Glissonean pedicle, *BDTT* bile duct tumor thrombus, *TT* tumor thrombus

## 5.3 Parenchyma-Sparing Resection for Centrally Located Tumors

The principal output of this approach is to make feasible small-sized resections even in the presence of a tumor in contact with first- or second-order portal branches, which can be represented schematically by a new resection planning as shown in Fig. 5.2. This becomes feasible by performing more complex dissection under strict IOUS guidance, and even standardizing procedures based on the pattern of lesion distribution and IOUS tumor-vessel relationships: this is the case for the so-called lower transversal hepatectomy (Fig. 5.3) [11], liver tunnel (Fig. 5.4) [12], and horseshoe hepatectomy (Fig. 5.5) [13].

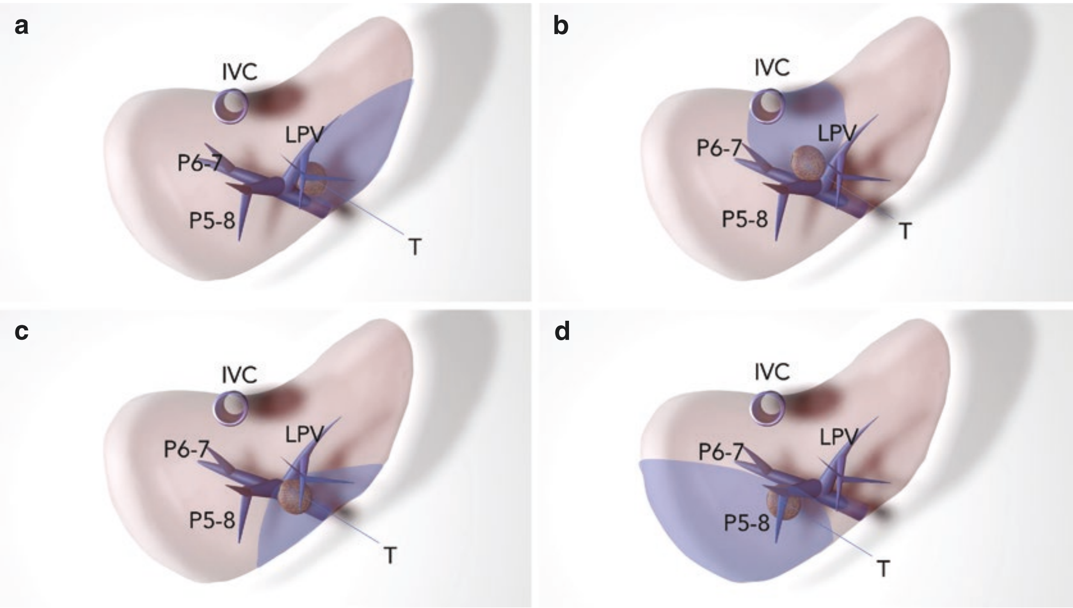

**Fig. 5.2** Resection areas (blue) adopted for lesions centrally located due to contact with the first- or second-order Glissonean pedicles (**a**) on the left, (**b**) posteriorly, (**c**) anteriorly, and (**d**) on the right. *T* tumor, *IVC* inferior vena cava, *LPV* left portal vein, *P5-8* portal branch to the right anterior section, *P6–7* portal branch to the right posterior section, *UP* umbilical portion

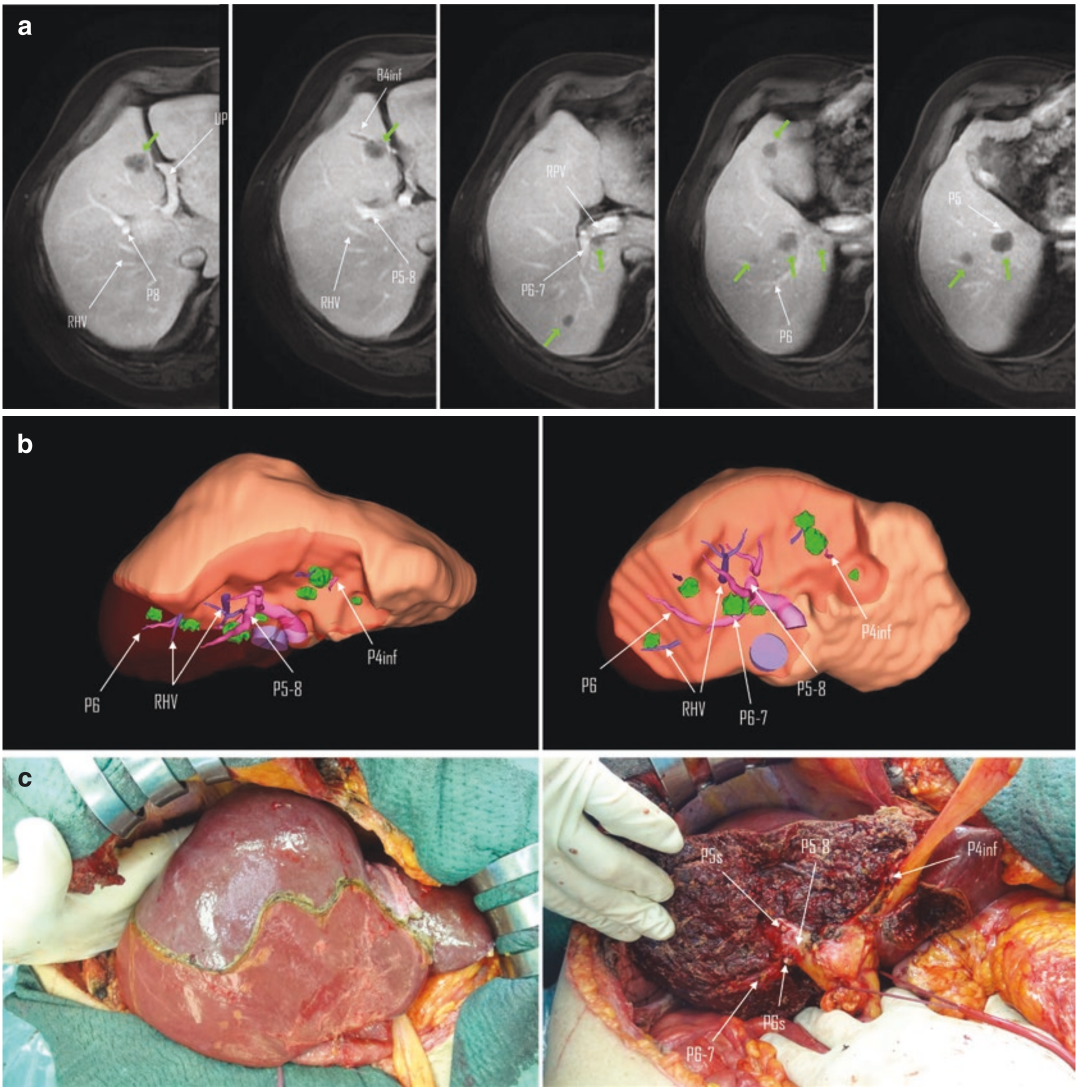

**Fig. 5.3** Lower transversal hepatectomy for multiple colorectal liver metastases. (**a**) Preoperative magnetic resonance imaging shows multiple lesions (green arrows) with one in contact with portal branch to right posterior section and one involving the Glissonean pedicle for segment 4 inferior with subsequent segmental bile duct dilation. (**b**) Preoperative three-dimensional virtual cast showing the bilateral distribution of the lesions in an estimated future liver remnant of 70% and the surgical plan. (**c**) On the left, demarcation area of the lower transversal hepatectomy (red area); on the right, the cut surface at the end of the removal of colorectal liver metastases with exposure of stumps of pedicle for segment 4 inferior (*P4inf*), pedicle for segment 5 (**P5s**), pedicle for segment 6 (*P6s*), and exposure of the portal branches to right anterior (*P5–8*) and posterior section (*P6–7*). *RHV* right hepatic vein

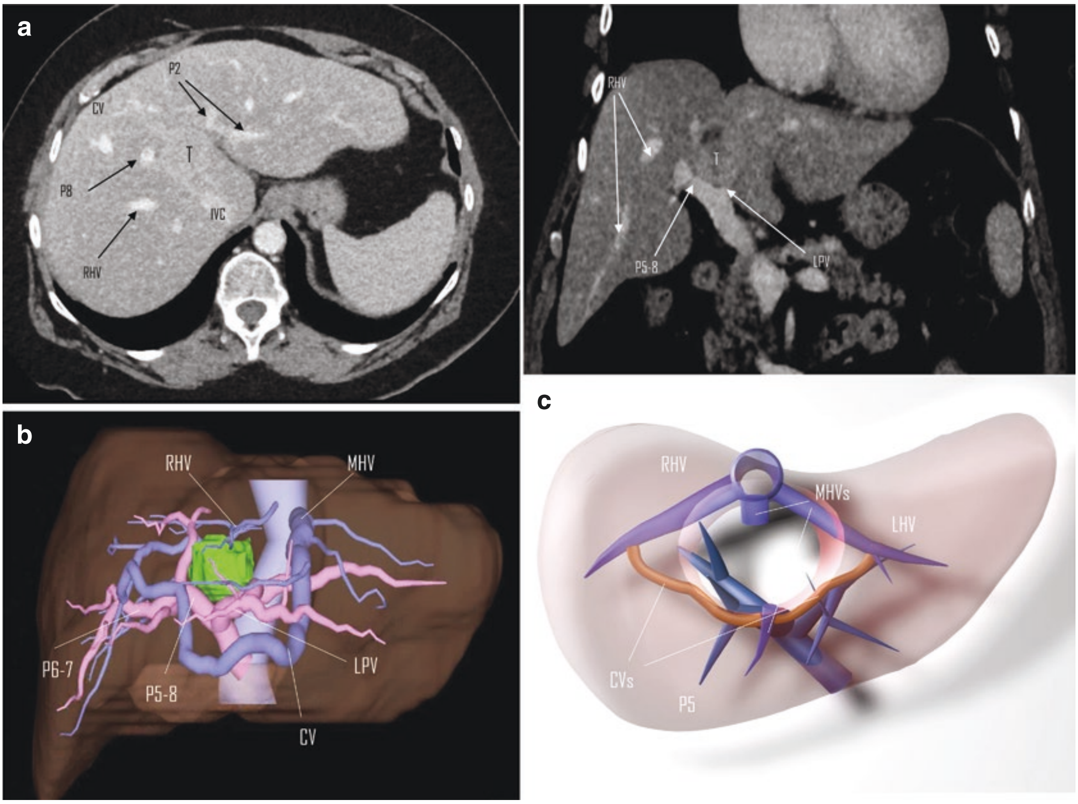

**Fig. 5.4** (**a**) Computed tomography showing a tumor located between the segment 8 and the paracaval portion of the segment 1 closed to the portal vein bifurcation. (**b**) The preoperative three-dimensional virtual cast showing the relationship between the tumor and the intrahepatic vascular structures; (**c**) the schema of the surgical plan consisting in the liver tunnel. (**d**) IOUS imaging shows the contact of the tumor with the right (*RPV*) and left portal vein (*LPV*) at their origin and the invasion of the middle hepatic vein (*MHV*) at the caval confluence. (**e**) Identification and mapping at the color Doppler of communicating veins between RHV and MHV. (**f**) Liver tunnel at the end of the resection with exposure of the stumps of MHV (*MHVs*), pedicle for segment 8 (*P8s*), pedicle for segment 4 superior *(P4sup*), and exposure of the left portal pedicle (*LPV*), portal branch to right anterior section (*P5–8*), and inferior vena cava (*IVC*)

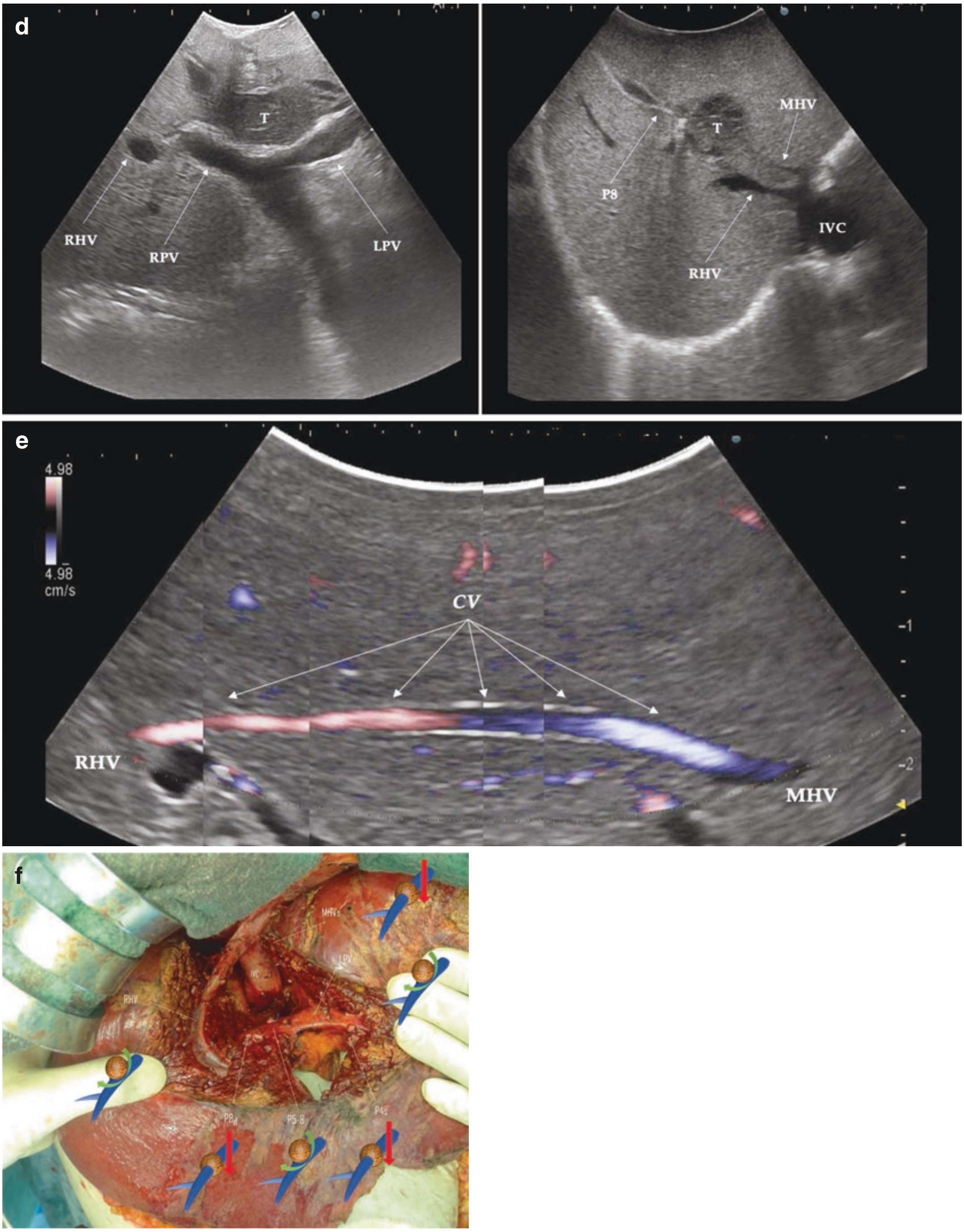

**Fig. 5.4** (continued)

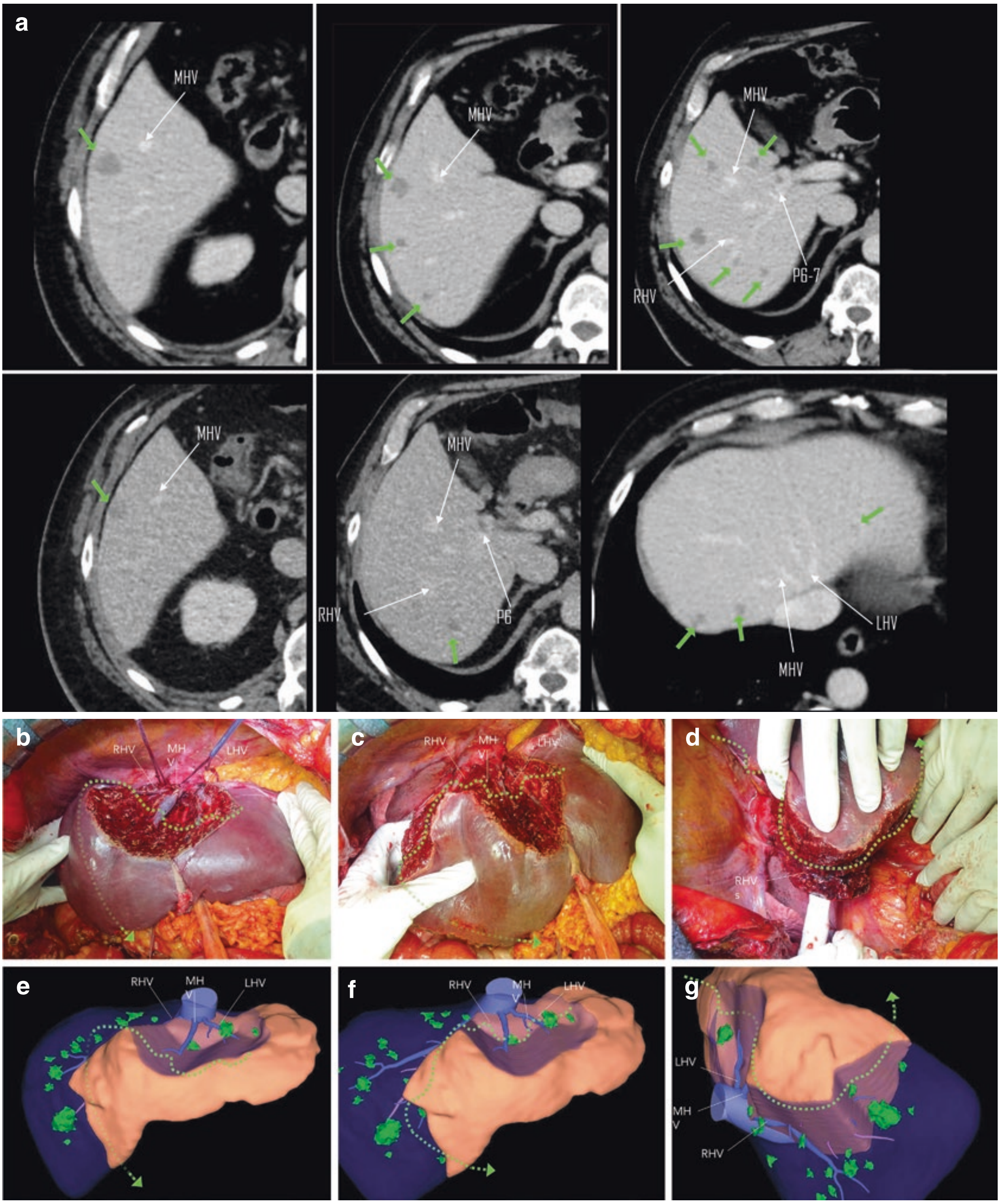

**Fig. 5.5** (**a**) Preoperative CT scan showing multiple bilobar colorectal liver metastases (marked by green arrows). Two major clusters in right posterior section are visible (**b**–**d**). Intraoperative images and comparison with the three-dimensional reconstruction (**e**–**g**). The green-dotted arrows indicate the transection plane. The three hepatic veins (left, LHV; middle, MHV; and right, RHV) are exposed on the cut surface, and the RHV has been cut at its proximal third (stump is visible on the cut surface (RHVs). P6–7, right posterior portal branch; P8d, stump of P8 dorsal; P4s, stump of P4 superior; P5-8, anterior portal branch

## 5.4 Anatomical Resections by Intraoperative Ultrasound-Guided Glissonean Pedicle Compression

These resections are carried out by following the planes that divide hemilivers, sections, segments, and subsegments. Technical requirements for accomplishing truly anatomic sectionectomies and formal major hepatectomies are uniformly accepted and could be divided into two modalities: one based on the dissection of the vascular elements at hepatic hilum and one based on blunt encirclement of the hemiliver or sectional pedicles from the hepatic hilum. Conversely, an anatomical segmental and subsegmental resection demands the recognition of the feeding Glissonean pedicle, its branching, and the related area perfused. Segmentectomy and subsegmentectomy are mainly selected for removing HCC with the purpose to balance between the need to be oncologically radical and the need to preserve the underlying liver function, which is often compromised. The first procedure described in this area was the systematic segmentectomy devised in the early 1980s [14], which consists of puncture of the portal branch feeding the tumor and subsequent injection of dye; more recently, ICG-fluorescence has substituted the dye injection [15, 16]. Initially used for HCC located in the left hemiliver [17], Glissonean pedicle compression has been successfully extended to any segmental location [18, 19] and sectionectomies [20, 21]. This approach has proven its oncological suitability both in terms of long-term local control and overall survival [22].

### 5.4.1 Segmentectomies and Subsegmentectomies

The procedure can be summarized as shown in Fig. 5.6. Once the feeding Glissonean pedicle is identified at IOUS (Fig. 5.7c, e), it is compressed by using the IOUS probe on one side of the liver and a finger on the opposite side, confirming a proper compression by IOUS real-time control (Fig. 5.7d, f); in this way, it is possible to induce a transient ischemia of the portion of the liver distal to the compression site (Fig. 5.7g). This portion can be marked with electrocautery, the compression is released, and the resection is carried out (Fig. 5.7h). This technique is simple, fast, noninvasive, not dependent on the vessel diameter, and most importantly, reversible, with the possibility of modifying the site of compression if necessary. More recently, ICG intravenously injected by the anesthesiologist once the compression has been started has allowed to further enhance the demarcation with a counter-fluorescence of the area to be spared, overcoming those situations of nuanced demarcation (Fig. 5.8) [23].

The compression can be also used in a counter-compression manner, borrowing from the counterstaining technique proposed by Takayama and colleagues [24] for defining the adjacent segmental margins. For segments such as I and IV supe-

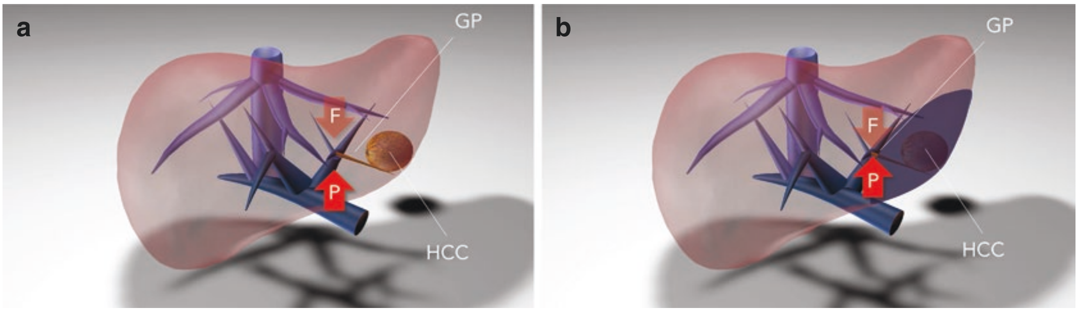

**Fig. 5.6** (**a**) For segmentectomy by means of compression, the feeding Glissonean pedicle (GP) is identified and compressed at the point targeted by intraoperative ultrasound (red arrows), resulting in discoloring of the segmental area (blue area in **b**), which in this way can be marked with the electrocautery and selectively removed. *F* finger, *P*, probe, *HCC* hepatocellular carcinoma

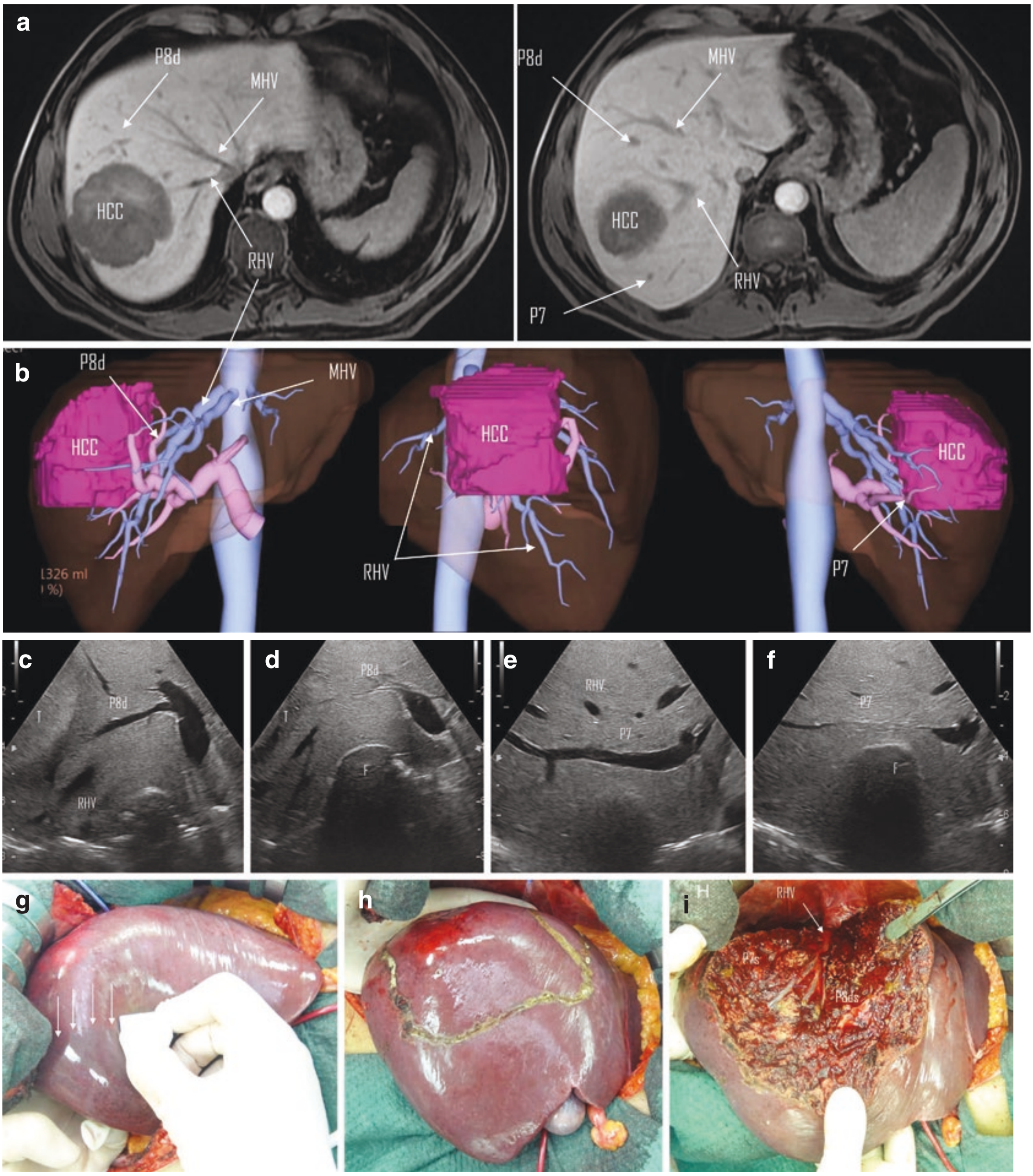

**Fig. 5.7** Anatomical segment 7–8 dorsal subsegmentectomy by intraoperative ultrasound (IOUS) compression technique. (**a**) Preoperative imaging showing the tumor's location and its relation with intrahepatic vessels. (**b**) Preoperative virtual cast on preoperative CT scan. (**c**) The IOUS scan shows the portal branch (*P8d*) feeding the tumor in segment 8 dorsal. (**d**) Once identified under IOUS guidance, P8d compression is carried out by means of the probe and the surgeon's finger (*F*) positioned on the opposite side: the segmental area results then discolored (*arrows in* **g**). (**e**) The portal branch feeding the segment 7 (*P7*) is identified at IOUS and compressed (**f**). (**h**) Resection area. (**i**) After anatomical resection of segment 7–8d subsegmentectomy showing the right hepatic vein (*RHV*) and the stumps of P7 (*P7s*) and P8d (P8ds) on the cut surface as landmarks of a true anatomical resection. *HCC* hepatocellular carcinoma, *MHV* middle hepatic vein, *T* tumor

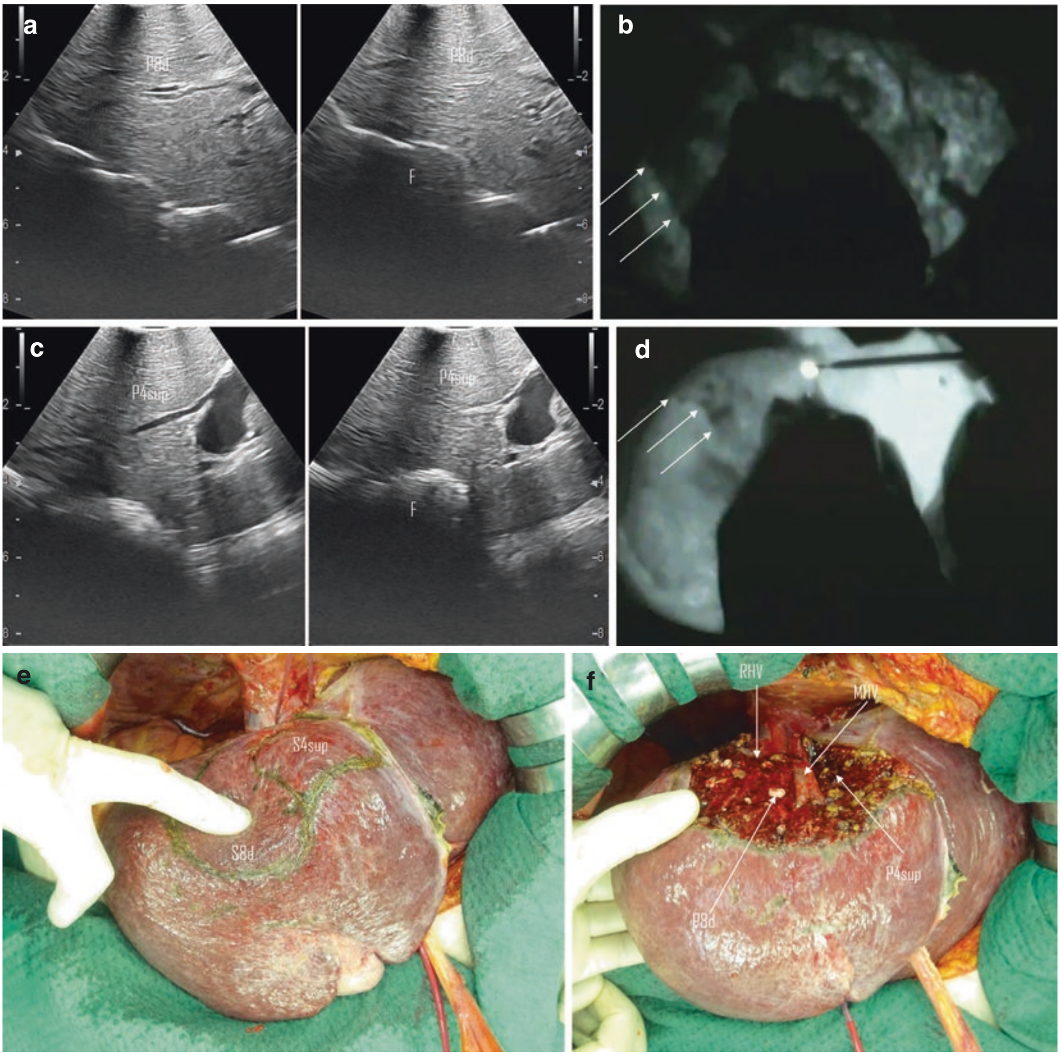

**Fig. 5.8** This sequence of pictures shows the ICG compression technique provided by compression of multiple tumor-bearing pedicles to cover the entire tumor located into segments 8 dorsal and 4 superior. (**a**) At IOUS on the left, the P8 dorsal is shown at the site the surgeon aims to start the compression maneuver, and, on the right, the compression is carried out using the probe and the surgeon's finger (indicated by F). (**b**) Under IOUS-guided P8 dorsal compression, ICG is administered intravenously, so that the compressed area results in a not-stained one, and it is then marked on the liver surface (**e**) using electrocautery. (**c**) At IOUS on the left, the P4 superior is shown and then, on the right, compressed under IOUS guidance. (**d**) The additional demarcation area is identified by visualizing a slight decrement of fluorescence intensity and then (**e**) marked on liver surface. (**f**) The cut surface at the end of the resection where the root of right hepatic vein (RHV) and the middle hepatic vein (MHV) are shown. *P4sup* Glissonean pedicle to segment 4 superior (S4sup), *P8d* Glissonean pedicle to S8 dorsal (S8d)

rior, for which direct compression of the feeding portal branch is difficult, if not unfeasible, compressing the adjacent segmental branch allows definition of their segmental margins [17].

In the event of HCC with tumor thrombus in the feeding portal branch, staining and compression techniques cannot be performed to demarcate the segment. In such cases, intravenous injection of ICG once the proper hepatic artery is selectively clamped at the hepatic hilum enables the demarcation of the segmental margin by counterfluorescence [25].

### 5.4.2 Right Posterior Sectionectomy

As for segmentectomies, the demarcation of the sectional area to be removed is advocated. Among methods proposed for obtaining this demarcation, extrahepatic isolation of the right-sided sectional pedicles consists of careful and meticulous skeletonization of each sectional arterial and portal branch [26]. Alternatively, the three Glissonean pedicles in their surrounding fibrous sheath could be encircled as a whole, with or without the use of a hepatotomy incision [27]. As an alternative to these established techniques, the compression technique could be applied [21]. The hepatic pedicle is encircled with a tourniquet but not dissected.

At IOUS, the portal pedicle for the right posterior section (segments VI and VII) is identified as well as the branches for segments VI and VII; the level targeted for compression is then decided (Fig. 5.9a). The surgeon's nondominant hand is positioned behind the right hemiliver, and the probe is positioned with the dominant hand to show the sectional portal branch at the level of interest, which corresponds to the most distal portion of the vessel in relation to its origin but proximal to the tumor to be removed. The surgeon next uses the fingertips of the nondominant hand and the IOUS probe as instruments to compress the liver bilaterally at the targeted position, resulting in compression of the sectional portal branch in the previously identified tract. When there is no common sectional pedicle to segments VI and VII, compression is applied to the respective segmental portal pedicle as previously described. This maneuver is constantly monitored in real time by IOUS by means of the probe used for compression, and compression is maintained until the surface of the right posterior section lateral to the compression site starts to discolor (Fig. 5.9b). At this time, the assistant marks the discolored area with the electrocautery device, and the compression is released. In this way, a 3D plane has been drawn on the liver surface that passes through the portal branch at the level of compression; liver resection is then carried out following this plane (Fig. 5.9c).

For right posterior sectionectomy, the demarcation could be emphasized adopting the counter-fluorescence technique, as described for segmentectomies [23].

### 5.4.3 Right Anterior Sectionectomy

As for the right posterior section, the hilar dissection or the encirclement of the sectional Glissonean pedicles are the most commonly adopted techniques for defining the resection area in a fully anatomic manner. The counter-compression technique has also been applied for this purpose [20]. The portal pedicle feeding the right posterior section (segments VI and VII) is identified at IOUS, and the level targeted for compression is then detected just after its origin from the right portal branch. Demarcation of the right posterior section is carried out as previously described. To demarcate the left-sided demarcation line, the left portal vein (LPV) is identified at IOUS, and the level targeted for compression is then identified just past

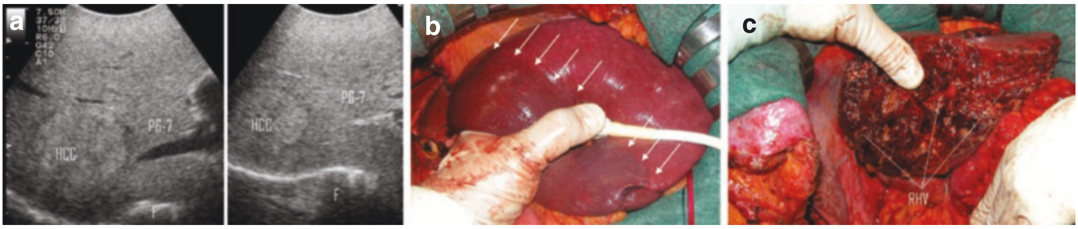

**Fig. 5.9** (**a**) At IOUS on the left, the right posterior pedicle (P6–7) is shown at the site the surgeon aims to start the compression maneuver, and, on the right, the compression is carried out using the probe and the surgeon's finger (indicated by F). (**b**) Under IOUS-guided P6–7 compression, the right posterior section area results then discolored. (**c**) After anatomical right posterior sectionectomy showing the right hepatic vein (*RHV*), *HCC* hepatocellular carcinoma, *RHV* right hepatic vein, *P6-7* right posterior Glissonean pedicle

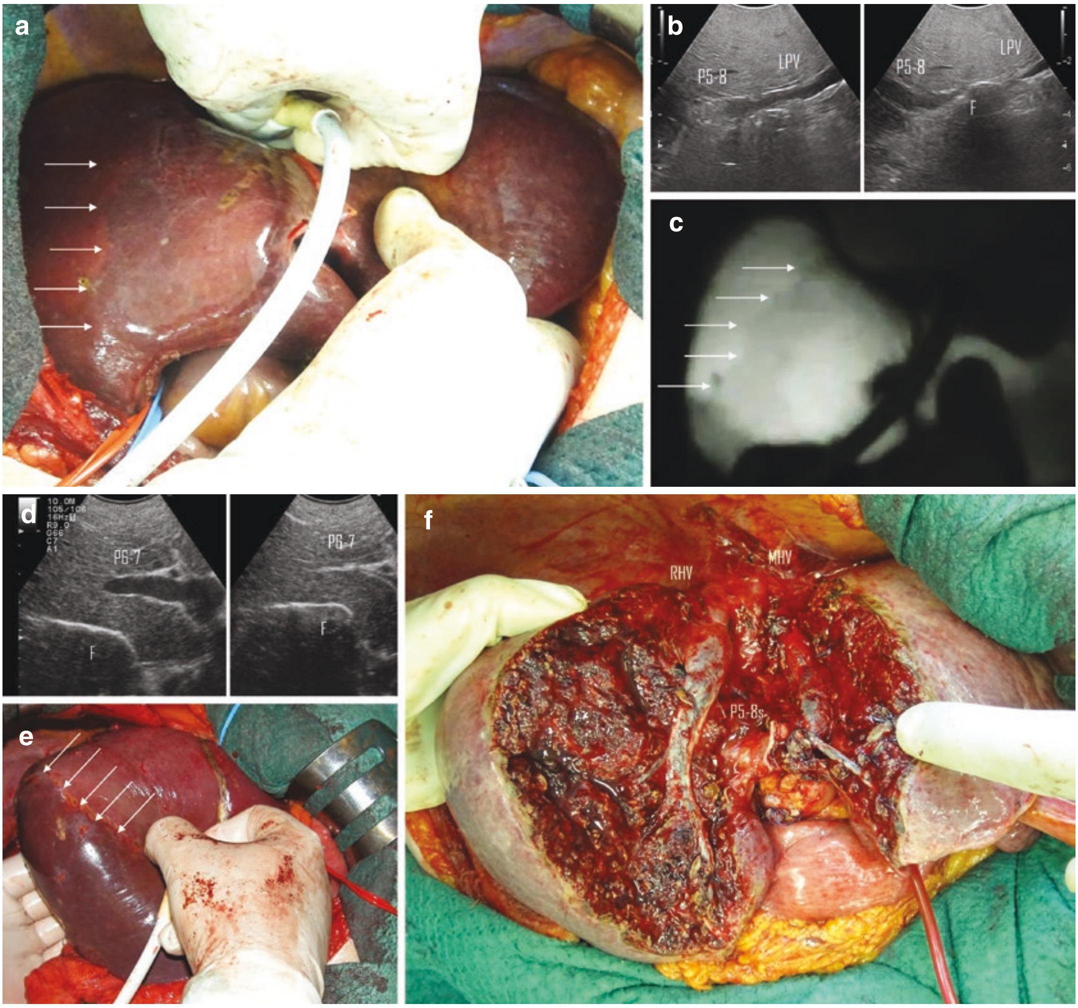

**Fig. 5.10** This sequence of pictures shows the counter-compression technique in order to demarcate the right anterior section (**a**). To demarcate the left-sided demarcation line, the left portal vein (LPV) is identified at IOUS (**b**), and the level targeted for compression is then identified just past its origin from the main portal vein. LPV compression is performed and is released once Cantlie's line becomes evident by left hemiliver discoloration (**a**) and enhanced as a not-stained area after intravenous ICG injection (**c**). (**d**) At IOUS on the left, the right posterior pedicle (P6-7) is shown at the site the surgeon aims to start the compression maneuver, and, on the right, the compression is carried out using the probe and the surgeon's finger (indicated by F) with discoloration of the right posterior section (**e**). (**f**) The cut surface at the end of the right anterior sectionectomy with the exposure the right (RHV) and middle hepatic vein (MHV) and the stump od the right anterior Glissonean pedicle (P5-8s)

its origin from the main portal vein. LPV compression is performed and is released once Cantlie's line becomes evident by left hemiliver discoloration, and it is demarcated with electrocautery (Fig. 5.10). Once the right anterior section is defined, resection can be performed.

In the event of a tumor thrombus occluding the right anterior portal branch, as described for the segmentectomy, the counter-fluorescence can be realized just clamping the proper hepatic artery and injecting intravenously the ICG [25].

## 5.5 Dissection Plan and Intraoperative Ultrasound-Guided Hooking Technique for Main Glissonean Pedicle Section

The main advantage of IOUS-guided resection is modification of the traditional way to dissect the liver tissue, which was originally done on vertical planes to avoid the tumor exposure on the cut surface. IOUS allows the surgeon to follow the dissection plane in real time, to see it constantly in relation to the tumor edge, and then to modify its direction when needed. This is because the dissection plane can be visualized on the IOUS image, which appears as an echogenic line because of the entrapment of air bubbles and clots between facing cut surfaces. If the dissection plane is not clearly visible, it can be better visualized by inserting plain gauze between facing surfaces. These techniques allow the surgeon to keep the proper dissection plane and early recognition of an improper one. In this way, it is possible to carry out a rounded trajectory of the dissection plane around the tumor, avoiding tumor exposure, its eventual disruption, and potentially cancer seeding other than allowing the surgeon to spare important vascular structures. This results in more conservative but radical treatments and in a lower rate of major hepatectomies.

The artifacts that may appear on IOUS sometimes mask structures critical to the dissection plan, such as portal branches, which should be either ligated or preserved. For this reason, to better visualize the targeted point where the portal branch should be divided, the "hooking technique" has been devised [28–30]. When the Glissonean sheath is exposed and skeletonized, it is encircled with a stitch. Under US control, the stitch hooking the exposed vessel is then gently pulled up, which stretches the portal branch slightly; this traction point is demonstrated clearly by IOUS. If the exposed portal branch is not clearly visible because it has collapsed, the portal triad is unclamped. If the target site is correct, the portal branch is ligated and divided, and resection is completed under IOUS guidance. Conversely, if the exposed vessel was not the targeted one, it is spared, and unnecessary sacrifice of further liver parenchyma is avoided. A practical example of using the hooking technique is during ventral or dorsal subsegmentectomy of segment VIII. The portal trunk to this segment may show bifurcation in its dorsal branch and ventral trunk near the origin of the portal vessel to segment V. In this situation, there is the risk of ligating and dividing the portal branch of segment V, instead of the planned subsegmental branch of segment VIII, and necrosis of segment V may occur. Under IOUS control, the hooking technique enables the identification of the branch, which was encircled, and then the surgeon can decide with certainty whether to ligate it (Fig. 5.11).

The hooking technique is also useful with tumor thrombus in portal branches [1]. Once the portal branch is skeletonized, it is encircled with a stitch, which is gently pulled up under IOUS control; this traction stretches the portal branch slightly, and the traction point is demonstrated clearly by IOUS. If the traction point is not at the level of the tumor thrombus, it is possible to ligate the portal branch and proceed with the liver resection, ensuring that the thrombus will not migrate because of surgical manipulation.

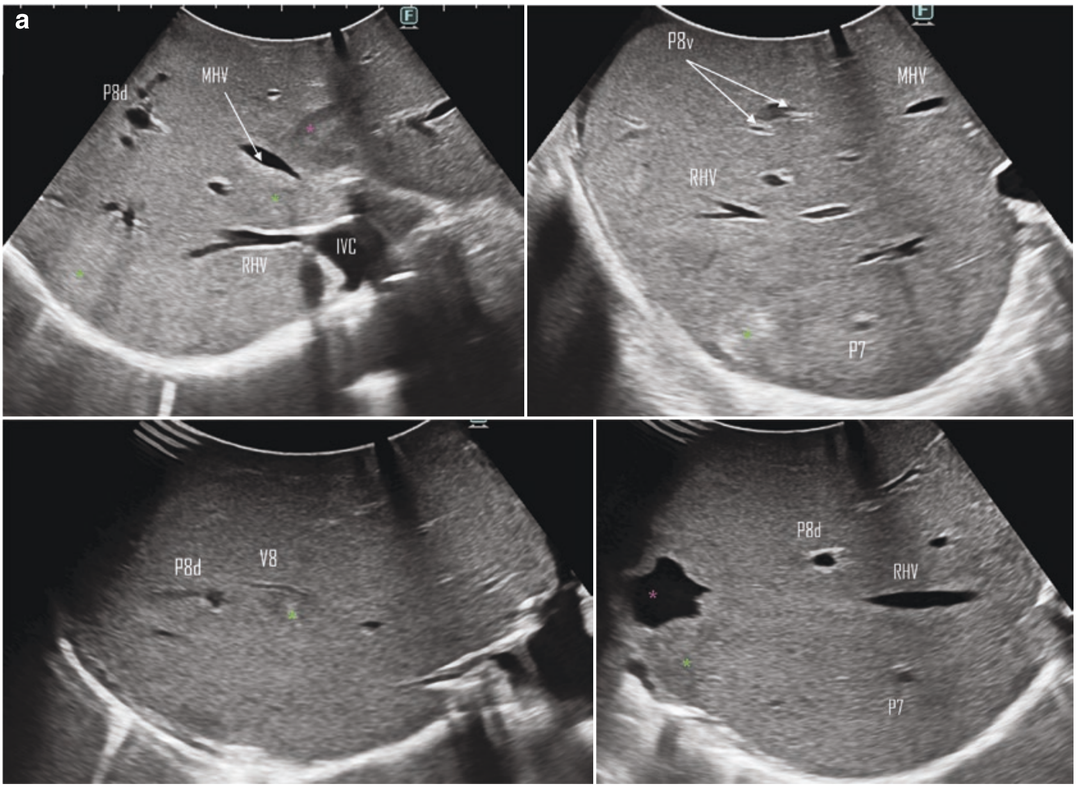

**Fig. 5.11** (**a**) IOUS images showing multiple colorectal liver metastases (marked in green) with a lesion in contact with the middle (MHV) and right hepatic vein (RHV) at the hepato-caval confluence. Benign lesions located in segment 4 superior and in segment 7 are marked in purple. (**b**) At IOUS, on the left, the subsegmental pedicle for segment 8 dorsal encircled by stitch (yellow arrow) is visualized; on the right, the encircled vessel is pulled up by the stitch (yellow arrow), and at IOUS the visualization of the traction point makes sure which vessel is the one encircled, and then it is divided, accordingly. (**c**) Three-dimensional virtual cast showing in blue the extension of the resection area in the case of division of the portal branch of segment V, instead of the planned subsegmental branch of segment 8. (**d**) The cut surface with the exposure of the middle hepatic vein (MHV), the right hepatic vein (RHV), and the stumps of the portal pedicle for subsegment 8 dorsal (P8d) and an accessory vein for segment 8 (V8s). *P7* portal branch for segment 7, *IVC* inferior vena cava

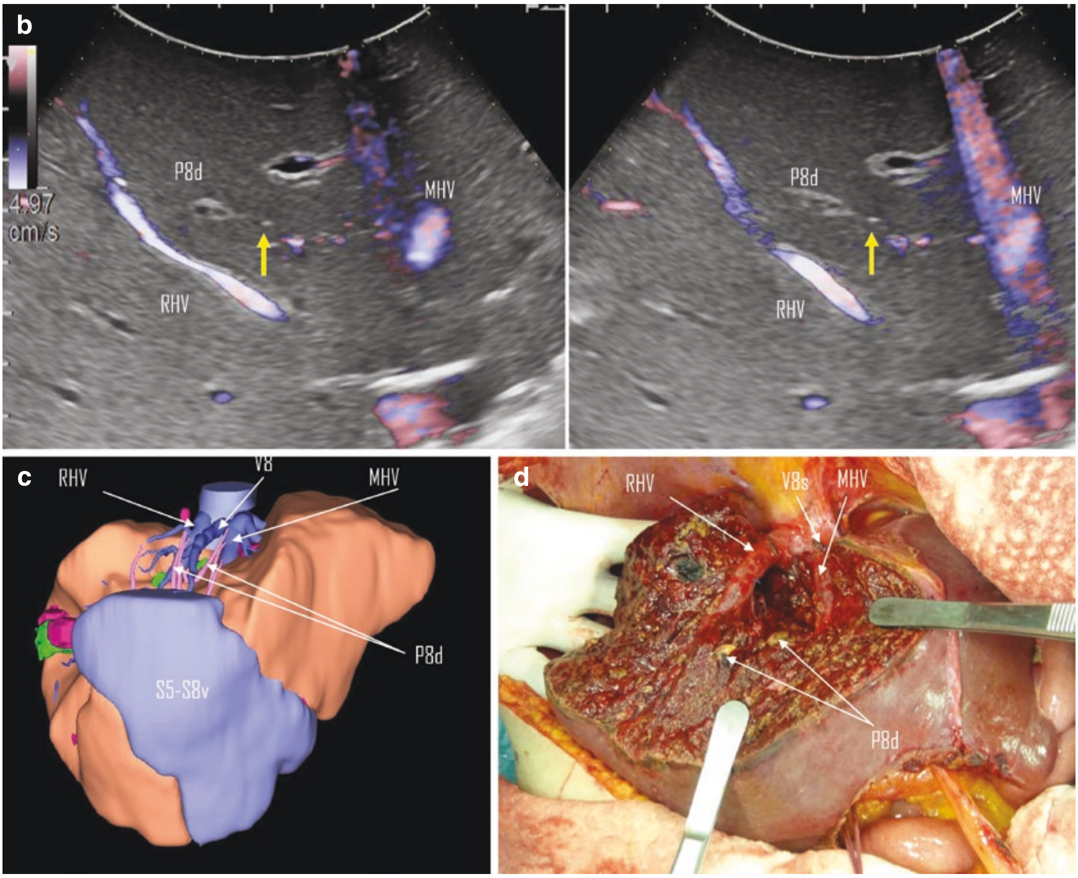

**Fig. 5.11** (continued)

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# Anatomic Versus Nonanatomic Resection

# 6

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Francesco Enrico D'Amico, and Enrico Gringeri

## 6.1 Introduction

The difference between anatomical (AR) and nonanatomical (NAR) liver resection is based on a different approach to the drainage and blood supply of the anatomical location of the tumor during the resection. In ARs the tumor is resected along with the anatomical functional portion of the liver where it is located, thereby achieving complete excision of the tumor-bearing portal tributaries supplied by a major branch of the portal vein and hepatic artery. NARs (also known as atypical, wedge, partial, parenchymal sparing or *a la demande* resections) do not respect precise anatomical planes, usually involving a less extensive parenchymal removal, such as a portion of a liver segment or portions of adjacent segments, just to obtain negative margins regardless of the drainage and blood supply of the anatomical location of the tumor.

The concept of anatomic resection was introduced by Goldsmith and Woodburne in the mid-1950s describing a liver resection (lobectomy) performed strictly in accordance with the internal anatomy of the liver [1]. The term "anatomic resection" (AR) was first proposed with dye-staining technique by Makuuchi in the 1980s [2] and later with the Glissonean pedicle transection method [3].

In 1992, Gagner et al. reported the first laparoscopic nonanatomical resection of a focal nodular hyperplasia and colorectal liver metastases [4]. In 1996, Azagra et al. published the first laparoscopic AR (left lateral segmentectomy) [5]. Despite an increasing interest and spread of minimally invasive liver resection (MILR) in the last years, major anatomical hepatectomies are still performed with an open approach by most [6].

## 6.2 Main Indications and Contraindications of Anatomic and Nonanatomic MILR

MILR indications vary from nonmalignant and trauma to primary and secondary tumors. The most frequent indications of liver resection for malignancy are hepatocellular carcinoma (HCC), colorectal liver metastases (CRLM), and cholangiocarcinoma (CCA) and most studies investigating differences between AR and NAR concerns these tumors.

The choice of AR vs NAR is guided by the patient's general conditions, location, dimensions and number of the target parenchymal

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lesions, proximity to major vessels, future liver volume, liver function, operative time, and predicted procedural difficulties. In complex cases the indication for surgery should be carried out after discussion in a multidisciplinary meeting.

The preoperative complexity should be evaluated using scoring systems such as IWATE score system [7, 8].

First of all the surgeon should consider the limits of the minimally invasive approach according to his personal experience: MILR is usually preferred for anterolateral segments of the liver (II, III, IVb, V, VI), while resection of the posterior segments (I, VII, VIII, IVa) is considered more complex and should be performed only in high volume centers.

Another key point is the planning of the amount of parenchyma to be removed to avoid liver recurrence in malignant tumors. AR should ideally guarantee an excision of the high-risk area for micro-portal invasion and occult intrahepatic metastases in HCC [9].

In NAR, the necessity of maintaining an adequate vascular inflow and outflow of the adjacent parenchyma can be useful in preserving the liver parenchyma as much as possible, with consequent improved postoperative liver function (especially in patients with cirrhosis), allowing to perform multimodality treatments in the case of tumor recurrence, including iterative resections.

Preoperative 3D study is recommended for evaluating the future liver remnant and the anatomical relationship of the target lesion/s and thus to guide the choice of AR vs NAR.

One randomized controlled trial comparing AR vs NAR in HCC is available, concluding that AR is potentially more oncologically effective with better results in recurrence rate in the same hepatic section, with no significant differences in complications rates [10]. AR seems to provide better DFS, OS, and wider surgical margins compared to NAR also in a meta-analysis for solitary HCC, although being associated with a longer operating time and greater blood loss [11].

However, whether to perform AR or NAR in HCC still remains controversial, as for CCA for which few literature is available.

AR does not seem to bring prognostic benefits compared to NAR for the treatment of CRLM and seems to be inferior to NAR in terms of duration of operation and incidence of postoperative morbidity and mortality. [12].

## 6.3 Surgical Technique (Key Issues and Technique Details)

Nowadays the terminology used for AR usually refers to the Brisbane terminology [13], recently updated [14] with the recommendation to not use the terms “segmentectomy” and “subsegmentectomy” for NAR. A “New World terminology” for liver resection has also been published recently [15].

In MILR the patient position and trocar placement is usually similar for AR and NAR and is arranged according to the location of the target parenchyma. The trocars position should reflect the transection line that the surgeon would like to approach and the planning of the consecutive opening of planes needed to have a better exposition and safety.

The technique to perform AR contemplates intraoperative ultrasonography, Glissonean approach, dye injection into the portal vein, and/or ICG staining (negative/positive).

In AR the key steps are the exposition of the intersegmental planes (IPs), achieved by exposing the intersegmental/sectional veins (IVs), which is performed by the majority of surgeons during major hepatectomies. Fundamental landmarks are the root of major hepatic veins, the demarcation line on the liver surface, the IVs, and the root of the responsible Glissonean pedicles. Other beneficial landmarks are IVC, falciform ligaments, umbilical fissure, Rex-Cantlie’s line, hilar plate system, Rouviere’s sulcus, and gallbladder fossa.

As the major or larger veins are the most important landmarks to perform an AR, their continuous exposition from the root side can be considered an alternative to the Glissonean approach. Regarding such hepatic vein-guided approach, a new three-categories classification has been recently introduced, dividing it in cranio-ventral, cranio-dorsal, and caudo-peripheral approach. To expose the root of the major hepatic veins from the inferior vena cava (IVC) during anatomic MILRs, inferior phrenic veins, Arantius ligament, and the IVC ligament are important landmarks. Arantius ligament is the most important to identify the middle and left hepatic veins, while to identify the root of the right hepatic vein the intrahepatic and extrahepatic approach could be both applied.

Considering NAR, anatomical landmarks are still important for a correct surgical plan, and ultrasonography, contrast-enhanced US, and ICG fluorescence are useful intraoperatively. Preoperative 3D simulation is a recommended tool for understanding the anatomical relationship between the tumor and remnant liver vasculature.

It should not forget that, not following anatomical planes, NAR can sometimes be trickier than AR, even though target lesions for which NAR is indicated are usually smaller.

NAR can lead to an ischemic area to the remnant part of the liver (DEBRIS) which may imply infectious complications, when dimensionally relevant [16].

In NAR the basic technique of parenchymal transection is similar to the AR, but the principle is to achieve a safe surgical margin regardless of Couinaud's segments. The devices used for the transection are the same described in Chap. 5, but being target lesions usually smaller and superficial, advanced bipolar are used more frequently.

Either Pringle maneuver or selective vascular control can be applied to both AR and NAR.

## 6.4 Main Key Points

The choice between AR and NAR in minimally invasive liver surgery should be tailored to the patient, disease, and functional features. NAR can spare hepatic parenchyma and can be useful especially in compromised liver function, but its oncological outcomes are still controversial.

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# Trocars and Patient Position

7

Gemma Bosch Silvela
and Patricia Sánchez-Velázquez

## 7.1 Introduction

Positioning the patient on the operating table is as much important as any other pre-surgical preparation, and it belongs to safety care in terms of patient recovery.

Therefore, the choice of a correct position and an adequate weight distribution is of utmost importance for the protection of the patient, preventing from nerve or pressure injuries. The position in which the patient is placed is closely related to the surgical procedure to be performed, taking into account the access route chosen by the surgeon and other factors contemplated by the anesthesiologist (e.g., cardiopulmonary problems).

In liver cancer, as in other cancers, surgical treatment consists of removing the tumor while respecting safety margins. To that purpose, the knowledge of the anatomy and the relationship of the tumor to the different Glissonean pedicles and its isolation will be essential to know which gates and landmarks must be identified (Chap. 2).

Therefore, it is easy to understand the relevance of patient positioning and trocar placement according to the anatomical area and liver segments affected by the tumor, allowing to ease safe and comfortable access for the operating surgeon.

In this chapter, the author's aim is to get the readers familiarized with the trocars placement and patient position in the anatomical liver resection.

## 7.2 Key Issues and Technique Details of Trocars and Patient Position in Main Extrahepatic Glissonean Pedicle Isolation by Laparoscopic and Robotic Approach

### 7.2.1 Left Liver Resections

- Segmentectomy I
- Segmentectomy II
- Segmentectomy III
- Segmentectomy IV
- Left lateral bisegmentectomy (II + III)
- Left hepatectomy (II + III + IV)
- Extended left hemihepatectomy (I + II + III + IV + VIII+V)

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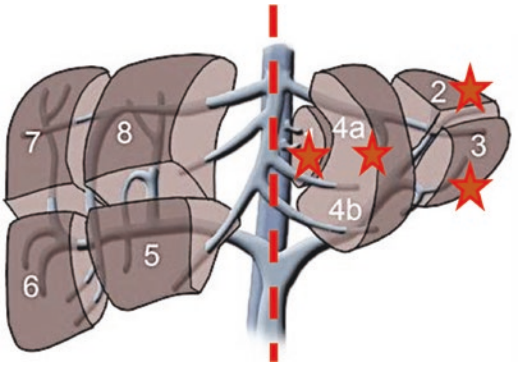


### 7.2.1.1 Patient Position and Trocars Placement for Laparoscopic and Robotic Approach

1. In left-side resection, the patient is placed supine, in a 20° reverse Trendelenburg position with legs apart and arms tucked along the body (robotic technique) or totally open (laparoscopic technique) (Fig. 7.1). The table is slightly tilted to the right side to better expose the left liver.
2. A 10-mm supraumbilical port is placed using the open Hasson technique, especially in the laparoscopic approach. Closed pneumoperitoneum with Veress needle technique is equally correct, depending on surgeon's preferences and is preferred in the robotic approach to avoid gas leakage.
3. A pneumoperitoneum is created by insufflation using carbon dioxide. Intra-abdominal pressure is maintained below 10–12 mmHg.
4. A flexible laparoscope is subsequently inserted through the supraumbilical port or directly the robotic optical in robotic approach in order to proceed with the placement of the rest of the trocars under direct vision.
5. For the laparoscopic technique, four additional ports: 10 mm, 1 port 8–10 cm from the umbilical port on the right side and 1 port 8–10 cm on the left side and 5 mm, 1 port at lateral third of right clavicle in transversal level and 1 port 2–3 cm below the left costal margin (Fig. 7.2) are inserted. The 10-mm ports are operational ports, while the 5-mm ports are used for retraction and suction instruments.
6. For laparoscopic approach, the surgeon is positioned mainly between patient's legs and occasionally on the patient's right (Fig. 7.3).
7. For robotic approach, the 8-mm trocar for the first robotic arm, which is the optical port (n°2), is placed in the right midclavicular line. The second trocar (n°1) is placed in the same line of the previous one (with at least 6–8-cm distance from the previous) at left side. The trocar for the third robotic arm (n°3) is placed in the left anterior axillary line (6–8 cm from the optical trocar). The last robotic arm port is placed in the left side at the same line of the previous one. An auxiliary 10-mm assistant port (A) is placed in supraumbilical area (Fig. 7.4a) in order to apply suction. In some cases, another assistant port (T) can be necessary 5–6 cm below the left costal margin (Fig. 7.4b) in order to utilize extra instruments, specially the cavitron ultrasonic surgical aspirator (CUSA) and dissect the Gate 1 in Arantius ligament.

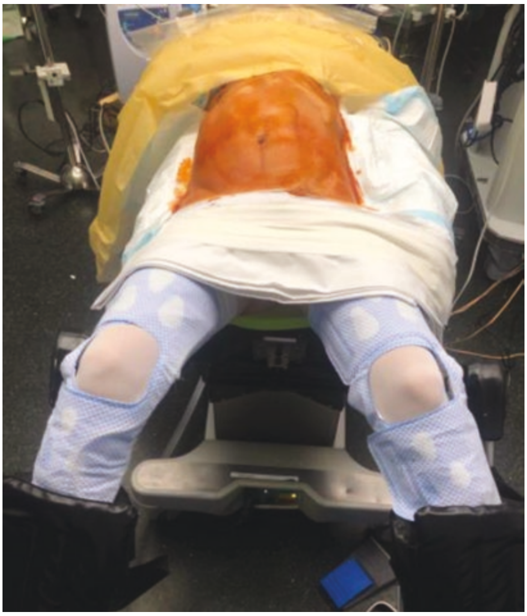


**Fig. 7.1** Supine position in robotic approach, with legs apart and arms tucked along the body

### 7.2.2 Right Liver Resections

- Segment V and VI segmentectomy
- Segment VIII and VII segmentectomy

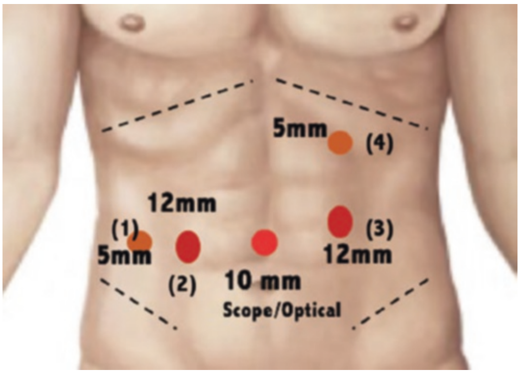
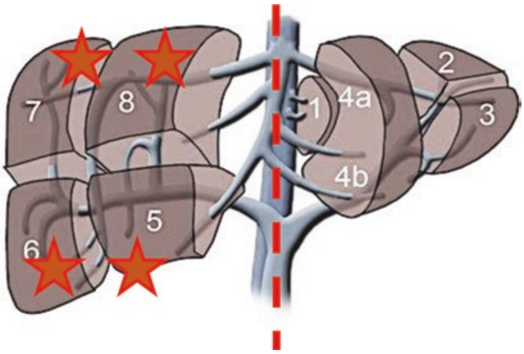


**Fig. 7.2** Trocars placement in laparoscopic technique. Optical supra-umbilical port (scope) and four additional port: (*1*) 5 mm: lateral third of right clavicle, (*2*) 10 mm: 6–8 cm on the right side of optical port, (*3*) 10 m:; 6–8 cm on the left side of optical port, and (*4*) 5 mm: left subcostal port also known as subxiphoid trocar

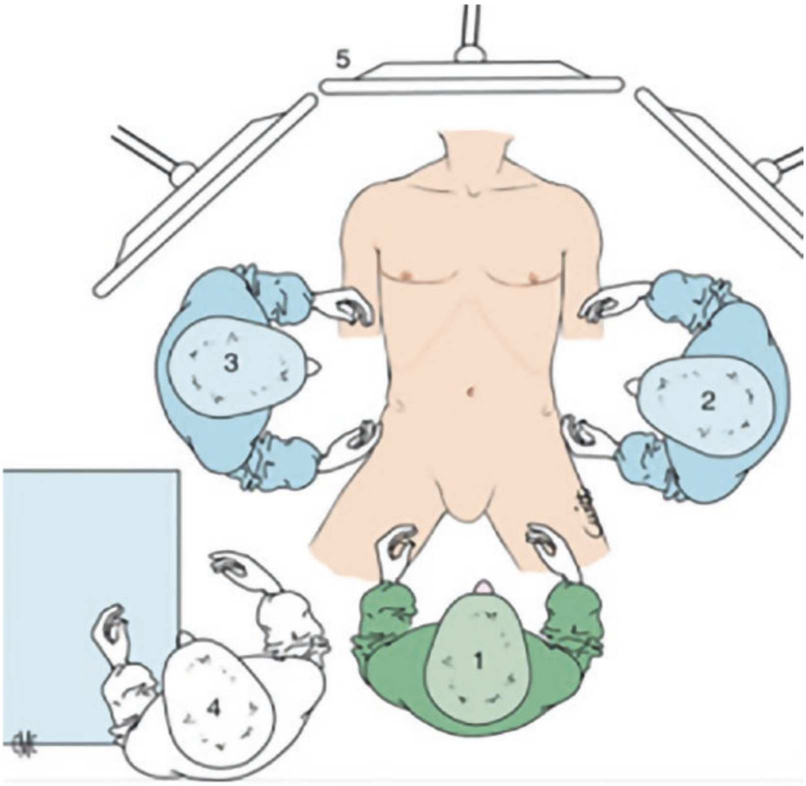
- Right posterior sectionectomy (VI + VII)
- Right anterior sectionectomy (V + VIII)
- Right hepatectomy



The right anterior segments are approached in the same way as the left liver, simply with the table slightly rotated to the left to expose—in this case—the right liver.

Therefore, we will focus on patient positioning and trocar arrangement in the right posterior sectionectomy.

**Fig. 7.3** A. Surgeons position in laparoscopic approach



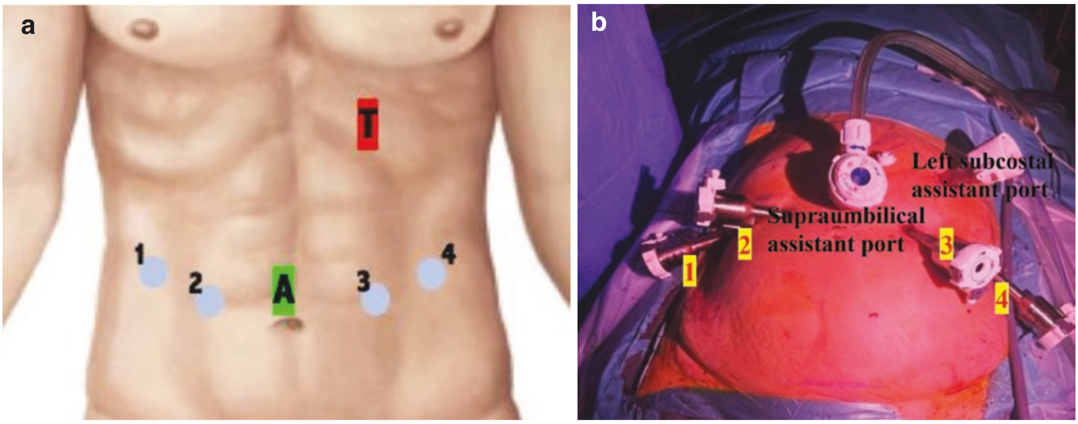
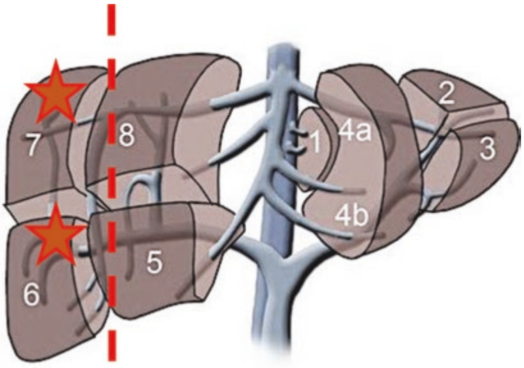


**Fig. 7.4** (**a**) Robotic ports (numbers 1 to 4) are placed as shown. Number 2 port is usually used for the endoscope. An additional 12-mm assistant trocar (**a**) is placed between robotic ports number 2 and 3, usually as an umbilical port. T represents the site of the left subcostal assistant port. (**b**) Assistant ports

### 7.2.3 Right Posterior Sectionectomy (VI, VII)

The position of the patient is particularly important when approaching the posterior segments of the right liver, as these are difficult to access. Down below, we discuss the most important positions, step by step.



#### 7.2.3.1 Patient Position and Trocars Placement For Laparoscopic and Robotic Approach

1. In the right-side resection, the patient is placed in the left decubitus, common known as "sims" position (Fig. 7.5), or semi-decubitus position, also known as "swimmer" position (Fig. 7.6)—with the right arm brought to the left side. Both positions are valid, and the choice or indication of each of them depends basically on the surgeon's preferences.
2. A pneumoperitoneum is created by insufflation using carbon dioxide. Both techniques (open or closed) are valid; it depends on surgeon's preferences and endoscope placement. Intra-abdominal pressure is maintained below 10–12 mmHg.
3. A flexible laparoscope is subsequently inserted through the optical port in order to proceed with the placement of the rest of the trocars under direct vision.
4. For the laparoscopic technique, *in the left lateral decubitus*, four ports in the right of the patients are placed: first 10-mm port is placed subcostal (1–2 cm below costal rim) in the right midclavicular line, and the next 10-mm port 6–8 cm to the right and equidistant to the previously described; 5-mm port at the lateral limit of the patient about 2–3 cm above the iliac crest rim and 1 subxiphoid port discreetly to the right, below the subcostal rim (Fig. 7.7a, b). An extra intercostal trocar could be used as an additional retractor if necessary (Fig. 7.7c).

   *In the semi-decubitus or swimmer position*, the trocars placement is very similar to the previous (Fig. 7.8a, b).
5. For robotic approach, *in the left decubitus*, the 8-mm trocar for the first robotic arm, which is the optical port, is placed on the middle third of the right costal margin. The

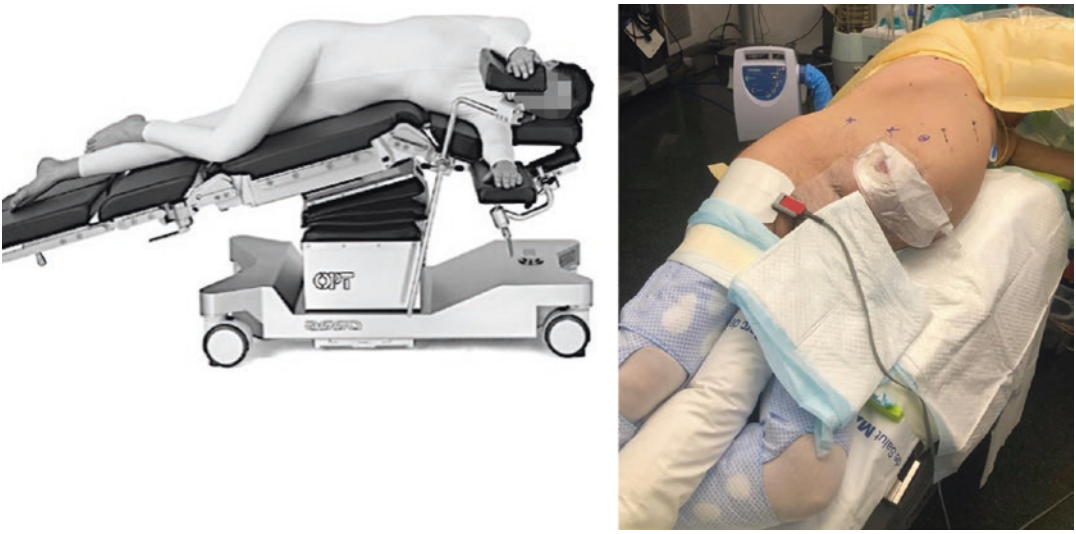


**Fig. 7.5** Left lateral decubitus or *sims* position. The patient is placed in lateral decubitus position, with the upper extremities placed on armrests, making sure that the head is aligned with the trunk. The lower limbs will be overlapped, usually leaving the lower limb fully extended and the upper limb at a slight angle of inclination, to avoid overlapping the protrusions of the knee and ankle joints. They can also be crossed backward as shown in the figure on the right. To ensure patient stability and safety, two lateral fixators are installed on hard areas (e.g., the anterior fixator can be supported on the pelvis and the posterior fixator on the coccyx)

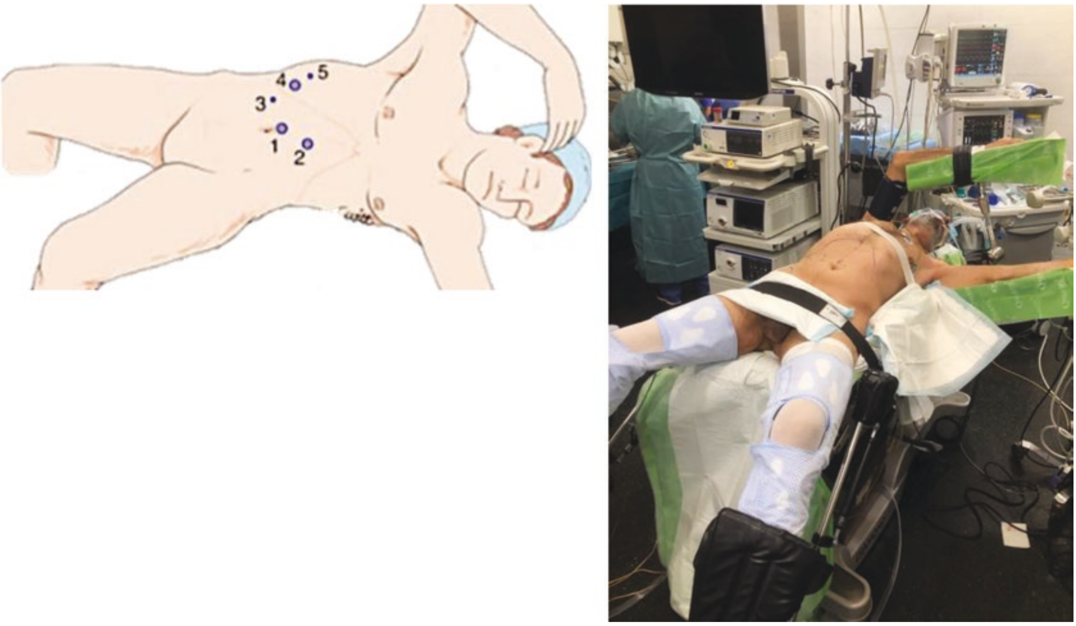


**Fig. 7.6** Semi-decubitus or swimmer position. It is about placing the patient in a supine position with legs apart and upper trunk rotated contralateral to the side in which we are going to intervene, that is to say, with the right arm inclined and fixed toward the left side. In this way, with a maximum rotation of the patient a good exposure of the right liver is achieved

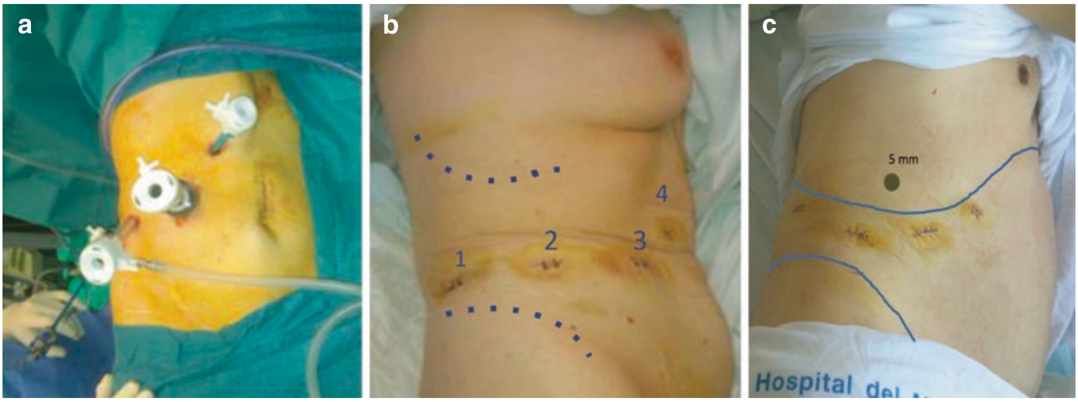


**Fig. 7.7** (**a**–**c**) Left lateral decubitus: trocars placement in laparoscopic technique

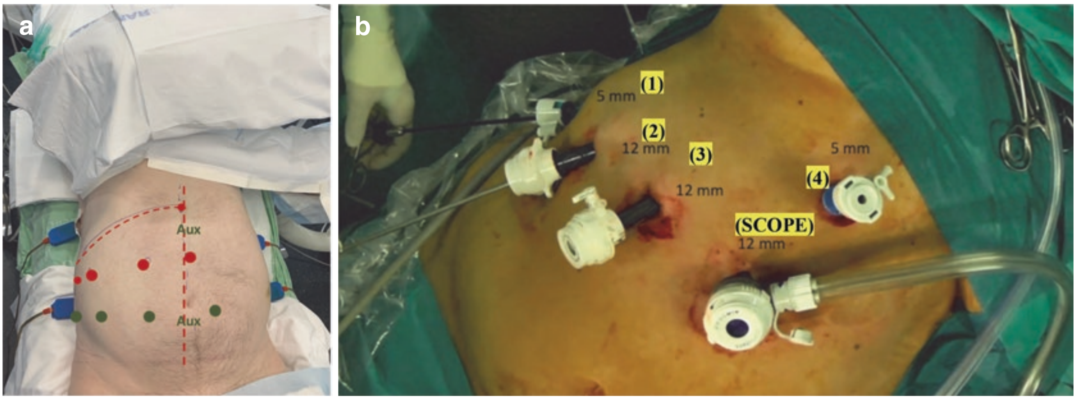


**Fig. 7.8** Swimmer position: trocars placement in laparoscopic and robotic technique. In laparoscopic approach, optical supra-umbilical port (scope) and four additional port are used: (*1*) 5 mm: lateral third of right clavicle, (*2*) 10 mm: 12–16 cm in the right side of optical port, (*3*) 10 mm: 6–8 cm in the right side of optical port, and (*4*) 5 mm: midline subxiphoid trocar (Fig. 7.9b). In Fig. 7.9a, in red we show the laparoscopic placements. In green, robotic ports (numbers 1 to 4) are placed as shown. Number 2 port is usually used for endoscope. An additional 12-mm assistant trocar (Aux) is placed between robotic ports number 2 and 3, usually as an infra-umbilical port. In some cases, another assistant port can be useful 5–6 cm below the subxiphoid site

second and third trocar are placed in the same line of the previous one (almost 6–8 cm of separation) at left and right side, respectively. The last robotic arm port is placed in the subxiphoid site. An auxiliary 10-mm assistant port may be necessary in supra-/infra-umbical area (Fig. 7.9). As a trick, all trocars have to be equidistant from each other and follow an oblique line below the costal rim.

In *semi-decubitus*, trocars are placed equidistant and tracing an oblique line, very similar to laparoscopy but with more flow rates. In addition, if necessary, an auxiliary trocar may be added between position 3 and 4, subxiphoid, or both (Fig. 7.8a).

optical port (scope) and tree additional port: (*1*) 5 mm; the most lateral port in the extern limit up to the iliac crest; (*2*) 10 mm: optical port, 15 cm in the right side of umbilical site, between 1 and 3; (*3*) 10 mm: 6–8 cm in the left side of optical port; and (*4*) 5 mm: right subcostal port also known as subxiphoid trocar. In some cases, an extra 5-mm intercostal port can be necessary as we can see on the left

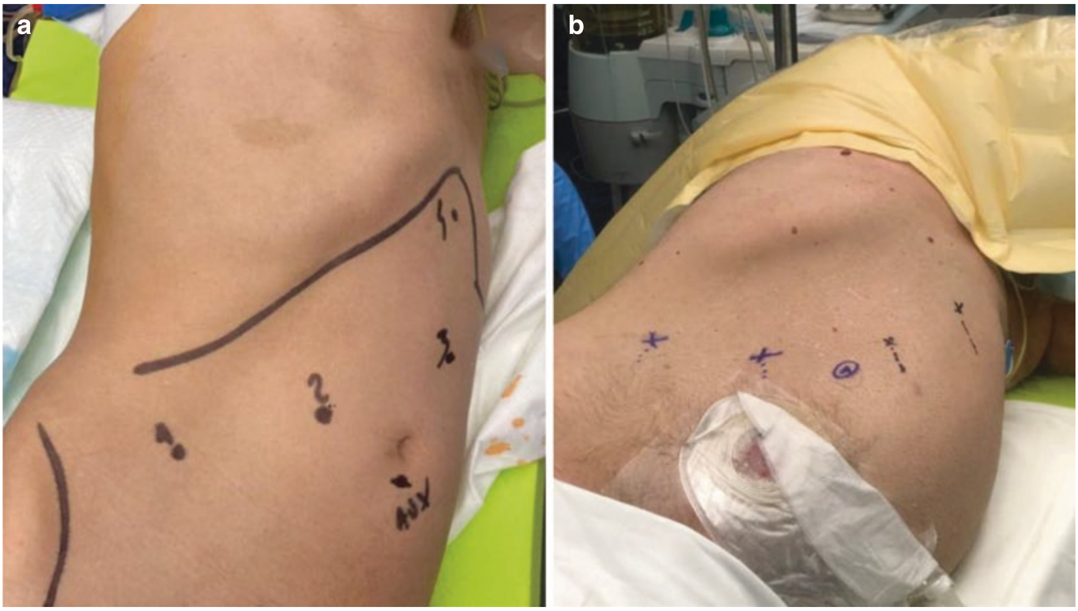


**Fig. 7.9** (**a**, **b**) Left lateral decubitus: trocars placement in robotic technique: Robotic ports (numbers 1 to 4) are placed as shown. Number 2 port is usually used for endoscope. An additional 12-mm assistant trocar (A/aux) is placed between robotic ports number 2 and 3, usually as an infra-umbilical port

## 7.3 Tips and Tricks

- Each patient's different body architecture might jeopardize the standard port placement and position; therefore, surgeons have to learn how to adapt the position of the patient and the arrangement of the trocars to facilitate the procedure. Thus, sometimes it is necessary to exchange assistants or auxiliary ports on demand.
- In the lateral decubitus, adding thoracic or abdominal partition, also known as *pillet* can be a great help when it comes to enlarging the space in the abdominal cavity.
- In some special resections as well as the right extended hemihepatectomy—segments (V + VI + VII + VIII ± IV) and the mesohepatectomy (segments IV + V + VIII)—it may be necessary to change the patient's position from supine to lateral decubitus in order to correctly approach the posterior right segments.
- In auxiliary ports may be helpful to use specific insufflation management system which provides constant smoke evacuation, stable pneumoperitoneum, and valve-free access along with a 12-mm port which enables its use as an operating port.

## Suggested Reading

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# Part II

# Anatomical Approach Glissonean Pedicles (Left Liver)

# 8 Segment I Hepatectomy

Gianluca Cassese and Roberto Ivan Troisi

## 8.1 Introduction

Minimally invasive isolated anatomical liver resection (MILS) of segment I (S1), also known as caudate lobectomy, is a technically challenging surgical procedure. The difficulty of this procedure is mainly due to the complex anatomic location of the caudate lobe, with its close relationships to major vessels, including the inferior vena cava (IVC) behind it, the portal bifurcation and the middle (MHV) and right hepatic veins (RHV) representing the upper limit or roof of its intrahepatic part. Furthermore, the caudate lobe is an independent lobe with a special vascular and biliary anatomy, with many anatomical vascular variations [1]. Classically, it can be considered as composed by three anatomical portions: the Spiegel lobe, that is, the portion protruding toward the left of the IVC; the paracaval portion that lies on the IVC; and the caudate process that protrudes on the right side of IVC (the so-called segment IX), between the main right portal branches, the IVC and the right posterior section (SVI). Similarly, each portion of the segment I can have one or more portal branches making its dissection complex. Indeed, previous anatomical studies reported that caudate lobe usually has a total of five portal branches (48% of cases) or four branches (26%) [2]. The biliary ducts (often very thin) are usually 3–4 (39% and 34% of cases, respectively). For the Spiegelian lobe, portal pedicles mainly derive from the left portal vein (60%) or both left portal vein and mean portal trunk (17%). For the paracaval portion, portal branches arises mainly from the left portal vein (>70%). For the caudate process, portal vessels are originating from the left portal vein in almost 50% of cases, but a portal branch cannot be identifiable in up to 20% of cases. In the case of direct right posterior branching of the main portal vein trunk, the caudate vessels can come from the right posterior pedicle. All the hepatic veins draining S1, go directly into the IVC on its anterior surface.

Despite the aforementioned difficulties, isolated caudate lobectomy is being increasingly performed and reported in literature, since isolated segment I resection offers the possibility of both a radical anatomical resection and a sparing of the functional surrounding hepatic parenchyma. As expected, laparoscopic resection of the caudate lobe is even more challenging and rarely performed. To date only six comparative studies can be found in the literature, and still describe few cases. A propensity score-matched

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study comparing 18 laparoscopic with 36 open resections concluded that the MILS approach is characterized by a significant lower bleeding (100 vs. 300 mL, respectively; $p$ <0.001) and shorter length of stay (6.0 vs. 8.0 days, respectively, $p$ = 0.003) respect to the conventional approach [3]. Another experience from a high-volume institution on 21 patients showed no differences with regard to median operation time (204.5 vs. 200 min, $p$ = 0.397), estimated blood loss (250 vs. 400 mL, $p$ = 0.214), hospital stay (4 vs. 7 days, $p$ = 0.298), and overall postoperative complication rate ($p$ = 0.375) [4]. No comparative studies referring the role of the robotic approach have been published so far.

In this chapter, the authors aim to familiarize readers with the Glissonean approach for anatomical MILS of segment I through the recognition of the surgical anatomy: technical steps, indications, and tips are herein presented.

## 8.2 Main Indications

Minimally invasive isolated anatomical liver resection of segment I is indicated mainly for primitive or secondary (i.e., colorectal liver metastases) liver malignancies located in S1. Owing to its complexity, vascular supply, and to oncological reasons described elsewhere, parenchymal sparing nonanatomical resections are preferred for benign and metastatic diseases [5].

A tumoral invasion of major vessels is considered a relative contraindication, and the need for vascular and/or biliary reconstruction should be discussed case by case.

## 8.3 Surgical Technique

The S1 resection generally consists only of the Spigelian lobe (Video 8.1). More rarely, it is necessary to remove the entire caudate anatomically, i.e., also resecting the portion situated on the right side of the cava (segm IX). Different surgical approaches for open caudate lobectomy have been described: left-sided, right-sided, combined left- and right-sided, retrograde, and anterior transhepatic [6–8]. The most common approach is the intraglissonian one, with identification of the left hepatic artery, the left edge of the portal trunk, and the left portal vein with the small branches originating from the caudate. For the purposes of this manual, the extrafascial approach will be described, with the combined left- and right-sided approaches that should be preferred in the case of minimally invasive resection of the entire S1. Indeed, the Glissonean approach for the inflow control through the Sugioka's Gates is a possibility, but more complex to implement in the case of a caudectomy. However it has been reported as technically feasible and safe, and it can be useful to help a careful demarcation of the caudate lobe, since S1 anatomy may vary [9]. The Glissonean approach for the inflow control can be performed through the selective isolation and ligation of the portal branches for segment I (gates 1 and 6 according to Sugioka), found at the caudal end of the Arantius plate and at the space between right posterior pedicle and the gate 1, as described elsewhere [10]. However, while the Spigelian lobe is clearly separated from the left lobe of the liver, the margins of the caudate process can be difficult to identify. Furthermore, the portal vascularization can have several variations at this level. Thus, the authors can suggest an alternative procedure: to selectively isolate the pedicle S6–7 and then to temporarily clamp the right and left portal veins. Right after, ICG can be injected directly into the portal trunk, allowing to obtain a positive staining of the whole caudate lobe (cfr below). This technique can be technically challenging but is extremely useful in guiding a complete anatomical S1 resection, including the whole supracaval portion that has the middle hepatic vein as its roof between the two hepatic lobes [11].

### 8.3.1 MILS: Patient Position and Trocar Placement

1. Patient is positioned in supine position, with 15° reverse Trendelenburg inclination, with legs apart and arms tucked along the body; the table is slightly tilted to the left side.

2. A 10-mm umbilical port is placed through the open Hasson technique.
3. A pneumoperitoneum is created by insufflation using carbon dioxide. Intra-abdominal pressure is maintained below 12 mmHg.
4. The laparoscopic high-definition camera is inserted through the umbilical port. A careful exploration of the abdominal cavity is carried out to rule out any undetected organ or peritoneal metastases.
5. For the laparoscopic approach, four ports are needed. Another 10-mm port is then placed around 10 cm above and on the left with respect to the first one, and another 10 mm is placed around 10 cm on the right of the first one. A 5-mm trocar is placed at the epigastrium. The 10-mm ports are operational ports, while the 5-mm ports are used mainly for retraction instruments and suction. In the case of robotic resection with the Intuitive Xi platform, the 8-mm trocars are placed in a linear fashion as for every hepatic resection, and the first umbilical trocar is used by the assistant surgeon.

### 8.3.2 Exploration and Mobilization

6. The left liver is mobilized and rotated to the right. To this aim, the falciform ligament is divided from the anterior abdominal wall toward the supra-hepatic IVC. A useful tip is to leave the falciform ligament and round ligament long enough to use them for the traction during the following steps. The left triangular ligament is then divided to free the left lateral section. Usually, some mobilization of right hemi-liver is also required, in particular the right-posterior section from the retroperitoneum with the right adrenal gland, and from the diaphragm.
7. The gastro-hepatic ligament is divided to expose and mobilize the Spigelian lobe. The fibrous attachments between the caudate lobe and the IVC are divided. Intraoperative ultrasound is performed to ensure the tumor is limited to the S1 segment and to investigate its relationships with the major vessels.
8. Laparoscopic ultrasonography (LUS) is performed to confirm the position and the nature of the disease, as well as its relationships with the adjacent vascular structures to exclude macrovascular invasion.
9. The liver is lifted up and mobilized using the stump of the round ligament (by the assistant in laparoscopy, or arm 4 in robotic surgery).

### 8.3.3 Transection of the Pedicle

10. A vascular tape is placed around the main hepatic pedicle and placed into a tourniquet, in case extracorporeal Pringle maneuver is necessary.
11. Laparoscopic cholecystectomy will make easier the access the Gate 6, to control and entirely remove the caudate process.
12. The caudate end of the Arantius plate is approached at Gate 1. The first Glissonean pedicle for the Spiegel lobe is carefully isolated with blunt dissection and encircled on a vascular tape. There are usually two Glissonean pedicles at this level.
13. Moving on the right, the Gate 6 is approached between the right posterior Glissonean pedicle and the Gate 1. The Glissonean pedicle for the caudate process is then carefully isolated and encircled on a vascular tape.
14. The right posterior Glissonean pedicle is carefully isolated and temporarily clamped with a bulldog clamp, as described in detail in previous chapters. The counter demarcation between the caudate process and the right posterior section is marked with electrocautery. The bulldog clamp is the removed.
15. The previously isolated pedicles for S1 are now secured with two hem-o-locks or titanium clips and sectioned (Fig. 8.1).
16. The entire demarcation of the caudate lobe can be refined, even by using IV ICG (see below) (Fig. 8.2).

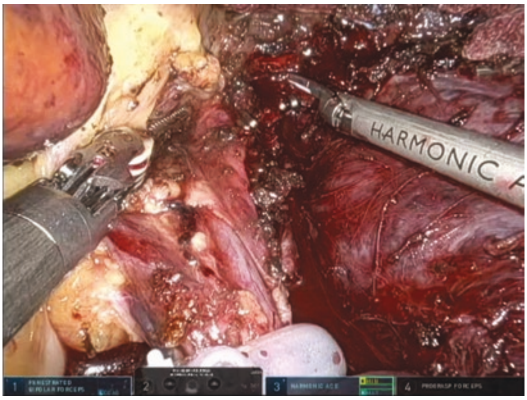

**Fig. 8.1** Securing a portal branch for S1 from the left portal vein

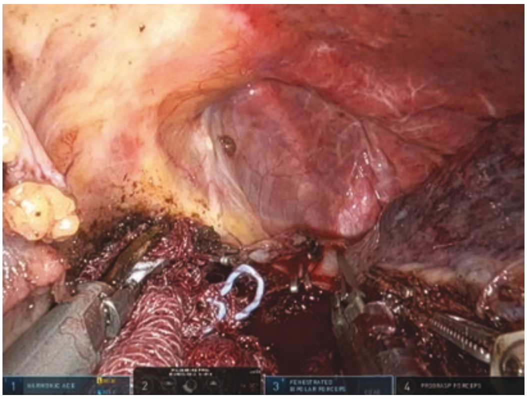

**Fig. 8.3** Securing a Spiegelian vein with a titanium clip

**Fig. 8.2** ICG-guided negative counterstaining of S1 (Spiegelian lobe)

### 8.3.4 Hepatic Transection

17. Superficial parenchymal transection is performed with harmonic scalpel, and the deeper portion is usually performed with laparoscopic CUSA. This however remains at the discretion of the surgeon. CUSA is preferred to peel the inferior part of the portal vessels in case of larger lesions pushing the hilum below the bifurcation.
18. Usually starting from the left side, following the natural anatomic division of the Spiegel lobe, the posterior surface of the caudate lobe is freed from the IVC and the short hepatic veins that are controlled with clips (Fig. 8.3). All the additional portal branches to the Spiegel lobe encountered during the transection are ligated and cut. The liver parenchyma is resected just below the Arantius ligament, separating the liver parenchyma from the inferior surface of the MHV and LHV that are identified and preserved.
19. The peripheral part of the RHV is identified and spared, after continuing the transection of the paracaval portion until its inferior margin.
20. The caudate process and the paracaval portion are retracted to the left side. Moving to the right, lifting the right hepatic pedicle, and having the middle hepatic vein as "roof" of the excavation cavity, the resection of the caudate process is carried out, dividing it from the surrounding right liver parenchyma. Eventual additional branches from the caudate process are secured and divided.
21. This transection line will meet the section started from the left side. A caudal inferior approach will resolve parenchymal resection of the right part of segment I, until the inferior surface of RHV.
22. The specimen is extracted through an extension of the umbilical incision, if small, or through a Pfannenstiel incision, using a vinyl bag.
23. The tourniquet for Pringle maneuver is removed.
24. After specimen extraction, a final check of the hemostasis is performed. Very useful is to check also some bile leaks from the hilar plate. A white dye test could be a good solution to identify small leaks. A closed drain can be placed behind the hepatic hilum.

## 8.4 Special Tricks and Tips

- In the case of bleeding, Pringle maneuver is very efficient during S1 resection and can be applied to facilitate the parenchymal transection. Additionally, clamping the IVC may be helpful.
- ENDOGIAs is not recommended because of the narrow spaces for the transection and the small vessels.
- ICG can be injected to obtain a positive counterstaining and check the transection margins. After the isolation of the pedicle S6–7, by closing the right and left portal veins and injecting ICG green directly into the portal trunk, it is possible to have a positive staining of the whole caudate lobe.
- Intravenous ICG injection of 0.025 mg/kg of ICG can be injected after the closure of the Glissonean pedicles for S1 to obtain a negative counterstaining and check the transection margins.

## 8.5 Main Key Points

Laparoscopic liver resection of S1 with the Glissonean approach for the inflow control is a challenging procedure requiring great care in dissection, identification of anatomical structures, and preservation of portal bifurcation to carry out a proper (oncological) resection.

A deeper knowledge of the surgical anatomy, with eventual vascular and biliary variations, is crucial for S1 anatomical resection. Both open and MILS skills should be mastered in order to avoid rare but life-threatening complications for such deep-located challenging lesions.

While technically challenging, the advent of technological advances and the development of new methodological approaches could reduce the difficulty of such an approach, while retaining the benefits of the traditional operation.

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# 9 Segment II Hepatectomy

Riccardo Memeo

Isolated segment II liver resection could be performed in the case of parenchymal sparing strategy, to preserve as much as possible parenchyma of the left lobe, especially in patients who underwent liver resection with an underlying liver disease. To achieve this anatomical segmentectomy, a correct study of preoperative CT scan is mandatory to correctly understand the anatomy of the left lobe of the liver, even if left lobe anatomical variations are fewer compared to the right lobe of the liver.

In this case, a Glissonean approach represents the ideal approach to achieve an anatomical resection, associated with the use of indocyanine green fluorescence to correctly define the limits of anatomical resection.

## 9.1 Indications and Contraindications

Main indication for this selective liver resection is most commonly a malignant lesion occupying Segment II, with no evidence of extrahepatic diseases nor infiltration of the left main pedicle, allowing to achieve a correct R0 resection. A more conservative attitude could be accepted in the case of benign disease or in the case of necessity to perform a R1-vascular resection.

Contraindication could be considered the contact with the origin of the left hepatic vein because a correct outflow should be guaranteed to Segment III.

## 9.2 Surgical Technique (Key Issues and Technique Details)

The Glissonean approach is recommended for minimally invasive approach, either in robotic and laparoscopy, and it's feasible and safe once anatomical landmark are recognized. For a correct identification of the anatomy of the left lobe, a section of the round and falciform ligament could allow to lift the left lobe in order to identify the anatomy of the left liver pedicles for Segment II, III, and IV (Fig. 9.1). In most cases we can find a separate pedicle for Segments II and III on the preoperative study on the CT scan.

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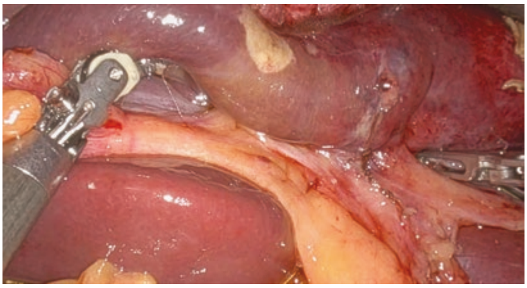

**Fig. 9.1** Overview of left liver pedicles

Once the ligament between the left lobe and the caudate lobe is sectioned, we could identify the left side gates. Gate 1 could be localized at the end of the Arantius plate, while Gate 2 is at the connection between the round ligament and umbilical plate. The connection of Gates 1–2 allows to identify Segments II and III pedicle. A division among pedicle 2 and 3 could be identify, and if it's not visible, a small parenchymal transection could be performed to find the origin of the pedicle for Segment II.

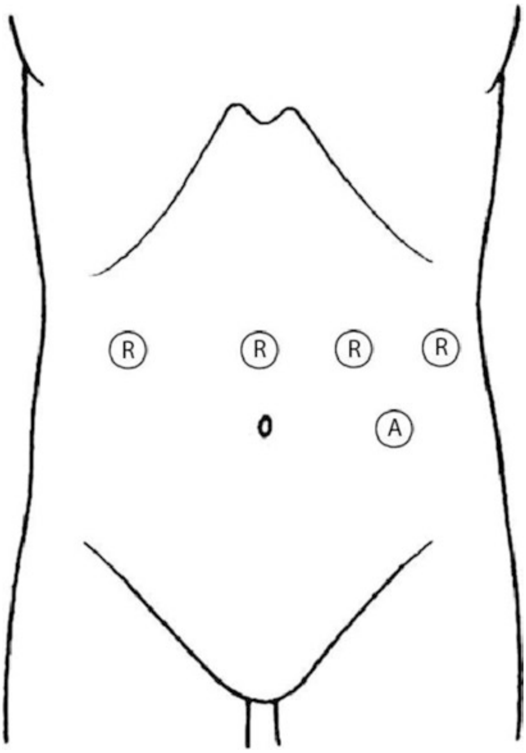

**Fig. 9.2** Trocar placement

## 9.3 Patient Position and Port Placement

A more detailed description of the technical steps is found below.

### 9.3.1 Patient Position and Trocar Placement (Fig. 9.2)

1. Patient is positioned in a supine, 15° reverse Trendelenburg position with legs apart and arms tucked along the body; the table is slightly tilted to the right side.
2. A 10-mm upper umbilical port is placed using the open Hasson technique.
3. A pneumoperitoneum is created by insufflation using carbon dioxide. Intra-abdominal pressure is maintained below 12 mmHg.
4. A laparoscope is subsequently inserted through the umbilical port.
5. For the laparoscopic technique, four additional ports (10 mm, 1 port 8–15 cm from the optical port on the right side and 1 port 8–15 cm from the optical port on the left side; 5 mm, 1 epigastric port 1 port 2 cm below the left costal margin) are created under direct vision. The 10-mm ports are operational ports, while the 5-mm ports are used for channel retraction instruments and suction.
6. For robotic approach, the 8-mm trocar for the first robotic arm is placed on the umbilical line, which is the optical port. The second trocar is placed in the same lime of the previous one (almost 6–8 cm) at left side. The trocar for the third robotic arm is placed in the left anterior axillary line (6–8 cm from the optical trocar). The last robotic arm port is placed in the left side at the same line of the previous one.
7. For laparoscopy approach, the surgeon is positioned mainly between the patient's legs and occasionally on the patient's right. In robotic approach, the assistant surgeon is placed between patient's legs.

### 9.3.2 Exploration and Mobilization

8. Following complete examination, ultrasonography is performed to detect disease missed at preoperative imaging, to identify the lesion's proximity with major structures, and to further define their anatomy in view of transection.
9. The round ligament is identified and divided close to the abdominal wall, while the falciform ligament is divided from the anterior abdominal wall toward the suprahepatic inferior vena cava. The round ligament will be used to lift and traction the liver. In the initial phase, there is no necessity to mobilize the left triangular ligament.
10. The traction of the round ligament, performed via epigastric port or robotic arm NR4 (below left subcostal margin), could better expose the left pedicle, with the identification of pedicle for Segments II, III, and IV.
11. Five-mm tape is subsequently placed around the hepatoduodenal ligament for use in the Pringle maneuver if needed.

### 9.3.3 Transection of the Glissonean Pedicle

12. The liver is retracted using a fan retractor in order to identify the gates.
13. As shown in the previous chapter, Gate 1 is first localized at the caudal end of the Arantius plate, while Gate 3 is localized at the junction between the round ligament and the umbilical plate. Connecting Gates 1 and 3 allows the selective identification of the Glissonean pedicle of Segments II, III, and IV, allowing for an anatomical left hepatectomy.
14. The dissected Glissonean pedicle of Segment II is temporarily clamped using a bulldog clamp or a laparoscopic forceps in order to confirm the demarcation between the left and right liver based on ischemic discoloration. This can be further confirmed through the use of indocyanine green fluorescence, as well.

**Fig. 9.3** Segment II pedicle

15. The Glissonean pedicle (Fig. 9.3) is then sectioned using various means, depending on surgeon's preference. This includes using endo-GIA vascular stapler (as showed in the video), hem-o-lok clips or direct ligation.

### 9.3.4 Hepatic Transection (Fig. 9.4)

16. A cavitron ultrasonic surgical aspirator (CUSA) and harmonic scalpel is used to transect parenchyma, following the ischemic demarcation of Segment II. In the case of robotic approach, a double kellyklasia with bipolar forceps could be used in order to achieve correct resection margin.
17. The intraparenchymal anatomy of the middle hepatic vein is again confirmed via ultrasonography.
18. The liver transection plane continues between the Segments II and III, following the demarcation line, with the section of venous branches of left hepatic vein (Fig. 9.5) among clips or hem-o-lok or using endo-GIA vascular stapler is then used to staple the vein transversely.
19. After complete resection and hemostasis, an hemostatic patch might be used.
20. The specimen is placed in an endobag and extracted through a Pfannenstiel incision.

**Fig. 9.4** Robotic liver transection

**Fig. 9.5** Left hepatic vein branch section

# 10 Segment III Hepatectomy

Gabriella Pittau and Daniel Cherqui

## 10.1 Introduction

Hepatic resection is considered the optimal treatment for primary and secondary liver tumors. However major hepatectomy for hepatocellular carcinoma (HCC) is limited because the high incidence of cirrhosis.

Anatomical segmentectomy has better oncological results compared to nonanatomical liver resection in the surgical treatment of HCC [1].

Anatomical segmentectomy is often more complicated and difficult than major hepatectomy even in open surgery [2].

However, the difficult of the procedure does not justify a more extensive resection with a laparoscopic approach than that which would be required by open approach.

Over the last decade, laparoscopic hepatectomy has been increasingly performed throughout the world [3]. Left lateral sectionectomy has been recognized as the standard approach for tumors located in segments 2 and/or 3 [3], but there have been few reports about laparoscopic segmentectomy of segment 2 or 3 [4, 5]. We think that for the segment 3, the thickness of parenchyma, anatomical position, and Glissonean pedicle located in front of the camera makes this procedure easier than the right anatomical segmentectomy.

In this chapter, the authors describe the main points of anatomical segmentectomy of segment 3 (S3), technical steps, indications, and tips.

## 10.2 Indications and Contraindications

Indications of anatomical segmentectomy of S3 are malignant tumors as HCC, very small intrahepatic cholangiocarcinoma, and colorectal metastases. Also, some benign lesions as adenoma can be treated by segmentectomy.

But the main indication remains the HCC in cirrhotic patients when a parenchymal sparing is needed.

The contraindications of this approach are only anatomical:

- Tumors of segment 3 located very close to round ligament and infiltrating the left portal vein or pedicle of segment 2
- Tumors located close to left hepatic vein

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In both cases anatomical segmentectomy of S3 can be replaced by a left lateral sectionectomy.

### 10.2.1 Surgical Technique (Key Issues and Technique Details)

The Glissonean approach is the most important point in anatomical segmentectomy. The first step in this intervention is the dissection and clamping of S3 pedicle. The consequent demarcation line in concerned territory allows an anatomical parenchymal resection. In the majority of cases, especially in cirrhotic livers, the pedicle is located more deeply, and parenchyma transection is needed to access as showed in the video.

A more detailed description of the surgical procedure will be given later in the chapter.

## 10.3 Equipment and Instruments

Apart from standard laparoscopic surgery equipment, the following instruments are required:

- Grasping forceps with long jaws to hold and spread the left lobe.
- A 10-mm dissector to control the Glissonean and venous structures specifically treated.
- 30° camera.
- We recommend a device for maintaining the pneumoperitoneum and smoke aspiration allowing the use of an insufflation pressure at a maximum of 12 mmHg (IFS Airseal, Ò, Conmed, Utica, NY, USA).
- A linear stapler (Endo GIAÒ, Covidien, Mansfield, MA, USA or EchelonÒ, Ethicon Endo Surgery, Cincinnati, OH, USA).
- Five- and 10-mm secure plastic clips (Hem-o-lokÒ, Teleflex Medical, Research Triangle Park, NC, USA and/or Lapro-ClipÒ, Covidien, Mansfield, MA, USA).
- An ultrasonic energy device such as HarmonicÒ, Ethicon Endo-Surgery, Cincinnati, OH, USA, or thermo-fusion device such as LigasureÒ, Covidien, Mansfield, MA, USA, or mixed type ThunderbeatÒ, Olympus, Tokyo, Japan.
- An ultrasonic dissector coupled to a monopolar coagulator (CUSAÒ, Integra, Plainsboro, NJ, USA).

## 10.4 Patient Position

The patient is placed in supine 15° reverse Trendelenburg position with split legs. Right arm is placed along the body.

We usually use intermittent pneumatic compression device.

The surgeon stands between the patient's legs, the first assistant is to the left of the patient, and the second one to the right.

## 10.5 Trocarts Placement (Fig. 10.1)

We usually use five ports.

- A first 10-mm upper umbilical port is placed with the open technique. A pneumoperitoneum

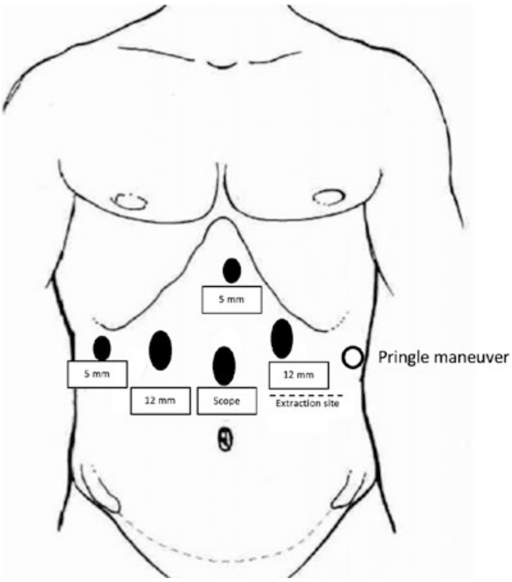

**Fig. 10.1** Trocars position

is insufflated to maintain an intrabdominal pressure below 12 mmHg.

- Then a 30° camera is inserted through the umbilical port.
- Four additional ports are placed under direct vision:
  - A 12-mm port used for insufflation is placed on the left midclavicular line 2 cm below the costal margin.
  - A second 12-mm port is placed on the right midclavicular line in traversal level.
  - A 5-mm port is placed in the right flank and another 5-mm port 2 cm under the xiphoid process.

The 12-mm ports are operational ports, and the 5-mm ports are used for retraction or suction.

## 10.6 Surgical Procedure

### 10.6.1 Exploration and Mobilization

- The patient is positioned progressively in reverse Trendelenburg, as much as the hemodynamic status allows, taking advantage of gravity to facilitate exposure.
- The object of exploration is to exclude contraindication to surgery: ascites, signs of portal hypertension, and peritoneal carcinomatosis in the event of malignancy. We always realize a preoperative ultrasound of the whole liver to detect missed lesions and to identify the exact position of the lesion especially in relation to major vascular structures.
- The means of fixity of left lobe are divided: the round ligament and the falciform ligament. Since cholecystectomy is not indicated during this procedure, it is preferable not to grasp the gallbladder. When a left hepatic artery is present, it can be dissected in order to clamping it during the parenchymal transection.
- The round ligament and the initial part of falciform ligament must be divided as close as possible to the anterior abdominal wall because the residues of tissues located in the axis of the camera tend to defile the optic with each passage in the trocar. The triangular ligament can be divided at this moment.
- A 5-mm tape is subsequently placed around the hepatoduodenal ligament for the Pringle maneuver.

## 10.7 Transection of Glissonean Pedicle

- The parenchymal “bridge” between the S3 and the segment 4 is divided if it exists.
- Rarely, the Glissonean pedicle of S3 can be is identified on the left side of round ligament and then encircled and clamped. In majority of cases, this maneuver can be difficult and dangerous. In our practice the standard of care is to section liver parenchyma on the left side of round ligament. In this way we have a safe access to pedicle of S3 that can be dissected and clamped with a bulldog (Fig. 10.2).
- The consequent ischemia of S3 allows a real anatomical resection (Fig. 10.3a, b) The use of indocyanine green fluorescence (ICG) can also help to define the demarcation line (negative staining technique).
- The Glissonean pedicle is then sectioned usually with an endo-GIA vascular stapler. According to the surgeon’s preference, hem-o-lok clips can be used (Fig. 10.4).

**Fig. 10.2** Clamping of pedicle S3 after parenchyma transection

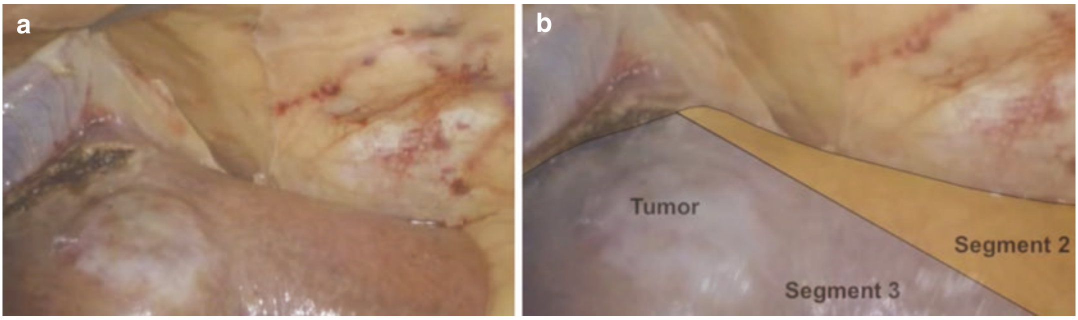

**Fig. 10.3** (**a**, **b**) Demarcation line

**Fig. 10.4** Division of pedicle of segment 3 using endo-GIA vascular stapler

## 10.8 Parenchyma Transection

- The ischemic margin of S3 is marked using electrocautery.
- The Glisson capsule and the first millimeters of liver parenchyma can be sectioned using a harmonic device. In healthy liver all the hepatectomy can be realized using this instrument, but in the case of cirrhotic liver, we always use cavitron ultrasonic surgical aspirator (CUSA) as showed in the video.
- Pringle's maneuver is performed by clamping the hepatoduodenal ligament using the tourniquet method for 15 min with following a 5-min release period.
- The round ligament is retracted to the up and the right of the patient using a laparoscopic forceps inserted in the 5-mm right port. A second forceps in the 5-mm epigastric retract the surface of segment 3 to the left. This opposite retraction opens the liver as a book along the round ligament.
- The transection continues in the superior surface of the left lobe along the left hepatic vein and in inferior surface following the demarcation line.
- Small vessels can be coagulated using harmonic device. Vessels more than 5 mm should be dissected and clipped with 5- or 10-mm hem-o-lok.
- After complete resection the specimen is placed in an endobag and extracted through a short lateral incision.
- Then we check the hemostasis of the liver section, and we remove the tape around the hepatoduodenal ligament.
- Usually, we don't leave a drain after anatomical segmentectomy.
- The trocars are removed under direct vision, and we try to suck all the pneumoperitoneum to reduce postoperative pain.
- The abdominal aponeurosis of 12-mm ports is closed, and we realize an intradermal suture for the skin.

## 10.9 Tips and Tricks

- Preoperatively computed tomography scan should be analyzed in order to detect some vascular variation, especially the presence of an accessory left artery located in hepatoduodenal ligament.
- ICG is more and more useful for segmentectomy: hepatic segments can be identified as ischemic regions by intravenous injection of ICG (0.05 mg/kg) following clamping of the

corresponding portal pedicle (negative staining technique) [6].

- We suggest examining the transection with a low pneumoperitoneum pressure in order to detect some missing bleeding.

## 10.10 Main Key Points

Anatomical S3 segmentectomy is a good alternative to left lateral sectionectomy especially in patient with HCC in a cirrhotic context when a parenchymal sparing is needed. The key to realize this intervention is the Glissonean approach of S3 pedicle. The use of ICG fluorescence can help and implement this procedure.

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# 11

# Segment IV Hepatectomy

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## 11.1 Anatomy

Segment 4 is divided into two portions: 4a (superior portion) and 4b (inferior portion). On the left side, the boundary between S4 and the left lateral sector (S2–3) is along the plane of the umbilical ligament. On the liver surface, the left external anatomic landmark is the falciform ligament. The right transection plane has no external landmarks. Indeed, the boundary between S4 and the right anterior sector (S5–8) is along the plane of the middle hepatic vein (MHV). Arterial and portal blood supply of S4 arises from the left portal pedicle, at the level of the Rex recessus, where the round ligament is joined anteriorly. Here is where portal pedicles to S2, S3, and S4 originate. The Rex recessus is an important radiological landmark that is easy to recognize and evaluate by intraoperative ultrasound (IOUS). This landmark appears at IOUS with a typical "T-shaped" vascular structure. From the left side, a branch arises to the anterior portion of the left lobe (P3: portal branch to S3) (Fig. 11.1). Another branch arises from the right side to S4b (P4b) (Fig. 11.1).

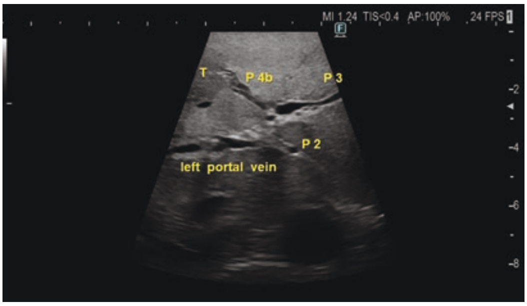

**Fig. 11.1** Sixty-two-year-old female patient with a 3-cm colorectal liver metastasis in S4b (T). At IOUS the "T-Shaped" vascular structure of the left portal vein with its bifurcation in pedicles to S4b and S3 is clearly evident. The metastasis is in contact with S4b portal pedicle

## 11.2 Surgical Technique

An isolated laparoscopic anatomic segmentectomy 4 is a technically demanding operative procedure due to two transection planes: on the left, along the umbilical ligament and, on the right, along the MHV [1, 2].

The main indication for anatomical segmentectomy 4 is a tumor without involvement of the left portal pedicle, without extent to the umbilical ligament and without involvement of the right anterior sector (S5–8).

Under general anesthesia, the patient is placed in the supine position. The right arm is along the body and the left arm is open. The surgeon is between the patient's legs, with two assistants on the left side of the patient. Using an open tech-

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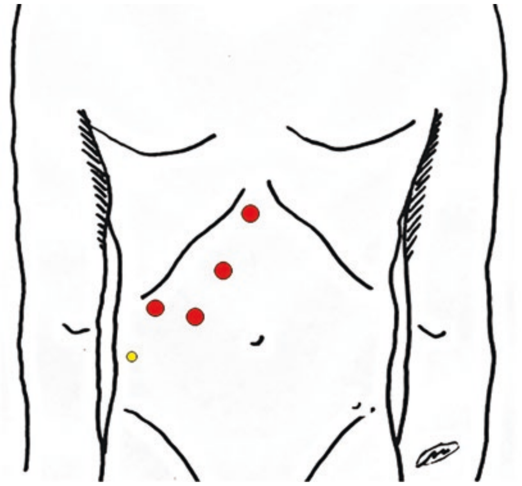

**Fig. 11.2** Trocar position for anatomic segmentectomy 4. Four 12-mm trocars (red). Place of extracorporeal tourniquet for pedicle clamping (yellow)

nique, a 12-mm trocar is placed about 3 cm above the umbilicus, along the right midclavicular line. Through this port a 30° laparoscope is introduced, and three additional 12-mm trocars are placed at the sites, as shown in Fig. 11.2.

For an isolated anatomic segmentectomy 4, the Glissonean pedicle transection method consists in the identification, isolation, and division of all the portal branches to S4 along the umbilical ligament. This technique may be considered as effective for a rapid and safe control of the pedicles, with consequent ischemia of the entire S4 that facilitates the anatomical removal of the segment [2, 3].

The procedure is performed according to the following steps:

1. The falciform ligament and left coronary ligament are dissected.
2. IOUS is performed in order to confirm the location of the tumor, to study its relationships with the vascular structures of the left portal pedicle and to ensure adequate resection margin.
3. The portal pedicle is systematically encircled with a tape to allow intermittent pedicle clamping (15-min clamping and 5-min release periods), if required. Cholecystectomy is usually performed.

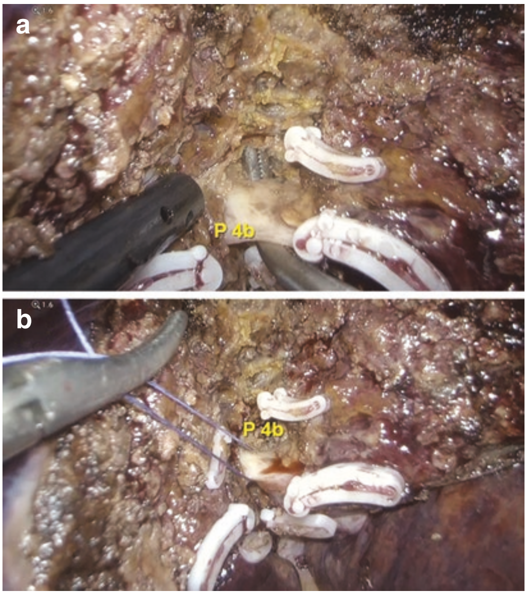

**Fig. 11.3** Portal pedicle to S4b (P4b) is isolated by ultrasonic dissector (**a**) and encircled with a tape (**b**)

4. *First line of parenchymal transection: from the periphery to the cranial side.*

   If the preoperative surgical plan of segmentectomy 4 is confirmed, the first line of liver transection starts on the left side, along the umbilical ligament. The parenchymal transection moves from the periphery to the cranial side. This transection plane is an anatomic plane and easy to follow because it is located along the falciform ligament.

1. At the level of the fissure of the round ligament, P4b is identified and encircled with a tape (Fig. 11.3a, b).
2. By IOUS the correct line of transection is confirmed (Fig. 11.4a). By color Doppler the portal flow to S4b is well documented (Fig. 11.4b). The correct isolation of P4b is confirmed by pulling the tape with consequent stop of the portal flow at color Doppler (Fig. 11.4c).
3. After division of P4b, liver ischemia of the subsegment 4b is evident, and the boundary between S5 and S4b is determined (Fig. 11.5).
4. Liver transection continues along the right side of the umbilical ligament by dividing all the portal branches to S4 (Fig. 11.6).

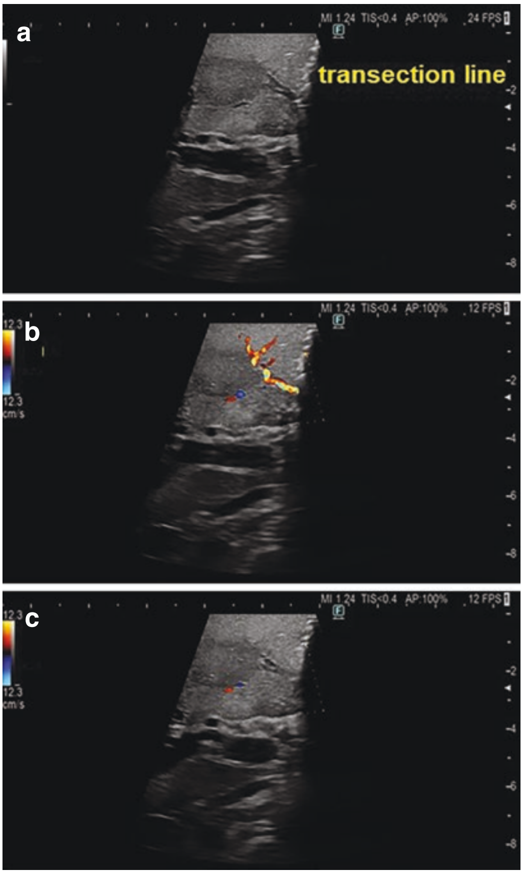

**Fig. 11.4** The line of transection along the umbilical ligament is checked by IOUS (**a**). The correct isolation of P4b is checked by the color Doppler: the portal flow to S4b is well documented (**b**). After pulling the tape, the consequent stop of the portal flow at color Doppler is well visible (**c**)

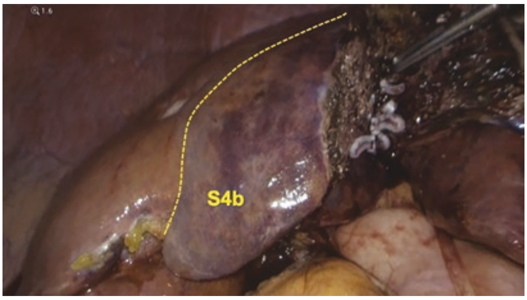

**Fig. 11.5** Anatomic hepatic subsegmentectomy 4b during multiple IOUS-guided liver resections in a patient with bilateral colorectal metastases. After division of P4b, liver ischemia of the subsegment 4b is evident, and the boundary between S5 and S4b is determined

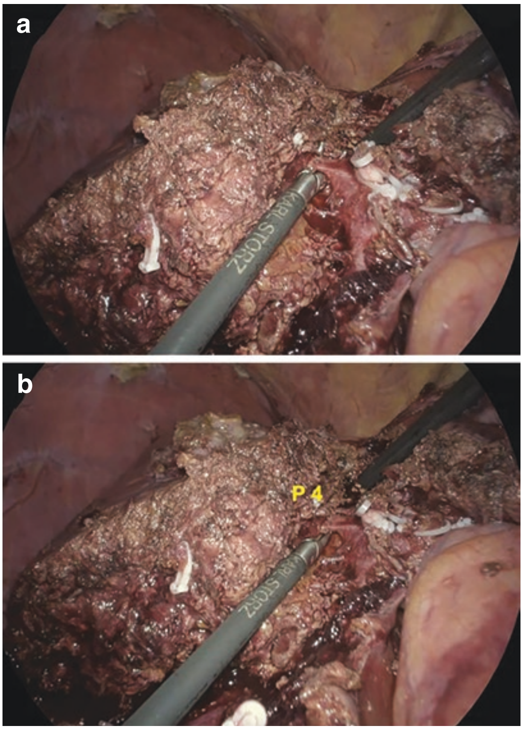

**Fig. 11.6** All the portal branches to S4 are isolated along the right side of the umbilical ligament and they are divided between clips (**a**, **b**)

5. *Second line of parenchymal transection: from MHV root side to the periphery*.

   After division of the portal pedicles, the second transection plane on the right side starts. On the liver surface, the liver parenchyma is dissected along the area of ischemic demarcation of the entire S4. In the deep parenchyma, the transection plane moves by exposing the MHV [4]. The exposure of the MHV during liver transection may proceed from cranial to caudal side by following the ventral side of the MHV (cranio-ventral approach) [5].

The cranio-ventral approach to the MHV may be considered as safe, with a reduced risk of injuring the small venous branches to S4 [5]. Furthermore, by following this plane, it is easier to follow the boundary between S4 and the anterior sector (S5–8).

The correct transection plane on the right side of the anatomical segmentectomy 4 can be fol-

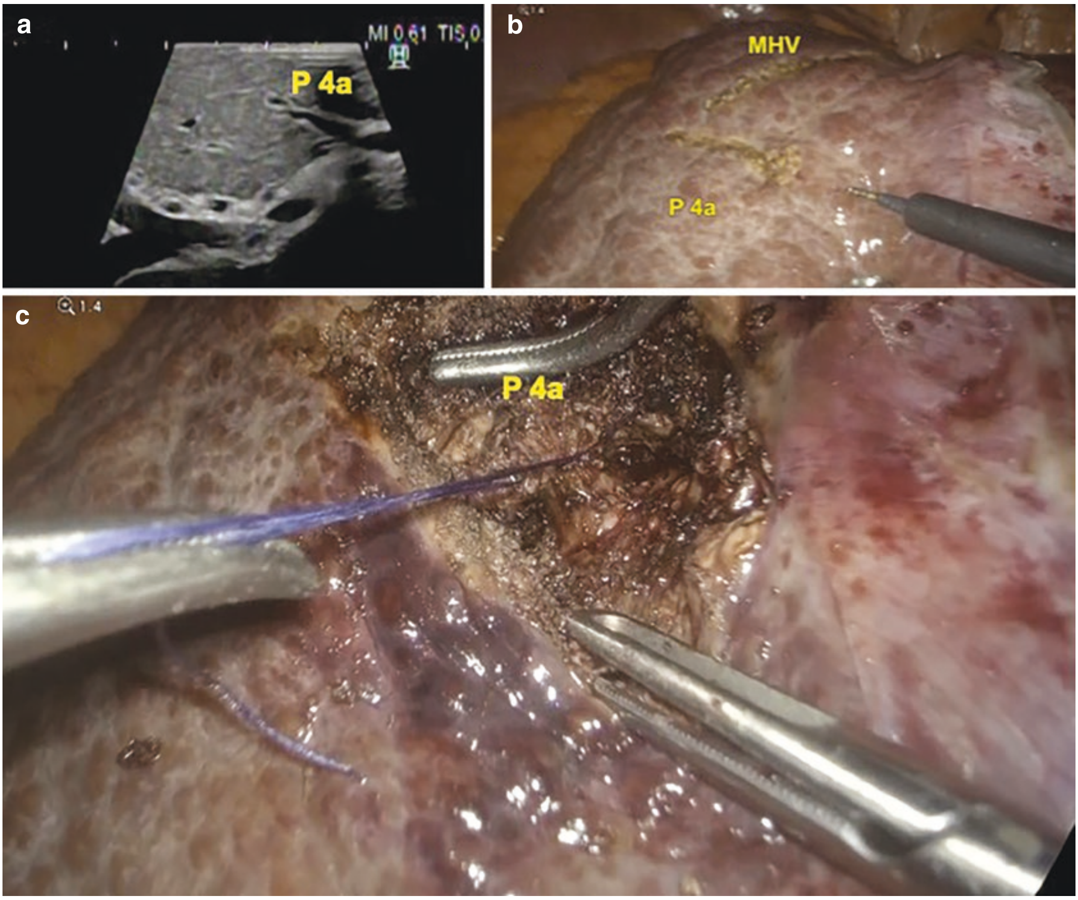

**Fig. 11.7** Anatomic subsegmentectomy 4a for hepatocellular carcinoma on cirrhosis. The portal branch to S4a is identified by IOUS (**a**) and marked on the liver surface (**b**). After a small hepatotomy, the portal branch to S4a is dissected and encircled by a tape (**c**)

lowed also with the use of fluorescence negative staining by the intravenous administration of indocyanine green (ICG), after clamping or division of the portal pedicles to S4 [6, 7].

An isolated anatomic subsegmentectomy 4a can also be performed. In this case, the portal branch to S4a is identified by IOUS (Fig. 11.7a) and marked on the liver surface (Fig. 11.7b). After a small hepatotomy, the portal branch to S4a is dissected and encircled by a tape (Fig. 11.7c).

After division of the portal branch to S4a, an intravenous bolus of ICG is then administered and the liver ischemia of the subsegment 4a is clearly evident by the ICG negative staining (Fig. 11.8). Also in the case of subsegmentectomy 4a, the cranio-ventral approach to the MHV is performed in order to follow the right side of the parenchymal transection. In this way the

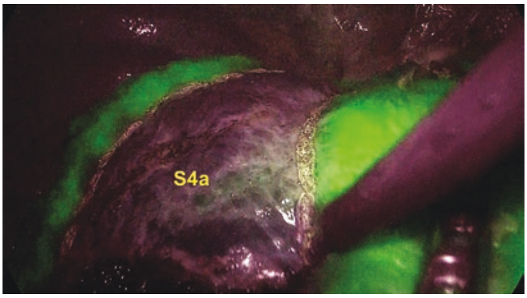

**Fig. 11.8** Ischemic demarcation of the subsegment 4a by ICG negative staining

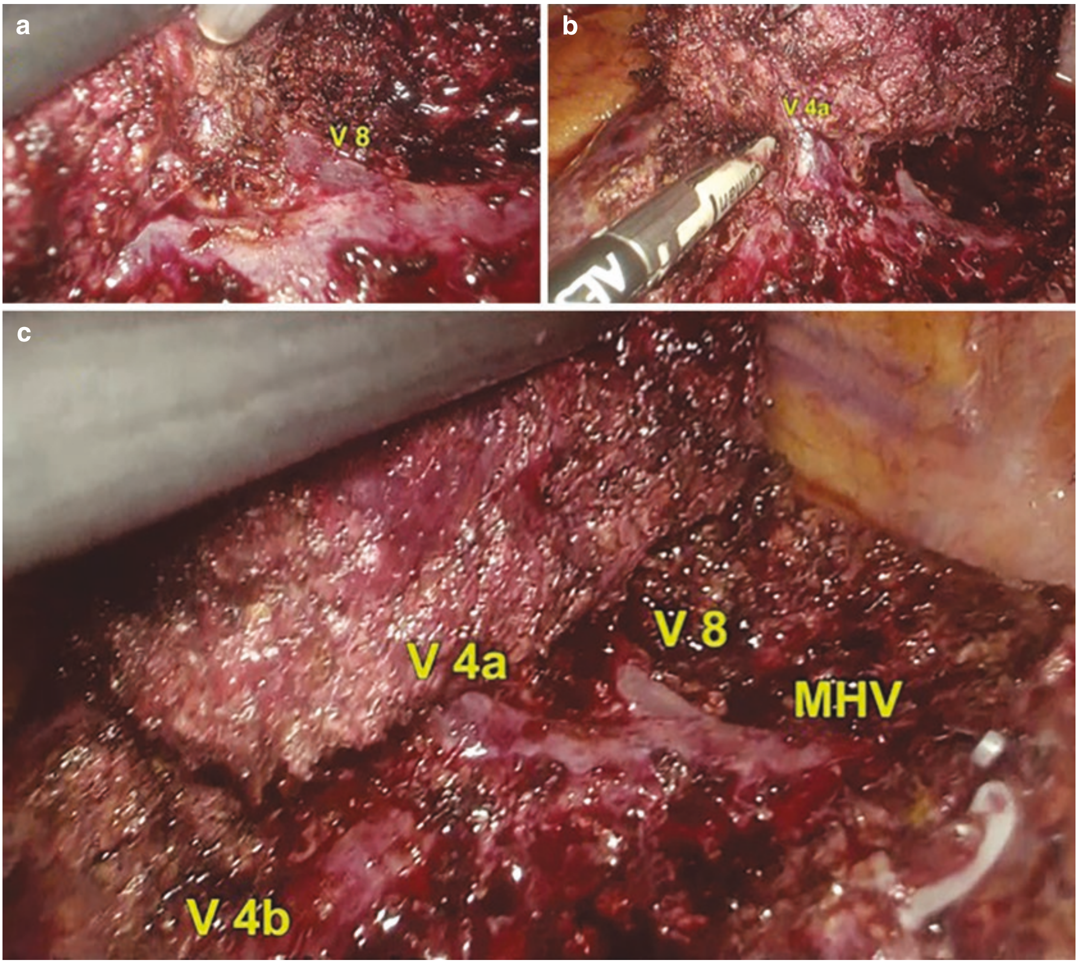

**Fig. 11.9** Cranio-ventral approach to the MHV in order to perform the right side of the parenchymal transection during subsegmentectomy 4a. The branches to S8 (V8) (**a**), to S4a (V4a) (**b**), and to S4b (V4b) (**c**) are safely dissected and isolated

branch to S8 (V8) and to S4b (V4b) are dissected and preserved, while the branch to S4a is isolated and divided (Fig. 11.9). At the end of subsegmentectomy 4a, the correct transection plane is indicated by the exposure of the ventral side of the MHV (Fig. 11.10).

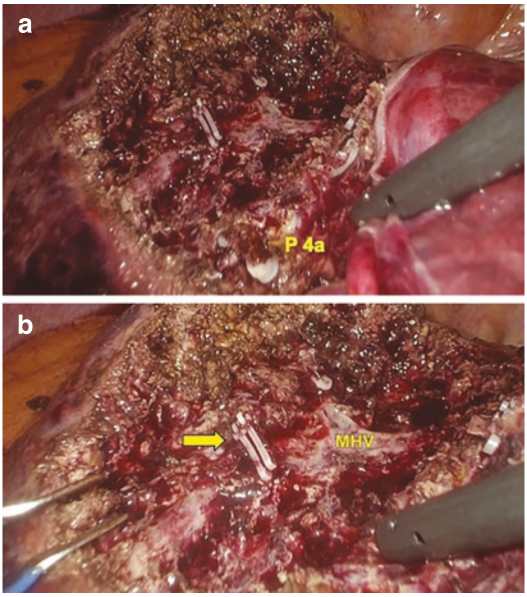

**Fig. 11.10** Surgical field after subsegmentectomy 4a. The stump of the portal branch to S4a (P4a) (**a**) and the stump of V4a (yellow arrow) (**b**) are evident on the surface

## 11.3 Conclusion

Isolated laparoscopic anatomical segmentectomy 4 is a technically demanding procedure, not frequently reported in the literature. The use of IOUS and of the negative staining by ICG administration are fundamental tools in order to correctly perform the removal of S4. The two lines of transections may be performed: first, from the periphery to the cranial side and second, from the cranial side to the periphery. The cranio-ventral approach to the MHV from its root side may be considered as an effective technique for the second line of transection in order to follow the correct plane of segmentectomy, by decreasing the risk of injury of its venous branches.

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# 12

# Left Lateral Bisegmentectomy

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Minimally invasive procedures have significantly changed the surgical practice worldwide in the last decades thanks to the reported improvements in terms of the postoperative pain, morbidity, length of hospitalization, aesthetic results, and overall cost-effectiveness in different surgical subspecialties, including colorectal, urology, gynecology, and thoracic surgery [1–4]. Despite a slower diffusion as compared to the abovementioned specialties, the application of minimally invasive surgery (MIS) to the liver is nowadays established, with many hepatobiliary centers worldwide employing laparoscopy or robotics as part of their practice. The first laparoscopic wedge resection was reported in 1991 [5], followed by the first anatomic and major hepatectomy in 1996 and 1997, respectively [6, 7]. Later, case series, comparative studies, and multicenter experiences have further increased the body of evidence [8–11]. To date, two consensus conferences and one European guideline meeting have been held, and the International Laparoscopic Liver Society has been established to promote minimally invasive techniques in liver surgery [12–14].

Left lateral bisegmentectomy or left lateral sectionectomy (LLS) is defined as the removal of the left lateral sector as described by Couinaud and classified in the 2000 Brisbane nomenclature of liver resections [15]. Segments 2 and 3 of the left liver are resected to remove benign or malignant lesions located in this area. The first laparoscopic LLS was described by Azagra et al. in 1996 [6]. In this paper, the case report of a woman with a symptomatic adenoma was described. Operative time was 6 h and 30 min, with 600-cc blood loss and 8 days of hospitalization. Nowadays, significant improvements in perioperative care, advancements in technology, and learning curve allowed this procedure to be standardized and one of the most common procedures performed in minimally invasive surgery [16]. Indeed, given the improved perioperative outcomes as compared to open, and the short learning curve, MIS for LLS can be considered as the standard approach, even in the setting of living donor hepatectomy [17–19]. In 2010, a randomized controlled trial with the aim to compare the results of laparoscopic and open LLS was promoted but prematurely closed for slow accrual [20].

Minimally invasive LLS can be performed in the standard fashion or by the extrahepatic Glissonean approach. In the standard procedure, the umbilical fissure is approached, dissecting the

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liver parenchyma on the left side of the Rex recessus. Segment 3 pedicle is encountered, sealed, and cut first, followed by segment 2 pedicle after 3–4 cm of further parenchymal transection. Finally, the left hepatic vein is identified and stapled at its confluence with the inferior vena cava. The specimen is extracted trough a small midline or Pfannenstiel incision. The extrahepatic Glissonean pedicle approach was first described by Takasaki et al. in 1998 and further employed by many surgeons for both open and laparoscopic liver resections [21]. This technique involves the isolation of the pedicles of the given anatomical resection, respecting the Glissonean sheet wrapping the serving artery, portal vein, and bile duct [22]. This technique is facilitated by the recent description of a further anatomical layer surrounding the Glissonean sheet and encircling the pedicles within the parenchyma, called the Laennec's capsule [23]. By respecting this capsule and identifying the fundamental landmarks and gates, Sugioka et al. described that the Glissonean pedicle approach can be employed to perform any anatomical hepatectomy, from major resections to segmentectomies and cone unit resections, both right and the left sided. In this chapter, we describe our technique for both standard and Glissonean approach for minimally invasive left lateral sectionectomy.

## 12.1 Surgical Technique

Under general anesthesia, the patient is in supine position, with 16–18° head up and slight left side tilt. The surgeon stands in between the patient's leg with two assistants on each side. At least two screens should be used for surgeons' comfort, and a further dedicated screen should be used for 3D reconstructions. Four trocars are placed: one umbilical, one left and one right flank, and one subxiphoid (Fig. 12.1). It is our experience to use all 10-mm trocars to be able to introduce large instruments (ultrasonic dissector, staplers, gold finger, etc.) from any angle. This is pivotal in challenging resections and/or with lesions located close to major vascular structures. However, as LLS is a relatively easy and standardized procedure, 5-mm trocars can be placed in the right flank and subxiphoid. After abdominal cavity exploration, the intraoperative ultrasound is performed to stage and confirm the disease. Pringle maneuver is then prepared; we prefer to use an extracorporeal Pringle maneuver, using a thoracic tube that exits from the right flank (Fig. 12.1). When needed, the extracorporeal Pringle maneuver is pulled for hilar clamping. We do not use systematic clamping, but we do use intermitting 15-min Pringle with 5-min release when needed, using a 5-min clamping to

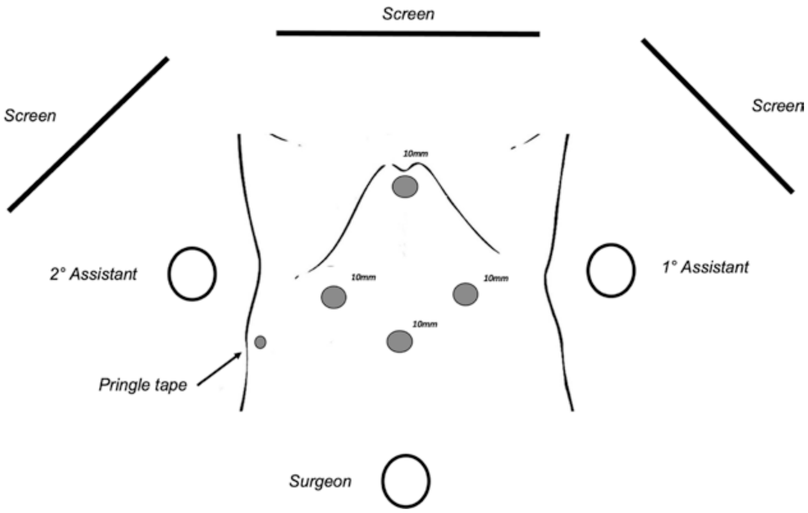


**Fig. 12.1** Patient and trocar position for laparoscopic left lateral sectionectomy

start as preconditioning. Falciform ligament is then cut, reaching and partially dissecting the hepatocaval confluence, identifying the origin of the left hepatic vein and middle hepatic vein cuff. The round ligament is kept in place in the case of severe cirrhosis and significant portosystemic shunts to avoid any possible postoperative decompensations [24]. Otherwise, we cut the umbilical ligament and use it for traction. Parenchymal transection is started on the left of the umbilical fissure, keeping the Rex recessus on the right. Our favorite parenchymal transection technique employs an ultrasonic dissector, energy device, and bipolar forceps for hemostasis. The Glissonean pedicle for segment 3 is immediately identified, looped, and clipped or stapled. Parenchymal transection is further carried on cranially toward the left hepatic vein, and the Glissonean pedicle for segment 2 is identified, looped, and clipped or stapled. Finally, the left hepatic vein is identified at its confluence with the inferior vena cava (IVC), looped, and stapled (Fig. 12.2). Specimen is extracted in a plastic bag trough a Pfannenstiel incision. No drains are left in place in standard left lateral sectionectomies at our institution.

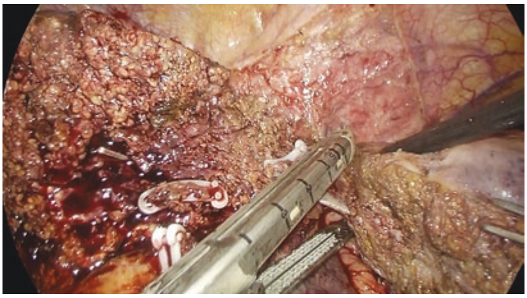
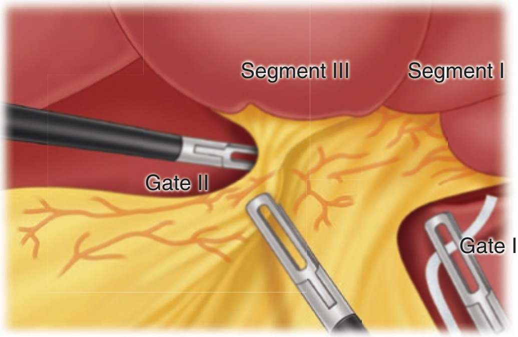


**Fig. 12.2** Left hepatic vein is identified, looped, and stapled

For the extrahepatic Glissonean approach, the same patient and trocar position are used, and same extracorporeal Pringle maneuver preparation is performed. Following left liver's mobilization, the Arantius ligament is dissected to approach gate I. Then, gate I and gate II are approached respecting the Lannaec's capsule, using bipolar forceps and gentle smooth dissection. The maneuvers are generally performed under pedicle clamping given the chance of bleeding. Gates I and II are connected using a gold finger, encircling both the Glissonean pedicles for segment II and III, thereby having the left lateral section's inflow under control (Fig. 12.3). A bulldog is used to clamp these pedicles, and 1 mg of indocyanine green (ICG) dye is injected by the anesthesiologist. This allows to negatively stain the left lateral section using a dedicated camera. Indeed, the ICG will stain green the whole liver, except for the left lateral section which is clamped. This allows for a precise guidance during both superficial and deep parenchymal transection (Fig. 12.4). Once dissected free, the looped segment 2 and 3 Glissonean pedicles are stapled. Finally, the left hepatic vein is identified, lopped, and stapled at its confluence with the IVC. Specimen is extracted in a plastic bag trough a Pfannenstiel incision. No drains are left in place.

**Fig. 12.3** Gate I and II are connected, encircling the Glissonean pedicles for segments 2 and 3 during extrahepatic Glissonean approach technique



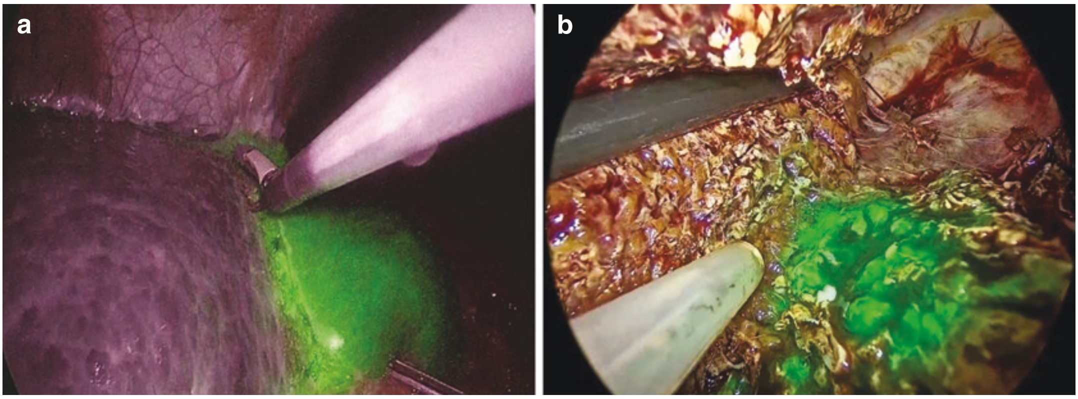


**Fig. 12.4** Indocyanine green-dye-guided parenchymal transection. (**a**) Superficial parenchymal transection. (**b**) Deep parenchymal transection

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# 13 Left Hemihepatectomy (Segment II + III + IV)

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## 13.1 Introduction

Left hepatectomy is one of the most common types of hepatectomy.

Even if the left lobe presents less variations in vascular and biliary anatomy compared to the right lobe, it remains a challenge in itself due to the complexity of the resection that requires identification of the anatomical boundaries [1–3]. Despite the possible technical pitfalls, part of current literature emphasizes the benefits of a Glissonean approach, where intraoperative bleeding and conversion rates, as well as postoperative mortality rate and resection margins, appear to be lower in expert hands [4].

With the increasing pressure to make laparoscopic left hemihepatectomy the standard of care for patients with left lobe pathology, there has been a significant increase in the number of trials and studies to validate its safety and efficacy [4, 5]. As it possibly represents the ideal technique for anatomical liver hepatectomy, it is also becoming a fundamental technique to be added to modern surgeon skill set.

Therefore, surgeons nowadays need to possess all the basic knowledge and skills to be able to accomplish a left hepatectomy liver resection based on the Sugioka gates and landmarks.

In this chapter, the authors aim to familiarize readers with the Glissonean approach to a laparoscopic left hepatectomy of the liver through the recognition of the surgical anatomy, technical steps, indications, and tips presented.

## 13.2 Indications and Contraindications

There are various indications for performing a laparoscopic left hemihepatectomy.

Firstly, malignant lesions such as tumors occupying the left liver portion, metastases (e.g., colorectal metastasis) with no evidence of extra-

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hepatic disease, and intrahepatic or perihilar cholangiocarcinoma infiltrating the left main duct or its branches. Tumors invading the left portal vein or left hepatic vein are also an indication for left hepatectomy.

In addition, even benign lesions such as huge hemangiomas occupying the left lobe of the liver, multiple hydatid cysts, intrahepatic bile duct stones with irreversible diseases (e.g., biliary stricture) and symptomatic benign masses that have a risk of rupture may represent an indication for left hemihepatectomy [6].

Before proceeding, it is fundamental to ensure on patient factors side that liver function is adequate (Child B or less) [7].

On the other hand, contraindications of this approach consist of standard liver resection contraindications including insufficient liver volume and parenchymal insufficiency from previous chemotherapy, alcoholic liver disease, and nonalcoholic fatty liver disease. There are also anatomical contraindications for this approach, namely, malignant tumors involving the porta hepatis or the presence of extrahepatic biliary strictures. In the latter, it is essential to perform main portal dissection, which limits the extra-Glissonean approach.

Patient factors are also important to consider relative contraindications of this approach: a history of biliary surgery such as common bile duct exploration and cholangiojejunostomy may increase the complexity of such a procedure, as well as the presence of active acute suppurative cholangitis [7].

## 13.3 Surgical Technique (Key Issues and Technique Details)

The Glissonean approach is recommended for laparoscopic left hemihepatectomy as it is a safe and feasible method for segment-oriented hepatectomy, facilitating a tailored liver resection by removing only the very involved liver segments [8]. In this particular approach, it is crucial to recognize two anatomical landmarks and gates [9]. The gates, as described in the previous chapters, are gaps between the Laennec's capsule and the Glissonean capsule. Identification of these gates is critical, as it allows the isolation of main hepatic pedicles through the connection of two gates. The first anatomical landmark to be known for left hepatectomy is the Arantius plate, where the Arantius ligament is located; the second is the umbilical plate, which ends in the round ligament.

Gates to be identified for left hepatectomy are gate 1, which is placed at the caudal end of the Arantius plate, and gate 3, placed at the right edge of the root of the umbilical portion.

A more detailed description of the technical steps is found below.

### 13.3.1 Patient Position and Trocars Placement

1. Patient is positioned in a supine, 15° reverse Trendelenburg position with legs apart and arms tucked along the body; the table is slightly tilted to the right side (Fig. 13.1)
2. A 10-mm upper umbilical port is placed using the open Hasson technique.
3. Pneumoperitoneum is created by insufflation using carbon dioxide. Intra-abdominal pres-

**Fig. 13.1** Patient position

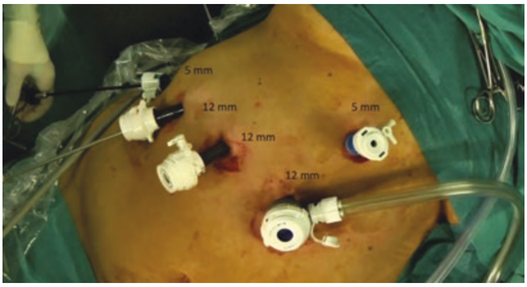

**Fig. 13.2** Laparoscopic port placement

sure is maintained below 12 mmHg. By using the AirSeal system, we suggest to lower this pressure (up to 8 mmHg) in order to decrease the risk of venous embolization during hepatectomy.

4. 30° Optique is subsequently inserted through the umbilical port.
5. For laparoscopic approach, four additional ports are inserted under vision: 10 mm, one port 8–15 cm from the optical port on the right side and one port 8–15 cm from the optical port on the left side and 5 mm, one port at lateral third of right clavicle in transversal level and one port 2 cm below the left costal margin. The 10-mm ports are operational, while the 5-mm ports are used for retraction instruments and suction (Fig. 13.2).

   Regarding robotic approach five/six ports are placed. An 8-mm trocar for the first robotic arm, the optical port, in the right midclavicular line, at the same level of the umbilicus. The distance between the robotic ports and the target of the surgery must be around 10–12 cm. In the case of obese patients, we suggest placing the trocar almost 2 cm above the umbilicus line on the second trocar along the same line of the previous one (almost 6–8 cm) at left side. The trocar for the third robotic arm is placed in the left anterior axillary line (6–8 cm from the optical trocar). The last robotic arm port is placed in the left side at the same line of the previous one (Fig. 13.3). One or two auxiliary assistant ports can be placed between the second and third robotic trocar and in the left midclavicular line, 1–2 cm below the subcostal arch. We suggest placing these last two trocars below the robotic trocars line in order to achieve a better liver parenchymal field with any further laparoscopic devices, such as CUSA or any other sealer if it is required.
6. In laparoscopy, the surgeon is positioned between the patient's legs, just occasionally on patient's right.

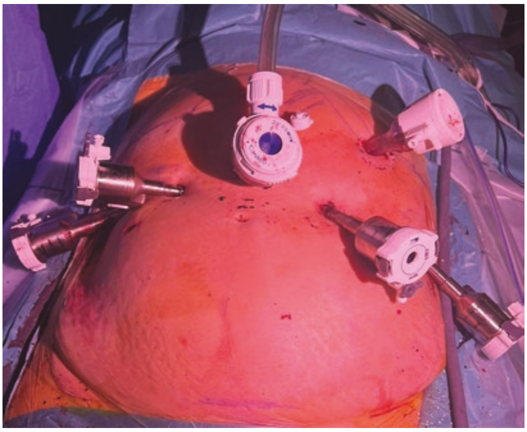

**Fig. 13.3** Robotic port placement

## 13.3.2 Exploration and Mobilization

7. Following a complete abdominal cavity exploration, laparoscopic ultrasonography is performed to detect possible missing lesion at preoperative imaging and also to identify lesion proximity to major structures and to further define their anatomy in view of transection.
8. The round ligament is identified and divided close to the abdominal wall, while the falciform ligament is divided from the anterior abdominal wall toward the suprahepatic inferior vena cava. An important tip is to leave the falciform ligament and round ligament long enough to be tractioned properly during the liver mobilization as shown in the Fig. 13.4, where it is sectioned just below the abdominal wall. This is done until the anterior surface of the left hepatic vein and mid-

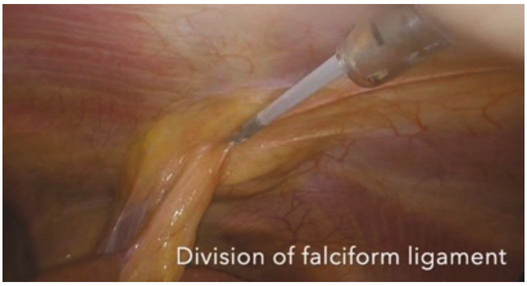

**Fig. 13.4** Falciform liver division

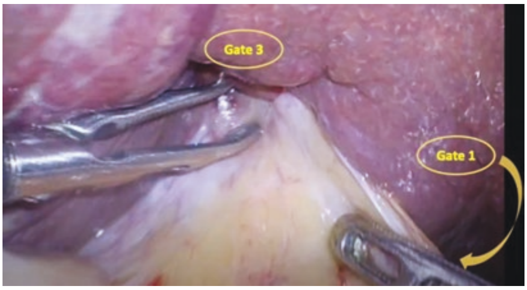

**Fig. 13.5** Gate 1 and gate 3 location

dle hepatic vein is exposed. The left triangular ligament is then divided to free the left lateral section.

9. Retraction of the left lateral segments exposes partially the left hepatic vein, which is identified by its connection to the lesser omentum. Depending on surgeon experience and surgical field, at this step, it is also possible an early dissection of the left hepatic vein, which allows for a better outflow control.
10. Preparation for the Pringle maneuver can be obtained in two fashion:

    A: external Pringle: As shown in the video, a 5-mm tape is subsequently placed around the hepatoduodenal ligament, and a chest tube is placed through the abdominal wall. An important tip for left hepatectomies is to make sure that the chest tube comes from the right side of the abdominal wall. In this way the tape is tractioning the liver to the right side, helping liver parenchymal transection. In this case the Pringle maneuver is performed by pushing the tube directly in the direction of the hepatoduodenal ligament.

    B: internal Pringle: As shown in the video, a Foley tube is placed around the hepatoduodenal ligament. It might be tightened whenever the Pringle maneuver is needed. This last fashion might be more useful in the robotic approach as it is easier and faster its placement and tie.

### 13.3.3 Transection of the Glissonean Pedicle

11. The liver is retracted using a retractor in order to identify the gates.
12. As shown in the video, gate 1 is first localized at the caudal end of the Arantius plate, while gate 3 is localized at the junction between the round ligament and the umbilical plate (Fig. 13.5). Connecting gates 1 and 3 allows the selective identification of the Glissonean pedicle of segment II, III, and IV, allowing for an anatomical left hepatectomy.
13. The dissected Glissonean pedicle is temporarily clamped using a bulldog clamp or a laparoscopic forceps in order to confirm the demarcation between the left and right liver based on ischemic discoloration. This might be further confirmed through the use of indocyanine green fluorescence.
14. The Glissonean pedicle is then sectioned depending on surgeon's preference. This includes using endo-GIA vascular stapler (as shown in the video), hem-o-lok clips, or direct ligation.
15. To facilitate the correct parenchymal dissection route, as shown in the video, a hanging maneuver can be performed with a tape passing from the anterior to the posterior surface of the liver. Lifting up this tape allows a better parenchymal exposure.
16. At this stage, if the left hepatic vein, previously dissected, may be sectioned.

### 13.3.4 Hepatic Transection

17. A cavitron ultrasonic surgical aspirator (CUSA) and harmonic scalpel is usually used to transect parenchyma, following the ischemic demarcation of the left hepatic parenchyma.
18. As shown in the video, the intraparenchymal anatomy of the middle hepatic vein is again confirmed via ultrasonography and marked at the surface of the liver. This is an important tip that decreases the intraparenchymal damage of the vein during the parenchymal transection.
19. The liver transection plane continues between the segment I and IVA, following the middle hepatic vein, until full view of the left hepatic vein. As shown in the video, several devices can be used for a safe and effective hepatectomy. It may vary according to the surgeon personal experience.
20. When the middle hepatic vein-left hepatic vein confluence is reached, the medial side of the left hepatic vein is dissected peripherally, and stapling of the vein using endo-GIA vascular stapler is then used to staple the vein transversely in order to prevent damage to the middle hepatic vein. As shown in the video, we mainly use the white vascular stapler. In both robotic and laparoscopic approach, the endo-GIA stapler can be inserted through the right lateral 12-mm port. From this right port side, the stapler entering into the abdomen is easily moved forward the left hepatic vein.
21. After complete resection and hemostasis, an hemostatic patch might be used.
22. The specimen is placed in an endobag and extracted through a Pfannenstiel incision.

## 13.4 Tip and Tricks

Preoperatively, the authors recommend to use Iwate criteria to assess the difficulty of laparoscopic left hemihepatectomy and to predict postoperative complications in these patients. The Iwate criteria is a modified four-level difficulty scoring system comprising the extent of liver resection, tumor location, tumor size, proximity to major vessels, and the severity of fibrosis [10].

Furthermore, the use of indocyanine green fluorescence (ICG) is an effective method to confirm the ischemic area of the respective segments. Dosages of indocyanine green fluorescence varies and is dependent on different cases—however, common doses the authors use are 2.5 mg/body for the negative staining method and 0.25 mg/body for the positive staining method.

ICG also allows the identification of the biliary duct and its right and left branches. This technique is particularly useful any time there is an anatomical variation of the duct.

Proper radiological preoperative studies are paramount to identify preoperatively any vascular and biliary anatomical variation. Given that through the extra-Glissonean approach the surgeon is not visualizing the pedicle elements, each patient anatomy knowledge is particularly important to avoid any intraoperative severe adverse event. We suggest performing a 3D study any time a major hepatectomy is planned.

Additionally, the authors recommend the use of endo-GIA vascular stapler to section the Glissonean pedicle as it is the fastest method based on the authors' experience.

Moreover, in order to increase exposure of the surgical field, traction of the liver and free the surgeons' hands, the authors offer the alternative of using a technique known as the extracorporeal rubber band traction, where traction rubber bands can be placed at the border of the liver transection through the abdominal wall. They can be progressively tractioned during the parenchymal transection.

## 13.5 Main Key Points

Laparoscopic left hemihepatectomy utilizing the Glissonean approach is a useful technique for surgeons to develop and learn. While technically challenging, the advent of technological advances and the development of various methodological modifications has improved the difficulty of such an approach, while retaining the benefits of the traditional operation.

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# Part III

# Anatomical Approach Glissonean Pedicles (Right Liver)

## 14

# Laparoscopic Anatomical Resection of Segment VI of the Liver

Darren W. Q. Chua, Yoshio Masuda, and Ye Xin Koh

## 14.1 Introduction

The laparoscopic anatomical resection of segment VI utilising a Glissonean pedicle approach is an unfamiliar territory for many surgeons due to technical difficulties associated with the approach. While a small tumour located peripherally in segment VI is easily accessible for laparoscopic resection, a large tumour located in close proximity to the right main pedicle, sectorial or segmental branch and its second- or third-order ramification can limit the operative field and the approach of the laparoscopic instrument, thus increasing the surgical complexity. Moreover, the Glissonean approach is a challenge in itself due to the complexity in identifying anatomic boundaries [1]. This is especially relevant in anatomical resections of the right lobe, where it features greater variations in the vascular and biliary anatomy compared to the left lobe [2]. The most common anatomical variation was branches from segments VI and VII arising from the right posterior pedicle, followed by the variation of branches from the segments V, VI, and VII arising from the main right anterior pedicle [3]. Such variations affect the decision-making behind considering an anatomical or non-anatomical approach to a segment VI resection.

Despite the challenges of this approach, anatomical resections are ultimately preferred to non-anatomical resections for tumours such as hepatocellular carcinoma, due to the tumour's ability to invade the portal veins and spread along the intrasegmental branches [4]. Furthermore, anatomical resections are shown to be superior in terms of obtaining clear resection margins and removing micro-metastases [5]. It is thus an important technique to be added to the armamentarium of the modern surgeon.

In this chapter, the authors aim to familiarise readers with the approach to a laparoscopic anatomical resection of segment VI of the liver through the technical steps, indications and tips presented.

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## 14.2 Indications and Contraindications

There are various situations in which a laparoscopic anatomical liver resection of segment VI is beneficial. Firstly, when tumours are situated deep within segment VI, an anatomic resection allows for optimal oncologic clearance while preserving liver. Secondly, there exist situations where preoperative imaging may identify a small lesion within segment VI but is not identified intraoperatively either through imaging adjuncts such as indocyanine green (ICG) or ultrasound. In this setting, an anatomic resection of segment VI can also be considered rather than a 'blind' non-anatomic resection.

On the other hand, there are numerous contraindications to this approach. This consists of, firstly, patients with parenchymal insufficiency [6, 7], graded according to scoring systems such as the Child Pugh's Score or Makuuchi's criteria for ICG. Secondly, anatomical contraindications, namely, tumours in close proximity to the right main pedicle or right posterior sectorial pedicle, may necessitate a right hemihepatectomy or posterior sectionectomy respectively, thus precluding an anatomic segment VI resection.

## 14.3 Surgical Technique

The Glissonean approach is recommended for the laparoscopic anatomical liver resection of segment VI as it is a safe and feasible method for segment-oriented hepatectomy, facilitating a tailored liver resection by removing only involved liver segments [8]. Briefly, the major Glissonean pedicle of the right posterior section is first isolated, and further peripheral dissection subsequently reveals the Glissonean pedicle of segments VI and VII. The Glissonean pedicle of segment VI is then isolated and ligated, before identification of the transection plane between segments V, VI and VII as determined by the ischemic line. A more detailed description of the technical steps is found below.

### 14.3.1 Patient Position and Trocar Placement

1. Patient is positioned in a modified Lloyd-Davis position with a 45° right-side-up adjustment.
2. A 12-mm umbilical port is placed using the open Hassan technique.
3. A pneumoperitoneum is created by insufflation using carbon dioxide. Intra-abdominal pressure is maintained below 12 mmHg.
4. A flexible laparoscopic is subsequently inserted through the umbilical port.
5. Four additional ports (5 mm, one port at the subxiphoid level and one port at level of anterior axillary line 1–2 cm below the costal margin, and 10 mm, one port at lateral side of left rectus muscle and one port between the two 5-mm ports) are created under direct vision. Another port is inserted between the two 10-mm ports for the Pringles manoeuvre (Fig. 14.1).

### 14.3.2 Cholecystectomy (Optional)

6. The gallbladder may be taken down and used as a landmark to trace the posterior sectoral pedicle via the cystic plate.
7. Cholecystectomy is performed when it obstructs the view of the posterior sectorial pedicle or the anterior segment pedicle.

### 14.3.3 Exploration and Mobilisation

8. The falciform ligament is identified and transected, together with the right triangular ligaments in order to mobilise the right hepatic lobe of the liver.
9. Further mobilisation of the vena cava of the liver is obtained through division of the short hepatic veins.
10. Intraoperative ultrasound is performed to confirm the tumour location in segment VI.
11. The portal hepatitis is slung with an umbilical tape for use in the Pringle manoeuvre whenever necessary.

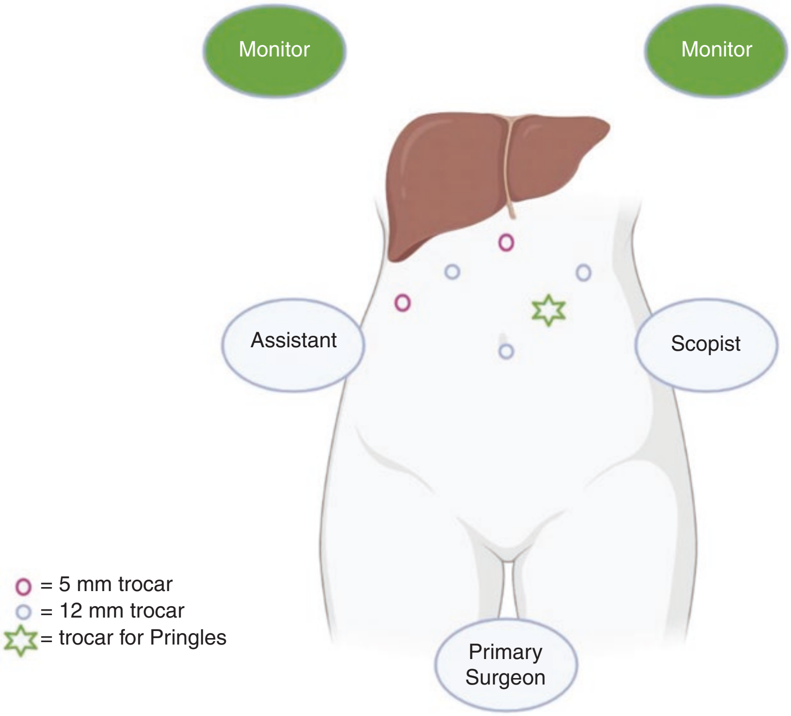

**Fig. 14.1** Trocar placement and surgeon positions

### 14.3.4 Transection of the Glissonean Pedicle

12. The liver is retracted.
13. The posterior Glissonean pedicle is dissected at the level of Rouviere's sulcus, separating Laennec's capsule from the Glissonean pedicle.
14. Dissection is continued inside the liver parenchyma until the branches of segments VI and VII are reached.
15. The Glissonean pedicle of segment VI is temporarily clamped using a bulldog clamp to confirm the ischemic demarcation of segment VI. This can be further confirmed using ICG.
16. The ischemic line is marked using a monopolar diathermy.
17. Intraoperative ultrasound is performed to confirm the tumour location within segment VI and adequacy of resection margins.
18. The Glissonean pedicle of segment VI is then clipped and divided between Hem-o-lok clips.

### 14.3.5 Hepatic Transection

19. The parenchymal transection is performed using the harmonic scalpel or cavitron ultrasonic surgical aspirator (CUSA). When isolating larger veins (i.e. the distal hepatic vein), the CUSA is the preferred instrument. The rest of the parenchymal resection can be performed through the harmonic scalpel.
20. After complete resection and haemostasis under the Valsalva manoeuvre, fibrin glue is used to enhance biliostasis (Fig. 14.2).

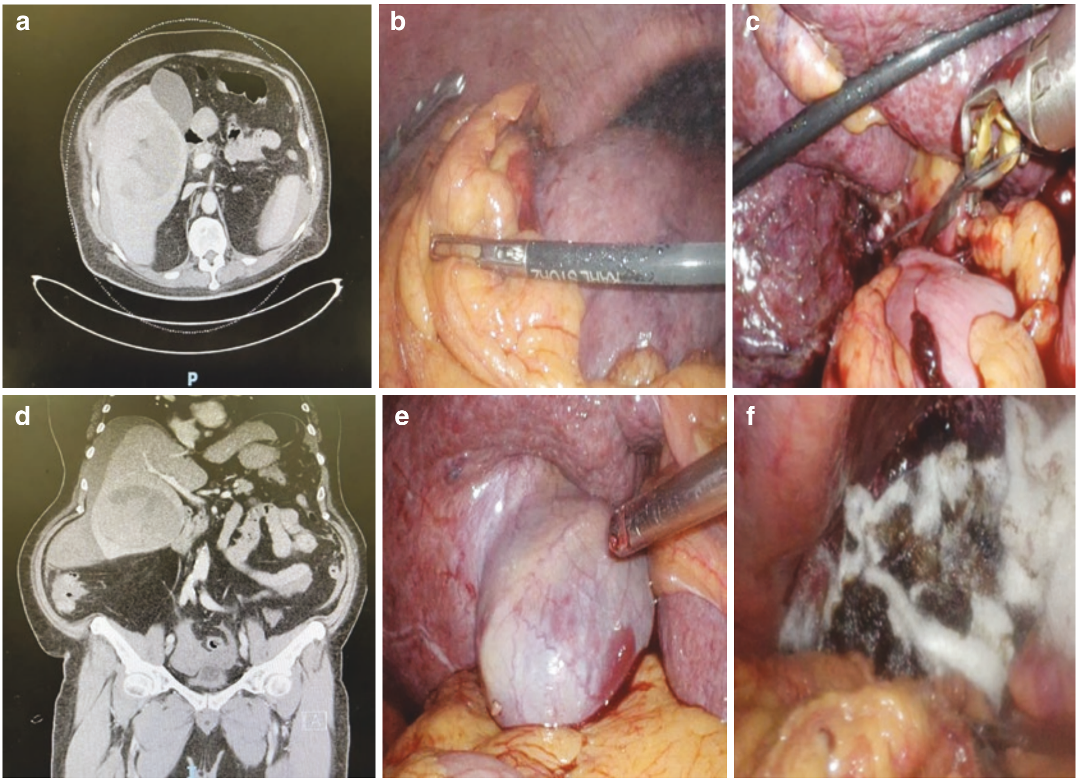

**Fig. 14.2** Laparoscopic anatomic resection of segment IV of a ruptured liver cancer in a 66-year-old male. Performed at Singapore General Hospital, Singapore. (**a**, **b**) Preoperative computed tomography scans of the patient in axial and coronal views respectively. (**c**) Displacement of omental adhesions. (**d**) Gallbladder obscuring view of the posterior pedicle, thus necessitating cholecystectomy. (**e**) Pringle manoeuvre performed. (**f**) Completed view of the remnant liver

### 14.3.6 Specimen Extraction

21. The specimen is placed in an endobag and extracted through the extension of the umbilical port.

## 14.4 Tricks and Tips

Preoperatively, the authors recommend the use of the Iwate criteria to classify the difficulty of laparoscopic anatomical resection of segment VI. The Iwate criteria is a modified four-level difficulty scoring system comprising the extent of liver resection, tumour location, tumour size, proximity to major vessels and the severity of fibrosis [9].

At Singapore General Hospital, laparoscopic anatomic resections are generally pursued for hepatocellular carcinomas, while laparoscopic non-anatomic parenchymal sparing resections are done for colorectal liver metastases [10].

In terms of patient positioning, a modified Lloyd-Davis position with a slight incline is generally sufficient for the operation. Intraoperatively, the authors recommend the use of ICG as a useful adjunct to better delineate the anatomical transection planes. This is especially critical in deeper resection margins. On occasions when the foramen of Winslow cannot be reached, a laparoscopic bulldog clamp can be raised across the porta hepatitis to occlude the blood flow. Parenchymal resection through a crush-clamp technique using a harmonic scalpel should be coupled with a suction device to improve visualisation. Furthermore, exposure can be improved via rubber band traction. This provides the additional advantage of freeing up the surgeon's hands.

## 14.5 Summary

Laparoscopic anatomic resection of segment VI of the liver remains a useful technique for surgeons to develop and learn. While technically challenging, the advent of technological advances and the development of various methodological modifications has increased the feasibility of this approach.

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# Segment VII Hepatectomy

# 15

Felice Giuliante, Francesco Ardito, and Francesco Razionale

## 15.1 Introduction

Laparoscopic resections of posterosuperior liver segments are complex procedures. However, the minimally invasive approach in such cases may present better immediate outcomes than the open technique, especially in cirrhotic patients because it avoids large subcostal incisions that are needed to reach the superior portion of the liver behind the ribs [1]. During the years, with the improved surgeons' expertise, indications to laparoscopic liver resections for tumors located in segment 7 (S7), increased. Indeed, the Southampton Guidelines [2] stated that in expert hands, laparoscopic liver resections for lesions in the posterosuperior segments may maintain the advantages seen in the anterolateral segments.

## 15.2 Main Indications to Anatomic Hepatic Segmentectomy 7

Surgical indications for anatomic segmentectomy 7 are determined according to the tumor-vessel relationships. In patients with hepatocellular carcinoma (HCC) localized in S7, the anatomic resection of S7 is the treatment of choice [3]. Tumors invading the right posterior portal pedicle are contraindications or the bifurcation between S6 and S7, that are contraindications to segmentectomy 7.

## 15.3 Surgical Technique

An isolated laparoscopic anatomic segmentectomy 7 is a technically demanding operative procedure due to the deep and posterior location of S7 and to the lack of clear anatomical landmarks. The left boundary of S7 is represented by the right hepatic vein (RHV). An anatomically correct segmentectomy 7 should expose on the cut surface the right wall of the RHV.

Several approaches for anatomic resection of S7 have been described [4–6].

The intrahepatic Glissonean approach is a feasible technique which allows to first dissect and clamp the portal pedicle to S7 (P7) [7, 8]. Indeed, the right posterior portal pedicle presents a posterior course along the dorsal liver surface. This peculiar anatomy allows to perform a direct transparenchymal approach to the entire right posterior portal pedicle (P6–7) or selectively to P6 or P7 for the anatomic segmentectomy. The entire right posterior portal pedicle is easily recognized because it is localized at the level of Rouviere's sulcus. The course of portal pedicle to S7 (P7) may be identified by using the intraoperative ultrasound (IOUS).

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Under general anesthesia, the patient is placed in the supine position. The right arm is along the body and the left arm is open. The surgeon is between the patient's legs, with two assistants on the left side of the patient. Using an open technique, a 12-mm trocar is placed about 3 cm above the umbilicus, along the right midclavicular line. Through this port a 30° laparoscope is introduced, and three additional 12-mm trocars are placed at the sites, as shown in Fig. 15.1.

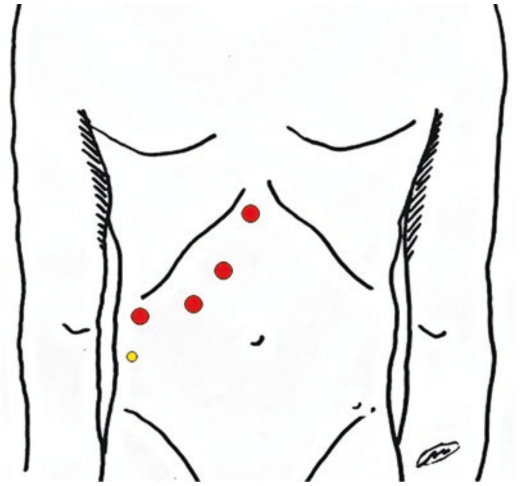

**Fig. 15.1** Trocar position for anatomic segmentectomy 7. Four 12-mm trocars (red). Place of extracorporeal tourniquet for pedicle clamping (yellow)

The procedure is performed according to the following steps:

1. The portal pedicle is systematically encircled with a tape to allow intermittent pedicle clamping (15-min clamping and 5-min release periods), if required.
2. The right hemiliver is fully mobilized by dividing the falciform ligament and the right coronary and triangular ligaments. The mobilization proceeds first from medial to lateral direction.
3. The right hemiliver is lifted, and the mobilization is continued from below up to reach the posterior surface of segment 7.
4. IOUS is performed in order to confirm the location of the tumor, to study its relationships with P7, and to ensure adequate resection margin.
5. The course of P7 is identified by IOUS and sketched on the liver surface (Fig. 15.2).
6. By a small hepatotomy P7 is intraparenchymally reached and isolated by a tape (Fig. 15.3).
7. The correct isolation of P7 is checked by IOUS (Fig. 15.4).

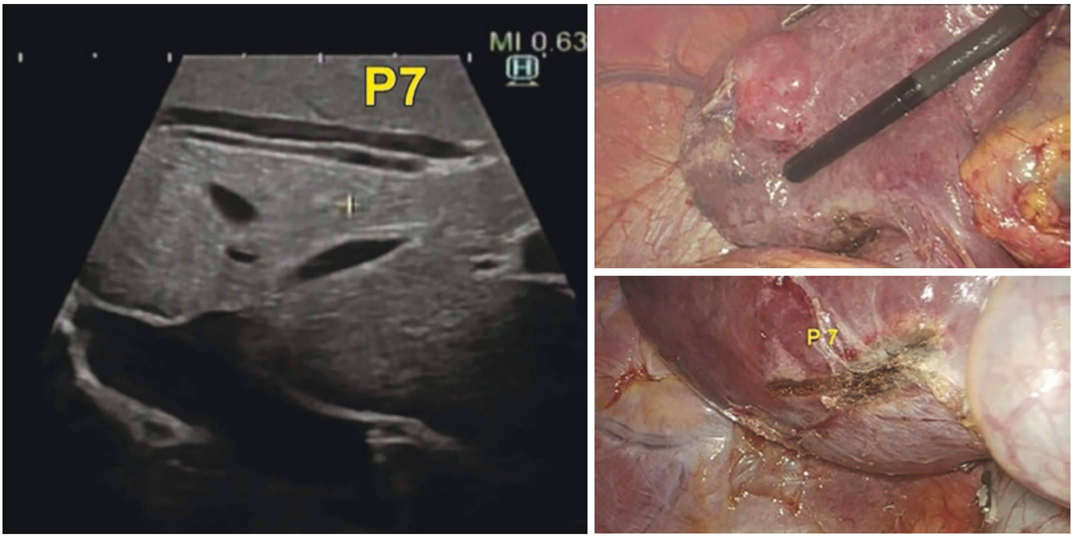

**Fig. 15.2** The course of P7 is superficial (about 1 cm above the liver surface), and it may be easily identified by IOUS along the dorsal liver surface

8. P7 is clamped in order to induce ischemia of segment 7. After clamping or division of P7, an intravenous bolus of indocyanine green (ICG) is administered, and the liver ischemia of S7 is clearly evident by the negative staining technique (Fig. 15.5).
9. At this time, parenchymal transection starts along the ischemic demarcation line by ultrasonic dissector. The direction of parenchymal transection may vary according to different techniques. The cranio-caudal approach to the RHV may be considered as a safe technique, with a reduced risk of injuring the small venous branches to S7. This approach starts at the level of the hepato-caval junction and proceeds caudally till reaching the plane of the stump of P7, previously divided.
10. During transection, the venous branch from the RHV to S7 (V7) in isolated and divided (Fig. 15.6a).
11. At the end of resection, the stump of P7 and of V7 are visible on the cut surface. The correct plane of the anatomic segmentectomy 7 is confirmed by the presence of the RHV exposed on the cut surface (Fig. 15.6b).

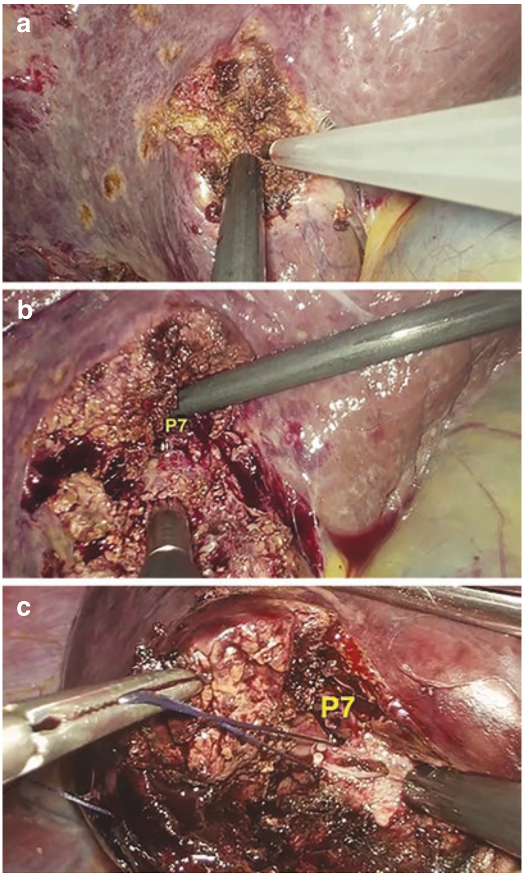

**Fig. 15.3** A small hepatotomy is performed by ultrasonic dissector on the dorsal liver surface (**a**). P7 is intraparenchymally reached and isolated by a tape (**b**, **c**)

The cranio-caudal approach to the RHV may be considered as a safe technique to perform an anatomically correct segmentectomy 7. Indeed, by following this plane, it is easier to follow the boundary between S8 and S7 [9, 10].

The correct transection plane can be followed also with the use of fluorescence negative staining by the intravenous administration of ICG, after clamping or division of P7 [11, 12].

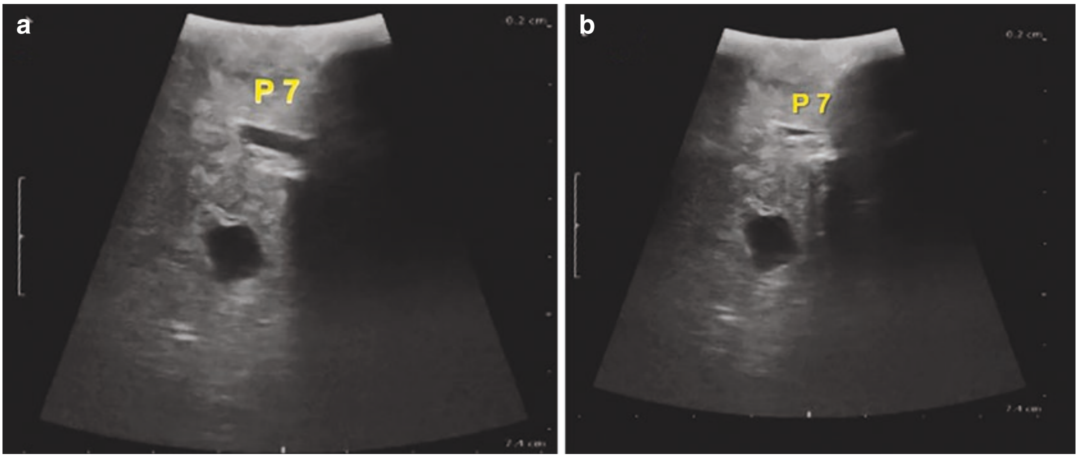

**Fig. 15.4** The correct isolation of P7 is checked by IOUS (**a**). After pulling the tape, the consequent closure of the portal pedicle to S7 is well visible (**b**)

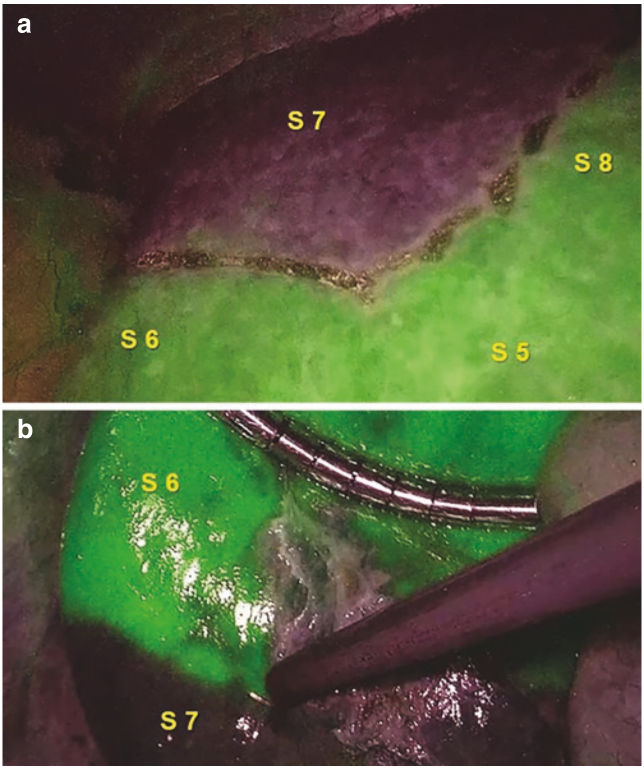

**Fig. 15.5** Intravenous bolus of ICG is administered, and the liver ischemia of S7 is clearly evident by the negative staining technique on the anterior surface (**a**) and on the posterior surface (**b**)

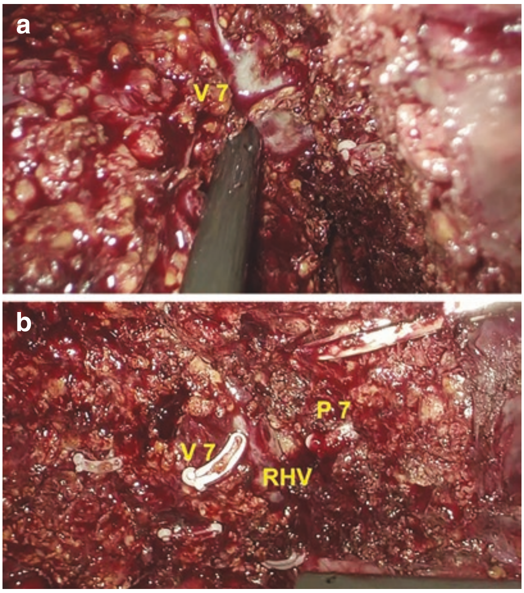

**Fig. 15.6** The venous branch from the RHV to S7 (V7) in isolated (**a**). At the end of resection, the stumps of P7 and of V7 are visible on the cut surface (**b**). The correct plane of the anatomic segmentectomy 7 is confirmed by the presence of the RHV exposed on the cut surface (**b**)

## 15.4 Conclusion

Isolated laparoscopic anatomical segmentectomy 7 is a technically demanding procedure. The intraparenchymal Glissonean approach to P7 on the dorsal liver surface is a safe and feasible technique which allows to isolate and clamp P7 with consequent ischemia of S7. In this way, by the use of the negative staining by ICG administration and by the cranio-caudal approach to the RHV, it is possible to correctly follow the anatomical boundaries in order to perform the removal of S7.

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# 16 Segment VIII Hepatectomy

Julio Santoyo-Santoyo, Julio Santoyo-Villalba,
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## 16.1 Introduction

Minimally invasive liver resection is the standard of care in many centers for liver surgery, comprising more than 90% of all liver resections. However, specific operations remain particularly challenging and are generally performed by open surgery. Laparoscopic liver resection of S8 (LLRS8) is considered to be one of the most challenging due to its anatomical segmentation characteristics, its difficult access due to its subdiaphragmatic position, the deep location of Glissonean pedicle, and the limits of the segment which are in close contact with the inferior vena cava and the right and middle hepatic veins. This requires an exposure of these major vascular structures, with an intrinsic risk of life-threatening hemorrhage [1]. Moreover, this position in the abdomen of S8 restricts comfortable access with laparoscopic instrumentation resulting in inadequate control of dissection and view of the surgical field. On the other hand, there are no external landmarks for identification of the S8 portal pedicle (G8). Finally, the anatomy of S8 is so complex and variable that its understanding, even now, is still incomplete, and no current classification can consistently explain individual cases [2].

Latest evidence suggests that the classical right anterior tertiary division (right anterior sector) of the liver, the caudal S5 and a cranial S8 described by Couinaud, only accounts in 50% of cases. In fact, S8 exists as such in 80% of cases, because in 20% there is an anatomical variant of the anterior sector (S5 and S8) denominated ventro-dorsal type. The other variants of anterior sector are cranio-caudal type (main pedicle for S8 and S5), trifurcation type (ventral and dorsal pedicle of S8 and unique pedicle of S5), and quadfurcation type (ventral and dorsal S8 and ventral and dorsal S5) (Fig. 16.1). In 25–50% of cases, it exists a ventral (G8v) and dorsal pedicle (G8d) for S8, separated by a plane limited by a segmentary vein of S8 (V8), which depends on middle hepatic vein (MHV) in 90% of cases and right hepatic vein (RHV) in 10%. Moreover, in nearly 50% of cases, it exists an additional medial pedicle of S8 [3].

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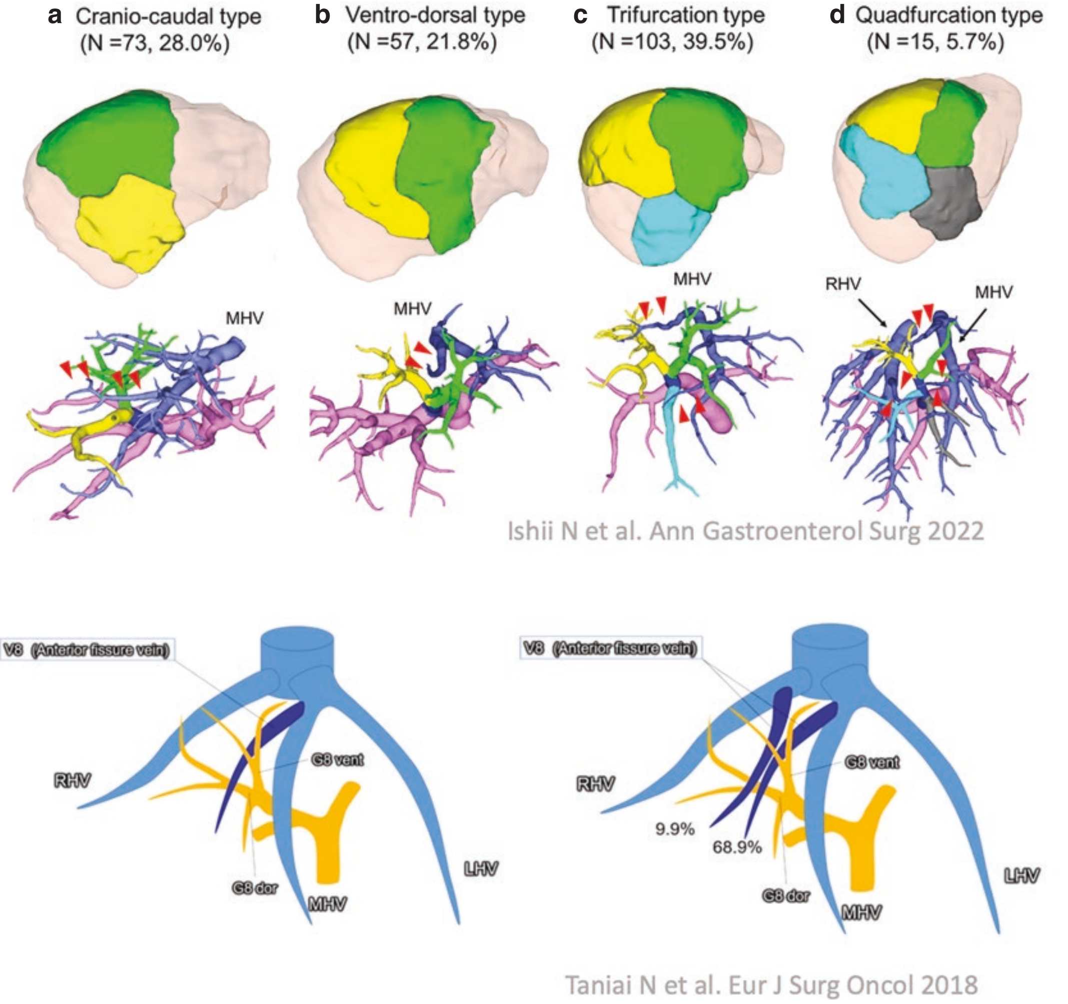

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**Fig. 16.1** Variants of anterior sector

Functionally, S8 represents more than 25% of total liver volume, and this is important when we plan a liver resection in patients with impaired liver function (cirrhosis and chemotoxicity livers). In these cases, it is possible to perform limited anatomical resections of the ventral or dorsal part of this segment, allowing parenchymal preservation (for liver metastasis) and anatomical liver resection (for hepatocellular carcinoma).

For all those reasons, LLRS8 is considered a “technically major and complex” hepatectomy and has been introduced later in the hepatobiliary units. Therefore, this resection has a more difficult learning curve than other liver resections, with a prolonged operative time and an increase rate of conversion, but with comparable short- and long-term outcomes. In fact, current evidence suggests that LLRS8 compared to open surgery offers all the benefits of minimally invasive surgery in terms of blood loss, length of stay, and rapid recovery, without affecting the oncological results [4, 5].

## 16.2 Main Indication of LLRS8

The goals of liver resection are to achieve an adequate oncological result, preserving liver function, avoiding ischemic areas, and minimizing postoperative complications (mainly biliary leaks). All these premises are optimally met by an anatomical approach to liver surgery.

The main *indications* (more than 90%) for LLRS8 are hepatocellular carcinoma (HCC) and liver metastases, mainly from colorectal cancer. In the case of HCC, anatomical resection (segmental or cone unit) has been shown to be more oncologically appropriate. For metastases, especially superficial ones, there is a consensus that parenchyma-sparing surgery should be the objective, although for deeply located lesions, anatomical resection is associated with better oncological control of the deep edge (less R1 resections) and involves fewer ischemic areas. Other less frequent indications are intrahepatic cholangiocarcinoma, some benign tumors (adenomas), and liver hydatidosis.

*Contraindications* to LLRS8 would be a tumoral invasion or proximity of the G8, and the existence of a very voluminous S8 whose complete resection would imply an insufficient functional liver remnant in cases of severe cirrhosis. In these cases, as it has already been said, it is possible to perform an isolated partial resection of the S8 (cone unit) of the ventral (G8v) or dorsal part (G8d). In cases of very large tumors (>10 cm), LLRS8 can be very complicated and potentially hemorrhagic.

Therefore, the indications for S8 Glissonean pedicle approach are as follows:

- Resection of the entire segment 8 (particularly in HCC and liver metastases located at depth)
- Selective temporary segmental ischemia of segment 8 for atypical or nonanatomical partial resections of part of S8 (superficial metastases, benign tumors)
- Resection of cone units of segment 8 (part of ventral or dorsal unit of S8, for HCC or metastases between 2 and 3 cm located in these locations)
- Ischemic demarcation of the limits of segment 8 for lesions located in limits with segments 4A, 5, and 7

## 16.3 Surgical Technique

Before doing an LLRS8, it is mandatory to know the real anatomy of the patient and the vascular relationships of the tumor through preoperative image studies of the liver (CT) and 3D virtual simulation (VR-CT). Intraoperatively, it is essential to perform an adequate vascular visualization using high-quality Doppler ultrasound and ICG-based fluorescence navigation.

There are *three different approaches* to carry out a Glissonean control of G8 [6].

1. The first is an *initial hilar approach to the G8 pedicle*, either extrahepatically maintaining Laennec's capsule (Sugioka gates 4 and 5) [7] (which is possible if the bifurcation of G5 and G8 is relatively superficial), or hilar-intrahepatic, opening the parenchyma along the pedicle of the right anterior sector, progressing, and identifying G5 and G8. The advantage of this approach is that the entire right anterior pedicle is dissected in continuity, differentiating the G5 (not always easy) and G8 pedicles, and allows selective clamping of G8, achieving ischemic delimitation (and ICG counterstaining) before opening the parenchyma [8].
2. The second approach to G8 is through a *dissection based on the middle and right hepatic veins*, which are the medial and lateral intersegmental limits of S8. After an initial approach to the root of the MHV vein, identified by ultrasound, the liver parenchyma is opened, progressing in a craniocaudal fashion, avoiding injury to the vein, until G8 is identified [9]. To do this, some surgeons place intercostal trocars to obtain a more cranial view of the hepatic veins. This venous dissection can be carried out maintaining the cardiac Laennec's capsule that accompanies the hepatic veins [10]. In 80% of cases, there is a vein for S8 (V8), running from the MHV (90%) or RHV (10%), which divides the plane between the ventral (S8v) and dorsal portion of segment 8 (S8d) (Fig. 16.2). Once G8 has been identified, it is possible to clamp it using a bulldog, allowing an ischemic delimitation and counterstaining with ICG of the surface and deep limits of S8. The main advantage of this technique is that it does not touch the hepatic pedicle, avoiding biliary leaks and ischemic areas due to the section of branches of S4 or S5, and it does not alter the hilar anat-

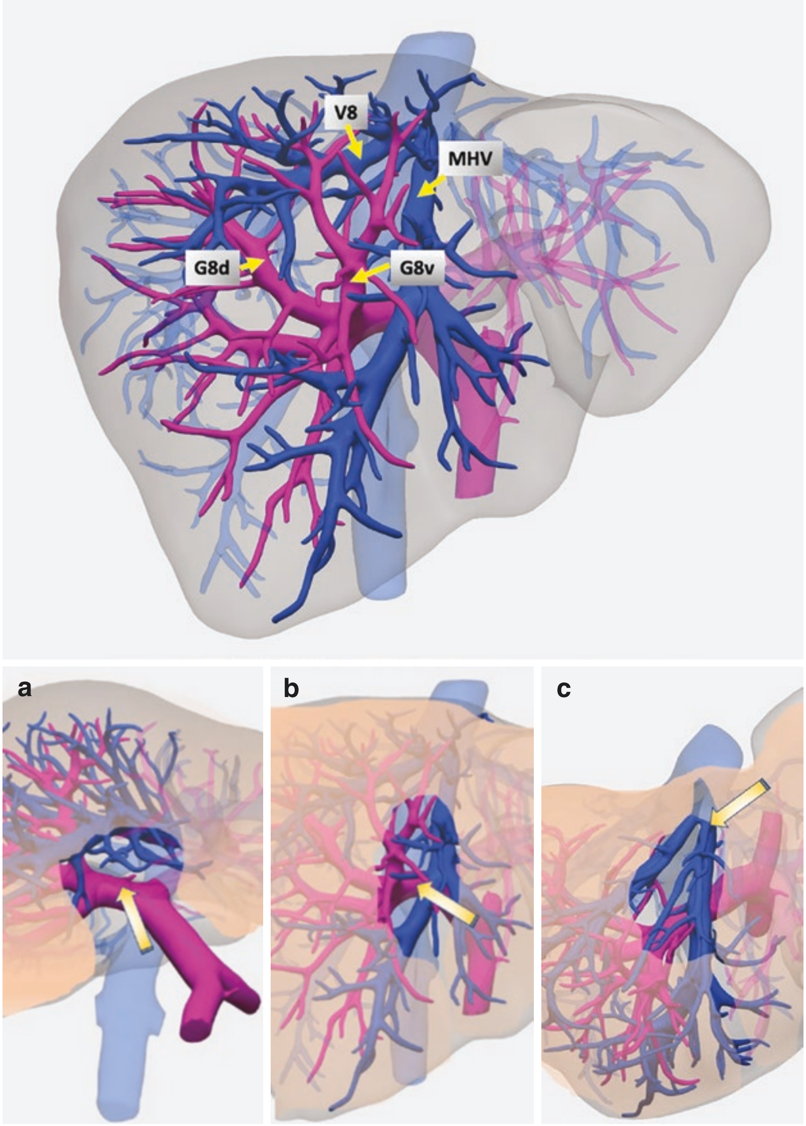

**Fig. 16.2** Different Glissonean approaches for S8: hilar (**a**), transcissural (**b**), and root vein based (**c**)

omy for subsequent re-hepatectomy or even a liver transplantation. The main problems with this approach are the difficult control of eventual bleeding in depth and the congestion of S5 in cases where it is mandatory to ligate branches of this segment.

3. A third possible approach to G8 is with a *direct or transcissural transhepatic approach*, locating the intersection of the MHV plane and G8 using ultrasound. Once this point is located, you can progress through the vertical plane of the MHV and later through the caudal and transverse plane until locating G8 with the help of a cranial traction of S8. After G8 ligation, the segmentectomy is completed following the lateral plane of the RHV. The main advantages of this technique are that it avoids hilar dissection, that it is not necessary to open the entire main fissure, and that it avoids injuring G5 branches [11].
4. Other techniques have been described for the resection of the ventral or dorsal part of G8, such as the dorsal approach of RHV [12, 13], but they are technically more complex and require greater experience in liver surgery [14, 15]

The choice of one technique or another depends on many factors such as the following:

- Experience and preference of the center and surgeon
- Indication for resection: HCC, metastases, benign tumors, etc.
- Location and number of lesions: peripheral, hilar, deep intrahepatic, etc.
- Size of the lesion and relationship with vascular structures of G8
- Quality of the liver parenchyma: cirrhotic, steatosic, and chemotoxicity
- Segment 8 anatomy
- Previous liver surgery and planned subsequent surgery (resections or liver transplantation)

All these factors influence the decision and the surgical strategy, which ranges from an atypical, limited, and superficial nonanatomical resection to a complete segmentectomy of S8, sometimes combined with other superior segments, such as segments 4A or 7, or a subsegmentary or a cone unit resection. On these premises, it is easy to imagine that at the moment there is no standardized approach to LLRS8, and many authors have proposed new and different technical approaches in an effort to overcome the many surgical difficulties. Overall, the modern laparoscopic hepatobiliary surgeon should master one of these techniques and be familiar with multiple approaches. The ultimate choice of the approach should be tailored to the individual case to maximize the oncological benefit and the safety profile.

## 16.4 Technical Details

- *Equipment*. We prefer the 3D visualization system, equipped with ICG fluorescence technology. Ultrasound multifrequency laparoscopic probe, Doppler, and puncture channel. It is important to have material on the table for vascular control (arterial and venous bulldogs, Glover and Satinsky vascular clamps), as well as barbed sutures (3–4/0). The transection is done with an ultrasonic dissector (Sonastar), an energy device (Thunderbeat® or similar), and bipolar coagulation.
- *Patient position*. The patient is placed in the French position, with legs and arms opened, and with the main surgeon standing between the legs. The table is arranged in anti-Trendelenburg 15–30°, and with left rotation when required.
- *Trocar placement*. It depends on the patient's anatomy, degree of obesity, and previous interventions. Pneumoperitoneum is performed with a Veress needle at Palmer's point, even if there is previous surgery. The initial optical trocar is located supraumbilical (later we will place the extracorporeal tube for the Pringle maneuver in this access). The rest of the working trocars are placed under direct vision, in relation to the liver anatomy, about 2–3 cm below the costal margin: three of 12 mm, the most central which will be the optical one in the right midclavicular line and another two lateral ones about 6–8 cm from it, and two of 5 mm in the right subxiphoid position and in the anterior axillary line (Fig. 16.3). We do not use thoracic trocars, since with an adequate position of the patient in forced anti-Trendelenburg, with the trocars near the costal margin, and with the section of the falciform and right coronary ligaments (sometimes a greater mobilization of the right liver is necessary with the section of the right triangular ligament), we think that they are not necessary, and it can be a source of potential complications. The pneumoperitoneal pressure is established at 12 mmHg, and it is sometimes necessary to raise it to 14–15 or lower it to 8 mm depending on bleeding or airway pressure (which must be normal, avoiding PEEP). Hemodynamics should be with a CVP <5, SVV between 12 and 15, and BP >80 mmHg.
- *Exploration and mobilization*. Once the trocars are positioned, a first intraoperative ultrasound is performed to visualize the tumor and the vascular ultrasound anatomy. Hepatic mobilization begins with the division of the round, falciform, and right coronary liga-

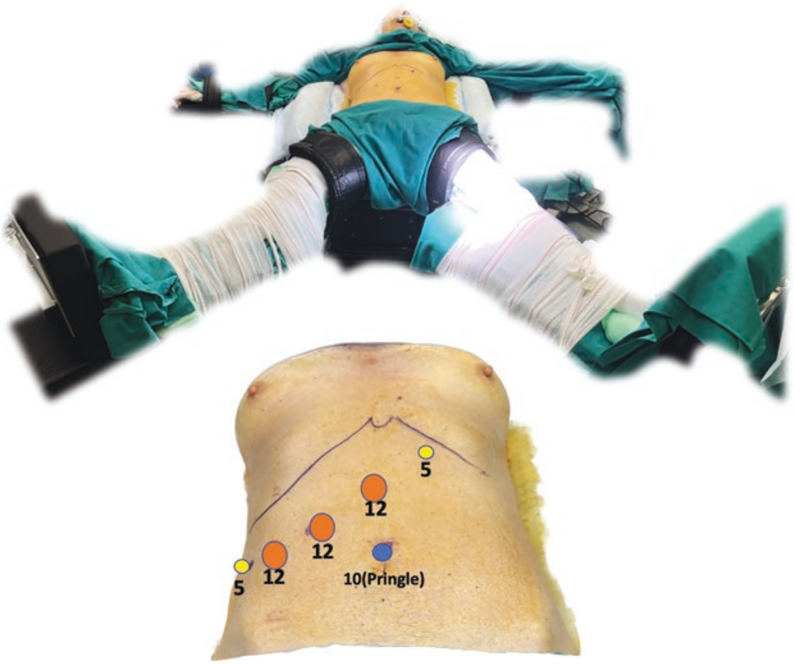

**Fig. 16.3** Patient position and usual trocars placement for S8. It is very important to place the trocar 2–3 cm under the costal margin to access the most posterosuperior aspect of S8

ments, exposing the origin of the middle and right hepatic veins. The round ligament is ligated with an endoloop that is exteriorized to the left to pull the liver to the left and down. In some cases of very latero-posterior segment situation, it will be necessary to mobilize the right liver more extensively.

- *Dissection of the pedicle*. We prefer the hilar dissection of G8, accessing the right anterior pedicle by extra-Glissonean dissection through the Sugioka gates [4 and 5]. Due to the depth of G8, it is almost always necessary to open the parenchyma at the base of the cystic plaque (cholecystectomy is usually performed) and progress the dissection under Pringle maneuver with ultrasonic dissector along the pedicle of the anterior sector, identifying G5 (one or more branches) and the deeper G8. Once G8 is dissected, it is clamped using a bulldog and the ischemic delimitation is observed. This delimitation is not always evident on the liver surface (more frequent in toxic livers due to chemotherapy or cirrhosis); therefore, the absence of flow in this segment is also verified by Doppler ultrasound and delimited by counterstaining with intravenous administration of ICG (2.5 mg).
- *Hepatic transection*. Liver transection is performed on the surface (1 cm) using an energy device (Thunderbeat® or similar) and is continued with ultrasonic dissection (Sonastar®) and bipolar coagulation. We usually use the Pringle maneuver for 15 min, or 25 min if the patient's tolerance to ischemia and reperfusion is adequate according to the anesthetist, with 5-min release. The tumor margin of the resection is checked by ultrasound and the segment transection by ICG. For the section of the vasculobiliary pedicles larger than 3 mm, metal clips are used; for those larger than 5–6 mm, Hem-O-Loks are used and for the main trunks (V8 or G8), Hem-O-Lok or stapler sutures with vascular cartridge depending on the caliber.
- *Hemostasis and closure*. Hemostasis of the surgical bed is achieved using bipolar coagulation and some powdered hemostatic substance and checked lowering the pneumoperitoneum pressure below 6 mmHg. The resection piece is extracted by widening a trocar port or by an

incision on a previous scar. In cases of posterior colorectal surgery, a Pfannenstiel incision is used, avoiding midline laparotomies. Intra-abdominal drainage is usually not necessary.

## 16.5 Key Point

- Extensive study of preoperative images (TC, RM, V-TC).
- Perfect anesthetic management (PVC, VVD, thoracic pressure).
- Navigation by ultrasonography in dynamic fashion during all the procedure. ICG counter-staining is very useful.
- Pedicular dissection and liver transection under Pringle clamping in order to have a clean surgical field.
- Ultrasonic dissector, vascular bulldog, and suturing skills are mandatory.

## 16.6 Personal Experience (In ShortData Santoyo-Santoyo J et al.)

In our experience, with total experience of liver surgery of nearly 400 LLR, we have performed a resection of S8 isolated or associated with S5, S4A, or S7, in 68 cases. The indications have been metastases in 36 cases, HCC in 20 cases, intrahepatic cholangiocarcinoma in 3 cases, hydatidosis in 2 cases, and other indications in 7 cases. In 8% of the patients, at the beginning of the experience, conversion to an open approach was necessary, due to continuous bleeding in very chemotoxic livers or due to doubts about the oncological margin. The perioperative transfusion rate was 10%, the median surgical time 259 min (90–540 min), and Clavien-Dindo grade III–IV complications 10%. The mean length of hospital stay was 4 days and mortality 0%.

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# 17

# Right Posterior Hepatectomy (Segment VI + VII)

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and Javier Briceño

## 17.1 Introduction

The liver pedicles are the critical structures within the liver parenchyma that contain both bile ducts, artery, and portal veins surrounded by the Glissonean sheet. Access to the liver pedicles is necessary for liver surgery. The traditional approach to accessing the liver pedicles has been through a Glissonean approach, which includes incision in the Glissonean sheet and individual exposure, control, and section of the portal vein, hepatic artery, and bile duct. However, extra-Glissonean approaches have gained popularity in recent years due to their potential to reduce bleeding and improve surgical outcomes.

One of the most widely used extra-Glissonean approaches is the so-called Takasaki approach. This technique was developed by Dr. Koji Takasaki in Japan in the early 2000s and has since been adopted by liver surgeons worldwide. The Takasaki approach involves accessing the liver pedicles from outside the Glissonean capsule by dissecting along the plane between the liver and the pedicle keeping the capsule intact. From a practical point of view, the Takasaki approach may offer potential advantages over the traditional Glissonean approach. The main one is the standardization and avoidance of individual dissection. This may lead to reduced bile leaks and iatrogenic damage of other pedicles [1–3]. Very recently, a manuscript from Sugioka established the gate theory as a feasible and practical approach to Glissonean pedicles by identifying six gates in the liver from which, in an extra-Glissonean way, primary and secondary pedicles could be encircled to perform left and right hemihepatectomies (from Gate 3 to 1, and from Gate 4 to 6, respectively) and left lateral, medial, right anterior, and right posterior sectionectomies (from Gate 2 to 1, 3 to 4, 4 to 5, and 5 to 6, respectively) [4]. Several studies have investigated the efficacy and safety of the Takasaki approach. Glissonean approach has been reported safe and feasible for minimally invasive liver resections with several reported advantages compared to the conventional hilar approach [5].

## 17.2 The Laparoscopic Right Posterior Sectionectomy

The laparoscopic right posterior sectionectomy is a minimally invasive surgical procedure for the removal of the right posterior section of the liver which is composed of segments 6 and 7. These are the so-called posterior segments of the liver and were traditionally considered as more difficult and a potential contraindication for minimally invasive approach. However, laparoscopic right posterior sectionectomy offers several advantages

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over traditional open surgery. Several studies have demonstrated that laparoscopic right posterior sectionectomy compared to open is associated with a shorter operating time, less blood loss, faster recovery time, and a lower incidence of postoperative complications compared to open surgery [6–8]. A recent subgroup analysis of the OSLO-COMET randomized trial demonstrated that in the setting of patients undergoing laparoscopic or open-liver resection of colorectal liver metastases in the posterosuperior segments, laparoscopic surgery was associated with shorter hospital stay and comparable perioperative outcomes [9]. Nevertheless, laparoscopic right posterior sectionectomy is not without its challenges. The laparoscopic approach requires specialized training and expertise, and not all patients are suitable candidates for the procedure. In addition, the laparoscopic approach may be more technically challenging in patients with obesity or previous abdominal surgery, and a proper learning curve is mandatory. It has been recently reported that the learning curve in the posterosuperior segments is estimated to be 40 procedures for wedge and 65 for anatomical resections [10].

## 17.3 Technical Standardization of Laparoscopic Right Posterior Sectionectomy (Video)

Laparoscopic right posterior sectionectomy can be well standardized by considering extra-Glissonean approach and root dissection of hepatic vein. In our Department, unless a need for hilar approach which may involve hilar dissection of right posterior structures due to tumor close to the confluence, our steps are the following:

1. Placing Pringle on the left side of the patient or in the theoretical further Pfannenstiel incision by using a chest tube and a long tape [11]. We recommend this technique rather than the Huang's loop technique to keep a firm countertraction to properly dissect the right posterior pedicle.
2. By pulling the gallbladder toward the medial side, access to Gates 5 and 6 can be obtained. We advocate to try to get access keeping Laennec's capsule intact. In fatty livers it is not easy to be obtained. This procedure is usually performed by observing the Rouviere's sulcus and dissecting it on its origin on both sides [12].
3. Encircling and clamping the right posterior pedicle. This process may be slightly complex depending on the intrinsic anatomy of the right posterior pedicle (Fig. 17.1).
4. After clamping the pedicle, indocyanine green is administered IV in order to demarcate ischemic line. Before proceeding to any demarcation, it is strongly advisable to perform exhaustive ultrasonic exploration and double check that this is the desired transection line. After superficial demarcation, artifacts may be observed in the ultrasound exploration. We also do not recommend to perform any kind of section at this moment. This is because of the potential damage that may be caused to right anterior or S1 pedicle. We recommend to perform the section of the right posterior pedicle when parenchymal transection is advanced and a safer section is ensured.
5. After checking the transection line, it is recommended to fully mobilize the right lobe of the liver from triangular and coronary ligaments. It is also necessary to fully detach it

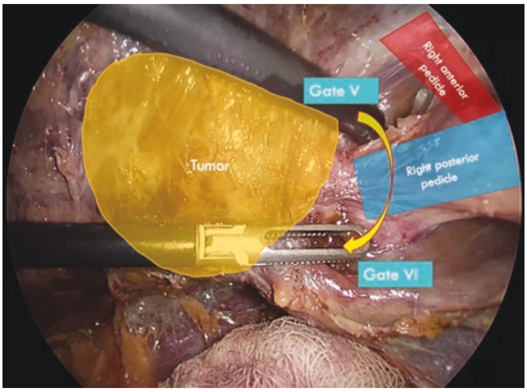

**Fig. 17.1** Figure showing a case in which tumor was just above the right posterior pedicle. A feasible margin-free access could be obtained by moving from Gate 5 to Gate 6 and encircling right posterior pedicle

from IVC and reach up to the confluence of IVC and right hepatic vein. Careful dissection and transection of the hepatocaval ligament should be performed. At this stage, several problem may happen, including tears in the liver surface due to discrepant pull-push movements and mainly bleeding from IVC or during isolation of hepatocaval ligament of RHV. We strongly recommend to get a 3/0 4/0 polypropylene stitch ready as well as thrombin-derived hemostatic agents for a rapid control.

6. When reaching up to the RHV, our preferred technique is to make a root approach of the RHV with a dorsoventral and cephalo-caudal dissection by using the tip of the ultrasonic dissector. This approach has several advantages over anterior approach. First, it allows identification of the main trunk of the RHV avoiding multiple clips of bifurcated branches to the right posterior sector; the second real advantage is that damage to the vein is far more limited with this approach. This effect was widely reported by Honda et al. This group reported that root approach and dissection of hepatic veins may cause small bleeding from tiny branches in a so called "pull up injury," rather than a "split" injury on anterior approaches. Pull-up injuries are easy to be controlled as they are tiny holes in the vein surface. On the contrary, split injuries are tears which are far more difficult to be controlled as they are large injuries due to the dissection mechanism and direction [13, 14].
7. When the full main trunk of RHV is exposed, clip and section of its main branches to segments 6 and 7 is easily performed. At this moment, parenchymal transection may be quite advanced, and access to the previous bulldog placed in the right posterior pedicle may be easier to grant insertion of hem-o-locks or staplers in a proper direction to avoid damage to right anterior pedicle. At this stage, portal pedicle section is recommended and safer.
8. By performing this root venous approach, at this stage, transection of the anterior surface of the liver is easier to be performed, and few important branches may be found. The final step would be to proceed to the transection of the right hepatic vein mostly by using endostapler.
9. Two main important difficulties must be considered during any step of the right posterior sectionectomy:
    - First difficulty: In the event that the tumor may be too close to the bifurcation between the right anterior and right posterior pedicles, extra-Glissonean approach may not be the best option as resection margins may be compromised. We recommend to locate the Rouviere's sulcus, open the Glissonean sheet, and make individual section of the artery, portal vein, and bile duct.
    - Second difficulty: Depending on the ribs positioning and BMI, it may be quite difficult to access the upper part of segment 7. In this case, it has been reported the use of transthoracic trocars (up to two) to be able to bring the camera to the right sided abdominal trocars and use the transthoracic ones for dissection. In this case, 10-mm ones should be closed at the end of the procedure to prevent pneumothorax [14].

## 17.4 Conclusions

Approaching the right posterior sector is one of the most difficult ones in minimally invasive liver surgery. As reported in most of the currently used difficulty scoring systems, this resection can be considered as advanced or expert. Our technique is an easy and reproducible way of performing a right posterior sectionectomy including extra-Glissonean approach, ICG demarcation, and root dissection of the right hepatic vein.

## 17.5 Summary and Key Points

- A well-defined preoperative imaging protocol is strongly advisable in order to have a surgical mapping. In this sense, 3D models and virtual reconstructions may help accuracy and surgical strategy (Fig. 17.2).

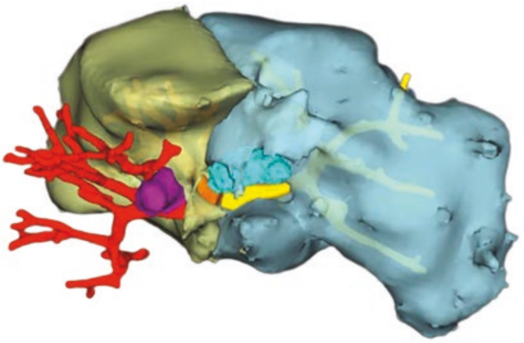

**Fig. 17.2** Three-dimensional preoperative modelling of a right posterior sectionectomy. The resected area has been removed to study the anatomy of right hepatic vein and right posterior pedicles

- Extra-Glissonean access is safe in right posterior sectionectomy. It is strongly advisable to create countertraction with the Pringle tourniquet and move between Gates 5 and 6 in order to control the right posterior pedicle.
- Hepatic vein dissection should be performed from a dorsoventral and cephalon-caudal approach to avoid severe injuries.
- ICG is strongly recommended to create anatomical precise resection, including intersectorial planes.

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# Right Anterior Hepatectomy (Segment V + VIII)

18

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## 18.1 Introduction

Laparoscopic liver surgery has evolved to become a common approach to liver tumors [1]. Nevertheless, anatomical resection of the right anterior sector (RAS) is still considered challenging due to its central location, its vascular relations, and the need for two large parenchymal transections. As a type of central hepatectomy, RAS is considered a procedure of great difficulty during minimally invasive liver surgery (MILS) [2, 3].

Anatomical boundaries of the liver RAS include the middle and the right hepatic veins. Unfortunately, there are no anatomical marks on the liver surface, and so the best way to correctly identify the anatomy of the RAS is to observe the demarcation line created by ischemia after clamping the right anterior portal pedicle.

The Glissonean approach has been considered preferable for the second- and higher-order Glissonean pedicles during MILS [4]. The Glissonean approach to the portal pedicles can be implemented either in an intra- or an extrahepatic manner [5, 6]. The gate theory proposed by Sugioka et al. [7] defines clear anatomical landmarks making the extrahepatic Glissonean approach easier.

In this chapter, the authors will describe the technique for the extrahepatic Glissonean approach for a right anterior hepatectomy (RAH) including the technical steps along with some tips and tricks. Surgeons considering performing complex anatomical MILS should be familiar with the extrahepatic Glissonean approach of the portal pedicles.

## 18.2 Indications and Contraindications

Although there are multiple indications to performing a minimal invasive RAH, this is not a common procedure. These indications include benign and malignant tumors affecting segments V and VIII or lesions close to the right anterior portal pedicle. Benign lesions susceptible of being treated with a RAH include giant hemangiomas, adenomas, and hydatic cysts, while malignant tumors include liver metastases when a parenchymal sparing resection is not pos-

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sible, hepatocarcinoma and intrahepatic cholangiocarcinoma.

Due to the significant amount of liver parenchyma resected, the future liver remnant should be studied thoroughly. Central anatomical liver resections can be contraindicated in patients with insufficient liver remnant due to the volume or to the quality of the liver parenchyma. Prior chemotherapy, cholestasis, patient age, or medical history may influence the quality of the liver parenchyma. Moreover, a RAH may not be the most advisable technique when adequate tumor margins cannot be obtained in tumors located centrally and close to other second Glissonean pedicles. In these cases, a right hepatectomy or a mesohepatectomy might be better options.

We must warn that the extrahepatic Glissonean approach may not be the best technical option in those patients with tumors close to or in contact with the root of the anterior portal pedicle or the hilar plate. In these situations, a right hepatectomy should be considered.

Indeed, prior abdominal surgeries around the portal pedicle such as cholecystectomy, peptic ulcers, liver resections, and common bile duct explorations can make the extrahepatic Glissonean approach difficult or even contraindicate its use.

## 18.3 Surgical Technique

Two gates, defined by Sugioka et al. [7] as gaps between Laennec's capsule and the Glissonean sheath, should be identified to perform a RAH with an extrahepatic Glissonean approach. Gate IV is located on the left edge of the cystic plate or the right anterior pedicle, while Gate V is located at the bifurcation of the main right Glissonean pedicle.

A detailed description of the laparoscopic RAH is provided in this section with special interest in the extrahepatic Glissonean approach.

### 18.3.1 Patient Position and Trocar Placement

1. The patient is placed in a supine position with the legs abducted slightly tilted to the left side (Fig. 18.1). We name this position as "the walker position." The surgeon stands between the legs, and the first assistant stands to the left side of the patient.
2. Pneumoperitoneum is created using a Veress needle, but an open Hasson technique can also be used.
3. The optic trocar is inserted in the right mid clavicular line. Though we prefer a 30° optic, a 0° optic can be also used.
4. Other trocars are inserted after a general examination of the abdominal cavity according to the positions shown in Fig. 18.2.
5. Although we prefer using four trocars and one assistant, five trocars and two assistants can be considered according to the surgeon's preference.

### 18.3.2 Exploration and Mobilization

6. At this time, an ultrasound examination is performed to rule out other lesions, to confirm the portal anatomy, and to assess the location of the tumor and its relationship with the portal pedicles. Discarding tumoral infiltration or contact with the root of the right anterior pedicle is paramount to an extrahepatic Glissonean approach being adopted.
7. No liver mobilization is needed for an RAH. Not even the round or falciform ligament need to be sectioned.
8. The hepatic pedicle is encircled with a cotton tape externalized around the navel to perform an extracorporeal intermittent Pringle maneuver [8] (Fig. 18.2).

**Fig. 18.1** "The walker position": supine position with the legs abducted and slightly tilted to the left side

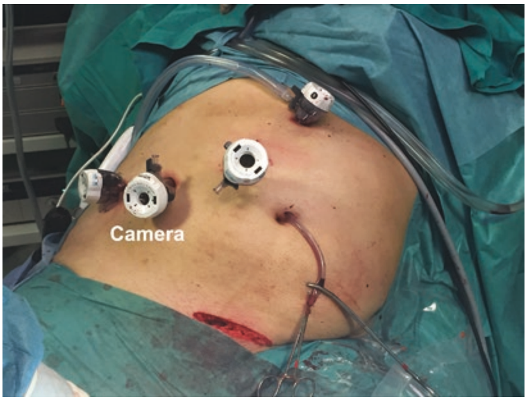

**Fig. 18.2** Placement of trocars and extracorporeal Pringle

### 18.3.3 Transection of the Glissonean Pedicle

9. A standard cholecystectomy can be performed; however, the right anterior pedicle (RAP) can be reached by a "cystic plate cholecystectomy" according to Sugioka's description. This is achieved by detaching the cystic plate from Laennec's capsule but not completing the section of the cystic structures [7].
10. A blunt instrument is inserted though the 5-mm trocar to pull the liver superiorly to explore the hepatic hilum.

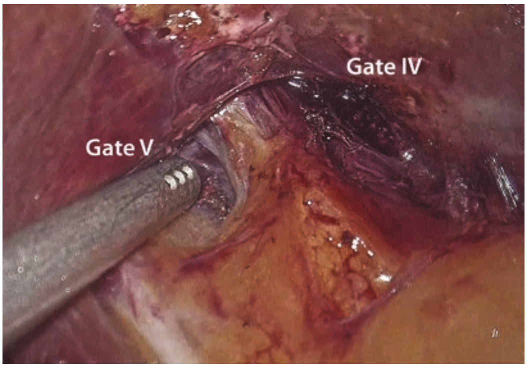

**Fig. 18.3** View of the Sugioka's gates

11. To isolate the RAP, Gates IV and V should be identified and connected. For this purpose, the gallbladder can be pushed downward to create tension that facilitates access to the gates. If the gallbladder has been removed, tension can be created by pulling down the cotton tape placed for the Pringle maneuver.
12. Gates IV and V are gradually opened by blunt dissection and finally connected behind the RAP (Fig. 18.3).
13. The isolated RAP is clamped to assess the extension of the ischemic area.
14. The pedicle can be sectioned extrahepatically at this point in time or left clamped to be sectioned subsequently.

### 18.3.4 Hepatic Transection

15. Liver transection starts following the main portal scissura within which runs the middle hepatic vein. In cases where there is no need to take the middle hepatic vein, it remains with the left hepatic lobe. The medial transection plane therefore runs along the right border of the vein.
16. Liver transection is performed under an intermittent Pringle maneuver. Transection is performed according to the parenchyma features and the surgeon's preference. In our case, we prefer using a cavitron ultrasonic surgical aspirator (CUSA) and a harmonic scalpel.

**Fig. 18.4** Division of the right portal scissura which contains the right hepatic vein

17. Once the middle hepatic vein is localized, it should be followed to its root dissecting and dividing small branches from the RAH and specially the two main branches from segments V and VIII.
18. Once this transection plane has been completed, this is the moment to proceed with the section of the RAH if it has not been done before. The section of the pedicle can be made by using an endo-GIA vascular stapler, hem-o-lock clips, or with a direct ligation according to the size of the pedicle and the surgeon's preferences. Care must be taken to avoid damaging the right posterior biliary duct that occasionally runs behind the RAP Hjortsjö's crook [9].
19. Now the right liver should be divided following the right portal scissura which contains the right hepatic vein. The right hepatic vein is left with the right posterior sector (Fig. 18.4).
20. The right portal scissura can be dissected from the periphery to the root of the right hepatic vein or from cranial to caudal starting at the root of the vein [10].
21. When the RAH is completed and the Pringle maneuver is released, the surgeon will find an extensive parenchyma surface for hemostasis.
22. If a "cystic plate cholecystectomy" has been performed for the dissection of the RAP, cholecystectomy can be completed before final hemostasis.

23. After an initial hemostasis, the specimen is placed in an endobag and extracted though a Pfannenstiel incision.
24. A final thorough exploration of the transection surface must be performed to rule out any bile leakage and to ensure an adequate hemostasis.

## 18.4 Tricks and Tips

As RAH is a demanding surgical procedure especially during MILS, surgeons willing to perform this technique should have completed their learning curve [11].

The authors do not recommend mobilization of hepatic ligaments during RAH to avoid malposition of any of the two lateral liver remnants after surgery. Malposition of the liver remnant may lead to liver inflow and outflow problems. The possibility of performing this complex procedure without any mobilization is of particular benefit in cirrhotic patients, in whom all vascular and lymphatic collaterals are therefore preserved.

The Pringle maneuver is advisable during the extrahepatic dissection of the RAP to avoid oozing and to facilitate the procedure. Exteriorizing the tape for the external Pringle close to the navel may help with the hilar traction during pedicle dissection.

To enter the gates, blunt instruments are recommended to separate the hilar plate from Laennec's capsule, thus reducing the chance of breaking the delicate sheaths.

The final dorsal connection of the two Sugioka's gates can be easily done with a 5-mm blunt dissector (Endo mini-retract™, Medtronic, Minnesota, USA). This final step is usually a blind movement during which the Laennec's capsule can be opened. The possible fracture of Laennec's capsule at any time during the extrahepatic Glissonean approach does not significantly increase blood loss when it occurs under the Pringle maneuver and has no impact on the oncological outcomes provided that the tumor margins are respected.

Once the Sugioka's gates have been opened and connected, encircling the pedicle is not absolutely needed to place a clamp to create ischemia. The demarcation of the RAH after clamping can be better confirmed by using indocyanine green fluorescence. This allows confirmation of the ischemic parenchyma not only on the surface but also intrahepatically. This is particularly useful during the transection procedure facilitating and ensuring a precise procedure. After clamping any portal pedicle, Doppler ultrasound can be used to assess intrahepatic flows and to define the parenchyma to be resected when ischemic demarcation is not clearly defined and indocyanine green fluorescence is not available.

The placement of an endo-GIA vascular stapler for section of the RAP can be challenging in a purely extrahepatic manner. If this is the elected method for pedicle section, placing the stapler after opening the main portal scissura is easier and safer. Moreover, for the resection of a benign lesion when wide margins are not necessary, section of the portal pedicle intrahepatically can be safer, avoiding potential injuries to other pedicles or the hilar plate. If the middle and right hepatic veins are not completely exposed, ultrasonography can be used during the parenchyma transection to assess the location of the veins and maintain the adequate transection line.

Reducing the pneumoperitoneum pressure during the extraction procedure of the specimen and the final moments of the intervention may help ensure correct hemostasis. If a "cystic plate cholecystectomy" has been performed for the dissection of the RAP, cholecystectomy can be completed during any of the periods of the Pringle release to take advantage of these waiting moments. Due to the extensive area of transection after RAH, some hemostatic material can be very helpful to achieve hemostasis as shown in the video.

## 18.5 Main Key Points

RAH is a high-difficulty procedure during MILS and is reserved for experienced surgeons. The extrahepatic Glissonean approach is feasible and safe following the anatomical landmarks defined as Sugioka's gates. Connecting Gate IV and Gate

V is advisable; however, a rupture of Laennec's capsule during the procedure is not detrimental to the success of the intervention. The most important landmarks during the RAH are the main portal scissura within which runs the middle hepatic vein and the right portal scissura which contains the right hepatic vein. Both veins are the boundaries of the anatomical RAH.

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# 19 Right and Right Extended Hemihepatectomy

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## 19.1 Introduction

Techniques and technologies have evolved dramatically in recent years, allowing to perform procedures with high degree of technical complexity by the means of minimally invasive approach [1]. Right hepatectomy and right trisectionectomy are recognized as the most challenging minimally invasive major hepatectomies, and specific technical adjustments have been highlighted to favor their accomplishment, thus increasing their feasibility and reproducibility [2–4]. Challenges associated with these procedures have been confirmed by recent classifications and scores stratifying minimally invasive resections according to their difficulty [5, 6]. Thus, laparoscopic and robotic right hepatectomy (LRH) should be regarded to as a procedure with a not negligible possibility of conversion [7, 8].

The magnification of images provided by minimally invasive approach allows a very sharp and precise dissection of the hilum, together with the possibility of specifically recognize the structures of the hepatic pedicle and exclude vascular infiltration by disease spread [9, 10]. Nevertheless, minimally invasive right hepatectomy and trisectionectomy should be completed only in expert centers, with an adequate expertise in minimally invasive resection with a high degree of technical complexity and an adequate technological availability. Both laparoscopic and robotic approaches seem to confer advantages over the open counterpart for these procedures (reduced blood loss, morbidity, and length of stay), likely with a further advantage provided by robotics in terms of reduced conversion rate, shorter learning curve, and better performance in case of need of lymphadenectomy [1–4, 11, 12]. Nevertheless, criteria for cases allocation between laparoscopic and robotic approach are still under investigation.

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## 19.2 Main Indications and Contraindications

Within procedures of right hepatectomy and right trisectionectomy, some preoperative characteristics of the liver and of the lesion should be taken into consideration to discriminate between procedures with a standard or with an increased level of difficulty. Specifically, four elements should be evaluated at CT scan or MRI, and if two or more are present, minimally invasive approach should be considered only from surgeons already skilled with laparoscopic major hepatectomies.

1. *Shape of segment 1*. Thickness of segment 1 is generally a sign of chronic liver disease which is itself an element of technical difficulty. Furthermore, in right hepatectomy, a thick liver parenchyma between the posterior aspect of the right portal vein and the anterior face of the inferior vena cava reduced the possibility to easily encircle and hang on a loop the right portal vein since the parenchyma of the paracaval portion of Sg1 pushes the portal vein hence reducing the space of maneuver.
2. *Length of right portal vein*. A short length of the right portal vein may indicate the need to separately dissect ventral and dorsal pedicles, hence increasing the risk of damaging these vessels. Consequently, cases with early dorsal/ventral bifurcation should be reserved to already expert surgeons, as well as cases with ventral portal vein originating from left side.
3. *Size of the lesion*. When right hepatectomy/trisectionectomy is required in patients with huge liver lesions, technical difficulties are enhanced. Space for maneuvers inside the abdominal cavity is generally reduced, limiting the possibility of movement of instruments. Furthermore, liver mobilization is complex because of the volume of the mass (and indeed in this situation an anterior approach is generally the optimal choice). Finally, laparoscopic and robotic instruments may cause lesion rupture with consequent bleeding and dissemination of tumoral cells, jeopardizing the oncological outcome.
4. *Relationship with hepatocaval confluence*. Management of right hepatic vein and hepatocaval confluence is definitively the most challenging issue of minimally invasive right hepatectomy, still leading to risk of conversion and intraoperative morbidity and mortality. When the lesion is directly in contact with right hepatic vein close to hepatocaval confluence, the risk of damage during dissection maneuvers is specifically high and the room to place the vascular stapler is minimal: In this situation the use of vascular stapler may be inadequate (a running suture on right hepatic vein should be taken into consideration), possibly leading to incomplete closure of the vessel or stapler misfiring or misfunctioning.

Ideal and challenging situations for each item are reported in Fig. 19.1.

Furthermore, even in presence of a wide experience in minimally invasive right hepatectomy/trisectionectomy, the risk of conversion should always be evaluated, even in the preoperative setting [7, 8]. Converted laparoscopic hepatectomies are indeed known to lose some advantages of the minimally invasiveness, being their risk of postoperative morbidity and mortality significantly higher even compared with upfront open procedures [13]. Risk factor for conversion during laparoscopic right hepatectomy have been specifically analyzed, provided the expected usefulness in clinical practice. In a previous series of 130 right hepatectomies by our group, 22 were converted (16.9%) [7]. Most frequent reasons were oncologic inadequacy (45.5%), bleeding (31.8%), adhesions, and biliostasis. At multivariate analysis, factors associated with an increased risk of conversion to open approach were previous laparoscopic liver surgery, preoperative chemotherapy, malignant diagnosis, closeness to hepatocaval confluence or inferior vena cava, and tumor volume [7]. Taking into consideration these factors, a risk score was developed (assigning one point to detection of each of these conditions) and conversion rates correlated positively with the score, raising from 0 to 100% when the score increased

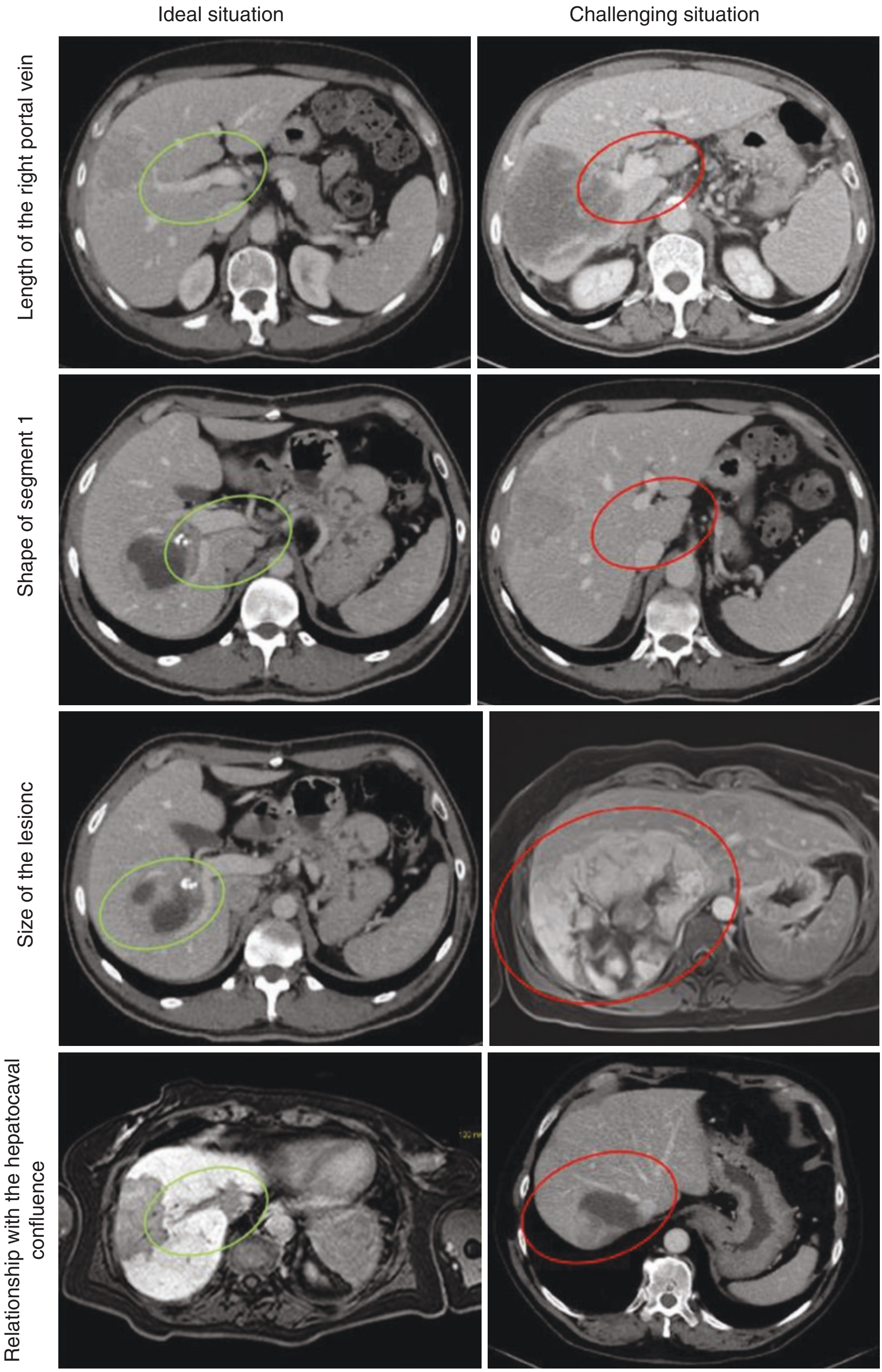


**Fig. 19.1** Preoperative characteristics of liver anatomy and disease to be evaluated at preoperative CT scan to grade the difficulty of minimally invasive right hepatectomy

from 0 to 5: Specifically, the risk of conversion showed a sharp increase passing from class 3 to 4, reaching a probability estimated between 60 and 71.4% [7]. It is likely that robotic approach may change this scenario, provided the increased feasibility (i.e., reduced conversion rate) in the setting of complex procedures [8, 12].

## 19.3 Surgical Technique

### 19.3.1 Patient and Trocar Position

Laparoscopic approach: The patient is placed in the French surgical position, with both arms and legs apart. The first operator is standing between the patient's legs, the first assistant to the right of the operator and the camera holder to the left. The first trocar is positioned along the right mid-clavicular line and, under 4K view, four other 10–12-mm accesses are placed in the configuration of an inverted J (respectively, in the supraumbilical position, on the right flank, in the epigastrium, and in the left ipocondrium). Pneumoperitoneum is created with a $CO_2$ pressure of 12 mmHg, which can be potentially increased to 14 mmHg in case of need. An anti-Trendelenburg position is kept during all the phases of the procedure, associated with mild left tilting to ease phases of hilar approach and liver mobilization. A more pronounced left tilting or positioning of an inflatable pillow under the right flank may constitute a valid option if a complete liver mobilization prior to liver transection phases is planned.

Robotic approach: The first surgeon seats at the console, and the first assistant is located between patient's legs, which are apart. Four robotic trocars are positioned in a standardized configuration with one trocar in right flank, one along the mid-clavicular line, one along the midline, and one in left hypochondrium, and the robotic platform is docked to operating table coming from the head (Da Vinci X platform) or from the right side (Da Vinci Xi platform) of the patient, oriented in reverse-Trendelenburg position. A laparoscopic 10-mm trocar is positioned in a right pararectal position; a second laparoscopic access may be required on the right flank (between robotic arms 1 and 2): The second laparoscopic access should be positioned only after docking of robotic arms, to exclude conflicts among laparoscopic and robotic instruments and to improve ergonomic.

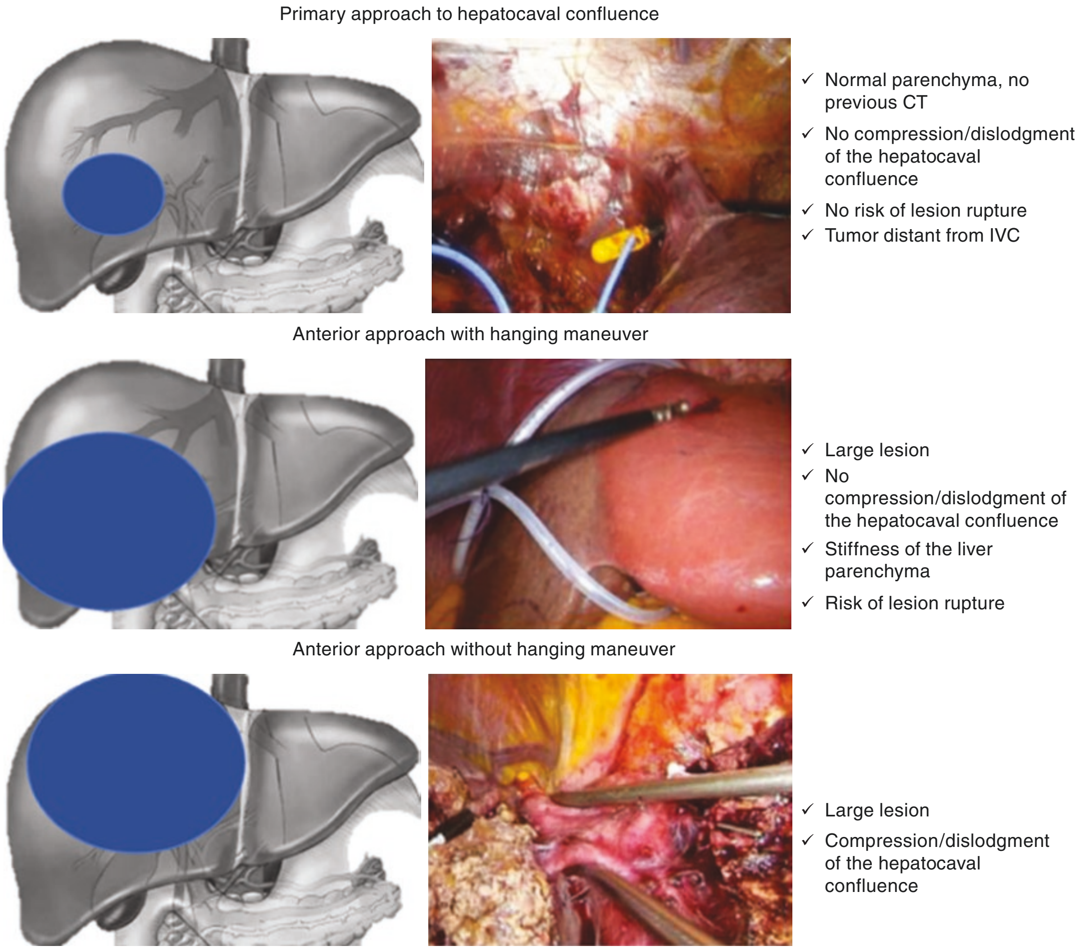
### 19.3.2 Liver Mobilization and Approach to Hepatocaval Confluence

Regarding liver mobilization, standard approach includes a top-down mobilization as first (section of round, falciform and upper part of right coronary and triangular ligament) and a counterclockwise mobilization of the right hemiliver by section of the lower part of the coronary and triangular ligaments, allowing a shift towards the left of posterosuperior segments by pulling the round ligament towards the left hypochondrium [14].

The approach to the hepatocaval confluence, with eventual isolation of the right hepatic vein, may be defined according to the characteristics of the parenchyma and of the lesion (specifically its size and position) [15].

Primary extrahepatic approach: Whenever the liver parenchyma is healthy and the lesion is not huge (hence with no specific risk of rupture) with no close relationship with the hepatocaval confluence, a primary extrahepatic approach of the right hepatic vein can be taken into consideration, therefore requiring complete liver mobilization.

Anterior approach with hanging maneuver: In the case of huge lesion with no close relationship with the hepatocaval confluence, a partial liver mobilization and partial dissection of the anterior aspect of the inferior vena cava can be performed, without encircling the right hepatic vein but instead passing a tube between the right and the middle hepatic vein and performing a minimally invasive hanging maneuver. Anyway, the possibility to perform an adequate traction and hemostasis as in open approach is reduced when



Primary approach to hepatocaval confluence

- ✓ Normal parenchyma, no previous CT
- ✓ No compression/dislodgment of the hepatocaval confluence
- ✓ No risk of lesion rupture
- ✓ Tumor distant from IVC

Anterior approach with hanging maneuver

- ✓ Large lesion
- ✓ No compression/dislodgment of the hepatocaval confluence
- ✓ Stiffness of the liver parenchyma
- ✓ Risk of lesion rupture

Anterior approach without hanging maneuver

- ✓ Large lesion
- ✓ Compression/dislodgment of the hepatocaval confluence

**Fig. 19.2** Possible approaches to hepatocaval confluence during minimally invasive right hepatectomy according to disease and liver characteristics

hanging is applied in laparoscopic or robotic setting. Furthermore, a damage of the hepatocaval confluence during the placement of the loop for hanging maneuver may lead to early conversion.

Anterior approach without hanging maneuver: Strongly indicated in the case of huge masses, fragile parenchyma, and in the case of lesions close to the hepatocaval confluence. A partial liver mobilization is anyhow indicated, since it allows to easily handle and manipulate the liver in the case of emergent conversion during any phase of the procedure. Since this approach is feasible and safe in any situation, many centers adopt it as a standard approach.

A visual summary of possible scenarios to guide decision-making is provided in Fig. 19.2.

### 19.3.3 Approach to Right Portobiliary Pedicle

It is advisable to load the hepatic hilum for Pringle maneuver during the first steps of the procedure, or at least before hilar approach and parenchymal transection, in order to have the possibility to occlude the vascular inflow whenever required (and even in the case of vascular damage during isolation of right hepatic artery and portal vein). Pringle maneuver can be performed either with and intra- or extracorporeal technique: This latter is generally preferred because of the possibility of fast inflow occlusion and because it can be autonomously handled by the first assistant from outside (leaving the first surgeon free to deal with active bleedings in the case of need).

Despite extra-Glissonean approach has been reported for right hepatectomy, most centers adopt the intra-Glissonean approach as a standard. After isolation and section of cystic duct and cystic artery—still with the gallbladder in place—the right hilum is sharply dissected to identify the right hepatic artery which can be encircled and hanged on a vessel loop but a gentle pulling toward the abdominal wall from the assistant. In this way, the space between the artery and the right portal vein opens, and the right portal vein can be dissected and encircled (either in its main right trunk or by separate approach to ventral and dorsal portion). Right artery and portal vein can be at this stage clamped to obtain an ischemic demarcation along the Cantlie line, patency of flow toward the left liver can be checked by ultrasound, and ICG injection can be performed at this stage to obtain a negative staining of the hemiliver to be resected. While the right artery can be comfortably sectioned at this stage, the room to place hem-o-locks or vascular stapler to section the right portal vein may be not enough: In this situation, the sectioning can be postponed during liver transection phases when the hepatic parenchyma is open, and this procedure can be safer and more effective. Isolation and section of right biliary duct should generally be performed transparenchymally, in order to rule out the possibility of iatrogenic lesions of the biliary tree of the remnant liver in the case of undetected biliary anatomy variations.

If a right trisectionectomy is planned, it is recommended to proceed as in standard right hepatectomy and then isolate and section, either by extra-Glissonean or transparenchymal approach, portobiliary branches for segment 4, keeping on the right side of the falciform ligament.

### 19.3.4 Parenchymal Transection

Laparoscopic approach: Liver transection should be performed along the Cantlie line, following the ischemic demarcation and hence the middle hepatic vein as a landmark. An energy device can be used at initial stages, while an alternating use of ultrasonic dissector, bipolar forceps, and energy device is advisable as a standard method of transection. In order to allow a correct opening of the transection line, the first assistant should pull the gallbladder toward the left, and the anterior aspect of the middle hepatic vein should be exposed, leaving the vessel in the remnant liver sectioning tributary branches on its right side. Along parenchymal transection, vessels can be either coagulated or clipped according to their size. After the section of the biliary duct (and eventually of the right portal vein if not performed before parenchymal transection), the transection should proceed following the anterior aspect of the inferior vena cava until the hepatocaval confluence, to identify the shelter between the right vein and the inferior vena cava. In right trisectionectomy, the transection proceeds along the right side of the falciform ligament until identification of the middle hepatic vein, then sectioned, before proceeding as described for right hepatectomy (Video 19.1).

Robotic approach: Parenchymal transection can be either performed by an alternating use of the bipolar forceps (by kellyklasia technique) and monopolar scissors (both used by the surgeon at the console) or by the so-called Robo-Lap approach [16]. In this last technique, suggested for robotic resections with high degree of technical difficulty, ultrasonic dissector is used for parenchymal transection by the surgeon at the table, dissecting the liver parenchyma while preserving vessels and biliary branches that were then coagulated or clipped according to their size [16]. Dissection technique should follow the same principles of ultrasonic mediated transection in laparoscopic surgery. The direction of the tip of the ultrasonic dissector should be optimized in order to obtain an effective transection without being limited in its movement by robotic arms outside and robotic instruments inside. Maintaining the principle of having the transection area in the center of the visual field of both operators, it is possible to use the ultrasound dissector and the robotic bipolar for coagulation at the same time (Video 19.2.

### 19.3.5 Specimen Removal

The specimen following right hepatectomy or right trisectionectomy is generally bulky and requires an incision large enough to allow its retrieval without the risk of squeezing or morcellation especially in the case of procedures performed for malignancies. The extraction is generally accomplished by Pfannenstiel incision or upper midline incision. The decision to use a supraumbilical or a midline should be done according to several items: the presence of previous laparotomy and consequently adhesions in the lower abdomen, presence of portosystemic shunts, and lesion rupture in the case of huge and fragile lesions. In a previous series by our group, the concern about jeopardization of minimally invasive benefit because of the use of a midline incision was analyzed: No differences in postoperative recovery from hemi-hepatectomies were observed between those patients whose specimen was retrieved through supraumbilical or midline incision [17]. Consequently, both accesses can be used alternatively after careful evaluation of patient's characteristics.

## 19.4 Tricks and Tips

- Before starting, carefully evaluate the preoperative CT scan or MRI to study vascular anatomy. If a technique for hepatic hypertrophy is planned, glue or other embolizing material should be placed, leaving enough room to close the portal vein adequately (at least 1 cm of the right portal vein trunk should be not embolized) [18–20].
- During laparoscopic liver mobilization, the first surgeon should use the epigastric trocar to insert the energy device for ligaments section: This position indeed allows to have a correct triangulation.
- The gallbladder can be used as an effective traction element, in order to avoid lesions of the remnant liver during pulling movements.
- If negative staining by ICG is planned, after intravenous staining injection clamping of right artery and right portal vein should never be removed in order to avoid the reperfusion of the parenchyma to be resected. ICG staining can even be used to check the biliary anatomy (and avoid strictures of the left bile duct) and to check final biliostasis.
- Before starting the liver transection phase, it is advisable to mark the position of the middle hepatic vein which should be used as a landmark during the whole parenchymal dissection. In order to increase its visibility, a positive airway pressure and a reduced pneumoperitoneum pressure can be temporarily created.
- After all the elements of the portobiliary pedicle have been sectioned, the correct landmark to guide liver transection is represented by the anterior wall of the inferior vena cava.
- Always remember to lower the pneumoperitoneum and restore normal volemic status at the end of liver transection, to check for hemostasis and biliostasis.
- Always keep instruments for fast conversion ready (scalpel, open bipolar forceps, clamps, and retractors).
- Always evaluate the transfusion risk of the patient in order to optimize perioperative management [21].
- In order to proceed with expertise acquisition of the whole team, specific steps of the procedure may be performed by the most expert surgeon, while others (e.g., mobilization) may be reserved to new generations of surgeons [22].

## 19.5 Main Key Points

At least partial liver mobilization is generally useful even an anterior approach is planned. The most frequently used technique is the primary intra-Glissonean approach with isolation of the right hepatic artery and portal vein. Liver parenchymal transection benefits from the accuracy provided by ultrasonic dissector and should proceed exposing the middle hepatic vein (in right hepatectomy) and then following the inferior vena cava. Anterior approach with transparenchymal isolation and section of the right portal vein is the safest technique to avoid injuries of the hepatic veins leading to emergent conversion.

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# 20 Mesohepatectomy

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## 20.1 Introduction

The mesohepatectomy (MsH) (in Greek, *meso* means middle or central), a major segment-oriented procedure, was first described by McBride and Wallace in 1972. This technique is also known as middle hepatic resection, central hepatectomy, central bi-trisegmentectomy, and middle lobectomy [1]. The objective of this technique is the removal of the central liver segments, namely, segments 4, 5, and 8, together with the middle hepatic vein at the hepatocaval confluence, leaving the lateral sectors as liver remnant.

Centrally located liver tumors can be removed by either right or left trisectionectomies. However, these procedures imply the removal of 60–85% of the liver parenchyma. Conversely, mesohepatectomy is a parenchyma-sparing technique that allows the surgical resection of deep liver tumors [2]. Subsequently, it significantly reduces the risk of liver failure secondary to a small for size syndrome, and it increases the chance of a further hepatic resection in case of hepatic recurrence of the disease. MsH is technically demanding, requiring a complete knowledge of intrahepatic anatomy. Complexity lies in the fact that there are two wide intersegmental planes, exposing in their surfaces the right hepatic vein and the umbilical fissure vein, together with the need of preserving the Glissonean pedicles in the remaining liver segments bilaterally [3]. This implies that the liver transection surface is extensive and therefore takes a prolonged transection time, as well as an increasing bleeding risk. Another consequence of the extensive transection surface is an upraised bile leak risk which is the most reported surgical complication after this procedure. This is because the injury of biliary structures can occur, while the small intrahepatic duct branches are divided at the two wide section planes as well as when the superior surface of the biliary confluence is exposed [4].

## 20.2 Main Indications and Contraindications

The main indication for MsH are centrally located primary or secondary liver tumors that cannot be resected with less extensive surgery, mainly related to middle hepatic vein (MHV) involvement. Another rarer indication is for hilar cholangiocarcinoma affecting selectively the right anterior pedicle [5–7].

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This procedure is contraindicated in case of inferior vena cava invasion (IVC) or in rare cases of congenital absence or hypoplasia of the left branch of the portal vein [8].

## 20.2.1 Surgical Technique (Key Issues and Technique Details)

### 20.2.1.1 Patient Position and Trocars Placement

The patient is placed in a left semi decubitus split-leg French position, and the table is mobilized on reverse Trendelenburg. The surgeon is positioned between the patient's legs, first assistant surgeon on the right side, and second assistant directing the camera on the left side of the main surgeon. The recommended trocar placement is a 12-mm optic trocar in a paraumbilical position for the flexible laparoscopic optic and three additional ports: a 12-mm port on left midline and 12-mm port on right flank to be used for the of the main surgeon and a 5-mm port on the epigastrium for the assistant surgeon.

### 20.2.1.2 Exploration and Mobilization

Following complete laparoscopic examination and before any kind of liver manipulation that could hamper the quality of the images, a laparoscopic ultrasound navigation is performed to discard unknown malignancies, examine liver anatomy, and check the tumor relations with the main liver structures.

No division of the round ligament, falciform ligament, or liver mobilization is mandatory in this procedure. This "liver attachments preservation" decreases the risk of a kinking of the remaining hepatic veins in the postoperative course.

The hepatoduodenal ligament is encircled with a tape for Pringle maneuver. This tape can be easily placed, while the assistant surgeon suspends the gallbladder to expose the underside of the liver and the main surgeon introduces laparoscopic forceps with his left hand between the hepatic pedicle and the IVC. With the right hand, the tape is introduced, and it is given to the left laparoscopic forceps which then gently stretch it until it surrounds the hepatic pedicle. This tape is exteriorized through a thoracic tube in the hypogastric position.

### 20.2.1.3 Transection of the Pedicles and Hepatic Transection

In order to expose the cystic plate and the anterior pedicle, the first step is achieving the critical view of safety during the cholecystectomy. The gallbladder is left in place as a traction point.

Between Sugioka gates 2 and 3, an extra-Glissonean dissection of segment 4 pedicle/s (g4) is performed (Fig. 20.1). For a better access of the whole g4, a liver transection through the umbilical fissure is done with a combination of cavitron ultrasonic surgical aspirator (CUSA), ultrasonic energy dissector, and bipolar coagulation. We routinely perform all hepatic transections under intermittent hilar clamping. After g4 is dissected, it is divided with an endostapler.

The next step is the exposure of the hilar plate toward the right anterior Glissonean pedicle (g58). This dissection continues through the cystic plate until g58 is identified (Fig. 20.2). After clamping the right anterior pedicle with a laparoscopic bulldog clamp, the ischemic demarcation of the right anterior section is established. The bulldog will be let in place since the division of g58. Once all the inflow is occluded, the lateral and medial resection lines are drawn. For a better visualization of the ischemic parenchyma and to confirm the correct sealing of all the feeding Glissonean pedicles, a counterstaining of the liver parenchyma with indocyanine green (0.5 mg IV) can be performed.

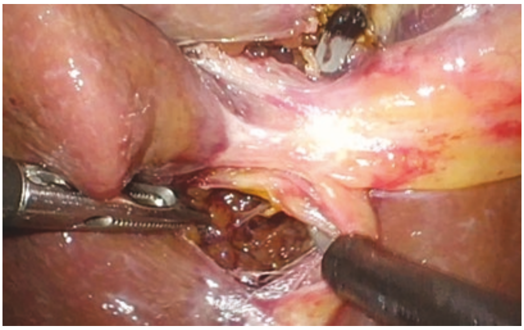

**Fig. 20.1** Segment IV dissection

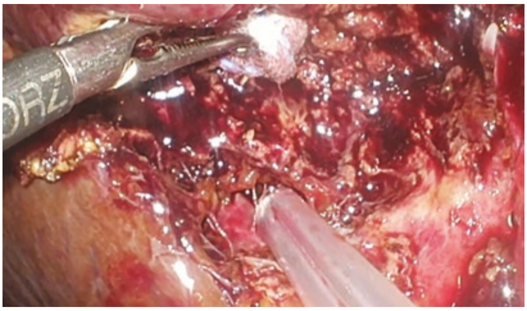

**Fig. 20.2** Right anterior pedicle identification

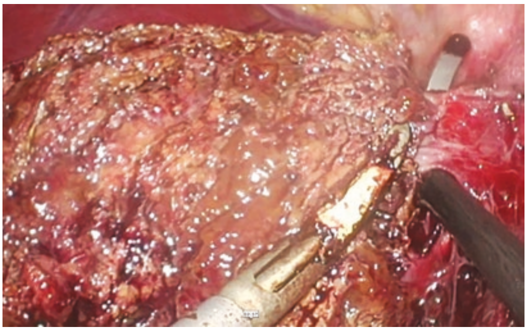

**Fig. 20.3** Identification of the middle hepatic vein root

**Fig. 20.4** Right anterior Glissonean pedicle division

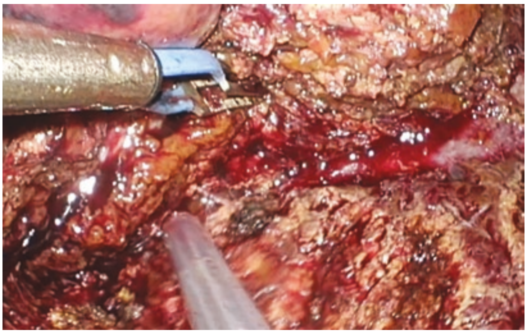

**Fig. 20.5** Right hepatic vein exposure

Liver transection continues widening the umbilical fissure until the identification of the MHV root (Fig. 20.3). Once the MHV root is dissected, it is divided using a vascular endostapler.

After that, the liver transection progresses exposing the anterior surface of paracaval portion of caudate lobe, with the objective of providing enough room for the g58 division. Once the transection plain allows the correct placement of a vascular endostapler with the left hand of the main surgeon, the laparoscopic bulldog is removed and the g58 is divided (Fig. 20.4).

The next anatomical landmark is the right hepatic vein (RHV). Its dissection is achieved by following the transection plain from left to right and from the root of the RHV towards the periphery (Fig. 20.5). Here, it is highly recommended to continue the RHV exposure with craniocaudal CUSA movements to avoid injuring the small veins emerging from its surface. The RHV should be completely exposed to the surgical surface. Once the RHV is completely identified the parenchymal transection can be completed, connecting this vein with ischemic demarcation on liver surface. Then the specimen is removed through a Pfannenstiel incision protected on a bag and removed.

## 20.3 Special Tricks and Tips (Personal Experience)

- An extra trocar can be placed in a hypogastric position to exteriorize the Pringle tape tourniquet through a thoracic tube. This allows a smooth caudal traction on the hepatic pedicle and facilitate the extra-Glissonean approach. This hypogastric port can be easily converted to a Pfannenstiel incision for the specimen removal at the end of the surgery.
- When both transection planes are advanced, taping the specimen for guidance is a good option for facilitate completing the transection without disorientation.

- When possible, it is better to perform the surgical dissection of the RHV with craniocaudal movements to prevent the disruption of the small branches arising from its surface and reduce the bleeding risk.
- It is better to divide g58 after stapling the MHV and exposure of anterior surface of paracaval portion of caudate lobe, because at that moment the vascular stapler can be placed much more easily.

## 20.4 Main Key Points

- The MsH is a technically demanding parenchyma-sparing technique for centrally located liver tumors.
- The principal complication is a biliary leak due to the extensive surface of parenchymal transection, but can be minimized if we follow the correct intersegmental plane.
- A left to right sequential division of s4 pedicles, middle hepatic vein and right anterior pedicle and exposure of right hepatic vein at the raw surface, is the safest way to avoid disorientation.

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# Part IV

# Special Subjects

# 21

# How to Prevent Pitfalls

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## 21.1 Aberrant Vascular and Biliary Anatomy

Intrahepatic anatomic variants are quite frequent. Between 24 and 57% of the general population have biliary variants, and between 31 and 49% have hepatic arterial variants. Portal vein anomalies are reported as less common, affecting 16–26% of the population [1].

When these variants are present, it is important to recognize them because they may have profound implications on performing a successful hepatic resection. In particular, to ensure feasibility and safety of the Glissonean approach, a detailed knowledge of portal and venous anatomy along with its principal variants is essential to allow an exact detection of the lesion and a proper surgical planning.

Normally, the portal trunk divides in the liver hilum into two branches: the left portal vein branch and the right portal vein branch. The portal bifurcation may be extrahepatic (48% of cases), intrahepatic (26%) or located right at the liver entrance (26%). The right portal vein branch divides secondarily into two branches: the right anterior portal vein feeding segments V and VIII and the right posterior vein feeding segments VI and VII. Any deviation from this anatomy is to be considered an anatomical variation.

According to the Madoff's classification [2], there are four main types of portal vein variations:

Type 1: the right anterior segment portal vein may branch from the left main portal vein
Type 2: three branches the posterior, the anterior and the left branch main arise from the main portal trunk (portal trifurcation)
Type 3: right portal trifurcation with the segment VI branch, the segment VII branch and the anterior segmental branch sharing a common origin
Type 4: right portal vein bifurcation into anterior and posterior segmental branches supplying V/VIII and VI/VII, respectively, the right posterior segmental branch arising from the portal vein before the portal bifurcation

Mouly et al. [3] described the feasibility of the Glissonean approach for right hepatectomy. Failure was reported for 25% of patients (8/32) as a result of the incomplete clamping of the right

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branch or extended clamping of the left portal branch. Extended clamping to the left portal branch was observed in four patients with type 1 portal anatomy. In patients with types 2 and 3 portal anatomy, clamping was incomplete, with the right posterior branch outside the clamping area.

Recently, Clipet et al. [4] used a large series of abdominal contrast-enhanced computed tomography (CT) with routine 3D reconstruction to predict the risk of right Glissonean pedicle clamping failure during right hepatectomy. This prospective multicentre study included 346 patients in which evaluated the value of the liver perfusion index through abdominal CT as a prognostic factor of liver metastases for nonmetastatic colon cancer (Perfusion IndeX: evaluation for liver metastases). According to Madoff's classification, Clipet observed that the type 1 and the type 2 represented the most common portal variations with an incidence, respectively, of 11 and 17%, while type 3 was detected in 0.8% cases. Types 2 and 3 were associated most frequently with an incomplete clamping of the right pedicle, while type 1 variation was correlated with a right pedicle clamping extended to the left portal vein and a consequently complete closure of portal blood flow. This risk also occurred when the angle formed by the portal trunk and the left portal vein measured less than 50°. The reason is that with a closed angle the bifurcation is deflected to the right and the clamping area consequently changes.

Finally, although the type 4 variant was not described by either Mouly or Clipet, this anatomical condition is also associated with an increased risk of incomplete clamping due to the more proximal onset of the posterior segmental branch from the portal vein.

Arterial and biliary abnormalities are also a predictor of morbidity and should be investigated as they are frequently reported in literature. Radtke et al. [5] described the central hilar and peripheral segmental vascular/biliary anatomy in right graft living donor liver transplantation performed 3D CT reconstructions and virtual 3D hepatectomies. He reported that the hepatic artery has the highest incidence of central hilar anomalies and that bile duct branching is most frequently abnormal at the peripheral segmental level. Moreover, 14% of patients presented a triple peripheral segmental anomaly.

The importance of anticipating and recognizing such variants is because there is existing evidence that complex anatomic patterns are associated with excessive tissue handling, leading to microcirculatory injuries and biliary complications.

In literature, biliary fistula rate for Glissonean pedicle clamping procedures ranges from 6%, as reported by Mouly for right hepatectomy [3], to 10% as described by Figueras [6] without distinguishing between right and left hepatectomy and 14% for right hepatectomy and 46% for left hepatectomy as referred by Nakai et al. [7]. This discrepancy is probably explained by the presence of the bile duct in the caudate lobe and the frequent drainage of the right posterior segment into the left bile duct. Intraoperative cholangiography before and after procedure is widely recommended in cases of unclear anatomy or evidence of biliary tract lesions.

A detailed preoperative study of the patient's anatomy together with a precise evaluation of the disease extension is mandatory in order to plan surgery avoiding procedural failures. Thanks to recent technological advances, routine diagnostic imaging such as CT scans, MRI scans and PET/CT scans have been complemented by more advanced imaging techniques. Three-dimensional imaging allows the exact location of the tumour, the individual variations together with the viability and extent of the resection, the exact point of transection and reconstruction of the biliary continuity in order to have an oncologically free margin.

## 21.2 Parenchymal Bleeding

Another possible failure of the Glissonean approach is represented by excessive bleeding. The underlying causes can be linked primarily to surgeon inexperience, often not beyond the learning curve. In order to preserve the Glissonean capsule and therefore protect the biliary, portal and vascular structures, it is mandatory to avoid forced manoeuvres in Glissonean pedicles encirclement, and it is paramount to rigorously pass the clamp around the Glisson sheath [8]. Opening and extensive dissection of the hepatic parenchyma is unnecessary, since the parts of the liver with the corresponding pedicle of the segments to be resected are accessed only through small incisions on the hepatic capsule previously demarcated [9].

Furthermore, the presence of a cirrhotic liver could make pedicle encirclement manoeuvres difficult due to the fibrotic liver parenchyma and the greater bleeding susceptibility of these patients. In addition, the occurrence of venous bleeding during a technically correct manoeuvre, although usually self-limiting and easy to control, could become difficult to manage in case of high central venous pressure (CVP) [10]. In these cases, it is useful to obtain a reduction of CVP which can be achieved commonly by anaesthesiologic interventions such as fluid restriction or surgically by infrahepatic IVC clamping. However, the potential association with postoperative pulmonary embolism represents a significant concern [11].

In all cases to avoid excessive bleeding, the basic recommendations are to achieve the correct exposure and to obtain the complete isolation of the Glissonean pedicle.

Tokumitsu et al. [12] in this regard described 'the cystic plate traction method' based on the theory that the cystic plate is continuous with the hilar plate. Cystic plate traction can be useful for right-sided extrahepatic Glissonean pedicle isolation, because such traction can draw out and thus lengthen the extrahepatic Glissonean pedicle. The anterior Glissonean branch can be easily isolated with sufficient length by connecting the space on the upper side of the hilar plate with that on the lateral side of the anterior branch. The right posterior pedicle can be encircled by subtracting the anterior branch from the right main pedicle.

Recently Ikeda et al. [13] proposed the semi-prone position and a modified hanging manoeuvre in order to minimise the intraoperative bleeding during a pure laparoscopic right hepatectomy using the intrahepatic Glissonean approach. Ikeda concluded that the semi-prone position allows for a maximal amount of space between the subphrenic region, using the weight of the right lobe to expand the field of view and facilitating the mobilisation of the liver. The hanging manoeuvre that was originally described by Belghiti et al. [14] is a technique that hangs the liver with tape, thus allowing for the control of bleeding in the deeper parenchymal plane. When performing hanging manoeuvre laparoscopically, the tape is replaced to just above the cutting plane after the right Glissonean pedicles are divided and is pulled up only to move the parenchyma to the back cranial direction. This method, named the 'suspender manoeuvre', allows an effective traction to expand the field of view with an easy control of bleeding in the deeper parenchymal plane, especially surrounding the middle hepatic vein area.

## 21.3 Intraoperative Tumour Spread and Recurrence

The adoption of Glissonean approach to tumours located in the perihilar area is still debated due to the risk of breakage during manipulation, even for the most experienced surgeons, with consequent spread of tumour cells. In particular, perihilar cholangiocarcinoma represents an absolute contraindication to the Glissonean approach. Indeed, as widely demonstrated in the literature, in this case the resection margin is not a sufficiently objective criterion to judge surgical radicality because a tumour placed in the bile ducts of the hilar area can easily spread tumour cells to the surrounding structures. For this reason, perihilar cholangiocarcinoma is considered a regional tumour lesion more than a local tumour lesion. Therefore a 'no touch' technique avoiding any hilar dissection is recommended.

In conclusion, recognizing the possible pitfalls of a technique are the best way to avoid them. Preoperative knowledge of the pedicle anatomy is mandatory for the success of Glissonean approach. In the next chapters, it will be further discussed the impact of new technologies such as 3D visualisation techniques, indocyanine green (ICG) fluorescent navigation and augmented reality that will surely increase precision and safety in pedicle liver surgery.

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# 22

# The Use of Indocyanine Green and Near-Infrared Fluoroscopy for Glissonean Approach

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## 22.1 Introduction

Surgical resection is considered the gold standard potentially curative treatment for patients with liver malignancies and selected benign diseases. Nowadays, liver surgery has become a safe approach with mortality rate of 1–2% even for advanced open and laparoscopic operation [1, 2]. During liver resections, the transection plane is usually determined using ultrasound-guided technique [3], but correct intraparenchymal margin is technically challenging, and defining the exact resection plane is often difficult, especially in cirrhotic parenchyma. To improve quality and precision of anatomic resection, Makuuchi et al. [4] proposed a combined approach of ultrasound guided resection with methylene blue dye injection into portal branches to clarify the shape and borders of segments on liver surface.

The worldwide spread of minimally invasive liver surgery enlighten the need for a real-time visualization of precise liver anatomy and encouraged the implementation of intraoperative navigation tools. Navigation enables to overcome the technical and oncological challenges encountered during laparoscopic liver resection, due to the lack of tactile sensation, unique caudal and dorsal view, and the difficulty in performing precise intraoperative ultrasound. Based on the study by Tanaka and Aoki [5, 6], the use of blue dye was progressively abandoned and replaced with indocyanine green (ICG), an anionic solution that is rapidly extracted and excreted by the liver. When intravenously administered, ICG emits fluorescence that can be detected with the use of near-infrared cameras in living tissue. Recently, ICG applications have progressively gained attention in liver surgery for the segmentation of the liver, to localize subcapsular lesions [7, 8], and to recognize biliary anatomy [9] in addition to the evaluation of preoperative liver function [10].

### 22.1.1 Glissonean Pedicles

Glisson's capsule was discovered by Johannis Walaeus in 1640 and described by Francis Glisson in 1654 [11, 12]. The Glisson's capsule covers the liver surface and wraps the hepatic artery, the portal vein, and the bile duct forming a morphological system known as the Glissonean

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pedicle. At the inferior part of the liver, this capsule forms a thick plate which is referred to as the hilar plate and extends itself into the liver parenchyma continuing to follow and cover each pedicle. Each pedicle is formed by a portion of the artery, portal vein, and bile duct, together with connective tissue and covered with the peritoneum; this bundle originated from the hepatoduodenal ligament to the intrahepatic portion and can be seen as a tree with various ramifications, namely, the Glissonean tree. The Glissonean pedicle tree is divided into three main orders of branches according to Brisbane 2000 terminology [13]: first, second, and third. The entire length of the primary branches of the Glissonean pedicle and the origin of the secondary branches are located outside the liver, and the trunks of the secondary and more peripheral branches run inside the liver parenchyma. The main trunk is ramifying into two branches in the hepatoduodenal ligament, right and left first-order branches. The right branch is divided into two secondary branches inside the liver parenchyma, while the left branch proceeded inside the liver giving rise to a single secondary branch and continuing to the umbilical portion [14–17].

As first described by Takasaki in 1998 [14], the three secondary branches divide the liver into three functional area: right, middle, and left, and each of these areas accounting for about 30% of total liver volume, with the remaining 10% occupied by the caudate area that is feed by small branches directly originating by the first-order ones. Comparing this segmentation with the Couinaud classification of liver anatomy [15], the left area corresponds to S2, S3, and S4: the middle area to S5 and S8 and the right area to S6 and S7. Each area is separated into small parts according to the branching pattern of the third order of Glissonean pedicle. Each of these areas is a cone-shaped zone nourished by one of the tertiary branches, the base lies on the surface of the liver, and the apex in the direction of the origin of these tertiary branches; this area is called “cone-unit.” Each of these cone-units is a smallest area of the liver for which a tertiary branch can be transected selectively. The distribution of these cone-units differs from person to person, but generally is considered that 3–4 units compose a Couinaud segment [15, 17, 18].

The hepatic veins runs across the three segments in a space called intersegmental plane; the right hepatic vein (RHV) is between the right and middle areas, and the middle hepatic vein (MHV) between the middle and left areas. Because, in most of the individuals, the middle and the left hepatic veins combine each other forming a common trunk draining into the inferior vena cava (IVC), there is a general rule for considering the left vein (LHV) as a branch of MHV. In addition, short hepatic veins coming from the caudate lobe directly drain into the IVC [14, 15, 17, 19].

### 22.1.2 The Glissonean Approach

First-, second-, or third-order Glissonean pedicles can be isolated from the hilar plate and dethatched from the liver parenchyma through a space that exists between the Glissonean pedicles and a continuous liver membrane called the Laennec’s capsule. The Laennec’s capsule, first described by Rene T. H. Laennec in 1802, is a dense fibrous layer covering the entire surface of the liver, just beneath the serosa, including the bare area and the intrahepatic parenchyma surrounding the Glissonean pedicle surface [16]. This structure has an essential role in encircling the important vessel structures, especially in anatomic liver resections, which involve the isolation of the extrahepatic Glissonean pedicles and the exposure of the hepatic veins.

To standardize the extrahepatic Glissonean pedicle isolation technique, Sugioka et al. proposed a strategic theory for encircling Glissonean pedicles, namely, the Gate theory in 2017 [20, 21]. The authors postulated a space between Laennec’s capsule and Glissonean pedicle as a specific anatomic landmark, which allows extrahepatic selective pedicle isolation without parenchymal destruction. The selective pedicle isolation based on the Gate theory is essential for anatomical parenchymal sparing liver resection. The four essential anatomical landmarks are mentioned as the cystic plate, the umbilical plate, the Arantius plate, and the pedicle for the caudate process (G1c). The gates account for six and are delimited by the four landmarks. The space between Laennec's capsule and the Glissonean pedicles could be entered only at the six gates. The gates are located as follows: Gate I, caudal end of the Arantius plate; Gate II, the junction between the round ligament and the umbilical plate; Gate III, the right edge of the root of the umbilical portion; Gate IV, the left edge of the right anterior Glissonean pedicle and cystic plate; Gate V, bifurcation of the right Glissonean pedicle; and Gate VI, the space between G1c and the posterior right Glissonean pedicle [20]. By connecting two of the six gates, each Glissonean pedicle could be systematically isolated.

On the other hand, three approaches to the inflow vasculature at the hepatic hilum were described by Couinaud as intrafascial, extrafascial, and extrafascial and transfissural approach [15–21]. The intrafascial approach consists of the individual separation of each element in the hepatoduodenal ligament, known as "control method," which is considered the standard approach for anatomic hemi-hepatectomies. The extrafascial and extrafascial and transfissural approach are considered to be the "Glissonean pedicle approach" [17–21]. The extrafascial approach can be divided into the extrafascial extrahepatic pedicle approach, known as Takasaki's approach, and the extrafascial intrahepatic approach [17–21]. The extrahepatic approach entails isolation of Glissonean pedicle at the hilum before liver parenchyma's dissection, while the intrahepatic approach is carried out with minor liver transection before Glissonean isolation and division. The former technique is usually used for hemi-hepatectomies and sectionectomies, while the latter technique is used for segmentectomies or subsegmentectomies which requires isolation of the tertiary branches of the Glissonean pedicles. Finally, the extrafascial and transfissural approach, or Ton That Tung approach, involved a major parenchymal transection followed by intrahepatic isolation and division of Glissonean pedicle [17–21].

### 22.1.3 Indocyanine Green

Indocyanine green (ICG) is a sterile, anionic solution of a nontoxic tricarbocyanine dye with a peak spectral absorption at 790 nm, a molecular mass of 776 Dalton, and a half-life of 150–180 s. This molecule was developed in the Second World War as a dye in photography, tested at the Mayo Clinic for human medicine in 1957 and approved by the FDA in 1959 [22]. Upon intravenous administration, ICG rapidly binds to plasma protein and extracted and nearly exclusively excreted unconjugated by the liver about 480 s after injection [23, 24], mainly depending on liver function and vascularization. ICG becomes fluorescent once excited with a near infrared spectrum light of approximately 820 nm or a laser beam [15], and the fluorescence released from ICG can be detected using specifically designated scopes and camera.

ICG can be used as a quantitative liver function test (ICG-R15) [25]. Furthermore, ICG has several applications for intraoperative navigation in liver surgery. For instance, the biliary secretion of the dye allows to visualize the bile ducts during cholecystectomies, donor hepatectomies, or liver resections. When administered 1–2 weeks before the surgery, ICG helps to intraoperatively identify different hepatic tumors, including HCC, cholangiocarcinoma, and CRLM. In addition, intraoperative administration is useful to identify the portal territories and perform anatomic liver resections [26].

On the other hand, the exact dosage and timing of administration of the dye is still a matter of debate [27]. Generally, a dose of 0.5 mg/kg is administered 14 days before surgery for tumor detection in normal liver parenchyma. In cirrhotic or fibrotic livers, the dose should be decreased due to the impaired function of the parenchyma and had better not exceed 0.3 mg/kg [25, 27, 28]. In literature, it is described that the dye is accumulated and then progressively excreted by the normal liver parenchyma, while it is retained by the tumor. Besides, tumor fluorescence patterns varies depending on its histological differentiation [24–29]. Total or partial fluorescence staining pattern is generally observed in hepatocellular carcinoma and rim fluorescence in liver metastasis, while the staining pattern is variable in the case of cholangiocarcinomas [27].

In the case of intraoperative injection, there are two main method of administration: the negative staining, in which the ICG is administered intravenously after clamping the portal pedicle of the target segments that must be resected, and the positive staining, where the dye is directly injected into the portal venous branches of the target segments. The most frequent dosage is 2.5 mg/body in the case of the negative staining method and 0.25 mg/body in the case of the positive staining.

### 22.1.4 Positive and Negative Staining Technique

The intraoperative administration of ICG enables to identify the portal territories and, thus, helps to perform anatomic liver resections. There are two techniques to achieve the liver segmentation: the positive staining and the negative staining. The positive staining technique is based on Makuuchi's systematic segmentectomies [4]. The portal pedicle of the tumor-bearing segment that needs to be resected is identified by ultrasonography and directly punctured with an 18–22-gauge spinal needle or percutaneous transhepatic cholangiodrainage needle introduced through the abdominal wall [24]. Subsequently, ICG is slowly injected into the portal branch to avoid the risk of ICG retrograde flow into neighboring segments without clamping the hepatic artery [30]. The ICG is directly taken up by hepatocytes after the injection into the portal branch, the target segment is going to shine green, and the remaining liver parenchyma is going to be cyanotic at near-infrared light [4, 25, 27–31].

The negative staining technique is more frequently performed in laparoscopic setting as it is easier and ensures the clear demarcation of the portal territories. This technique is achieved by the intravenous ICG injection after clamping or ligating of the target portal pedicles. In theory, the Glissonean pedicle is isolated until the third-order branches from the hepatic hilum using the Glissonean approach. Using near-infrared light camera, the whole liver could shine green except the portal territory that is going to be resected [4, 25, 27–31].

The failure of staining is defined as not uniform or incomplete delineation of the tumor-bearing segment or staining of undesired segments after ICG injection [32]. The failure is based on different reasons according to each staining method. In the case of negative staining, it can occur because of the presence of collateral circulation or multiple portal branch suppling the segment. As a consequence, undesired segments can be stained. In the case of positive staining, retrograde flow or puncturing wrong branches or hepatic vein collaterals is the main causes of failure.

## 22.2 Surgical Technique

The preoperative routine test and planning for the patient have been described elsewhere [33]. ICG-R15 tests will be conducted 2 weeks before surgery to assess patients' hepatic reserve using an ICG dose of 0.5 mg/kg. Surgical planning is fashioned in line with the "cone unit" theory instead of Couinaud's segmentation. Laparoscopic near-infrared camera is used, and overlay function which enables to superimpose the fluorescent green onto white light image on the screen is preferred. The extra-fascial approach will be used to encircle the target Glissonean pedicle according to the preoperative simulation. Liver parenchyma division will be performed precisely according to the watershed between color-coded and noncolor-coded areas. During the extra-hepatic Glissonean approach, the 3D simulation model will be repeatedly referred to on a screen to ensure that the targeted pedicle tree is addressed.

### 22.2.1 Tips and Tricks (with Video)

The right anterior Glissonean pedicle could be reached by detaching the cystic plate from the

Laennec's capsule ("cystic plate cholecystectomy"). Pringle maneuver is useful to pull the entire Glissonean sheath from the hilar plate. Dividing small branch of the hilar plate (the so-called anchors) with clips, the right Glissonean pedicle is isolated by connecting Gate IV and VI. G6 is directly taped when running superficially in the liver parenchyma in Rouviere's sulcus. The right anterior Glissonean pedicle could be encircled extrahepatically. When target Glissonean pedicle (G5 in this case) is far from the hilar plate, Lennec's capsule can be broken, and the liver parenchyma is divided on the ventral side of the anterior branch of the Glisson. After securing G5 and G6 with vascular tape and clamping with bulldog forceps, the ischemic area was confirmed by with the ultrasound contrast agent Sonazoid™ (contrast agent), and ICG 0.5 mg/body was administered to visualize the demarcation line on the liver surface. Liver superficial layer transection is performed following the surface marking with soft coagulation device. Parenchymal transection is performed between ICG fluorescent green color-coded and noncolor-coded areas owing to overlay mode of the near-infrared camera. After securing enough space around the Glissonean pedicles, they are divided with double clips. We believe that split injury of the hepatic vein can be reduced by dissecting the hepatic vein from the medial (or cranial) to lateral (or caudal) side, that is, from the proximal side to the peripheral side of the hepatic vein.

## 22.3 Conclusions

ICG fluorescence navigation can be a complement to the ergonomics and tactile sensation in minimally liver surgery facilitating parenchymal transection precisely according to the proper liver watershed. Our extra-hepatic Glissonean approach is the simple procedure based on Takasaki's cone unit and Sugioka's gate theories. Once combined with the Glissonean approach, ICG negative staining technique makes the staining stable without overtime contamination from adjacent segments.

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# 23

# The Use of 3D Virtual Surgical Planning

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Over the last 50 years, surgical procedures have undergone a remarkable transformation; in all probability, more sophisticated than any that have occurred in previous centuries. Most recently, many surgical procedures have reached their zenith, demonstrating exponential growth. Liver surgery is a notable exponent of this extraordinary evolution. Dramatic improvements in surgical techniques and important technological advances have undoubtedly contributed to this evolution. Thus, the mortality of liver surgery has been significantly reduced [1].

Anatomy represents the fundamental guide for the development of oncological liver surgery. The surgeon must analyse and evaluate the specific characteristics of each patient. For this purpose, adequate diagnostic tools must be available to identify anatomical anomalies, the number and precise location of tumour lesions and the possible involvement of neighbouring organs or vascular structures. In summary, in the preoperative study, the surgeon must 'see, interpret and plan in order to subsequently perform'. In the twenty-first century, the old surgical aphorism of 'open and see' is now obsolete.

Technology has been able to change the present of surgery. Liver surgery is one of the specialties that has required the most technological innovations. Its incorporation has been slower than in other medico-surgical specialties. From a diagnostic point of view, hepatic surgery has benefited from important advances obtained in other specialties, such as radiology, nuclear medicine and gastroenterology.

A new concept has been introduced that has had an enormous and dramatic impact on digital medicine, that is, artificial intelligence (AR). In the future, it could become a support system in clinical or surgical decision making, which, in the case of surgery, would facilitate precision surgical treatment [2–5]. The integration of this type of process into the various aspects of HPB surgery could lead to improved postoperative and oncologic outcomes.

In liver surgery, most surgeons use two-dimensional (2D) computed tomography (CT) or magnetic resonance imaging (MRI) to assess the position of a lesion and its relationship to surrounding structures in preoperative planning. In recent years, the axial and 2D view of the anatomy has been modified by new three-dimensional (3D) images, with planes in any direction in space. The development of new generations of

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helical CT equipment, together with the improvement of computerised support, has led to a spectacular evolution in image processing and the enlargement of 3D reconstruction, in less time and with greater resolution. In addition, the fusion of images obtained with the new helical CT as a radiological/metabolic test, such as PET/MRI or PET/CT, is a new resource available to the surgeon to remove liver tumours in a much more precise way.

## 23.1 Our Model

### 23.1.1 Next-Generation 3D Modelling (Cella Medical Solutions)

*Data acquisition*: All available preoperative imaging of the patient (CT, NMR, PET-CT, PET-MRI) are used to document tumour distribution, estimate remnant liver volume and identify tumour-vessel relationships in order to clearly determine the intraoperative vascular anatomy. Image capture protocols are used to normalise the characteristics of the acquired images.

*Image fusion*: The different modelled elements are delineated into the most appropriate sequences of imaging diagnostics. Therefore, it is necessary to use image fusion techniques that correct errors derived from breathing, movement and position in the patient. Rigid registration techniques are used for alignment in rotation, translation and scaling of the image and related non-rigid and 3D techniques for the correction of tissue deformation.

*Image pre-processing and segmentation*: Segmentation of the hepatic parenchyma, inferior vena cava, suprahepatic veins, portal vein, hepatic artery, biliary tract and tumour is performed. Other processes/structures, such as cysts, hilar adenopathies, prostheses or drains, are also reconstructed. Active contouring techniques, adaptive region growing and neural networks, such as SesRegNet and UnetR, are used for segmentation. Noise is previously reduced with anisotropic diffusion filters and N3 algorithms.

*Modelling processing*: Laplacian filters with smoothing are used in the 3D reconstruction of the model to correct the staggering derived from the slice thickness. In addition, techniques are used to divide the parenchyma into hepatic segments I–VIII and to subdivide the vascular elements: suprahepatic veins into left, middle and right; the portal vein into right and left; the arteries into right and left hepatic artery, celiac trunk, superior mesenteric artery and aorta; and the biliary tract into gallbladder, cystic duct, common bile duct, common hepatic duct and intrahepatic bile ducts. The distribution of the parenchyma in vascular and biliary territories is also performed. The models are processed in order to allow the performance of regulated and nonregulated resections, virtual ablations and safety margins of 5, 10 and 15 mm, obtaining the remnant and tumour volumes. Finally, algorithms are developed for the identification of portal and arterial anatomical variants based on atlas and other 3D pattern recognition.

### 23.1.2 Current Value of 3D Reconstruction in Liver Surgery

The current role of 3D planning in liver surgery is fundamentally focused on preoperative planning. Reflecting the anatomical structure of the liver is the theoretical basis of anatomical hepatectomy. Accurate information on the number, size and location of existing tumour lesions is obtained. The incorporation of metabolic tests into the 3D planning and virtual simulation is of enormous support, as unnecessary or incomplete surgeries are avoided. In addition to this, preoperative 3D reconstruction could accurately determine the presence of vascular invasion with endoluminal navigation and vascular-biliary anatomical anomalies.

Liver volumetry is a useful clinical tool for patients undergoing major hepatic resection [6]. The total liver volume (TLV) and the future liver remnant (FLR) should always be known prior to major liver resections. The FLR volume has been shown to be an indicator of both postoperative liver function and clinical outcome [7]. With specialized software, complete auto-segmentation of the liver by segments, sectors or lobes is possible.

The surgery of hilar cholangiocarcinoma of Bismuth grades III and IV is possibly one of the most complex liver surgeries. The involvement of the second- or third-order intrahepatic bile ducts is often associated with vascular infiltration. Although they are fundamental to obtaining an R0 resection, in many cases, both are very difficult to diagnose. The benefits of obtaining information on both aspects are achieved with the use of 3D virtual surgical planning [8, 9]. Navigation inside the bile ducts is also possible.

The characterization of the liver tissue using the 3D models of virtual surgical planning is a real possibility to be achieved in the next few years. It is already possible to know the characteristics of the liver parenchyma and its possible alterations, such as fibrosis, cirrhosis or steatosis. Furthermore, after performing procedures that facilitate liver hypertrophy, preoperative portal embolization or associating liver partition and portal vein ligation for staged hepatectomy (ALPPS), we can determine whether the increase in liver volume is due to compensatory hypertrophy or congestion. In addition to other factors, this information contributes to reducing the risk of postoperative liver failure.

Three-dimensional imaging in liver surgery provides more precise information on the resectability of hepatobiliary tumours than that obtained in 2D, especially in lesions that may require extreme surgery due to their size or vascular involvement [10, 11]. Patients who underwent surgery based on a 3D planification had less operation time, less hepatic inflow occlusion, reduced amount of intraoperative bleeding and fewer postoperative high-grade complications (Clavien-Dindo grade III–V) compared with patients who underwent surgery without 3D planning [10–13].

Three-dimensional virtual surgical planning has been used for the training of medical trainees and young surgeons to assist in virtual liver resections, with a positive impact on the understanding of liver anatomy, better visualization and increased learning efficiency [14, 15].

The future of 3D navigation will most likely be related to: first, the ability to pre- and intraoperatively characterize tumour tissue, especially that which has undergone neoadjuvant treatment, and second, the integrated use of augmented reality in laparoscopic and robotic surgery.

In recent years, the concept of virtual systems has been modified to improve the limitations of minimally invasive surgery (MIS). Thus, the development of AR as a new and promising innovation appears to be progressively consolidating. AR makes it possible to blend real scenarios with virtual objects, by superimposing 3D images on the affected organ in the surgical field itself and in real time. This increases the visual signals perceived by the surgeon in the MIS. The AR is able to project onto the patient his own radiological tests, with a reconstruction of his pathology and even surgical planning previously performed. With AR, 'image-guided surgery' can be performed and represents the combination of the real with the virtual world, with the rapidly developing technology adding virtual components to the existing reality.

This 'expansion of reality' also improves the surgeon's 'brain-eye-hand' coordination response, compensating for the loss of tactile perception of the MIS. The benefit to the patient is evident, as the precision and safety of the surgery is increased. Once again, it has been demonstrated that technological innovation is associated with an increase in surgical precision, minimizing the risk of the intervention and without comprosiming safety and efficacy.

## 23.2 Conclusion

Three-dimensional virtual survival planning with images obtained via ultrasound, positron emission tomography, computed tomography scan or magnetic resonance imaging can help surgeons to more precisely locate tumours and vessels, as well as better visualize the surgical sites with added depth perception. It consolidates the term 'precision surgery' and allows surgeons to offer the patient an individualized surgical treatment 3D technology that has an educational value to both surgeons and students.

The concept of 3D visualisation and virtual simulation is closely related to one of the most attractive challenges of modern surgery, that is, augmented reality. The future of AR is difficult to imagine, but it is quite possible that improved visual perception may be associated with obtaining other perceptions, such as strength, tissue stiffness and even temperature: in other words, having the same options of a surgeon in open surgery, where the surgeon's hand plays a transcendental role.

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# 24

# Robotic Versus Laparoscopy Approach for Glissonean Pedicle Dissection

Mathieu D’Hondt and Dennis A. Wicherts

## 24.1 Introduction

The Glissonean approach was developed in order to prevent extensive hilar dissection and to reduce operative time and blood loss [1, 2]. With this technique, small hepatotomies are made over well-defined anatomical landmarks to approach the pedicles, making dissection of the hilar plate unnecessary.

Several reports have demonstrated the feasibility of this technique in laparoscopic liver surgery [3–5]. Mainly for right posterior sectionectomies, the Glissonean approach often is the preferred technique. Usually, the Glissonean sheath of the right posterior pedicle is easily accessible inside Rouviere’s sulcus in 70% of cases [6]. It allows for safe control of the portal structures of the right posterior sector without prolonged dissection, resulting in less blood loss.

Over the past decade, there has been a steady increase in robotic liver resections [7]. Compared to conventional laparoscopic liver surgery, robotic liver surgery has the advantages of a three-dimensional view, tremor filtration, and improved dexterity. In this chapter, we aim to provide a detailed technical description of a robotic versus laparoscopic approach for Glissonean pedicle dissection.

## 24.2 Technical Aspects

### 24.2.1 Conventional Laparoscopic Approach

For a laparoscopic Glissonean approach, two hepatotomies are made above and beneath a specific pedicle. After test clamping and demarcation, the pedicle is divided using a linear vascular stapler. Further superficial parenchymal transection is generally performed using a laparoscopic sealing device. Deeper parenchymal dissection or dissection near major vascular and biliary structures is done using an ultrasonic cavitation device (CUSA®, Integra LifeSciences, Plainsboro, NJ, USA) [8]. Intrahepatic vascular and biliary structures are controlled with clips when necessary. The origin of the hepatic veins is transected with a vascular stapler in most cases.

### 24.2.2 Robotic Approach

Due to the articular movement of the robotic instruments, dissection and isolation of the hepatic pedicles is often more easily performed

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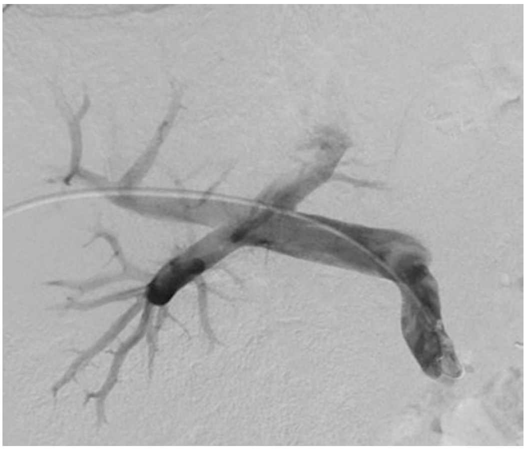
as compared to conventional laparoscopy. For an intrahepatic Glissonean approach, the portal pedicle is encircled with robotic forceps. Temporary clamping is performed to ensure ischemic demarcation. The portal pedicle is then divided using a robotic or laparoscopic stapler device. Preoperative imaging is essential to be aware of anatomical variations risking injury to sectoral branches of the future remnant liver.

Parenchymal transection during robotic hepatectomy is done using the Kelly clamp crush technique with a robotic Maryland, vessel sealer, or SynchroSeal device. Clips or robotic staplers are used to divide larger vascular or biliary structures when needed.

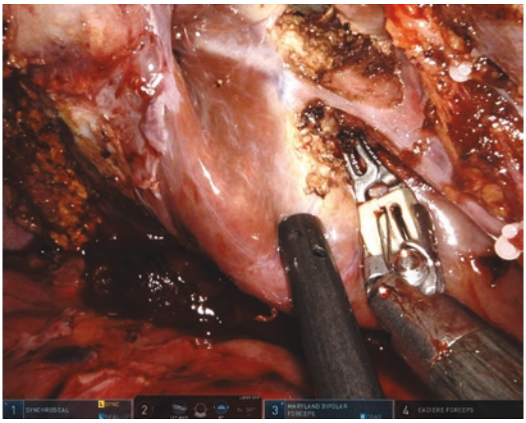
- **Tip**: *Use ICG or intraoperative Doppler ultrasound to confirm preserved inflow to the nearby segments following selective portal clamping*.

## 24.3 Cases

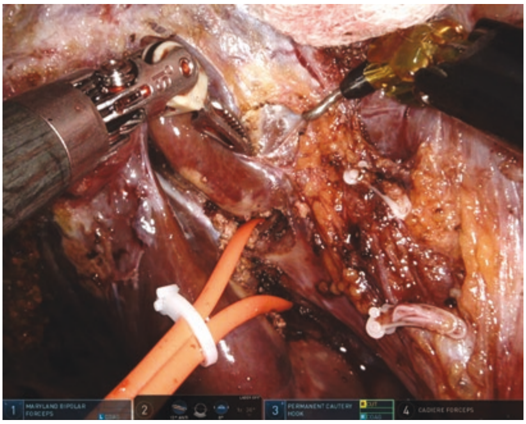
### 24.3.1 Case 1: Robotic Right Hemihepatectomy for Colorectal Liver Metastases in a Patient with a Portal Trifurcation (Repeat Hepatectomy 1.5 Years After Multiple Metastasectomies)



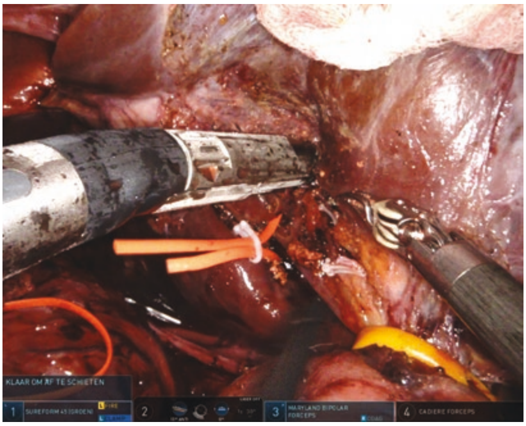
Patient who requires a right hemihepatectomy (repeat hepatectomy after previous metastasectomies 1.5 years earlier). Patient had a portal trifurcation. A portal vein embolization was performed of the right anterior sectoral portal vein and right posterior sectoral portal vein increasing the volume of the left hemiliver from 22% to 45%.



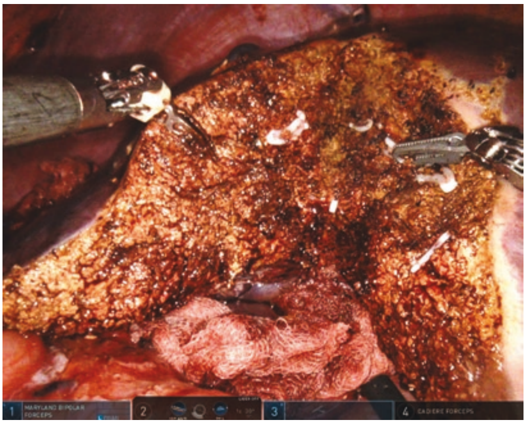
The posterior sectoral pedicle is isolated (Glissonean approach).



Isolation of anterior sectoral pedicle (Glissonean approach).

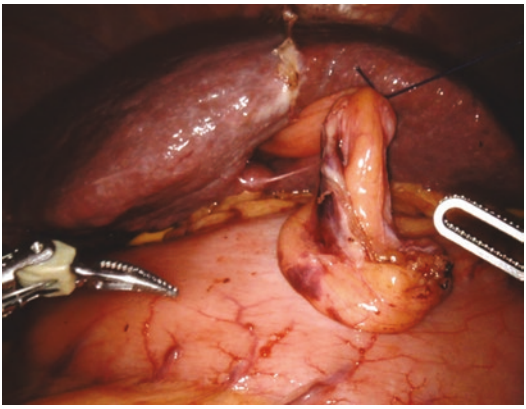


The right anterior and right posterior pedicle are transected using the robotic stapler.

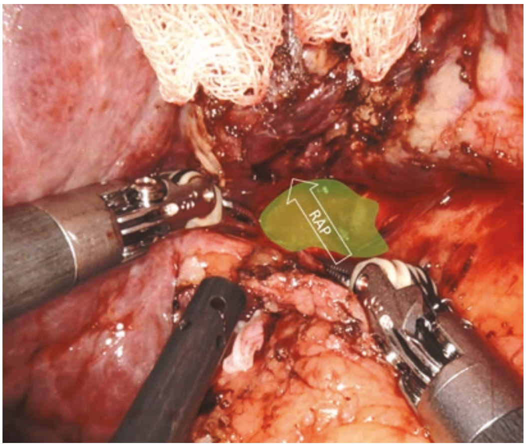


Robotic parenchymal transection for right hemihepatectomy.

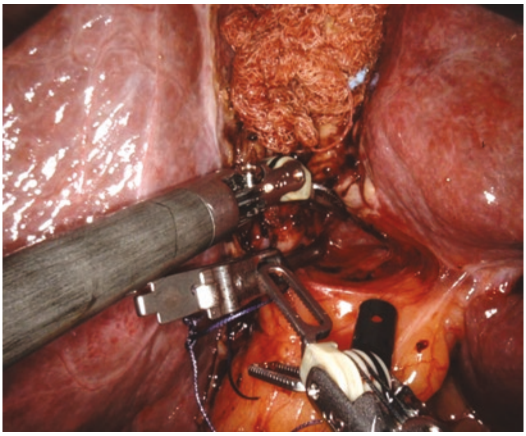
### 24.3.2 Case 2: Robotic Right Anterior Sectionectomy (Glissonean Approach)



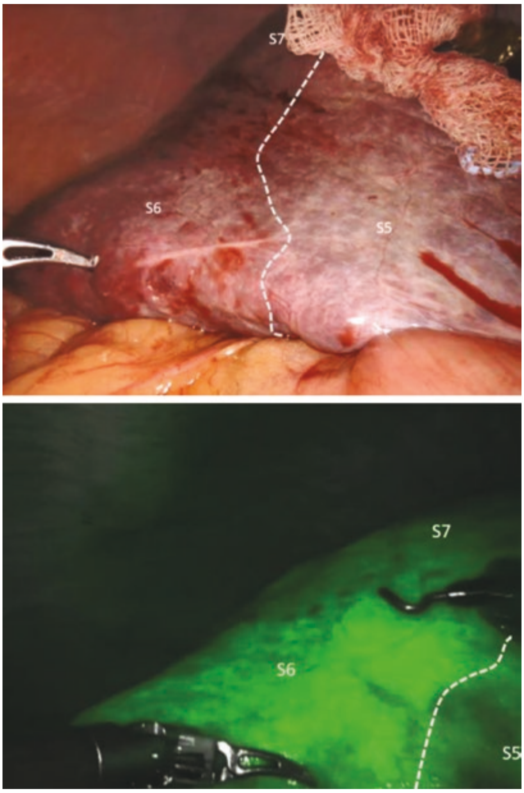
Percutaneous suture around round ligament to allow traction to the left. This brings the anterior sector centrally in the operative field.



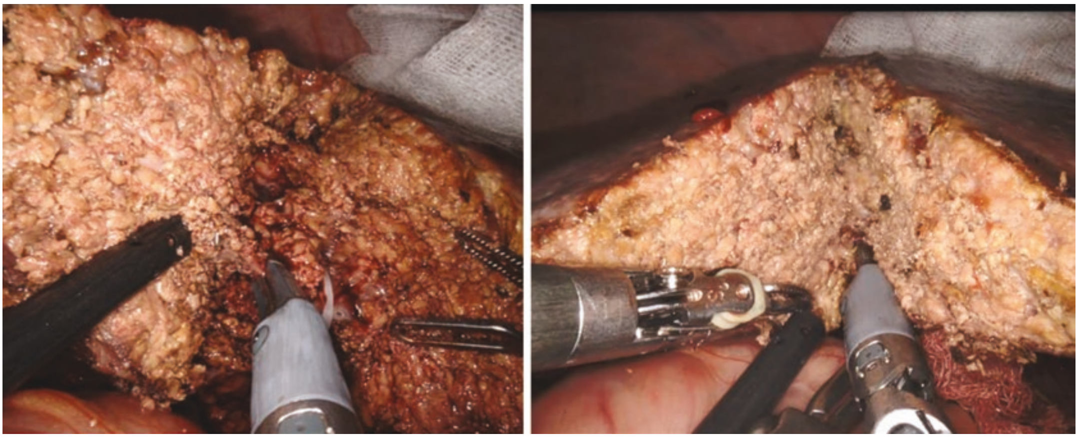
Identifying the right anterior sectoral pedicle (RAP: green) and isolating the pedicle.



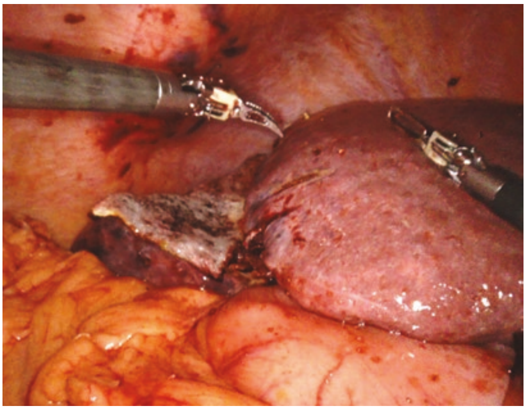
Clamping the right anterior sectoral pedicle with a bulldog clamp.



Ischemic demarcation after clamping the right anterior sectoral pedicle with bulldog clamp. ICG image with ischemic segments 5 and 8 (segment 8 not shown) and well-perfused segments 6 and 7.



Medial transection line between segment 4 and segment 5 and lateral transection line between segments 5 and 6.



Final aspect after right anterior sectionectomy and liver in natural position.

## 24.4 Conclusions

A Glissonean pedicle approach is feasible in both conventional laparoscopic and robotic liver resections. The advantage of improved dexterity and instrumental articulation using the robotic platform may allow for easier dissection and isolation of specific portal pedicles. Therefore, robotic liver surgery has the potential to broaden the application of minimally invasive liver surgery.

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# Correction to: Glissonean Pedicles Approach in Minimally Invasive Liver Surgery

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The original version of this book has been revised.

Author name changes have been made for Chapters 13, 14 and 19.

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