



Liver gates to access everywhere in the liver: how can we learn?

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Abstract: In 1986, Takasaki reported the whole control of the Glissonean pedicle without dissecting the portal vein, hepatic artery, and bile duct. In this approach, the hilar fascia is kept intact and liver pedicles are clamped and sectioned from the liver hilum. In the last decade, these techniques have been widely refined for minimally invasive procedures. By accessing the hilum, pedicles to hemilivers, sectors and individual segments can be dissected and encircled. In the last decades, many studies and randomized trials have been published highlighting the feasibility and reproducibility of the Glissonean pedicle approach. The recently reported “Gate theory” standardizes the access to first and secondary order liver pedicles by defining six gates from which Glissonean pedicle isolation is possible by maximizing the benefits of laparoscopic surgery. One of the main advantages of this technique is that potential damage to hilar structures is avoided. The access to liver gates is different considering left or right sides. The left gates (1, 2 and 3) are an easy guide to left lateral segmentectomies or left hepatectomies. On the right side, Rouviere’s sulcus is a more complex area from which isolating right posterior pedicle by encircling from Gates 5 to 6 to perform right posterior sectionectomy. Right anterior sectionectomy may be performed by accessing from Gates 4 to 5 and may probably be the most difficult one and should be considered only for expert laparoscopic liver surgeons. The gate-guided strategy is useful for both laparoscopic and open approaches and may be a useful tool to be kept in the mind of junior and experienced liver surgeons. It should, however, not replace proper intraglissonian dissection when needed, mostly in cases of tumours very close to the hilum, perihilar biliary tumors and in those cases in which lymphadenectomy should be done meticulously.

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Introduction

Minimally invasive liver surgery (MILS) has exponentially increased in the last few years. Both in its laparoscopic and robotic variations, the number and the complexity of the procedures are rising up. Since the first laparoscopic left lateral sectionectomy, published in 1996 (1,2), a wide number of techniques have been published. The First Consensus Meeting held in Louisville in 2009 settled the

basis of the incoming future of MILS (3). In 2014, the Consensus Meeting held in Morioka raised new incoming concepts such as caudal approach, vein-guided dissections and a renewed interest in the extraglissonian approach (4).

In 1986, Takasaki reported the whole control of the Glissonean pedicle without dissecting the portal vein, hepatic artery, and bile duct. In this approach, the hilar fascia is kept intact and liver pedicles are clamped and sectioned from the liver hilum (5). Certainly, one of the

main advantages of this technique is that potential damage to hilar structures is avoided. By accessing the hilum, pedicles to hemilivers, sectors and individual segments can be dissected and encircled. In the last decades, many studies and randomized trials have been published highlighting the feasibility and reproducibility of the Glissonean pedicle approach (6,7). Both approaches have been routinely performed in traditional open major hepatectomy. In the last decade, these techniques have been widely refined for minimally invasive procedures (8,9). We will explain how Glissonean approach may be performed during laparoscopic liver surgery and how to achieve precise control of pedicles for adequate anatomical resections.

The modern conception of Glissonean approach

Very recently, the Tokyo Guidelines on Minimally Invasive Liver Surgery have updated the anatomical concepts of the 2000 Brisbane Terminology and have given clear instructions about what is considered anatomical resection and Glissonean approaches (10). The most important definitions and recommendations are as follows:

- ❖ The Glissonean approach is a reasonable technique during minimally invasive anatomic liver resection (MIALR).
- ❖ During formal left and right hepatectomies using the Glissonean approach, it is safe to isolate and divide the 2nd order portal pedicles for inflow control. For the isolation of the 2nd and 3rd order portal pedicles during MIALR, the Glissonean approach appears to be more feasible than individual vessels and biliary ducts isolation.

There is a concept called “Gate Theory” in performing Glissonean pedicle isolation. According to this theory, Glissonean pedicle isolation is possible by maximizing the benefits of laparoscopic surgery (11).

Recognizing the following structures (Rouviere’s sulcus, cystic plate, umbilical plate, Arantius plate, and the Glissonean pedicle of the caudate process) as a landmark to isolate the Glissonean pedicle during MIALR is recommended.

Recognizing Laennec’s capsule as a landmark to isolate the extrahepatic Glissonean pedicles during MIALR is recommended.

Strategies to access the liver hilum by Glissonean approach

It should be kept in mind that the main aims when

performing a hepatectomy (and mostly a minimally invasive hepatectomy) are:

- (I) To keep patient’s safety independent of the approach.
- (II) To minimize blood loss for postoperative recovery and for oncological reasons.
- (III) To minimize the risk of bile leak to reduce the length of stay and postoperative infections.

To keep ischemic areas as small as possible as they may have an impact on postoperative recovery and oncological success (12).

To preserve as much parenchyma as possible in order to avoid postoperative liver insufficiency and to ensure enough volume for potential recurrence mostly in cases of metastases.

To keep oncological margins adequate and try to minimize the rate of R1 and R2 resections unless vascular R1 which is considered equal to R0 whenever vascular invasion is discarded.

There are two main strategies to access pedicles in order to perform anatomic hepatectomies (*Figure 1*):

- (I) To open the fascia and approach portal, arterial and biliary structures individually (intrafascial or intraglissonian approach).
- (II) To keep fascia intact and encircle portal pedicles without dissecting individual structures (extrafascial or Glissonean approach). This approach can be divided in further two approaches.

Both abovementioned approaches have advantages and disadvantages and should be kept in the armamentarium of the surgeon to improve the success rate for a proper and safe hepatectomy. During hilar approach, the individual dissection of structures of the first-order portal pedicles can be safely performed, even during minimally invasive access. However, 2nd order or more peripheral pedicles may be troublesome for this approach as hilar plate must be dissected really proximal and potential injury may be caused to other structures. On the contrary, it has been well-defined the safety of the Glissonean approach for 2nd and 3rd order divisions on both sides, minimizing the risks of anatomical variations at this level. We strongly advocate for a precise preoperative planification including 3D reconstructions to properly plan an adequate surgical strategy (13).

A progressive and carefully monitored learning curve is strongly recommended. The access to liver gates is different considering left or right sides. The left gates (1, 2 and 3) and access to them is probably the best starting point. In this area, left lateral segmentectomies or left hepatectomies

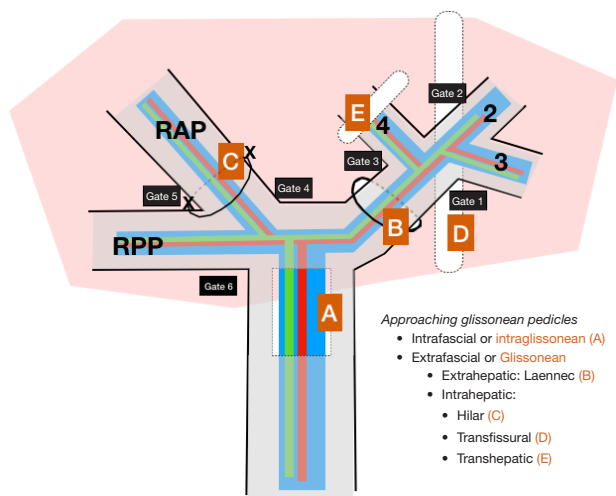
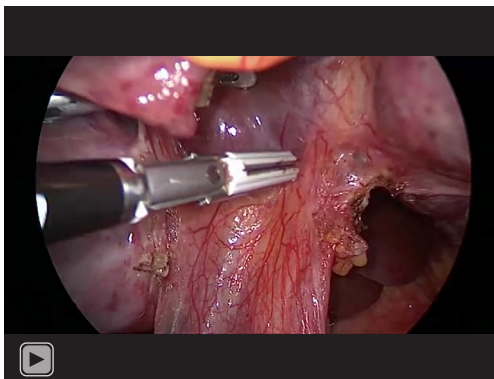


Figure 1 A schematic perspective of the hilar plate including primary and secondary bifurcations and Gates as defined by Sugioka. Glissonean pedicles can be accessed with previous incision of Glissonean sheet (A) or not (B). If this fascia is not incised, Glissonean approach is defined (B), which can be divided in extrahepatic or intrahepatic depending on whether liver parenchyma is disrupted (C-E) or not (B). RAP, right anterior pedicle; RPP, right posterior pedicle.



Video 1 Accessing from Gate 3 to Gate 1 for a safe anatomical full left hepatectomy. As observed, the Laennec's capsule is gently detached which leads to isolation of left pedicle.

are strongly encouraged to be practiced before moving to the right side. In the right side, Rouviere's sulcus is probably a next level area from which isolating right posterior pedicle by encircling from Gates 5 to 6. In our opinion, and considering current difficulty scoring scales, right anterior sectionectomy and accessing from Gates 4 to 5 is the most difficult one and should be considered only for expert

laparoscopic liver surgeons (14).

Our main recommendations for performing a safe Glissonean approach are:

- ❖ For first order division:
 - For left-sided bifurcation, it is recommended to dissect from Gate 3 to Gate 1. Gate 3 is easily found just to the right of the falciform ligament above the hilar plate (15). Gate 1 should be found above G1 and Arantius ligament. An oblique approach from Gate 3 to Gate 1 may be useful to avoid damage to the posterior part of the left pedicle (*Video 1*).
 - For primary bifurcation on the right side, a potential access is dissecting Gate 6 above G1R and moving upwards towards Gate 4. This approach has been widely used with good results. However, there is a potential risk in damaging bile duct as it usually divides further above the right portal vein bifurcation. To prevent this potentially harmful event, two maneuvers have been proposed: first, to pull firmly from the external tourniquet to stretch the hilar plate and be able to do the section of the right pedicle safely (16); and second, to make individual sections of right posterior and right anterior pedicles (*Figure 2*), moving from Gates 6 to 5 and from Gates 5 to 4, respectively (17,18).
- ❖ For second order division:
 - When moving towards 2nd order division, accessing the Gates of Sugioka seems an even safer approach to avoid damage to other structures. In the left side, accessing the second order division is the most useful and safe technique for a left lateral sectionectomy. In this sense, transfissural approach using the falciform ligament landmark may clearly lead to the left lateral pedicle and ensure a safe section using a staple (*Video 2*). However, this approach is also the easiest strategy to reach up to G3 and make an individual anatomical segmentectomy (*Video 3*).
 - On the right-sided 2nd order division, it is mandatory to get excellent preoperative planification by angiographic computed tomography (angi-CT) scan, magnetic resonance imaging (MRI) and cholangio-MRI. Our protocol also includes preoperative 3D reconstruction to ensure perfect preoperative knowledge of all anatomic variations. For this area, we strongly advocate for Glissonean approach using Gates 4–6. From Gates 4 to 5 for

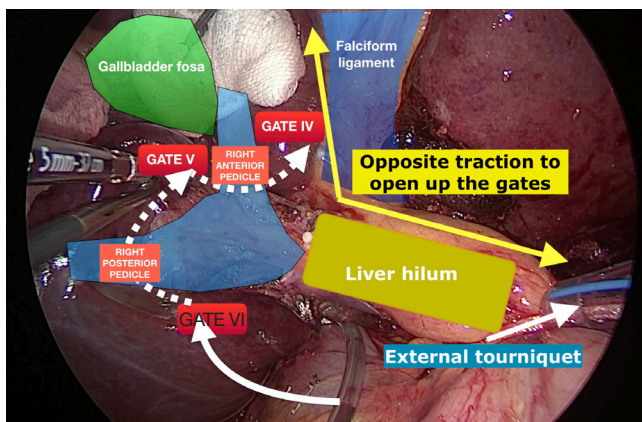
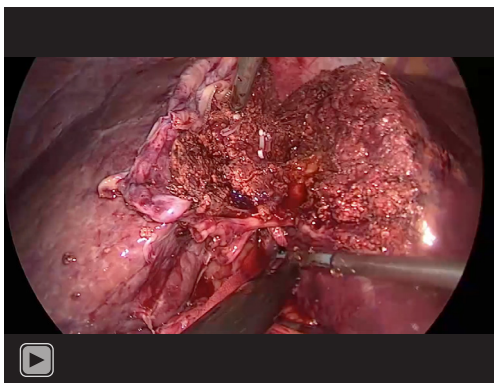
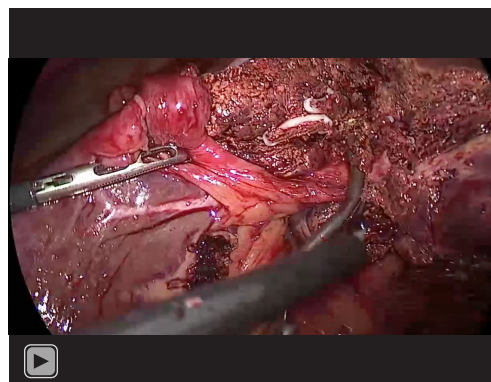


Figure 2 A schema of how to access Gates 6, 5 and 4 in order to perform a right hepatectomy. It is advisable to perform individual transections of right posterior (from Gate 6 to Gate 5) and right anterior (from Gate 5 to Gate 4) pedicles in order to avoid damage to bile duct division and create a iatrogenic injury to left bile duct or confluence.

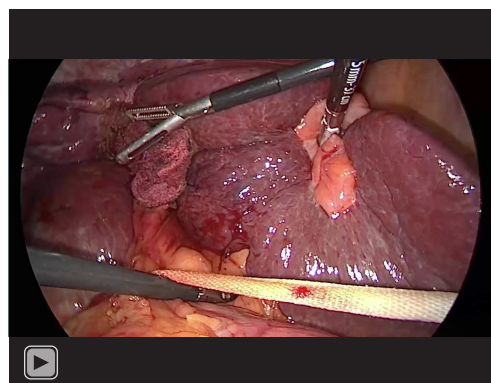


Video 2 By using transparent approach, it can be easily isolated the pedicle to segments 2 and 3 to perform a left lateral sectionectomy.

a right anterior sectionectomy and from Gates 5 to 6 for a right posterior sectionectomy. Using the Laennec's capsule or not will just depend on several factors, mainly personal experience, cirrhotic liver, steatosis, neoadjuvant chemotherapy and previous surgeries. Cirrhotic livers are very prone for a Glissonean approach using the Laennec's capsule as this is usually thicker (*Video 4*). On the contrary, steatotic grafts and postchemotherapy are more difficult and usually a hilar Glissonean transhepatic approach is usually preferred as Laennec's capsule



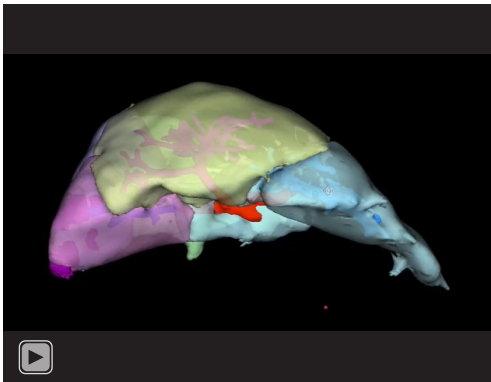
Video 3 This is a convenient approach to anatomical segment 3 resection by using transparent approach by moving to the left side of the umbilical fissure. A few centimeters below liver surface, the first pedicle is segment 3 one, which can be isolated and sectioned. By using ICG, intersegmental borders can be controlled. ICG, indocyanine green.



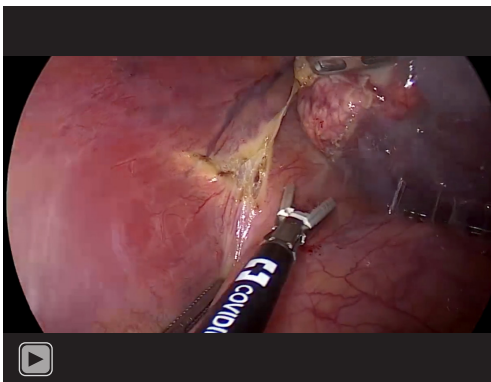
Video 4 Redo right hepatectomy in a cirrhotic liver. In this clip, Gates 4, 5 and 6 are accessed by preserving Laennec's capsule. Right anterior pedicle is clipped and right posterior pedicle is sectioned by stapler.

disrupts easily.

- ♦ To approach Gates 4 and 5, "Cystic plate cholecystectomy" is often useful especially in performing a right anterior sectionectomy, S8 subsegmentectomy and S5 subsegmentectomy. The gallbladder including the cystic plate is pulled to develop a good view of hepatic hilum. It brings the good countertraction to the right anterior Glissonean pedicle (19).
- ♦ Central hepatectomy includes resection of medial and right anterior sectors. It is considered one of



Video 5 Gates 5 and 6 are accessed but only pedicle to segment 6 is clamped. By a transparenchymal approach, a cone unit pedicle that belongs to segment 7 is also clamped. A full anatomical resection of segment 6 and one cone unit was performed.



Video 6 Pure transparenchymal approach of third order pedicles to perform an anatomical resection by controlling 2 cone units in segment 6.

the most difficult laparoscopic liver resections. It has been clearly standardized by using hilar approach accessing Gate 3 and Gates 4 to 5. This approach may preclude iatrogenic damage to left and right posterior pedicles (20).

- ❖ For third order divisions and cone units dissection:
 - ◆ Third order division needs Glissonean approach as dissection of individual structures seems too risky and unnecessary. Approaching third order pedicles by hilar approach is complex and needs advanced training and expertise. It is strongly advisable to approach second order branches, encircle and the move towards third order branches although this is variable and

depends on personal experience and individual anatomy. All individual Glissonean pedicles can be accessed from the hilum using both Laennec's capsule or intrahepatic. It is interesting to note that, if necessary, both approaches can be combined and start with a hilar approach for a main tertiary pedicle and then move transhepatic to find a closer pedicle from a cone unit that may complement a precise anatomical resection (Figure 1 and Video 5) (9,21).

- ◆ It should also be considered that transhepatic approach may be highly useful for performing anatomical parenchymal sparing resections by performing precise clamping of specific anatomical areas. It is really convenient in segments 6–7, in which transhepatic approach following the root of right hepatic vein leads to G7 in a very easy-to-standardize way (22,23).
- ◆ Transhepatic approach is probably the best way to approach cone units in peripheral areas. Rather than performing a non-anatomical ultrasound-guided resection, it is a valid and elegant option to locate individual pedicles that may combine cone units which should be resected in order to fully include the tumor with negative margins (Video 6). This approach is particularly useful and easy in the visceral surface of segments 6–7 and 2–3.

Conclusions

A very recent survey preparatory for the Tokyo 2020 Guidelines performed on more than 500 hepatobiliary surgeons showed that nearly half of them had never performed a Glissonean approach for a laparoscopic liver resection (24). The abovementioned maneuvers require experience and adequate training but are very much appropriate for achieving optimal results and precise anatomical resections. The gate-guided strategy is useful for both laparoscopic and open approaches and a perfect knowledge of the gates may be a useful tool to be kept in the mind of junior and experienced liver surgeons. It should, however, be noted that this strategy is just that. It should not replace proper intraglissonian dissection when needed, mostly in cases of tumours very close to the hilum, perihilar biliary tumors and in those cases in which lymphadenectomy should be done meticulously. However, we consider that this strategy is the most adequate for left-sided first order division, for secondary-order division and for third-order

division (this last one only in very experienced hands).

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Footnote

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