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# Optimized approach for blood vessel excavation within liver parenchyma

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## Abstract

The most practical approach for dissecting the liver parenchyma involves first visualizing and subsequently addressing the blood vessels within the parenchyma while maintaining a dry operative field. This process is similar to "excavation" of ancient artifacts from soil without causing any damage. To excavate the blood vessels in a dry operative field during liver parenchymal dissection, proficiency in both blood flow control and parenchymal dissection techniques is mandatory. For blood flow management, inflow control is achieved using an externally applied Pringle maneuver, whereas outflow control is achieved by decreasing the central venous pressure. Precision in parenchymal dissection lies in dissecting the liver parenchyma in areas devoid of the Glissonean branch, such as the intersegmental plane, using the back-scoring technique with a cavitron ultrasonic surgical aspirator (CUSA) to read the grain of the blood vessels.

**Keywords:** Laparoscopic hepatectomy, blood vessel excavation, blood flow control skill, cavitron ultrasonic surgical aspirator

## INTRODUCTION

The most practical approach for dissecting the liver parenchyma involves first visualizing and then addressing the blood vessels buried in the parenchyma while maintaining a dry operative field. This process is similar to "excavation" of ancient artifacts from soil without causing any damage. Moreover, proficiency in blood flow control and parenchymal dissection techniques is essential to excavating blood vessels in a dry operative field during liver parenchymal dissection. In this section, we elaborate on these techniques. These techniques are essentially the same as open liver surgeries, excluding the external tourniquet system for the Pringle maneuver and a part of outflow control utilizing several effects of pneumoperitoneum pressure. We also describe the parenchymal dissection technique utilizing the cavitron ultrasonic surgical aspirator (CUSA) which is our preference.

## BLOOD FLOW CONTROL SKILLS

Blood flow control skills for maintaining a dry operative field during liver parenchymal dissection include inflow and outflow controls. Generally, the inflow and outflow of blood in the human body can be controlled because they follow similar paths. However, in the liver, the portions that control inflow and outflow are distinct; therefore, they must be individually controlled.

### Inflow control

Inflow control involves clamping of the hepatoduodenal ligament, thereby occluding the hepatic artery and portal vein. The Pringle maneuver, which involves the intermittent occlusion of the inflow, has been extensively adopted as a safe method. Typically, an external tourniquet system comprising a 100 cm-long polyester tape and a 20 cm-long 22 French-diameter silicone tube is used for this purpose. This tube is designed to fit into the hole left by removal of a 5-mm trocar[1] [Figure 1]. Using this external tourniquet system, initiating and suspending the total inflow occlusion can be performed swiftly, similar to open hepatectomy.

### Outflow control

The blood pressure within the hepatic vein (HV) and inferior vena cava (IVC), known as the central venous pressure (CVP), is affected by the cardiac pumping motion and positive ventilation pressure and changes cyclically. During hepatectomy, elevated pressure levels in these vessels can cause the operative field to become wet owing to bleeding from small perforations in the HV or IVC[2]. Clamping the root of the HV is a method to manage the bleeding[3]; however, encircling the root is not always straightforward or safe for effective clamping. Hence, decreasing the CVP is a widely used alternative approach[4]. One basic means of decreasing the CVP is to restrict the venous infusion volume. The reverse Trendelenburg position [5] and maintaining a low ventilation pressure[2] are also effective approaches. Furthermore, particularly during laparoscopic surgery, pneumoperitoneal pressure contributes to a reduction in the extent of bleeding from the HV.

Bleeding from the HV/IVC is determined by the difference between the blood pressure of the HV/IVC (venous pressure) and the pneumoperitoneum pressure (abdominal air pressure)[2]. The higher the venous pressure relative to the abdominal air pressure, the greater the extent of bleeding, which leads to a wetter operative field. When the venous pressure equals or falls below the abdominal air pressure, bleeding diminishes, leading to a drier operative field. However, there is a risk of pulmonary arterial gas embolism when abdominal air pressure is elevated, although carbon dioxide ($CO_2$) gas can dissolve rapidly in the bloodstream[2] [Table 1].

## PARENCHYMAL DISSECTION TECHNIQUE

### Read the grain

Understanding the typical course of blood vessels such as the Glissonean cords and HVs within the liver parenchyma is valuable when excavating blood vessels that are not visible from the exterior of the liver.

**Table 1. Effects of elevated abdominal air pressures summarized by high and low airway pressure**

| Airway pressure | Abdominal air pressure | CVP | Possibility to control bleeding |
|---|---|---|---|
| High | ↑↑ | ↑↑↑ | Impossible |
| Medium (usual pressure) | ↑↑ | ↑ | Possible |
| Extremely low | ↑↑ | ↑⇨↓ | Possible (high risk of gas embolism) |

The arrows indicate the relative increase (↑) or decrease (↓) in pressure levels. CVP: Central venous pressure.

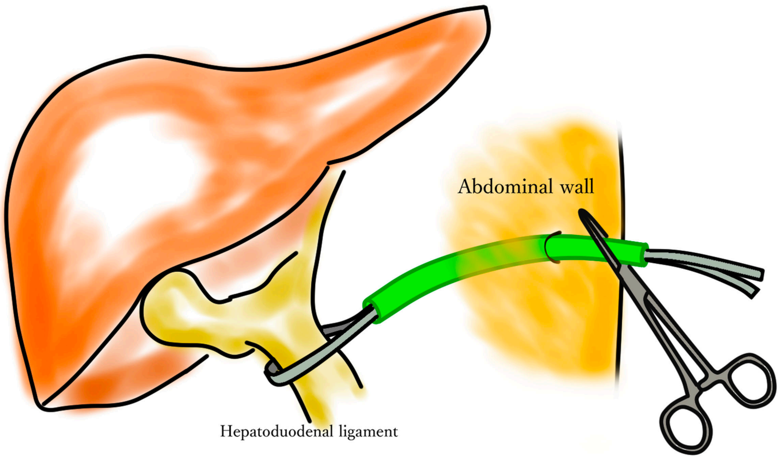


**Figure 1.** Pringle maneuver. Effective inflow control can be swiftly and easily initiated and suspended using an extracorporeal tourniquet system, similar to that in an open surgery.

Three-dimensional images created from preoperative computed tomography images are helpful for individually predicting each case. Furthermore, understanding the directional pattern, often referred to as the “grain”, of blood vessels running at the portion where parenchymal dissection occurs is advanced by knowledge of universal branching patterns of both the Glissonean cords and HVs, resembling the branching seen in a tree. In the caudal view, where the liver is upturned, both trees radiate to the ventral side from the dorsal center of the liver [Figure 2]. They never run side by side; instead, they are arranged alternately from the root to the periphery. In the ventral view, although the trees of the HVs radiate from the cranial center, the trees of the Glissonean cords rise from the dorsal side [Figure 3]. Thus, the grains of both blood vessels can be read more easily in the caudal view than in the ventral view, whereas only the grains of the HVs can be read easily in the ventral view.

### Cone unit theory

To understand the grains of the Glissonean cords, the cone unit theory proposed by Takasaki[6] is also useful [Figure 4]. Each cone unit delineates the area supplied by each of the tertiary branches of the Glissonean cord, similar to the branches of a tree. A cone unit is a cone with the root of the tertiary branch as the cone point and the liver surface as the bottom portion. The number and array of each cone unit varies for each individual. The boundary between cone units is called the intersegmental plane in the case of a boundary between segments or sectors. Theoretically, the intersegmental plane contains only the HVs without Glissonean cords. Thus, liver resection becomes easier and safer by selectively dissecting the intersegmental plane, thereby minimizing the risk of injuring HVs[7].

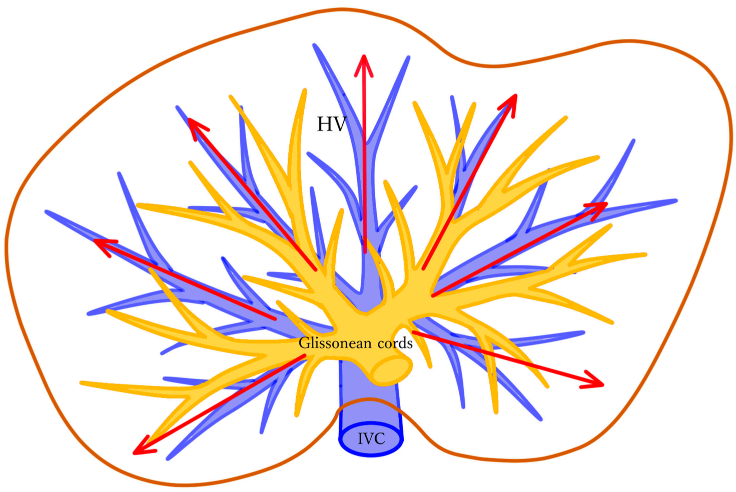


**Figure 2.** Caudal view of the Glissonean cords and HVs. The Glissonean cords and HVs radiated to the ventral side from the dorsal center of the liver, similar to a tree in the caudal view. The grains (red arrows) can be easily observed. HVs: Hepatic veins.

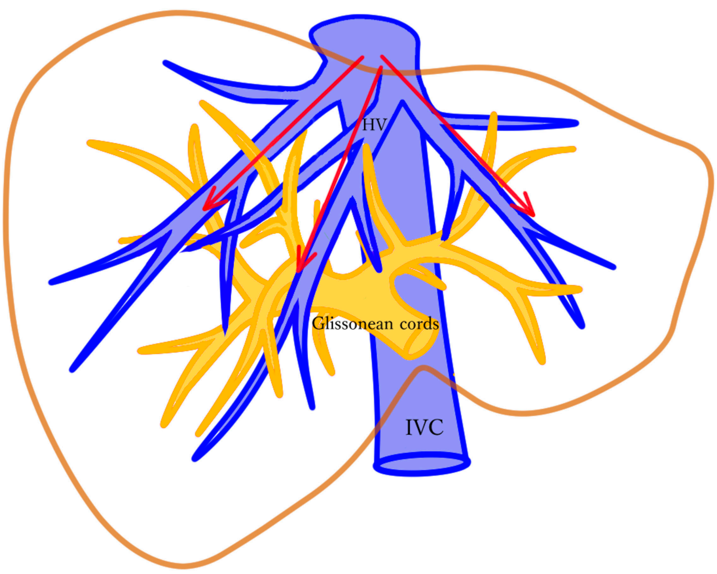


**Figure 3.** Ventral view of the Glissonean cords and HVs. The trees of the HVs radiated from the cranial center; however, the trees of the Glissonean cords rose from the dorsal side. Thus, only the grains of the HVs were easily seen (red arrows). HVs: Hepatic veins.

### Avoid split injury

A split injury, in which the fork between the branches of the blood vessel is injured from the peripheral side, often causes deterioration because it easily extends toward the main trunk of the blood vessels[8]. However, such injuries can be avoided by moving the device used for liver parenchymal dissection from the thicker (root) to the thinner (peripheral) sides of the blood vessels [Figure 5]. Even when blood vessels emerge unexpectedly during dissection, moving the device tip from the root toward the periphery of these vessels and estimating their branching patterns can prevent split injury[7].

### Dissection using the cavitron ultrasonic surgical aspirator

The CUSA serves as the primary tool for excavation, offering multiple functions within a single device. It is

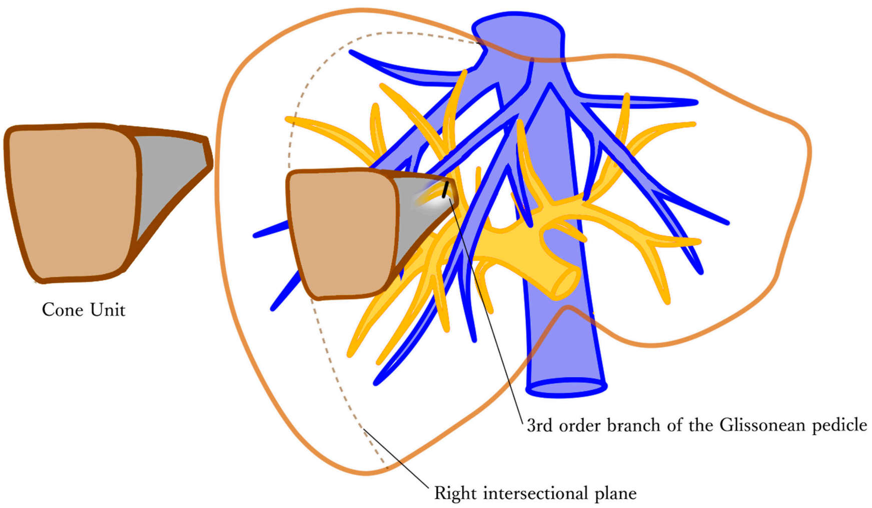


**Figure 4.** Cone unit theory. The cone unit is a cone-shaped area, with the root of the tertiary branch of the Glissonean cord as the cone point and the liver surface as the bottom.

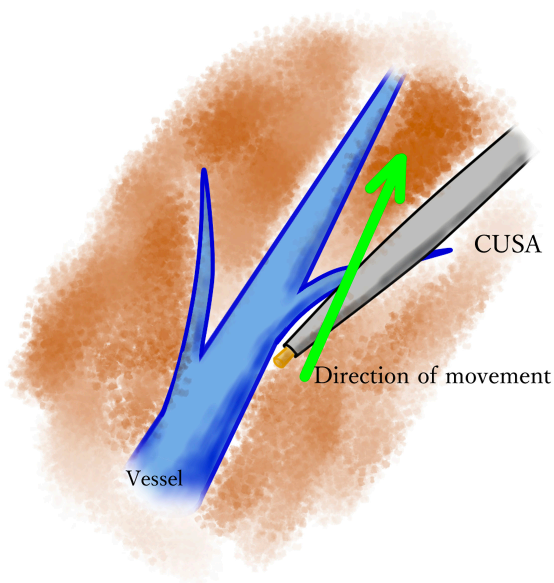


**Figure 5.** Movement direction for CUSA tip to prevent split injury. Split injuries can be avoided by moving the device from the root to the periphery (green arrow) of the vessels. CUSA: Cavitron ultrasonic surgical aspirator.

highly beneficial for excavation, especially in laparoscopic liver parenchymal dissection, because it is an all-in-one device. Its versatility minimizes the need for frequent device changes. Herein, we describe a method for excavation using a CUSA (CUSA EXcel system or CUSA Clarity system provided by the Integra LifeSciences Corporation). The CUSA EXcel system can fracture the liver parenchyma, aspirate both blood and fractured tissue, and stanch bleeding and oozing from the dissected plane through thermal denaturation by applying electrocautery in the soft coagulation mode at the cylindrical metal tip. By fully utilizing these functions, the frequency of device changes and the duration of parenchymal dissection are dramatically reduced[7].

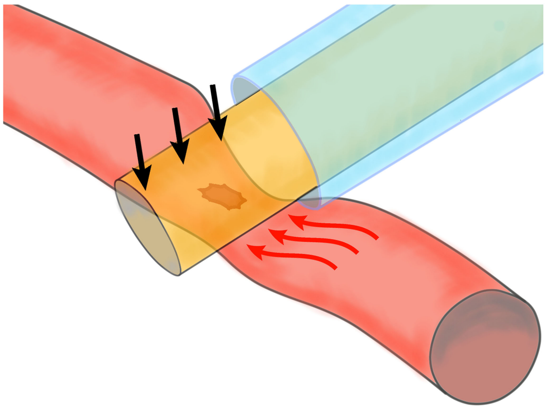

**Figure 6.** Stanching with the CUSA. The injured blood vessel is compressed at the bleeding point with the flank of the cylindrical metal tip (black arrows) and the blood flow is blocked (red arrows). Then, the injured part of the blood vessel is sealed by activating electrocautery in the soft coagulation mode. CUSA: Cavitron ultrasonic surgical aspirator.

When using the CUSA for excavation, we primarily used the back-scoring technique, in which the edge of the cylindrical metal tip was moved in the counter direction, scratching the dissecting line. In this technique, only blood vessels that are denser than the liver parenchyma remain at the dissection portion owing to a blunt impingement by the round edge of the cylindrical metal tip. The back-scoring technique is suitable for selectively dissecting the intersegmental plane in which no Glissonean cord runs, such as the intersegmental plane. If the CUSA tip is moved from the root toward the periphery of the Glissonean tree, by applying an appropriate amount of stress to the cutting line, the CUSA tip will automatically advance in the intersegmental plane. If the surgeon can read the grains of the HVs, the CUSA tip can be moved safely considering the direction to avoid split injury [Figure 5]. Even when the dissection plane is not the intersegmental plane, liver parenchymal dissection can be safely performed without split injury to the blood vessels by reading the grain.

When using CUSA for stanching, the bleeding point is compressed with the flank of the cylindrical metal tip, activating electrocautery in the soft coagulation mode. Simultaneously activating the ultrasonic output of the CUSA reduces sticking of the burned tissue to the flank surface of the metal tip. Damage to other tissues or vessels can be prevented by focusing on the edge of the round tip. The fundamental concept behind using thermal denaturation to stop bleeding from a relatively thin blood vessel involves sealing the section of the blood vessel through which the blood flows. For a swift and secure seal, the bleeding point should be compressed to block the blood flow [Figure 6]. However, burn injuries to the bile duct, which cause postoperative bile leakage or bile duct stenosis in the late phase, can easily develop when activating the electrocautery function and inadvertently touching the surface of the Glissonean branch supplying the spared area. In any case, a dry operative field is crucial in performing adequate pinpoint stanching.

## DISCUSSION

Utilizing our concept and techniques described in this review, we have standardized laparoscopic procedures for almost all types of anatomical and partial hepatectomies and applied them to more than a thousand cases[9-18]. Meanwhile, we have established exclusion criteria for a laparoscopic approach, such as cases in which the surgical margin abuts the root of the Glissonean or HV trunks or IVC, cases requiring biliary and vascular reconstruction, or cases expected to exceed eight hours of operation time. Furthermore, cases in which cardiopulmonary function cannot be safely maintained under pneumoperitoneum and/or low CVP due to cardiac and/or respiratory dysfunctions are also generally excluded from a laparoscopic approach [2]. Continual achievement of favorable outcomes of laparoscopic hepatectomies requires not only standardized procedures but also these exclusion criteria.

## CONCLUSION

Dissecting the liver parenchyma in the plane where no Glissonean branch runs is crucial, such as in the intersegmental plane. This is achieved to the greatest extent possible using the back-scoring technique, which reads the grains of the blood vessels.

## DECLARATIONS

### Author contributions

Manuscript writing: Hashida K
Manuscript revision, supervision: Honda G
Surgical procedure: Ome Y, Tanahashi T, Ubukata C, Kawamoto Y, Matsunaga Y, Ariizumi S

### Availability of data and materials

Not applicable.

### Financial support and sponsorship

None.

### Conflicts of interest

Honda G reports receiving lecture fees from Johnson and Johnson, Medtronic, and Integra Japan. Hashida K, Ome Y and Kawamoto Y report receiving lecture fees from Integra Japan. Other authors declared that there are no conflicts of interest.

### Ethical approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.



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