

METHODS OF HEPATIC VASCULAR CONTROL FOR LIVER RESECTION

Ninh Viet Khai, Chu Minh Phuc

ABSTRACT

Controlling and reduction of the bleeding are one of the key factors in liver resection, to ensure a safe resection, and to reduce post-operative complication, especially post-operative liver failure. Hepatic vascular clamping helps to reduce intra-operative bleeding. Each method of controlling hepatic vascular needs to be applied accordingly to each injury, liver parenchymal condition. Understanding of hepatic vascular control techniques in liver resection is very useful for surgeons when conducting hepatectomy.

I. INTRODUCTION

Controlling and reduction of the bleeding are one of the key factors in liver resection, to ensure a safe resection, and to reduce post-operative complication, especially post-operative liver failure. Hepatic vascular clamping helps to reduce intra-operative bleeding. The main disadvantage of this is parenchymal damage due to ischemia and reperfusion after clamping. Especially prolonged vascular clamping in those with pre-existing disease such as cirrhosis, hepatosteatosi... can cause post-operative liver failure, which is a major cause of post-operative mortality. Vascular control can be done for the inflow, or both the inflow and outflow. With the advance in liver anatomy knowledge and in anesthesiology, and especially with the introduction of modern devices to resect liver parenchyma (bipolar electrocautery, CUSA and ultrasonic scalpel...), liver resection, especially major hepatectomy can be done without vascular control. Each method of controlling hepatic vascular needs to be applied accordingly to each injury, liver parenchymal condition and cardiovascular

disease of patient concerned with the benefits of controlling blood loss with the risk of parenchymal damage due to anemia when the vascular control clamping. Understanding of hepatic vascular control techniques in liver resection is very useful for surgeons when conducting hepatectomy.

II. PHYSIOLOGICAL AND ANATOMICAL BASIS OF HEPATIC VASCULAR CLAMPING IN LIVER RESECTION

The liver is a very vascularized organ, with blood supply from both portal vein and hepatic artery. Liver blood flow accounts for $\frac{1}{4}$ of total cardiac output, about 1500ml/minute. Blood from the portal vein into the liver accounts for 75%, 25% from proper hepatic artery, however, the amount of oxygen supply to the liver is the same between these two sources of 50 %. The arterial and portal blood ultimately mixes within the hepatic sinusoids, and is taken to the central lobes vein, before draining into the systemic circulation via the hepatic venous system. Three hepatic veins are right hepatic vein, middle hepatic vein, left hepatic vein, all flow into IVC just below the diaphragm.

1. Viet Duc Hospital

Corresponding author: Ninh Viet Khai

Email: drninhvietkhai@gmail.com

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Middle hepatic vein usually converges with left hepatic vein into hepatic vein confluence before draining into IVC. Besides, minor hepatic vein and right accessory hepatic vein lead the hepatic blood into the IVC. Hepatic vascular clamping in liver resection is to control the inflow or both the inflow and outflow of the hepatic vessels

III. METHODS OF CONTROLLING HEPATIC BLOOD FLOW IN LIVER RESECTION

3.1. Hepatic blood inflow control

3.1.1. Total hepatic pedicle control

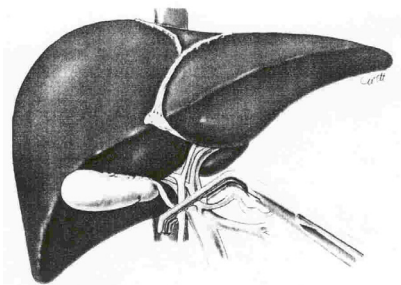
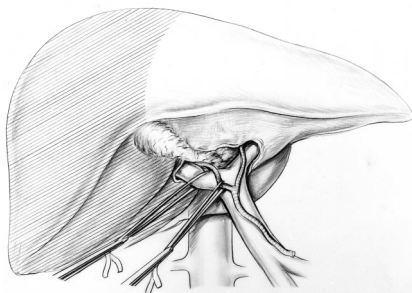


Figure 1: Total hepatic vascular control

Total hepatic pedicle control, also called Pringle maneuver, to temporary occlusion the flow of portal vein blood and hepatic artery blood into the liver while resecting the liver parenchyma. Pringle first demonstrated this maneuver in 1908[1]. Lesser omentum is opened near the left side of hepatic pedicle, encircling the tape around the hepatic pedicle through the foramen of Winslow or occluded using vascular clamp. Sometimes, left accessory hepatic

3.1.2. Selective control of the hepatic pedicle

3.1.2.1. Selective control of the right or left hepatic vascular pedicle



*Figure 2. Dissecting right hepatic artery and right portal vein separately. * Malassagne. B (1998) [8]*

artery originates from left gastric artery, thus careful checking is required to control this branch. There're 3 ways possible:

+ Continuously clamping the hepatic pedicle until hepatic parenchyma resection is completed[2].

+ Intermittent clamping - Clamp the hepatic pedicle for 15-20 minutes then unclamp for 5 minutes before the next period[2].

+ Preconditioning method - Clamp the pedicle for 10 mins and unclamp for 10 mins then continuously clamp the pedicle until hepatic parenchyma resection is completed[3].

This maneuver can cause intestinal blood stasis and liver anemia resulting in reperfusion injury, causing damage to hepatic cells. The problem here is the clamping time. The continuous clamping of hepatic pedicle time for normal liver in normal condition might be 60 to 70 mins, however, according to Belghiti it must be less than 35 mins in the case of cirrhosis[2]. The intermittent clamping of hepatic pedicle time is 15 to 20 minutes and unclamp in 5 minutes, allow the total time of clamping up to 120 minutes, even at maximum 322 minutes for normal liver and 202 or 204 minutes for cirrhotic liver[4], [5], [6], [7]. There is no statistically significant different in the amount of blood loss during the surgery between continuous and intermittent clamping, but the tolerance of the liver with intermittent clamping is better so it is most often used in patient with hepatic disease.

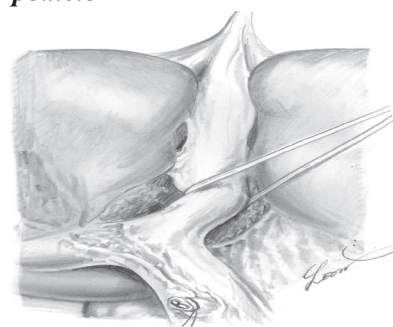


Figure 3. Controlling left Glissonean pedicle en bloc. Takasaki. K (2007) [9]

Two methods of selective control right or left hepatic pedicle are often used:

- Dissecting and separate hepatic artery and portal vein clamping: Extrahepatic dissection of right or left hepatic artery and portal vein then clamp while liver resection but not clamping the bile duct were proposed by Henry Bismuth (1982) and Makuuchi (1987) [8], [10]. Dissecting to control the right hepatic artery, right portal vein by opening the peritoneum at the upper part of the right side of the hepatic pedicle. For better exposing and dissecting of the right hepatic artery and right portal vein, cholecystectomy is usually performed. Dissecting to control left hepatic artery and left portal vein by opening the peritoneum on the left side of hepatic pedicle next to the bottom of round ligament [11]. During selective control of the left hepatic pedicle if one notices the left accessory or alternative hepatic artery separating from left gastric artery, it also needed to control this branch.

- Dissecting, en bloc clamping of right or left Glisson pedicle

- + Takasaki dissected lower the hepatic hilum plate out of hepatic parenchyma just beneath and below right or left Glisson pedicle, then reeved around the pedicle [9].

- + Galperin, Launois and Machado open the hepatic parenchyma close to the hepatic hilum to control en bloc right or left Glisson hepatic pedicle. Particularly, while dissecting the right Glisson hepatic pedicle, Machado understands the risk of bleeding during resecting the hepatic parenchyma of the caudate lobe (Launois' method) so he recommended the opening at the junction of the 7th segment and caudate lobe to control the right hepatic pedicle [12], [13], [14], [15]. In the case of selective control of the left hepatic pedicle in using bloc method, it is necessary to open a small line just above the hepatic hilum near the right side of the base of

hilum's groove (the base of round ligament) to lower the hilum plate and the left hepatic pedicle from parenchyma, open the lesser omentum and dissect the Arantius ligamentum venosum near the hepatic pedicle locating on the upper side of Spiegel's lobe. Using dissector to dissect between these two incisions will allow control of the left hepatic pedicle [15]. En bloc clamping is useful in case the patient has previous surgery that cause adhesions in the liver hilum.

Selective control of the right or left Glisson's hepatic pedicle is also performed continuously or intermittently, especially continuous clamping can be proceeded easily with no need to consider the time of clamping when the right or left hepatic pedicle are appropriately clamped with the part of right or left liver which will be resected. Intermittent clamping might be 15 minutes-clamp and 5 minutes-unclamp or up to 30 minutes-clamp and 5 minutes-clamp [16], [17].

When performing selective control of the right or left Glisson hepatic pedicle, there is almost no hemodynamic changes in patient. It also causes no hepatic ischemia to the half residual liver and no intestinal blood congestion [10]. The blood loss control is as effective as total pedicle clamping when the resected area is smaller than the part supplied by the Glisson's pedicle. At the same time, when resecting right or left liver, clamping right or left Glisson hepatic pedicle appropriately will mark a clear ischemic line, which is a mark to resect the liver. However, even if right or left hepatectomy with appropriate selective control right or left Glisson hepatic pedicle, the remnant liver and its hepatic vein will still bleed out. Malassagne (1998) perform selective control of right or left Glisson hepatic pedicle (partially dissect hepatic artery and portal vein) for 43 patients with major hepatectomy found that this method was safe and reduced bleeding in surgery effectively among 79% of the patients [8].

3.1.2.2. Selective control of hepatic segment vessel

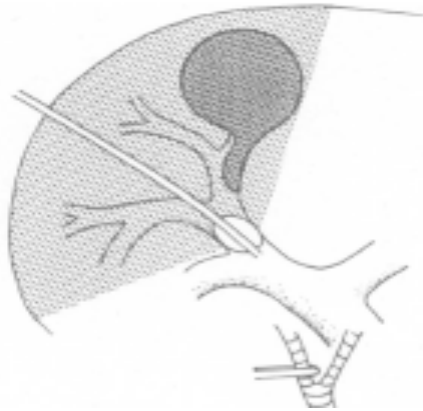


Figure 4. Controlling the intrahepatic segmental portal vein branch by balloon catheter. Castaing. D (1989) [18]

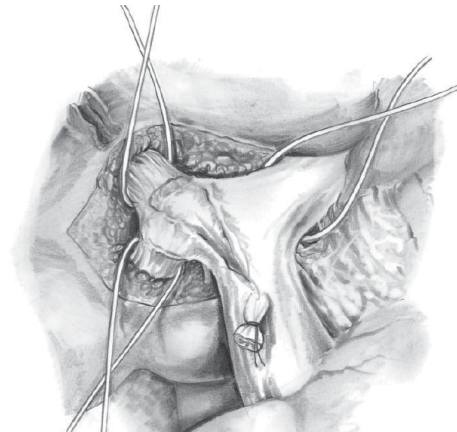


Figure 5. Controlling segmental Glissonean pedicle en bloc. Takasaki. K (2007) [9]

Three methods Selective control hepatic segment vessel are usually applied:

- Using ultrasonic probe to recognize the portal vein of the resected segment. Then reeve a catheter into the portal vein branch of the segment to block portal vein by plumb up the ball. The appropriate artery branch is dissected at the hepatic pedicle [18].

- Dissecting and selective control of segmental Glissonean pedicle was performed by Takasaki and Launois, which called intrahepatic Glissonean pedicle dissecting with posterior approach [9],[13]. Selective segmental Glissonean pedicle clamping is clamping both 3 elements of Glissonean pedicle en bloc because these 3 elements are enclosed in strong and tough Glisson's capsule when going intrahepatically.

- Machado described the opening parenchyma closed hepatic hilum marks to control dissect the segment Glisson pedicle and realized that control clamping helping reduce bleeding, this is the improvement of Launois technique [14], [15].

- Yamamoto described Laenec's capsule structure between hepatic parenchyma and Glisson's capsule, so that dissecting segment Glisson pedicle of Takasaki based on Laenec's capsule at hepatic hilum was convenient and safe [19].

In addition, it is also able to dissect extrahepatic segment of the hepatic artery and portal vein partially to clamp. But this can sometimes damage vascular branches because these branches are enclosed in a strong and tough Glisson's capsule. This method is usually proceeded with the aim to exactly determine the range of resected hepatic segment depending on boundary of ischemic and non-ischemic region better than to control the amount of blood loss during liver resection.

3.2. Control both the hepatic blood inflow and out flow

3.2.1. Total hepatic vascular exclusion

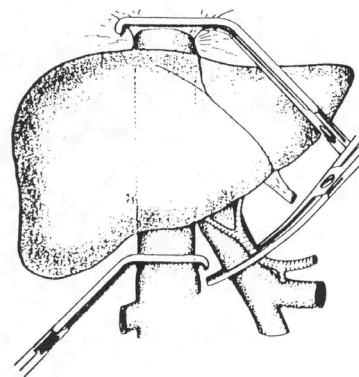


Figure 6: Complete hepatic vascular exclusion. Bismuth. H (1989)[20]

Complete hepatic vascular exclusion is contemporary clamping both the hepatic inflow and outflow, so

the liver is isolated from the circulatory system. The liver must be completely freed from both the right and the left by removing ligaments, the backside of the right liver must be released to clearly expose the right side of the IVC. The vena cava above and below liver are exposed and reeved around. Hepatic pedicle is also totally clamped. Before total hepatic vascular exclusion, it is necessary to report the anesthetist to infuse adequately. The order of clamping is:

Hepatic pedicle → subhepatic IVC → suprahepatic IVC.

Trial clamping must be made in 5 mins after enough infusion, if the decrease of average artery pressure is over 30% or systolic blood pressure decrease over 80mmHg or cardiac output reduced over 50%, one must consider unclamping because the patient are unfit to perform the technique [21]. After complete resection through the parenchyma, clamps are opened in this order:

Suprahepatic IVC → subhepatic IVC → hepatic pedicle.

Total hepatic vascular exclusion might be performed in 70 mins with normal liver[22]. Intermittent hepatic vascular exclusion can not be performed, because the IVC cannot be clamped and unclamped alternately. Despite sufficient hemodynamic monitoring and adequate infusion, total hepatic vascular exclusion clamping cannot be proceeded in 10-15% of the cases. Total hepatic vascular exclusion is usually proceeded in major hepatectomy when the lesion is closed to or adhesive to the IVC.

3.2.2. Total selective hepatic vascular exclusion

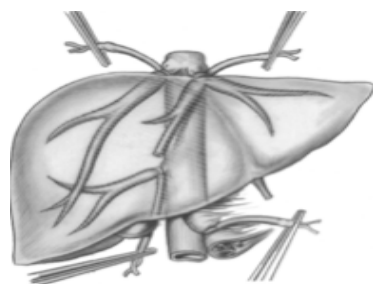


Figure 7. Total selective hepatic vascular exclusion. Smyrniotis. V (2004) [23]

Total selective hepatic vascular exclusion is a combination of total pedicle clamping with extrahepatic vein control so that hepatic vessels are exclusive clamped without interrupting IVC flow[24].

- **To expose and control right hepatic vein:**
The liver must be released to the right border of backside hepatic IVC, some minor hepatic vein can be tie and cut. On the upper part of backside hepatic IVC near where the right hepatic vein flow into IVC there is the inferior vena cava ligament which need to be dissected and cut. Inside the inferior vena cava ligament there might be some small vein branches so all must be carefully tied. After cutting this ligament, the right hepatic vein reveals, using dissector to dissect between the right hepatic vein and the hepatic venous confluence flow into IVC will be able to reeve around to control the right hepatic vein.

- To expose the trunk of middle and left hepatic vein: opening the lesser omentum, dissect and cut the upper part of ligamentum venosum (Aratus ligament) right close to where this ligament cling to the prior of IVC-equal to upper pole of Spiegel's. After ligamentum venosum resection, part of the hepatic venous confluence will reveal. Using dissector to dissect carefully between this region and the region between right hepatic vein and hepatic venous confluence vein which flow into IVC will be able to be reeved around to control this combination of hepatic vein.

Selective hepatic vascular exclusion can be proceeded continuously or intermittently (clamp in 15-20 mins, unclamp 5 mins to next period).

3.2.3. Partial selective hepatic vascular exclusion

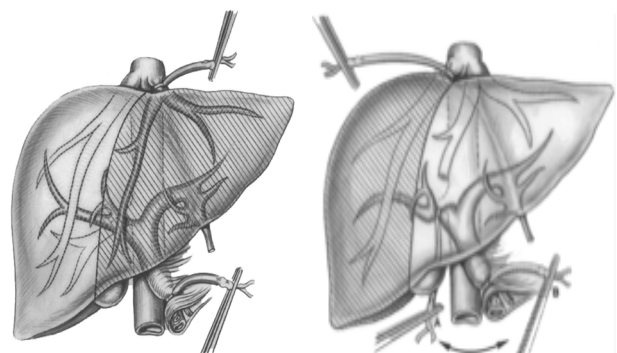


Figure 8. Partial selective hepatic vascular exclusion. Smyrniotis. V (2004) [23]

This method is the combination of selective hepatic pedicle or total hepatic pedicle clamping with right hepatic vein or combination of middle and left hepatic vein clamping. For example: In resecting posterior segment, selective right hepatic pedicle clamping combines with right hepatic vein clamping, is enough to exclude the blood supply of the resected liver. This technique can be proceed as following:

- Total hepatic pedicle clamping, or selective right hepatic pedicle clamping combines with right hepatic vein clamping, applied to resection of right hepatic segments or subsegments.
- Similarly, total hepatic pedicle clamping or selective left pedicle control with combination of middle and left hepatic vein clamping, applied to resection of the left liver.

3.3. Other vascular control method for hepatic resection

3.3.1. Decreasing the central vein pressure

A decrease in central vein pressure (CVP) will lead to the decrease in pressure of hepatic veins, decrease pressure of blood flow from hepatic vein branches in hepatic resection. Therefore, decrease CVP can control the amount of blood loss (in proportion with the pressure) from hepatic vein. Research showed that decrease CVP under 5cmH₂O make a decrease in the loss of blood during surgery[25], [23], [26]. There are two ways to control CVP:

a. Decrease CVP by anesthesiologist

The anesthesiologist can decrease CVP by some methods such as: restricting infusion, reduce the rate the infusion by 0.5-1 ml/kg/h until the liver resection is completed. One can use anesthetics such as Isoflurane has a characteristic of causing vasodilation but has little effect on the heart or one can use vasodilators[27]. Low volume ventilation also helps to decrease CVP[28].

However, decrease CVP by anesthesia has some limits, such as the risk of air embolism and when the circulatory volume increases or decreases, it may affect post-operative renal function. To prevent

the risk of air embolism, many authors suppose that patients should be put in the Trendelenburg position and especially one can use esophageal echocardiogram to detect air in the vena cava, heart chambers for timely treatment.

b. Infrahepatic inferior vena cava control

This technique decreases the return of blood to the heart through IVC, so it makes CVP decrease and reduces the loss of blood from hepatic vein in resection. With this technique, CVP reduction will be performed in case of anesthesia technique fails to decrease CVP or when there is no experienced anesthesiologist [29].

This technique is usually combined with total hepatic pedicle clamping or selective hepatic pedicle clamping. IVC is clamped sub-hepatically and above the two renal veins, which can be dissected to be clamp or not dissected. IVC can be clamped totally or partially.

When IVC clamping technique is performed, CVP decreases in an average of 70%, 13-14mmHg, and the artery pressure is reduced under 10%. This is a simple technique, not technically demanding, the patient tolerates well with the procedure and does not need special monitoring for anesthesia. With this technique it is possible to control bleeding from hepatic veins without needing to control these veins.

3.3.2. Portal vein clamping

Portal vein supply 75% blood amount for the liver and hepatic artery does the remaining 25%, but O₂ supply given by both sources are equal. Simple portal vein clamping will prevent the majority of blood flow from the portal vein but the hepatic artery will still supply O₂ for the liver, so the risk of liver ischemia is reduced or absent. However, this technique still cause intestinal blood stasis and due to the venous clamping increasing adenosine through the humoral pathway leading to hepatic artery dilatation and increased blood flow to the liver. This technique is usually used in patients with cirrhosis, hepatosteatosi...

IV. CONCLUSION

There are many methods to control blood vessels in hepatectomy to reduce blood loss during surgery. Understanding these techniques

as well as applying them appropriately to each type of injury when resecting liver is very useful in controlling blood loss and limiting adverse effects on patients.

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