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TOPICS

Highly advanced surgery in the hepatobiliary and pancreatic field (Liver Section)

Control of the inflow and outflow system during liver resection

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Abstract Control of blood loss is a serious problem during liver resection. Bleeding from the inflow system can be controlled by the Pringle maneuver. The time limit for clamping is up to 10–15 min. A shortcoming of the Pringle maneuver is that it causes blood congestion in the portal vein. To avoid this problem other techniques have been developed including selective vascular occlusion and selective clamping of segmental branches. Bleeding from the outflow system is closely related to central venous pressure (CVP). Lowering the CVP reduces blood loss; in particular, keeping CVP <5 cmH_2O by anesthesiological management is a simple and effective way to reduce blood loss. CVP remains high in some cases despite anesthesiological efforts, but in these circumstances other techniques are available including inferior vena cava clamping below the liver and intraoperative blood salvage.

Keywords Hepatectomy · Bleeding control · Pringle maneuver · Central venous pressure · Portal vein

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Introduction

There are two main sources of bleeding during hepatic resection. One is the inflow system, which consists of the hepatic artery and portal vein. The other is the outflow system, which consists of reflux from the hepatic vein. It is important to control the inflow and outflow systems to reduce bleeding during liver resection.

Inflow system control

All inflow control techniques are performed through operative procedures.

The Pringle maneuver

To control the inflow system, the Pringle maneuver is a useful initial technique, and is the most effective method [1]. It stops blood flow through the hepatic artery and portal vein by clamping the hepatoduodenal ligament (Fig. 1a, b). The time limit for clamping is 10–15 min, followed by 5 min declamping. Brisk bleeding after application of the Pringle maneuver suggests an anomalous hepatic artery.

Other techniques of inflow control

Makuuchi et al. [2] developed hemihepatic vascular occlusion which clamps the hepatic artery and portal vein of the resected area, and Takasaki [3] developed selective clamping of segmental branches. These techniques can avoid portal congestion. The technique for selective clamping of segmental branches is as follows. First, the left, anterior and posterior Glissonean pedicles are taped,

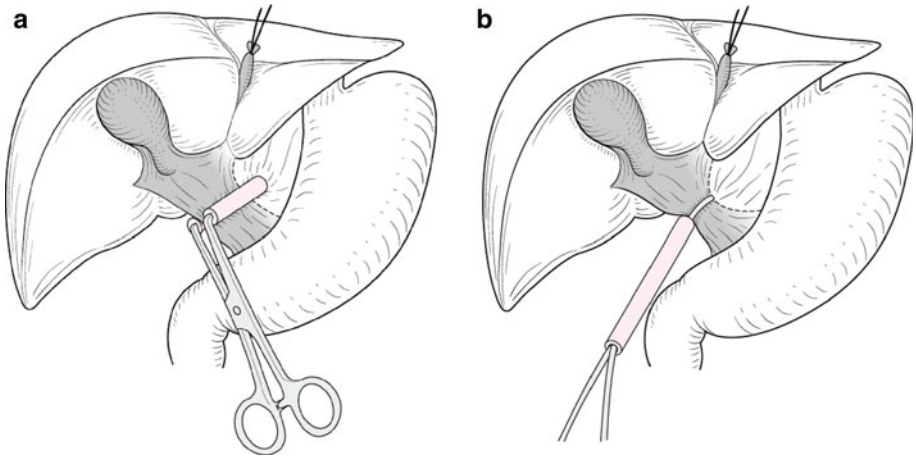

Fig. 1 Pringle maneuver. **a** Inflow clamping using forceps with a sponge to clamp gently and avoid injury. **b** Inflow clamping using tape and tourniquet

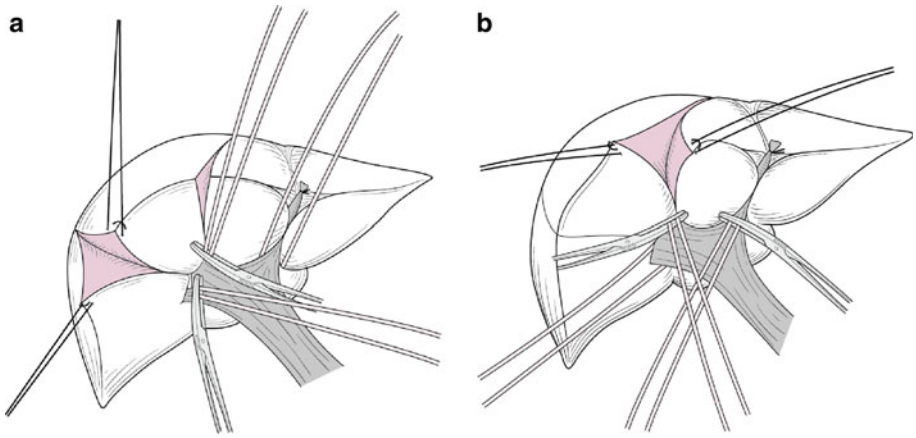

Fig. 2 Selective clamping of segmental branches. **a** Schema of selective clamping of the dissection on the intersegmental plane between left lobe and anterior segment. The posterior branch is free from clamping. **b** Schema of selective clamping of the dissection on the intersegmental plane between the anterior and posterior segments. The left lobe branch is free from clamping

then both sides of the pedicle of the cut surface are clamped (Fig. 2a, b).

Outflow system control

Non-operative procedure

Lowering the central venous pressure by anesthesiological management.

The estimated blood loss from the outflow system strongly correlates with central venous pressure (CVP). It is very important to maintain a low CVP by anesthesiological management. In particular, keeping the CVP below 5 cmH_2O is very effective at reducing bleeding during liver resection [4, 5].

Operative procedure

Total vascular exclusion

To control bleeding from the hepatic vein, Heanly et al. [6] reported the total vascular exclusion (TVE) method, which involves clamping the aorta, the portal pedicle and the infra- and supra-hepatic inferior vena cava (IVC). Huguet and Gavelli [7] modified the TVE method, avoiding clamping of the aorta (Figs. 3, 4).

Total vascular exclusion is used when a liver tumor has invaded the hepatic vein and IVC, so that it is necessary to open the vein before combined resection.

Other techniques of outflow system control

Some patients still have high CVP despite anesthesiological management, in which case clamping the vena cava below the liver is an alternative technique [8]. By clamping the vena cava below the liver, CVP decreases by approximately 4 cmH_2O and bleeding from the cut surface of the liver decreases.

Usually CVP is measured in the superior vena cava (SVC). During clamping of the vena cava below the liver, the mean pressure in the SVC (pSVC) is higher than the mean pressure in the IVC (pIVC) by 2 cmH_2O, and the lowest pIVC is lower than the mean pIVC by 2 cmH_2O. Therefore, when the pSVC is below 4 cmH_2O, the lowest pSVC has negative pressure, which may cause air

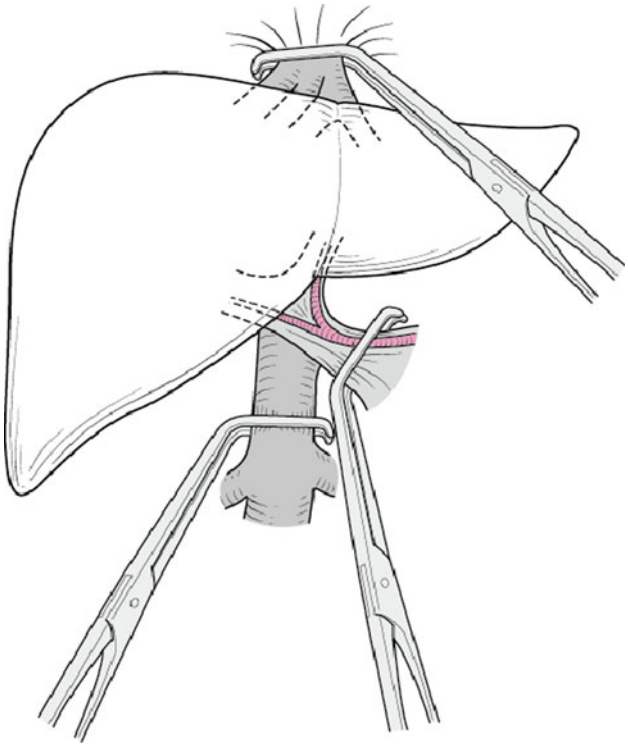

Fig. 3 Schema of total vascular exclusion. The portal pedicle and the supra- and infra-hepatic IVC are clamped

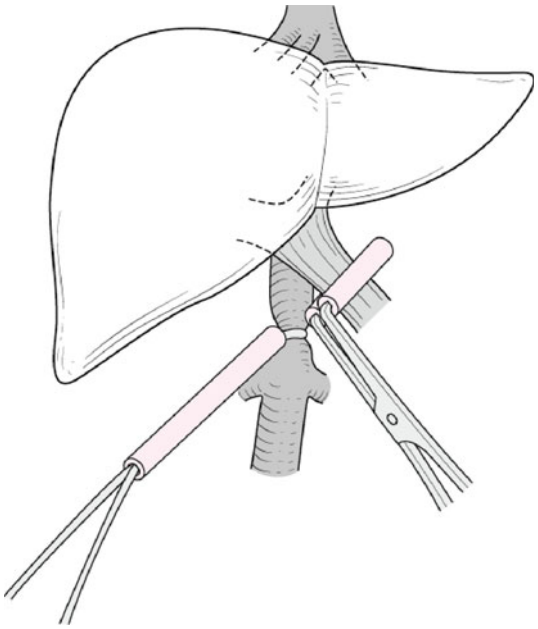

Fig. 4 Schema of IVC clamping below the liver. The portal pedicle and IVC below the liver are clamped

embolism. Thus, the vena cava below the liver should only be clamped when the pSVC is over 4 cmH_2O [10] (Fig. 5).

During IVC clamping below the liver, if the blood pressure decreases below 80 mmHg because of central hypovolemia, the tape is loosened gradually to bring the blood pressure above 80 mmHg. The time limit for clamping is up to 15 min, as in portal pedicle clamping.

Hashimoto et al. [9] reported that modest intraoperative blood salvage with a blood volume equal to approximately 0.7% of the patient's body weight significantly and safely reduced blood loss during hepatic parenchymal manipulation in liver transplantation patients.

Discussion

Many techniques which control the inflow and outflow systems to reduced bleeding during liver resection have been reported (Table 1).

The Pringle maneuver was reported as a means to control bleeding due to liver injury with a limit of clamping time allowed of up to 1 h. The effectiveness of the Pringle maneuver was attested through a randomized controlled study [11].

A shortcoming of the Pringle maneuver is intestinal congestion. To avoid this problem Makuuchi et al. [2] and Takasaki [2] reported new techniques.

To control the outflow system Heaney et al. [6] reported TVE involving clamping the portal pedicle, the supra-hepatic IVC and the infra-hepatic IVC which is the point on the upper side of the branch of the adrenal vein. Recently, to simplify this method, we usually clamp the IVC at the lower side of the branch of the adrenal vein. After these vascular clamping techniques, the drainage roots of the adrenal vein and the infra-phrenic vein stop working, which causes bleeding and high CVP. This is paradoxical bleeding of TVE. In comparison with the Pringle maneuver, TVE is not used in conventional liver resection since the latter needs a longer operation time and therefore clamping time, and requires a large volume of transfusion to compensate for the lowered cardiac output. The large transfusion volume causes lung complications after the operation. However, TVE may be used in cases in which a liver tumor has invaded or formed tumor thrombi in the hepatic vein or IVC, so that in order to resect the tumor, exposure of large vessels or combined resection of these vessels is required.

Another technique of outflow system control, lowering the central venous pressure during the operation by anesthesiological management, is very effective. To keep low central venous pressure, the transfusion should be reduced to 1 ml/kg/h [6]. The technique requires the understanding and cooperation of the anesthesiologist. Sometimes we experience a case in which the central venous pressure remains high despite strict anesthesiological control. When this occurs, the central venous pressure and total estimated blood loss can be reduced by clamping

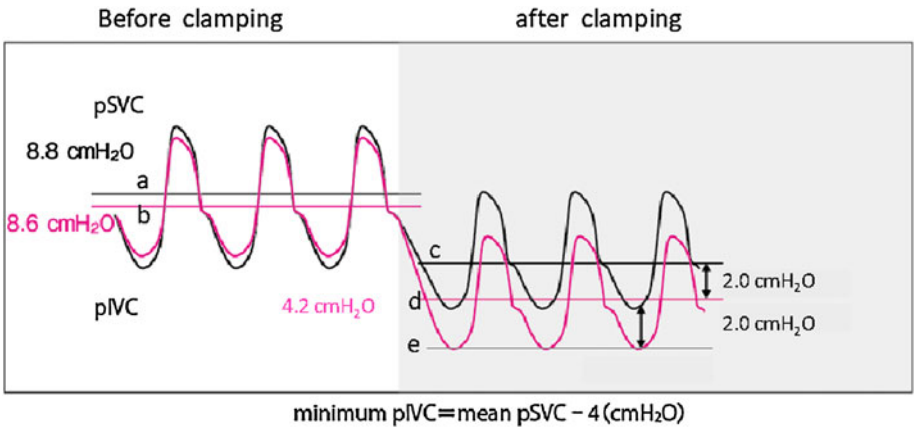

Fig. 5 Change of CVP before and after IVC clamping below the liver. **a** Mean pSVC before clamping, **b** mean pIVC before clamping, **c** mean pSVC after clamping, **d** mean pIVC after clamping, **e** minimum pIVC after clamping

Table 1 Chronological table of vascular control of liver surgery

Inflow system control		
1907	Pringle [1]	Pringle maneuver
1987	Makuuchi et al. [2]	Hemihepatic vascular occlusion during resection of the liver
1993	Takasaki [3]	Selective clamping of segmental branches
Outflow system control		
1966	Heaney et al. [6]	Total vascular exclusion
1978	Huguet and Gavelli [7]	Modified total vascular exclusion
1998	Melendes et al. [4], Jones et al. [5]	Low central venous pressure anesthesia
2001	Belghiti [12]	Liver hanging maneuver
2004	Otsubo et al. [8]	IVC clamping below the liver
2007	Hashimoto et al. [9]	Intraoperative blood salvage

the inferior vena cava below the liver. The technique of IVC clamping below the liver was developed as follows. A hepatic resection was being performed in which bleeding from the cut surface could not be controlled even by using the TVE technique. The upper side of the IVC was then declamped while maintaining the lower side clamping, resulting in decreased bleeding from the cut surface of the liver parenchyma.

Conclusion

A surgeon should consider the concept of the inflow and outflow system in order to reduce blood loss during liver resection.

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Conflict of interest I declare that I have no conflict of interest.

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