Review Articles

Protection of the liver during partial hepatectomy

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BACKGROUND: **Liver failure is the most common cause of mortality for patients undergoing partial hepatectomy. Given adequate liver function and remnant liver volume and absence of co-morbid illness, the cause of liver failure is frequently related to technical errors, which induces massive bleeding and ischemic damage to the liver remnant.**

DATA RESOURCES: **From author's practice at Queen Mary Hospital, the University of Hong Kong.**

RESULTS: **To avoid technical errors leading to liver ischemia and failure, adequate exposure, control of bleeding during liver transection, and planning of transection plane are important. Ultrasonic dissector is the best instrument in liver transection. Its careful use can reduce blood loss and help recognize the hepatic vein, the exposure of which serves as an important landmark for a correct transection plane. Even without Pringle maneuver, minimum bleeding during transection could be achieved.**

CONCLUSION: **Protection of the liver remnant is important to patient survival after partial hepatectomy. It is achieved by meticulous surgical techniques that reduce bleeding to a minimum.**

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KEY WORDS: **anterior approach; middle hepatic vein; ultrasonic dissector**

Introduction

The outcome of the patients undergoing partial hepatectomy depends on the preoperative liver function, surgical technique and postoperative care. Much has been written on preoperative assessments of liver function[1] and remnant liver volume,[2] but little is on the surgical technique, especially the protection of the liver remnant. Given adequate liver function and remnant liver volume and absence of co-morbid illness,[3] the majority of operative deaths of hepatectomy are due to liver failure, which occurs as the liver remnant sustains various forms of injury, such as prolonged ischemia and hyperdynamic injury to small liver remnant, especially in small livers and liver congestion as a result of inadvertent injury or resection of the major hepatic veins. Massive bleeding which may occur during hepatectomy induces ischemia in many organs, including the liver. It also predisposes the patient to sepsis[4] and systemic inflammatory response syndrome,[5] both result in multi-organ failure and mortality (Fig. 1).

Exposure

Adequate exposure is important to avoid injury to the liver. In general, bilateral subcostal incision with midline extension is sufficient for the majority of cases. However, for a large right lobe tumor or a tumor located in segment 7 or 8, exposure is much facilitated by J-shape incision.[6] It consists of midline incision followed by a thoraco-abdominal extension along the seventh, eighth or ninth intercostal space. With a strong self-retaining retractor, exposure of the entire anterior surface of the liver is possible. Such exposure will allow easy mobilization of the right lobe of the liver, safe dissection of the retroperitoneum and the space in between the inferior vena cava (IVC) and the posterior surface of the caudate lobe. Thoracotomy was once thought to be unnecessary and dangerous in hepatectomy. In recent years, however, comparative studies have shown that if needed, it resulted in less blood transfusion requirement than in cases using the abdominal approach.[7,8] There was no increase in postoperative morbidity and mortality rates even though the operation time was longer.[8]

Anterior approach of right-sided hepatectomy

Mobilization of the right lobe and detachment from the anterior surface of the IVC are the standard procedures before transection of the liver. With adequate inflow

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and outflow control, liver transection could then be carried out expeditiously. A normal liver can be easily rotated to the left or brought out of the abdominal cavity, but for a fibrotic or cirrhotic liver, mobilization could be difficult. Moreover, twisting of inflow and outflow pedicles and compression of the left lateral segment against the left subcostal wound frequently occurs during rotation of the right lobe.[9] When a piece of gauze is left inadvertently at the liver hilum during mobilization, the ischemic effect from compression of the gauze onto the portal vein is even more pronounced. To avoid ischemic injury, the rotation has to be intermittent and any gauze in the liver hilum or pack over the duodenum and stomach should be removed. Forceful mobilization is also disadvantageous as avulsion of the hepatic vein may occur leading to severe bleeding, iatrogenic rupture of the tumor, which may lead to peritoneal cancer cell seeding and massive bleeding, and squeezing of the tumor, which may lead to systemic dissemination of cancer cells. To avoid all these hazards, the anterior approach is advisable.[10] By the anterior approach, after initial hilar dissection, the liver is transected by an ultrasonic dissector from the anterior surface down to the liver hilum and anterior surface of the IVC without prior mobilization of the right lobe of the liver. A comparative study showed that the anterior approach could reduce bleeding volume and blood transfusion requirement, and prolong disease-free and overall survival rates.[10] A potential problem of the anterior approach is the difficulty of control of major bleeding from the hepatic vein branches on the liver transection surface. A modification of the anterior approach has recently been proposed mainly to enhance posterior control and hemostasis. Called the liver hanging maneuver,[11] it consists of passing a long instrument followed by a sling in the space between the anterior surface of the IVC and the back of the liver. Though claimed to be advantageous,[12,13] it has not undergone any comparative studies. The blind passage of the instrument in front of the IVC could sometimes lead to tearing of the IVC or caudate hepatic vein, which could not be controlled until liver transection is completed or the procedure is converted to mobilization of the right lobe. The sling may provide a direction for liver transection. However, it is important to recognize that the transection plane, if along the Cantlie line in right or left hepatectomy, is not vertical, but oblique along the course of the middle hepatic vein. Thus, in the case of right or left hepatectomy, the original plane of transection should initially be guided by the middle hepatic vein. Only when the middle hepatic vein is passed, then the sling may provide the correct direction of transection.

Control of bleeding during liver transection

Bleeding volume and transfusion requirement play a major role in determining the long-term survival of liver tumor patients undergoing hepatectomy.[14] A perfect hepatectomy should therefore be one with little blood loss, and, in addition, adequate tumor-free resection margin, maximum preservation of non-tumorous liver, infliction of little ischemic damage to the liver remnant, and exposure of the middle hepatic vein for right or left hepatectomy. Exposure of the middle hepatic vein is important as it shows the landmark and guideline for the transection plane so that the transection plane is exact, with little devitalized tissue on one side or no sacrifice of normal tissue on the other side (Fig. 2). Exposure of the middle hepatic vein is also important in the situation where a large tumor encroaches onto the middle hepatic vein, which must be preserved for adequate drainage of the liver remnant (Fig. 3). Exposure of the middle hepatic vein is facilitated by the use of an ultrasonic or wa-

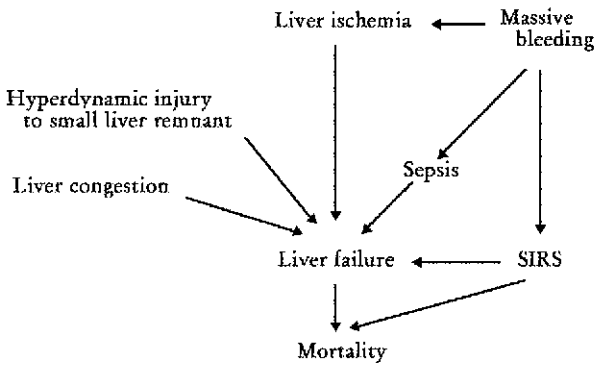

Fig. 1. Reasons for operative mortality in partial hepatectomy.

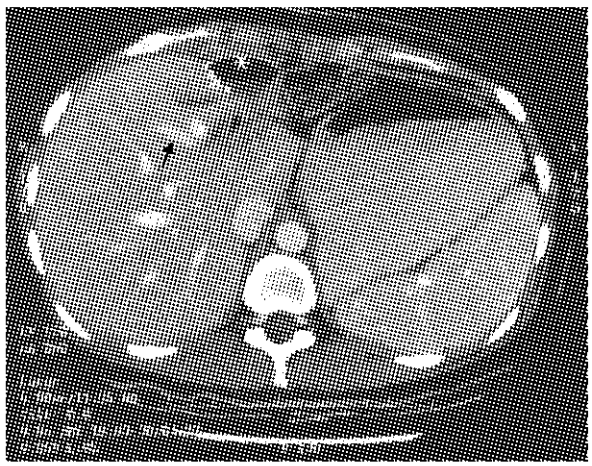

Fig. 2. Computed tomography of a patient undergoing left hepatectomy for intrahepatic stones in the left intrahepatic duct. The operation was complicated by subphrenic abscess (white asterisk). A portion of segment 4 was left behind and might have contributed to subphrenic abscess formation as many segregated segment 4 ducts might have leaked into the subphrenic space. The middle hepatic vein was clearly seen (black arrow).

ter-jet dissector, whereas other types of liver transection device, e. g. harmonic scalpel, may not be able to achieve the goal. Exposure of the major hepatic vein is thought to be dangerous. With a low central venous pressure, however, bleeding from the minor holes of the hepatic vein could be readily controlled by pressure, hemostatic materials, or fine sutures, whereas larger hepatic vein branches could be seen clearly and controlled by metal clips or ligatures.

Pringle maneuver facilitates the liver transection by producing a relatively bloodless field, but bleeding can still occur from the hepatic vein. To control the bleeding, total vascular occlusion could be employed, but it may produce substantial hemodynamic disturbance.[15] If the suprahepatic and infrahepatic IVCs are occluded in addition to the portal pedicle, lumbar vein blood may regurgitate into the liver, producing severe liver congestion. Therefore, to reduce bleeding from the hepatic vein, a low central venous pressure of 5 cmH_2O is preferred to any kind of outflow control.[16] Intermittent Pringle maneuver is perhaps better than continuous Pringle maneuver. It was shown in a prospective randomized trial that intermittent Pringle maneuver could reduce bleeding volume from the transection surface.[17] But the trial also demonstrated that the beneficial effect of the Pringle maneuver in chronic liver disease patients is lost when the accumulated ischemia is more than 120 minutes as reflected by higher levels of postoperative alanine aminotransferase and plasma interleukin-6, an inflammatory reaction marker, in the first week.[18] Thus, prolonged Pringle maneuver is not totally harmless.[3]

To get rid of the time constraint of Pringle maneuver and the inherent pressure induced, we currently practise liver transection without inflow or outflow control. With cautious application of the ultrasonic dissector, we were able to reduce bleeding volume during transection year by year to a median volume of about 600 ml in fibrotic or cirrhotic liver (Fig. 4) and about 200 ml in right lobe liver donors (Fig. 5). On the other hand, many surgeons believe that intermittent Pringle maneuver is beneficial.[19] Apart from reduction of bleeding volume, there is a possibility of protective effect of ischemic preconditioning.[20] The issue of Pringle maneuver is still controversial. Perhaps, for training

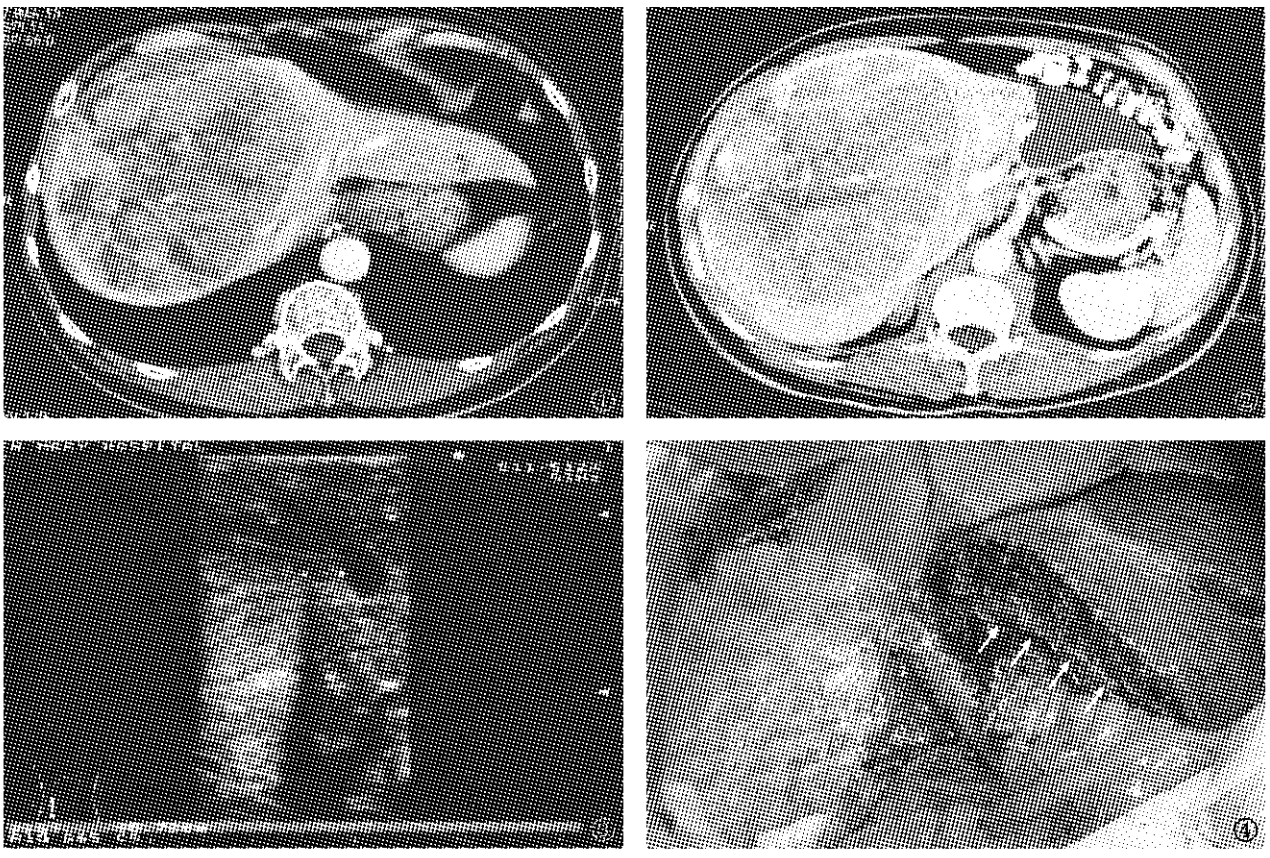

Fig. 3. ① Computed tomography of a patient with huge hepatocellular carcinoma displacing the middle hepatic vein. ② The left lateral segment was relatively small and the patient may die of liver failure if a right trisegmentectomy is performed. ③ Intraoperative ultrasonography showing that the distance between the tumor and middle hepatic vein was 7.2 mm. ④ Post-resection photo showing the liver transection and the exposed middle hepatic vein (white arrow). By keeping the transection close to and exposure of the middle hepatic vein, a reasonable tumor-free resection margin could be obtained.

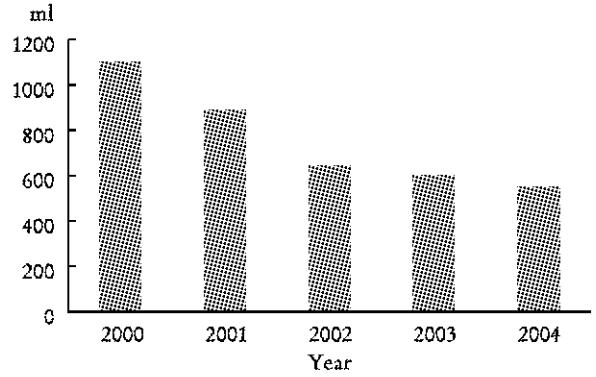

Fig. 4. Median volume of blood loss of patients undergoing partial hepatectomy for liver tumors without Pringle maneuver at Queen Mary Hospital, Hong Kong.

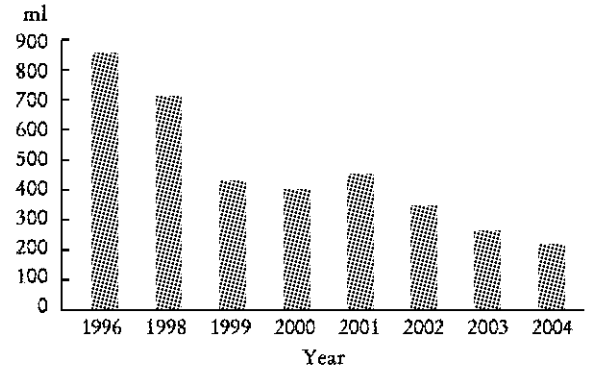

Fig. 5. Median blood loss of donors of right lobe donor hepatectomy at Queen Mary Hospital, Hong Kong.

purpose, the Pringle maneuver is useful. Once the surgeons have acquired their technique, it would be worthwhile to practise liver transection without the Pringle maneuver (and hence no chance of liver damage) and prepare for the occasion when liver transection requires more than 120 minutes or live donor hepatectomy is practised. It may be true that liver transection rarely requires longer than 120 minutes. The fact is that whereas liver transection could be completed hastily under Pringle maneuver within a short time, much time and effort are required to achieve hemostasis after delivery of the specimen. By applying an ultrasonic dissector cautiously and slowly, a completely dry transection liver surface is obtained after delivery of specimen and time and effort for further hemostasis is usually not required.

The ultrasonic dissector is currently the most frequently used instrument for liver transection.[21] Though it can reduce bleeding volume, it is not yet a perfect instrument for liver transection because it may damage the hepatic vein, especially when the power of the machine is set too high. Massive bleeding can also occur when the surgeon is impatient and uses it as a mechanical dissector instead. To avoid bleeding, the ultrasonic dissector should be used gently and the amplitude of the movement of the tip of the dissector should not be too wide to avoid inducing so much bleeding that the assistant cannot manage to stop. Radiofrequency ablation,[22] saline-link and radiofrequency dissecting sealer,[23] and ligasure[24] have been introduced in recent years for bloodless liver transection. They are probably useful for resection of peripherally located tumors and when recognition of major intrahepatic portal pedicles is not important. Thus far, they could not replace the ultrasonic dissector in the case of "perfect" right or left hepatectomy.

Other liver protection strategies

Liver injury may occur if the liver remnant is small and portal hypertension is severe, a condition that is increasingly realized upon increasing application of adult-to-adult live donor liver transplantation. If such damage could be anticipated, splenic artery ligation or splenectomy could reduce portal inflow and alleviate liver damage.[25]

On completion of right hepatectomy, the left lobe may be rotated into the right subphrenic cavity causing left hepatic vein torsion and liver congestion.[26] The phenomenon is especially obvious when the entire caudate lobe is resected with the right lobe. To prevent liver rotation, the falciform ligament must be reconstituted. Over-correction, however, must be avoided. Vascular sling around the hepatic artery and portal vein or their branches may be employed during hilar dissection, not so much for partial hepatectomy for liver tumor but for Klatskin tumor. Such slings may produce spasm and narrowing of the inflow vessels. Papaverine or lignocaine may be useful to restore blood flow into the liver. Similarly, sling around the hepatic vein may inadvertently induce outflow obstruction. Therefore, all vascular slings must be removed once they are not required.

Summary

To avoid liver failure, the surgeon should avoid any ischemic injury to the liver remnant as far as possible. Prolonged vascular occlusion and rotation of the liver should be avoided. Meticulous surgical technique and careful liver transection must be exercised. A maximum amount of liver remnant must be retained and any injury or sacrifice of the major hepatic vein avoided. The survival of the patient depends much on the surgeons' wisdom, technique and knowledge in protection of the liver during the operation.

Competing interest

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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