

REVIEW ARTICLE

The liver hanging manoeuvre

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Abstract

The liver hanging manoeuvre (LHM) facilitates the anterior approach (AA), which is one of the most important innovations in the field of major hepatic resections. The AA confers some definite advantages over the classical approach, in that it provides for: less haemorrhage; less tumoral manipulation and rupture; better haemodynamic stability by avoiding any twisting of the inferior vena cava; reduced ischaemic damage of the liver remnant, and better survival for patients with hepatocellular carcinoma (HCC). The LHM makes the AA easier because it serves as a guide to the correct anatomical transection plane and elevates the deep parenchymal plane. The LHM is a safe technique, in which minor complications have been reported in $\leq 7\%$ of patients and $>90\%$ feasibility has been demonstrated in experienced centres. Over the years, different variants of the LHM have been developed to facilitate almost all anatomical liver resections. In view of its advantages, feasibility and safety, the LHM should be considered for most anatomical hepatectomies.

Keywords

liver, hanging manoeuvre, anterior approach, anatomic resection, caval avascular plane, hepatocellular carcinoma

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Introduction

Complete liver mobilization and extrahepatic vascular control for right hepatectomy was first described by Lortat-Jacob and Robert in 1952.¹ This technique increased the safety of major hepatectomies and hence was adopted by most hepatic surgeons as the conventional approach to right hepatic resection.^{2–4}

However, over the years, some drawbacks of liver mobilization have emerged, including: (i) a high risk of haemorrhage as a result of the difficulty of right-sided mobilization, especially in cases in which a huge tumour invades the surrounding structures;^{5–7} (ii) manipulation of the tumour with risk of tumour rupture or systemic dissemination of cancer cells;^{8–10} (iii) intraoperative systemic haemodynamic instability caused by the twisting and compression of the inferior vena cava (IVC),¹¹ and (iv) damage to the remnant liver caused by mechanical compression of the parenchyma and inflow reduction by pedicle torsion.^{11,12}

To circumvent these problems, the ‘anterior approach’ (AA) was proposed by Ozawa in 1992¹³ and later developed by practitioners

in Hong Kong.^{6,11,14} This unconventional approach consists of parenchymal transection without prior mobilization of the liver.

The beneficial effects of this technique in relation to decreased intraoperative blood loss and transfusion requirements have been demonstrated in the literature.^{6,11,14–18} These advantages may reflect the fact that mobilization of the right liver is easier after parenchymal transection, even with large tumours. Secondly, the AA is a ‘no-touch’ technique because it involves minimal manipulation of the tumour. In a prospective randomized study comparing right hepatectomy for hepatocellular carcinoma (HCC) using the AA and a conventional approach (CA), the overall cumulative survival of the AA group was significantly better than that of the CA group, probably as a result of reduced blood loss and less tumour cell dissemination. The study also showed that all postoperative mortalities in the CA arm were related to liver failure, whereas none of the patients in the AA group suffered this complication.¹⁴ This result is in accordance with Ozawa’s theory that the AA might contribute to better preservation of postoperative liver function by avoiding pedicle torsion and mechanical

compression of the remnant liver.^{12,13} Moreover, in cases of cholangiocarcinoma with cholangitis or pyogenic abscesses, this no-touch technique may reduce the risk of bacterial translocation into the bloodstream.^{15,18}

However, the significant drawback of the AA concerns bleeding control in the deeper parenchymal plane as a result of the difficulty involved in elevating the liver and providing effective manual compression for haemostasis.^{6,14}

The liver hanging manoeuvre

In order to overcome this drawback, in 2001 our group described a technique termed the 'liver hanging manoeuvre' (LHM). In this

procedure, the liver is lifted by a tape passed between the anterior surface of the vena cava and the liver, thereby providing effective vascular control, in order to make the AA safer and easier.¹⁹

Anatomical basis

The most important step of the LHM is the dissection along the anterior aspect of the retrohepatic IVC (RHIVC) (Fig. 1).¹⁹ The existence of a longitudinal avascular plane between the IVC and the liver makes this manoeuvre feasible (Fig. 2).

The anatomy of the RHIVC and its venous tributaries is complex and variable; however, some general characteristics remain constant. The left anterolateral part of the RHIVC receives

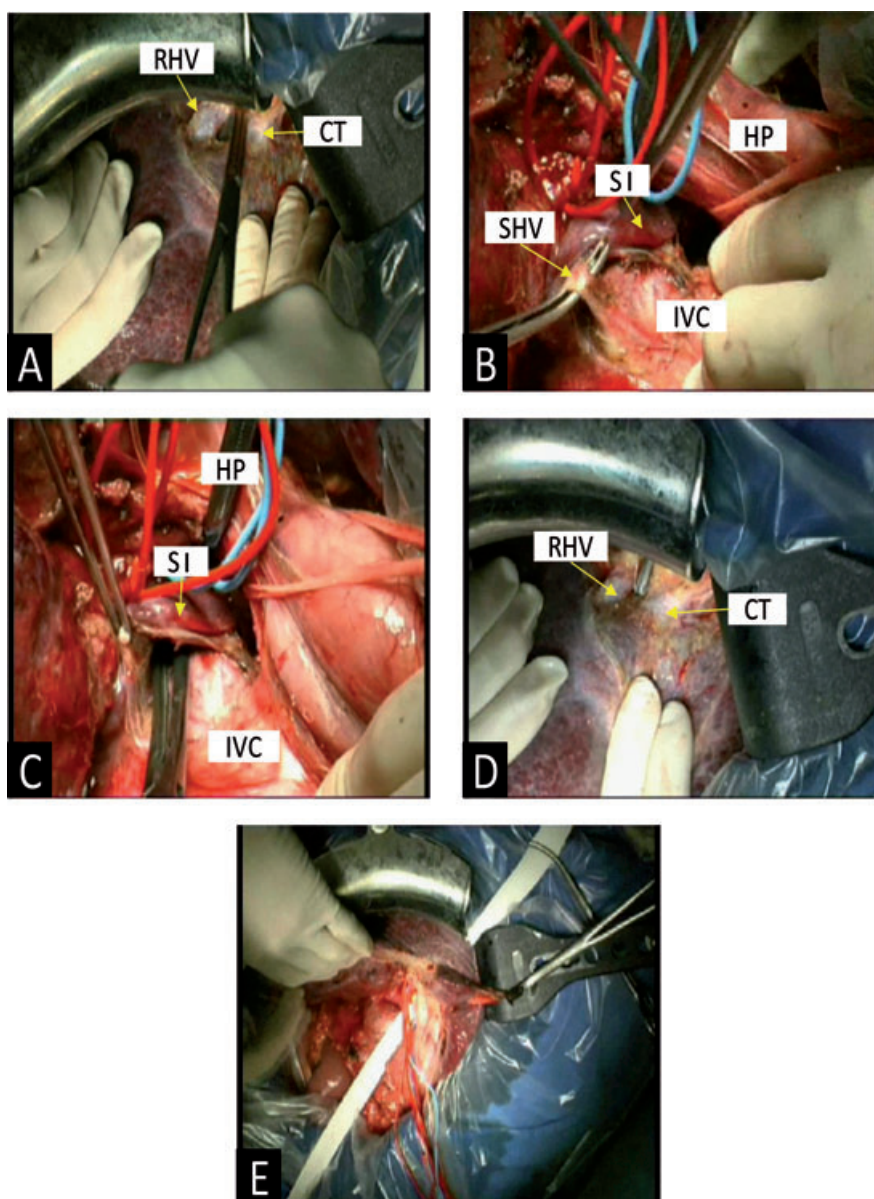


Figure 1 Classic technique for the liver hanging manoeuvre. (A) A dissection of approximately 2 cm is made between the right hepatic vein (RHV) and the middle hepatic vein (MHV). (B) Ligation and section of the lower short hepatic veins (SHVs) are performed. (C) Cranial dissection of the avascular space is facilitated by a vascular clamp. (D) At the end of dissection, the clamp appears between the RHV and MHV. (E) A tape is positioned in the avascular space. CT, common trunk; SI, segment I; HP, hepatic pedicle; IVC, inferior vena cava

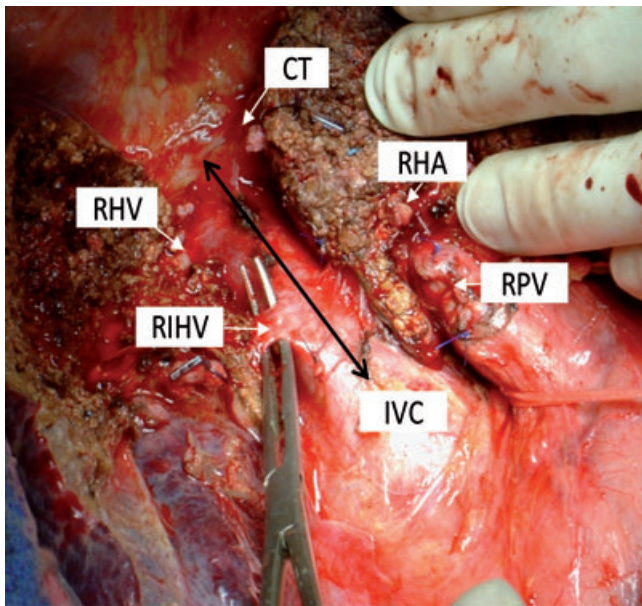


Figure 2 Right hepatectomy by anterior approach. The parenchymal transection is performed without prior mobilization of the liver. The black arrow shows the avascular space located at 10–11 o'clock along the anterior wall of the inferior vena cava (IVC). RHV, right hepatic vein; CT, common trunk; RIHV, right inferior hepatic vein; RHA, right hepatic artery; RPV, right portal vein

the caudate processus vein in its middle portion. The right anterolateral part of the RHIVC receives the caudate processus vein in its caudal part and, if present, the right middle hepatic vein and/or the right inferior hepatic vein (RIHV) in its cranial part. The caudate short hepatic veins (SHVs) are variable in number, position and dimension, but most of them are submillimetric.^{20–24} Although the SHVs can be theoretically present over the whole anterior aspect of the RHIVC, in 1981 Couinaud described the presence of a longitudinal avascular plane between the IVC and the liver.²⁵ Since the first description of the LHM, several anatomical studies have been performed to confirm the existence of this space.^{21–23,26–29} The presence of a constant avascular channel located at the 10–11 o'clock position along the anterior wall of the RHIVC has been confirmed by a majority of authors.^{21,23,29} Others have reported the presence of small SHVs in the avascular space in 7–15% of cases.^{21,22}

The classic technique

The LHM was first described to facilitate right hepatectomy by AA. In this first variant of the procedure, the anterior aspect of the suprahepatic IVC is exposed and the space between the right hepatic vein (RHV) and the middle hepatic vein (MHV) is dissected along the IVC axis for 2–3 cm (Fig. 1A).

The rest of the dissection is carried out on the infrahepatic IVC. The hepatic pedicle is retracted to the left and segment I is lifted from the IVC. The anterior aspect of the infrahepatic IVC is dis-

sected and the SHVs are ligated and divided if necessary (Fig. 1B). When present, the RIHV should be safeguarded. A long, lightly curved aortic clamp is inserted behind the caudate lobe just to the left of the RIHV and passed cranially along the anterior surface of the IVC between the 10 and 11 o'clock positions towards the space between the previously dissected RHV and MHV (Fig. 1C, D). When the dissection is complete, the hepatic parenchyma is looped up with a tape (Fig. 1E).

During the parenchymal transection, continuous upwards traction is applied on the tape by holding both its ends together. The tape ensures the safety of the underlying major vascular structures during transection in a manner akin to dissecting on the finger to protect an important underlying structure. The tape elevates the liver, making it easier to transect, and constantly guides the surgeon towards the correct plane, thereby enabling a vertical transection along the shortest possible route. The traction on the tape can also be regulated to provide control in instances of venous bleeding to help identify the bleeding vessel.

Technical evolutions

Since the LHM was first described, the technique has come to be considered very useful,^{30–32} but potentially dangerous as a result of the possible risk of injury to SHVs during the blind dissection.^{19,27,32,33} For this reason, various techniques have been developed to facilitate retrohepatic dissection and make the LHM safer.

- 1 *'Guided' dissection techniques.* Kokudo and colleagues described a retrohepatic dissection assisted by intraoperative ultrasound (IOUS). This allows for the identification of most SHVs during the entire course of the dissection and thus avoids possible injuries. No substantial bleeding and no other complications related to retrohepatic dissection were encountered using this technique.³² Other authors have proposed an endoscopically³³ or laparoscopically²⁹ assisted LHM, whereby the retrohepatic tunnel is directly visualized and safely dissected using the endoscope or laparoscope. Other techniques proposed to reduce the risks of LHM consist of 'bimanual bi-finger' dissection of the avascular space^{34,35} and dissection using small surgical instruments such as paediatric suction devices³⁶ or small surgical probes.³⁷
- 2 *'Up-to-down' technique.* In our centre, we have modified the classic technique of LHM in recent years and have significantly increased its feasibility by ensuring that no major bleeding occurs during the manoeuvre.¹⁷ The entire blind dissection of the RHIVC tunnel is performed in a cranio-caudal direction in order to avoid the possible risk of RHV or MHV injury by the clamp inserted caudally. The manoeuvre is begun between the RHV and MHV; this space usually does not contain SHVs^{21,26,38,39} and can be safely dissected for 3–4 cm downwards with a right-angled vascular clamp (Fig. 3A) without any risk. The long axis of the RHIVC does not always represent a straight perpendicular line, but may take a straight-oblique or slightly curved course (Fig. 4A).^{21,32,40} For this reason the dissection

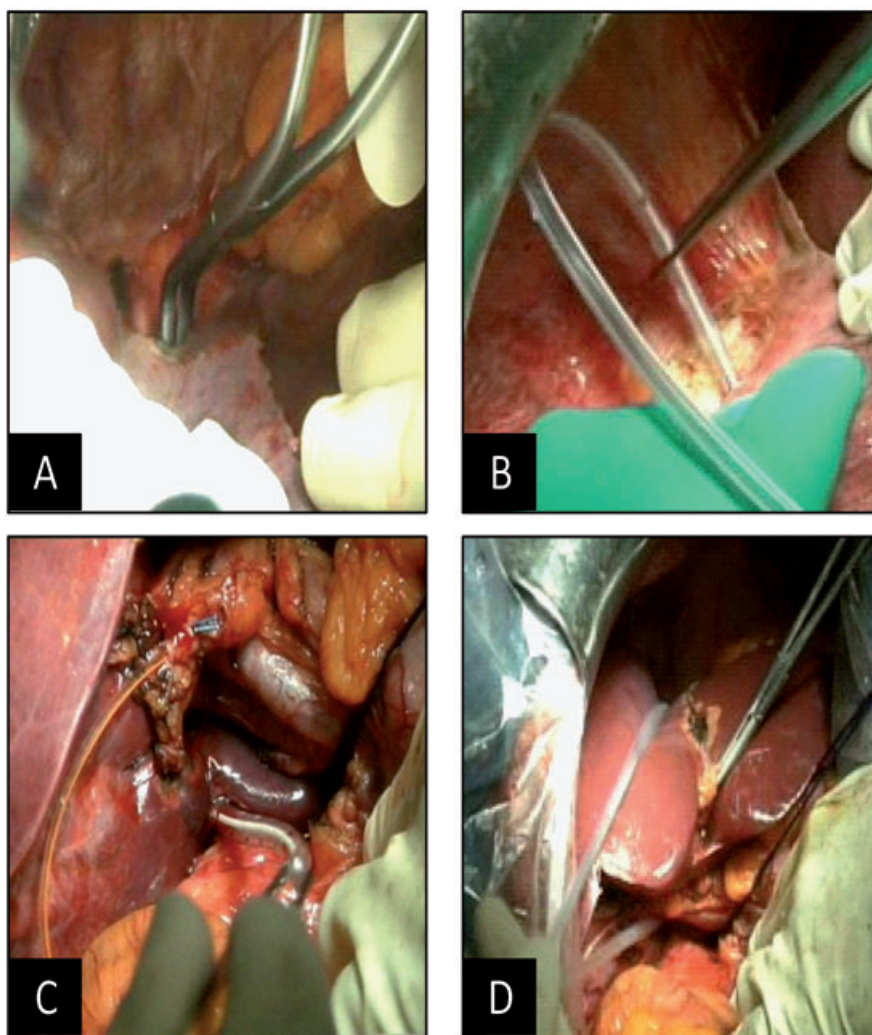


Figure 3 Technical variation of the liver hanging manoeuvre. (A) Dissection between the right and middle hepatic veins with a right-angled vascular clamp for approximately 4 cm. (B) Dissection of the avascular space is completed by a 14-Fr nasogastric tube. (C) Recovery of the nasogastric tube on the right of the infrahepatic inferior vena cava. (D) The technique is completed

should be performed along a right oblique axis rather than in a vertical direction to reduce the risk of injury to the caudate process veins (Fig. 4B). Once achieved, the clamp is replaced by a 14-Fr nasogastric tube. This tube is pushed caudally to complete the dissection of the avascular space (Fig. 3B–D). The rigidity of the nasogastric tube allows it to be used as a dissector to prepare the avascular space. Moreover, its rounded tip allows for atraumatic dissection and prevents any damage to SHVs. In our experience, the feasibility of this ‘modern LHM’ is greater than that of the original LHM. In our initial practice of the procedure, we recorded a failure rate of 6%, but, recently, <1% of LHM procedures as practised currently have failed.¹⁷ Compared with the original version of the procedure, the modern LHM is safer, less time-consuming and less haemorrhagic.

The nasogastric tube has been used by other authors as a substitute for the tape, but not for dissection.^{30,41–43} In fact, the tube is very useful during hepatic transection because it is less traumatic to the liver parenchyma, is very effective for traction and is less

likely to be accidentally damaged by the ultrasonic dissector, electrocautery or scissors. It also protects the cava from injury at the end of transection.

Another strategy to facilitate the LHM involves reducing the length of the blind dissection. This can be achieved by a caudal ligation of the SHVs up to the level of the RIHV.^{17,38,39,44} A further reduction can be achieved by an associated caudate process resection.⁴⁵

3 Double-tape technique. To obtain an optimal vascular control during transection, double hanging tapes can be inserted in the avascular space. When the two tapes are lifted in opposite directions, this double LHM achieves complete control of outflow along the transection plane. In a variation of this technique, Chen *et al.* recently proposed the passage of a double tape into a tunnel prepared on the right of the IVC to avoid any risk of bleeding.⁴⁶ This manoeuvre is performed in an avascular space and maintains some of the advantages of the standard LHM, such as bleeding control and exposure of the deeper parenchy-

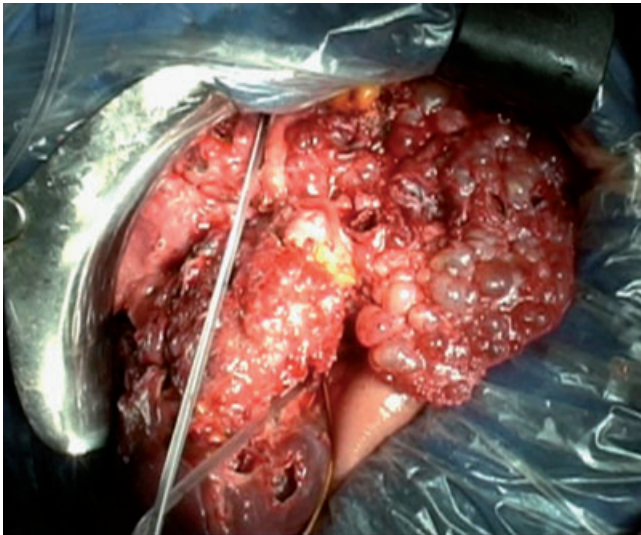


Figure 4 Liver resection for polycystic liver disease: in conditions in which liver anatomy is severely distorted, the hanging tape is useful to guide the resection along the correct plane

mal plane. However, this manoeuvre cannot act as a guide to the right transection plane because the tapes are not positioned along the anatomical axis of resection.

The combination of IOUS, reduction of the longitudinal length of the avascular space by SHV ligation, a cranio-caudal direction of dissection and use of atraumatic instruments (i.e. the nasogastric tube) can increase the feasibility of the procedure and reduce the risk for major bleeding.

Advantages of the hanging manoeuvre

Many reports in the literature demonstrate that the LHM makes the AA easier and safer.^{17,19,31–33,35,36,41,44,45,47–49} One of the most important advantages is that the tape guides the surgeon along the correct anatomical plane, thereby facilitating a vertical transection along the shortest possible route.^{17,30,41,43,44,48,50,51} This can be especially useful in maintaining good orientation in conditions in which the liver anatomy is distorted, such as portal vein embolization, segmental liver atrophy, large tumours and in polycystic disease (Fig. 4). Lifting the hanging tape elevates and opens up the transection plane, which makes it easier to identify and manage vessels and bile ducts, even in the deep parenchymal plane.^{30,43,44,51} Moreover, this traction helps to reduce venous backflow bleeding in a similar manner to finger compression, thus facilitating a bloodless transection.^{17,19,26,44}

A retrospective non-randomized study comparing hepatectomies with or without LHM showed similar levels of intraoperative blood loss in the two groups. However, the authors demonstrated a shorter transection time in the LHM group.⁴¹ In addition to the double-hanging technique described earlier, LHM combined with a Pringle's manoeuvre can help to achieve complete vascular

exclusion localized only along the transection plane. Compared with the classic total vascular exclusion techniques,^{52–55} this manoeuvre allows total inflow and outflow control in a technically easier and less daunting manner. Moreover, the vascular exclusion is limited to the transection line and, consequently, the remnant liver is spared the ischaemic insult associated with classic total vascular exclusion.

Thus the LHM enhances the safety of the AA and facilitates the approach without involving any manipulation of either remnant or diseased liver, thereby improving the oncological advantages of the AA and reducing the ischaemic damage to the remnant liver.

Complications during the procedure

No cases of procedure-related mortality in the LHM have been reported in the literature. Mishaps during this procedure are uncommon (0–7%) and are usually minor. Complications are almost always vascular in nature.^{17,30,31,38,39,47}

One of the most common causes of bleeding during the procedure is dissection into the subcapsular plane.^{17,30,56} At the beginning of the dissection between the RHV and MHV, all the fibrous tissue in front of the IVC must be incised. If it is not, the dissection may begin in too superficial a plane and may lead into the capsule and cause haemorrhage. Bleeding is generally minor and self-limiting and is associated with progressively increasing resistance to the dissecting instrument. The key to avoiding this complication is to expose the anterior aspect of the IVC completely by dissecting all the overlying fibrous tissue. In such cases, the LHM can be safely reattempted after better caval exposure or by performing the entire dissection in a cranio-caudal direction.

Another cause of bleeding is injury to an SHV.^{17,32,48,56} This can occur if the dissection is performed in the wrong direction (i.e. too far to the left of the IVC) (Fig. 5) or, more rarely, if an unusual SHV is present in the avascular plane.^{30,32} Given the small size of these vessels and the potential contraction of circular muscular fibres at the junction of the SHVs with the RHIVC,^{22,26,56} this complication can be managed by inserting gauze in the dissection plane and releasing the traction on the liver. The weight of the liver usually provides sufficient tamponade to achieve haemostasis. In instances of persistent bleeding, mobilization of the liver may be necessary to achieve haemostasis.⁴⁸ The blind dissection must be performed with particular care in cases of major hepatic vein compression or thrombosis. This situation may lead to compensatory hypertrophy of the SHVs⁵⁷ with considerable reduction or obliteration of the avascular space.¹⁷

Limits and contraindications

According to our experience and the literature, there are few contraindications for LHM.

The only definite contraindication to this manoeuvre is infiltration of the avascular plane by the liver lesion.^{17,35,43} However,

it is difficult to determine whether or not direct invasion to the IVC exists by preoperative imaging alone. Hashimoto *et al.* found that only 11.5% of patients with suspected caval invasion on preoperative computerized tomography (CT) had caval involvement intraoperatively.⁵⁸ Several reports of hepatectomies with IVC resection have shown that resected specimens often do not exhibit direct histological invasion of the IVC wall.^{59–62} For these reasons, a careful attempt of the LHM may be worthwhile even when there is suspicion of IVC involvement on preoperative imaging.^{38,43}



Figure 5 (A) The normal anatomical course of the retrohepatic inferior vena cava (RHIVC) is straight-oblique or curved. (B) The dissection of the avascular space should be performed cranio-caudally following a right oblique axis (arrow). A straight vertical dissection (dotted line arrow) falls on the left aspect of the RHIVC and carries a risk of lesion to the short hepatic veins

Direct invasion of tumours to distal major hepatic veins, the diaphragm, the retroperitoneum, or tumour contact with the IVC except the avascular space are not considered as contraindicative to the LHM. Although an initial assessment may show tumour infiltration of the anterior surface of the IVC, tumour regression induced by systemic chemotherapy may render the retrohepatic space free of tumour, thereby allowing consideration of the LHM.¹⁷

Other situations pose a relative contraindication to the LHM. In an univariate analysis of our series of 242 cases, adhesion between the IVC and liver was the only significant factor negatively affecting the feasibility of the procedure.¹⁷ This can result from previous surgery or severe inflammation of a tumour or benign lesion in close proximity to the RHIVC. In these cases, the avascular plane can be replaced by fibrous tissue, which makes dissection hazardous and introduces a high risk of damage to the IVC or liver, leading to haemorrhage.

Conditions such as cirrhosis, large tumour size, preoperative transcatheter arterial chemoembolization and/or portal vein embolization were previously considered as relative contraindications; however, recent studies have demonstrated that these factors do not significantly affect success rates of the LHM.^{17,38,39,51,63}

Feasibility

The feasibility and limits of the LHM were established in a series of 242 patients considered for major hepatectomy in our centre. Fourteen (6%) patients in whom tumour infiltration of the anterior surface of the retrohepatic IVC was considered to represent a preoperative contraindication to the procedure were excluded. This manoeuvre was subsequently performed in 228 subjects and

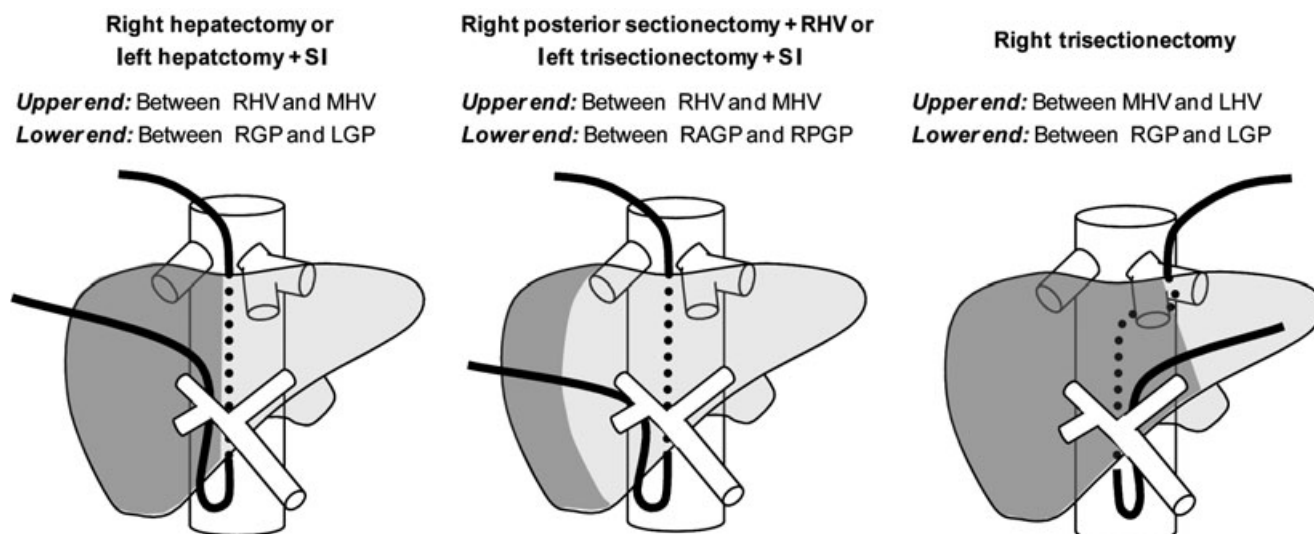


Figure 6 Various techniques for liver resection by hanging manoeuvre using a single tape along the anterior surface of the retrohepatic inferior vena cava. IVC, inferior vena cava; RHV, right hepatic vein; MHV, middle hepatic vein; LHV, left hepatic vein; RGP, right Glisson's pedicle; LGP, left Glisson's pedicle; RAGP, right anterior Glisson's pedicle; RPGP, right posterior Glisson's pedicle; SI, segment I

was successful in 201 of them, demonstrating feasibility rates of 88% overall and 94% for the later period of the study.¹⁷ Similarly high feasibility rates have been obtained in other experienced centres.^{30,38,41,48}

Extended applications

Since it was first described in 2001, the LHM has gained worldwide popularity. It has been utilized not only for liver

tumours, but also in living donor liver transplantation,^{30,50} in orthotopic liver transplantation^{38,39,63} and in benign liver disease.^{17,35} Furthermore, many authors have applied the principles of the classic LHM to facilitate various anatomical liver resections.^{30,41–43,45,47–49,51,64}

Depending upon the type of resection required, the technique involves extrahepatic dissection and isolation of the left, right anterior or right posterior Glisson's pedicles below and the hepatic veins above. One or two hanging tapes are positioned

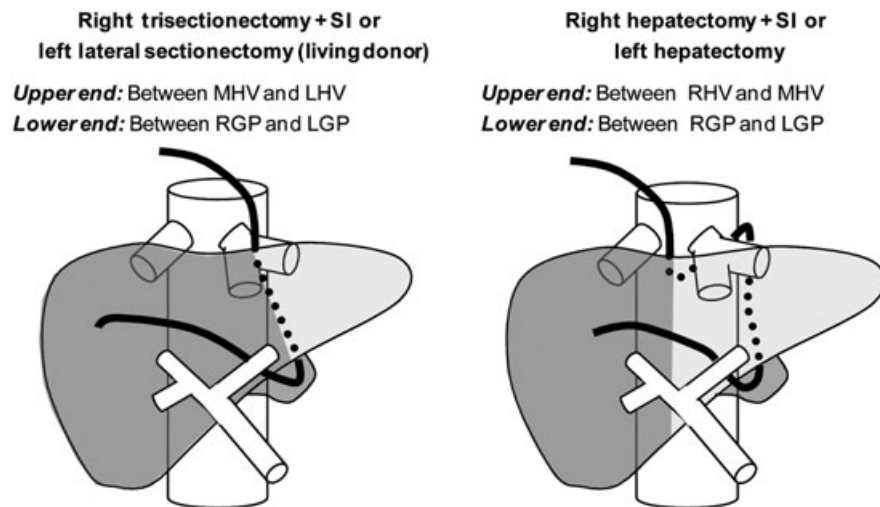


Figure 7 Various techniques for liver resection by hanging manoeuvre using a single tape along the ligamentum venosum. IVC, inferior vena cava; RHV, right hepatic vein; MHV, middle hepatic vein; LHV, left hepatic vein; RGP, right Glisson's pedicle; LGP, left Glisson's pedicle; SI, segment I

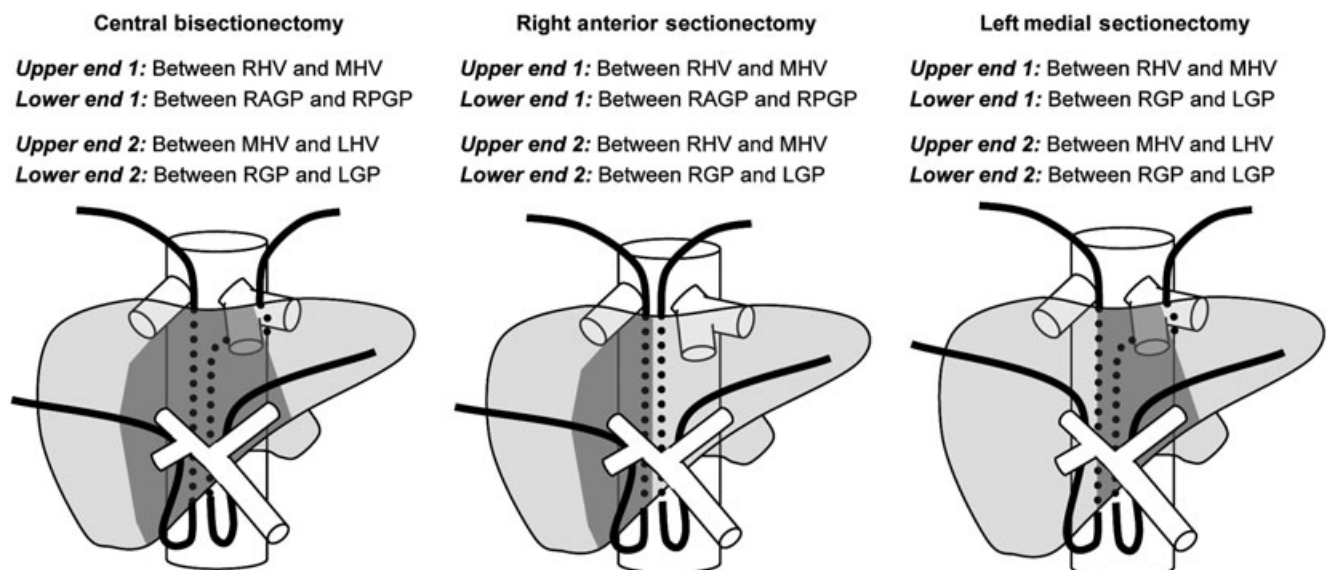


Figure 8 Various techniques for liver resection by hanging manoeuvre using two tapes along the anterior surface of the retrohepatic inferior vena cava. IVC, inferior vena cava; RHV, right hepatic vein; MHV, middle hepatic vein; LHV, left hepatic vein; RGP, right Glisson's pedicle; LGP, left Glisson's pedicle; RAGP, right anterior Glisson's pedicle; RPGP, right posterior Glisson's pedicle

Tape passed between RHV and MHV → behind MHV and LHV → under GP

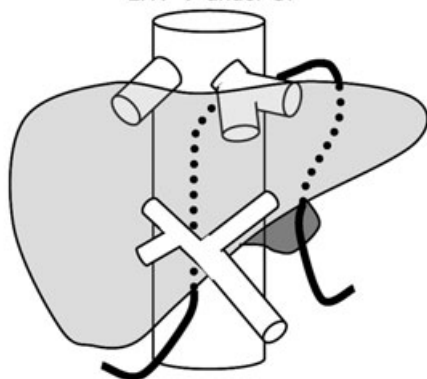


Figure 9 Caudate lobectomy by hanging manoeuvre using a single tape along the anterior surface of the retrohepatic inferior vena cava and along the ligamentum venosum. IVC, inferior vena cava; RHV, right hepatic vein; MHV, middle hepatic vein; LHV, left hepatic vein; GP, Glisson's pedicle

along the anteromedian surface of the RHIVC or the ligamentum venosum (LV) with the upper end between the appropriate hepatic veins and the lower end between the appropriate Glisson's pedicles. Figures 6–9 give a concise summary of the various types of liver resection that can be performed using this technique.

Conclusions

The LHM minimizes the risks associated with the AA and enhances its benefits over the conventional technique. These advantages include reduced haemorrhage, less tumour dissemination, improved intraoperative haemodynamic stability and less ischaemic damage to the liver remnant.

Moreover, LHM serves as a guide to the correct anatomical and vertical transection plane, thereby improving the exposure of the deep parenchymal plane and providing vascular outflow control.

The LHM is a safe technique, in which minor complications have been reported in $\leq 7\%$ of subjects and for which experienced centres have reported feasibility rates of $>90\%$. In recent years, different variants of the LHM have been developed to facilitate almost all types of anatomical liver resection.

The viability of a surgical technique lies in its reproducibility by other surgeons. The increasing numbers of publications concerning the AA by LHM reflect the growing acceptance of this technique worldwide. Given the obvious benefits of the AA by LHM, we believe there is compelling evidence to support the adoption of this procedure as the standard technique for most liver resections.

Conflicts of interest

None declared.

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