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<td>Author(s)</td>
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How I do it

Left Hepatectomy accompanied by Resection of Whole Caudate Lobe using the Dorsally Fixed Liver-Hanging Maneuver

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Running title: Dorsal fixed liver-hanging maneuver

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Abstract.
Resection of the caudate lobe needs to be combined with hemi-hepatectomy for hilar cholangiocarcinoma or liver tumor in segment 1. To achieve complete resection of the whole caudate lobe, the cut-line between the right edge of paracaval portion and right lateral sector should be controlled. The liver-hanging maneuver (LHM) is useful for anterior approach without mobilization of the remnant liver. The precise set up of cut-line of the right edge was not indicated by previous reports yet. We herein introduce a new modification of LHM named “dorsally fixed liver-hanging maneuver” (DF-LHM) by the results in 5 patients who underwent left hepatectomy combined total resection of segment 1. This technique provided adequate cut planes along the right edge of the caudate lobe, shortening the transection time and reducing intraoperative blood loss. DF-LHM can be a key technique for this hepatectomy and further applications to other anatomical resections can be expected.

Key words. Left hemi-hepatectomy· caudate lobe· liver hanging maneuver
Introduction

Resection of the caudate lobe often needs to be combined with hemi-hepatectomy for hilar cholangiocarcinoma or liver tumor mainly located in segment 1.1,2 This procedure is relatively difficult in comparison with conventional hemi-hepatectomy, particularly left hemi-hepatectomy.3 To achieve complete resection of the whole caudate lobe, the cut-line between the right edge of the paracaval portion of the caudate lobe and the right lateral sector must be controlled.4 With such liver resection, transection of the liver parenchyma by an anterior approach without mobilization of the remnant liver is preferable to maintain blood supply as much as possible.5 However, achieving an appropriate transected area on cut lines is not always easy for surgeons without substantial experience.

Belghiti et al.6 proposed the liver-hanging maneuver (LHM) for right hepatectomy without liver mobilization using a tape inserted between the anterior surface of the vena cava and the liver. By lifting this tape, cut lines or planes can always be fixed by the tube placement with consideration of liver anatomy. LHM has gained worldwide popularity for major hepatectomy or hepatectomy for large-size liver tumors or those involving surrounding tissues.7-10 LHM can be applied for various anatomical hepatectomies at this stage. However, few reports have shown the application of LHM to complete resection of segment 1 with or without hemi-hepatectomy.11-13 To the best of our knowledge, this technique has not been fully applied for hepatectomy of the left liver combined with total resection of segment 1 in hilar cholangiocarcinoma or liver tumor located in segment 1.13 We
introduce herein a modified application of LHM for this hepatectomy, named “dorsally fixed liver-hanging maneuver” (DF-LHM).

**Methods**

*Operative Technique*

The patient underwent a J-shaped incision laparotomy (upper median plus right-sided transverse incision to the 10th intercostal space) in a supine position. The falciform ligament was cut to expose the bifurcation of the right, middle and left hepatic veins, and the anterior surface of the vena cava. Mobilization of the left hemi-liver and caudate lobe was performed, but mobilization of the right liver was not. The space between the left and middle hepatic veins was bluntly dissected using a right-angled clamp. A small naso-gastric tube (8-Fr size) was placed between the middle and left hepatic veins in the retrohepatic space (Fig. 1). After mobilization of the right edge of the caudate lobe by dividing all short hepatic veins, this tube was fixed on the scheduled cut line (right edge of the inferior vena cava (IVC)) by a few sutures (Fig. 2). The inferior right hepatic vein was only secured for maintaining outflow from segment 6. Eventually, this tube was repositioned between the hepatic parenchyma and right Glissonian pedicle at the hepatic hilum. Hepatic transection was performed using a combination of the crush clamping method and use of an ultrasonic dissector during intermittent occlusion of hepatic inflow (15-min occlusion, 5-min de-clamping) using hepatic inflow occlusion (Pringle’s maneuver). After transection along the middle hepatic vein on Rex-Countlie line, a cut was made below the middle hepatic vein and transected by always targeting the right edge of the hanging tube (Fig. 3). By
hanging and pulling this tube, the cut plane could be gradually extended toward the paracaval part of segment 1 (scheduled cut line) (Fig. 4). Eventually, adequate total resection of the entirety of segment 1 with left hemi-hepatectomy was successfully achieved by DF-LHM using fixation of the hanging tube in the retrohepatic part on the cut-line in all 5 cases (Figs. 5a and b, Table 1). No severe complications were encountered during hepatectomy.

Statistics

Continuous data were expressed as mean ± SD. Data for different groups were compared using the Mann-Whitney U-test. A two-tailed P value of less than 0.05 was considered significant. All statistical analyses were performed using the StatView Software for Windows, version 5.0 (SAS Institute, Inc., Cary, NC).
Results

Since 2002, LHM has been applied in 43 patients who underwent major hepatectomy. In 7 patients with hilar bile duct carcinomas, left hepatectomy with combined resection of the caudate lobe was performed without LHM. These patients were examined as controls for patients undergoing DF-LHM. In 2009, we performed DF-LHM for left hepatectomy combined with resection of the whole of segment 1 in 5 patients, including 4 patients with hilar cholangiocarcinoma and 1 patient with hepatocellular carcinoma (HCC) in the caudate lobe (Table 1). Scheduled procedures were successfully accomplished in all patients. No trouble was seen during DF-LHM procedures. Mean transection time was significantly lower in the DF-LHM group (39.2±6.5 min) than in controls (50.1±10.3 min; p=0.047). Mean volume of blood loss was significantly lower in the DF-LHM group (720±166 ml) than in controls (1480±690 ml; p=0.01). Hepatectomy-associated complications were not observed in the DF-LHM group, although minor complications were observed in 2 patients. All patients underwent resection without the tumor being exposed at the cut end.
Discussion

In patients with hilar cholangiocarcinoma or tumors in the caudate lobe, major hepatectomy with total resection of the caudate lobe (Spiegel lobe, caudate process and paracaval portion) is usually selected as anatomical curative resection. The cut line of the hilar bile duct without remnant tumor or right side edge of the paracaval portion is technically important point for curative operation. Such hepatectomy often requires a longer time for transection or is associated with a larger volume of blood loss due to the deep location and neighboring major vessels. Transection time or intraoperative bleeding must thus be reduced using innovative techniques. In addition, the key marker of transection during hepatectomy is needed to confirm achievement of transection at an adequate cut plane between the paracaval portion and right lateral sector. In such liver resections, the key marker of transected lines for hepatectomy is fixation of cut lines or interaction with vascular anatomy. An experienced surgeon can easily accomplish such a hepatectomy and a newly devised procedure would be expected for trainees in liver surgery.

LHM proposed by Belghiti et al. has been widely accepted in liver resection and living donor liver transplantation. Mobilization or rotation of the resected liver with liver tumor can be avoided, helping to prevent tumor dissemination by twisting the liver during operation. This technique has been applied not only for right hemihepatectomy but also for left hepatectomy, isolated caudate lobectomy, right or left trisectionectomy, and central hepatectomy. Kim et al. reported that LHM can be applied for various anatomical hepatic resections. To achieve such hepatectomies, devices such as hanging tape or tubes must be placed according to the
vascular anatomy (Glissonian pedicles, hepatic veins and surrounding ligaments).\textsuperscript{24} Kim et al. and López-Andújar et al. reported isolated resection of the caudate lobe using LHM.\textsuperscript{11,12} However, precise explanations regarding the cut-line between the paracaval portion and right lateral sector and the transection procedure on this cut plane were not described. In cases of right hepatectomy with caudate lobe resection for hilar cholangiocarcinoma, LHM can be similarly applied because fixation of the hanging tape or tube along the Arantius veno-portal ligament (between the left lateral sector and Spiegel lobe) is possible in our experience (data not published). Hwang et al. reported application of LHM for left hepatectomy with caudate lobe resection for hilar cholangiocarcinoma.\textsuperscript{13} That report explained the cut-line at the edge of the paracaval portion (right anterolateral wall of the retrohepatic vena cava). Using their technique, the retrohepatic cut-line may slip out of position, leading to failure of cutting in an adequate plane.

Our proposal regarding left hepatectomy with caudate lobe resection using LHM is a simple technique, but fixation of the cut-line can facilitate achievement of the scheduled cut line and plane. By fixating the hanging tube, resected liver parenchyma is always pulled and rotated toward the resected direction (i.e., the left side) by the liver hanging as shown in Fig. 4. We have already reported this mechanism of counter-rotation between the resected liver and remnant liver by a fulcrum of the hanging point in cases of trisectionectomy.\textsuperscript{23} Fixation of the hanging point should be an important procedure. Applying this technique, other anatomical resections by LHM can be made easier, such as right lateral sectoriectomy. In such a hepatectomy, liver hanging tape or tube cannot usually be fixed by the hepatic veins. Using the technique
of fixed LHM, an adequate cut plane along the trunk of the right hepatic vein would be obtained. Furthermore, applications for segmental resection using this technique can be expected, but have not yet been described. When transection of the right edge of the caudate process is performed, the caudal tip of the hanging tube can be replaced between the liver parenchyma and hilar vessels using Kokudo’s gradual repositioning technique. The liver parenchyma of the right edge of the caudate lobe can then be easily resected alone by LHM in the final step. The problem with this procedure is to confirm the right boundary between right lateral sector and the caudate lobe. Counter staining is a useful option to confirm this line of fixation by the previous report. Confirming the right boundary by the counter staining procedure may increase the usefulness of the DF-LHM.

As a preliminary investigation, the present study examined surgical records in 5 cases that underwent left hepatectomy with caudate lobe resection applying DF-LHM compared to those with the conventional procedure. This preliminary analysis showed the usefulness of LHM in left hepatectomy with caudate lobe resection based on results of reduced transection time and decreased blood loss, as well as meeting the expectations described above. Hwang et al. also reported significant reductions in the time required for caudate dissection (by approximately 20 min). Our previous reports have shown reduced transection time in hemi-hepatectomy without caudate lobe resection and transection along the right hepatic vein. With respect to blood loss, some investigators have reported reduced blood loss by LHM, but our previous report did not show any difference in intraoperative blood loss between LHM and non-LHM groups in cases of hemi-hepatectomy without caudate resection.
Differences in blood loss would be associated with transection of the caudate lobe and this point is important to improve surgical results. Using the LHM technique in the present study, we were always able to understand adequate cut planes and control parenchymal hemorrhage without any hesitation during hepatic transection. Differences in transection time might be influenced by the easy transection of the right border of the paracaval portion using DF-LHM and usefulness of LHM can be recognized in the deeper part of the liver. Furthermore, shortening of the hepatic transection in this area may reduce blood loss. When the surgical record of the present 5 patients were compared to that of the 9 patients who underwent the conventional left hepatectomy with LHM in our series, the transection time and blood loss were not significantly different (38.3±9.8 min and 812±590 ml) (p=0.59 and 0.51). DF-LHM may provide results similar to those of conventional left hepatectomy even for more complicated hepatectomy as the present 5 cases. These advantages might result in better surgical results in comparison with the conventional operation for hilar bile duct carcinoma or tumor in the caudate lobe. The DF-LHM procedure itself is very simple and convenient. This technique can thus be recommended to standardize hepatectomy for young trainees in the field of liver surgery.

In summary, we attempted the DF-LHM for left hepatectomy with total caudate lobe resection in 5 patients with hilar cholangiocarcinoma or HCC. This modified LHM with the device of tube fixation provided adequate cut planes along the right edge of the caudate lobe, shortening the transection time and reducing intraoperative blood loss. DF-LHM can be a key technique for left hepatectomy with caudate lobe resection and further applications to other anatomical resections can be expected.
References


FIGURE LEGENDS

Fig. 1 Placement of hanging tube (nasogastric; NG tube) in front of the vena cava. The tube was passed between the middle and left hepatic veins on top of the liver and the caudal tip of the tube was pulled at the right edge of the caudate process.
Fig. 2 Fixation of the NG tube at the cut line (right edge of paracaval portion) behind the liver. Caudate lobe was fully dissected from the vena cava and a few stitches were applied to fix the tube on the cut line.
Fig. 3 During parenchymal transection of the caudate lobe. The tube was fixed at the target cut line behind the liver and hepatic resection was always targeting the right side of the tube.
Fig. 4 Theoretical schematic showing usefulness of liver-hanging maneuver for caudate resection. During resection of the right edge of the caudate lobe, liver hanging (thin arrow) facilitates opening of the adequate cut plane by rotation of the caudate lobe toward the left side (thick arrows).
Fig. 5 Pictures for confirmation of the complete resection of the entire caudate lobe by a) the remnant liver and b) the resected specimen. Thin arrow shows the cut end of the hepatic ducts and arrowhead shows the exposed middle hepatic vein. Thick arrow showed a fixed tube at the right edge of the paracaval portion. IVC: inferior vena cava, PV: portal vein, RHA: right hepatic artery, C: the entire caudate lobe
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M, male; F, female; HBDC, hilar bile duct carcinoma; HCC, hepatocellular carcinoma; PV, portal vein.

*: Transection under hepatic inflow occlusion

#: Cancer-free margin at the hepatic cut end