Preoperative imaging of candidate donors for living donor liver transplantation (LDLT) - What the radiologist needs to know

Poster No.: C-0782
Congress: ECR 2012
Type: Educational Exhibit
Authors: K. I. Ringe¹, J. Weidemann¹, B. P. Ringe¹, H.-O. Shin¹, F. Wacker¹, B. Ringe², ¹Hannover/DE, ²Philadelphia, PA/US
Keywords: Biliary Tract / Gallbladder, Vascular, CT-Angiography, MR-Angiography, MR, Cholangiography, Computer Applications-3D, Diagnostic procedure, Transplantation, Liver
DOI: 10.1594/ecr2012/C-0782

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Learning objectives

The aim of this exhibit is to outline an approach for systematic assessment of relevant imaging information in the preoperative evaluation process of potential living liver donors.
Background

Since the first report of a successful living donor liver transplantation (LDLT) in 1990\textsuperscript{1}, LDLT has become a valuable treatment for patients with end-stage liver disease who cannot receive deceased donor livers. Particularly in children, in whom a graft is required that is small enough in size, the use of liver transplantation is limited due to shortage of deceased donor organs.

Since the safety of volunteer living donors in LDLT has always been considered paramount, evaluation of potential candidates plays a crucial role to confirm suitability and to identify possible contraindications. Overall donor morbidity is estimated to be approximately 35\% (in particular due to bile leakage, wound infection, ileus)\textsuperscript{2}. A recent survey identified 33 living liver donor deaths, including 3 donors who succumbed after an attempted rescue with a liver transplant\textsuperscript{3}.

Each transplant center has its own protocol for living donor evaluation, which typically includes a comprehensive medical and psychosocial examination as well as non-invasive imaging and other studies to assess size, anatomy and function of the liver. CT and MRI have evolved into important components in the process of donor evaluation, and are being used concurrently in different centers throughout the world\textsuperscript{4,5}. 
Imaging findings OR Procedure details

Preoperative imaging of the living liver donor has three major objectives: (1) to identify any intraparenchymal lesions or abnormalities; (2) to visualize the extra- and intrahepatic vascular and biliary anatomy; (3) to determine the size of the whole liver and calculate the graft and remnant liver volumes.

1. Parenchymal assessment:

Assessment of liver parenchyma includes the appraisal of general parenchymal changes, such as fatty infiltration, as well as the detection and characterization of eventual focal liver lesions (Figure 1).

The degree of fatty infiltration in hepatic grafts in known to be an important risk factor for primary graft nonfunction in deceased donor liver transplantation as well as in LDLT. Liver grafts with a mild degree of fatty changes can be used for liver transplantation without ill effect, but liver grafts with moderate or severe degree of fatty changes have been found to have a negative effect on post transplant graft function and patient survival. Marcos et al estimated that 1% of hepatic steatosis can decrease the functional graft mass by 1%. In our institution the acceptable upper limit of fatty changes in the liver graft is 30%.

2. Evaluation of intra- and extrahepatic vascular and biliary anatomy:

In this educational poster only few anatomic variations are shown representatively. For more interactive movies please visit www.knowledgecontainer.de.

a. Hepatic artery

The typical hepatic artery anatomy can be found in approximately 55% (Figure 2). It comprises a right and left hepatic artery arising from the common hepatic artery (and a middle hepatic artery arising either from the left or right hepatic artery). Hepatic arterial variations can be classified according to Michel. Variations may include accessory vessels as well as dystopic branching of the hepatic arteries (Figure 3, 4). Certain variations may require modification of the surgical procedure, while others may be a contraindication for surgery. Due to the greater variability of the right hepatic vascular anatomy right hepatectomy can be one of the most challenging surgical procedures.
b. Portal vein

The portal vein is formed by the confluence of the splenic vein and the superior mesenteric vein (Figure 5). In the liver hilum it branches into left and right portal vein, respectively. The left portal vein divides into a superior and inferior branch, whereas the right portal vein divides into an anterior (segment 5+8) and posterior (segment 6+7) branch. The caudate lobe (segment 1) is most often supplied by the left portal vein. Variations of the central portal veins can be found in up to 20%, on a segmental level in nearly every patient (Figure 6, 7).

c. Hepatic veins

The typical hepatic vein anatomy consists of three hepatic veins draining into the hepatic inferior vena cava (Figure 8). Segment 1 is usually drained by a small separate vein. The left hepatic vein usually drains segments 2-4a, the middle hepatic vein segments 4b-5 and the right hepatic vein segment 6-8, respectively. It is important to describe the number and size of additional hepatic veins, because they might cross initially planned resection lines (Figure 9, 10).

d. Bile ducts

Biliary complications, including bile leakage and stricture occur in 7-10%, and represent the most common cause for morbidity in LDLT. Knowledge of bile duct anatomy is further important as anatomic variants may require modification of graft procurement and ductal anastomosis, or even exclude living donation. Intrahepatic variations of the bile ducts can be classified as suggested by Ohkubo 2004 [10].

The classic biliary anatomy appears in approximately 52%. The common hepatic duct branches in the hilum into the left (LHD) and right hepatic duct (RHD). Tributaries draining segments 2-4 form the LHD. Segment 1 drains into the left or right hepatic duct. The RHD branches into the right hepatic posterior duct (RPD), draining segment 6+7, and into the right hepatic anterior duct (RAD), draining segment 5+8. The RPD usually runs posterior to the RAD and inserts medially. The cystic duct drains approximately halfway between the porta hepatis and the Ampulla of Vateri from a lateral position into the common hepatic duct, giving rise to the common bile duct [11,12] (Figure 11, 12). Normal diameters: common bile duct 6-7mm, post CHE up to 9mm, in children <4mm; cystic duct 1-5mm.

Anatomic variations of intrahepatic ducts: Congenital variants occur in 21-54% [9, 13, 14] (Figure 13-16).

- Right hepatic posterior duct (RPD) draining into the left hepatic duct (LHD) (6,7-19%)
• Right hepatic anterior duct (RAD) draining into the left hepatic duct (LHD) (3-4%)
• Hilar trifurcation due to confluence of the RPD, RAD and LHD (7.9-22%)
• Right hepatic posterior duct draining into the common hepatic duct (3.3-5%)
• Accessory hepatic ducts, most often in the right lobe (4%)
• Cysticohepatic ducts (Luschka): hepatic ducts emptying directly into the gallbladder (1-2%)

**General implications of intrahepatic bile duct variations:**

• Usually of no clinical significance, but may lead to diagnostic confusion on imaging studies
• Increased potential risk for iatrogenic injury during surgery
• Aberrant ducts near the cystic duct / gallbladder have the greatest risk of iatrogenic injury

**Anatomic variations of the cystic duct:** Congenital variations occur in 18-23% \(^\text{14}\) (Figure 17-20).

• Variable **level of insertion** into the common hepatic duct (high <> low)
• Variable **insertion position** into the common hepatic duct
  • Right lateral insertion (49.9%)
  • medial insertion (18.4%)
  • anterior or posterior insertion (31.7%)
  • Variable **course** of the cystic duct
    • Parallel or spiral to common hepatic duct
• **Dystopic** insertion
  • Into the right hepatic duct or common hepatic duct near the hilum (0.3%)
  • Rarely into the duodenum

• **Double cystic duct** with / without duplication of gallbladder
• **Absence of cystic duct** with gallbladder emptying directly into the common bile duct

**3. Liver volumetry:**

Preoperative assessment of total, graft and remnant liver volume is of utmost importance, since inadequate liver volume can influence patient and graft survival. There are several formulas for calculating total liver volume depending on the body weight, body surface and gender \(^\text{15, 16}\). Results do not always correlate and liver volume is often overestimated \(^\text{17}\). Depending on the individual method used, it is considered acceptable when the ratio between graft weight and recipient body weight or between graft volume and the estimated standard liver volume of the recipient are at least 0.8% and 40%, respectively
In case of left lateral donation remnant liver volume is usually safe for the donor, whereas graft size might be too large in small children (Figure 21).
Fig. 1: Donor candidate in whom the left lateral segments where resected for LDLT. Simultaneously, a focal nodular hyperplasia (FNH) in the right lobe, incidentally detected in the CT scan, was resected.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE
Fig. 2: Typical hepatic artery anatomy.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE

Hepatic Artery Anatomy Variations I
(Michel Type IV)

CT-Angiography: Axial (A, B) and coronal (C) maximum intensity projections. Replaced left hepatic artery arising from the left gastric artery, and replaced right hepatic artery arising from the superior mesenteric artery.

Fig. 3: Exemplary hepatic artery variation: Michel Type IV

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE
Fig. 4: Exemplary hepatic artery variation: Michel Type IX.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE
Fig. 5: Normal portal vein anatomy.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE
Fig. 6: Exemplary variation of the portal vein.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE
**Fig. 7:** Exemplary variation of the portal vein.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE
Normal Hepatic Vein Anatomy

Fig. 8: Normal hepatic vein anatomy.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE
**Fig. 9:** Exemplary variation of the hepatic veins.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE

**Hepatic Vein Anatomy Variation II**
**Fig. 10:** Exemplary variation of the hepatic veins.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE

**Fig. 11:** Bile duct anatomy.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE
Fig. 12: Typical bile duct anatomy (Ohkubo Type A).

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE
Anatomic Variations of Intrahepatic Ducts
Ohkubo Type C

**Fig. 13:** Ohkubo Type C.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE
Anatomic Variations Intrahepatic Ducts
Ohkubo Type E

CT-Cholangiography: Coronal MIP (B), axial MIP (C) and 3D VR image (D) show dystopic insertion of the RPD (*) into the common hepatic duct.

Clinical Implications:
- high risk of iatrogenic injury during surgery
- right lobe LDLT possible with two bile duct anastomosis required and higher risk of postoperative complications
- in case of left lobe / left lateral LDLT no difference to normal anatomy

Fig. 14: Ohkubo Type E.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE

Anatomic Variations Intrahepatic Ducts
Ohkubo Type B

MR-Cholangiography: Coronal MIP (B), axial MIP (B) and 3D VR image (C) showing hilar trifurcation (confluence of LHD, RPD, and RAD).

Clinical Implications:
- right lobe LDLT possible with two bile duct anastomosis required, higher risk of postoperative complications
- in case of left lobe / left lateral LDLT no difference to normal anatomy

Fig. 15: Ohkubo Type B.
Anatomic Variations of Intrahepatic Ducts (not classified by Ohkubo)

**Fig. 16:** Anatomic bile duct variation.

CT-Cholangiography: Coronal MIP (B), axial MIP (C) and 3D VR image (D) depicting long right hepatic duct (→) which branches into multiple smaller ducts draining the right lobe of the liver.

**Clinical Implications:**
- suited for right lobe LDLT and left lobe / left lateral LDLT with one bile duct anastomosis
Anatomic Variations of the Cystic Duct

CT-Cholangiography: Coronal MIP (B), axial MIP (A) and 3D VR image (D) showing high insertion of the cystic duct into the common hepatic duct.

Clinical Implications:
- suited for right lobe LDLT and left lobe / left lateral LDLT with one bile duct anastomosis (suprahilar no difference to normal anatomy)
- mistaking the cystic duct for a bile duct can result in iatrogenic injury
- ligation of the cystic duct too close to the common hepatic duct at CHE may result in stricture of the latter

Fig. 17: Anatomic variation of the cystic duct.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE

Anatomic Variations of the Cystic Duct

CT-Cholangiography: Coronal MIP (B), axial MIP (C) and 3D VR image (D) depicting low insertion of the cystic duct into the common hepatic duct from a medial position.

Clinical Implications:
- suited for right lobe LDLT and left lobe / left lateral LDLT with one bile duct anastomosis (suprahilar no difference to normal anatomy)
- a long parallel course implies a common fibrous sheath of the cystic duct and common bile duct (cave at CHE !)
- a low cystic duct can be mistaken for the common bile duct on imaging studies
- cannulation of the common bile duct might be difficult at ERCP and intraoperative cholangiography
Fig. 18: Anatomic variation of the cystic duct.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE

Variations of the Cystic Duct

CT-Cholangiography: Coronal MIP (B) and 3D VR image (C) show spiral course of the cystic duct with a medial insertion into the common hepatic duct. In addition hilar trifurcation of the intrahepatic bile ducts is present.

Clinical Implications:
- right lobe LDLT possible with two bile duct anastomosis required, higher risk of postoperative complications
- in case of left lobe / left lateral LDLT no difference to normal anatomy

Fig. 19: Anatomic variation of the cystic duct.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE
Fig. 20: Anatomic variation of the cystic duct.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE
**Fig. 21:** Typical resection planes for LDLT.

© Institut für Diagnostische und Interventionelle Radiologie, Zentrum Radiologie, Medizinische Hochschule Hannover - Hannover/DE
Conclusion

In LDLT donor safety is of paramount importance. The preoperative imaging process is demanding and conscientious. The radiologist plays a key role in filtering and providing the required information to the surgeon, and may help to identify unsuitable donors during the complex evaluation process. This tutorial is an aid to young as well as advanced radiologists that helps to understand the complexity of living donor liver transplantation and the importance of non-invasive imaging modalities in the process of donor evaluation.


