3D-CT ANGIOGRAPHY OF HEPATIC VESSELS PRIOR TO LIVER TRANSPLANTATION USING 8-MDCT

An Essay
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Abstract

Living donor liver transplantation is increasingly being used to help compensate for the increasing shortage of cadaveric liver grafts. However, the extreme variability of the hepatic vascular systems can impede this surgical procedure. Detailed knowledge of the hepatic angioarchitecture is essential to ensure safe and successful liver surgery. 3D- helical CT angiography is a promising method of determining vascular anatomy. Evaluation of potential living donors was conducted in which an 8-detector-row CT scanner was used to obtain arterial phase and portal dominant phase images following the intravenous injection of contrast material, after which 3D MIP and VR images were created. The vascular anatomy was evaluated, with special attention given to the presence of variants, especially those considered relative or absolute contraindications for donation, those requiring reconstruction, or those potentially altering the surgical approach.

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List of Abbreviations

2D	Two-dimensional
3D	Three-dimensional
CHA	Common hepatic artery
CT	Computed Tomography
DTPA	Diethylenetriamine pentaacetic acid
ERCP	Endoscopic retrograde cholangiopancreatography
EUS	Endoscopic US
GB	Gall Bladder
GBWR	Graft to body weight ratio
GDA	Gastroduodenal artery
HU	Hounsfield Unit
IOUS	Intraoperative US
IVC	Inferior Vena Cava
LDALT	Live donor adult liver transplantation
LDLT	Living donor liver transplantation
LHA	Left hepatic artery
LHV	Left hepatic vein
MDCT	Multidetector CT
MHA	Middle hepatic artery
MHV	Middle hepatic vein
MIP	Maximum intensity projection
MRCP	Magnetic resonance cholangiopancreatography
MRI	Magnetic resonance imaging
PV	Portal vein
RHA	Right hepatic artery
RHV	Right hepatic vein
RLDLT	Right lobe donor liver transplantation
RLT	Reduced-sized transplantation
SLT	Split-liver transplantation
SMA	Superior mesenteric artery
SSD	Shaded Surface Display
US	Ultrasonography
VR	Volume Rendering

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Introduction & Aim of Work

Adult living donor liver transplant (LDLT) programs are increasingly used as a response to a growing demand for liver transplantations and the limited availability of cadaveric livers. Adult living donor transplantation has been found to be a safe and efficacious treatment for patients with end-stage liver disease. However, LDLT may cause morbidity in an otherwise healthy donor who generously takes such an important risk for a loved one. Therefore, donor safety is a primary concern, and selection protocols are of paramount importance to preserve donor health by excluding unsuitable candidates for either medical or anatomic reasons.

The success of the technique depends on whether the surgeons leave enough viable liver for the donor and transplant enough liver to the recipient. Preoperative imaging evaluation of the hepatic vascular anatomy is crucial for surgical planning and has been shown to minimize mortality and morbidity

Multidetector CT (MDCT) angiography is being used to non-invasively evaluate the liver and its vascular anatomy. MDCT angiography is also useful for evaluation of the liver parenchyma and other intra-abdominal disease or abnormality, thus replacing the many imaging studies once needed to obtain that information.

This work is a review of the hepatic segmental anatomy, the normal anatomy & anatomic variations of the hepatic vasculature and a discussion with illustration of their multidetector CT features as well as the surgical implications of some important vascular variants.

Chapter I
Review of Literature

1. Liver Transplantation

- **Historical perspectives**

Early history of liver transplantation

The history of liver transplantation began with experimentation by *Stuart Welch* in Albany, NY, in 1955. Welch described the experimental transplantation of an auxiliary liver to the right paravertebral gutter in mongrel dogs. Experiments at the University of Miami from 1956-1958 led the way to orthotopic♣ liver transplantation. In 1958, orthotopic liver transplantations following hepatectomy were performed, although these attempts were marred by poor performance of the transplanted liver. The operative procedures were further refined by *Jack Cannon* at the University of California at Los Angeles in 1956 and by several investigators in Boston and Chicago from 1958-1960. These animals did not survive for more than 4 days due to a lack of effective immuno-suppression; however, technical principles such as optimal portal revascularization, allograft♥ preservation, and other techniques were perfected [1].

Human liver transplantation

Thomas Starzl attempted human liver transplantation in 1963, at the University of Colorado [1].

In the 1960s and the 1970s, liver transplantation was slowly developed to become a feasible option in the treatment of end-stage liver disease [2].

♣ Orthotopic graft. Transplantation of a tissue or organ into its normal anatomical position.

[1]♥ Allograft. An organ transplanted between individuals of the same species.

1984, the first successful transplantation of a partial liver allowing the transplantation of a child with part of the liver of a larger donor was reported by *H. Bismuth*, see [2]. Reduced-sized (RLT) liver transplantation involves ex-vivo resection of an adult cadaveric liver in order to create an appropriate sized liver graft for an infant or small child [3]. Introduced as a surgical solution for decreasing the pediatric liver transplant waiting list mortality, RLT uses organs from donors much larger than the recipient, but does not increase the total number of livers available for transplantation. This is because the reduced-sized portion not used and discarded [3].

If until then, liver donor shortage was not a major problem, this was going to change radically in the following decade. The number of liver transplantations performed per year rose at an exponential pace both in Europe and in the American continent. Finally, this growth was limited by an increasing shortage of donors, leading to prolonged waiting times and high mortality on the waiting list [2].

The development of the knowledge of segmental anatomy of the liver and in particular the systematic description by Couinaud contributed a great deal to liver surgery. Based on this knowledge, anatomical liver resections, respecting the vascular perfusion of the remaining segments, could be performed [2].

In 1988, *Pichlmayr* in Germany and Bismuth in France simultaneously performed split-liver transplantation (SLT), an ex-vivo splitting of a cadaveric liver allowing transplantation to a pediatric recipient and one adult. Unlike RLT, SLT resulted in an increased number of organs in the donor pool with each cadaveric liver giving rise to two functioning allografts [2,3]. The practical feasibility of SLT as well as the increased safety of conventional liver surgery suddenly opened up the idea of removing part of the liver from a living donor to transplant it in a smaller recipient [2]. First cases were performed in 1989 in

Australia and in South America and finally a first series was produced under close institutional control by *Broelsch et al.* in Chicago [2].

Despite initial heavy criticism in the Western world, living donation soon proved to be an inevitable development if one was to run a successful pediatric transplant program. Indeed, in centers performing SLT and living donor liver transplantation (LDLT), mortality of children on the waiting list fell to almost zero [2].

- **Rationale for live donor adult liver transplantation (LDALT)**

Over the past decade, the number of people awaiting liver transplant has increased more than 15-fold, while the number of cadaveric donors has increased only three-fold [3]. The organ shortage problem is further exacerbated by the reality that over 200 million people around the world are infected with hepatitis C - an overall incidence of around 3.3% of the world's population - with the prevalence in Egypt among the highest in the world [4]. Cirrhosis develops in about 10% to 20% of persons with chronic infection, ultimately leading to the need for liver transplant [4].

The success in pediatric liver transplantation and the shortage of organs provided the necessary incentive to attempt living donation for adults [2]. The expansion of LDLT to the adult population began in countries where the availability of cadaveric donors was scarce, and in some cases, totally unavailable. The law for cadaveric organ retrieval was instituted in 1998 in Japan, however, the lack of societal acceptance of organ retrieval from brain-dead donors results in live liver donation being the main source of grafts for patients waiting transplantation in much of Asia [3]. In some countries, as Egypt, cadaver donor liver transplants are legally prohibited thus living donor liver transplant is the only form of transplantation applicable.

The obvious advantage of LDALT is the ability to electively transplant patients when medically indicated and avoid the serious decompensation or death that occurs while patients are waiting for cadaveric transplantation. In addition, the occurrence of primary graft non-function is rare since donor quality and cold ischemic times* are more favorable with LDLT. The undisputed disadvantage is the risk of serious complications or death in the otherwise healthy donor undergoing a partial liver resection and general anesthesia [3].

Living liver donation certainly counts amongst the great surgical achievements of the 20th century and has saved the lives of many patients.

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* Cold Ischemic Time (CIT). The time interval that begins when an organ is cooled with a cold perfusion solution after organ procurement surgery and ends when the organ is implanted.

2. Pre-Operative Radiological Evaluation of the Donor

The radiological component of donor evaluation is pivotal in donor selection and exclusion. Its first objective is to detect factors that would preclude or complicate hepatic resection and transplantation.

In adult SLT, a delicate balance exists between providing adequate liver volume to the recipient, and leaving sufficient volume in the donor to sustain metabolic function. In most cases, it is necessary to harvest the right hepatic lobe. The surgical procedure is technically complex, since important vascular and biliary structures traverse the surgical plane. Unlike a conventional right lobe resection, these structures must be preserved in a manner that will permit reanastomosis. Thus, it is crucial that the presence of these structures be known prior to surgery to prevent injury to both the right lobe being harvested and the left lobe remaining in situ [5].

• Pertinent Imaging Information

A. Liver volume:

Total liver volume is reported to have a relatively constant relation to body weight, ranging between 2-2.7% in healthy subjects. However, the right and left lobe volumes are widely variable. Therefore, graft size cannot be predicted preoperatively by body weight [6].

The healthy liver contains significantly greater mass than required to sustain normal function. Liver function remains intact in many patients with cirrhosis and those with a significant portion of normal liver surgically resected [7].

Although neither the minimum hepatic volume nor the optimal hepatic volume has been determined, graft-to- body weight ratios (GBWR) have been used to predict graft function in the recipient. *Kiuchi et al.*, see [8], note that small-for-size grafts that represent less than 1% of the recipient's body weight are predisposed to lower graft survival than larger grafts, likely related to diminished metabolic and synthetic capacity. In the case of donors, *Fan et al.,* see [8], report that the remnant liver must equal at least 30% of the total liver volume to ensure function in the donor [7-10].

Preoperative determination of the volume of both the recipient and the donor liver is critical [11]. Specifically, the volume of the resected right hepatic lobe and the volume of the remainder of the liver must be adequate to provide function in the recipient and donor, respectively [8]. In general, the surgeon attempts to transplant a donor organ that is similar in size to the native organ. A donor liver up to 20% larger than the optimal estimated volume is acceptable. Transplantation of larger livers makes the operation technically difficult if not impossible. A large liver creates problems in performing anastomoses and in controlling bleeding, since retrohepatic exposure may be markedly compromised. Furthermore, closure of the abdominal wall may be difficult. Small donor allografts, on the other hand, are tolerated much better. A donor liver as small as 50% of the optimal estimated volume is acceptable. The main problem in these situations is that the portal venous and hepatic arterial anastomoses may be difficult [7].

Determining the liver volume in the recipient is also helpful in assigning priority to transplant candidates. Small livers in cirrhotic patients have the poorest function, making transplantation more urgent [12].

In general, the left lateral graft (segments 2 and 3) serves the need of a pediatric recipient up to 30 kg of body weight. Children over 30 kg and small adults up to 60 kg can be transplanted with the left graft (segments 1–4). Medium sized and large adults have to be transplanted with the right liver lobe. If the remnant left liver of the donor is less than 30% of the donor's total liver volume, safe donation is not possible. To overcome this problem of an insufficient remnant left liver, the right posterior segment graft was introduced as an alternative liver graft. *Leelaudomlipi et al.*, see [2], described that 25% of the donors had a large right lobe that accounted for more than 70% of the whole volume. Thus, right lobe donation would be dangerous in this donor population. In 72% of these donors, the right posterior segment (37%) was larger than the left lobe with the caudate lobe (33%).The experience with right posterior sectorial grafts is still very limited. This procedure should, therefore, still be considered as experimental. If none of these types of resections allows obtaining a large enough graft, leaving sufficient liver volume to guarantee safety for the donor, one should opt for cadaveric liver transplantation. In countries in which LDLT is the only available option, the simultaneous transplantation of two small (full left or left lateral) liver grafts from two different donors can provide a solution to obtain a sufficient total volume of transplanted liver tissue [2].

B. <u>Hepatic Steatosis:</u>

It is well known that the risk for primary nonfunction after transplantation of a cadaveric graft increases proportionately with the degree of steatosis. Steatosis has been shown to reduce the rate of hepatic regeneration and to increase mortality after major hepatic resection. It therefore is reasonable to assume that steatosis also would have a negative impact on the function of a living donor graft. It has been suggested that steatosis simply reduces the percentage of functioning liver, both transplanted and remaining in the donor; this must be taken into account when calculating the GBWR [7].

Marsman et al., see [8], note that the acceptable upper limit of steatosis in a donor liver is 30%; liver grafts with greater than 30% steatosis are at risk for dysfunction and nonfunction in the recipient.

The detection of fatty change is so important that many surgeons routinely biopsy the donor's liver before surgery to exclude it, despite the fact that parenchymal liver biopsy carries an estimated complication rate of 1% [12].

C. <u>Focal liver disease:</u>

The first step in the comprehensive preoperative evaluation of a potential donor is a screening test for the presence of focal liver disease. In a study reported by *Fulcher et al.* [8], focal liver lesions were detected in 18% of living liver donors. Although almost all such lesions are benign cysts or hemangiomas, the presence of any lesion, especially when large, can preclude a right lobe transplant.

D. <u>Vascular Assessment:</u>

Preoperative knowledge of vascular anatomy is important in the comprehensive workout of a liver donor because transplant survival mandates patency of all supplying and draining vessels.

Up to one-third of potential donors may be ineligible for transplantation because of unsuitable hepatic arterial anatomy [13].