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Imaging of liver transplantation

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ABSTRACT

Liver transplantation (LT) is the treatment of choice for end-stage chronic liver disease, fulminant liver failure and early stage hepatocellular carcinoma. As discussed in this review, state-of-the-art imaging modalities including ultrasonography (US), computed tomography (CT) and magnetic resonance imaging (MRI) play a pivotal role in the selection of patients and donors, as well as in early detection of those complications at risk of impairing graft function and/or survival. We also illustrate main imaging findings related to the wide spectrum of clinical problems raised by LT.

1. Introduction

Since its introduction in 1963, liver transplantation (LT) has benefited from considerable advances in surgical technique, organ preservation and immunosuppressive agents. Not surprisingly, LT is now regarded as the therapy of choice for chronic end-stage liver disease, fulminant hepatic failure, and early stage hepatocellular carcinoma (HCC) [1–3]. Currently, the 5-year patient survival rate and graft survival rate approximate 74% and 67%, respectively [4]. Depending on the type of donor, there are two variants of LT, namely orthotopic liver transplantation (OLT) and living donor liver transplantation (LDLT). OLT is the most frequently performed approach in Western countries, given larger availability of deceased donors [5]. LDLT is the preferred choice in most Asian countries because of increased organs availability and decreased time to transplant, which in turn balance the disadvantages related to potential risks for the donor and a higher postoperative complication rate [5,6].

Despite its effectiveness, LT is a complex procedure, associated with still significant morbidity and mortality [6]. Multidisciplinary management is mandatory to reduce the occurrence and severity of complications and increase graft and patient survival. Radiologists have a pivotal role in this scenario, given the versatility of currently available imaging techniques including ultrasonography (US), contrast-enhanced ultrasonography (CEUS), computed tomography (CT) and magnetic resonance imaging (MRI) [4]. Each of them should be used according to its specific capabilities to face main tasks for radiologists both in the preoperative and postoperative phases, as discussed below [4,7,8].

This review aims to discuss and illustrate the role for state-of-the-art imaging in LT both in the preoperative and postoperative phases, focusing on the adult population and abdominal complications.

2. Surgical techniques and postoperative anatomy

Radiologists should be aware of the type of LT that has been planned or performed, in order (i) to report anatomical aspects that may influence surgical planning or (ii) correctly differentiate between normal and pathological postoperative findings.

2.1. Surgical technique and graft anatomy

OLT can be performed as cadaveric LT or split-liver cadaveric LT. Cadaveric LT is the most frequent, less technically demanding approach, in which the entire donor liver is transplanted into the recipient [7]. Split-liver transplant implies the transection of the liver into two separate grafts: 1) usually, a right trisegment graft (segments I and IV–VIII according to Couinaud classification) and a left lateral graft (segments II–III) for an adult and a pediatric recipient, respectively; 2) more rarely, a right hemiliver graft (segments V–VIII with or without segment I) and a left hemiliver graft (segments II–IV with or without segment I) for two adult recipients [7].

In the case of LDLT, the most frequent approach implies right hemiliver graft transplantation, though left hemiliver can be used as well [7]. Adequate liver function and preservation from small-for-size syndrome in the recipient are minimized if the residual donor liver is > 30% of the total hepatic volume and the graft-to-recipient ratio is > 0.8, respectively [7]. Middle hepatic vein (MHV) is the most important anatomic landmark for right lobe transplant, since the transection line courses about 1 cm to the right, close to the Cantlie

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Fig. 1. Vascular and biliary anatomy after liver transplant. Axial (a) and oblique sagittal (b) maximum intensity projection (MIP) reconstructions from multidetector computed tomography (CT) show a "piggy back" side-to-side anastomosis (arrow) between donor's suprahepatic inferior vena cava and the common stump of recipient's hepatic veins. Coronal MIP reconstruction in the same patient (c) illustrates the typical bulbous fish-mouth appearance of the end-to-end hepatic artery anastomosis (arrow). On thick coronally reformatted CT image (d), the end-to-end anastomosis along the portal trunk appears as a zone of relative, slight luminal narrowing, as may occur in the early postoperative period due to surrounding oedema (arrow). The biliary tract is most commonly reconstructed with the duct-to-duct technique, such as in the case shown after T-tube cholangiography (arrowhead in e), presenting with minimal discrepancy in caliber between the donor and recipient ducts.

line.

2.2. Vascular and biliary anatomy

Once donor and recipient hepatectomy has been performed, surgeons reconstruct the continuity of vascular and biliary pedicles and perform cholecystectomy. Vascular and biliary anastomoses are critical points to be identified and evaluated after LT, since they represent the major sources of graft-threatening complications.

In many institutions, the preferred reconstruction technique for inferior vena cava (IVC) is the "piggyback" approach, in which the recipient IVC is left in situ together with a common stump of the hepatic veins, which is in turn connected to the donor's suprahepatic IVC with and end-to-side anastomosis (Fig. 1) [9]. In the conventional technique, the recipient's IVC is removed along with the liver, with subsequent side-to-side anastomosis of superior and inferior edges with the donor's IVC. This technique is associated with higher surgical complexity (venous by-pass is needed to maintain the venous flow) and a higher complications rate (because of caval dissection) [10]. Both portal vein and hepatic artery are reconstructed with an end-to-end anastomosis. Arterial anastomosis has a typical "fish-mouth", bulbous configuration, and usually involves the junction between hepatic and splenic artery of the donor and the origin of gastroduodenal artery of the recipient (Fig. 1) [4]. In most difficult surgical cases (e.g., because of anatomic variants) vascular reconstruction may be performed differently, e.g. by inserting an iliac artery jump from the donor between the donor hepatic artery and the recipient aorta [11].

There are two main choices for biliary reconstruction, namely the duct-to-duct technique and bilioenteric anastomosis (Fig. 1) [12]. The first technique consists in an end-to-end anastomosis between the donor common bile duct and the recipient common hepatic duct, and is usually preferred because it prevents bacterial colonization by preserving the physiological barrier of the sphincter of Oddi [12]. Bilioenteric anastomosis is performed as an end-to-side connection between the donor hepatic duct and a recipient jejuneal loop (Roux-en-Y hepaticojejunostomy). This technique has selected indications, including technical challenge (e.g., short common bile duct), retransplantation or primary sclerosing cholangitis as the cause of LT.

In many institutions a T-tube is placed within the reconstructed common bile duct for the first 1–3 months after LT, with the purpose of monitoring bile output and providing an access for direct cholangiography (T-tube cholangiography) (Fig. 1). There has been a trend towards a decreased use of T-tube over the last years because of increased risk of biliary leakage and late strictures [6].

3. Imaging techniques

As summarized in Table 1, a wide spectrum of noninvasive and invasive imaging techniques is now available for evaluating donors or LT patients, each of them having definite indications in the preoperative and postoperative periods [4,5,8,12–21]

Choosing the correct examination in the correct order is crucial to manage patients promptly and adequately, especially in the postoperative period. Indeed, complications often manifest with a subtle and/or nonspecific pattern (typically increased liver enzyme and/or bilirubin level), showing a large spectrum of overlapping clinical and laboratory manifestations [4]. A suggested workup for postoperative complications is shown on Fig. 2. Once imaging excludes causes of complications requiring surgical and/or interventional approach, further steps include the exclusion of primary graft dysfunction, rejection or drug toxicity [5,6]. Imaging shows nonspecific findings in those conditions, having no direct role in the diagnosis. Not surprisingly, liver biopsy is mandatory for diagnosing and monitoring primary parenchymal complications [22].

3.1. Noninvasive techniques

Noninvasive techniques include US, CEUS, CT and MRI/magnetic resonance cholangiopancreatography (MRCP).

US should be performed on last-generation equipment implementing [14,16]: 1) B-mode for investigating graft parenchyma, bile ducts dilation and abdominal free fluid and/or collections; 2) color Doppler, pulsed wave Doppler and power Doppler modes to assess vascular patency, as well as direction, velocity and spectral profile of vascular flows. Doppler technique needs optimization to detect lower flow or avoiding misdiagnosis of hepatofugal flow. Recommendations include the use of appropriate angle, low wall filter, and lowest pulse repetition frequency without aliasing [4].

Harmonic imaging allows the opportunity to complete US with CEUS within an unique examination session. CEUS shows the advantage of assessing graft microcirculation and complement Doppler US by offering the possibility of real-time angiographic studies [16,18]. Low mechanical index should be used for real-time continuous imaging, together with microbubble-specific imaging mode to maximize non-