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Review

Role of imaging in pre-hepatic transplantation evaluation

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Abstract

Infectious diseases of the liver are major causal factors leading to acute or chronic liver failure and end-stage liver failure necessitating Liver transplantation (LT). Parasitic infections (Alveolar echinococcosis) and viral hepatitis (HBV and HCV) in particular are prominent infectious diseases in China which carry substantial morbidity rate. Chronic infections of HBV and HCV have a high potential to develop Hepatocellular cancer (HCC). At the end stage or acute liver failure due to these infectious diseases, LT places itself as an effective treatment option. It is a complex procedure requiring the collaborative planning of a radiologist, transplant surgeon, oncologist, and hepatologist. The criteria required for liver transplantation are constantly being optimized with an aim of decreasing the risks involved and increasing the post-transplant survival rate. Role of imaging is crucial in differentiating the normal from abnormal anatomy of the liver, anatomical variants of the vasculature and biliary tree. It helps the transplant surgeon in deciding the technique which benefits both the donor and recipient, putting the graft to optimal use. In this article, we review the literature on infectious diseases (viral and parasitic) of the liver, their impact on the necessity to undergo hepatic transplantation while highlighting the role of imaging evaluation during pre-transplantation stage.
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Keywords: Auto liver transplantation; Viral hepatitis; Hepatic alveolar echinococcosis; Hepatocellular carcinoma (HCC); Cirrhosis; Biliary system

1. Introduction

Infectious diseases of the liver have high rates of morbidity and mortality. For the clinicians, it is essential to understand the various manifestations of these infections. In the Asian population chronic infections due to HBV is more prevalent with the exception of Japan where HCV is more common [1]. Chronic viral hepatitis infections carry high propensity to cause cirrhosis of the liver which is seen in 80−90% cases of HCC [2]. According to a study HBV is the leading etiology (78.32%), followed by HCV (6.49%) and cirrhosis is major pathological diagnosis (72.27%) followed by tumors (not related to cirrhosis; 0.59%), among the patients who underwent LT (N = 20,877) in China between the period 1980−2011 [3]. Echinococcosis granulosus species is responsible for the development of hepatic alveolar echinococcosis (HAE) and is endemic to regions like Xinjiang, Gansu, Ningxia in China. It has the tendency to slowly grow like cancer. Due to its long latency periods, the patients usually present to the hospital at advanced stages. Although LT is limited for only end-stage liver failure due to HAE, according to a study only 35% of patients with hepatic alveolar echinococcosis are eligible for partial hepatectomy by the time they present to the clinician making LT a viable and efficient treatment option [4].

The first record of attempted hepatic transplantation in the world dates back to 1963 by Dr. Thomas E Starzl and the first successful liver transplantation in 1967 [5]. Hepatic transplantation techniques have been evolving since its inception with the aim of improving the overall survival and long-term survival rates in patients. In China, the number of Liver Transplantation cases have been steadily increasing since 1980. Over the decades the synchronous functioning of radiologists, hepatologists, transplant surgeons and oncologists towards a common goal have significantly improved the

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survival rates, decreased rates of postoperative complications and rejection percentages. At the same time, there is a growing disparity in the number of recipients and available liver grafts. LT is a procedure which requires each and every discipline involved to perform a specific task at particular stages of the transplantation. Imaging plays a crucial role in the preoperative and postoperative stages of liver transplantation. In this review, we put forth the role of imaging and its various modalities in evaluating the donors and recipients in pre-operative stages of hepatic transplantation.

2. Types of liver transplantation

Being a radiologist, it is very essential to understand the various types of LT techniques currently being practiced. It will help us understand the types of Liver transplantation currently being practiced, namely Deceased Donor Liver Transplantation (DDLT), Living Donor Liver Transplantation (LDLT), Split liver grafting and ex-vivo hepatic auto-transplantation. According to a study, in China DDLT is the major type accounting for 92.63% of 20,877 LT done between the period of 1980–2011. 7.37% of 20,877 LT underwent LDLT [3].

In DDLT the recipient receives the complete Liver graft from a deceased donor, but the organ availability is limited.

Liver tissue is capable of regeneration [6]. In Split liver grafting the liver from a deceased donor is anatomically split into two grafts and transplanted in recipients. Currently, 2 split liver grafting techniques namely extended right split and left lateral split are employed. The segments involved in the right and left grafts of the donor's liver vary depending on the type of split used. The right liver graft typically includes the common bile duct and inferior vena cava (IVC), while the left liver graft has the main arterial trunk and middle hepatic vein [7].

LDLT recipients usually have an urgent need for LT. LDLT have an advantage of smaller ischemic times and the surgery can be done on an elective basis, but it also may carry an increased risk of complications in both donor and recipient. Pre-operative donor imaging studies should give due importance to understanding the anatomic variants of the vasculature and biliary tree as it determines the technique of LT.

Left lateral hepatectomy is the most common LDLT technique performed. To obtain a reasonably large left liver graft, left lobectomy liver graft (II, III and IV segments of the liver) is harvested with a middle hepatic vein. As the right hepatic vein is the dominant vein in most patients, the inclusion of MHV in the graft will not cause any clinically significant congestion of liver in the donor. At the same time, the inclusion of the middle hepatic vein in the graft may also reduce congestion of the right para-median segment in the recipient [7]. A right hepatectomy graft is often collected without MHV and is at a higher risk for congestion of right para-median sector with increased risk of dysfunction and complications. To avoid such outcomes, vascular grafts can be used to reconstruct MHV drainage to recipient IVC for segment V and VIII veins. The caudate lobe is not collected in case of a large graft due to direct venous drainage into the IVC, but in case of smaller left sided grafts the caudate lobe needs to be harvested together with the left lobe requiring separate venous drainage reconstruction for the caudate lobe. Factors such as the size of the recipient and donor safety aid the transplant surgeon in deciding whether to perform a right or left hemi-hepatectomy. Right, hemi-hepatectomy is performed only if the volume of donor's left lobe constitutes more than 30% of the total hepatic volume. It is advisable to maintain a graft to recipient body weight ratio of 1:100 to avoid " small for size " syndrome. Left lateral hepatectomy graft best serve the small size recipients (children), while a large size recipient (Adults)would benefit from a right or left hepatectomy grafts.

China harbors more than 90% of the world's burden of Alveolar echinococcosis. Orthotopic liver transplantation has been reported for end-stage AE. Factors such as immediate- and long-term post-transplant complications, especially disease recurrence associated with immunosuppressive agents, the lack of donors, and the high economic cost made surgeons consider ex-vivo hepatic auto-transplantation as a better choice for end-stage hepatic AE which is unresectable by conventional radical surgery as it has similar success rates as LT and 100% disease-free life in survivors [8].

3. Indications and contraindications

LT is indicated in cases of acute liver failure and chronic liver disease when the medical management fails. HBV and HCV infection are the most common etiologies, leading to LT in China. Cirrhosis is the leading pathological diagnosis in China, followed by HCC that mandated LT (Table 1) [3]. Currently, indications for LT in adults include advanced cirrhosis from hepatocellular disease, cholestatic syndromes, metabolic liver disease, unresectable hepatic malignancies. Cirrhosis per se in a patient doesn't mandate for LT, but cirrhosis accompanied with serious complications such as recurrent variceal hemorrhage, spontaneous bacterial peritonitis, ascites, and hepato-renal syndrome should be evaluated for LT. To achieve better outcome after transplantation, American Association for Study of Liver diseases and American society of transplantation have made a few recommendations for patients with pre-existing medical conditions or surgical histories. For instance, tobacco consumption is prohibited in LT candidates. Patients with alcoholic cirrhosis have to fulfill the criteria such as abstaining from alcohol for 6 months, register and participate in ongoing withdrawal program and should have a strong psychosocial support system. Ongoing Pneumonia, sepsis, fungal infections are all absolute contraindications for LT and should be treated adequately before considering LT [9].

In case of end-stage hepatic alveolar echinococcosis, ex-vivo auto-transplantation is indicated in cases with severe invasion and even obliteration of the RHVC (longer than 1.5 cm); three hepatic veins and hepato-caval confluence involvement; involvement up to the tertiary portal and arterial branches that require critical reconstruction [10].

Table 1
Indications of liver transplantation.

Acute Liver Failure:
HBV, HCV, HAV, HDV, Acetaminophen, Cryptogenic hepatitis, Autoimmune hepatitis, Wilson's disease, Budd-Chiari syndrome and Fatty infiltration (acute fatty liver of pregnancy, Reye's syndrome).
Cirrhosis from Chronic Liver disease:
Chronic HBV and HCV infections, alcoholic liver disease, non-alcoholic fatty liver disease, autoimmune hepatitis
Malignant diseases of the liver:
Hepatocellular carcinoma, Carcinoid tumor, Islet cell tumor, Epithelioid hemangioendothelioma, Cholangiocarcinoma.
Metabolic liver disease:
Wilson's disease, Hereditary hemochromatosis, Alpha-1 antitrypsin deficiency, Glycogen storage disease, Cystic fibrosis, Glycogen storage disease I and IV, Crigler-Najjar syndrome, Galactosemia, Type 1 hyperoxaluria, Familial homozygous hypercholesterolemia, Hemophilia A and B.
Vascular diseases of the liver:
Budd-Chiari syndrome, Veno-occlusive disease.
Cholestatic liver diseases:
Primary biliary cirrhosis, Primary sclerosing cholangitis, Secondary biliary cirrhosis, Biliary atresia, Alagille syndrome, Byler's disease.
Miscellaneous:
Hepatic Alveolar Echinococcosis, Adult polycystic liver disease, Nodular regenerative hyperplasia, Caroli's disease, Severe graft-versus-host disease, Amyloidosis, Sarcoidosis, Hepatic trauma.

Absolute contraindications for LT include active infection or sepsis, ongoing alcohol or substance abuse, extrahepatic malignancy, Acquired Immunodeficiency Syndrome (AIDS), severe cardiopulmonary disease, lack of adequate social support system, poor compliance with medical regimen and fulminant hepatic failure with sustained ICP >50 mmHg. Relative contraindications include HIV infection, advanced age, psychological instability, and cholangiocarcinoma.

4. Patient selection

Model for End-stage Liver Disease (MELD) scoring system is used to assess the severity of chronic liver disease in a patient. It is now employed by United Network of Organ Sharing (UNOS) to prioritize livers for transplantation [11]. MELD does not give priority to patients depending on the amount of time spent on the waiting list. MELD scoring is given based on the values of total bilirubin, creatine, and INR of the patient (score ranges from 6 to 40, 6 for least sick patients and 40 for most sick patients).

However, pre-transplantation MELD score is not useful in assessing the post-transplantation outcome and mortality of the patients because of poor correlation between pre-transplant disease severity and post-transplant outcome.

4.1. Hepatic alveolar echinococcosis

For achieving optimum results in ex-vivo auto-transplantation it is essential to follow an ever-improving list of criteria for patient selection. Based on a case series on 15 patients Wen et al. have proposed selection criteria of patients for ex-vivo auto-transplantation. It is proposed that the patients with the indications for auto-transplantation should have graft volume of 40% estimated standard liver volume or greater, serum total bilirubin level less than twice of upper limit of normal value; routine PTCD is mandatory for patients with obstructive jaundice; and patients with multi-organ AE, for whom such surgery is not an absolute contraindication unless extra-hepatic lesions are not controllable with albendazole [10]. Possible disease recurrence should not be a contraindication to LT in patients with end-stage AE [12].

4.2. Hepato cellular carcinoma

In 2015 Wanqing Chen et al. projected the rates of incidence and mortality of cancers in China. HCC incidence and mortality rates are projected at 466,100 cases and 422,100 cases respectively in their estimate [13]. While selecting a hepatic cancer patient for liver transplantation priority should be given to T2 disease (TNM classification). T1 have better survival rates without transplantation when compared with patients who underwent transplantation. T3 patients have a high rate of tumor recurrence. The MELD score is not a reliable indicator of mortality in patients with HCC. The criteria for eligibility for LT have been evolving over the decades to include more patients from Milan criteria (a solitary lesion of <5 cm, or 2 to 3 nodules < 3 cm and without vascular invasion or extra-hepatic disease) to Up to 7 criteria (HCCs with 7 as the sum of the size of the largest tumor in centimeters and the number of tumors) with comparable 5 year overall survival rate [14]. Patient outcomes are also being evaluated based on tumor volumes at a few centers, where total tumor volume (TTV) with a cut off of 115 cm^3 is used for candidate selection. This enhanced the accuracy of pre-transplant radiological assessment, with post-transplant outcomes similar to results achieved with Milan and UCSF classifications even after opting to more inclusive patient population. In a study which included TTV <115 cm^3, AFP concentration <400 ng/mL, and no macro-vascular invasion, the 3-year tumor recurrence rate was significantly low [15,16].

5. Transplantation imaging

Over the decades the paradigm of liver transplantation evaluation has shifted from liver biopsy to imaging techniques owing to their non-invasive nature. USG is the primary imaging modality used to find and follow up the early and late complications of LT. Ultrasound examination requires a grey scale and Doppler evaluation for the assessment of the liver parenchyma, biliary tree, and vessels. With the advent of cross-sectional imaging modalities CT and MRI, their various sequences have become the mainstay of pre-transplantation evaluation and early diagnosis of post-transplantation complications of LT.

5.1. Pre-transplantation imaging evaluation

In LDLT, pre-transplantation imaging must include parenchymal, vascular and biliary tract studies of donor and recipient. Exclusion of intra-hepatic and extra-hepatic malignancy, venous thrombosis, extensive peri-hepatic varices, celiac stenosis, splenic artery aneurysm, and incorrect location of a transjugular portosystemic shunt in recipients is clinically helpful.

5.1.1. Parenchymal evaluation

Imaging is performed to detect liver parenchymal abnormalities that may hinder living-donor liver transplantation. Although malignant liver lesions in a potential donor are a contraindication, benign lesions such as hemangioma, particularly if single and small in size (2–3 cm), may be transplanted safely and do not exclude liver donation [17]. Parenchymal evaluation in donor mainly focuses on steatosis status, which, if present >30% can cause post-transplantation graft dysfunction in the recipient and Liver dysfunction or failure in the donor.

Although USG, CT (Fig. 1) can detect hepatic steatosis, they are not reliable in quantifying the degree of steatosis. In an animal model conducted by Nathan S et al., Dual-energy CT is comparable to CT but not better. Furthermore, MRI may provide an excellent reference standard for liver fat quantification when validating new CT or DECT methods in human subjects [18]. In a meta-analysis by Bohte A E, et al. comparing the diagnostic accuracy of USG, CT, MRI (which included various protocols of MRI including in phase and out of phase chemical shift imaging) and 1H MRS with histopathology as a reference standard, it was found that MRI and 1H MRS have better sensitivity and specificity compared to US and CT in quantifying hepatic steatosis. Furthermore, it is also elicited that 1H MRS has better specificity compared to MRI (in and out of phase protocol included) at quantifying hepatic steatosis (Fig. 2) [19]. In a comparative study conducted by H.-J.Chiang et al., it was found that 1H MRS fat fraction quantifies hepatic steatosis in LDLT accurately and can be finished in a single breath hold when it was compared with intra-operative liver biopsy for fat quantification. This can be helpful in reducing the morbidities associated with liver biopsy in donor following quantification of hepatic steatosis [20]. In a study by Eskreiswinkler S et al., comparing IDEAL-IQ and in and out of phase chemical shift MRI (IOP), it is demonstrated that IDEAL-IQ is better at steatosis screening in cancer population where there is concomitant iron deposition [21].

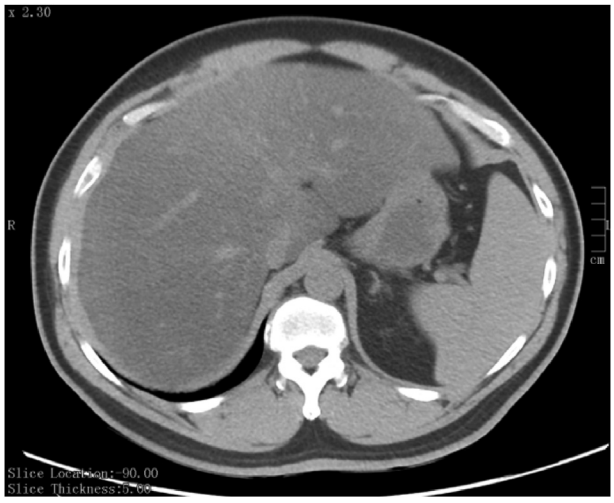

Fig. 1. CT image showing the fatty changes in the liver.

5.1.2. Liver volumetry

To meet the metabolic demands and to permit volume regeneration of the graft it is essential to maintain an accurate size matching of donor and recipient. Grafts which are “small for size” have increased the risk of primary non-function and dysfunction, whereas “large for size” grafts are associated with poor blood perfusion, vascular compression and thrombosis of the hepatic vasculature. A recipient requires a graft of 0.8% of his body weight ratio to avoid a small for size syndrome. With normal liver parenchyma, a liver remnant volume of 30–40% of the total liver volume is considered adequate for donor survival.

There are several formulae to estimate the liver volume with varying degree of accurately predicting the volume of the liver. In their study to determine a formula predicting the standard liver volume based on body surface area (BSA) or body weight in Chinese adults, Yan Lu-Nan et al., suggested that Standard Liver volume can be calculated by multiplying the body weight of the individual in Kg with 11.508 and then adding the result to 334.024 [22].

With the advent of imaging, cross-sectional imaging techniques such as CT and MRI have been adopted to estimate the liver volumes, with CT being at the better edge due to higher spatial resolution yielding sharper images [23]. However, a study conducted on 100 living donors suggested that the actual liver graft volume (GV) differs from the GV predicted by radiological estimation and GV predicted using formulae. It is also suggested that formulae derived GV are marginally concordant with actual GV when considering a Right lobe graft, while MRI based GV have lower error ratio when considering a left lateral graft [24]. Recently Semi-automated/automated MRI and CT protocols are being used at many centers, to estimate the liver volumes and various studies are being conducted to understand the level of accuracy of the volumes estimated by the protocols [25]. A study on an automated scheme using MRI 3D geodesic active contour segmentation showed that liver volumes measured with automated schemes agreed excellently with the standard liver volume and with substantially less completion time [26].

5.1.3. Functional hepatic tissue evaluation

The function in healthy hepatic tissue is homogeneous in all segments. Hence CT/MRI based volumetry studies are sufficient in case of a normal liver and a 30% of the total liver volume is considered as an adequate remnant liver volume for normal functioning in the donor. The liver function is

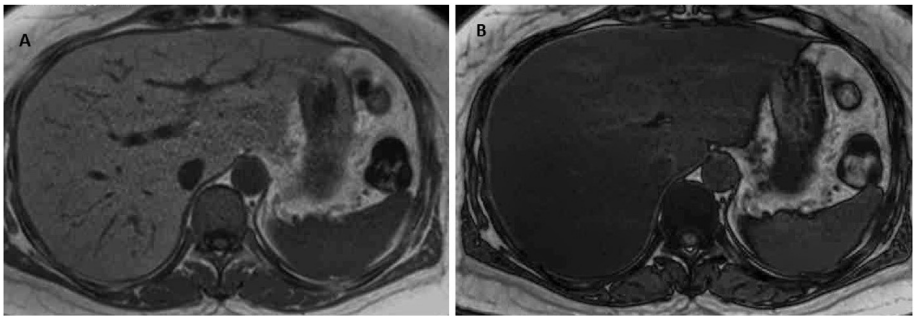

Fig. 2. MRI Axial T1 in-phase image (A: diffusely increased hepatic signal intensity) and Axial T1 out -of-phase image (B: decreased hepatic signal intensity) show a significant decrease in hepatic signal intensity indicating fatty liver changes.

heterogeneous and varies segmentally in a liver with a parenchymal disease such as cirrhosis [27,28]. In such cases impaired liver function has to be considered in the pre-operative decision making and increasing the size of the functional liver remnant in relation to the degree of dysfunction is ideal.

Global liver function tests and pure volumetry studies deliver adequate results and predict post-transplant liver remnant function in case of normal hepatic tissue but fail when the heterogeneity of function in a diseased hepatic tissue is taken into consideration [26,27]. In a study by Henrik Nilsson et, al global liver function assessment tools over-estimated the remnant liver function in the diseased liver, while under-estimating the same in normal hepatic tissue. The study also suggested Dynamic Gd-EOB-DTPA-enhanced MRI can assess segmental liver function and improve the prediction of post-operative remnant liver function [29] resulting in an improved post-transplantation outcome.

5.1.4. Vascular evaluation

Over the period of embryonic development, the hepatic vasculature undergoes a change in its organization. During the course, few embryonic branches regress and lead to the conventional anatomy of the vasculature. Sometimes the regression of these branches may fail to lead to variant anatomy. Evaluating a donor for the variations in hepatic and portal vasculature is crucial for the decision on inclusion of the individual as a donor. In a study by Tsang et al., 10.9% of potential donors were excluded because of anatomic considerations [30].

Michel has classified the anatomic variants of the hepatic artery into 10 sub-types (Table 2). Among which sub-types II, III, V and IX most significantly concerned with LDLT. Multiple arterial feeders in the grafts may result in poor perfusion of the graft in the recipient and may necessitate an alternate inflow source like aorta-hepatic interposition graft [31]. According to a study on 1025 Egyptian patients, the most common variant in the origin of the hepatic artery is Michel's subtype III (Fig. 3) [32]. Hepatic artery variants do not influence liver transplant results unless the RHA arises from UMA, which requires for bench reconstruction [33]. Rarely, RHA branches may originate from the distal end of LHA and may traverse the left liver parenchyma to enter the right lobe, making donor hepatectomy impossible. But arterial complications were more frequent in cases where there were recipient anomalies or both versus without anomalies or with donor anomalies. CT arterial phase sequences are more accurate at detecting the hepatic arterial variants [24] due to high spatial resolution.

Hepatic Venous drainage determines the plane of transection. In around 30% of patients, variants of hepatic venous

Table 2

Type	Description
Type I	Hepatic artery originates from the CHA and bifurcates into the RHA and LHA
Type II	Replaced LHA arising from the LGA
Type III	Replaced RHA arising from the SMA
Type IV	Replaced RHA and LHA arising from the LGA
Type V	Accessory LHA arising from LGA
Type VI	Accessory RHA arising from SMA
Type VII	Accessory RHA arising from SMA and accessory LHA arising from LGA
Type VIII	Replaced RHA and accessory LHA or replaced LHA and accessory RHA
Type IX	CHA arising from SMA
Type X	CHA arising from LGA

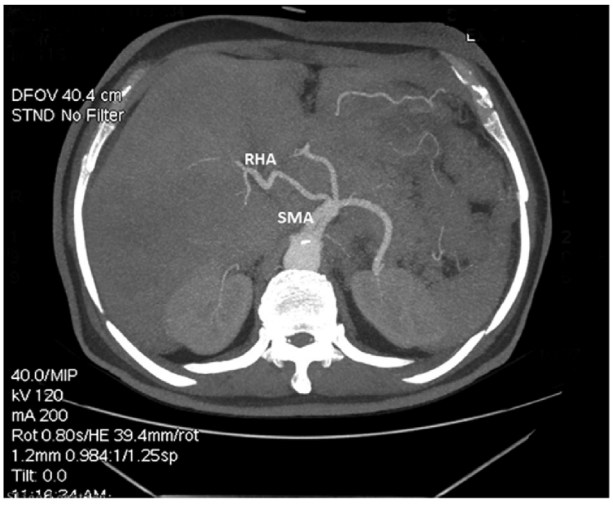

Fig. 3. Enhanced arterial phase CT image showing RHA arising from SMA (Michel's type III).

anatomy have been reported [34]. In LDLT, presence of accessory hepatic veins demands special attention as they drain directly into the IVC and require to be dissected separately as they can be a source of excessive hemorrhage if not identified pre-operatively [35]. Both CT and MRI are good at interpreting the hepatic venous system. Higher confidence is observed while interpreting with non-contrast T1W MRI images [36].

Portal venous variants account for 20% all significant vascular variants [37,38]. According to a retrospective study on 300 donors, the most common variant of portal vein anatomy is the trifurcation of the portal vein (Fig. 4) [39]. It is important to identify the features of portal vein thrombosis (Fig. 5) in recipients as it can help to decide whether the recipient is suitable for transplantation. Measuring the diameter of the portal vein at the probable anastomosis level can help in avoiding the chances of possible stenosis.

5.1.5. Biliary tract evaluation

Biliary complications accounted for 8.74% of late post-operative complications in mainland China and the 1-year, 3-year, and 5-year cumulative rate of biliary complications were 11.41%, 15.41%, and 17.73%, respectively [3]. It is possible to avoid the biliary complications with proper pre-planning.

CT and MRI evaluation of potential donors may include magnetic resonance cholangiopancreatography (MRCP) (Fig. 6), intravenous administration of liver-specific contrast agents in excretory MRCP (eMRCP) and CT cholangiogram (CTCh). At our center, MRCP is readily done for studying the biliary tree. Various studies found CTCh images superior to eMRCP [40]. CTCh allows the depiction of tracts to 2nd order bile ducts and very useful in identifying the anatomical variants.

The classic biliary anatomy appears in about 64.5% on an average in the European population [41]. A study by Lee et al. showed 28% of subjects had biliary variants and statistically significant association between biliary and portal vein variants [42]. An understanding of the variants with the use of imaging can help in preventing various biliary complications such as biliary leaks.

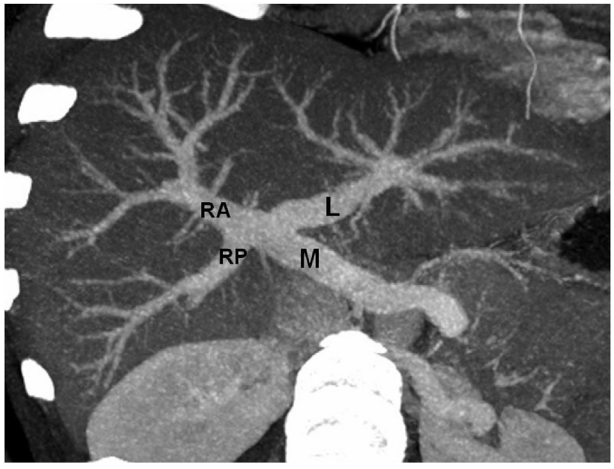

Fig. 4. Trifurcation of portal vein MIP image demonstrates trifurcation pattern of portal vein. The main portal vein(M) enter the porta hepatis and divide into right anterior (RA), right posterior (RP) and left portal(L) branches without right portal vein.

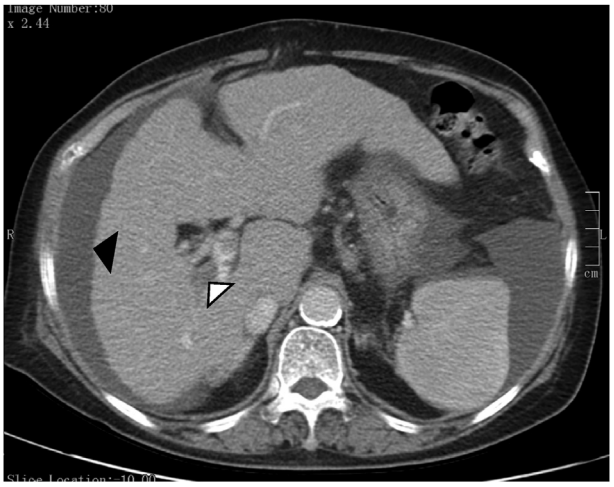

Fig. 5. CT image showing thrombosis in the portal vein (white arrowhead) with marked ascitic fluid collection (black arrowhead) surrounding the liver.

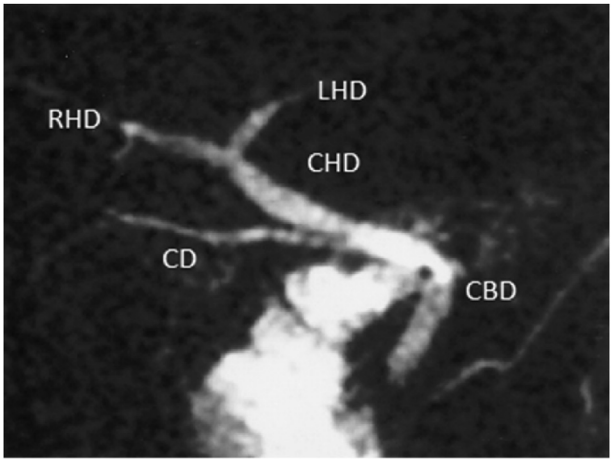

Fig. 6. MRCP image showing the right hepatic duct (RHD) and left hepatic duct (LHD) joining to form the common hepatic duct (CHD), the cystic duct (CD) joins the common hepatic duct distally to form the common bile duct (CBD).

5.1.6. Imaging evaluation of HAE

Pre-transplantation assessment for HAE includes studying the location of the lesion, extensions, extra-hepatic metastasis, portal hilum and hepatocaval involvement using various imaging modalities.

A study has suggested that HAE lesions in the peripheral regions of the liver can be detected by contrast-enhanced ultrasound (Fig. 7) and could be a cost-effective alternative for FDG-PET to estimate disease activity and to concomitantly adjust the treatment with benzimidazole [43].

Hepatic tissue with alveolar echinococcosis has rich collateral circulation which can be established by preoperative CT angiography, 3D reconstruction, and, invasively by digital subtraction angiography-based phlebography (Fig. 8). CT

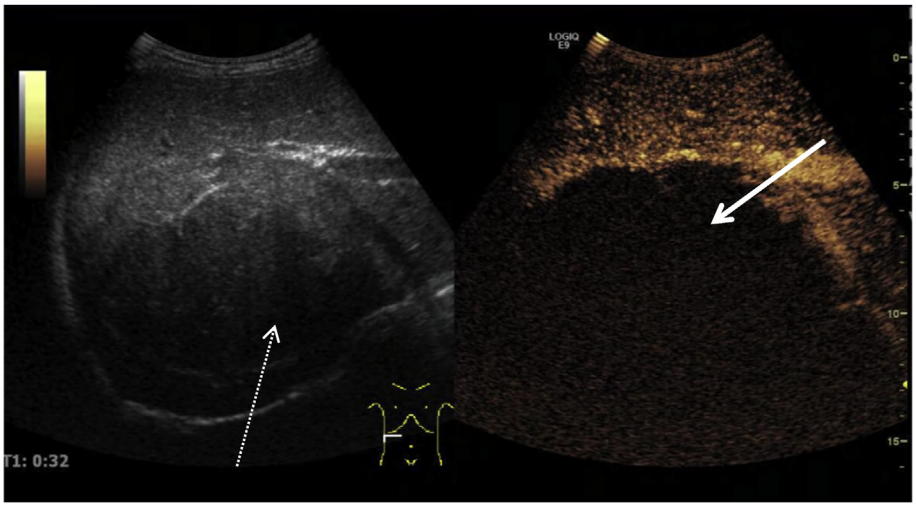

Fig. 7. Ultrasound image showing mixed lesion (Dotted white arrow) in the right posterior lobe of the liver combined with contrast-enhanced ultrasound image showing hepatic alveolar echinococcosis (White arrow) with surrounding activity.

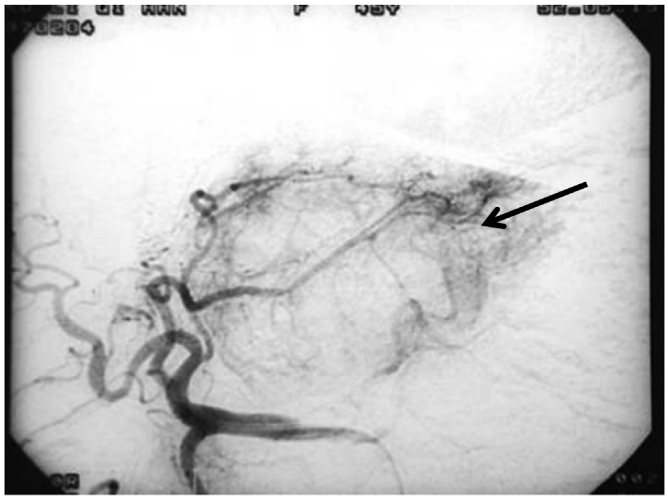

Fig. 8. DSA image showing the rich collateral circulation (Black arrow) in the hepatic tissue surrounding hepatic alveolar echinococcosis.

perfusion studies HAE lesions showed a greater degree of blood perfusion at lesion periphery, and the association between blood flow, blood volume and micro-vessel density (MVD) in the same regions of HAE lesions [44].

18F-FDG PET/computed tomography (CT) reveals more biological characteristics of the lesions, disease activity, remote metastasis, and recurrence. Due to this, 18F-FDG PET/CT is considered as a non-invasive evaluating tool for 3D detection of metabolic activity and extra-hepatic invasion prior to ex-vivo auto liver transplantation [45]. However, a comparative study between spectral CT and 18F-FDG PET concluded that spectral CT could be a more practical tool in the clinical routine as there was a good correlation [46].

6. Conclusion

In view of the prevalence of the infections of the liver (HBV, HCV, and HAE in particular) and their potential to progress to end-stage liver disease or HCC, an understanding of various manifestations and patterns of progression is crucial for early diagnosis along with improved patient care. An effective pre-operative imaging evaluation is essential to deliver a comprehensive understanding of the pathological states and anatomical variants of vascular and biliary structures of the donor's liver.

Though CTCh is superior to MRCP in giving more details of the biliary tree, eMRCP is much practiced due to the non-availability of contrast agent for CTCh in many countries. MRS H1 fat fraction study is better than US and CT in quantifying hepatic steatosis in donor hepatic tissue. IDEAL IQ protocol can be used to screen the recipients with hepatic steatosis with concomitant iron deposition. Automated liver volumetric schemes are showing promise in evaluating the volumes comparable to standardized liver volumes.

Further research can be directed towards integration of artificial intelligence (AI) to devise protocols based on volumetry, parenchymal and functional imaging features to predict outcomes in the donor and recipient to improve the effectiveness of transplantation. Imaging plays a key role in pre-transplantation surgical planning and Radiologist is an integral part of the multidisciplinary transplantation team aiming to achieve the best outcome for the donor and recipient.

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