Clinical Radiology (2008) 63, 136–145

REVIEW

Imaging evaluation of potential donors in living-donor liver transplantation

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Received 4 June 2007; received in revised form 24 August 2007; accepted 29 August 2007

Liver transplants, originally obtained from deceased donors, can now be harvested from living donors as well. This technique, called living-donor liver transplantation (LDLT), provides an effective alternative means of liver transplantation and is a method of expanding the donor pool in light of the demand and supply imbalance for organ transplants. Imaging plays an important role in LDLT programmes by providing robust evaluation of potential donors to ensure that only anatomically suitable donors with no significant co-existing pathology are selected and that crucial information that allows detailed preoperative planning is available. Imaging evaluation helps to improve the outcome of LDLT for both donors and recipients, by improving the chances of graft survival and reducing the postoperative complication rate. In this review, we describe the history of LDLT and discuss in detail the application of imaging in donor assessment with emphasis on use of modern computed tomography (CT) and magnetic resonance imaging (MRI) techniques.

Introduction

Liver transplantation, introduced by Starzl et al.[1] in 1968 is the recognized treatment of choice for patients suffering from end-stage liver disease. Over the years, surgical refinements, greater clinical expertise, and more effective immunosuppression have contributed greatly to the improved technical success of this operation. The growing clinical and political profile of liver transplantation has led to an expansion of the indications for transplantation, and as a consequence an escalating clinical demand for the procedure. Data from the USA, obtained from the United Network for Organ Sharing (UNOS), shows that from January 1 1988 to January 31 2007, a total of 82,157 liver transplants [78,882 (96%) deceased-donor liver, 3275 (4%) living-donor liver] were performed. In 2006 alone there were 6363 deceased and 288 living-donor liver transplants. Despite this, there remains an organ crisis due to a demand and supply imbalance with many more patients requiring liver transplants than there are available. UNOS data shows that a total of 17,429 patients are currently on the waiting list for liver transplantation, and of these patients, 2767 have been waiting for between 1–2 years and 4323 have been waiting 5 years or more. A significant proportion of patients die from their liver disease while on the waiting list. From 1 January 1995 to 31 January 2007, a total of 19,289 people died on the waiting list, while in 2006 alone, there were 1583 deaths.

Out of the need to expand the donor pool (cadaveric supply remaining stable at about 4000 a year) and alleviate this critical organ shortage, the innovative concept of living-donor liver transplantation (LDLT) as a surgical strategy was introduced. Since its inception over a decade ago, it has become a recognized and effective alternative means of liver transplantation for paediatric and adult patients. The number of LDLTs is increasing

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0009-9260/$ - see front matter
doi:10.1016/j.crad.2007.08.008

rapidly, as are the number of transplant centres offering the procedure. There were over four-times more living-donor operations performed in 2006 (288 cases, 4.3% of total liver transplants) than there were 10 years ago in 1996 (62 cases, 1.5% of total liver transplants). Sixty seven centres in the USA had performed at least one LDLT and 24 centres had performed more than 50 cases.

Imaging plays a central role in living-donor programmes by assessing whether potential donors are eligible candidates for donation based on anatomical considerations, and whether co-existing pathology is present. Alongside the evolution of LDLT, developments and refinements in imaging have created techniques that provide robust donor evaluation. In this review, we describe briefly the history of LDLT and discuss in detail the application of imaging in donor assessment with emphasis on use of modern CT and MRI techniques.

History of LDLT

The viability of LDLT as a concept is made possible because of the unique ability of the liver to regenerate following surgery and because its anatomical organization, as defined by Couinaud,[2] into independently functioning segments (each with separate vascular inflow and outflow and biliary drainage) favours segmental transplantation. Its introduction as an innovative surgical option grew out of the need to reduce the paediatric waiting list mortality (around 20–30%) by providing appropriate size-matched segmental grafts from donor parents to their children, and drew from earlier technical experience gained from cadaveric reduced-size transplantation[3] and split-liver transplantation.[4] In 1988, Raia et al.[5] from Brazil performed the first two LDLT, although both recipients later died of medical complications. In 1989, Strong et al.,[6] from Australia successfully performed a left lateral segment transplant from a mother to her son, with good outcome for both patients. In 1991, Broelsch et al.,[7] from the University of Chicago, in a paediatric LDLT series of 20 patients that used left lateral segment grafts, showed that the survival of LDLT was comparable with that of cadaveric transplantation. Tanaka et al.[8] from Kyoto, Japan, reported good results in paediatric transplant patients 2 years later. The success of paediatric LDLT programmes provided the impetus for its introduction into adult transplantation. The first adult living-donor transplant was performed at the University of Chicago in 1991 as an emergency procedure.[9] Adult-to-adult LDLT using left-lobe grafts did not prove to be as successful as it did in children, as these grafts were unable to provide sufficient functional mass for most adult recipients.[8] To overcome this problem, Yamoaka et al.,[10] after gaining experience from more than 200 cases of paediatric LDLT, performed the first successful adult-to-adult right lobe transplant in 1994. Lo et al.[11] performed the first extended right lobe (right lobe with rim of segment IV containing the middle hepatic vein, MHV) LDLT in 1997. Marcos et al.,[12] in 1999 published the first series of 25 patients using right-lobe grafts and this showed minimal risks to both donor and recipient. Today, adult-to-adult LDLT is the most rapidly growing transplant procedure, with results equivalent to cadaveric whole-liver transplantation.

Imaging evaluation of potential liver donors

Hepatic steatosis

Imaging is performed to detect liver parenchymal abnormalities that may preclude living-donor transplantation. Although malignant liver lesions in a potential donor are a contraindication, benign lesions such as haemangioma, particularly if single and small size in size ($\leq$2–3 cm), maybe transplanted safely and do not exclude liver donation.[13] However, in the vast majority of cases, parenchymal imaging focuses mainly on detecting hepatic steatosis, which, if present in a significant quantity, can cause postoperative graft dysfunction in the recipient and liver dysfunction or failure in the donor.[14] As a consequence of the demand and supply imbalance for transplants, suboptimal grafts may sometimes be used with some centres prepared to accept mildly steatotic grafts ($\leq$30% concentration).[15,16] Transplants with steatotic grafts of up to 50% have also been used, but are associated with a greater risk of ischaemic–reperfusion injury.[17] Imaging studies [ultrasound (US)/computed tomography (CT)/magnetic resonance imaging (MRI)] can detect the presence of hepatic steatosis, but maybe of limited value in quantifying the degree of steatosis. Ryan et al.,[18] in a study of 100 prospective right-lobe liver donors, could not accurately quantify the degree of hepatic steatosis using imaging (US or contrast-enhanced CT or both). However, Iwasaki et al.[19] suggested that quantification of steatosis may be possible by calculating the liver to spleen ratio (L:S) on unenhanced CT (a L:S of $\leq$1.1 has a sensitivity of 0.83, specificity of 0.82 and accuracy of 0.82 in detecting steatosis of $\geq$30%). Raptopoulas et al.[20] suggest