Living-Related Liver Transplantation

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Overview
Living donor liver transplantation (LDLT) was established due to desperate need with a background of cadaveric organ shortage. Currently, LDLT is considered a lifesaving procedure by validated safety and feasibility, especially in countries where there are few or no options for cadaveric organ donation. Major technical factors for successful LDLT are adequate graft volume to avoid small-for-size syndrome, sufficient portal vein inflow for liver graft regeneration, good hepatic vein outflow to prevent graft congestion, and secure bile duct anastomosis to prevent sepsis. Biliary stricture is one of the most common complications following LDLT and has been considered the Achilles' heel of LDLT. To minimize the risk of biliary stricture, it is important to keep the basic principles of anastomosis such as tension-free, regular intervals between stitches, approximation of mucosa, and avoidance of injury to bile duct epithelium. ABO-incompatible (ABO-I) LDLT could be a useful option for expanding pool of available organs. Since the use of rituximab in ABO-I LDLT, the paradigm of ABO-I LDLT has dramatically changed, and the outcomes of ABO-I LDLT have been comparable to those of the ABO-compatible group. The paramount concern in LDLT is donor safety. To minimize donor risk, strict selection criteria, standardized surgical technique, and stepwise application of new procedure are needed. However, conventional

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large abdominal scar may cause stress for living donors. Minimally invasive liver surgery could increase the willingness of potential donors to donate for LDLT. Nowadays, most experts agree that laparoscopic left lateral sectionectomy for graft procurement in living donor is the standard of care in pediatric LDLT. Although some expert teams have published successful series, the application of pure laparoscopic right or left hepatectomy remains controversial. It is still in the developmental phase. Technical innovation and expansion of living donor pool to overcome the limitation of using a partial graft in LDLT will progress and evolve. However, the paramount concern in LDLT is donor safety. It is important to consider the balance between donor risk and recipient outcome.

13.1 Introduction

In countries with scarce deceased donor liver graft, deceased donor liver transplantation (DDLT) is always short in demand. There is no doubt that Asian countries are in great need of living donor liver transplantation (LDLT). Since the first successful LDLT of a left lateral section graft from a mother to her son was performed by Strong et al. [1] in Australia in 1989, LDLT has been well established for pediatric recipients. However, LDLT for adults was desperately needed in the 1990s in Japan due to legal difficulties associated with cadaveric donation, unlike western countries. Makuuchi et al. [2] in Japan performed the first successful adult LDLT using a left lobe graft in 1993. After that, the need to overcome insufficient volume of left lobe graft for metabolic demand in adult recipients led to LDLT using a right lobe graft. Fan et al. [3] in Hong Kong performed the first LDLT using an extended right lobe graft, which includes Couinaud segments 5, 6, 7, and 8 with middle hepatic vein (MHV) in 1996. To overcome potential donor safety concerns caused by not leaving the MHV on the donor's remnant left lobe and right anterior congestion or insufficient functional liver volume of right lobe graft caused by leaving the MHV on the donor's remnant left lobe, LDLT using modified right lobe graft in which tributaries of MHV were reconstructed using autologous greater saphenous vein was performed by Lee et al. [4] in South Korea in 1999. Major Asian liver transplant (LT) centers have great effects on technical innovations and expansion of the criteria for LDLT as well. Its safety and feasibility have been well documented over the past several decades. LDLT is considered a valid and lifesaving procedure, especially in countries where there are few or no options for deceased organ donation.

13.2 Donor Safety Issues

Since the introduction of right lobe LDLT, adult LDLT has spread rapidly across the world. In the United States in 2000, there was a high level of enthusiasm for adult LDLT. However, such enthusiasm was quickly tempered by the death of a donor in

2002 in the United States. Since then, the number of patients undergoing LDLT has declined [5]. A literature review of donor hepatectomy reported that the risk of morbidity in donor hepatectomy increased when hepatectomy mass increased from left lateral section donation (8.2%) to left lobe donation (12.0%) and right lobe donation (19.0%) [6]. Recently, a worldwide survey on living donor risk documented that overall donor mortality and morbidity rates were 0.2% and 24%, respectively [7]. Therefore, strict donor selection criteria are required. Each LDLT center has developed its own evaluation criteria and selection protocol for living donor candidates. Although there are some differences between centers, there is a consensus that donor age, remnant liver volume (RLV), and degree of steatosis are the most important determining factors for donor safety [8]. In general, with increasing donor age, combined medical comorbidity also increases. Potential donors for right lobe hepatectomy are generally confined to healthy volunteers under 55 years old [9]. The minimally accepted RLV of right lobe donors should be individualized by donor age and the degree of steatosis. Steatosis affects hepatocyte function and impairs regeneration after major hepatectomy. It has been shown that steatosis is strongly associated with a high risk of morbidity and mortality after donor hepatectomy [10]. However, there are no guidelines for the acceptable range of steatosis in LDLT. In general, donor candidates with hepatic steatosis of more than 30% are rejected for right lobe donation [11]. As for unsuitable donor candidate due to obesity and steatosis, Hwang et al. [12] have demonstrated that active short-term reduction of body weight could alleviate excessive hepatic steatosis.

13.3 Surgical Procedures

13.3.1 Left Side Liver Graft (Left Lateral Section, Left Lobe Graft)

13.3.1.1 Donor Procedure

In general, donor hepatectomy can be performed through J incision, inverted L incision, or midline incision according to surgeon's preference. At first, the falciform, coronary, and left triangular ligaments are divided to free left liver. After removing the gallbladder, intraoperative cholangiography via cystic duct is performed to check biliary anatomy and rule out anatomical variants. The left hepatic artery (LHA) and left portal vein (LPV) are identified and taped. Some small branches going to the caudate lobe are clipped and divided to obtain sufficient length of LHA and LPV. Liver parenchyma is transected using a cavitron ultrasonic surgical aspirator (CUSA) along the right-side margin of the umbilical fissure in the left lateral section graft. Glissonean pedicles of segment 4 are ligated. The left bile duct is exposed after complete division of the liver parenchyma. The proposed target level of the left hepatic duct is then transected. In LDLT, cold ischemic time can be reduced when adjusting the harvest time according to the progress of the recipient's operation. When the recipient's operation has been completed, the LHA and the LPV are ligated and transected. After that, the left hepatic vein (LHV) is clamped and transected. The hepatic vein stump is oversewn in the donor side. If the vascular clamp for hepatic vein is slipped, it can lead to surgical disaster. Putting stay sutures at both ends below vascular clamp before transecting the LHV is commonly used to avoid accidental slippage of hepatic vein stump from vascular clamp. In case of left lobe graft, differences from what is described above are that the parenchyma is transected along the right side of the Cantlie line and the MHV should be included in the graft side. The graft is then removed and flushed immediately through the LPV with cold preservation solution at the back table.

13.3.1.2 Recipient Procedure

The order of basic recipient hepatectomy in LDLT is similar to that in DDLT. However, it should be done with caval preservation, and hilar division should be started at hilar plate level to make the hepatic artery and portal vein as long as possible. Hepatoduodenal dissection is completed by fully dissecting until it is above the bifurcation level of hepatic artery and portal vein. Liver mobilization starts from right side liver and moves to the left liver and caudate lobe division from inferior vena cava (IVC) by separating all short hepatic veins and hepatocaval ligament. After that, IVC total clamping test should be done in order to check the preservation of hemodynamic stability for hepatic vein anastomosis. If hemodynamic instability is present, veno–veno bypass can be performed using a biopump. When preparing for organ procurement in recipient and donor operation rooms, LHA and middle hepatic artery are transected first. Right anterior and posterior hepatic arteries are then transected. Then, LPV and right portal vein (RPV) are transected. Subsequently, right and middle-left hepatic vein common trunks are transected. Finally, the liver is removed. Hepatic vein anastomosis is performed using a single orifice of left and middle hepatic veins of the recipient or a wide window between the hepatic vein and the IVC by making incision at the IVC under total IVC clamping. Following completion of hepatic vein anastomosis, portal and arterial anastomoses are performed anatomically. Biliary reconstruction can be conducted as duct-to-duct or hepaticojejunostomy according to the condition of recipient's bile duct.

13.3.2 Right Side Liver Graft (Right Lobe, Extended Right Lobe, and Modified Right Lobe Graft)

13.3.2.1 Donor Procedure

The initial procedure like dividing falciform ligament and performing intraoperative cholangiography via cystic duct stump is the same as with left liver donor hepatectomy. In hilar division, small portal branch entering the caudate lobe is ligated first. After that, RPV is encircled, and right hepatic artery (RHA) is identified from bile duct and divided. After completion of hilar division, liver mobilization is started by dividing the right triangular ligament, right adrenal gland, and IVC ligament. Small short hepatic veins and right inferior hepatic veins (RIHV) less than 5 mm encountered during right lobe mobilization are ligated. However, sizable veins (> 5 mm) should be preserved for anastomosis later. The right hepatic vein (RHV) is encircled, and Penrose tube or umbilical tape can be placed between RHV and MHV for hanging maneuver. Demarcation line can be shown by temporary occlusion of RHA and RPV. Intraoperative ultrasonography is also used to make a demarcation line by visualizing the course of MHV. Liver parenchyma is transected using CUSA along the demarcation line. MHV is included in the donor side in case of right lobe graft. It is included in the graft side in case of extended right lobe graft. The right bile duct is exposed and marked with radiopaque marker after complete division of the liver parenchyma. After conducting intraoperative cholangiography, duct is transected at the proposed target level of the right hepatic duct. When parenchymal transection is completed, RHA and RPV are ligated and transected. RHV and any preserved short hepatic veins or RIHVs are clamped and transected, and the graft is removed. Cold preservation solution is flushed immediately through the RPV at the back table.

13.3.2.2 Recipient Procedure

The procedure of recipient hepatectomy for right lobe LDLT is the same as described above. Whether hilar dissection or liver mobilization is performed first is entirely up to the surgeon's personal preference. Several things need to be kept in mind regarding recipient hepatectomy in LDLT: (1) Hepatic artery and portal vein should have sufficient length for reconstruction; (2) Excessive dissection around bile duct should be avoided to prevent damage of small arterial branches supplying bile duct that can lead to the biliary stricture; (3) Excessive traction of hepatic artery should be avoided to prevent intimal dissection that can lead to hepatic artery thrombosis. Currently, major concerns for right lobe LDLT are focused on donor safety and reconstruction of MHV to avoid congestion of anterior sector as well. Therefore, three anatomical outflow drainage routes should be meticulously reconstructed to make a congestion-free allograft in back table. First, the anterior sector drainage should be performed through an extended right lobe (ERL) graft in which the MHV trunk is included in the liver graft or by a modified right lobe (MRL) graft in which venous tributaries of MHV (V5/V8) are connected via interposition vascular grafts to the recipient's hepatic vein or IVC. Second, wide RHV reconstruction is doubly assured by venoplasty not only in the recipient's hepatic vein and IVC, but also in the liver graft's intrahepatic venous ostium. Third, if multiple RIHVs exist, perfect posterior sector drainage is better ensured by transforming multiple RIHVs to a common, large opening instead of individual anastomosis [13].

13.3.2.3 Modified Right Lobe Graft

From the viewpoint of donor safety, ERL grafts may increase donor risk because donor's remnant left lobe does not include MHV. For this reason, Lee et al. [4] have claimed that MRL grafts are safer option than ERL grafts because they can provide similar functional liver volume if sizable (caliber >5 mm) MHV tributaries are reconstructed at the back table. Cryopreserved homologous vessels, autologous greater saphenous vein (GSV), portal vein bifurcation Y-graft, umbilical collateral vein, and hepatic vein excavated from resected liver have been used as an interposition vascular graft. When these vessels are unavailable, a synthetic vascular graft such as a polytetrafluoroethylene is a good alternative with acceptable patency rate [14].

13.3.2.4 Right Hepatic Vein Reconstruction

The RHV is the primary outflow pathway for right lobe graft. Its successful reconstruction is essential for full graft function. The graft can rapidly regenerate in all directions within 2–3 weeks in the limited right subphrenic space. This may compress the RHV anastomotic site [15]. To cope with possible conformational change and prevent venous outflow obstruction, making a wide orifice is essential (Figs. 13.1 and 13.2) [13].

13.3.2.5 Hepatic Vein Reconstruction of Extended Right Lobe Graft

Various techniques of hepatic vein reconstruction have been created to secure the venous outflow drainage of ERL grafts. They are classified as follows: (1) unification of venoplasty of RHV and MHV trunk and corresponding triangular excision of the recipient's IVC [16]; (2) large patch venoplasty to accommodate RHV and MHV simultaneously and corresponding large opening at the IVC [17]; (3) direct RHV anastomosis and separate reconstruction of MHV with an interposition graft

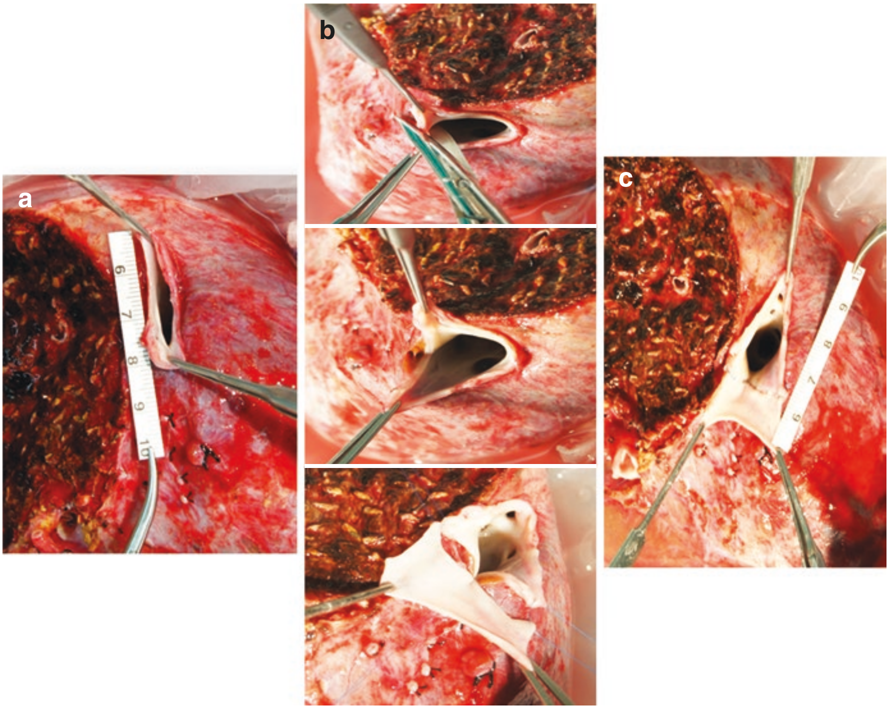

Fig. 13.1 Right hepatic vein reconstruction for a wide orifice in the liver graft at back table. (**a**) Right hepatic vein is approximately 3 cm in diameter. (**b**) Downward incision is made into the liver parenchyma at the caudal end of the right hepatic vein. Near half-circumferential greater saphenous vein patch, venoplasty around downward incision is made. (**c**) After patch venoplasty, right hepatic vein can be enlarged to have wide orifice (>4 cm)

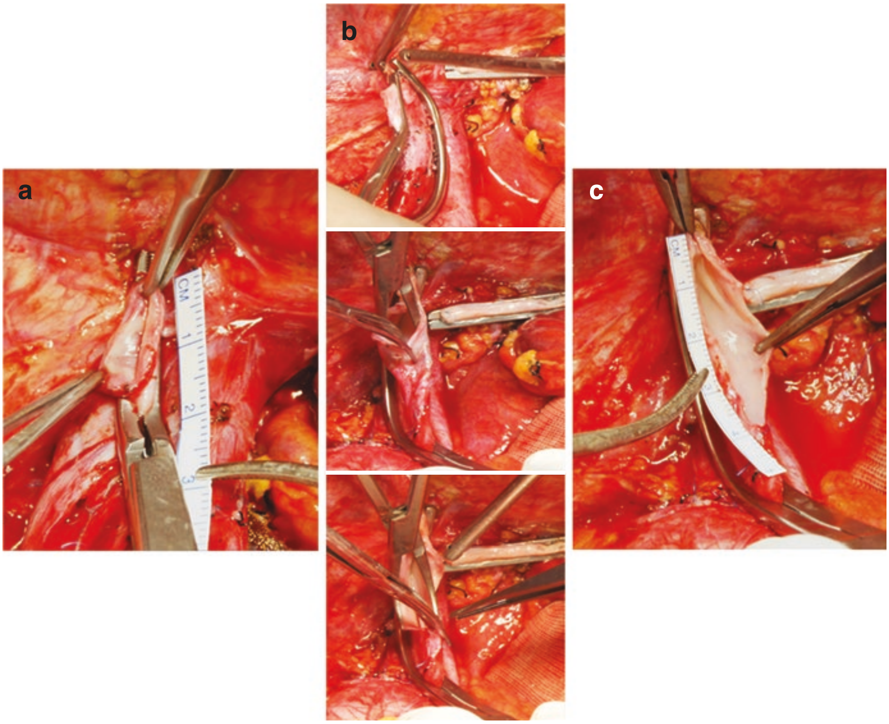

Fig. 13.2 Recipient right hepatic venoplasty to counteract conformational change at the anastomotic site by regenerated graft's compression. (**a**) Right hepatic vein orifice of 3 cm in diameter in recipient is partially clamped. (**b**) Downward incision into inferior vena cava comparable to the diameter of the enlarged graft's right hepatic vein is made. (**c**) Right hepatic vein orifice can be larger than 4 cm comparable to the enlarged diameter of graft's right hepatic vein. Creation of a reservoir on ventral wall by patch venoplasty can help prevent anastomotic stenosis

[18]; and (4) redundant large dome-shaped reservoir made by autologous saphenous vein patch (quilt venoplasty) corresponding large opening at the IVC (Fig. 13.3) [13, 19].

13.3.2.6 Right Inferior Hepatic Vein Reconstruction

RIHV larger than 5 mm in caliber has been indicated for revascularization. Because separate anastomoses of multiple RIHVs are vulnerable to obstruction or regeneration-related torsion, a common large opening of RIHVs can be introduced as follows: (1) Double vena cava technique using cryopreserved IVC graft [20], and (2) quilt venoplasty using autologous GSV patch with circumferential GSV fence [13, 19].

► Tip In left side liver graft donor procurement, LHV is relatively short, so the vascular clamp may slip at the moment of transection. To prevent this disastrous accident, putting stay sutures at both ends below vascular clamp before transecting the LHV is highly recommended. The essential points of recipient hepatectomy in LDLT are (1) hepatic artery and portal vein should have sufficient length for reconstruction; (2) excessive dissection around bile duct should be avoided to prevent biliary stricture; (3) excessive traction of hepatic artery should be avoided to prevent hepatic artery thrombosis.

In right lobe LDLT, regeneration of the graft in the limited right subphrenic space can lead to conformational change of the graft. To prevent possible regeneration-related torsion or obstruction of the venous outflow routes, making a wide orifice of the venous outflow is essential.

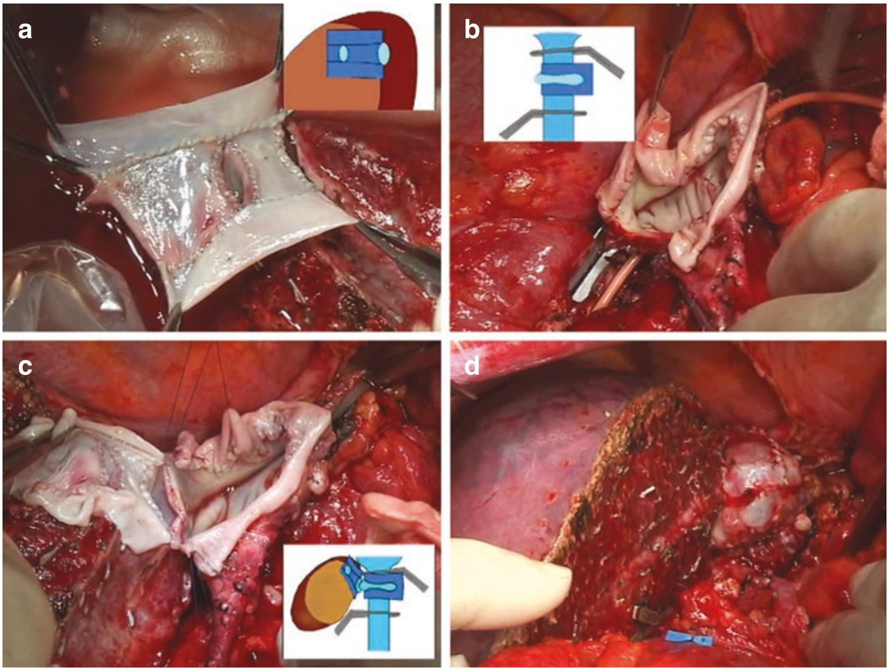

Fig. 13.3 Outflow vein reconstruction of extended right lobe graft using quilt venoplasty technique. (**a**) Rectangular patch of greater saphenous vein was first sutured between orifices of the right hepatic vein and the middle hepatic vein. Next, a segment of saphenous vein was attached to ventral side of middle hepatic vein as a center of a large cuff. Another two long segments of saphenous vein were attached to superior and inferior side of the large cuff. (**b**) All hepatic veins were opened altogether at the recipient inferior vena cava, and a fence with saphenous vein was made on the ventral side. (**c**) Posterior wall of right hepatic vein orifice was directly anastomosed with the IVC wall. (**d**) Ventrally abundant dome-shaped reservoir was made after completion of anastomosis

13.4 Minimally Invasive (Laparoscopic) Donor Hepatectomy

In LDLT, the most important concern is donor safety following the "do no harm" principle. However, permanent large abdominal incision scar following conventional open surgery may cause mental and physical stress for some living donors, especially young women, leading to hesitancy in donation. In this regard, minimally invasive liver surgery with many advantages such as less wound morbidity and faster recovery over conventional open surgery could increase the willingness of potential donors to donate for LDLT [21]. Laparoscopic hepatectomy was first performed for patients with benign tumors in the early 1990s. With accumulation of surgical experience and technical innovations during the past two decades, laparoscopic hepatectomy is now applied for almost all indications of hepatectomy [21]. The implementation of laparoscopic hepatectomy into LDLT started in the early 2000s. Cherqui et al. [22] reported the first laparoscopic donor hepatectomy (LDH) with left lateral sector for pediatric LDLT in 2002. Since then, its feasibility, safety, and reproducibility have been confirmed by experts [23, 24]. Nowadays, most experts agree that laparoscopic left lateral sectionectomy for graft procurement in living donor is the standard of care in pediatric LDLT [25, 26]. For adult LDLT, Kurosaki et al. [27] and Koffron et al. [28] have reported LDH using laparoscopy-assisted method, in which liver mobilization is performed under laparoscopic guidance, while hilar dissection and parenchymal transection are performed under direct vision through mini-laparotomy incision. Laparoscopy-assisted donor hepatectomy is the most popular and better option for right lobe graft procurement because difficult dissection of hilum including vascular and biliary anomaly and parenchymal transection can be performed under direct vision with standard instruments used in conventional open hepatectomy. It can be used as a good bridge to pure laparoscopic donor hepatectomy [27, 28]. Pure laparoscopic donor hepatectomy is the closest technique to the concept of minimally invasive surgery. Although some expert teams have published successful series, the application of pure laparoscopic right or left hepatectomy remains controversial. It is still in the developmental phase [29–31]. We should consider balanced insights regarding benefits and potential risks toward pure laparoscopic right lobe graft procurement. LDH can be performed only by surgical teams with extensive expertise in both minimally invasive surgery on the liver and donor hepatectomy in LDLT for selected individuals with favorable anatomy.

13.5 Expansion of Living Donor Pool

13.5.1 ABO-Incompatible LDLT

In most Asian countries, the number of deceased donors is insufficient. Thus, the waiting time for DDLT is very long, resulting in a high dropout rate. Because ABO incompatibility is one of the major reasons for dropout during evaluation of living donor candidates, ABO-incompatible (ABO-I) LDLT could be a useful option for expanding pool of available organs [32]. Although there are different protocols for different centers, preoperative management for ABO-I recipients includes plasmapheresis, rituximab, and postoperative local infusion therapy of immunosuppressant via the portal vein or hepatic artery with or without splenectomy [13]. Before rituximab was introduced, clinical outcomes of ABO-I adult LDLT in the literature were unfavorable in most reports. Since the first report of the use of rituximab in ABO-I LDLT in 2005, the paradigm of ABO-I LDLT in adult patients has dramatically changed [33]. According to a Japanese multicenter study, the incidence of antibody-mediated rejection dropped from 23.5% to 6.3% after the use of rituximab [34]. Recently, the largest single-center study has reported a desensitization protocol including a single dose of rituximab and plasmapheresis while excluding local graft infusion therapy, cyclophosphamide, and splenectomy due to adverse events. Cumulative 3-year graft and patient survival rates were 89.2% and 92.3%, respectively, comparable to those of ABO-compatible group [35].

13.5.2 Dual Grafts LDLT

Liver volume discrepancy between right lobe and left lobe in donors is also one of the major reasons for donor dropout in LDLT. To cope with this issue, Lee et al. [36] have introduced dual grafts LDLT which provides sufficient graft volume without additional donor risk. If right lobe donation is not possible and the left liver is too small, left liver grafts can be procured from two living donors and then implanted into one recipient [11, 13]. Dual LDLT using right lobe and left lobe grafts can expand application of adult LDLT by satisfying the required graft-to-recipient weight ratio of recipients when the available single right lobe graft cannot meet the recipient's metabolic demand [13, 37]. Prevalence and severity of donor complications of dual left lobe grafts LDLT are lower than those of single right lobe graft LDLT [13]. Several LDLT centers have reported the feasibility and successful outcome of dual grafts LDLT. However, expansion of living donor pool using dual grafts LDLT is limited due to technical complexity and high demands for manpower and facilities [11, 38–40].

13.6 Technical Challenges in LDLT

Basically, the following four technical factors must be met for successful LDLT: adequate graft volume to avoid small-for-size syndrome, sufficient portal vein inflow for liver graft regeneration, good hepatic vein outflow to prevent graft congestion, and secure bile duct anastomosis to prevent sepsis [13]. In most Asian countries, there have been numerous technical innovations to overcome anatomical barriers in LDLT. Despite recent advances, technical challenges remain because of anatomical conditions such as Budd–Chiari syndrome (BCS) and extensive portal vein thrombosis (PVT) [11].

13.6.1 Budd–Chiari Syndrome

BCS is a clinical condition characterized by hepatic venous outflow obstruction due to underlying various causes. BCS has a predisposition to thrombosis of major hepatic veins and/or IVC at any point proximal to the right atrium [41]. LT for BCS is indicated for patients with decompensated liver cirrhosis due to hepatic venous obstruction leading to liver congestion and progressive liver fibrosis [11]. Depending on the location of the hepatic vein occlusion in patients with BCS, different approaches ranging from cavoplasty to IVC replacement are required to create a new orifice for implantation of graft vein in LDLT in contrast with DDLT [8, 41]. Yamada et al. [41] have introduced an innovative surgical technique called patch venoplasty of IVC using autologous venous grafts derived from the recipient after resection of thrombosed IVC. Another option to allow venous outflow in LDLT for BCS is by replacing diseased retrohepatic IVC with a cryopreserved IVC or autologous vein graft [42, 43]. However, these procedures have limitations in retrohepatic IVC dissection which may result in a lot of bleeding and sternotomy or pericardiotomy is necessary for exposure in case of thrombotic obstruction of the suprahepatic IVC which extends almost to the junction of the right atrium and intrapericardiac IVC. In addition, available homografts are limited. Moon et al. [44] have described a technique that involves IVC replacement with a large-caliber synthetic graft (> 35 mm Dacron) between right atrium and intrahepatic IVC for such cases.

13.6.2 Portal Vein Thrombosis

Unlike the past, PVT is not considered a contraindication at most centers due to surgical innovations. However, LDLT for patients with PVT is technically difficult. It is usually complicated by extensive collaterals around the obliterated portal vein as well as significant intraoperative bleeding. For such cases, it is important to make a precise surgical plan based on sufficient information on the portal vein and portosystemic collaterals [11]. Egawa et al. [45] have suggested an operative strategy including thrombectomy and venoplasty for PVT according to the location and extent of PVT. However, due to significant risk of bleeding following accidental tearing of the PV during thrombectomy, combination technique including thrombectomy and portal vein stent placement by intraoperative cineportography has been suggested [46]. In cases of extensive PVT or complete obliteration of the PV, extra-anatomical portal vein anastomosis is a feasible alternative. Large portosystemic collateral itself can be used for portal vein inflow, and a jumping graft from the SMV or any available splanchnic vein is an alternative method for complete occlusion of the main portal vein [11, 47–49].

13.7 LDLT for HCC

Asian countries have no choice but to perform LDLT due to scarce cadaveric organs. At present, tocellular carcinoma accounts for 50% of indications for adult LDLT in Asia [4]. There are two controversial issues concerning LDLT for

Hepatocellular carcinoma (HCC). First, LDLT has a higher recurrence rate than DDLT. Second, expansion of selection criteria for LDLT to patients with advanced HCC may not be justified [4]. Compared to DDLT, LDLT provides several advantages such as shorter waiting time, better quality graft with normal liver function, shorter ischemic time, and pretransplant treatment optimization for HCC that might contribute to improved survival of LDLT recipients. However, these characteristics may lead to favorable condition for tumor progression and recurrence [50]. There are some hypotheses on higher recurrence rates in LDLT: (1) those with biologically aggressive HCC might drop off from the waiting list during the waiting time in DDLT setting. However, due to relatively short waiting time for LDLT candidates, progression of HCC with aggressive tumor biology might not be recognized. This is the so-called fast-track effect. (2) Growth factors and cytokines released during rapid regeneration of the partial grafts might contribute to tumor progression and recurrence. (3) Dissection and mobilization of the liver during recipient hepatectomy might increase tumor dissemination through the hepatic vein and increase the potential of leaving residual tumor cells [50–52]. However, there is no prospective study on this matter so far. According to several studies including two systematic reviews [53–55], there is no evidence to support higher HCC recurrence after LDLT than DDLT. Nevertheless, higher recurrence rates in LDLT recipients have been reported [50]. Milan criteria or the University of California at San Francisco criteria have been considered as the gold standard of selection criteria of LT for HCC. However, these criteria are based on DDLT and focused on maximizing efficacy using limited social resources. These criteria are too restrictive in LDLT setting. Moreover, liver grafts in LDLT are not considered public resources, but rather as private gifts [11]. Therefore, most Asian centers have adopted their own expanded selection criteria for LDLT for HCC with comparable long-term outcome based on both the number and size of HCC lesions [56, 57]. Whether these new criteria can replace the Milan criteria remains controversial. Tumor characteristics and biology seem to have significant impact on the recurrence while graft type and waiting time are less important as possible risk factors [50].

13.8 Biliary Stricture

Biliary stricture is one of the most common complications following LDLT, accounting for 7.3–60.0% in right lobe grafts in contrast with 5% in DDLT. It has been regarded as the Achilles' heel of LDLT [58]. As a bile duct reconstruction method, duct-to-duct anastomosis has replaced hepaticojejunostomy because of its some advantages including technically simpler and faster method, preservation of physiologic bilioenteric integrity, and no need to manipulate bowel. However, there are several possible risk factors, including multiple or small diameter of graft bile duct, ischemic damage to stumps of graft bile duct, and previous biliary leak. To minimize the risk of biliary stricture in LDLT, it is important to keep the basic principles of anastomosis such as tension-free, regular intervals between stitches, approximation of mucosa, and avoidance of injury to bile duct epithelium [11, 15].

Key Points

- Due to shortage of cadaveric organs, LDLT has been established as an alternative to DDLT in most Asian countries.
- Major technical factors for successful LDLT are adequate graft volume to avoid small-for-size syndrome, sufficient portal vein inflow for liver graft regeneration, good hepatic vein outflow to prevent graft congestion, and secure bile duct anastomosis to prevent sepsis.
- In case of using right lobe graft, to maximize graft function, meticulous reconstruction of three anatomical outflow drainage routes is essential. First, use ERL or MRL graft to avoid congestion injury of anterior sector. Second, perform stable reconstruction of RHV to prevent conformational change by graft regeneration-induced stenosis. Third, make a common large orifice of multiple RIHVs to avoid anastomotic torsion or stenosis.
- Laparoscopic procedure for liver graft procurement continues to progress towards right-side and pure laparoscopic methods. However, due to donor safety, pure laparoscopic donor hepatectomy should be performed in selected individuals with favorable anatomy by expertise team in both laparoscopic hepatectomy and LDLT.
- Technical innovation and expansion of living donor pool to overcome the limitation of using a partial graft in LDLT will progress and evolve. However, the paramount concern in LDLT is donor safety. It is important to consider the balance between donor risk and recipient outcome.

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