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Excellent outcomes of living donor liver transplantation: A contemporary report from Western Center

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A B S T R A C T

Background and Aims: Living donor liver transplantation (LDLT) helps address organ shortages but remains complex, particularly in Western countries where deceased donor liver transplantation (DDLT) is preferred. This study evaluates improvements in LDLT outcomes over time for both donors and recipients.
Study Design: A single-center retrospective analysis from 2001–2023 including two periods: P-ONE (2001–2003, 36 cases) and P-TWO (2020–2023, 27 cases). Donor surgery after October 2022 marked the shift to a full robotic approach. Recipient procedures preserved the retro-hepatic vena cava, with standard vascular and biliary reconstruction. Comparisons include demographics, complications, and survival.
Results: P-ONE donors were younger (median age 32 vs. 46, P=0.003), while P-TWO recipients were older (63 vs. 56 years, P=0.005) with more comorbidities. P-TWO had more cases of hepatocellular carcinoma and low-MELD cirrhosis. Donor safety improved in P-TWO, with similar major complication rates (14% vs. 11%). Recipients in P-TWO had fewer severe complications (7% vs. 81%, P<0.001) and better 3-year graft survival.
Conclusions: Advances in patient selection, minimally invasive surgery, and perioperative care have significantly improved LDLT outcomes. Despite persistent biliary challenges, LDLT remains a promising solution for end-stage liver disease and liver cancer.

1. Introduction

Liver transplantation (LT) is a curative treatment for many patients affected by life-threatening liver diseases with very short life-expectancy worldwide [1]. Despite the escalating global numbers of LT procedures annually, a substantial gap persists between the demand for organs and their availability [2]. Living donor liver transplantation (LDLT) has emerged as the primary alternative to deceased donors. Initially considered a potential panacea due to its seemingly unlimited resource [3,4], LDLT faced challenges, resulting in a disproportionately low use in Western countries compared with deceased donor LT (less than 5%) [5,6], with approximately 10% of listed patients succumbing while awaiting transplant. This limitation can be attributed to concerns surrounding donor risks, inferior recipient outcomes, and increased surgical complexity [7-9].

In line with these findings, a marked decrease in LDLT programs and cases occurred in Europe and the USA between 2007 and 2017, following an initial surge in the early 2000s [7-9]. Studies demonstrated a significant rate of donor morbidity (approximately 50% with varying complications) [10,11] and a higher incidence of patient and graft loss in LDLT compared with deceased donor LT (DDLT) [8-11]. Additionally, LDLT recipients experienced a higher rate of perioperative morbidity, particularly concerning

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biliary and vascular complications compared with DDLT [12-14]. Furthermore, hepatitis C virus (HCV) related cirrhosis at that time was the first indication for transplant, and HCV recurrence rate exceeded 70% of cases, with a possibly significantly higher risk in LDLT recipients rather than deceased donor transplants [15]. Unlike Eastern countries, where the scarcity of deceased donors necessitates LDLT, Western surgeons often prefer DDLT, avoiding the complexities associated with LDLT. This is particularly evident in Italy, which boasts one of the world's highest rates of deceased donors per million people [16] and organ utilization.

However, advancements in liver surgery over the last fifteen years, including improvements in patient selection, pre-operative assessment, and surgical techniques in open and minimally invasive approaches [17-20], have contributed to a significant reduction in perioperative complications for both donors and recipients. Consequently, concerns regarding the outcomes of LDLT have diminished, and the advantages of optimal grafts and transplant timing suggest that LDLT results could be on par with or even superior to DDLT.

This study aims to compare the outcomes of donors and recipients undergoing LDLT at the same center during two different periods. It is important to note that our LDLT program was interrupted between 2003 and 2020 due to both a national increase of organ availability from deceased donors and concerns about results of LDLT for both donors and recipients. The program restarted in 2020 reflecting renewed interest in LDLT, driven by advances in surgical techniques, perioperative care, and donor-recipient selection criteria.

2. Materials and methods

All consecutive cases of LDLT performed at Modena University's HPB and Transplantation Center were collected, spanning two distinct programs: P-ONE (2001-2003) and P-TWO (2020-2023, and still ongoing). Surgical teams differed between programs except for one surgeon (FDB). Table 1 outlines key differences between programs, encompassing surgeon experience, program organization, pre-operative patient assessment and intra/post-operative management. The gap between these two periods reflects the temporary halt of the LDLT program, largely due to the availability of deceased donor grafts in Italy and an institutional focus on DDLT. The P-TWO program was re-established after nearly two decades, in light of technical, organizational, and clinical advances.

2.1. Donor management

Donor recruitment occurred mainly during recipients' early outpatient evaluations. After an accurate staging of recipients' diseases, assessment of their dropout risk, and priority in waiting list [21], the opportunity of a LDLT was proposed. Based on the availability of potential donors from the recipient's close contacts, first-level screening was offered. Donors with incompatible blood groups or medical history of chronic diseases, liver hepatitis (from any origin) or previous liver surgery were excluded (Table 1) as well as donors with psychological frailty (evaluated by a dedicated specialist team). Only selected candidates proceeded to level 2 and 3 screening (Table 1).

2.2. Recipient management

Indications for transplantation were the same for both DDLT and LDLT. In line with national regulations and institutional policy, every patient assessed for LDLT was also listed for DDLT. Generally, the proposal of living donation was preferred in patients with a high dropout risk (for P-ONE) and in patients with HCC (hepatocellular carcinoma) or low MELD (Model for End Stage Liver Disease) (<25) liver cirrhosis without exception points based on the isoscore algorithm (for P-TWO) [21]. However, all transplant-eligible patients were considered potential LDLT recipients. Table 1 reports the recipient pre-listing and pre-transplant workup and intra/post-operative management.

2.3. Surgical approaches for donor and recipient

Donor surgery consists in a major right (H5678) or left (H123 or H1234 or H234) liver hemihepatectomy [22]. All P-ONE cases were performed using an open approach; P-TWO donors underwent an open approach in 16 cases until October 2022 followed by 11 fully robotic procedures.

The preferred graft was the right hemi-liver (right liver resection H5678 without Middle Hepatic Vein, MHV). However, surgeons decided to procure a right hemi-liver extended to the MHV in selected cases or occasionally an extended left hemi-liver including the MHV. The main driver to move from the right to the left liver graft was donor safety [23], indeed once an expected GRWR (Graft-to-Recipient Weight Ratio) was >1.2 with the right liver and/or when the Donor-FRL-WR (Donor-Future Remnant Liver-Weight Ratio) was <0.5 the left lobe became the first, and sometimes, the only choice. However, in cases with appropriate GRWR and Donor-FRL-WR for both the right and left graft, the bile duct or vascular anatomies could also guide graft choice. Parenchymal transection was conducted with CUSA® (Cavitron Ultrasonic Surgical Aspirator; Dentsply Sirona) in open surgery and robotic Harmonic ACE® (with daVinci Xi platform; Intuitive Surgical Inc., Sunnyvale, CA) in robotic surgery. All livers were assessed with intraoperative ultrasound before resection. Standard cholangiogram and indocyanine green cholangiogram were adopted, respectively, for open and robotic approaches to confirm the anatomy of the bile ducts before cutting and to complete biliostasis before donor closure.

Recipient surgery followed a higher hilum approach compared with whole liver transplantation from deceased donors. The retrohepatic caval vein was always preserved. Main hepatic vein reconstruction was performed as end-to-side anastomosis modulating the caval vein ostium with 5/0 Prolene running sutures. The portal vein was anastomosed using an end-to-end running suture with a 6/0 Prolene. The hepatic artery was reconstructed differently using a running suture or interrupted stitches based by its diameter or the surgeon's preferences, this was the same as regards the bile duct anastomosis (with 6/0 or 7/0 absorbable monofilament). Table 1 details the surgical differences between programs.

2.4. Data collection

Data were prospectively collected starting from case #1, including demographics, clinical details, perioperative variables, and follow-up for both donors and recipients.

2.5. Statistics

Donors' and recipients' demographic, disease and treatment characteristics, stratified according to the two programs (P-ONE and P-TWO) were reported. Continuous data were reported as median and range or as mean and standard deviation (SD), categorical data were reported as counts and percentages.

Wilcoxon's signed-rank test for continuous variables and Fisher's Exact Test for categorical variables were used to compare the distribution of baseline features, surgery characteristics and intra-operative outcomes between the two programs, among both donors and recipients.

The overall survival (OS) function was defined as the time from the day of surgery until death or last contact, and was estimated

Table 1
Features of the LDLT programs setting, donor and recipient selection criteria and clinical management.

P-ONE (2001-2003)	P-TWO (2020-still open)
Team setting	
Two main surgeons	*Two main surgeons*
Multidisciplinary donor and recipient evaluation and approval	*Multidisciplinary donor and recipient evaluation and approval*
Recipient application form	*All Staff check-list approval*
-	*Preparation formal meeting*
Donor Management	
Level 1 screening	
Personal medical history	*Personal medical history*
Body measures evaluation	*Body measures evaluation*
Blood test	*Blood test*
Blood group determination	*Blood group determination*
HLA typing	*HLA typing*
Level 2 screening	
Abdominal Ultrasonography	*MRI (MRCP and MR-angio)*
Angio-CT-scan or MRI (MRCP and MR-angio)	*Angio-CT-scan*
Arteriography	*3D-Liver Reconstruction*
Liver Biopsy	*Liver Biopsy (only in People with clinical suspicion of liver steatosis and/or viral hepatitis and/or HIV co-infection)*
Level 3 screening	
Cardiologist – Cardiac ultrasonography and visit	*Cardiologist – Cardiac ultrasonography and visit*
-	*Pneumologist - Spirometry*
-	*Esophago-gastro-duodenoscopy (only > 50 yo)*
Colonoscopy (only > 50 yo)	*Colonoscopy (only > 50 yo)*
-	*OBGYN screening and Mammography (in Women)*
-	*Dermatologist – Skin lesion screening*
-	*Coagulologist – Blood coagulation disorder screening*
-	*Infectivologist –microbiology, virology, serological screening*
Anesthesiologist – Consult	*Anesthesiologist – Consult*
Psychologist – Interview	*Psychologist – Interview*
Intra-operative	
Ultrasonography	*Ultrasonography*
Cholangiography	*Cholangiography (only in open approach)*
-	*Indocyanine green cholangiogram (only in robotic approach)*
Pringle maneuver (in selected cases)	-
Parenchyma transection was conducted with Harmonic ACE® or CUSA®	*Parenchyma transection was conducted with CUSA® (only in open cases) and Harmonic ACE® (only in robotic cases)*
Post-operative and follow-up	
Blood test	*Blood test*
Serial ultrasonography	*Serial ultrasonography*
CT scan at 1 month (occasionally)	*MRI (MRCP and MR-angio) at 45 days from the donation and annually.*
Recipient Management	
Level 1 screening	
Staging of liver disease and indication for LDLT – mainly driven by urgency	*Staging of liver disease and indication for LDLT – mainly driven by survival benefit*
Personal medical history	*Personal medical history*
Body measures evaluation	*Body measures evaluation*
Blood test	*Blood test*
Blood group determination	*Blood group determination*
Cross-match testing	*Cross-match testing*
Level 2 screening	
Abdominal Ultrasonography	-
Angio-CT-scan	*Angio-CT-scan*
Cardiologist – Cardiac ultrasonography and visit	*Cardiologist – Cardiac ultrasonography and visit*
Pneumologist – Spirometry	*Pneumologist – Spirometry*
Esophago-gastro-duodenoscopy	*Esophago-gastro-duodenoscopy*
Colonoscopy	*Colonoscopy*
-	*Color Doppler Ultrasonography of supra-aortic trunk and lower limbs (only elderly people)*
OBGYN screening and Mammography (in Women)	*OBGYN screening and Mammography (in Women)*
Otolaryngologist – Laryngoscopy and visit (in Patient with alcoholic liver disease)	*Otolaryngologist – Laryngoscopy and visit (in Patient with alcoholic liver disease)*
-	*Toxicologist – Screening and visit*

(*continued on next page*)

Table 1 (*continued*)

P-ONE (2001-2003)	P-TWO (2020-still open)
Nutritionist – Consult	*Nutritionist – Consult*
Level 3 screening	
Psychiatric and Psychologist – Interview	*Psychiatric and Psychologist – Interview*
Infectivologist	*Infectivologist*
–microbiology, virology, serological screening	–microbiology, virology, serological screening
Anesthesiologist – Consult	*Anesthesiologist – Consult*
Intra-operative	
Portal vein perfusion with 1-2 L of Celsior solution	*Portal vein perfusion with 1-2 L of Celsior solution*
-	*Short arterial flush with 100 ml – 200 ml of Celsior solution*
-	*Retrograde hepatic veins temporary flush aimed to assess intraparenchymal venous shunt*
Temporary portocaval shunt (only in demanding cases)	-
Inferior hepatic veins and hepatic venous branches larger than 8-10 mm were reconstructed	*All inferior hepatic veins and hepatic venous branches of 5-8 segments larger than 3-4 mm were reconstructed*
Reconstruction of inferior hepatic veins and hepatic venous branches on cryopreserved vascular allografts *when available or autologous saphenous/umbilical vein*	*Always reconstruction* of inferior hepatic veins and hepatic venous branches on cryopreserved vascular allografts
Portal vein end-to-end anastomosis by a 6/0 or 7/0 prolene running suture	*Portal vein end-to-end anastomosis by a 6/0 prolene running suture*
Arterial end-to-end anastomosis by a 7/0 or 8/0 running suture or interrupted stiches	*Arterial end-to-end anastomosis by an 8/0 or 9/0 running suture or interrupted stiches*
Biliary anastomoses were mainly duct-to-ducts end-to-end with a 6/0 or 7/0 absorbable monofilament or bilio-jejunostomy in selected cases (often)	*Biliary anastomoses were mainly duct-to-ducts end-to-end with a 6/0 or 7/0 absorbable monofilament or bilio-jejunostomy in selected cases (very rarely)*
Invasive portal venous pressure measurements from inferior mesenteric vein (only in demanding cases)	*Intraoperative blood flow meter (only in demanding cases)*
Ultrasonography	*Ultrasonography*
Biliary tutors (only in demanding cases)	-
Cholangiography (only in demanding cases)	*Cholangiography (only in demanding cases)*
Post-operative and follow-up	
Blood test	*Blood test*
Serial Color Doppler ultrasonography	*Serial Color Doppler ultrasonography*
TC scan or MRI	*TC scan or MRI at 3 months and annually*
Cholangiography (in patient with biliary tutors)	-

HLA: Human Leukocyte Antigen; angio-CT-scan: Computed Tomography Angiography; MRI: Magnetic Resonance Imaging; MRCP: Magnetic Resonance Cholangiopancreatography; MR-angio: Magnetic Resonance Angiography; OBGYN: Obstetrician-Gynaecologist; CUSA®: Cavitron Ultrasonic Surgical Aspirator; LDLT: Living Donor Liver Transplantation.

using the Kaplan–Meier method. The log-rank test was used to assess differences between P-ONE and P-TWO.

The cumulative incidence of graft failure curve function (CIF) was estimated according to methods described by Kalbfleisch and Prentice [24], considering death not caused by graft failure as a competing event. Gray's test was used to assess differences between groups.

Univariable regression models were used to assess the association between post-operative outcomes and the two programs, using P-ONE as the reference. This analysis was conducted for both donors and recipients. For continuous outcomes, such as the Comprehensive Complication Index (CCI®) evaluated at various time points (30-day, 90-day, late, and overall), linear regression models were applied. Logistic regression was used to examine the association with binary outcomes, including ascites, small for size syndrome (SFSS), re-operation, 30-day readmission, complications, and severe complications (evaluated at 30-day, 90-day, late, and overall), as well as biliary and vascular complications. Accelerated failure-time (AFT) models were used to investigate the impact of the program on the length of stay in both Intensive Care Unit (ICU) and hospital. Additionally, the Cox proportional hazards model was used to analyze time-to-event outcomes, such as overall survival.

Moreover, multivariable models were developed for specific outcomes: length of hospital stay for both donor and recipients, overall complications for donors and 90-day severe complications for recipients. The selection of variables to include in the models was performed using a forward selection approach, with p-values of <0.10 for entry and <0.05 for retention in the model.

All reported p-values were two-sided, with p-value less than 0.05 considered as statistically significant.

All analyses were performed with the statistical software SAS 9.4 (SAS Institute, Cary, NC, USA).

3. Results

Between May 2001 and December 2023, 63 adult-to-adult LDLT (AA-LDLT) were performed at Policlinico of Modena, University of Modena. Among these, 36 patients were treated in the P-ONE program (10 cases in 2001, 16 in 2002, and 10 in 2003) and 27 in the P-TWO program (2 cases in 2020, 7 in 2021, 9 in 2022, and 9 in 2023).

Table 2
Demographic and baseline features (donors).

Variable	Level	P-ONE N=36	P-TWO N=27	P-value
Age at surgery (y), median (Q1-Q3)		32 (28-40)	46 (32-52)	***0.003***
Age at surgery (y), N (%)	≤34	21 (58)	9 (33)	***0.044***
	35-59	15 (42)	16 (59)	
	≥60	0 (0)	2 (7)	
Sex, N (%)	Female	17 (47)	12 (44)	1.00
	Male	19 (53)	15 (56)	
Donor-recipient relationship, N (%)	Non-biologically related	5 (14)	7 (26)	0.33
	Biologically related	31 (86)	20 (74)	
Co-pathologies, N (%)	No	30 (83)	17 (63)	0.084
	Yes	6 (17)	10 (37)	
ASA, N (%)	ASA II	36 (100)	22 (81)	***0.011***
	ASA III	0 (0)	5 (19)	
Previous abdominal surgery, N (%)	No	22 (61)	15 (56)	0.80
	Yes	14 (39)	12 (44)	
BMI (kg/m^2), median (Q1-Q3)		24.1 (21.4-26.5)	23.9 (22.9-27.0)	0.68
Total liver volume (ml), median (Q1-Q3)		1,265 (1100-1477)	1,333 (1149-1494)	0.59
Graft volume (ml), median (Q1-Q3)		715 (638-924)	760 (694-886)	0.45
Donor FRL-WR, median (Q1-Q3)		0.74 (0.64-0.99)	0.66 (0.59-0.86)	0.19
Percent remnant liver, median (Q1-Q3)		35.0 (35.0-50.5)	35.2 (32.3-40.6)	0.15
Estimated GRWR, median (Q1-Q3)		1.14 (0.90-1.37)	1.06 (0.94-1.28)	0.60
Anatomic variation of hepatic hilum, N (%)	No	13 (36)	11 (41)	0.80
	Yes	23 (64)	16 (59)	
Vascular liver variation of hepatic hilum, N (%)	No	20 (56)	15 (56)	1.00
	Yes	16 (44)	12 (44)	
Bile duct variation from Type I, N (%)[a]	No	23 (64)	11 (41)	0.080
	Yes	13 (36)	16 (59)	
Pre-op arteriography, N (%)	No	5 (14)	27 (100)	***<0.001***
	Yes	31 (86)	0 (0)	
Pre-op liver biopsy, N (%)	No	12 (33)	21 (78)	***0.001***
	Yes	24 (67)	6 (22)	

ASA: American Society of Anesthesiologists; BMI: body mass index; Donor-FRL-WR: Donor-Future Remnant Liver-Weight Ratio; GRWR: Graft-to-Recipient Weight Ratio.

[a] Anatomic variation in intrahepatic bile ducts: an analysis of intraoperative cholangiograms in 300 consecutive donors for living donor liver transplantation. Choi JW, Kim TK, Kim KW, Kim AY, Kim PN, Ha HK, Lee MG. Korean J Radiol. 2003 Apr-Jun;4(2):85-90. doi: 10.3348/kjr.2003.4.2.85. PMID: 12845303; PMCID: PMC2698075.

3.1. Demographic and baseline features (donors)

Donors in P-ONE were significantly younger compared with P-TWO (32 years vs 46 years of median age), with a lower co-morbidity rate (Supplementary Material 1) (17% vs 37%) (Table 2). Donors' body mass index (BMI), whole liver calculated volumes and volumes of remnant liver were comparable between the two groups (P-ONE and P-TWO, respectively, median volume of 1,265 ml vs 1,333 ml and median percentage of FRL of 35.0% and 35.2%). Pre-operative liver biopsy was more common in P-ONE (67% vs. 22%). The estimated GRWR was similar (1.14 vs 1.06). Biliary anomalies were more frequent in P-TWO (59% vs 36%), while vascular variations of hepatic hilum were similar (44% in both programs). Angiography was used in 86% of P-ONE donors in order to better assess the arterial anatomy but in none of the P-TWO cases.

3.2. Demographic and baseline features (recipients)

Recipients' median age at the time of the transplant was significantly lower in the P-ONE compared to the P-TWO (56 yr vs 63 yr; P=0.005) (Table 3). Comorbidities were similar, but cardiopathy was more common in P-TWO (3% vs 26%; data not shown). There was a significantly higher proportion of HCC patients during the P-TWO period (25% vs 56%; P=0.019) with a trend towards higher rates of previous liver resections (6% vs 19%). HCV-related cirrhosis was markedly more prevalent in P-ONE than in P-TWO (64% vs 26%; P=0.005). Liver function resulted significantly worse in P-ONE: higher median MELD scores (15 vs 9, P>0.001), lower rates of Child-Pugh A cases (17% vs 59%; P<0.001), higher rates of moderate or severe portal hypertension (83% vs 56%; P=0.024).

3.3. Donor surgery and outcome

Right liver (H5,6,7,8) was procured in 27 cases (75%) during P-ONE (in 3 of those including the MHV) and in 23 cases (85%) of P-TWO (in 1 case including the MHV); left liver (H1,2,3,4 or H2,3,4) was procured in 17% of cases during P-ONE (5/6 including the MHV) and 15% in P-TWO (in 3/4 cases including the MHV); in 3 (8%) cases a left lateral including the caudate lobe (H1,2,3) was procured only in P-ONE (Table 4). All the P-ONE cases were performed by an open surgical approach, in P-TWO 11 cases (41%) underwent a totally robotic approach while the remaining 16 patients had an open hepatectomy. Operation time was similar, however, blood loss, transfusions, and intra-operative episodes of hypotension were significantly higher in P-ONE (Table 4). Preventive pringle maneuver was adopted in 13/36 cases only in P-ONE, such as preventive ICU observation for the first 24 post-operative hours in four donors (11%) in P-ONE. Post-operative course was significantly shorter in P-TWO (median hospital stay = 3 days vs 7 days, time ratio (TR) = 0.44 (95% CI: 0.37-0.52), P-value <0.001). The 30-

Table 3
Demographic and baseline features (recipients).

Variable	Level	P-ONE N=36	P-TWO N=27	P-value
Age at surgery (y), median (Q1-Q3)		56 (48-60)	63 (54-69)	***0.005***
Age at surgery (y), N (%)	≤34	4 (11)	1 (4)	***0.047***
	35-59	23 (64)	11 (41)	
	≥60	9 (25)	15 (56)	
Sex, N (%)	Female	16 (44)	11 (41)	0.80
	Male	20 (56)	16 (59)	
BMI (kg/m^2), median (Q1-Q3)		24.6 (22.6-26.6)	26.0 (22.9-27.1)	0.41
Co-pathologies, N (%)	No	10 (28)	10 (37)	0.59
	Yes	26 (72)	17 (63)	
ASA, N (%)	ASA II	23 (64)	16 (59)	0.80
	ASA III	13 (36)	11 (41)	
Previous hepatic surgery, N (%)	No	34 (94)	22 (81)	0.13
	Yes	2 (6)	5 (19)	
Cirrhosis, N (%)	No	3 (8)	4 (15)	0.45
	Yes	33 (92)	23 (85)	
HBV-infection, N (%)	No	23 (64)	19 (70)	0.86
	Yes	4 (11)	2 (7)	
	Anti-core	9 (25)	6 (22)	
HBV/HDV co-infection, N (%)	No	36 (100)	25 (93)	0.18
	Yes	0 (0)	2 (7)	
HCV-infection, N (%)	No	13 (36)	20 (74)	***0.005***
	Yes	23 (64)	7 (26)	
HCV/HIV co-infection, N (%)	No	36 (100)	25 (93)	0.18
	Yes	0 (0)	2 (7)	
HCC at transplant, N (%)	No	27 (75)	12 (44)	***0.019***
	Yes	9 (25)	15 (56)	
AFP at transplant (ng/mL), median (Q1-Q3) [a]		4.9 (3.4-68.5)	8.0 (3.9-97.1)	0.35
Child-score, N (%)	Child A	6 (17)	16 (59)	***0.001***
	Child B	13 (36)	7 (26)	
	Child C	17 (47)	4 (15)	
MELD-score, median (Q1-Q3)		15 (13-20)	9 (8-15)	***<0.001***
Spleen diameter (cm), median (Q1-Q3)		16.0 (13.5-18.0)	12.5 (10.9-13.9)	***<0.001***
Varices, N (%)	No	9 (25)	15 (56)	0.096
	F1	11 (31)	6 (22)	
	F2	13 (36)	5 (19)	
	F3	3 (8)	1 (4)	
Ascites, N (%)	No	19 (53)	20 (74)	0.12
	Yes	17 (47)	7 (26)	
Portal hypertension, N (%)	No	6 (17)	12 (44)	***0.024***
	Yes	30 (83)	15 (56)	
Portal vein thrombosis, N (%)	No	29 (81)	25 (93)	0.28
	Yes	7 (19)	2 (7)	
Waiting list (months), median (Q1-Q3)		5.3 (3.6-10.8)	3.1 (2.1-5.2)	***0.006***

a. AFP at transplant was evaluated only for patients with HCC at transplant
BMI: body mass index; ASA: American Society of Anesthesiologists; HBV: Hepatitis B Virus; HDV: Hepatitis D Virus; HCV: Hepatitis C Virus; HIV: Human Immunodeficiency Virus; HCC: Hepatocellular carcinoma; AFP: Alpha-Fetoprotein; Child-score: Child-Pugh Score; MELD-score: Model For End-Stage Liver Disease.

day complications rate was significantly higher in P-ONE (36% vs 11%, odds ratio (OR) P-TWO vs. P-ONE = 0.22 (95% CI: 0.06-0.88), P-value = 0.032) such as the 30-day CCI (10.4 vs 3.8, β parameter P-TWO vs. P-ONE = -6.6 (95% CI: -13.7-0.4), P-value = 0.064). Donor safety improved significantly in P-TWO, however, considering the rate of 30-day morbidity of ≥3, the Clavien-Dindo score was similar (14% P-ONE vs 11% P-TWO) (Supplementary Material 2S). Among all the donors, only one death occurred 9 years after donation due to breast cancer (Supplementary Material 3S).

3.4. Recipient surgery and outcomes

Data are reported in Table 4 and 5. GRWR and graft weight were similar (1.03 and 1.00; 640 gr and 732 gr, respectively, for P-ONE and P-TWO). Duration of surgery was shorter in P-TWO (median time 520 min vs 588 min, P-value = 0.044). Right lobe was selected in 75% of cases in P-ONE (in 3 cases with MHV) and 85% in P-TWO (in 1 case with MHV). Total ischemia time was significantly shorter in P-ONE (median time 74 min vs 179 min, P-value <0.001); indeed, the rate of accessory venous branches reconstructed at the bench table was significantly lower in P-ONE rather than in P-TWO (36% vs 67%, respectively, P-value = 0.001) and it took longer before graft implantation. Intra-operative complications rate (mainly represented by acute bleeding) were more common in P-ONE rather than in P-TWO (75% vs 15%, respectively, P-value <0.001); particularly, the median intra-operative blood loss was significantly higher in P-ONE (3,500 ml vs 500 ml, P-value <0.001). Thymoglobuline induction therapy was administered only in P-ONE from case #18 (19/36 cases); no cases received thymoglobuline therapy in P-TWO, where the induction therapy was carried out with basiliximab. ICU and hospital stays were shorter in P-TWO (ICU: 2 vs. 3 days, TR = 0.36; hospital: 8 vs. 22 days, TR = 0.33; both P < 0.001). Recipients in P-TWO also experienced fewer post-operative complications. The overall complication

Table 4
Surgery characteristics and intra-operative outcomes in donors and recipients.

Variable	Level	Donors			Recipients		
		P-ONE N=36	P-TWO N=27	P-value	P-ONE N=36	P-TWO N=27	P-value
Type of surgery, N (%)	Open	36 (100)	16 (59)	***<0.001***			
	Robotic	0 (0)	11 (41)				
Procured graft, N (%)	Right hepatectomy without MHV	24 (67)	22 (81)	0.57	24 (67)	22 (81)	0.57
	Right hepatectomy with MHV	3 (8)	1 (4)		3 (8)	1 (4)	
	Left hepatectomy without MHV	1 (3)	1 (4)		1 (3)	1 (4)	
	Left hepatectomy with MHV	5 (14)	3 (11)		5 (14)	3 (11)	
	Left lateral hepatectomy	3 (8)	0 (0)		3 (8)	0 (0)	
Graft weight (gr), median (Q1-Q3)		640 (550-784)	732 (625-795)	0.39			
Operative time (min), median (Q1-Q3)		410 (380-481)	435 (385-470)	0.62	588 (528-653)	520 (435-598)	***0.044***
Estimated blood loss (mL), median (Q1-Q3)		475 (100-1000)	150 (100-300)	***0.013***	3,500 (2425-5000)	500 (425-800)	***<0.001***
Intra-op transfusion, N (%)	No	14 (39)	27 (100)	***<0.001***	0 (0)	13 (48)	***<0.001***
	Yes	22 (61)	0 (0)		36 (100)	14 (52)	
Number of RBC units, median (Q1-Q3)					8 (4-14)	1 (0-2)	***<0.001***
Hypotensive episodes, N (%)	No	12 (33)	27 (100)	***<0.001***			
	Yes	24 (67)	0 (0)				
Pringle maneuver, N (%)	No	23 (64)	27 (100)	***<0.001***			
	Yes	13 (36)	0 (0)				
Intra-op complications, N (%)	No	26 (72)	27 (100)	***0.003***	9 (25)	23 (85)	***<0.001***
	Yes	10 (28)	0 (0)		27 (75)	4 (15)	
Intra-op cholangiography, N (%)	Standard cholangiography	36 (100)	16 (59)	***<0.001***			
	Indocyanine green cholangiography	0 (0)	11 (41)				
Actual GRWR, median (Q1-Q3)					1.03 (0.80-1.20)	1.00 (0.87-1.06)	0.62
Total ischemia (min), median (Q1-Q3)					74 (56-94)	179 (155-215)	***<0.001***
Biliary stent, N (%)	No				8 (22)	25 (93)	***<0.001***
	Yes				28 (78)	2 (7)	
Number of hepatic venous branches and accessory right inferior hepatic vein reconstructed, N (%)	0				23 (64)	9 (33)	***0.001***
	1				8 (22)	2 (7)	
	2				4 (11)	5 (19)	
	3				1 (3)	7 (26)	
	4				0 (0)	4 (15)	

MHV: Middle Hepatic Vein; RBC: Red blood cells; GRWR: Graft-to-Recipient Weight Ratio,

rates were significantly higher in P-ONE (97% vs 63%, P = 0.006). Short-term complication rates were also significantly higher in P-ONE (94% vs 63%, P = 0.006), particularly considering 90-day ≥3b Clavien-Dindo (81% vs. 7%, P <0.001).Small for size syndrome (SFSS) occurred in 6 cases (17%) in P-ONE; none in P-TWO. Four patients in P-ONE needed an early re-transplant (within 6 months from the transplant) due to SFSS in 2 cases, 1 for portal vein thrombosis and 1 for late hepatic artery thrombosis with ischemic cholangiopathy (Fig. 1.A). A total of 23 patients died in P-ONE after LDLT at different time periods: eight deaths were caused by graft failure (3 SFSS & Sepsi, 3 HCV recurrence with graft loss, 1 late liver complication – infection, 1 hepatic HCC recurrence) and 15 deaths for unrelated liver causes (Fig. 1.B). In P-TWO one death occurred not caused by graft failure (extra hepatic HCC recurrence). There is too much discrepancy in follow up to make a comparison, however, in Fig. 1.B we report the KM survival curve after transplant in the two series.

The univariate and multivariate analysis (Supplementary Material 4S, 5S, 6S, 7S) showed a significant impact of the era of donation and transplant (P-ONE vs P-TWO) on the length of donor hospital stay, donor's overall complication rate, length of recipient hospital stay and rate of 90-day recipient severe complications. Moreover, graft volume was significantly related with donor complication risk (the larger the graft volume, the higher the risk for the donor) and the recipient higher MELD score was associated with longer hospital stay.

4. Discussion

The adoption of adult-to-adult living donor liver transplantation (AA-LDLT) in Western countries was initially limited by concerns over donor safety and recipient complications. The availability of deceased donor organs reduced the perceived need for LDLT, despite risks of patient dropout or reduced survival [23,25–27]. In contrast, Eastern countries advanced LDLT programs due to a scarcity of deceased donors [28–30], achieving excellent outcomes that reignited interest in the West.

The present study, although limited by its single-center design and relatively small numbers, provides insight into how LDLT has evolved over two distinct periods in a Western country. The nearly 20-year gap between the two periods must be acknowledged and reflects the specific context of our center, where high availability of deceased donors reduced the need for LDLT. Thus, the study does not aim to provide a continuous program evaluation but rather a comparison of two distinct experiences. It is clear that many of the improvements observed in P-TWO mirror the general global

Table 5
Post-operative outcomes in donors and recipients.

Variable	Level	Donors					Recipients				
		P-ONE N=36	P-TWO N=27	P-TWO vs. P-ONE			P-ONE N=36	P-TWO N=27	P-TWO vs. P-ONE		
				Parameter	95% CI	P-value			Parameter	95% CI	P-value
ICU stay (days), median (Q1-Q3)							3 (3-10)	2 (1-2)	TR=0.36	0.25-0.52	***<0.001***
Hospital stay (days), median (Q1-Q3)		7 (6-8)	3 (3-4)	TR=0.44	0.37-0.52	***<0.001***	22 (15-45)	8 (7-11)	TR=0.33	0.23-0.45	***<0.001***
Ascites, N (%)	<1000mL						22 (61)	23 (85)	OR=0.27	0.08-0.96	***0.043***
	≥1000mL						14 (39)	4 (15)			
SFSS, N (%)	No						30 (83)	27 (100)	OR N.e.	N.e.	***0.033***
	Yes						6 (17)	0 (0)			
Re-operation, N (%)	No						12 (33)	25 (93)	OR=0.04	0.01-0.20	***<0.001***
	Yes						24 (67)	2 (7)			
30 days re-admission, N (%)	No						16 (52)	17 (63)	OR=0.63	0.22-1.80	0.39
	Yes						15 (48)	10 (37)			
	N.ev. [a]						5	0			
30-days (donors) / 90-days (recipients) complications, N (%)	No	23 (64)	24 (89)	OR=0.22	0.06-0.88	***0.032***	2 (6)	10 (37)	OR=0.10	0.02-0.51	***0.006***
	Yes	13 (36)	3 (11)				34 (94)	17 (63)			
30-days (donors) / 90-days (recipients) complications - Clavien-Dindo Score, N (%)	0	23 (64)	24 (89)	-	-	-	2 (6)	10 (37)	-	-	-
	2	8 (22)	0 (0)				3 (8)	5 (19)			
	3a	2 (6)	2 (7)				2 (6)	10 (37)			
	3b	1 (3)	0 (0)				10 (28)	2 (7)			
	4a	2 (6)	1 (4)				13 (36)	0 (0)			
	4b	0 (0)	0 (0)				2 (6)	0 (0)			
	5	0 (0)	0 (0)				4 (11)	0 (0)			
30-days (donors) / 90-days (recipients) severe complications, N (%)	Clavien 0	23 (64)	24 (89)	OR=0.78	0.17-3.57	0.74 [c]	2 (6)	10 (37)	OR=0.02	0.01-0.10	***<0.001*** [c]
	Clavien 1-2	8 (22)	0 (0)				5 (14)	15 (56)			
	Clavien ≥3 [b]	5 (14)	3 (11)				29 (81)	2 (7)			
30-days (donors) / 90-days (recipients) CCI, mean (SD)		10.4 (15.5)	3.8 (11.1)	β=-6.6	-13.7-0.4	0.064	55.1 (25.2)	17.7 (14.9)	β=-37.4	-48.3–26.5	***<0.001***
Late complications, N (%)	No	28 (78)	26 (96)	OR=0.14	0.02-1.15	0.067	8 (25)	21 (78)	OR=0.10	0.03-0.32	***<0.001***
	Yes	8 (22)	1 (4)				24 (75)	6 (22)			
	N.ev. [a]	0	0				4	0			
Late complications - Clavien-Dindo Score, N (%)	0	28 (78)	26 (96)	-	-	-	8 (25)	21 (78)	-	-	-
	2	2 (6)	0 (0)				7 (22)	1 (4)			
	3a	3 (8)	0 (0)				6 (19)	3 (11)			
	3b	3 (8)	1 (4)				2 (6)	2 (7)			
	4a	0 (0)	0 (0)				2 (6)	0 (0)			
	5	0 (0)	0 (0)				7 (22)	0 (0)			
	N.ev. [a]	0	0				4	0			
Late severe complications, N (%)	Clavien 0	28 (78)	26 (96)	OR=0.19	0.02-1.70	0.14 [c]	8 (25)	21 (78)	OR=0.15	0.03-0.77	***0.023*** [c]
	Clavien 1-2	2 (6)	0 (0)				13 (41)	4 (15)			
	Clavien ≥3 [b]	6 (17)	1 (4)				11 (34)	2 (7)			
	N.ev. [a]	0	0				4	0			

(*continued on next page*)

Table 5 (*continued*)

Variable	Level	Donors					Recipients				
		P-ONE N=36	P-TWO N=27	P-TWO vs. P-ONE			P-ONE N=36	P-TWO N=27	P-TWO vs. P-ONE		
				Parameter	95% CI	P-value			Parameter	95% CI	P-value
Late CCI, mean (SD)		6.5 (13.0)	1.2 (6.5)	β=-5.3	-10.8-0.2	0.057	38.4 (36.4)	7.2 (14.0)	β=-31.2	-46.1–16.3	***<0.001***
N.ev. [a]		0	0				4	0			
Biliary complication, N (%)	No	32 (89)	26 (96)	OR=0.31	0.03-2.92	0.30	17 (47)	17 (63)	OR=0.53	0.19-1.46	0.22
	Yes	4 (11)	1 (4)				19 (53)	10 (37)			
Type of biliary complication, N (%)	No	32 (89)	26 (96)	-	-	-	17 (47)	17 (63)	-	-	-
	Stenosis	2 (6)	0 (0)				10 (28)	3 (11)			
	Fistula	2 (6)	1 (4)				9 (25)	7 (26)			
Vascular complication, N (%)	No	36 (100)	27 (100)	OR N.e.	N.e.	1.00	30 (83)	25 (93)	OR=0.40	0.07-2.16	0.29
	Yes	0 (0)	0 (0)				6 (17)	2 (7)			
Overall complications, N (%)	No	20 (56)	23 (85)	OR=0.22	0.06-0.76	***0.017***	1 (3)	10 (37)	OR=0.05	0.01-0.41	***0.006***
	Yes	16 (44)	4 (15)				35 (97)	17 (63)			
Overall complication - Clavien-Dindo Score, N (%)	0	20 (56)	23 (85)	-	-	-	1 (3)	10 (37)	-	-	-
	2	7 (19)	0 (0)				1 (3)	1 (4)			
	3a	4 (11)	2 (7)				4 (11)	12 (44)			
	3b	3 (8)	1 (4)				7 (19)	4 (15)			
	4a	2 (6)	1 (4)				11 (31)	0 (0)			
	4b	0 (0)	0 (0)				1 (3)	0 (0)			
	5	0 (0)	0 (0)				11 (31)	0 (0)			
Overall severe complications, N (%)	Clavien 0	20 (56)	23 (85)	OR=0.52	0.14-1.92	0.33 [c]	1 (3)	10 (37)	OR=0.04	0.01-0.14	***<0.001*** [c]
	Clavien 1-2	7 (19)	0 (0)				5 (14)	13 (48)			
	Clavien ≥3 [b]	9 (25)	4 (15)				30 (83)	4 (15)			
Overall CCI, mean (SD)		14.5 (18.5)	5.0 (12.5)	β=-9.5	-17.7–1.2	***0.025***	68.7 (26.0)	21.5 (17.9)	β=-47.3	-58.9–35.6	***<0.001***
Re-LT, N (%)	No						32 (89)	27 (100)	OR N.e.	N.e.	0.13
	Yes						4 (11)	0 (0)			
HCC recurrence, N (%) [d]	No						10 (83)	13 (87)	-	-	-
	HCC						1 (8)	2 (13)			
	iCCA						1 (8)	0 (0)			
Deaths, N (%) (Overall survival)	Alive	35 (97)	27 (100)	HR N.e.	N.e.	0.95	13 (36)	26 (96)	HR=0.10	0.01-0.75	***0.025***
	Dead	1 (3)	0 (0)				23 (64)	1 (4)			

ICU: intensive care unit; SFSS: small for size syndrome; CCI: Comprehensive Complication Index; LT: Liver Transplant; HCC: Hepatocellular carcinoma; iCCA: Intrahepatic Cholangiocarcinoma. N.e.: not estimable (the model could not be performed due to the absence of events in one of the periods examined. An exact p-value was calculated)

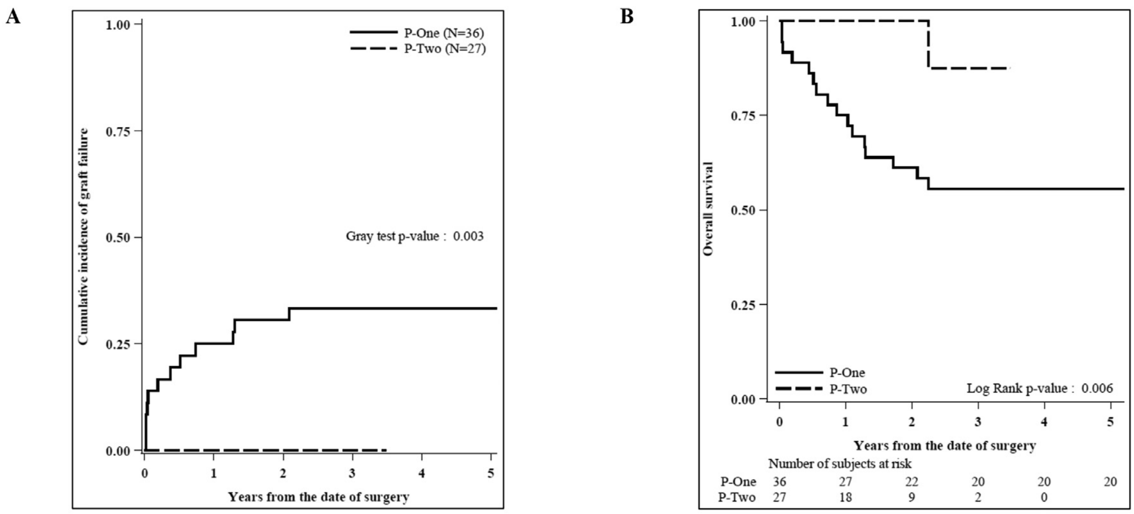
TR: Time ratio; OR: Odds ratio; β: Linear regression parameter; HR: Hazard ratio

[a] N.ev.: not evaluable. Four recipients died less than one month after the surgery, while one recipient died approximately 9 months after the surgery, never having been discharged from the hospital. The first four patients were excluded from the analysis of late complications, and all five patients were excluded from the 30-day re-admission analysis

[b] For donors, Clavien ≥3a was considered as a severe complication, while for recipients, Clavien ≥3b was considered as a severe complication

[c] In this model "Severe complications" was considered as a binary outcome: Clavien ≥3 vs. Clavien <3

[d] HCC recurrence was evaluated only for patients with HCC on histological examination



	Events	Competing events	Censored	1-y CIF (95% CI)	3-y CIF (95% CI)	5-y CIF (95% CI)
P-ONE	12 (33%) [a]	11 (31%) [b]	13 (36%)	25 (12-40)	33 (19-49)	33 (19-49)
P-TWO	0 (0%)	1 (4%) [c]	26 (96%)	0	0	0

	Deaths	Median FU (Q1-Q3) in years	1-y OS (95% CI)	3-y OS (95% CI)	5-y OS (95% CI)
P-ONE	23 / 36 (64%) [a]	7.5 (1.0-21.1)	75 (58-86)	56 (38-70)	56 (38-70)
P-TWO	1 / 27 (4%) [b]	1.6 (0.6-2.3)	100	88 (39-98)	-

Fig. 1. A Cumulative incidence of graft failure (recipients). **B** Overall survival (recipients). **a.** Four re-transplants (2 SFSS with PNF, 1 Early portal vein thrombosis, 1 Late hepatic artery thrombosis with ischemic cholangiopathy) and 8 deaths caused by graft failure (3 SFSS & Sepsis, 3 HCV recurrence with graft loss, 1 Late liver complication – infection, 1 hepatic HCC recurrence). **b.** Eleven deaths not caused by graft failure (1 Early sepsis due to immunodeficiency in combined liver and bone marrow transplant, 1 Sepsis, 1 Sepsis and Liver abscesses due to late hepatic artery thrombosis, 1 Ischemic stroke, 1 iCCA recurrence, 1 Pancreatic Cancer, 1 Cerebral haemorrhage, 4 Cardiovascular cause, 2 Late haemorrhagic shock (1 for ruptured splenic aneurysm and 1 for 3rd re-transplant) **c.** One death not caused by graft failure (extrahepatic HCC recurrence) CIF: Cumulative incidence of graft failure curve function. **a.** Cause of death: 2 Missing, 3 SFSS with sepsis, 1 Early sepsis due to immunodeficiency in combined liver and bone marrow transplant, 1 Sepsis, 1 Sepsis and Liver abscesses due to late hepatic artery thrombosis, 1 Late liver complication – infection, 3 HCV recurrence with graft loss, 2 HCC/iCCA recurrence, 1 Pancreatic Cancer, 1 Ischemic stroke, 1 Cerebral Haemorrhage, 4 Cardiovascular cause, 2 Late haemorrhagic shock (1 for ruptured splenic aneurysm and 1 for 3rd re-transplant). **b.** Cause of death: extra hepatic HCC recurrence. FU: Follow-up; OS: Overall survival.

progress in hepatobiliary surgery, transplant oncology, and peri-operative medicine. Nevertheless, the comparison is meaningful in showing how such advances translated into safer donor operations and improved recipient outcomes in the specific context of our institution.

The present study showed, over nearly two decades, that significant improvements occurred in outcomes and refinements in surgical technique and patient selection in AA-LDLT in a single European Transplant center. The first relevant result of the present study was the evolution of the donor post-operative outcome. Indeed, considering intra-operative transfusions, the post-operative length of hospital stay and the overall rate of post-operative complications in P-TWO showed a significant improvement of post-operative course of the donors although the donor selection criteria were more extended in P-TWO than in P-ONE in terms of age, co-morbidity, and anatomical complexity. Complication rates were more than halved as well as hospital stay. These results are comparable to other larger experience worldwide [31-34] and are strongly related to the surgery. The P-ONE experience was, however, paramount in shifting the LDLT procedure to using more Left Lobes and in adopting portal flow modulation. Through the P-ONE experience we were able to understand how to choose the portal flow modulation, to use grafts with GRWR $<$ 0.6 and we understood the burden of HCV re-infection and high MELD in affecting post-transplant outcome. New generations of surgeons may benefit from the experience of pioneers, they may express a higher level of meticulous surgery that may be translated into safer donations. Liver Transplant Surgeons in the Western world, in the most recent period, took advantage of planning better the donor and the recipient procedure thanks to the evolutions achieved by CT-scan, MRI, and 3D-liver reconstruction plus the larger experience of radiologists. Certainly, the introduction of minimally invasive donor hepatectomy has played a role in improving donor outcomes [35-38].

Moreover, in P-TWO, there was more accurate donor selection and donor/recipient matching. In P-ONE there was significantly more advanced cirrhosis and higher MELD scores and portal hypertension parameters amongst recipients.

At the beginning of this extraordinary global experience of LDLT, living donation was interpreted as an alternative to deceased donors. Candidates for LT could be transplanted by a living or deceased donor based on their availability, aside from the recipient characteristics and privileging their urgency [39–41]. After the first large experiences in the 90s', some authors described the SFSS that made surgeons pay attention in matching recipient features with the donor and graft characteristics [42]. Since then, surgeons have started to improve the inflow control by measurement of portal flow and pressure and the vascular outflow. Combining the modulation of portal inflow (such as splenic artery ligation, splenectomy, portal vein partial transposition) with an extended outflow reconstruction (not only the main hepatic vein but also the minor accessory intra or extra-parenchymal hepatic veins) we were able to significantly increase the performance of the graft. Moreover, several studies well stratified the GRWR in classes of risk (i.e. GRWR $<$0.5, 0.5-0.8, 0.8-1, $>$1), giving accurate thresholds of recipients at high or low risk of SFSS and, consequently, needing more or less efforts of inflow and outflow surgical management [23,43]. In P-TWO the accessory hepatic vein reconstruction was significantly more frequent with success (with preserved vascular flow after transplant) and in all the cases using a cryopreserved iliac or caval graft. In parallel, transplant oncology has taken huge steps over the last 20 years even in patient selection for LT and in treatment before the transplant [44,45]. In this way, oncological indications for LT are almost half of all indications [46]. Therefore, patients with HCC and low cirrhosis scores became optimal candidates for LDLT [47,48]. Finally, the revolutionary treatment of HCV reduced the rate of pure cirrhotic candidates for LT, the severity of HCV related cirrhosis, and the post-transplant outcomes that were severely impaired by HCV recurrence, particularly after LDLT [49]. Recipient biliary complications still remain the real Achilles' heel of LDLT. Although a significant increase in good results in biliary complications occurred comparing our experience with P-ONE and P-TWO, however, their rate still remains high in liver transplantation [50]. In P-TWO the biliary complications were not associated with patient or graft loss and their management appeared more effective in the most recent experiences [51]. Biliary fistula is more frequent than stenosis, and the majority of these fistulas may be effectively treated by one or more endoscopic stentings [51,52]. However, the incidence of recipient biliary complications marks the largest discrepancy between Western and Eastern experiences [51,52]. Overall, the present study showed a significant increase of AA-LDLT results for both the donors and the recipients comparing the two periods, particularly P-TWO showed an independent protective factor of shorter hospital stay and lower complication rate for both donors and recipients. The reasons for this are related to the periods themselves. Surgeons of the first experience (P-ONE) were pioneers of this new frontier and thanks to their efforts, experiences, and studies P-TWO achieved better results. Benchmarks changed over time and both the experiences were extraordinary considering the two periods and the two different benchmarks and referrals [52]. These results may encourage Western centers to reconsider adult-to-adult LDLT programs and to identify indications where living donor transplantation could offer superior outcomes compared with deceased donor transplantation. The limitations of this study are mainly the retrospective nature of the study itself and the difference in follow up time between patients transplanted in P-ONE and P-TWO. The identification of independent risk factors is difficult to achieve, however, the clinical and surgical data collected and analyzed may effectively support the study conclusions. In summary, new periods of LDLT programs may achieve significantly better results compared with the previous experiences for both donors and recipients. Accurate donor selection, donor/recipient matching, and inflow and outflow management are the keys for successful results. Low-MELD recipients are the ideal candidates for LDLT. Minimally invasive donor hepatectomy is the most recent innovation that may have a wide diffusion after larger analysis on its safety and technical aspects.

Declaration of competing interest

None of the authors have any conflict of interest, neither in terms of funding or of commercial associations.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.dld.2025.12.015.

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