A retrospective analysis of outcomes and complications of living- and deceased-donor split-liver transplantation in Johannesburg, South Africa

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Background. South African transplant centres are faced with significant challenges in meeting the need for liver transplantation, owing to the low and ever-decreasing number of deceased-donor organs. To increase organ utility, deceased-donor split-liver transplant (DDSLT) and living-donor liver transplant (LDLT) programmes were initiated in the Wits Transplant Unit.
Objective. To evaluate outcomes of the LDLT and DDSLT programmes.
Methods. A retrospective analysis of de-identified recipient and donor variables from all adult and paediatric DDSLTs and LDLTs conducted between 2013 and 2021 was performed. Comparison of categorical study variables between graft types was done with the χ^2 test. Continuous variables were compared by means of the independent samples *t*-test. Cox proportional hazards regression was performed to examine the effect of graft type on recipient and graft survival. All comparisons were made unadjusted, and adjusted for recipient age, recipient ethnicity, donor sex, and graft-weight-to-recipient-weight ratio (GWRWR) (for the paediatric cohort); and for donor age and GWRWR (for the adult cohort).
Results. A total of 181 paediatric and 48 adult liver transplants have been performed since the inception of the two programmes. Chronic liver failure, specifically intra- and extrahepatic cholestatic disease, was our main indication for liver transplantation in both cohorts. There were no significant differences between the DDSLTs and LDLTs in respect of pre- or post-discharge intervention, in-hospital mortality, length of stay, and recipient or graft survival within both the paediatric and adult groups. Our overall 1- and 3-year survival estimates (95% confidence intervals) were 77% (70% - 83%) and 71% (64% - 78%) for the paediatric cohort, and 77% (62% - 87%) and 66% (50% - 78%) for the adult cohort, respectively.
Conclusion. The results of this study demonstrate comparable outcomes between DDSLT and LDLT, indicating that both methods are effective approaches to optimise organ utilisation for liver transplantation within our setting.

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Liver transplantation (LT) remains the gold standard for definitive management of end-stage liver disease (ESLD) and recalcitrant acute liver failure (ALF).[1] In well-resourced, high-income countries, over 1 million liver transplants have been performed to date, with increasing demand for transplantation services.[1] Challenges continue, and the supply of deceased-donor (DD) organs is exceeded by the growing number of candidates waitlisted annually.[2] Various strategies have therefore been developed to further increase the donor pool. One such strategy, split-liver transplantation (SLT), was extrapolated from reduced-size LT in paediatric groups with good outcomes.[3] This technique has helped improve access to transplantation. For example, in Europe, 4 103 deceased-donor split-liver transplants (DDSLTs) and 3 079 living-donor liver transplants (LDLTs) were performed between 1988 and 2008.[2,3]

Access to LT remains severely restricted in many low- and middle-income settings, with very few liver transplant centres in Africa. South African (SA) transplant centres face significant challenges in meeting liver transplant needs, including the availability of DD organs.[4] There are numerous reasons for the paucity of DD organs, including limited governmental support for implementing and sustaining transplant services, the absence of national awareness and public education programmes, religious and other complex societal and social factors, and disease prevalence such as hepatitis B and HIV.[5] To increase organ utilisation within SA, both DDSLT and LDLT programmes were initiated in the Wits Transplant Unit, Johannesburg.[6] DDSLT is a procedure in which one DD liver is divided into two functional parts, allowing two recipients to benefit, consequently increasing the donor pool and decreasing local waiting times for both adult and paediatric recipients.[3]

LDLT is an excellent and viable additional donor source to DDLT in an organ-deplete environment with low donor-mortality risk (0.08% - 0.5%) and the potential for excellent outcomes.[2,7]

It involves the resection of an appropriately sized portion of liver from a living donor, with the graft then transplanted into a single recipient.[7] Additionally, although small, the potential for living donors to experience morbidity does exist,[8] but is mitigated by the experience gained in performing high volumes of these operations (15 - 20 per year).[9,10] While early patient survival is equivalent, a higher probability of technical complications including biliary complications, vascular complications, and re-transplantation are described more frequently in recipients of LDLT compared with DDSLT recipients in some centres; however, complications are also noted to significantly decrease as centre experience is gained.[8] LDLT is an important contributor in environments where living donation is more acceptable than deceased donation, as seen in Asia,[11] where 90% of liver transplants are LDLTs compared with 5% in the USA and 4.3% in Europe.[2,12]

Given that existing data around both DDSLT and LDLT in SA are limited and we have gained significant experience in more recent years, in this paper we present an analysis of the living-donor and split-liver transplant programmes at the Wits Transplant Unit.

Methods

We conducted a retrospective analysis of all adult and paediatric LDLT and DDSLT procedures performed from 1 January 2013 to 31 December 2021, allowing for a minimum of 1-year follow-up. Data were accessed from longitudinal Research Electronic Data Capture (REDCap)[13,14] paediatric (<18 years) and adult (≥18 years) liver transplant databases at Wits Donald Gordon Medical Centre, both of which had been approved by the Medical Human Research Ethics Committee at the University of the Witwatersrand (ref. nos M190723; M190749).

Data acquisition

The following data were collected for this study:

Recipient variables at time of transplant: age, sex, the primary cause of end-stage liver disease (ESLD), height, weight, body mass index (BMI), malnutrition *z*-scores, medical urgency: paediatric ESLD (PELD) score, model for ESLD (MELD) score (adults), viral serology (cytomegalovirus (CMV) immunoglobulin G, Epstein-Barr virus (EBV), hepatitis B, HIV), diabetes mellitus (adults), time on the waitlist, length of hospital stay (LOS) (defined as the number of days from transplant to discharge/death), graft-weight-to-recipient-weight ratio (GWRWR), immunosuppression agents, post-transplant bloodstream infections (BSIs) recorded prior to discharge, post-transplant complications (surgical re-operation, biliary, vascular and enteric), intervention as defined by Clavien-Dindo grade 3 complication or greater requiring a radiological or surgical procedure – predischarge and post-discharge (up to within 1 year after the transplant procedure), and recipient and graft survival at 1, 3 and 5 years post-transplant.

A malnutrition *z*-score was defined as follows:

- In paediatric recipients aged ≤5 years the mid-upper-arm circumference (MUAC) *z*-score was used, or if no MUAC was available, the BMI *z*-score was used.
- In recipients aged >5 years the BMI *z*-score was used.

Donor variables: sex, viral serology, blood type (ABO), donor type (living or deceased donor), graft type (left lateral or right tri-segmental), LOS.

Sample size

Sample size estimation was based on the key research question, in this case the comparison of recipient survival between the LDLT and DDSLT groups. For the paediatric cohort, given a DDSLT group comprising 25% of the total sample, accrual and final follow-up periods of 8 and 1 year respectively, at 80% power and the 5% significance level, the available sample size allows the detection of significant hazard ratios (HRs) of ≥1.6, which is adequate for a study of this nature.[16] Similarly, for the adult cohort, the available sample size allows the detection of significant HRs of only ≥2.5.

Statistical analyses

Comparison of categorical study variables between graft types was done with the χ^2 test (Fisher's exact test was used for 2 × 2 tables or where the requirements for the χ^2 test were not met). Continuous variables were compared by the independent samples *t*-test, or by the Wilcoxon rank sum test where the assumptions of the *t*-test were not met.

The relationship between graft types and categorical outcomes (interventions pre- and post-discharge, infections predischarge, death predischarge) was assessed by binomial regression. Hospital LOS was compared between the graft types using a general linear model (GLM). Cox proportional hazards regression was performed to examine the effect of graft type on recipient and graft survival. All comparisons were made unadjusted, and adjusted for recipient age, recipient ethnicity, donor sex, and GWRWR (for the paediatric cohort); and for donor age and GWRWR (for the adult cohort). The data analysis was carried out using SAS version 9.4 for Windows. A 5% significance level was used.

Results

Part 1. Paediatric liver transplantation

Overall, 181 liver transplant procedures were performed for the period under review (Fig. 1). Of these, 46 (25%) were DDSLTs and the remainder were LDLTs (135; 75%). No DDSLTs were performed in 2021 because of the global COVID-19 pandemic, while LDLTs continued to be performed throughout the study period.

Demographic and clinical characteristics of paediatric recipients are detailed in Table 1. The median (interquartile range (IQR)) age for the entire cohort was 2.3 (1.3 - 3.9) years with younger children undergoing LDLT compared with DDSLT. In both subgroups, chronic liver failure was the predominant indication for transplantation, with cholestatic liver disease being the most prevalent subtype (64% in DDSLT and 75% in LDLT), and viral infection, specifically hepatitis A, the leading cause of ALF. No significant difference in mean PELD score at time of listing to transplant was noted. Of the paediatric recipients, 57% fell within the moderate to severe malnutrition range at time of transplant with no significant difference in the median malnutrition *z*-score between the acute and chronic subgroups.

Clinical and demographic characteristics of donors are detailed in Table 2. Female donors predominated, and of the LDLT donors the majority were biological mothers of the recipients. ALF emerged in four patients following an unsuccessful LT: hepatic artery thrombosis caused this condition in three instances, while a combination of hepatic artery thrombosis and portal vein thrombosis led to ALF in one case. Serological testing showed that most donors had prior CMV and EBV exposure with far fewer exposed to HIV and hepatitis B. The prevalence of HIV in donors and recipients was far lower than the national prevalence in SA. The median GWRWR for DDSLTs was significantly higher than that for the LDLTs. With regard to the type of liver split in the DDSLT group, 87% (40/46) were left lateral while 13% (6/40) were a right tri-segmental split (not shown).

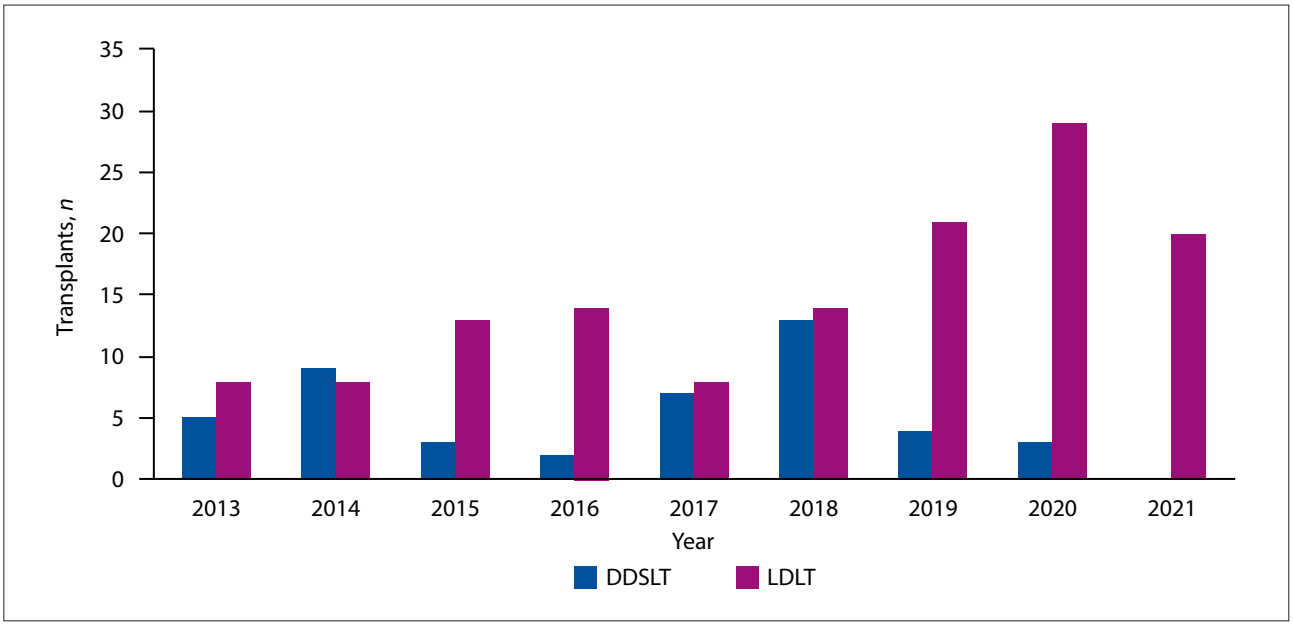

Fig. 1. Annual paediatric DDSLT and LDLT procedures performed in the Wits Transplant Unit.

In terms of immunosuppression regimens, all recipients in the DDSLT group received corticosteroid therapy while in the LDLT group 13% received induction therapy with basiliximab. Tacrolimus was the primary immunosuppressant used in both groups (99%).

Overall, the most common complication was related to biliary conditions, occurring in 41% of transplants (Table 3). Portal vein and hepatic artery thrombosis were our most common vascular complications. The need for post-transplant surgical intervention was assessed both pre- and post-discharge. Among the overall cohort, 92 (51%) required a surgical intervention predischarge, and 35 (24%) post-discharge (up to 12 months post-transplant). There was a significantly increased risk of a predischarge intervention for the DDSLT group compared with the LDLT group (unadjusted). However, after adjusting for recipient age, recipient ethnicity, donor sex and GWRWR, this effect was no longer significant. There were no significant differences between graft type and post-discharge intervention, in-hospital mortality, or BSI predischarge.

Graft and recipient survival are depicted in Figs 2a and b. Adjusted overall survival data show no significant differences between DDSLT and LDLT (HR for death (DDSLT v. LDLT 1.60, 95% confidence interval (CI) 0.78 - 3.30; graft loss HR 1.74, 95% CI 0.86 - 3.51). The overall 1-year, 3-year, and 5-year survival rates for the paediatric cohort (with the corresponding 95% CIs) were 77% (70% - 83%), 71% (64% - 78%), and 69% (61% - 75%), respectively.

Notably, the survival estimates for LDLT recipients were higher, with 1-year, 3-year, and 5-year survival rates (95% CIs) of 80% (71% - 86%), 75% (67% - 82%), and 74% (65% - 81%), respectively, compared with DDSLT, which demonstrated survival rates of 70% (55% - 82%), 61% (45% - 74%), and 56% (40% - 69%), respectively, although not statistically significant. The graft survival rates (95% CIs) at 1, 3, and 5 years for LDLT v. DDSLT were 79% (71% - 85%), 74% (65% - 81%), and 72% (63% - 79%) v. 70% (55% - 82%), 61% (45% - 74%), and 56% (40% - 69%), respectively, also noted as not statistically significant..

Part 2. Adult liver transplantation

In the adult cohort, a total of 48 DDSLT and LDLT liver transplants had been performed since 2013, with 26 recipients (54%) undergoing DDSLT and 22 (46%) undergoing LDLT. Fig. 3 shows the annual number of adult DDSLTs and LDLTs and highlights the higher proportion of LDLT cases in recent years and decreasing number of DDSLTs, with none being performed in 2021, reflecting the effects of the global COVID-19 pandemic.

Table 4 presents the clinical and demographic characteristics of the adult recipient cohort. The median age of the overall cohort was 44 years with the main indicator for liver transplant being cholestatic or metabolic associated fatty liver disease (MAFLD), with no significant difference between the two groups. The median (IQR) waiting period to transplantation was 3 (1.1 - 5.9) months.

The median age of the donors was 31 years, with a significantly lower median age observed in the DDSLT group compared with the LDLT group (Table 5).

All DDSLT cases received a right tri-segmental graft. The median GWRWR for the DDSLT group was significantly higher compared with that of the LDLT.

Overall, the most frequent complication encountered in adult liver transplants was related to biliary complications, occurring in 54% of cases (Table 6), with similar prevalence in both LDLTs and DDSLTs. The primary cause of these biliary complications was identified as a leak from the cut surface of the liver. Notably, no significant differences were observed between the two groups concerning the incidence of pre- or post-discharge intervention or in-hospital mortality.

The graft and recipient survival are presented in Figs 4a and b. In the adjusted overall survival analysis, no significant differences were observed between DDSLT and LDLT regarding recipient (HR 0.29, 95% CI 0.07 - 1.23) or graft survival (HR 0.70, 95% CI 0.15 - 3.22) within the adult cohort. Our overall adult cohort 1- and 3-year survival rates (95% CIs) were 77% (62% - 87%) and 66% (50% - 78%), respectively. Conversely although shown to be non-significant, LDLT recipients exhibited lower survival estimates, with 1-year and 3-year survival rates of 63% (40%-80%) and 56% (32%-75%), respectively, in contrast to DDSLT, which showed survival rates (95% CIs) of 88% (68% - 96%) and 77% (55% - 89%), respectively. The graft survival (95% CIs) at 1 year and 3 years for LDLT v. DDSLT was 63% (40% - 80%) and 56% (32% - 75%) v. 85% (64% - 94%) and 69% (47% - 83%), respectively, and were also shown to be non-significant.

Table 1. Demographic and clinical characteristics of paediatric DDSLT and LDLT recipients

Characteristic, *n* (%)*	Overall *n*=181	DDSLT *n*=46	LDLT *n*=135	*p*-value
Age (y), median (IQR)	2.3 (1.3 - 3.9)	3.1 (2.3 - 4.6)	2.0 (1.3 - 3.6)	0.0023
Sex				0.49
Female	105 (58)	29 (63)	76 (56)	
Male	76 (42)	17 (37)	59 (44)	
Aetiology				0.66
Acute	33 (18)	7 (15)	26 (19)	0.49
Viral infection	20 (61)	5 (71)	15 (58)	
Failed transplant	4 (12)	0 (0)	4 (15)	
Wilson's disease	2 (6)	1 (14)	1 (4)	
Drug/ toxin induced	2 (6)	1 (14)	1 (4)	
Other	2 (6)	0 (0)	2 (8)	
Unknown	3 (9)	0 (0)	3 (12)	
Chronic	148 (82)	39 (85)	109 (81)	0.35
Cholestatic	107 (72)	25 (64)	82 (75)	
Metabolic	13 (9)	3 (8)	10 (9)	
Budd Chiari veno-occlusive disease	8 (5)	4 (10)	4 (4)	
Malignancy	6 (4)	1 (3)	5 (5)	
Other	14 (9)	6 (15)	8 (7)	
Viral serology				
CMV IgG†	77	26	51	0.29
EBV IgG†	76	28	48	0.58
Hep B core antibody†	2	1	1	0.86
HIV-positive‡	3 (2)	2 (4)	1 (1)	0.18
Malnutrition *z*-score§				0.27
-3 to <-2	16 (10)	4 (10)	12 (9)	
-2 to <-1	47 (28)	7 (18)	40 (31)	
-1 to <0	54 (32)	18 (46)	36 (28)	
0 to <1	22 (13)	4 (10)	18 (14)	
1 or better	28 (17)	6 (15)	22 (17)	
Waiting period (mo.), median (IQR)	2.7 (0.3 - 5.3)	3.5 (0.5 - 7.8)	2.3 (0.2 - 4.6)	0.13
PELD at listing, mean (SD)¶	17 (13)	20 (12)	17 (13)	0.18
GWRWR ratio, median (IQR)**	2.4 (1.7 - 3.3)	2.6 (2.2 - 4.6)	2.3 (1.7 - 3.1)	0.0013
Left lateral		3.0 (2.4 - 4.6)		
Right tri-segment		1.9 (1.7 - 2.1)		
Immunosuppression				
Corticosteroid therapy	164 (91)	46 (100)	118 (87)	0.0074
Tacrolimus	179 (99)	46 (100)	133 (99)	>0.99
Other	3 (2)	0 (0)	3 (2)	0.57

* Unless otherwise indicated.
† Sample size: CMV IgG, EBV, hep B, *n*=125.
‡ Sample size: HIV, *n*=178
§ Sample size: Malnutrition *z*-score, *n*=167.
¶ Sample size: PELD, *n* =179.
** Sample size: GWRWR ratio, *n*=175.

Discussion

Globally, organ scarcity remains the leading cause of poor waitlist outcomes. A phenomenon which does not exclude SA,[6] with one of the lowest donor rates in the world of only 1.29 donors per million population.[4] For the period we reviewed, our paediatric and adult deceased- and living-donor numbers varied from year to year, with DD referrals significantly affected by the recent COVID-19 global pandemic.[16] Since then, there has been a gradual increasing trend in LDLTs, which indicates the growing recognition and acceptance of LDLT as a viable treatment option for paediatric and adult patients with ESLD.

The aetiology of ESLD and ALF has changed over time and varies across the world.[17] In international paediatric ALF reports, transplantation for ALF was rare;[7] however, it accounted for 18% of our cohort, with hepatitis A being the predominant viral cause. Chronic liver failure, specifically intra- and extrahepatic cholestatic disease, was our main indicator for LT in both our paediatric and adult cohorts, correlating well with global trends in children but differing from published data for adults.[2,7] Hepatitis C and alcohol-related liver disease predominate in the western regions of the world, while in the eastern parts, hepatitis B and C are the most common,[2] which accounted for only 7% and 2% respectively of transplants in our study. Alcoholic and non-alcoholic steatohepatitis accounted for our second highest cause of ESLD (24%). This reflects their increasing prevalence globally, with MAFLD in the USA becoming the leading cause of LT in non-hepatocellular cancer patients.[2]

Postoperative complications are often unavoidable owing to the intricate nature of liver transplant surgery. Although DDSLT and LDLT

Table 2. Demographic and clinical characteristics of paediatric DDSLT and LDLT donors

Characteristic, *n* (%)*	Overall *n*=181	DDSLT *n*=46	LDLT *n*=135	*p*-value
Sex				0.0021
Female	118 (65)	21 (46)	97 (72)	
Male	63 (35)	25 (54)	38 (28)	
Viral serology				
CMV IgG	150 (83)	31 (67)	119 (88)	0.0041
EBV IgG	167 (92)	41 (89)	126 (93)	0.53
Hep B core antibody†	14 (11)	2 (5)	12 (9)	0.0055
Hep B surface antigen†	0 (0)	0 (0)	0 (0)	>0.99
HIV-positive	3 (2)	0 (0)	3 (2)	0.16
ABO-compatibility				0.61
Identical	140 (77)	38 (83)	102 (76)	
Compatible	31 (17)	6 (13)	25 (19)	
Incompatibility	10 (6)	2 (4)	8 (10)	
LOS (d), median (IQR)	7 (6 - 9)		7 (6 - 9)	

*Unless otherwise indicated.
†Sample size: hep B surface antigen and core antibody, *n*=176.

Table 3. Comparison of the DDSLT and LDLT complications and outcomes for the paediatric cohort

Characteristic, *n* (%)	Overall *n*=181	DDSLT *n*=46	LDLT *n*=135	*p*-value	
Biliary complication	74 (41)	23 (50)	51 (38)	0.17	
Stricture	34 (46)	10 (43)	24 (47)		
Anastomotic leak	22 (30)	8 (35)	14 (27)		
Cut surface leak	26 (35)	7 (30)	19 (37)		
Blind-ending ductal system	2 (3)	0 (0)	2 (4)		
Blocked stent	2 (3)	1 (4)	1 (2)		
Enteric complication	19 (10)	6 (13)	13 (10)	0.58	
Vascular complication	29 (16)	8 (17)	21 (16)	0.82	
Portal vein thrombosis	7 (24)	2 (25)	5 (24)		
Portal vein stenosis	6 (21)	0 (0)	6 (29)		
Hepatic vein thrombosis	1 (3)	0 (0)	1 (5)		
Hepatic vein stenosis	7 (24)	3 (38)	4 (19)		
Hepatic artery thrombosis	6 (21)	1 (13)	5 (24)		
Hepatic artery rupture	1 (3)	0 (0)	1 (5)		
IVC stenosis	1 (3)	0 (0)	1 (5)		
Other	4 (14)	2 (25)	2 (10)		
				RR for event (95% CI)	
				Unadjusted	Adjusted
BSI*	46 (44)	8 (40)	38 (45)	0.85 (0.47 - 1.53)	0.54 (0.28 - 1.03)
Intervention					
Predischarge	92 (51)	30(65)	62 (46)	1.40 (1.04 - 1.86)	1.20 (0.86 -1.68)
Post-discharge	35 (24)	8 (23)	27 (24)	0.92 (0.46 - 1.84)	0.72 (0.31 - 1.65)
In-hospital mortality	35 (19)	11 (24)	24 (18)	1.32 (0.71 - 2.48)	1.03 (0.46 - 2.32)

IVC = inferior vena cava.
* Sample size: BSI, *n*=104.

have demonstrated favourable and comparable outcomes,[18] the choice between the two approaches remains a subject of debate. A direct comparison is complex, given that LDLT is most often performed electively in patients with lower PELD/MELD scores, presumably leading to better long-term recipient and graft survival.[3,6] LDLT carries with it a higher rate of technical complications than DDSLT, where more systemic complications such as cardiac, pulmonary oedema and renal dysfunction with ascites are noted in keeping with a sicker cohort of patients.[18]

A 2014 meta-analysis showed that LDLT is associated with higher rates of biliary complications (due to the smaller size ducts that are often rendered ischaemic by the LDLT harvest) and vascular complications (as hepatic arteries of smaller calibre are anastomosed as opposed to the larger arterial anastomosis performed in whole-liver transplants) compared with DDLTs.[8,18] This too has been demonstrated in developing countries where bile leaks, hepatic artery thrombosis and strictures have been noted more commonly in LDLTs than DDSLTs.[2]

The overall incidence of biliary complications varies significantly between centres and ranges between 5% and 40% in adults receiving a LDLT, higher than DDSLT,[11,18] and between 3.4% and 42% of paediatric LDLT transplants.[7,19] Bile leaks are well documented as the

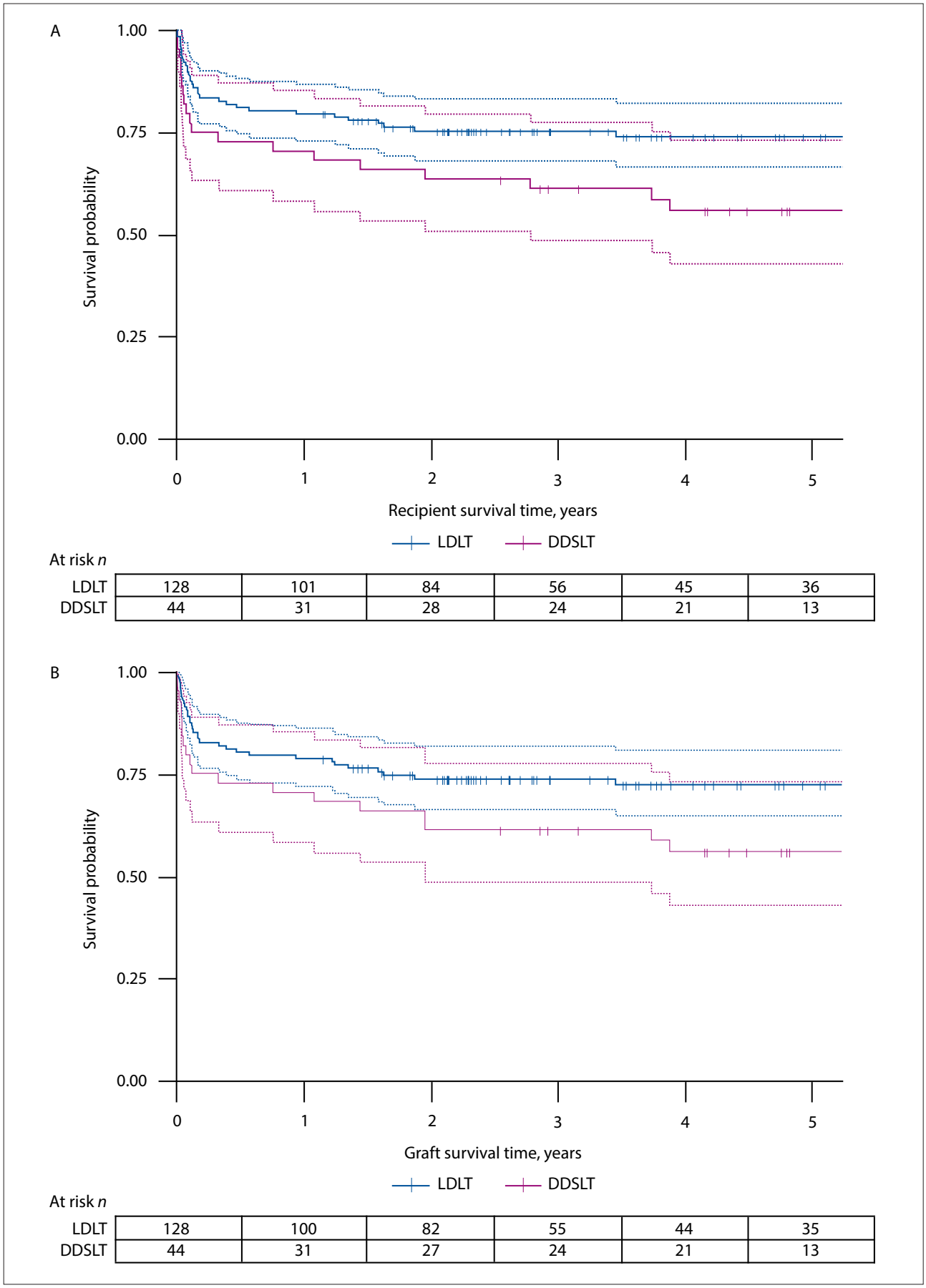

Fig. 2. Five-year paediatric liver transplant (a) recipient and (b) graft survival. (Dotted lines represent the 95% confidence bands for each plot.)

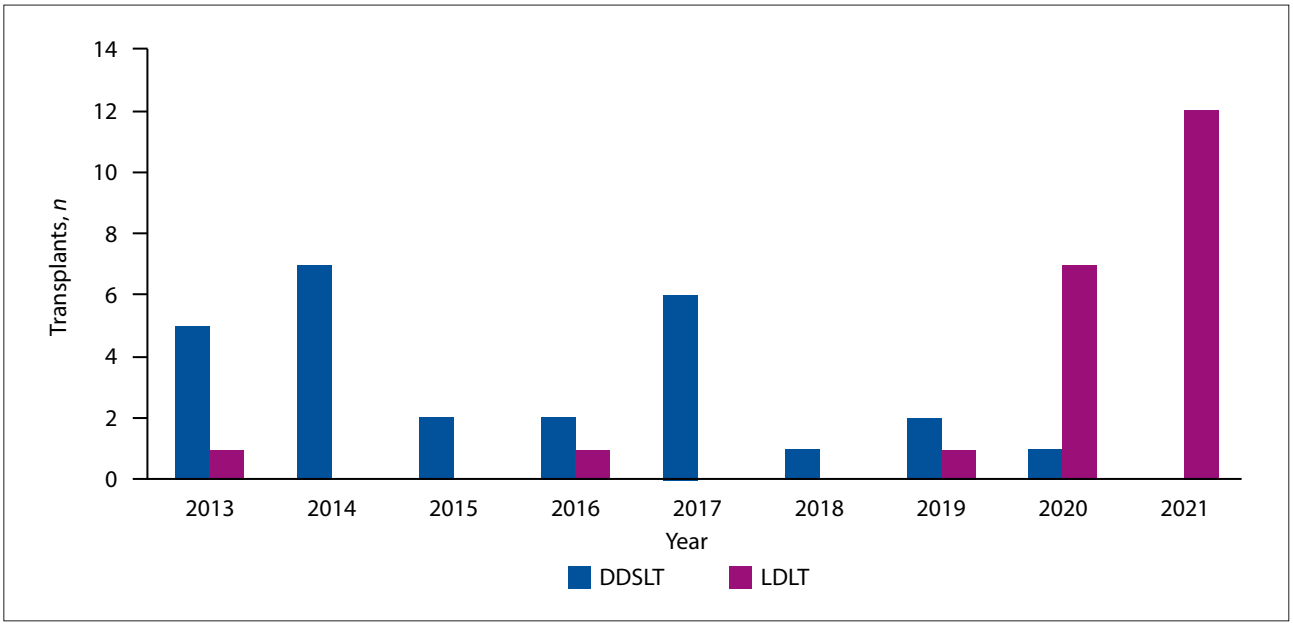

Fig. 3. Annual adult DDSLT and LDLT procedures performed in the Wits Transplant Unit.

primary early complication, and strictures are commonly observed as a late complication in the literature,[18] a pattern exhibited within our cohort. Although biliary complications were the prevailing concern, constituting 41% in our paediatric cohort and 54% in the adult cohort, the incidence of such complications was somewhat elevated within the DDSLT subgroup, observed in 50% of paediatric instances. This increase primarily stemmed from minor cut surface leaks, as opposed to anastomotic leaks and stricturing. However, the increased occurrence of biliary complications reported in global data is not mirrored in the results evident within our specific patient group.

The hepatic artery anastomosis carries with it the highest risk of thrombosis and is the main cause of vascular complications in adults (~6%),[18] seen more commonly in LDLT, and in 5% - 18% of children.[7,19,20] However, it is noteworthy that hepatic artery thrombosis (HAT) did not manifest within our adult LDLT cohort, with only two occurrences observed in the DDSLT cases. Conversely, in the paediatric group, HAT emerged in both LDLT and DDSLT recipients. Although our incidence of HAT remains relatively low, its impact on our paediatric transplant recipients was significant, resulting in transplant failure in four cases. This underscores the substantial risk and morbidity associated with HAT, with portal vein thrombosis having been noted in one case as well. Portal vein thrombosis, often attributed to portal venous hypoplasia, is more prevalent among patients undergoing transplantation for biliary atresia, typically affecting 5% - 10%[7] of paediatric cases according to prior reports. Our reported incidence, at 3.9% in our cohort, demonstrates a comparatively reduced frequency.

Across both the paediatric and adult cohorts, the incidence of complications is unchanged with the introduction of LDLT, and largely in keeping with international data, the study demonstrates no significant differences in outcome between DDSLT and LDLT recipients in respect of pre- or post-discharge intervention. Although our study cohort is limited in size and the observed outcomes did not reach statistical significance, an interesting trend emerged within our adult cohort. A greater proportion of LDLT recipients necessitated surgical intervention for managing post-transplant complications in comparison with the DDSLT group. Conversely, an intriguing contrast was observed within the paediatric cohort, where a heightened demand for intervention was evident in the DDSLT subgroup as opposed to the LDLT group. A possible reason for this is that timing and availability of DD organs is unpredictable, and therefore DDSLT grafts were used in recipients with higher PELD scores (mean of 20). The results of the study demonstrate that LDLT recipients are in a better physiological condition than recipients of DDSLT organs at the time of transplantation, a phenomenon demonstrated in other studies as well.[3] In our adult cohort however, the mean MELD score for DDSLT and LDLT was 16 v. 15, respectively, leaving us to postulate that the recipient condition rather than the mode of transplant is the greater determinant of complications within this study.

In terms of long-term postoperative outcomes, there were no statistically significant differences between the DDSLTs and LDLTs in respect of recipient or graft survival in both the paediatric and adult cohorts. This was similar to the Adult-to-Adult Living Donor Liver Transplantation Cohort Study (A2ALL), as well as other international studies showing that LDLT has equivalent long-term outcomes in risk-adjusted adults[10,21] and a survival advantage in paediatric recipients.[19,20] Within our study, we observed that the survival estimates for paediatric LDLT recipients were higher at 1, 3, and 5 years compared with DDSLT recipients, however non-significant, although still lower than the survival rates reported in the published international data analysis of United Network for Organ Sharing (UNOS) paediatric data for recipients <10 years old. The UNOS data showed 1-, 3-, and 5 -year survival rates of 97%, 95%, and 95% for LDLT, and 96%, 93%, and 91% for DDSLT.[20]

Regarding our adult population, in contrast to the findings from the UNOS data over a 15-year period, which showed that LDLT provided superior long-term survival outcomes compared with DDSLT,[18] our adult cohort exhibited different results. Interestingly, the risk-adjusted variables that account for the greater severity of disease in DD transplants believed to be prevented by earlier transplantation in LDLTs[11] did not manifest in our adult cohort. Published recipient survival rates for LDLT at 1 and 3 years are reported at 86.1% and 77.1%, while DDSLT recipients had survival rates of 77.3% and 71.5%, respectively. Notably, our survival estimates closely align and are slightly higher in the DDSLT group but are lower in the LDLT cohort a finding contrary to that of international data.[22] These disparities in our adult cohort warrant further investigation to understand the underlying factors influencing survival outcomes

Table 4. Comparison of the DDSLT and LDLT demographic and clinical characteristics of adult recipients

Characteristic, *n* (%)	Overall *n*=48	DDSLT *n*=26	LDLT *n*=22	*p*-value
Age (y), median (IQR)	44 (14)	44 (14)	43 (15)	0.72
Sex				0.56
Female	25 (52)	15 (58)	10 (45)	
Male	23 (48)	11(42)	12 (55)	
Aetiology				0.20
Acute	2 (4)	0 (0)	2 (9)	
Chronic				0.50
Cholestatic	28 (61)	16 (62)	12 (60)	
MAFLD	11 (24)	7 (27)	4 (20)	
Hep B	3 (7)	2 (8)	1 (5)	
Hep C	1 (2)	1	0 (0)	
Malignancy	2 (4)	0 (0)	2 (10)	
Metabolic	1 (2)	0 (0)	1 (5)	
Viral serology				
CMV IgG†	39 (81)	24 (92)	15 (71)	0.12
Hep B core antibody	8 (17)	6 (23)	2 (9)	0.26
Hep B surface antigen	4 (8)	3 (12)	1 (5)	0.61
HIV-positive‡	2 (4)	0 (0)	2 (9)	0.20
Comorbidity				
BMI (>30 kg/m^2)	5 (10)	1 (4)	4 (18)	0.16
Mean (SD)	24.8 (5.0)	25.1 (4.6)	24.4 (5.4)	0.65
Diabetes	5 (10)	1 (4)	4 (18)	0.16
Waiting period (mo.), median (IQR)	3.0 (1.1 - 5.9)	2.5 (1.0 - 5.5)	4.0 (1.1 - 7.1)	0.36
MELD at transplant, median (IQR)	15 (12 - 23)	16 (12 - 24)	15 (10 - 22)	0.59
GWRWR ratio, median (IQR)	1.2 (0.8 - 1.4)	1.4 (1.3 - 2.0)	0.9 (0.8 - 1.1)	0.0002

* Unless otherwise indicated.
†Sample size: CMV IgG, *n* =47.
‡Sample size: HIV-positive, *n*=90.

Table 5. Comparison of the DDSLT and LDLT demographic and clinical characteristics of adult donors

Characteristic, *n* (%)	Overall *n*=48	DDSLT *n*=26	LDLT *n*=22	*p*-value
Type	48 (100)	26 (54)	22 (46)	
Age (y), median (IQR)	31 (21 - 39)	28 (19 - 34)	35 (28 - 41)	0.0093
Gender				0.37
Female	17 (35)	11 (42)	6 (27)	
Male	31 (65)	15 (58)	16 (73)	
Viral serology				
CMV IgG	33 (69)	16 (62)	17 (77)	0.52
Hep B core antibody	2 (2)	1 (2)	1 (1)	>0.99
Hep B surface antigen	0 (0)	0 (0)	0 (0)	>0.99
HIV-positive	1 (2)	1 (4)	0 (0)	>0.99
Comorbidity				
BMI (>30 kg/m^2)	1 (2)	1 (4)	0 (0)	>0.99
ABO-compatibility				0.15
Identical	40 (83)	24 (92)	16 (73)	
Compatible	7 (15)	2 (8)	5 (23)	
Incompatibility	1 (2)	0 (0)	1 (5)	

in LDLT recipients. The observed discrepancy in long-term survival estimates between our study in the LDLT group and the UNOS data suggests potential differences in patient selection, surgical techniques, and postoperative management, reflecting that our unit is still developing its expertise in our adult-to-adult LDLT programme. To gain a comprehensive understanding, future studies should consider examining a larger and more diverse patient population, given our current cohort size as a limitation.

With up to 20% of paediatric patients and 11% of adult patients on the waiting list in SA demising before they receive a graft,[16] SLT provides the advantage of lowering the waiting list mortality rate by increasing the supply of organs. LDLT provides the advantage of lowering the waiting list mortality rate. LDLT also provides the benefit of transplanting at a lower ESLD score, with improved nutritional score and less severe renal failure,[10] while having equivalent outcomes to the well-established DDSLT. However, when evaluating the utilitarian

Table 6. Comparison of the DDSLT and LDLT complications and outcomes for the adult cohort

Characteristic, *n* (%)	Overall *n*=48	DDSLT *n*=26	LDLT *n*=22	*p*-value	
Biliary complication	26 (54)	14 (54)	12 (55)	>0.99	
Anastomotic stricture	6 (23)	1 (7)	5 (42)		
Non-anastomotic stricture	2 (8)	1 (7)	1 (8)		
Anastomotic leak	5 (19)	2 (14)	3 (25)		
Cut surface leak	15 (58)	8 (57)	7 (58)		
Unspecified leak	6 (23)	4 (29)	2 (17)		
Enteric complication	6 (13)	3 (12)	3 (14)	>0.99	
Leak	5 (83)	3 (100)	2 (67)		
Gastrointestinal bleed	1 (17)	0 (0)	1 (33)		
Vascular complication	9 (19)	5 (19)	4 (18)	>0.99	
Portal vein thrombosis	3 (33)	3 (60)	0 (0)		
IVC stenosis	1 (11)	0 (0)	1 (25)		
IVC thrombosis	3 (33)	1 (20)	2 (50)		
Hepatic artery thrombosis	2 (22)	2 (40)	0 (0)		
Hepatic vein thrombosis	1 (11)	1 (20)	0 (0)		
Hepatic vein stenosis	1 (11)	0 (0)	1 (25)		
				RR for event (95% CI)	
				Unadjusted	Adjusted
Intervention					
Predischarge	22 (46)	10 (38)	12 (55)	0.87 (0.47 - 1.60)	0.70 (0.31 - 1.55)
Post-discharge	14 (36)	10 (42)	4 (27)	1.46 (0.53 - 4.04)	2.75 (0.42 - 18.1)
In-hospital mortality	9 (19)	2 (8)	7 (32)	0.17 (0.02 - 1.23)	0.20 (0.02 - 1.65)

argument for splitting livers, it is crucial to consider the principles proposed by Vulchev *et al.* (quoted by Kim *et al.*[23]) which emphasise the importance of maximising the number of patients receiving organ transplants, provided that individual patients do not suffer disproportionate costs for societal benefit and that individual patient survival is maximised without society suffering disproportionate costs. Historically, SLT often led to less favourable outcomes for individual recipients, even though it increased the number of patients receiving organ transplants. The decision between a single whole graft for one recipient or splitting a liver for two recipients was challenging, as the post-transplant benefits were unequal. Recent advancements have improved the outcomes of SLT, making the utilitarian argument more compelling. Studies, such as the one by Hong *et al.*,[24] have reported that long-term graft survival rates for segmental grafts from deceased and living donors are comparable to those in whole-organ LT in both adult and paediatric groups. This suggests that SLT is not only a means to maximise the number of patients receiving grafts but also a viable option for maintaining patient survival and long-term graft success as pointed out throughout the discussion. The argument further aligns with the principles of the Organ Procurement and Transplantation Network (OPTN) and the UNOS, as well as the Joint Ethics Committee's white paper, which emphasises the ethical obligation to maximise organ outcomes while promoting equity.[23] The ethics committee recognises the fairness and efficiency of splitting the liver for both children and larger candidates, aligning with the utilitarian principle of maximising societal benefit.[23]

While the debate between LDLT and DDSLT is narrowing as outcomes improve, the utilitarian argument for split LT overall is gaining strength as a result of improved long-term outcomes and the potential to save more lives.

Limitations

There are several limitations to our study that should be taken into consideration. Firstly, our study is a retrospective observational design rather than a randomised controlled trial. Furthermore, the sample size in our study was relatively small, which could limit the generalisability of our findings, coupled with the fact that we do not have available data on the long-term outcomes of LDLT in adults beyond a 3-year period, which prevents us from providing comprehensive insights into the long-term efficacy of this procedure in adult patients. Lastly, this study focused on recipient outcomes and not donor outcomes in the LDLT group. While pooled international data place the living-donor mortality risk at 1 in 500 (0.2%) and morbidity risk at 24%,[11] being able to demonstrate our centre's risk profile is integral to assess the risk-benefit profile and to appropriately advocate for the procedure within our setting.

Conclusion

The results of this study are consistent with international literature, demonstrating that both DDSLT and LDLT are effective approaches for LT with comparable outcomes. The choice of the optimal transplantation method should be tailored to each individual, considering factors such as donor availability, organ suitability and recipient characteristics. LDLT, in particular, shows potentially improved outcomes in terms of recipient and graft survival globally and therefore should be seriously considered. It is evolving into the primary method of liver transplantation in our country where DDLT is declining.

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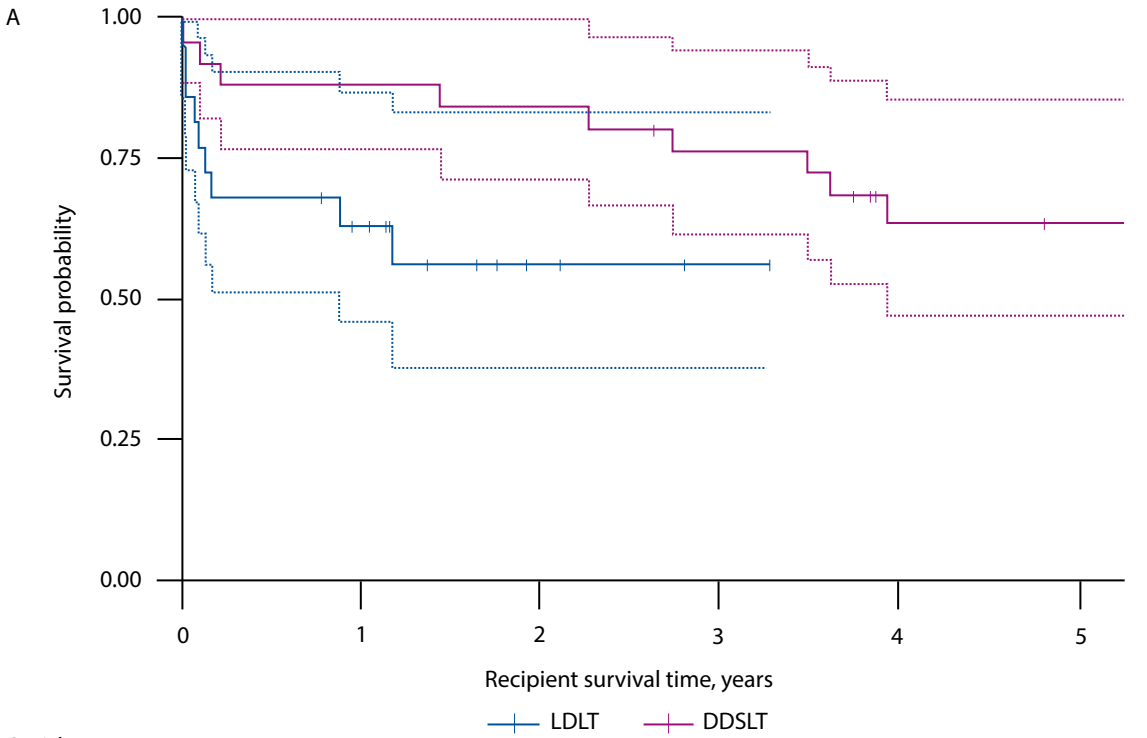
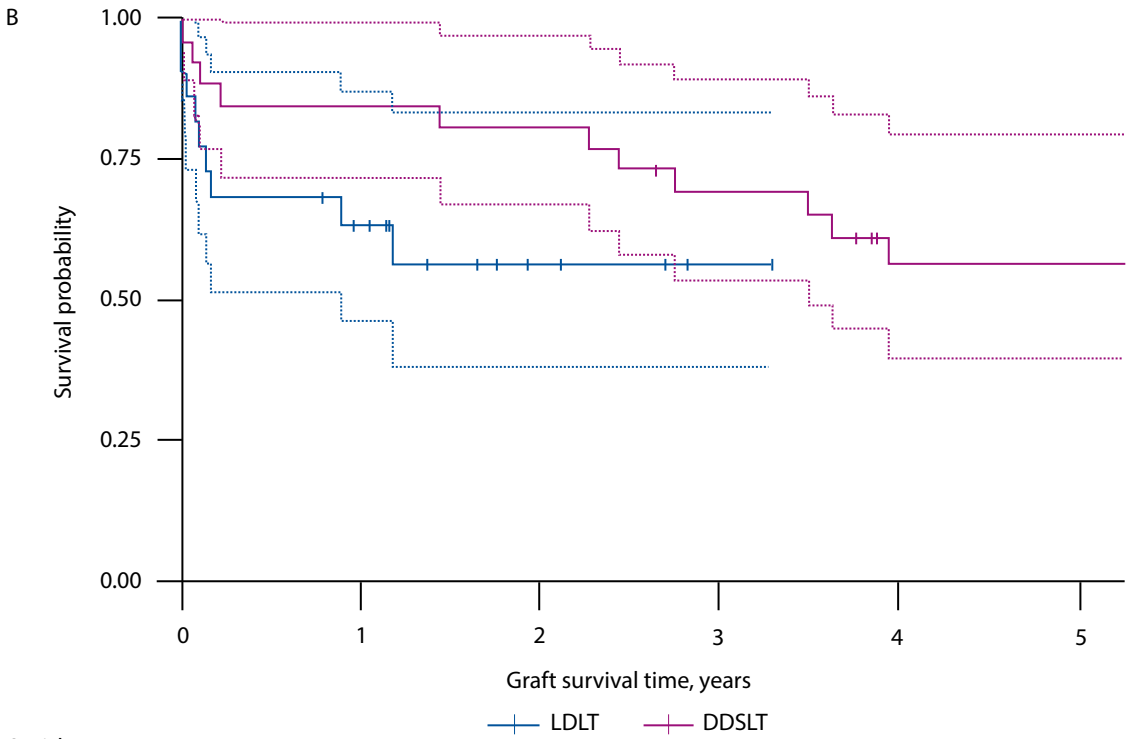


At risk *n*

LDLT	22	12	4	1	0	0
DDSLT	28	23	22	19	13	5



At risk *n*

LDLT	22	12	4	1	0	0
DDSLT	26	22	21	17	11	10

Fig. 4. Five-year adult liver transplant (a) recipient and (b) graft survival. (Dotted lines represent the 95% confidence bands for each plot.)

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