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ORIGINAL ARTICLE

Good outcomes of living donor liver transplant in primary sclerosing cholangitis: an experience from North India

Shekhar Singh Jadaun[1] · Rohit Mehtani[1] · Ana Hasnain[1] · Sushant Bhatia[2] · Vikash Moond[2] · Mukesh Kumar[2] · Vikash Kuhad[3] · Shweta Singh[4] · Shaleen Agarwal[2] · Subhash Gupta[2] · Sanjiv Saigal[1]

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Abstract

Background Primary sclerosing cholangitis (PSC) is a chronic cholestatic liver disease. In the absence of effective medical therapy, liver transplant is the definitive treatment for advanced stage. However, recurrence of PSC after liver transplant is of concern which can lead to graft failure and may require retransplant. There are limited data on outcomes of living donor liver transplant (LDLT) in PSC. Also, in LDLT as donors are genetically related there can be an increased risk of recurrence. We conducted this retrospective study to analyze the outcomes of LDLT in PSC at a tertiary liver transplant center in north India.

Methods We conducted a retrospective analysis of 3213 transplant recipients who underwent LDLT from January 2006 to May 2021. Of these 26 (0.80%) patients had PSC as indication for liver transplantation (PSC = 24, PSC-AIH overlap = 2). Data analysis was done to look for baseline demographics, clinical details, transplant outcomes, PSC recurrence, and survival.

Results Mean age of study group was 42 (± 13.8) years and 19 patients (73.1%) were males. All patients had decompensated cirrhosis at the time of transplant. Mean CTP score and MELD score were 9.5 (± 1.8) and 18.9 (± 7.1), respectively. Sixteen patients received modified right lobe graft, seven extended right lobe graft and five patients received left lateral graft. Median graft weight and mean graft to recipient weight ratio (GRWR) were 633.5 (IQR 473.5–633.5) grams and 1.23 (± 0.42), respectively. Most common biliary anastomosis was hepaticojejunostomy, done in 19 (73.1%) while duct to duct anastomosis was performed in 7 (26.9%) patients. Median follow-up was 96 (36–123) months. One patient had ulcerative colitis and none had cholangiocarcinoma. Two (7.7%) patients had bile leak during early post-transplant period. Three (11.1%) patients developed graft rejection and were managed successfully with steroid pulses. Three patients died during early post-transplant period while seven deaths occurred during long-term follow-up including one death due to COVID-19. Five (21.73%) patients had recurrence of PSC of which two patients had graft loss including one after retransplantation. The one year graft and patient survival rate was 88.5%.

Conclusion LDLT can be performed in PSC with good long-term outcomes with a risk of PSC recurrence in about one-fifth patients.

Keywords PSC · LDLT · Post-transplant PSC recurrence

Abbreviations

PSC	Primary sclerosing cholangitis
LDLT	Living donor liver transplant
AIH	Autoimmune hepatitis
NAFLD	Non-alcoholic fatty liver disease
NASH	Non-alcoholic steatohepatitis
MELD	Model for end stage of liver disease
CTP	Child–Turcotte–Pugh
MR	Magnetic resonance imaging
MRCP	Magnetic resonance cholangiopancreatography
USG	Ultrasonography
HIV	Human immunodeficiency virus
AFP	Alpha - fetoprotein
CEA	Carcinoembryonic antigen
CA-19.9	Carbohydrate antigen-19.9
ANA	Antinuclear antibodies
ASMA	Anti smooth muscle antibodies
AntiLKM1	Liver kidney molecule 1
IBD	Inflammatory bowel disease
CM	Anti-cytomegalovirus
BMI	Body mass index

✉ Sanjiv Saigal
sanjivsaigal@hotmail.com

Extended author information available on the last page of the article

COVID-19 Coronavirus disease-2019
DDLT Deceased donor liver transplant

Introduction

Primary sclerosing cholangitis (PSC) is a cholestatic disorder characterized with multifocal biliary strictures leading to progressive jaundice and subsequent liver failure. No medical therapy has been shown to slow the natural progression of liver disease. Liver transplant is the only definitive treatment in patients with advanced disease who develop decompensated cirrhosis.[1] There are limited data on outcomes of living donor liver transplant (LDLT) in PSC especially from India. Recurrence of PSC after liver transplant is of concern which can lead to graft failure and may require retransplant. Various studies have described 5–10 year recurrence rates of 20–50%. [2, 3] Also, in LDLT as donors are genetically related there is possibility of higher disease recurrence as compared to DDLT. But studies have shown conflicting results with one study showing blood related donor as risk factor for recurrence while others have not. [4, 5] We conducted this retrospective study to analyze the outcomes of LDLT and risk factors for recurrence of PSC at a tertiary liver transplant center in north India.

Patients and methods

Patients' selection

We conducted a retrospective analysis of 3213 transplant recipients who underwent ABO compatible LDLT from January 2006 to May 2021. Of these 26 (0.80%) adult patients had PSC as an indication for liver transplantation (PSC = 24, PSC-Autoimmune hepatitis (AIH) overlap = 2). These 26 patients were included in the study and clinical details of these patients were collected from medical records. Study was approved by the institute ethical committee. Primary objectives of the study were to study patient and graft survival at 1 year of liver transplant. Secondary objectives were to determine incident and risk factors of post-transplant recurrence of PSC.

Diagnosis of PSC and PSC–AIH overlap

Basic demographic details including age, sex, follow–up, and survival were recorded. Patients underwent relevant imaging and biochemistry tests. All patients with clinical suspicion of PSC underwent MR abdomen with MRCP examination before liver transplant. Liver biochemistry, complete blood count, kidney function tests, Alphaa fetoprotein (AFP), carcinoembryonic antigen (CEA), carbohydrate antigen-19.9 (CA-19.9), and other relevant investigations were done. Blood tests for autoimmune markers included antinuclear antibodies (ANA), anti-smooth muscle antibodies (ASMA), and liver kidney microsomal type 1 antibodies (antiLKM1). Diagnosis of PSC was made in patients with cholestatic pattern of deranged liver biochemistry not explained otherwise and MRCP finding suggestive of multifocal biliary strictures and segmental dilatations, after ruling out other causes of cholestasis and secondary sclerosing cholangitis. All patients received standard medical management. Both patients with PSC-AIH overlap syndrome received steroids and one of them also received azathioprine pre-transplant. All patients underwent colonoscopy for detection of inflammatory bowel disease (IBD). Characteristics of PSC like small duct/large duct, time of diagnosis, history of biliary interventions, and presence or absence of cholangiocarcinoma were documented. Details of transplant surgery like graft type, type of biliary anastomosis, cold and warm ischemia times, and explant histological details were recorded. Post-operative complications including graft rejection, hepatic artery thrombosis, CMV infection, and biliary strictures were also recorded.

Inclusion criteria

Adult patients more than 18 years of age with a preoperative diagnosis of PSC or PSC–AIH overlap syndrome who had intractable symptoms and or decompensated liver cirrhosis were included in the study.

Exclusion criteria

Patients with preoperative diagnosis of cholangiocarcinoma, ABO incompatible transplant were excluded from this study.

Donor selection

Our transplant center follows a strict donor selection criterion. All living donors were between 18 to 50 years of age and were related to recipients. Medical evaluation of donor included detailed medical history and physical examination. Blood investigations included complete blood count, liver function test, kidney function test, blood sugar, and lipid profile. Tests for viral infections included Hepatitis B surface antigen, Anti-hepatitis B core antibody, Anti-Hepatitis B surface antibody, Anti-Hepatitis C, Anti-cytomegalovirus (CMV) IgG, and HIV I & II IgG. Liver imaging included CT scan and MR abdomen with MRCP. Donor liver fat assessment was done using fibroscan, CT-based liver attenuation index (LAI), and MRI Fat fraction.

Criteria for donor liver biopsy

Liver biopsy was done in selected donors to rule out significant non-alcoholic fatty liver disease or steatohepatitis (NAFLD or NASH). Prospective donors with liver attenuation index (LAI) < 4, MRI Fat fraction > 13%, increased liver transaminases, body mass index (BMI) > 28 were considered for pre-transplant liver biopsy.

Post-transplant management

All patients were managed with standard protocol similar to patients transplanted for other indications. All these patients were started on triple drug immunosuppression including tacrolimus, mycophenolate and prednisolone. Immunosuppression protocols were also similar to other patients except for patients with AIH-PSC overlap for whom low-dose steroids were continued long-term. Mycophenolate was stopped after 1–2 year in most of the patients.

After discharge all patients were followed up closely with regular OPD visits. Initial follow-up after transplant was every week for first 3 months and monthly visits thereafter for first year. Complete blood counts, liver and kidney function tests and tacrolimus trough level were done during every hospital visit. Patients with deranged liver function tests were evaluated by viral serologiesUSG Doppler and MRCP examination. Liver biopsy was conducted if blood investigations and imaging were inconclusive.

Diagnosis of PSC recurrence was based on criteria laid down by Graziadei et al. [6] Confirmation of recurrence of PSC required a confirmed pre-transplant diagnosis of PSC along with MRCP and or liver biopsy suggestive of features of PSC after more than three months of liver transplant. Diagnosis was only made in the absence of chronic rejection and hepatic artery thrombosis.

Data record and statistical analysis

The data were documented in predesigned proforma. The case record forms were kept at safe places. Computer files were created in Microsoft excel for windows. Data analysis was done using STATA version 14 (StataCorp, Texas, USA). All variables were assessed for normality by the Shapiro–Wilk normality test. The normally distributed variables were expressed as mean ± standard deviation (SD), and continuous variables with skewed distribution as median (interquartile range). Categorical data were presented as frequency and proportions. Comparison of patients with and without recurrence of PSC was done by Student *t* test for normally distributed data and Kruskal–Wallis test for non-normally distributed data. Categorical variables were analyzed using chi-squared test or Fisher's exact test. Long-term survival analysis was done by plotting the Kaplan–Meier survival curve. All tests were two-tailed and a p value of ≤ 0.05 was considered as statistically significant.

Results

This was a retrospective study of patients with PSC and PSC-AIH overlap who underwent live donor liver transplantation. Total 26 patients were included in the final analysis. Two of them had PSC-AIH overlap while 24 patients had primary sclerosing cholangitis. Mean age of the patients was 42.5(± 13.8) years and 19 (73%) patients were male. All patients were transplanted for decompensated liver cirrhosis due to progressive PSC. All PSC patients had both intra and extrahepatic biliary system involvement. Mean MELD and CTP scores were 18.9 (± 7.1) and 9.57(± 1.8), respectively. No patient had cholangiocarcinoma at the time of transplantation. The mean carbohydrate antigen-19.9 and carcinoembryonic antigen values were 19 (± 6.1) and 4.6 ± 1.6 ng/ml, respectively. Only one study patient had ulcerative colitis which was diagnosed before transplantation and disease was in clinical and endoscopic remission at the time of transplant. Details of baseline characteristics and demographics are given in Table 1.

Donor relation

All donors were related to their respective recipients. Most common relation was brother in seven (26.9%) cases followed by cousin, wife and sister in four (15.3%) cases each. Genetically related donors were 20 (76.9%) while 6 (23%) donors were genetically non-related (wife or husband). Out of 26 donors 18 (69.2%) were male. Details of donor relation with recipients are provided in Table 2.

Liver transplant surgery (Table 3)

Most commonly used graft was modified right lobe graft, used in 16 (61.5%) patients followed by extended right lobe and left lateral in 7 (26.9%) and 3 (11.5%) patients, respectively. Median graft to recipient weight ratio (GRWR) was 1.1 (0.8–1.5). Mean weight of the liver allograft used in study patients was 640.7 g (± 205.3). Mean graft cold ischemia time and warm ischemia were 110.5 ± 32.6 min and 43.1 ± 12.7 min, respectively. Hepaticojejunostomy was the most common biliary anastomosis which was done in 19 (73.1%) patients. Remaining seven (26.9%) patients had duct to duct anastomosis.

Post-transplant complications (Table 3)

Three (11.5%) patients developed allograft rejection and were successfully managed with immunosuppression

Table 1 Baseline parameters and demographic characteristics of study patients

Variable	Values
Recipient age (years; mean ± SD)	42.5 ± 13.8
Male sex (*n*, %)	19 (73.0%)
Presence of jaundice (*n*, %)	22 (84.6%)
Presence of pruritus (*n*, %)	4 (15.3%)
Presence of ascites (*n*, %)	16 (61.5%)
Presence of hepatic encephalopathy (*n*, %)	2 (7.6%)
History of GI bleed (*n*, %)	4 (15.3%)
Comorbidities (*n*, %)	
Diabetes mellitus	5 (19.2%)
Hypertension	2 (7.6%)
Carcinoembryonic antigen (ng/ml; mean ± SD)	4.6 ± 1.6
Carbohydrate antigen-19.9 (ng/ml; mean ± SD)	19 ± 6.1
Child–Turcotte–Pugh score (mean ± SD)	9.57 ± 1.8
MELD (mean ± SD)	18.96 ± 7.1
Hemoglobin (gm/dL; mean ± SD)	9.7 ± 2.1
Total leucocyte count ($\times 10^3$/cu. Mm; mean ± SD)	6.6 ± 2.7
Platelets ($\times 10^3$/cu. Mm; mean ± SD)	153.1 ± 81.6
INR (median [IQR])	1.4 (1.2–1.9)
T. Bilirubin (mg/dL; median [IQR])	7.7 (3.3–17.6)
AST (IU/L; median [IQR])	113.5 (72–177)
ALT (IU/L; median [IQR])	64 (42–114)
ALP (IU/L; median [IQR])	354.5 (225–477)
Albumin (g/dL; median [IQR])	2.8 (2.6–3.2)
Creatinine (mg/dL; median [IQR])	0.6 (0.4–0.7)
AFP (ng/ml; mean ± SD)	2.79 ± 2.2

MELD model for end-stage liver disease, *INR* international normalization ratio, *AST* aspartate transaminase, *ALT* alanine transaminase, *ALP* alkaline phosphatase *AFP* alfa fetoprotein, *GRWR* graft recipient weight ratio, *PSC* primary sclerosing cholangitis

Table 2 Relationship of liver allograft donor with their recipients

Donor relation	*N* (%)
Genetically related donor	20 (76.9%)
Brother	7 (26.9%)
Mother	2 (7.6%)
Father	1 (7.6%)
Sister	4 (15.3%)
Son	1 (3.8%)
Daughter	1 (3.8%)
Cousin	4 (15.3%)
Genetically unrelated donor	6 (23.0%)
Wife	4(15.3%)
Husband	2 (7.6%)

modification and steroid pulse therapy. Bile leak in post-operative period was seen in two (7.6%) patients which was managed conservatively. Three (11.5%) patients developed biliary stricture during follow-up and underwent ERCP and biliary stent placement. None of the patient with hepatico-jejunostomy developed extrahepatic biliary stricture that needed intervention.

Three patients died in early post-transplant period within first six weeks of liver transplant. One of them had early graft dysfunction and died due to sepsis and multiorgan failure. Other two patients lost their graft after acute cellular rejection and hepatic artery thrombosis.

Table 3 Peri-operative characteristics and post-operative outcomes of study patients

Variable	Values
Graft weight (grams, mean ± SD)	640.76 ± 205.3
GRWR (median [IQR])	1.11 [0.83–1.5]
Graft type *n* (%)	
Modified right lobe	16 (61.5%)
Extended right lobe	7 (26.9%)
Left lobe	3 (11.5%)
Cold ischemia time (minutes; mean ± SD)	110.5 ± 32.6
Warm ischemia time (minutes; mean ± SD)	43.15 ± 12.7
Biliary anastomosis	
A. Hepaticojejunostomy (*n*, %)	19 (73.1%)
B. Duct to duct	7(26.9%)
Bile leak post-operatively (*n*, %)	2 (7.6%)
Rejection (*n*, %)	3 (11.5%)
Development of biliary stricture (*n*, %)	3 (11.5%)
Hospital stay (days; median [IQR])	24 [21–30]
PSC recurrence (*n*, %)	5 (21.7%)*
Median time to recurrence (months; median [IQR])	36 (27.5–40.2)
Mortality (*n*, %)	6 (23.0%)
Median follow-up in months (IQR)	79.5 [36–120]

*After excluding early post-operative deaths

Post-transplant long-term survival and PSC recurrence (Table 3)

Total five patients (21.7%) developed PSC recurrence over a median follow-up of 79.5 (36–120) months after excluding three early post-operative deaths. Median time to recurrence was 36 (27.5–40.2) months. No patient with recurrence of PSC had graft failure at 1 year. While 5-year graft failure was seen in seven patients, two of which were due to recurrence of PSC. Two patients developed advanced liver failure due to recurrent PSC leading to graft loss. One of them died while other patient underwent liver retransplant. Remaining three cases are doing well with stable graft function. However, one patient required ERCP and biliary stent placement for dominant biliary stricture. Of the five patients who had recurrent PSC after LT, three had genetically related donors (brother in two cases and sister in one case). Wife

was donor in remaining two cases who had recurrence. None of the patient with pre-transplant PSC-AIH overlap developed recurrence.

Patients were followed for median period of 79.5 (36–120) months. One-year graft and patient survival rate was 88.5%. Long-term survival was calculated for the patients who underwent liver transplant at least 5 years ago. Five-year graft and patient survival rates were 68.4 and 73.6%, respectively. During SARS-CoV-2 pandemic three patients had coronavirus disease-2019 (COVID-19) and one of them died due to COVID-19 related pneumonia and respiratory failure. In the patient with ulcerative colitis, disease remained in clinical and endoscopic remission. No study patients developed colorectal carcinoma or other malignancy during follow-up period.

Comparison between the groups with and without PSC recurrence (Table 4)

Patients were divided into two groups based on post-transplant recurrence of PSC and comparison was done. Only pre-transplant serum bilirubin was found to significantly differ between the two groups. Serum bilirubin was higher in those who had recurrence (6.1 mg/dl vs 17.6 mg/dL; *p* 0.04) Recurrence of PSC was not significantly different in the recipients who received liver allograft from genetically related and unrelated donor. No significant difference was found between two groups in type of allografts used (extended right lobe vs modified right lobe vs left lobe) or in type of biliary anastomosis (hepaticojejunostomy vs duct to duct). Rate of rejection and steroid pulse therapy use were also not significantly different in both groups.

Discussion

Ours was a retrospective study of PSC and PSC-AIH overlap patients who underwent LDLT. Total 26 patients were included in the study out of which two patients had PSC-AIH overlap. Overall PSC recurrence rate after liver transplant was 21.73%. One-year and five-year patient survival rates were 88.5 and 73.6%, respectively.

PSC although rare, can cause significant burden on health care resources. PSC is one of the leading indications for liver transplantation in many countries. [1, 7] Post-liver transplant course in PSC is further complicated by high rate of primary disease recurrence and graft loss as compared to other indications for liver transplantation. [8].

In our study 1-year and 5-year patient survival rates were 88.5 and 75%, respectively. Long-term liver transplant outcomes in PSC have been excellent and comparable to other indications for liver transplant. Kashyap et al. reported more than 90% survival at 5 years. Graft and patients survival rate were similar for deceased donor liver transplant (DDLT) and LDLT in their study. [9, 10] On the contrary, Heinemann et al., in a recently published study involving European transplant registry patients showed higher mortality in LDLT as compared to DDLT for PSC patients 3 months post-transplant. Study group also included pediatric PSC patients. Poor outcome in LDLT was mainly due to biliary complications and PSC recurrence. Higher donor and recipient age and male donor have also been cited as risk factors for mortality after LDLT. [11–13] Mean donor and recipient age in our study was 33.7(± 9.5) and 42.5 (± 13.8) years, respectively. Larger prospective studies are needed to assess the effect of donor and recipients age on transplant outcome in PSC.

Post-liver transplant recurrence of PSC is of particular concern and can lead to graft loss requiring a liver retransplant. Post-transplant recurrence rates vary from 20 to 50% in published studies depending on duration since liver transplant and diagnostic criteria used for PSC recurrence. [2, 3] Various studies have described steroid resistant graft rejection, use of OKT3, male sex, intact colon, CMV infection, high MELD, high donor age, cholangiocarcinoma, and gender mismatch as risk factors for PSC recurrence. In LDLT as donor and recipients are genetically related, risk of recurrence can be higher as compared to DDLT. One study reported recurrence rate as high as 50% in LDLT using allograft from biological related donors [5, 6] In a study by Egawa et al. liver allograft from related donor and cytomegalovirus were a risk factor for PSC recurrence. [4] However, other studies have found similar rate of recurrence in DDLT and LDLT. [5] In our study post-transplant PSC recurrence rate was 21.7% over a median follow-up of 79.5 months. Recurrence rates were not significantly higher in patients who received allograft from genetically related donor. Another study by Choudhary et al. from India presented similar recurrence rates of PSC after LDLT. [2].

We compared various parameters of transplant recipients who had PSC recurrence with those without recurrence. Other than pre-transplant serum bilirubin level no other parameter was significantly different between two groups. Higher MELD score has been reported a risk factor for PSC recurrence as we have discussed above. Although bilirubin is one of the components of MELD score, mean MELD score was not statistically different in both groups in our study.

Only one patient had IBD-UC in our study group and disease remained in clinical remission during post-transplant follow-up. Reported prevalence of IBD in PSC has been reported significantly less in Asian countries compared to the west. Differences in screening colonoscopy practices can be one of the reasons for low IBD prevalence other than genetic and environmental factors. [14–16] Also, ours being a liver transplant referral center, patients with PSC in our

Table 4 Comparison of parameters between patients with and without PSC recurrence

Variable	No PSC recurrence ($n=21$)	PSC recurrence ($n=5$)	P value
Age (years; mean ± SD)	44.4 ± 14.3	34.6 ± 7.8	0.15
Male sex (*n*, %) recipient	14 (66.6%)	5 (100%)	0.13
Presence of ascites (*n*, %)	13 (61.9%)	3 (69%)	0.93
Presence of HE (*n*, %)	2 (9.5%)	0	0.47
Presence of GI bleed (*n*, %)	4 (19.0%)	0	0.55
Comorbidities (*n*, %)			
Diabetes mellitus	5 (23.8%)	0	0.54
Hypertension	2 (9.5%)	0	1.00
CTP (mean ± SD)	9.42 ± 1.8	10.2 ± 1.4	0.40
MELD (mean ± SD)	18 ± 6.6	23 ± 8.8	0.16
Hemoglobin (gm/dL; mean ± SD)	9.97 ± 2.1	8.66 ± 1.6	0.10
TLC ($\times 10^3$/cu Mm; mean ± SD)	6.27 ± 2.5	8.28 ± 3.3	0.15
Platelets ($\times 10^3$/cu. Mm; mean ± SD)	151.43 ± 85.7	160.6 ± 69.6	0.82
INR (median [IQR])	1.4 (1.2–1.7)	1.6 (1.2–2)	0.40
T. Bilirubin (mg/dL; median [IQR])	6.1 (3.2–8.9)	17.6 (8.4–20.9)	0.04
AST (IU/L; median [IQR])	114 (87–16)	104 (72–206)	0.89
ALT (IU/L; median [IQR])	64 (54–11)	42 (38–132)	0.60
ALP (IU/L; median [IQR])	382 (226–47)	320 (191–345)	0.45
Albumin (g/dL; median [IQR])	2.8 (2.6–3.2)	2.7 (2.6–3)	0.71
Creatinine (mg/dL; Median [IQR])	0.6 (0.5–0.7)	0.4 (0.4–0.6)	0.33
Genetically related donors (*n*, %)	18 (85.71%)	3 (60%)	0.19
Donor age (years, mean ± SD)	34.33 ± 9.8	31.4 ± 9.2	0.54
Donor male sex (n, %)	14 (66.6%)	5 (100%)	0.13
Graft weight (grams, mean ± SD)	661.09 ± 200.4	555.4 ± 226.6	0.31
GRWR (median [IQR])	1.06 (0.93–1.5)	1.17 (0.83–1.3)	0.83
Cold ischemia time (minutes; mean ± SD)	111.90 ± 35.3	104.6 ± 18.8	0.66
Warm ischemia time (minutes; mean ± SD)	41.14 ± 11.7	51.6 ± 15.0	0.10
Graft type (*n*, %)			
Modified right lobe	13 (61.9%)	3 (60%)	0.574
Extended right lobe	5 (23.8%)	2 (40%)	
Left lobe	3 (14.3%)	0	
Hepaticojejunostomy (*n*, %)	14 (66.7%)	4 (80%)	0.562
Bile leak post-operatively (*n*, %)	1 (4.7%)	1 (20%)	0.35
Steroid pulse for acute cellular rejection (*n*, %)	3 (14.2%)	0	1.00
Mortality (*n*, %)	5 (23.8%)	1 (20%)	1.00
Median follow-up (months; median [IQR])	75 (36–12)	108 (39–132)	0.56

ANA antinuclear antibodies, *ASMA* anti-smooth muscle antibodies, *CTP* Child–Turcotte–Pugh, *TLC* total leucocyte count, *INR* international normalization ratio, *AST* aspartate transaminase, *ALT* alanine transaminase, *ALP* alkaline phosphatase *GRWR* graft recipient weight ratio, *MRL* modified right lobe, *ERL* extended right lobe *LL* Left lateral

study cohort may not be true representative of the spectrum of PSC in the community.

As ours was a retrospective study, it was not free of limitations. We had a small sample size highlighting the rarity of the disease in India. Many patients had a recent transplant, and complete 5-year and 10-years follow-up was not available. Due to small number of patients, we could not determine risk factors for post-transplant PSC recurrence and mortality. We only found pre LT serum bilirubin levels to be statistically different among patients with and without recurrence, which again could be due to the small number of patients experiencing PSC recurrence in our study. The main focus of our study was on providing a descriptive account of our experience of LDLT in patients with PSC and to identify risk factors for recurrent PSC. However, comparing complications and mortality among patients transplanted for PSC to a historical matched cohort of those transplanted for other indications could have helped us in our understanding of

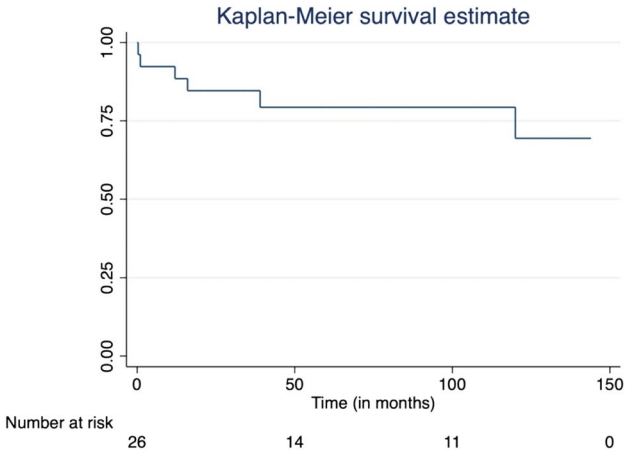

Fig. 1 Survival analysis of study patients

post LT recurrence better. Given the low prevalence of disease in India and Asia and limited LDLT experience in PSC, our study is significant in understanding post LDLT course of patients with PSC (Fig. 1).

Conclusion

Our study shows that LDLT can be performed in PSC with good long-term outcomes with a risk of PSC recurrence in about one-fifth patients. Genetically related donors may not be the risk factor for post-transplant PSC recurrence. However, more studies with larger number of patients are desirable for better understanding of the factors that affect post-transplant outcomes and PSC recurrence.

Author contributions SSJ MD, DM: draft writing, analysis, critical revision. RM, MD, DM: draft writing, analysis. AH, MBBS MSc: draft writing. SB, MS, MCh: draft writing. VM, MS, MCh: draft writing. MK, MS, DNB: draft writing. VK: draft writing. Dr. SAS, MD: draft writing. Dr. SA, MS, MCh: draft writing, critical revision. SG, MS, FRCSED, FRCS: critical revision SS, MD DM: critical revision.

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Declarations

Conflict of interest Shekhar Singh Jadaun, Rohit Mehtani, Ana Hasnain, Sushant Bhatia, Vikash Moond, Mukesh Kumar, Vikash Kuhad, Shweta Singh, Shaleen Agarwal, Subhash Gupta, Sanjiv Saigal declare no conflicts of interest. None of the authors have any financial, professional or personal conflict that are relevant to the manuscript.

Informed consent Written informed consent from all patients was obtained for this research. Study was approved by institute ethical committee and was conducted in accordance to research ethics guidelines of 1975 declaration of Helsinki. Liver transplant program at our institute strictly follows the 2008 declaration of Istanbul of organ transplantation.

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Authors and Affiliations

Shekhar Singh Jadaun[1] · Rohit Mehtani[1] · Ana Hasnain[1] · Sushant Bhatia[2] · Vikash Moond[2] · Mukesh Kumar[2] · Vikash Kuhad[3] · Shweta Singh[4] · Shaleen Agarwal[2] · Subhash Gupta[2] · Sanjiv Saigal[1]

Shekhar Singh Jadaun
dr.shekhar@outlook.com

Rohit Mehtani
rohitmehtani.14@gmail.com

Ana Hasnain
dr.anahasnain3@gmail.com

Sushant Bhatia
sushantbhatia123@gmail.com

Vikash Moond
drvikashmoond@gmail.com

Mukesh Kumar
mukesh.olaniya88@gmail.com

Vikash Kuhad
13vikashkuhar@gmail.com

Shweta Singh
drshwetasingh29@gmail.com

Shaleen Agarwal
agarwalshaleen@yahoo.com

Subhash Gupta
livertransplant@gmail.com

[1] Department of Gastroenterology and Hepatology, Centre for Liver and Biliary Sciences, Hepatology and Liver Transplant Medicine Saket, Max Super Speciality Hospital, New Delhi 110017, India

[2] Liver Transplant and Gastrointestinal Surgery, Centre for Liver and Biliary Sciences, Max Super Speciality Hospital, Saket, New Delhi, India

[3] Student's Scientific Circle of Surgery, Department of General, Endocrine and Transplant Surgery, Medical University of Gdansk, Ul. Smoluchowskiego 17, 80-214 Gdańsk, Poland

[4] Anesthesia and Critical Care, Centre for Liver and Biliary Sciences, Max Super Speciality Hospital, Saket, New Delhi, India