# Outcomes of pediatrics liver transplantation: comparison between cadaveric and live donor grafts

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**Background**
Pediatric liver transplantation (PLT) progressed extensively over the last few decades due to surgical, medical, and immunosuppression advancements. The only limiting factor for extension of PLT services is the limited number of available grafts. The sources of liver grafts include living and deceased donors. This study was conducted to compare the outcomes of both graft sources and to record short-term and intermediate-term living donor morbidity or mortality.

**Patients and methods**
This is a review of primary PLT recipients in Leeds Teaching Hospitals NHS Trust. Patients were divided into either recipients of cadaveric or living donor liver graft. Eighteen peritransplant parameters were recorded and classified into pretransplant recipients as well as donor parameters, operative parameters, and posttransplant outcomes. The primary endpoints of this analysis are the incidence of posttransplant rejection, vascular, as well as biliary complications in both groups, while the secondary endpoints are short-term and intermediate-term living donor morbidity or mortality.

**Results**
From November 2018 through December 2020, 33 PLTs were operated by the same consultant surgeons in The Leeds Teaching Hospitals with the following distribution: 18 PLT from deceased donors and 15 PLT from living donors. Median recipients' age was significantly lower in the living donor group than the deceased donor group (1.3 vs. 2.4 years; $P$=0.030). Similarly, median recipient weight was significantly lower in the living donor group than the deceased donor group (7.8 vs. 13.5 kg; $P$=0.007). From indication of transplant prospective, chronic liver failure was the main indication in both groups (73%). The most common indication for PLT was biliary atresia in 13 (39.3%) patients. In terms of donor sex, living donors tended to be females, while deceased donors tended to be males ($P$=0.046). The most common graft type used in both groups was left lateral segment. Warm ischemia time did not show a significant difference between both groups, while median cold ischemia time was significantly longer in the deceased donor group (94 vs. 469 min; $P \leq 0.001$). The only significant difference between two groups in terms of vascular complications was a higher rate of portal vein thrombosis in the living donor group (4 vs. 0; $P$=0.033). There was no statistically significant difference between two groups in terms of rates of bile leak or biliary stricture. The rates of rejection were higher in recipients of cadaveric grafts (33.3%) than living donor grafts (13.3%), but the difference was not statistically significant ($P$=0.242). None of the grafts from living or deceased donor source showed either primary nonfunction or delayed graft function. None of the recipients in both either living or deceased grafts required retransplantation. During the follow-up period, all recipients in both groups remained alive. No morbidity or mortality was recorded in the living donors in our series, either during posthepatectomy hospital stay or during outpatient follow-up appointments.

**Conclusions**
Patient and graft survival rates after deceased and living donor PLT do not vary substantially, and the rates of postoperative complications are similar. To reduce waiting list deaths, deceased and living donor PLT are two solutions that should go hand in hand.

**Keywords:**
acute liver failure, biliary atresia, chronic liver failure, deceased donor, living donor, pediatric liver transplantation

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## Introduction

Pediatric liver transplantation (PLT) has witnessed substantial progress in terms of surgical techniques, pretransplant and posttransplant intensive care, and medical services, especially immunosuppression protocols [1]. Due to such development, PLT is seen as one of the highly successful solid-organ transplants [2].

Graft options for pediatric candidates include either full or technical variant grafts. There are several technical variant graft alternatives, namely, reduced [3], split [4], monosegment, reduced left lateral, and live donor [5,6]. Reduced grafts result from graft 'cut-down' according to segmental anatomy, the segments not transplanted are discarded. Although the reduced grafts magnify the pediatric donor pool, this limits adult recipient options [7]. Therefore, split techniques developed, whereby a liver is separated so that it can be offered for two recipients. Live-donor techniques were inspired by split-liver transplantation, whereby a partial liver graft from a live donor is transplanted into an adult or pediatric recipient, the key difference is that mortality/morbidity is not accepted in living donors [8].

Deceased organ-donor shortage inspired the development of distinctive technical, psychological, and logistical advances in living-donor liver transplantation (LDLT) [9,10]. LDLT has considerably helped PLT candidates, especially in countries where there is restricted accessibility of deceased donor grafts for either cultural or legal purposes [6].

The rewards of getting a liver graft from living donors compared with deceased donors include the ability to offer transplant before the candidate becomes too ill, familiarity with donor history, avoiding of the physiologic insults initiated by brain death in the donor, and most importantly decreased cold ischemic time (CIT). Children suffering repeated cholangitis episodes after a Kasai procedure pose a unique challenge in terms of infectious complications and timing of transplant. In these cases, in this setting, LDLT is superior over deceased donor transplantation as it may be arranged electively when the patient is infection free [11]. LDLT also offers an opportunity for the preoperative management of graft steatosis by diet and exercise, this is possible as there is sufficient time for evaluation for potential donor [12,13].

The advantages of LDLT should be balanced by the threat to the donor, the added technical difficulty of accepting a partial graft, and the necessity for cautious medical and surgical assessment in selecting the appropriate donor and recipient. Autonomy is advised for the teams in charge of the evaluation and preparation of both live donor and recipient. Irrespective of possible recipient benefit, the security and welfare of the possible living donor must always take priority over the demands of the potential transplant recipient [14]. Single-donor mortality is too much for the transplant community, and the alterations in donors' quality of life in relation to their predonation status are less perceptible [15]. The lengthy biological costs of donor hepatectomy are yet to be entirely recognized [16].

Although LDLT is the preferred transplant procedure in Arab and Asian countries due to the unavailability of deceased donors in these areas, LDLT is not the most frequent practice in Western countries because of the greater accessibility of deceased donors [17]. This is especially true for the United Kingdom after the latest rise in the deceased donor pool (especially deceased circulatory death grafts). LDLT represents 7% of liver transplants performed per year in the UK [14]. Although the risk–benefit ratio may support LDLT practice in some portions of the world, the most appropriate position for LDLT in the UK is still to be defined [14].

Putting this in mind, we conducted this study with the aim of identifying if one graft has superior outcomes over the other and spot if living donors are at particular risk during the procedure or shortly after.

## Patients and methods

In the period between November 2018 and December 2020, data from PLT candidates admitted to The Leeds Teaching Hospitals, NHS Foundation Trust, UK, were collected. This research was performed at the Department of General Surgery, The Leeds Teaching Hospitals, NHS Foundation Trust, Leeds, UK, and Department of General Surgery, Faculty of Medicine, Alexandria University, Alexandria, Egypt. Ethical approval: This is a retrospective study. Hospital documents and electronic records were used to retrieve donor and recipient data. Inclusion criteria were recipients of the first liver transplant aged 12 years or less. Exclusion criteria were patients with uncontrolled systemic infection and high certainty of nonadherence, despite multidisciplinary interventions and support.

Eighteen peritransplant parameters were analyzed and classified into four categories: recipient parameters were age, sex, weight, and category, as well as PLT indication. Donor parameters were age, sex, weight, and donor morbidity as well as mortality (in the living donor group). Operative parameters were type of graft,

warm ischemia time (WIT), and CIT. Outcome parameters were patient and graft survival, incidence of rejection, and biliary and vascular complications. The primary endpoints of this analysis are the incidence of posttransplant rejection, vascular, as well as biliary complications, while the secondary endpoints are short-term and intermediate-term living donor morbidity or mortality.

#### Definitions

Patients were divided into five categories, depending on the underlying etiology/presentation: acute liver failure (ALF), chronic liver failure, acute on top of chronic, metabolic, and tumors. For the purpose of this study, ALF was defined based on the Paediatric Acute Liver Failure Study Group [18], as biochemical evidence of liver injury, no history of known chronic liver disease, coagulopathy not corrected by vitamin K administration, and international normalized ratio greater than 1.5 if the patient had encephalopathy or greater than 2.0 if the patient does not have encephalopathy.

Chronic liver failure was defined as an ongoing hepatic inflammation detected by clinical examination and biochemical investigations, over a period of more than 6 months, resulting in an irreversible liver damage or cirrhosis [19]. Metabolic liver diseases were defined as genetic disorders that lead to the production of aberrant transport proteins or enzymes and altered metabolic pathways [20]. Acute on top of chronic liver failure was defined as acute worsening of pre-existing, chronic liver disease, commonly linked to a triggering event and coupled with elevated mortality at 3 months because of multisystem organ failure [21].

CIT in deceased donor was defined as the time from donor aortic cross-clamp, until liver graft is out of ice, while in living donor, it was defined as the time between the start of cold graft preservation after complete resection to graft out of ice. WIT was defined as the time from liver graft out of ice, until reperfusion is established with portal venous (PV) blood. Primary nonfunction (PNF) was defined as initial graft failure after exclusion of vascular or immunologic causes. Delayed graft function (DGF) was defined as transient clinical and laboratory changes reflecting posttransplant graft dysfunction. Vascular complications were recorded after radiographic or operative confirmation. Suspected acute and chronic rejection were confirmed by graft biopsy.

#### Clinical management

Upon admission for potential transplantation, the patient is clinically examined by the surgical team and made sure that he/she does not have any unreported active infection or sepsis that would preclude transplantation.

#### Deceased donor

Acceptance of liver graft is the responsibility of the consultant surgeon, multiple factors interact to give the final decision, including donor age, comorbidities, and preretrieval liver functions. Upon arrival of liver graft to the recipient center, the backtable team examine the liver graft to check graft quality and size, ensure that there is no retrieval injury, and detect and report any anatomical variation to the recipient consultant. The graft can be used as whole graft or can be shared between pediatric and adult recipients, depending on the size of both donor and recipient. In the case of splitting, careful dissection and division of vascular and biliary structures is attempted. Liver parenchyma is divided using the energy device, cut-surface homeostasis is checked on the backtable by infusion of the University of Wisconsin Solution through the graft.

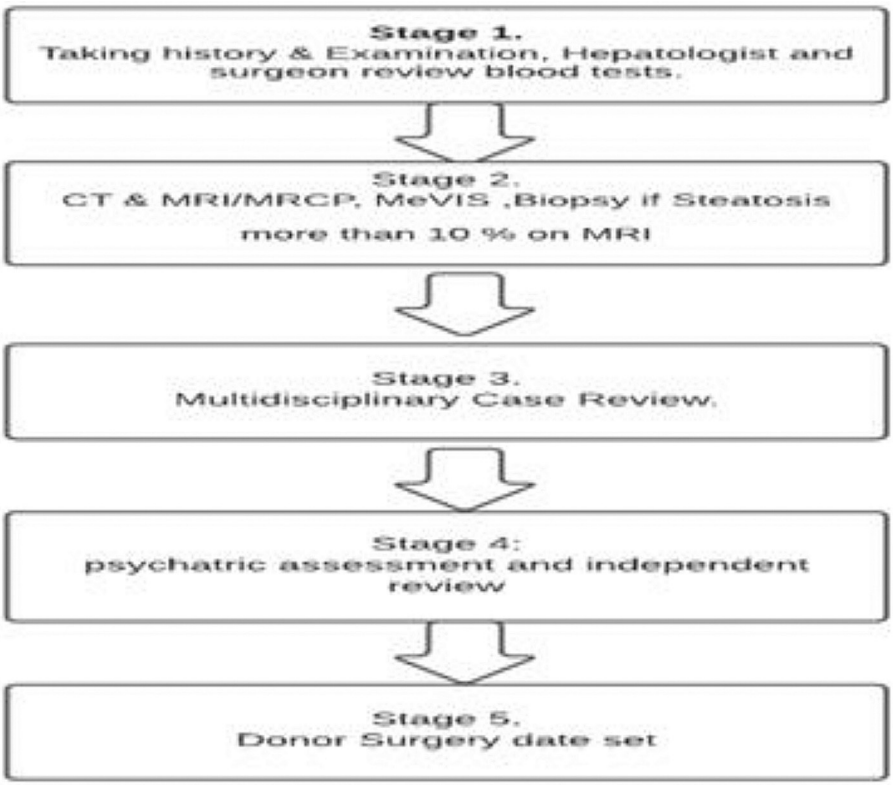
#### Living donor

Living donors in Leeds Teaching Hospitals pass through five consecutive stages, until they are considered clear to donate (Fig. 1). All these steps ensure suitability of the donor from both anatomical and psychological aspects. As a part of preoperative planning for living donor hepatectomy, detailed liver anatomy is obtained via Mevis imaging technique. Medical image (ultrasound, computed tomography, or MRI) are used to develop an augmented reality system that increases the surgeon's intraoperative vision by providing a virtual transparency. This technique helps to plan donor hepatectomy by identifying vascular anatomy and graft size, as well as remnant liver volume (Fig. 2a–d).

#### Operative phases

(1) Recipient hepatectomy: in children, a big portion of recipients would have previous abdominal surgery (failed portoenterostomy or Kasai) and this sometimes makes the hepatectomy challenging because of adhesions and bleeding caused by coagulopathy and portal hypertension. This phase usually takes place while the backtable team is doing the liver splitting to minimize CIT.
(2) Anhepatic phase during which positioning of the graft starts but the recipient is functionally between livers. The vascular anastomoses (vena cava, PV, and hepatic artery) are created during this phase. In case of hypoplastic PV, PV reconstruction using

**Figure 1**




Stages of living donor assessment.

**Figure 2**


(A) Portal vein anatomy, (B) Hepatic vein anatomy, (C) Left lateral graft hepatic vein, (D) Left lateral graft hepatic artery and portal vein.

donor iliac vein or venoplasty is done. If there is a discrepancy between donor and recipient hepatic artery, infrarenal aortic conduit using donor iliac artery is performed.

(3) Neohepatic phase: biliary reconstruction is done via either Roux en-Y or duct-to-duct anastomosis, depending on donor and recipient duct size.

**Posttransplant management**

Posttransplant protocol is identical for both groups; routine posttransplant immunosuppression is corticosteroids, MMF, and tacrolimus. Routine antimicrobial prophylaxis is intravenous Co-amoxiclav for 48 h. Doppler ultrasound of the graft is done routinely on postoperative days 1, 2, 3, 5, and 7.

## Results

From November 2018 through December 2020, 33 PLTs were operated by the same consultant surgeons in The Leeds Teaching Hospitals with the following distribution:

(1) Eighteen PLT from deceased donors.
(2) Fifteen PLT from living donors.

### Pretransplant recipient parameters

Both groups were homogeneous in terms of recipients' sex as living-donor recipients were seven males and eight females, while recipients of deceased-donor grafts were nine males and nine females ($P$=0.849) (Table 1).

Median recipients' age was significantly lower in the living-donor group than the deceased-donor group (1.3 vs. 2.4 years; $P$=0.030). Similarly, median recipient weight was significantly lower in the living-donor group than deceased-donor group (7.8 vs. 13.5 kg; $P$=0.007). From indication of transplant perspective, chronic liver failure was the main indication in both groups (73%).

All patients with urgent presentation (acute liver failure or acute on top of chronic liver failure) received cadaveric grafts, while patients with chronic liver failure, malignancy, or metabolic disorders received grafts from both graft sources. The most common indication for PLT was biliary atresia (BA) in 13 (39.3%) patients followed by progressive familial intrahepatic cholestasis in eight (24.4%) patients. All cases of PLT due to the underlying tumor were diagnosed with irresectable hepatoblastoma, while PLT was done for the following disorders in the metabolic group: citrullinemia, primary hyperoxaluria, and mitochondrial liver disease.

Eleven (84.6%) out of 13 BA patients had previous Kasai porto-entrostomy, while primary liver transplantation was done in two (15.4%) patients.

### Donor parameters

All deceased donors were donation after brain-death donors. There was no significant difference between two groups in terms of donor age or weight ($P$=0.094 and 0.283). In terms of donor sex, living donors tended to be females, while deceased donors tended to be males ($P$=0.046) (Table 2).

### Operative parameters

Operative data are illustrated in Table 3. The most common graft type used in both groups was left lateral segment. WIT did not show a significant difference between both groups, while median CIT was

**Table 1 Pretransplant recipient parameters**

| Parameters | Living donor [*n* (%)] | Deceased donor [*n* (%)] | *P* value |
|---|---|---|---|
| Sex | | | |
| Male | 7 (46.7) | 9 (50) | 0.849 |
| Female | 8 (53.3) | 9 (50) | |
| Age at transplant (years) | | | |
| Mean±SD. | 1.6±1.3 | 4.3±4.1 | 0.030* |
| Median (minimum–maximum) | 1.3 (0.5–5.5) | 2.4 (0.5–12) | |
| Weight | | | |
| Mean±SD | 9±3.3 | 15.5±8.7 | 0.007* |
| Median (minimum–maximum) | 7.8 (5.7–16) | 13.5 (6.5–37.7) | |
| Category | | | |
| Chronic liver failure | 11 (73.3) | 13 (72.2) | |
| Acute liver failure | 0 | 1 (5.6) | 0.531 |
| Tumor | 2 (13.3) | 2 (11.1) | |
| Metabolic | 2 (13.3) | 1 (5.6) | |
| Acute on top of chronic | 0 | 1 (5.6) | |
| Indication | | | |
| Biliary atresia | 9 (60) | 4 (22.2) | |
| Seronegative | 0 | 2 (11.2) | |
| Alpha one antitrypsin deficiency | 0 | 2 (11.1) | |
| Hepatoblastoma | 2 (13.3) | 2 (11.1) | |
| Cystic fibrosis | 0 | 1 (5.6) | 0.144 |
| Progressive familial intrahepatic cholestasis | 2 (13.3) | 6 (33.3) | |
| Citrullinemia | 1 (6.7) | 0 | |
| Primary hyperoxaluria | 1 (6.7) | 0 | |
| Mitochondrial liver disease | 0 | 1 (5.6) | |

*= significant

significantly longer in the deceased-donor group (94 vs. 469 min; $P \leq 0.001$).

PV reconstruction by interposition graft or venoplasty was required in 11 (33%) cases (four deceased and seven living donors) where nine (81.8%) of them had primary diagnosis of BA. Arterial conduit was required in two (6%) cases, one in each group. Biliary reconstruction was done using Roux en-Y hepaticojejunostomy in 26 (78.8%) cases, while duct-to-duct anastomosis was done in seven (21.8%) cases.

### Posttransplant recipient outcomes

#### *Incidence of vascular complications*

The only significant difference between two groups in terms of vascular complications was a significantly higher rate of portal vein thrombosis (PVT) in the living-donor group (4 vs. 0; $P=0.033$). The rates of other vascular complications (hepatic artery thrombosis–hepatic artery stenosis–PV stenosis–splenic artery steel) were comparable between two groups (Table 4).

**Table 2 Donor parameters**

| Parameters | Living donor [*n* (%)] | Deceased donor [*n* (%)] | *P* value |
|---|---|---|---|
| Donor age | | | |
| Mean±SD | 30.8±6.2 | 25.7±10.5 | 0.094 |
| Median (minimum–maximum) | 30 (23–42) | 25 (4.5–44) | |
| Donor sex | | | |
| Male | 1 (6.7) | 7 (38.9) | 0.046 |
| Female | 14 (93.3) | 11 (61.1) | |
| Donor weight (kg) | | | |
| Mean±SD | 69.8±15.2 | 63.9±14.8 | 0.283 |
| Median (minimum–maximum) | 65 (52–107) | 65.5 (16–80) | |

**Table 3 Operative parameters**

| Parameters | Living donor [*n* (%)] | Deceased donor [*n* (%)] | *P* value |
|---|---|---|---|
| Graft type | | | |
| Whole | 0 | 2 (11.1) | |
| Left lateral segment | 13 (86.6) | 15 (83.3) | 0.038 |
| Reduced left lateral segment | 2 (13.3) | 0 | |
| Reduced left lobe | 0 | 1 (5.6) | |
| CIT (min) | | | |
| Mean±SD | 107.2±40.3 | 490.7±112.9 | <0.001 |
| Median (minimum–maximum) | 94 (68–210) | 469 (302–798) | |
| WIT (min) | | | |
| Mean±SD | 39.7±5.4 | 40.8±5.1 | 0.550 |
| Median (minimum–maximum) | 40 (32–50) | 41.5 (30–48) | |

CIT, cold ischemia time; WIT, warm ischemia time.

**Table 4 Posttransplant outcomes**

| Parameters | Living donor [*n* (%)] | Deceased donor [*n* (%)] | *P* value |
|---|---|---|---|
| Vascular complications | | | |
| Hepatic artery stenosis | 1 (6.7) | 2 (11.1) | 1.000 |
| Hepatic artery thrombosis | 1 (6.7) | 0 | 0.455 |
| Portal vein stenosis | 1 (6.7) | 0 | 1.000 |
| Portal vein thrombosis | 4 (26.7) | 0 | 0.033 |
| Steal syndrome for splenic artery | 0 | 1 (5.6) | 1.000 |
| Biliary complications | | | |
| Bile leak | 1 (6.7) | 2 (11.1) | 1.000 |
| Anastomotic stricture | 1 (6.7) | 2 (11.1) | 1.000 |
| ICU stay (days) | | | |
| Mean±SD | 14.6±28.3 | 3±1.3 | 0.099 |
| Hospital stay (days) | | | |
| Mean±SD | 53.9±68.3 | 24.1±11.9 | 0.099 |

*Incidence of biliary complications*

There was no statistically significant difference between two groups in terms of rates of bile leak or biliary stricture ($P$=1.000).

*Incidence of rejection*

Rates of rejection were higher in recipients of cadaveric grafts (33.3%) than living-donor grafts (13.3%), but the difference was not statistically significant ($P$=0.242). All cases were confirmed by biopsy and responded to intravenous-pulse steroid therapy reflected by normalized liver function tests.

*Posttransplant pediatric intensive care unit stay*

Pediatric ICU stay post-PLT did not show a significant difference between recipients of two graft types ($P$=0.099).

*Posttransplant hospital stay*

Hospital stay posttransplant was comparable between recipients of cadaveric and living-donor grafts ($P$=0.099).

*Early graft function*

None of the grafts from living or deceased-donor source showed either PNF or DGF.

*Retransplantation rate*

None of the recipients in both either living or deceased grafts required retransplantation for graft failure.

*Patient survival*

During the follow-up period, all recipients in both groups remain alive and attend regular follow-up outpatient appointments. The minimum follow-up period was 6 months.

*Morbidity and mortality among living donors*

Grade-I morbidity was recorded in eight living donors involved in this study according to the Clavien–Dindo classification [22], this was in the form of regular antiemetics requirement in the first 48 h postprocedure. No mortality was recorded in this group and all donors attended regular outpatient follow-up appointments for at least 6 months with satisfactory outcomes.

Management of postoperative vascular and biliary complications are listed in Table 5.

## Discussion

Liver transplantation has flourished largely since it was first described by Starzl *et al*. [23]. As outcomes of the procedure demonstrated to be a success with the pioneering surgical techniques, progressive clinical care, and upgraded immunosuppression, the acceptance of transplantation increased swiftly. The number of possible liver-transplantation recipients is progressively expanding as indications for transplantation became broader [24].

Sadly, accessible donor grafts could not keep up with the rising number of potential recipients, producing lengthier waiting times and aggravating waiting-list mortality. Some reports estimated the annual liver transplant waiting-list mortality to be around 10.3% [25,26]. Others reported that waiting-list mortality can reach up to 18% and suggested that the percentage may be even higher in the youngest candidates where finding a matching graft may take prolonged times in candidates who do not afford to wait [27]. A possible justification of such high percentages is the low deceased organ donor rate and the occasional use of living-donor liver grafts.

To control this widening gap, transplant centers created approaches to enrich the organ-donor pool. These approaches consist of live donor-liver transplantation, split-liver transplantation, extended criteria donor livers such as elderly livers, and donation after cardiac death donors.

The most common indication for PLT in this study was BA, this has been consistently reported in the

**Table 5 Management of postoperative complications**

| Complication type | Management |
|---|---|
| Vascular complications | |
| Hepatic artery thrombosis | Hepatic artery thrombectomy |
| Hepatic artery stenosis | Two cases managed by arterioplasty and one case by arterial revision |
| Portal vein thrombosis | Portal vein thrombectomy in 4 cases |
| Portal vein stenosis | One managed by portal vein stenting |
| Steal syndrome for splenic artery | Embolized splenic artery to increase blood flow toward the hepatic artery |
| Biliary complications | |
| Biliary stricture | One managed conservatively, two managed by biliary reconstruction |
| Biliary leakage | Three managed conservatively |

literature as the most frequent indication of PLT [1,28–31]. Age of recipients in the living-donor group was significantly younger than patients in cadaveric donors, this can be partly explained by the shorter waiting time that recipients of living-donor grafts usually experience. In their series, Elisofon *et al.* [32] showed that living donation seems to be an essential method to achieve transplant in young recipients. Living donation gives an opportunity for elective transplantation in a timely manner and saves recipients of living-donor grafts from competing in the deceased graft pool waiting for a suitable matching graft.

Since the introduction of the University of Wisconsin solution, which substituted Euro-Collins solution [33], prolonged cold preservation of hepatic allograft has become possible [34]. Living donors' grafts in our study had significantly shorter CIT, this is obviously because the procedure is planned and donor hepatectomy is done in an adult center nearby the children hospital where implantation takes place. Numerous donor features have been found to unfavorably influence patient and graft survivals: age [35], sex [36], use of vasopressors [37], hypernatremia [38], cardiopulmonary arrest [39], and ischemic time [40–42]. Of all the factors studied, the CIT and WIT show the most substantial influence on hepatic allograft outcome [42,43].

Some authors studied whether concurrently extended CIT and WIT were related to initial graft dysfunction and potential loss after liver transplantation through a prospective assembly of donor and recipient data, they concluded that simultaneously prolonged CIT and WIT meaningfully triggered hepatic allograft failure. These conclusions lead to the suggestion of reducing the length of CIT as well as WIT to enhance graft survival after liver transplantation [44].

Prolonged CIT is an independent risk factor for DGF and PNF [45]. Ischemic damage injures the liver graft at the cellular level and can potentially increase the risk of ischemic cholangiopathy [46]. Reperfusion injury is correlated with the discharge of reactive oxygen species and proinflammatory mediators, which causes injury of the hepatic sinusoidal epithelium and serious hepatic microcirculatory mutilation [47].

None of the grafts in our study from living or deceased-donor source showed either PNF or DGF. This reflects the careful selection of donors, especially in the deceased-donor group where only young donation after brain-death donors with satisfactory liver functions and stable general condition are accepted with all efforts done to minimize the CIT and improve graft quality.

PVT occurs in 5–10% of PLT recipients [48]. It is more frequent in children transplanted for BA, because of pre-existing PV hypoplasia, which requires replacing the entire PV down to the confluence of the superior mesenteric vein with the splenic vein to avoid low-flow-related thrombosis. Early thrombosis following transplantation, detected by ultrasound screening, requires immediate anastomotic revision and thrombectomy [49]. Later thrombosis is usually detected by increasing spleen size or gastrointestinal bleeding. Interventional radiographic stent placement or balloon dilation has been successful in patients who have portal anastomotic stenosis, but is less successful when complete thrombosis has occurred [50].

LDLT recipients in our study had significantly higher PVT rate. This can be explained by the additive effect of significantly younger (smaller) recipients of this group, as well as more recipients in this cohort transplanted with background of BA. The incidence of PV complications in pediatric patients varies from 1.2 to 16.5% [22–25]. PV complications after LDLT have been a major concern in PLT, particularly in patients with BA [51] where PV complications can be as high as 14.7% [52]. In the pediatric age group, the risk factors for PV problems comprise pre-existing portosystemic shunts that cause reduced PV flow, graft interposition, age at transplantation (children $<1$ year old), weight ($<6$ kg), and retransplantation candidates [53–55]. Chardot *et al.* [52] described that PV diameter, age, weight at transplantation, and emergency transplantation are heavily associated with PV complications in BA. In Chardot's BA series, most PVT happened in the initial stages [53,56].

The difficulty in BA is that inflammation can extend to the hepatoduodenal ligament increasing the likelihood of inflammation of the PV. This is evident in candidates with multiple previous surgeries and intermittent cholangitis. Similar observation was reported by Sieders *et al.* [57] where more than 50% of children who suffered of PVT had a background of BA, these children also were younger and weigh less than children with other diagnoses. In their living-donor series, Gurevich *et al.* [58] reported 22 PV complications, 18 (81.8%) took place in the BA group.

Rejection is the leading reason of graft dysfunction following liver transplantation.

Despite prophylactic immunosuppression, rejection is seen in ~60% of children following transplantation [59,60]. While most common in the initial 3–6 months after the transplant, it may happen years later, and is frequently linked to immune-suppressant noncompliance. Rejection is usually presumed because of rising liver enzymes, frequently with aspartate aminotransferase level higher than alanine aminotransferase and higher g-glutamyl transpeptidase level. Occasionally, it is an upsurge only in the bilirubin level. These laboratory derangements happen prior to the commencement of symptoms such as fever, malaise, and jaundice. Liver biopsy is suggested for histologic confirmation and characteristic pathologic findings of acute cellular rejection (ACR) include portal tract inflammation with a mixed cellular infiltrate, bile duct injury, and endothelialitis. ACR is usually well controlled by pulsed steroid therapy, increasing calcineurin inhibitor drug levels, and possibly the addition of another immunosuppression line.

In our study, living-donor graft recipients were less susceptible to rejection, this was consistent with other authors' reports [61,62]. Early reports in the 1990s [63] suggested that rejection rates were comparable between LDLT and deceased-donor liver transplantation. With additional experiences and bigger patient samples, it was noted that LDLT was indeed associated with fewer ACR than deceased-donor liver transplantation. This is in harmony with similar observations in renal transplantation [64] and is related to several factors. Liver grafts from healthy living donors do not experience the stress caused by massive physiological shifts in brain-dead donors. In addition, the living-donor procedure is well planned with the synchronized recipient operation, and there is a briefer CIT. However, the hypothetical genetic advantage in LDLT with fewer HLA mismatches has not been proven [65], distinct from renal transplantation [66]. Maluf *et al*. [67] noted fewer rejection rates in LDLT, and lowered the immunosuppression in living-donor liver-graft recipients in the late portion of their series. Steroid was reduced earlier and the dose of calcineurin inhibitor was lowered, thus causing fewer septic complications and enhanced survival. This gives recipients of living-donor graft an immunological advantage over deceased-graft recipients.

Despite some fundamental resemblances, living donors may vary substantially in their views to donation process. From the sex-difference perspective, women are commonly found to be motivated by love, while men were more purposeful in their thoughts considering the pros and cons [68]. While numerous donors decide to donate promptly, show no major concerns, and do not believe they will alter their decision even after the evaluation [69,70], others need time to make up their mind and may express uncertainty [69]. Some express a readiness to accept a high level of risk for the recipient, particularly parents and spouses [70]. Such discrepancies may indicate different individual decision-making approaches. In our study, most of the living donors were females ($P$=0.046), with a dominant proportion of them having a maternal relation to the recipient.

Some authors [71] described that first-degree relative donors commonly feel that they must donate when they were informed that they matched compared with nonimmediate family relatives. Nonimmediate family relatives commonly need encouragement by others maybe because their distant connection made them feel less obliged. Dr Simmons noticed that the relationships among donor–recipient couples are crucial to a successful, conflict-free decision-making procedure. Family dynamics were less demanding, there was clearer communication, less pressure for others to donate, and more donors volunteered [72].

None of the ALF recipients in our study received a graft from living donor, this is most probably related to a short window of opportunity that does not give enough time for careful evaluation of potential living donor. Living donation for ALF patients has always been a subject of debate [73]. Some reports showed concerns regarding the ultrashort time used for clinical and radiological evaluation of the living donor in addition to the emotional component in case of children that may influence the outcomes of PLT [74,75]. Others argue that PLT from a living donor has a potentially superior outcome due to shorter waiting time as the sick child does not have to compete in the liver-graft allocation system and improved organ quality due to shorter CIT, as evidenced by lower incidence of PNF in the living-donor grafts [76].

A living-donor program, established corresponding to a well-specified ethical protocol, has a constructive influence on PLT activity, allowing recipient timely access to LT with reduction of the overall pretransplant mortality rate.

Patient and graft survival rates after deceased and living-donor PLT do not vary substantially, and the rates of postoperative complications are similar. This

can be achieved only by meticulous selection of the cadaveric donor for splitting and minimizing CIT. Living-donor PLT provides a solution for situations in which a cadaveric graft cannot be offered in time or if the choice of the ideal time point for transplantation is a crucial 'window of transplantation.'

To reduce waiting-list deaths, deceased-donor and living-donor PLT are two solutions that go hand in hand. The selection of technique should be the result of a thorough assessment of the recipient's condition, the donor's potential risk factors, and the chances of obtaining an outstanding cadaveric organ.

## Conclusion

The results of this study show comparable rates of survival between living and cadaveric liver-transplant recipients. However, several advantages of living donors' liver grafts could be identified:

(1) The usage of living-related donors heavily contributed to lessen the inadequate access to cadaveric organs.
(2) Living-donor recipients had a comparable level of hepatic artery thrombosis, despite being significantly younger in age and smaller in size.
(3) Living-donor recipients could have an immunological advantage evidenced by lower rejection rates.
(4) Living-donor transplantation offers an opportunity for PLT in younger-age and earlier stages of the liver disease as these children do not have to compete in the deceased-donor graft pool.
(5) Living donation could be achieved within significantly shorter CIT, which can be reflected on intermediate-term and long-term survival of both recipient and graft.

Living donors tend to be females and this could be explained by the emotional relationship, especially in the maternal situation, while deceased donors tend to be males, this could be attributed to being more exposed to road-traffic accidents.

On the other hand, recipients of living-donor liver graft in the current study had a significantly higher incidence of PVT, this was linked to a higher percentage of children transplanted with background of BA and a significantly smaller recipient size in this cohort.

Transplant centers should work out solutions to improve the logistics of living-donor assessment in the settings of recipients diagnosed with ALF, this can enhance the outcome of such critical groups without jeopardizing donor safety.

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There are no conflicts of interest.

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