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ORIGINAL ARTICLE

Anesthetic management in pediatric liver transplantation: a comparison of deceased or live donor liver transplantations

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Abstract

Purpose Pediatric liver transplantations (LT) are becoming increasingly more common in the treatment of a child with end-stage liver disease. The aim of this study was to evaluate the perioperative anesthetic experience of pediatric patients undergoing deceased and live donor liver transplantations.

Methods We performed a chart review of 164 patients between December 1997 and February 2009 in a retrospective cohort study design. Patient characteristics, operational variables, hemodynamic course, blood and fluid requirements, and extubation rates were evaluated in both deceased [deceased donor liver transplantation (DDLT, $n = 56$)] and live donor liver transplantation (LDLT, $n = 101$) patients.

Results The LDLT patients had a lower mean age and body weight than the DDLT patients ($p < 0.05$). The mean operation time was significantly longer and the mean anhepatic time was shorter for LDLT patients than for DDLT patients. The mean red blood cell (RBC) count and crystalloid and colloid requirements were significantly higher in LDLT patients. Relative to DDLT patients, significantly more patients in the LDLT group did not require fresh frozen plasma. The overall success rates of immediate extubation at the end of surgery were 74% in LDLT patients and 49% in DDLT patients ($p = 0.086$). The immediate extubation rate by year, including both groups, increased from 0% in 1997 to 95.6% in 2008.

Conclusion The results of this study show that among pediatric patients LDLT continues to become an 'obligatory' option that is associated with longer operation times and higher RBC and fluid requirements than DDLT. As a marker of successful LT, higher extubation rates immediately following surgery is achievable for both pediatric LDLT and DDLT patients.

Keywords Anesthesia · Liver transplantation · Pediatric

Introduction

Pediatric liver transplantations (LT) are becoming increasingly more common in the treatment of children with end-stage liver disease (ESLD). Continuing advances in our understanding of the pathophysiology of liver disease, major progress in preoperative management in terms of nutrition and control of portal hypertension-related bleeding and ascites, newer immunosuppressive regimens, and increased surgical and anesthetic experience, have greatly improved the graft and patient survival [1–3]. An anesthetist is an essential member of the transplantation team responsible for performing this major surgical procedure in infants. In order to successfully manage the anesthesia in these patients, it is particularly important that, depending on the stage of the procedure, the anesthetist must precisely correct for fluid and blood losses, constantly monitor electrolytes and blood gases, appropriately identify and correct bleeding diathesis, and maintain body temperature and diuresis [3]. In addition, perioperative management of these patients varies greatly between liver transplant centers in terms of fluid replacement, prevention and treatment of coagulopathy, transfusion requirements, and early extubation [4–6].

The aim of the study reported here was to evaluate the perioperative anesthetic experience of pediatric patients

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who have undergone deceased donor liver transplantation (DDLT) or living donor liver transplantation (LDLT) at our institution.

Patients and methods

We performed a retrospective chart review of 164 pediatric patients (<18 year of age) who underwent orthotopic liver transplantation (OLT) for ESLD, at the Ege University Organ Transplantation Center between December 1997 and February 2009. After excluding re-transplantations (7 patients), this cohort study included 157 patients. The patients' data were evaluated in two groups (DDLT vs. LDLT) and data were compared between the groups. The preoperative characteristics studied included primary diagnosis, age, gender, body weight, height, Child–Turcotte–Pugh (CTP) and pediatric end-stage liver disease (PELD) scores, baseline hemoglobin and hematocrit levels, prothrombin time (PT), activated partial thromboplastin time (APTT), and platelet count. Data on operative features during the operation included mean duration of operations and anhepatic periods, requirements for fluid, blood, and blood products, hemodynamic courses, frequency of postreperfusion syndrome (PRS), and metabolic course (hematocrit, PT, APTT, fibrinogen, sodium, potassium, and calcium levels, body temperature, base excess). PRS was defined as a decrease in mean arterial pressure (MAP) to >30% below the baseline value for at least 1 min, occurring during the first 5 min after reperfusion [7]. The distribution of DDLT and LDLT groups by year, the number of patients with successful immediate extubation in the operating room by year, and overall survival rates were also determined. Transfusion requirements were evaluated by the quantity of milliliters per kilogram of body weight of red blood cell (RBC) and fresh frozen plasma (FFP). The relationships between the extubation rates and RBC and FFP requirements with their related factors were evaluated in both groups.

Standard surgical technique without caval preservation was used for the operations. Venovenous bypass or temporary portocaval shunting was not applied to any patient.

Different agents were used to provide the general anesthesia throughout the years of the study. Sodium thiopental, midazolam, propofol or ketamine, and fentanyl were used to induce anesthesia, with ketamine only used in patients with unstable hemodynamics. Cisatracurium or rocuronium was used for muscular relaxation. Isoflurane in an oxygen air mixture at FiO_2 of 40–50% combined with fentanyl/remifentanil and cisatracurium/rocuronium infusions was used to maintain the state of general anesthesia. During the last 7 years, the anesthetic protocol consisted of propofol, fentanyl, and cisatracurium for the induction of anesthesia and isoflurane, remifentanil, and cisatracurium infusions for the maintenance of anesthesia. The patients were mechanically ventilated with a tidal volume of 8–10 ml/kg, and a respiratory rate of 12–30 breaths/min was adjusted to maintain an end tidal CO_2 of 32–35 mmHg by a volume-controlled mode. Monitoring of the electrocardiogram, pulse oxymeter, end-tidal CO_2 partial pressure, core body temperature, radial arterial and central venous pressures, and urine output was routinely performed in all patients. A central venous catheter with a three-way valve was used in all patients for the infusion of fluids and drugs and for monitoring central venous pressure. A pulmonary artery catheter (PAC) was inserted via the internal jugular vein in 37 patients for monitoring pulmonary artery and pulmonary capillary wedge pressures and cardiac output in older children.

A balanced electrolyte solution, including electrolytes [(mEq/L) sodium, 140; potassium, 5; chloride, 98; magnesium, 3] together with acetate (27 mEq/L), phosphate (1 mEq/L), and gluconate (23 mEq/L), pH 7.4 (Isolyte S; Eczacibasi, Istanbul, Turkey), 5% dextrose in water as crystalloid, 4% Gelofusine (Gelofusine; B. Braun Co, Melsungen, Germany), and 5% human albumin solutions as colloid, were used for balancing fluid and electrolyte status and replace to fluid loss. RBC transfusion was adjusted to keep the hematocrit level between 25 and 30%. In the management of coagulation disorders, FFP or fibrinogen concentrates were used to keep the PT at 20–25 s and the plasma fibrinogen concentration at >100 mg/dl. During the past 5 years, coagulation disorders have been managed only by thromboelastogram (TEG) variables (Thromboelastography analyzer model 500; Haemoscope Corp, Niles, IL). Based on TEG, a reaction time >8 min was corrected with FFP or cryoprecipitate, and a coagulation time >4 min, alpha angle <47%, and maximum amplitude <55 mm were corrected with fibrinogen concentrate and platelet suspensions. Primary fibrinolysis, based on the TEG measure of the variable lysis at 30 min (LY30) of <8%, was treated with tranexamic acid. During the operation, all patients were specifically protected from hypothermia using a hot-water blanket (model 231; Bicakcilar, Istanbul, Turkey), warming infusion lines (Hotline-Level 1; SIMS, Rockland, MA), and blowing devices (Bair-Hugger Warming Unit, model 505; Augustine Medical, Eden Prairie, MN).

Hemodynamic parameters, blood gas analysis, hemoglobin/hematocrit level, blood glucose and electrolyte concentrations, plasma coagulation profile, and the TEG were recorded at the beginning of the dissection period, at the end of the anhepatic period, immediately after the reperfusion period, and at the end of the operation, mainly in stable conditions.

Extubation immediately after the operation in the operation room has currently become a standard routine of our protocol. However, at the end of the operation, patients with advanced hemodynamic insufficiency, requiring ventilation support due to respiratory insufficiency or muscle weakness, with persistent coagulopathy or graft dysfunction and patients with previously acute liver disease with grade III and IV encephalopathy are not extubated and are transferred to the intensive care unit for mechanical ventilation and other supportive therapies.

Statistical analysis of the data was performed using SPSS ver. 15.0 for Windows (SPSS, Chicago, IL). Comparisons between the groups were performed by using either the Student's *t* test or chi-square test, as appropriate. The relationships between RBC and FFP consumption, extubation rate, and characteristics of the groups were analyzed using the Mann–Whitney *U*, chi-square, and Pearson's correlation tests. Data are expressed as the mean ± standard deviation (SD). A p value <0.05 was considered to be statistically significant.

Results

A total of 157 pediatric OLTs were evaluated in this study. Of these transplantations, 56 were performed from deceased and 101 from living-related donors after 1999. The distribution of the clinical diagnosis for transplantation was significantly different between the DDLT and LDLT groups ($p < 0.05$, Table 1), with the most common indications being biliary atresia and fulminant hepatic failure in the LDLT group and fulminant hepatic failure and Wilson's disease in the DDLT group. The number of patients undergoing LDLT increased over the last 10 years of the study, whereas the number DDLT patients remained variable. The distribution of DDLT and LDLT patients by year is shown in Fig. 1.

Disease severity scores (CTP and PELD), preoperative PT and APTT, and platelet count were similar in both groups (Table 1). However, LDLT patients has a lower mean age, body weight, and height than DDLT patients ($p < 0.05$; Table 1). The mean operation time was significantly longer for the LDLT group than for the DDLT group, while the mean anhepatic time was shorter ($p < 0.05$, Table 1). Preoperative hemoglobin and hematocrit values were lower in the LDLT patients than in the DDLT patients ($p < 0.05$; Table 1).

The mean RBC requirements, the number of patients who required FFP, and the mean crystalloid and colloid requirements were significantly higher in the LDLT group than in the DDLT group) ($p < 0.05$; Table 2). The number of patients requiring RBC and the mean number of units of FFP required did not differ between groups. In the entire population, underlying disease has no significant effect on blood consumption in terms of both RBC ($p = 0.395$) and FFP ($p = 0.155$). When biliary atresia was compared with other underlying diseases, the consumption of RBC was found to be higher for biliary atresia patients (35.9 ± 34.3 vs. 21.3 ± 18.2 ml/kg); however, the difference was not significant ($p = 0.06$). FFP consumption was similar for both biliary atresia and other underlying diseases (16.7 ± 16.9 vs. 16.5 ± 16.9 ml/kg). Pearson's correlation determined that there were significant correlations between RBC and FFP and some of the characteristics of the groups. For example, in the LDLT group, RBC consumption correlated with hemoglobin and hematocrit levels ($r = -0.206$, $p = 0.041$; $r = 0.250$, $p = 0.045$, respectively), CTP score ($r = 0.217$, $p = 0.031$), and the duration of surgery ($r = 0.260$, $p = 0.042$); FFP consumption only correlated with duration of surgery ($r = 0.206$, $p = 0.039$). In the DDLT group, RBC consumption correlated with hemoglobin and hematocrit levels ($r = -0.286$, $p = 0.038$; $r = 0.293$, $p = 0.033$, respectively) and the duration of surgery ($r = 0.482$, $p = 0.00$); FFP consumption only correlated with the Model for End-Stage Liver Disease (MELD) score ($r = 0.299$, $p = 0.028$). Since the management of coagulation using TEG only began after October 2004, we analyzed FFP and RBC requirements between the periods before and after October 2004 in both groups and found that FFP consumption significantly decreased after the use of TEG was introduced (27.4 ± 18.8 vs. 5.3 ± 7.8 ml/kg in DDLT; 27 ± 16 vs. 11.7 ± 18 ml/kg in LDLT; $p < 0.05$ for both groups). There were no significant differences between these two periods in terms of RBC consumption (20.3 ± 16.6 vs. 22 ± 24.2 ml/kg in DDLT; 34.8 ± 30.7 vs. 21.4 ± 15.2 ml/kg in LDLT; $p > 0.05$ for both groups). There was a significant, but weak correlation between FFP and RBC consumption ($r = 0.309$, $p = 0.000$).

The hemodynamic course during specific time periods of the operation was similar between both groups, with the exception of MAP, which was significantly lower in the LDLT patients than in the DDLT patients ($p < 0.05$, Table 3). The incidence of PRS occurrence was 27% for DDLT patients and 22% for LDLT patients, respectively ($p > 0.05$). The metabolic course during the operation was similar between the groups, except for hematocrit and serum potassium levels: significantly lower hematocrit levels during the anhepatic period and lower potassium levels during the reperfusion period were determined in LDLT patients compared to DDLT patients ($p < 0.05$; Table 4).

A detailed evaluation of the extubation rates by year revealed that there was no significant difference between the LDLT and DDLT groups ($p > 0.05$; Fig. 2). The overall success rates of patients extubated immediately at the end of surgery were 74% in the LDLT group and 49% in the DDLT group ($p = 0.086$). The immediate extubation

Table 1 Pre- and perioperative characteristics of the two liver transplantation groups

Pre- and perioperative characteristics of the study cohort	DDLT ($n = 56$)	LDLT ($n = 101$)	p value
Recipient age (year)	9.5 ± 6.1	4.6 ± 4.8	<0.0001
Recipient gender (M/F)	35/21	48/53	0.09
Weight (kg)	33.1 ± 22.6	17 ± 13.3	<0.0001
Height (cm)	123 ± 38	93 ± 31	<0.0001
CTP score	10 ± 3	10 ± 2	0.62
PELD score	18 ± 13	21 ± 12	0.25
Hemoglobin (g/dl)	10.2 ± 2	9.2 ± 1.7	<0.0001
Hematocrit (%)	30 ± 6	28 ± 5	<0.0001
Prothrombin time (s)	23 ± 9.5	24 ± 10	0.57
Activated partial thromboplastin time (s)	43 ± 15	43 ± 14	0.97
Platelet count (10^3/ml)	135 ± 124	157 ± 109	0.28
Duration of the operations (min)	339 ± 90	438 ± 96	<0.0001
Duration of anhepatic phase (min)	56 ± 15	51 ± 11	0.03
Primary indication for OLT			0.002
Biliary atresia	8	39	
Fulminant hepatic failure	9	12	
Wilson's disease	9	5	
Tyrosinemia	0	9	
Congenital hepatic fibrosis	7	2	
Cryptogenic cirrhosis	4	6	
Familial intrahepatic cholestasis	5	6	
Autoimmune hepatitis	5	4	
Hepatitis B	3	3	
Glycogen storage disease	1	3	
Others[a]	5	12	

Data are given as the mean ± standard deviation (SD)

PELD Pediatric end-stage liver disease; *DDLT* deceased donor liver transplantation; *LDLT* living donor liver transplantation; *OLT* orthotopic liver transplantation; *CTP score* Child-Turcotte-Pugh score

[a] Histiocytosis, Crigler–Najjar syndrome, idiopatic neonatal hepatitis, Byler's disease, Caroli disease, hepatoblastom, metabolic syndrome, hypercholesterolemia

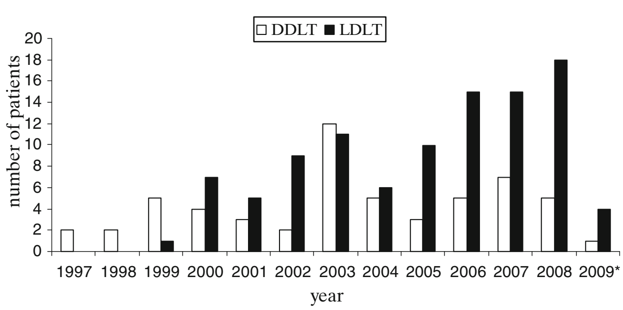

Fig. 1 Number of deceased donor liver transplantation (*DDLT*) and living donor liver transplantation (*LDLT*) patients by year. *Asterisk* Data up to February 2009

rate, including both groups by year, increased from 0% in 1997 to 95.6% in 2008 (Fig. 2). There was no reintubation in the early postoperative period. RBC consumption was similar between immediately extubated and non-extubated patients (25.2 ± 25.2 vs. 27.4 ± 24.7 ml/kg, respectively; $p = 0.616$), while FFP consumption was significantly higher in non-extubated patients than in extubated pones (26 ± 18.1 vs. 13.6 ± 17.2 ml/kg; $p = 0.000$). The underlying disease had no effect on the decision of immediately extubation ($p = 0.289$).

Intraoperative complications were anaphylaxis due to colloid administration (Gelofusine 4%) in one patient, severe bronchospasm during the induction of anesthesia in five patients, and severe air embolism requiring cardiac compressions during the dissection period in one patient. There was no patient mortality associated with these complications. Ten early re-operations were performed in the post-transplant period for bleeding control. There was no intraoperative death. The overall survival rates were 85% for the 1-year postransplant period and 73% for >3-year posttransplant period.

Table 2 Perioperative transfusion and fluid requirements for the liver transplantation groups

Perioperative transfusion and fluid requirements	DDLT ($n = 56$)	LDLT ($n = 101$)	p value
RBC (ml/kg)	20.4 ± 15.8	28.3 ± 27.2	0.02
Required (*n*/%)	50/89.3	93/92.1	0.57
FFP (ml/kg)	18.6 ± 18.8	15.5 ± 17.8	0.31
Required (*n*/%)	43/76.7	60/59.4	0.035
Crystalloid (ml/kg)	69 ± 51	90 ± 65	0.03
Colloid (ml/kg)	22 ± 17	32 ± 23	0.03

Data are given as the mean ± SD unless stated otherwise

RBC Red blood cell; *FFP* fresh frozen plasma; *n* number of patients

Table 3 Hemodynamic course during periods of the operation for the liver transplantation groups

Hemodynamic parameters	DDLT ($n = 56$)	LDLT ($n = 101$)
HR (bpm)		
Dissection	106 ± 20	112 ± 20
Anhepatic	111 ± 18	111 ± 15
Reperfusion	109 ± 17	112 ± 17
MAP (mmHg)		
Dissection	74 ± 15	65 ± 17*
Anhepatic	69 ± 14	62 ± 14*
Reperfusion	68 ± 17	61 ± 14*
CVP (mmHg)		
Dissection	8.3 ± 4	7.9 ± 3.6
Anhepatic	6.8 ± 4.8	6.5 ± 3.3
Reperfusion	7.7 ± 5	7.5 ± 3.1

Data are given as the mean ± SD

HR Heart rate; *MAP* mean arterial pressure; *CVP* central venous pressure

* $p < 0.05$ compared with the DDLT group

Discussion

The results of our study show that the number of patients in the LDLT group has increased over the past 10 years. This is an expected change due to the shortage of pediatric donor organs in Turkey. Although the patients in both groups had similar disease severity scores (CTP and PELD), there were some differences in terms of blood and fluid requirements. The pediatric LDLT patients in this study required more RBC, crystalloid, and colloid per kilogram body weight than the DDLT patients. However, significantly fewer LDLT patients than DDLT patients required FFP. This study is a follow-up on two early reports [4, 5]. It includes more patients, and the results are interesting in that they show an improvement in the success rate of early extubation and its relationship with other variables. On a whole, the rates of immediately extubating patients at the end of the surgery in the operating room (74% in LDLT and 49% in DDLT) were highly satisfactory and even increased from 0 to 95% by the last year of the study.

The shortage of deceased donor livers for pediatric transplantation together with an increasing demand for LT had led to the development of innovative techniques, such as LDLT [8, 9]. At our institution, between 1999 and 2009 there was a tendency towards an increase in the number of LDLT patients, primarily of younger children with a lower body weight. The most common indications were biliary atresia and fulminant hepatic failure in the LDLT patients and fulminant hepatic failure and Wilson's disease in DDLT patients.

The intraoperative management of the LT patient begins with the induction of anesthesia. Because of the increased intraabdominal pressure from ascites and organomegaly, together with delayed gastric emptying, some patients may require rapid sequence intravenous induction with cricoid pressure to facilitate tracheal intubation. At our institution, we standardly perform rapid sequence induction with cricoid pressure where there is a suspicion of need, especially during emergencies LT. The last step in anesthesia maintenance is the balanced technique composed of isoflurane and infusions of remifentanil and cisatracurium. Isoflurane, as used in adult recipients, is the volatile agent of choice because it has the least effect on hepatic blood flow. Isoflurane together with remifentanil and cisatracurium, which primarily have unrelated functions on organs, are anesthetic agents standardly used in our institutional protocol. As an opioid, remifentanil, which is metabolized by nonspecific esterases in the blood and tissues, has a short duration of action and provides more controllable hemodynamic changes [10]. Cisatracurium is a nondepolarizing neuromuscular agent metabolized by Hoffman elimination in the blood independent of liver metabolism [11]. During the last 7 years, the remifentanil and cisatracurium combination has changed our anesthetic practice by allowing rapid recovery and immediate early extubation after anesthesia for both pediatric and adult patients.

Although recent studies show a clear reduction of blood requirements during LT, this surgery is still associated with

Table 4 Metabolic course in the liver transplantation groups

Metabolic course parameters	DDLT (*n* = 56)	LDLT (*n* = 101)	*p* value
Hematocrit (%)			
Dissection	27.3 ± 5.7	25.8 ± 5.2	0.11
Anhepatic	27.5 ± 4.7	25.5 ± 5.1	0.001
Reperfusion	27.6 ± 4.5	26.2 ± 4.4	0.07
PT (s)			
Dissection	26.4 ± 16.6	26 ± 14.7	0.83
Anhepatic	30.2 ± 19.6	31.4 ± 18.1	0.68
Reperfusion	26.6 ± 13.8	27.4 ± 14.8	0.76
APTT (s)			
Dissection	47 ± 20	51 ± 26	0.39
Anhepatic	55 ± 27	69 ± 41	0.06
Reperfusion	56 ± 25	64 ± 46	0.32
Fibrinogen (mg/dl)			
Dissection	226 ± 123	220 ± 118	0.79
Anhepatic	189 ± 92	167 ± 73	0.30
Reperfusion	160 ± 69	156 ± 57	0.81
Na^+ (mmol/l)			
Dissection	138 ± 5.5	136 ± 5.4	0.24
Anhepatic	138 ± 5.2	137 ± 5.2	0.19
Reperfusion	138 ± 4.9	137 ± 5.1	0.16
Ca^{2+} (mmol/l)			
Dissection	0.88 ± 0.14	0.9 ± 0.19	0.70
Anhepatic	0.78 ± 0.14	0.85 ± 0.23	0.06
Reperfusion	0.89 ± 0.19	0.89 ± 0.21	0.83
K^+ (mmol/l)			
Dissection	3.5 ± 0.7	3.5 ± 0.6	0.94
Anhepatic	3.6 ± 0.6	3.5 ± 0.6	0.25
Reperfusion	3.6 ± 0.7	3.2 ± 0.5	0.001
Base excess (mmol/l)			
Dissection	−2.3 ± 5.5	−2 ± 5.9	0.77
Anhepatic	−3.8 ± 4.8	−3.9 ± 4.8	0.91
Reperfusion	−3.5 ± 5.6	−3.2 ± 5.3	0.7
Temperature (°C)			
Dissection	36 ± 1	36 ± 0.9	0.76
Anhepatic	35.8 ± 0.9	36 ± 0.8	0.08
Reperfusion	35.7 ± 0.9	36 ± 0.8	0.05

Data are given as the mean ± SD

APTT Activated partial thromboplastin time; *PT* prothrombin time

serious bleeding [12]. Surgical techniques together with an individual patient's coagulation status and institutional practices have been reported to affect the transfusion requirements during LT [13]. In pediatric LT, the loss of a small amount of blood may result in a significant blood loss relative to the patient's blood volume; consequently, the proper replacement of blood loss is essential. Ozier et al. [14] reported a wide range of interindividual RBC requirements (median 79 ml/kg; range 4–586 ml/kg) during pediatric LT. In their study of LDLT patients, Adachi et al. [13] showed a mean blood loss of 163 ml/kg, which necessitated a 130 ml/kg blood preparation. In another study, Djurberg et al. [15] reported their initial experience with 27 children undergoing LDLT and showed that the mean RBC and FFP requirements were 7.9 and 16.6 ml/kg/h, respectively, while the mean cristalloid and colloid requirements were 25 and 16 ml/kg/h, respectively. In our transfusion protocol, the replacement of blood loss is guided by a close observation of the patient's blood loss rate, in close cooperation with the surgical team, hemodynamic variables, hemoglobin concentration (>8 g/dl), and hematocrit levels (25–30%). However, some patients still meet the decreased target levels of hemoglobin and hematocrit during severe bleeding. The management of

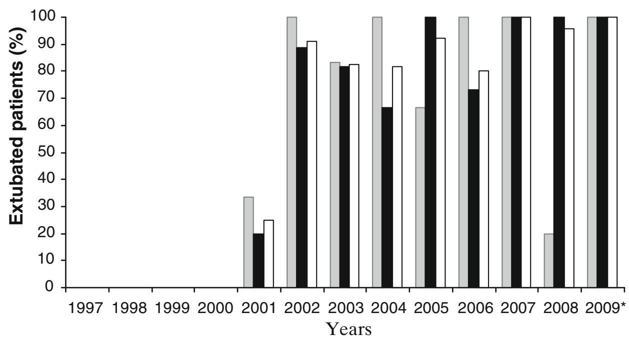

Fig. 2 The early extubation rates in the entire study cohort and in DDLT and LDLT patients separately by year. *Asterisks* Data up to February 2009. *Gray bars* DDLT, *black bars* LDLT, *white bars* overall data of the extubated patients

coagulation in patients has been successful achieved, and a patient's current coagulation status, results from routine laboratory-based coagulation tests (prothrombin time/International Normalized Ratio, activated partial thromboplastin time, fibrinogen), and platelet number are currently used as diagnostic factors. However, the value of these tests has been questioned in the acute perioperative setting because (1) there are always delays between blood sampling and the results of the sampling (45–60 min) as coagulation tests are determined in plasma rather than in whole blood, (2) no information is available on platelet function, and (3) the assays are performed at a standard temperature of 37°C rather than at the patient's temperature [16, 17]. The thromboelastogram provides rapid bedside information. For the last 5 years at our center, the administration of FFP and platelet suspensions has been based on TEG and clinical findings of bleeding, such as oozing from the surgical area, in addition to standard coagulation variables. Also, if the TEG is normal, we routinely do not use FFP even though the PT is increased. In one of our earlier studies [4], which involved our first experience with 46 pediatric patients, the mean transfusion requirements were 75 and 37 ml/kg of whole blood and 51 and 34 ml/kg of FFP for LDLT and DDLT patients, respectively. However, the difference was not statistically significant for the groups in that study since only a small number of patients were included [4]. In our study, in which we observed a marked lowering trend in RBC volumes compared with those reported in the previous study, the mean RBC (28 vs. 20 ml/kg), crystalloid (90 vs. 69 ml/kg), and colloid (32 ml/kg vs. 22 ml/kg) requirements were significantly higher in the LDLT patients than in the DDLT patients, respectively. Pearson's correlation revealed that the factors determining the increased requirement for a blood transfusion in the LDLT patients were related to the initial hemoglobin and hematocrit levels (negative correlations), CTP score, and the duration of surgery while FFP consumption only correlated with duration of surgery. In the DDLT group, RBC consumption correlated with initial hemoglobin and hematocrit levels and the duration of surgery, while FFP consumption only correlated with MELD score, which includes PT. A primary diagnosis of biliary atresia in LDLT patients is also expected to be a contributing factor to a high risk of bleeding due to adhesions, as it was present in most of the patients who had had prior procedures, such as a Kasai operation [1]. In the entire population, underlying disease has no significant effect on blood consumption in terms of both RBC and FFP. RBC consumption was found to be higher for biliary atresia patients, but the difference was not significant. FFP consumption was not related to either biliary atresia or underlying diseases. Distinct from increased surgical experience, anesthetic management of coagulation disorders using TEG did contribute to decreased FFP use. Since the management of coagulation using TEG began after October 2004, FFP consumption significantly decreased after that time point; in contrast, RBC consumption in both groups was similar between these periods (pre- and post-October 2004).

The maintenance of hemodynamic stability is important for the anesthetic management of pediatric patients throughout the entire LT procedure [1]. Decreased intravascular volume, low systemic vascular resistance, ongoing fluid and blood losses, decreased venous return to the heart during clamping of the inferior caval vein during the anhepatic period, and the reperfusion syndrome all contribute to hemodynamic instability. The heart rate, MAP, and central venous pressure in specific time periods of both groups were managed similarly; however, MAP in LDLT patients remained lower than that in DDLT patients, probably due to a higher blood loss in small children in the LDLT group.

One of the most important issues during LT is to prevent hypothermia. Infants and children are more prone to hypothermia because of transfusions, loss of ascites and blood, and a cooled liver in their abdomen [1]. The maintenance of normothermia is critical for maintaining normal hemodynamic stability and a normal coagulation system. A hot-water blanket, warming infusion lines, and blowing devices were used to stabilize the temperature of the patients. Thus, no difference was determined in our study in both LT groups.

Tracheal extubation is a critical step following LT. The concept of 'fast-tracking', defined as immediate or very early postoperative tracheal extubation, had been used since the mid-1990s [18]. This approach has beneficial effects on splanchnic and liver blood flow and reduces the risk of ventilator-acquired pneumonia [19]. The number of patients reported to have been immediately extubated has markedly increased in recent years among adults. Mandell et al. [20] reported that 75.5% of the 147 adult patients in their study were successfully extubated after surgery in which fast-track anesthesia was used, and 56% of these were transferred directly to the ward. In another study, Findlay et al. [21] reported that ventilation times could be reduced by fast-track anesthesia. However, there have been only a limited studies on pediatric recipients documenting the feasibility of immediate extubation [5, 22]. In our previous study, we showed that immediate extubation in the operating room is a safe procedure for selected pediatric liver transplant recipients and was associated with a reduction in complications and reduced stay in the Intensive Care Unit [5]. Since 2001, immediate extubation of pediatric LT patients is carried out routinely in most of the patients at our center. Our decision of immediate extubation at the end of LT, distinct from laboratory variables, is based on clinical measures, such as an awake patient who obeys verbal comments, spontaneous motor activity and behavior in very young children, adequate control of airway reflexes and spontaneous ventilation, hemodynamic stability, normothermia, clinical findings indicating complete reversal of neuromuscular blockade, and adequate hemostasis [5]. Our results show a similar extubation rate between the LDLT and DDLT groups according to year. The number of immediately extubated patients has markedly increased in recent years and reached to 95.6% for all pediatric LT. The underlying disease and RBC consumption had no effect on the decision of immediate extubation. We believe that the increased frequency of early extubation over the duration of the study was related to better anesthetic management and drug selection as well as better surgical techniques that enabled extubation criteria to be met at the end of LT.

In conclusion, Our results show that LDLT is continuing to become an 'obligatory' option in Turkey among the young pediatric patient population and that is associated with longer operation times and higher RBC and fluid requirements than DDLT. As a marker of successful LT, higher extubation rates immediately after the operation is achievable for both groups.

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