Table 2. Postoperative Complications

Variables	PD (n = 70)	AD (n = 1,051)	P
PNF (%)	7.1	6.3	NS
HAT (%)	12.9	3.8	.0003
Portal vein thrombosis (%)	2.1	1.5	NS
Bile leak (%)	5.7	3.8	NS
Bile duct stricture (%)*	5.7	5.8	NS
Septicemia (%)	28.6	19.8	NS
Acute rejection (%)	42.9	50.1	NS
Posttransplantation ascites (%)	7.1	10.5	NS

Abbreviation: NS, not significant.
* Intrahepatic and extrahepatic stricture.

Table 3. Independent Predictors of Inferior 1-Year Graft Survival in Recipients of PD Livers

Variables	Graft Survival (%)	Coefficient	Relative Risk	P
PT (s)				
<16	80.5	1		
≥16	51.7	1.165	3.206	.0115
FK506 use				
Yes	86.2	1		
No	57.5	1.499	4.477	.0078

group were only 40% and 20% compared with 73.2% and 57.1% in patients with a DLW/ERLW of 0.4 or greater. Although there was no statistical significance, probably because of the small sample size, diminished graft survival in this group of patients should be noted. When divided at a cutoff value of 0.5 for DLW/ERLW, postoperative complications and patient and graft survival were similar between the groups, except for a greater incidence of bile leak in patients with a DLW/ERLW less than 0.5.

Regarding chronological changes in serum TBil, glutamic-oxaloacetic transaminase, and PT values early after LT, we found that serum bilirubin levels tended to be greater in the group with a DLW/ERLW less than 0.4 at all points, but this did not reach statistical significance. PT POD 2 was significantly greater in the group with a DLW/ERLW less than 0.4 compared with the group with a DLW/ERLW of 0.4 or greater ($P < .05$).

Although females accounted for 39.8% of AD recipients, 78.6% of PD recipients were female. Primary biliary cirrhosis (21.4%) was a relatively frequent indication in the PD group compared with AD group (10.4%).

Table 1 lists surgical data. Mean CIT was significantly longer in PD recipients ($P < .04$). A piggyback procedure was used in 51.4% of PD recipients in contrast to only 4.6% of AD recipients ($P < .0001$). Patients in the PD group were significantly more likely to require Roux-en-Y hepaticojejunostomy than patients in the AD group because of the size discrepancy between donor and recipient ducts (26.7% *v* 12.7%).

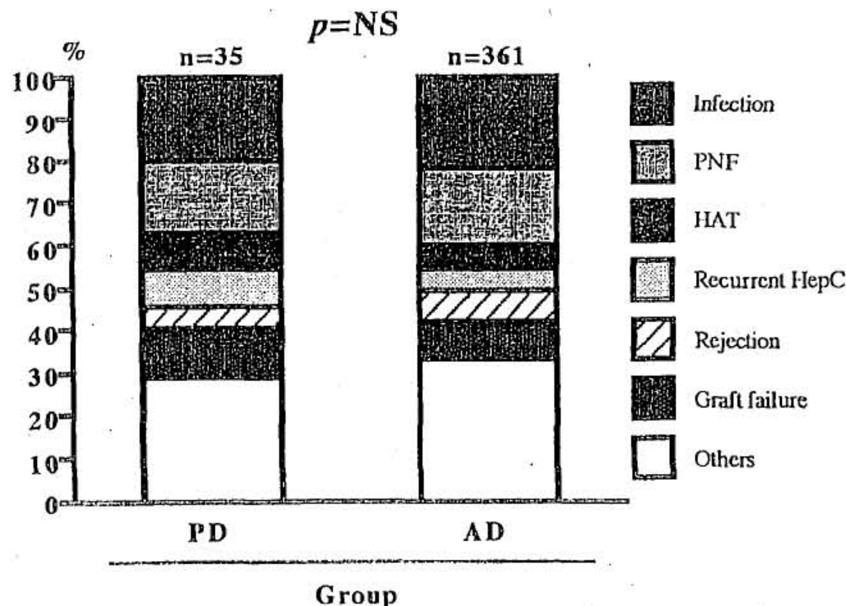

Figure 2. Comparison of causes of graft loss between the PD (n = 70) and AD groups (n = 1,051). (HepC, hepatitis C; NS, not significant.)

Table 4. Delayed Cholestasis After LT

Variables	TBil (mg/dL) POD 7 <5.0 (n = 41)	≥5.0 (n = 11)	P
Recipient age (yr)	51.1 ± 14.3	51.0 ± 14.5	NS
UNOS status (%)			NS
1	11.1	27.2	
2	36.1	18.2	
3	52.8	54.6	
Donor age (yr)	8.7 ± 2.1	9.7 ± 1.3	NS
DLW (kg)	855 ± 385	784 ± 147	NS
DLW/ERLW	0.63 ± 0.23	0.67 ± 0.49	NS
CIT (h)	10.5 ± 3.0	13.1 ± 4.3	.02
WIT (min)	45.5 ± 9.0	57.2 ± 13.0	.001
Intraoperative transfusions			
PRBCs (units)	10.9 ± 7.2	15.7 ± 14.9	NS
FFP (units)	17.9 ± 14.3	11.8 ± 8.7	NS
Patient/graft survival (%)			
1-yr	92.7*/80.5†	54.5*/36.4†	*†<.001
5-yr	80.5‡/65.9§	36.4‡/18.2§	‡§<.0001

NOTE. Values expressed as mean ± SD unless noted otherwise.
Abbreviations: PRBC, packed red blood cells; FFP, fresh frozen plasma; NS, not significant.
* 1-year patient survival.
† 1-year graft survival.
‡ 5-year patient survival.
§ 5-year graft survival.

Table 5. Preoperative Demographics and Postoperative Complications in the PD Group With Special Reference to DLW/ERLW at 2 Cutoff Points

Variables	DLW/ERLW <0.4 (n = 5)	≥0.4 (n = 56)	P	DLW/ERLW <0.5 (n = 21)	≥0.5 (n = 40)	P
Mean preoperative variables						
Recipient age (yr)	51.4	50.7	NS	51.5	50.4	NS
RBW (kg)	78.0	64.2	.04	69.0	63.4	NS
Donor age (yr)	8.6	8.7	NS	8.0	9.1	.06
Donor body weight (kg)	26.0	32.9	NS	26.6	35.2	.003
DLW (g)	555.6	883.2	.007	619.4	980.8	<.0001
DLW/ERLW	0.35	0.63	.001	0.42	0.71	NS
Postoperative complications						
PNF (%)	20.0	7.1	NS	5.8	10.0	NS
HAT (%)	40.0	10.7	.06	14.3	12.5	NS
Portal vein thrombosis (%)	0.0	3.6	NS	0.0	5.0	NS
Bile leak (%)	0.0	7.1	NS	19.0	0.0	.004
Septicemia (%)	60.0	25.0	NS	38.1	22.5	NS
Acute rejection (%)	40.0	44.6	NS	47.6	42.5	NS
Patient/graft survival (%)						
1-yr	80.0/40.0	85.7/73.2	NS	85.7/71.4	85.0/70.0	NS
5-yr	60.0/20.0	73.2/57.1	NS	66.7/52.4	75.0/55.0	NS

Abbreviation: NS, not significant.

Discussion

Currently, more than 14,000 patients are on the waiting list for liver transplants in the United States, with an expected supply of 4,500 donors per year.[7] The gap between the demand and supply of donor organs has been constantly increasing. As a result, centers have been expanding their donor acceptance criteria, including the use of small-for-size livers under certain conditions.

The use and allocation of pediatric livers in adult recipients is controversial. According to UNOS data,[7] approximately 20% of liver donors in the United States in 1997 were aged younger than 18 years, and 8.7% were aged younger than 10 years. Approximately 150 livers per year procured from PDs (defined as age < 13 years) were transplanted into adults (≥19 years; UNOS data request, 1999). According to Wight,[8] 28 pediatric livers were transplanted into adults in the United Kingdom in 1989, whereas 64 pediatric livers were transplanted into pediatric patients.

Because there was no UNOS policy for allocating PD livers to pediatric recipients during this study period, the use of pediatric livers in adult recipients was justified under certain urgent conditions. Recently, UNOS adopted a policy to allocate PD livers preferentially to pediatric recipients in the same region.

Our study showed that results with the use of pediatric livers in adults was similar to results with adult-to-adult combinations, although graft survival tended to be less in the former group. Of note, the incidence of HAT was significantly greater in the PD group compared with the AD group (12.9% *v* 3.8%). The incidence of HAT after primary LT varies from 1.6% to 8% in adults[9-13] and 5% to 38% in children.[14-16] Numerous factors have been implicated in HAT, including a prolonged CIT.[13,17-19] Not surprisingly, an increased incidence has been reported in pediatric recipients, in whom vessels are small.[14] It is also reported that size mismatching in vascular components could be problematic in LT using small-for-size grafts.[20] In our present study, CIT was longer in the PDs, and this may partly explain the high incidence of HAT. Furthermore, we believe the small size of the donor artery and inevitable size discrepancy between donor and recipient arteries might facilitate development of HAT. It is our policy to administer anticoagulation therapy with heparin to the recipient in this setting to prevent HAT.

Adam et al[21] reviewed their use of small donor livers in adult recipients and found that a very small graft size (<600 g), DRW ratio less than 0.5, and preservation time exceeding 12 hours were risk factors for complications. We did not confirm these findings in our patients (data not shown). Our multivariate analysis showed 2 independent risk factors for poor graft survival: preoperative PT greater than 16 seconds and no use of FK506 for primary immunosuppression. Patients with a preoperative PT less than 16 seconds who were administered FK506 had a 1-year graft survival rate of 94.1% (n = 17) versus a 37.5% (n = 16) 1-year graft survival rate in patients with a PT greater than 16 seconds preoperatively who were not administered FK506. The effect of a high preoperative PT on negative outcome can be explained by poor pre-LT patient condition and intraoperative blood loss (data not shown). These results suggest that restricting the use of small PD livers to relatively healthy adults may be the key to better graft and patient survivals. However, possibly because a cyclosporine-based immunosuppressive regimen was used earlier in our program, the improved graft survival in the FK506 era may reflect our learning curve related to increased surgical experience.

It is important to know the expected (or ideal) recipient liver weight before accepting a donor liver, especially when there is a size discrepancy between the donor and recipient. Urata et al[22] proposed a simple formula for predicting standard (or ideal) liver volume:

$$\text{Liver volume (milliliters)} = 706.2 \times \text{body surface area (square meters)} + 2.4$$

Since it was published in 1995, this formula has been widely used. However, we found that this formula tended to underestimate liver volume when we applied it to our donor population (data not shown). Heinemann et al[23] recently reported the same observation. The reason is not clear but is probably caused by the racial difference on which the formula was based. Thus, we adopted the formula developed at our institution:

$$\text{ERLW (grams)} = 6 \times \text{weight (lb)} + 4 \times \text{age (years)} + 350$$

Among 5 grafts with a DLW/ERLW less than 0.4, 1 graft (DLW/ERLW = 0.35) was lost to PNF, which was attributed to a small-for-size graft. The 2 smallest grafts (0.29 and 0.34) developed HAT on PODs 12 and 1. One graft (DLW/ERLW = 0.39) was lost to an unknown cause on POD 982. Thus, the 3 smallest of these 5 grafts were lost to causes attributable to the graft itself. Considering the high incidence of complications, including HAT (40%) and septicemia (60%), and the low graft survival, we currently believe we should not use grafts with a DLW/ERLW less than 0.4 in cadaveric LT.

In living related LT, small-for-size grafts are report-

edly associated with impaired graft function, indicated by prolonged hyperbilirubinemia, profuse ascites, and high PTs.[3] In our study, TBil levels in patients with a DLW/ERLW less than 0.4 tended to be greater, but the difference did not reach statistical significance. PT on POD 2 was significantly higher in patients with a DLW/ERLW less than 0.4. The incidence of post-LT ascites was similar between the PD and AD groups. In living related donor LTs, the development of increased ascites related to small-for-size livers may be caused by the large cut surface on the donor liver. This theory may explain why increased ascites was not seen in our transplant recipients, in whom the small-for-size livers were whole organs.

When we divided the PD liver recipients into 2 groups based on TBil level on POD 7, we found that graft volume (DLW/ERLW) was not associated with prolonged cholestasis (defined as TBil $\geq$ 5 mg/dL on POD 7). Conversely, grafts with long WITs and CITs developed cholestasis, suggesting that small-for-size livers were more vulnerable to ischemic insult. Furthermore, we found that graft and patient survival in patients who developed prolonged cholestasis were markedly inferior to those who did not.

In conclusion, the use of PD livers in adults was associated with a greater incidence of HAT, probably attributable to smaller donor vessel size and the inadequate capacity of the donor vessel for accommodating high arterial flow velocity in the recipient. Post-LT anticoagulation therapy is warranted when using PD livers in adults. The outcome of small-for-size grafts is more likely to be adversely affected by longer WITs and CITs. Grafts with a DLW/ERLW of 0.4 or greater (or $\geq$40% of ideal liver volume) can be used safely.

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