

M. Colledan
A. Segalin
M. Spada
A. Lucianetti
V. Corno
B. Gridelli

Liberal policy of split liver for pediatric liver transplantation. A single centre experience

M. Colledan (✉) · A. Segalin · M. Spada ·
A. Lucianetti · V. Corno · B. Gridelli
Liver Transplantation Unit,
Ospedali Riuniti, 1,
largo Barozzi, 20100 Bergamo, Italy
e-mail: mcolled@tin.it

Abstract We adopted a liberal policy of extensive use of split liver in a pediatric liver transplantation (LT) program. Over a 19-month period, we have performed 64 LT in 54 patients with pediatric indications. One patient received two liver grafts as a part of a liver-small bowel transplantation and was not considered. Of the 60 LT considered, performed in 53 patients, 34 were with split grafts. The 1-year actuarial survival for the patients transplanted with a split graft was 81 % and 89 %

when only elective cases were considered. The median time on the waiting list was 22 days with no mortality. The extensive use of split liver allowed transplantation in a large number of pediatric patients, with good results without the need for living donor liver transplantation. We envisage a trend towards systematic splitting of liver grafts.

Key words Split Liver · Liver transplantation · Pediatric · Organ sharing

Introduction

The split liver (SL) technique allows division of a cadaver liver into two parts that can be separately transplanted into two different recipients, most commonly a child receiving the left part and an adult receiving the right. Early experiences with this technique, in the 1980s, limited its use to extremely urgent cases, with discouraging results. In recent years, the technique has evolved and several centers involved in pediatric liver transplantation (LT) have reported excellent results using SL for elective cases [3–5]. However, restrictive selection criteria for the donor are often adopted, limiting the diffusion of SL.

We report our experience with a liberal policy of extensive use of SL in a pediatric LT program.

Materials and methods

We started our pediatric LT program in October 1997. From the beginning, we deliberated to adopt a liberal policy of SL, based on the hypothesis that any liver that could be transplanted as a

whole could also be safely split. The decision whether or not to split a graft was therefore based mainly on recipient's (R) rather than on donor's D criteria. The liver of every D that was assigned to our center was evaluated for transplantation when at least one ABO-compatible R with a D/R body weight ratio ≤ 12 was on our waiting list. Gross pathologic findings at the harvesting operation were the main criteria for organ refusal. Particular care was applied to the evaluation of D over 50 years of age, but age was not per se an exclusion criterion.

Every accepted graft was allocated to the most urgent ABO-compatible R on the waiting list. Length of waiting time was a further allocation criterion when more than one patient with the same urgency class existed. The liver was transplanted as a whole when the D/R body weight ratio was ≤ 2 and split when it was between 2 and 12, maintaining a graft/R weight ratio ≥ 0.8 .

Of the two grafts obtained from the split procedure, the left was transplanted at our institution, whereas the right was offered, as a rule, to another center, with the agreement of restitution of the split at the first opportunity. The allocation of the left grafts received from other centers according to this agreement was done with the same criteria described above. The splitting procedure was performed, whenever possible, in situ, as described by Rogiers [5], by a mixed surgical team composed of members of both the centers involved. It was, however, performed ex situ when required because of hemodynamic instability of the donor or for logistical reasons. During the last year, we have also employed an alternative in situ splitting technique (AST), that we have recently described [2].

Table 1 Indications for LT

Indication	Whole size	Reduced	Split
Elective			
Biliary atresia	14	2	23
Cryptogenic cirrhosis	1		
Crigler Najjar	1		
Budd Chiari	1		
Chronic rejection ^a	1		1
Byler		1	
Alagille S.		1	
Vascular malformation			1
Malignancy			3
Autoimmune hepatitis			1
Urgent primary			
Fulminant hepatitis			1
Cryptogenic cirrhosis			1
Urgent retransplantation			
Arterial thrombosis	2	1	2
Venous outflow thrombosis		1	1

^a First transplant performed at another institution

We used the left grafts thus obtained, substantially larger than those obtained with the standard technique, even for large R, with D/R body weight ratios between 1 and 2.

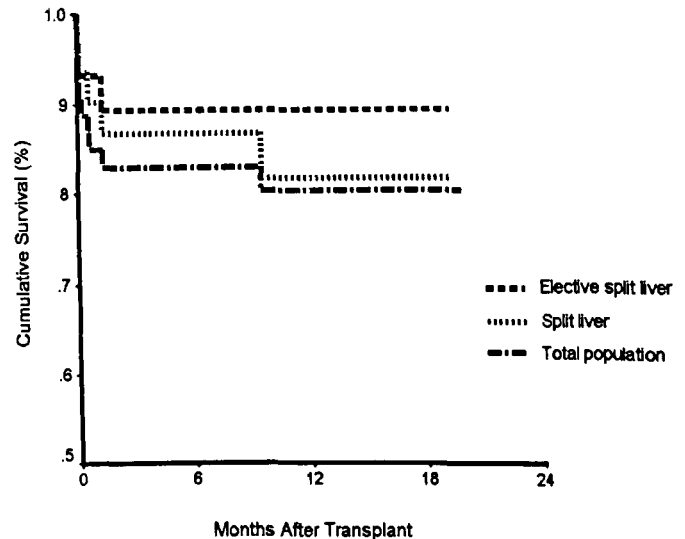
In all cases, an effort was made to limit the ischemia time as much as possible.

The LT in the recipients were performed with standard techniques.

The immunosuppressive treatment was based on a double-drug regimen with cyclosporin A and steroids, with progressive tapering of the steroid doses, to discontinuation over 3 months. Histologically proven acute rejection episodes were treated with steroid boluses and in cases of resistance, with conversion from cyclosporine to FK506. Actuarial survival was calculated by the Kaplan-Meier method.

Results

From October 1997 through May 1999 we have performed 62 LT in 54 patients. One patient, receiving two left grafts from split procedures, as a part of a liver-small bowel transplantation, was excluded from this analysis. Only 53 patients, receiving 60 LT, are therefore considered in this study. The series includes two patients of adult age, receiving three LT in total, who were transplanted for biliary atresia, which is typically a pediatric indication. Thirty-four (56.6%) transplants were performed with grafts obtained from split procedures, 20 (33.3%) with whole size grafts and six (10%) with reduced size grafts because it was logistically impossible to perform the splitting. The 34 split grafts were obtained from two ex-situ and 32 in-situ procedures; of these 30 were left lateral segments, three were left hemilivers obtained by AST and one was a right lobe. All the remaining right grafts were transplanted at other institutions. Table 1 reports the indication to transplantation

**Fig. 1**

for the three types of graft, stratified for elective, urgent primary LT and urgent retransplantation.

The age range of the donors for the split grafts was 2–60 years, with a mean \pm SD of 28 ± 17 years; their weight range was 14–85 kg, with a mean \pm SD of 66 ± 16 kg. The age range of the recipients of the split grafts was 2–21 years, with a mean \pm SD of 3 ± 4.5 years and their weight range was 3.4–55 kg, with a mean \pm SD of 14 ± 12 kg. The mean \pm SD donor to recipient weight ratio was 7 ± 3.2 .

The mean \pm SD ischemia time for the split grafts was 340 ± 122 .

A split graft was the first graft received at our center by 31 patients; five of them died while 26 (83.8%) are alive 1–18 months after the LT (median 10 months) and two of them were retransplanted. The 26 survivors were all in the group of 29 patients transplanted electively, thus representing 89.6% of them. The three recipients of the left grafts obtained with the AST, respectively, weighing 38, 48 and 55 kg, are all alive.

Figure 1 shows the actuarial survival curve after LT of all the pediatric patients, of those who received a split graft and of those who electively received a split graft.

The median time on the waiting list for LT for all our elective patients was 22 days and showed a progressive decrease to 7 days for the ten patients enlisted during the last 6 months. No patient on our waiting list for elective LT died while waiting for an organ.

Discussion

Our result show that a liberal policy of extensive use of the split liver technique, allows the performance of a

great number of pediatric liver transplantations after a very limited waiting time, possibly meeting all the demand, with excellent results, without the need for living donor transplantation [1] and without interfering with the adult waiting list.

A further step can be the extension of splitting to increase the number of adult LT. The AST that we have previously described proved effective in obtaining a left graft suitable successful for transplantation in patients of adult size. We believe that a trend towards sys-

tematic splitting of cadaveric livers should be one of the measures to face the progressively increasing liver graft shortage.

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References

1. Broelsch CE, Burdelsky M, Rogiers X, Gundlach M, Knoefel WT et al. (1994) Living donor for liver transplantation. *Hepatology* 20: 49S-55S
2. Colledan M, Andorno E, Valente U, Gridelli B (1999) A new splitting technique for liver grafts. *Lancet* 353: 1763
3. Goss JA, Yersiz H, Shackleton CR, Seu P, Smith CV, Markowitz JS, Farmer DG, Ghobrial RM, Markmann JF, Arnaout WS, Imagawa DK, Colquhoun SD, Fraiman MH, Mc Diarmid SV, Busuttil RW (1997) In situ splitting of the cadaveric liver for transplantation. *Transplant* 64: 871-877
4. Mirza DF, Achilleos O, Pirenne J, Buckels JAC, Mc Master P, Mayer AD (1998) Encouraging results of split liver transplantation. *Br J Surg* 85: 494-497
5. Rogiers X, Malagò M, Gawad K, Jauch KW, Olausson M, Knoefel WT, Gundlach M, Bassas A, Fischer L, Sternbeck M, Burdelski M, Broelsch CE (1996) In situ splitting of cadaveric livers, The ultimate expansion of a limited donor pool. *Ann Surg* 224: 331-341