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Split-Liver Transplantation

The Paul Brousse Policy

Daniel Azoulay, M.D., Ibrahim Astarcioglu, M.D., Henri Bismuth, M.D., F.A.C.S. (Hon), Denis Castaing, M.D., Pietro Majno, M.D., F.R.C.S., Rene Adam, M.D., and Marc Johann, M.D.

From the Hepatobiliary Surgery and Liver Transplant Center, Hôpital Paul Brousse, Université Paris Sud, Villejuif, France

Objective
The authors objective is to report their recent experience with split-liver transplantation, focusing on the results and the impact on organ shortage.

Summary Background Data
There is an insufficient number of organs for liver transplantation. Split-liver transplantation is a method to increase the number of grafts, but the procedure is slow to gain wide acceptance because of its complexity and the poor results reported in previous series.

Methods
During the year 1995, the authors split 20 of 83 transplantable livers allocated to the authors' center, generating 40 grafts: 23 were transplanted locally and 17 were given to partner centers. During the same period, the authors accepted four split-liver grafts proposed to them by other centers. Overall, 27 split-liver transplantations were done in the authors' unit, accounting for 30% of the 90 transplants performed in 1995.

Results
One-year patient and graft survival rates for split-liver transplantation were 79.4% and 78.5%, respectively. Arterial and biliary complications rates were 15% and 22%, respectively, with none leading to graft loss. Primary nonfunction occurred in one case (4%). By splitting 24 of 87 transplantable livers (4 of which were in partner units), a total of 111 transplantations were performed, increasing graft availability by 28%.

Conclusions
Split-liver transplantation is achieving graft and patient survival rates similar to that of whole liver transplantation despite a higher incidence of complications, which could become less frequent as experience is gained with this procedure. A wider acceptance of split-liver transplantation could markedly increase the supply of liver grafts.

The good results obtained by liver transplantation (LT) have led to a more general application of this procedure and extended the list of its indications. The consequence is an increasing discrepancy between the number of potential recipients and the number of available grafts. One of the possible approaches to augment the number of livers for transplantation is the division of the donor organ into two grafts (split-liver transplantation [SLT]). This procedure, more complex than whole LT, was associated at first with high morbidity, graft loss, and mortality. As experience is gained, better results are reported and SLT is obtaining wider acceptance; it is, however, still performed sporadically or reserved for emergencies, an attitude that is bound to give worse results and, as a consequence, to decrease the diffusion of this technique and its potential impact on organ supply.

The aim of this article is to report our recent experience with SLT and to evaluate the impact on organ shortage of a policy of systematically splitting all liver grafts that were considered suitable for this procedure.

PATIENTS AND METHODS

Between January 1, 1995, and December 31, 1995, 90 LTs were performed at the Centre Hépatobiliaire, Hôpital Paul Brousse, Villejuif, France. Sixty-two livers were transplanted as whole organs, 1 was a reduced-size liver graft for auxiliary LT in a case of fulminant hepatitis, and 27 were SLTs. The organs for the SLT procedures originated from 20 livers split at our center, generating 40 grafts, of which 23 transplanted in our unit (17 grafts given to other centers) and from livers split in other units in 4 cases. We report here the results of the 27 split-liver graft (SLG) transplantations (21 right and 6 left SLG) performed in our unit.

Patients

There were 15 male and 12 female recipients. There were 26 adults and 1 child (range, 2–65 years). The mean age in adults was 43.2 ± 12.8 years. Patient's indication for transplantation, clinical condition, and the main features of the grafts are summarized in Table 1. We had decided to exclude from the SLT program patients undergoing retransplantations and patients transplanted for fulminant hepatic failure. We over-ruled the decision, however, in two instances in which two patients with fulminant hepatitis presented simultaneously, one in our unit and the other in a nearby center, each time with only one graft available in the country.

Donors

There were 18 male and 2 female donors with a mean age of 39.5 ± 10.3 years (range, 16–61 years). Only the best grafts were considered for a split: donors younger than 60 years of age, with a body weight above 60 kg, in stable hemodynamic conditions, and with normal liver function tests. The main aspects of donor-to-recipient match are summarized on Table 2. Only one liver from a donor aged older than 55 years was split (for two recipients with fulminant hepatitis).

Graft Procurement and Preparation

Livers were procured according to the standard technique of multiple organ harvesting. All were perfused through the aorta with Collins' preservation solution and through the portal vein with University of Wisconsin (UW) solution. The bile duct was flushed with UW solution.

The grafts were prepared at our center in the operating room. The liver was submerged in cold UW solution during the preparation and the *ex situ* bipartition of the graft. Segmental anatomy is described according to the classification of Couinaud,[1] and the liver splitting was performed according to the following steps.

1. The organ was prepared as for a whole LT and weighted. The graft arteries were identified by inspection and the portal vein dissected to the bifurcation. The hepatic veins were explored from inside the lumen with a metal probe.
2. A cholangiogram and an arteriogram were performed through the common bile duct and the hepatic artery with contrast medium (amidotrizoate sodium, Radioselectan, Schering, Lys-Les-Lannoy, France) at 4 C. Immediately after the procedure, the bile duct and the artery were flushed with UW solution. The type of splitting then was decided according to liver anatomy.
3. The elements of the portal triad were separated in the following order: the branches of the portal vein first, the arteries next, the bile ducts last. The left hepatic duct was cut at the level of the biliary confluence together with the hilar plate to preserve the small arteries running into it and feeding the walls of the bile ducts. The main bile duct was retained in all cases with the right graft and shortened to an appropriate length.

Address reprint requests to Daniel M. Azoulay, M.D., Centre Hépato-Biliaire, Hôpital Paul Brousse, 94804, Villejuif, France.
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Table 1. DATA SUMMARY OF 27 RECIPIENTS OF A SPLIT-LIVER GRAFT

N	Age (yr)	UNOS*	Liver Disease	Graft R/L	Biliary Reconstruction	Artery Order	Technical Complication	Outcome	Status at Follow-up†
1	39	4	Amyloid	L	CJ	2	—	A 12 mo	1
2	42	4	PBC	L	CC	1	PNF	A 12 mo	1
3	59	4	Crypto	R	CC	2	—	A 12 mo	1
4	45	4	Amyloid	L	CJ	1	—	A 12 mo	1
5	32	3	SBC	L	CJ	1	Biliary leak	A 11 mo	1
6	45	4	HCV	R	CJ	2	—	A 11 mo	1
7	42	4	Amyloid	L	CJ	1	Biliary stenosis	A 11 mo	1
8	65	1	Alcohol	R	CC	2	—	D4 mo MOF	—
9	32	4	Amyloid	R‡	CC	2	—	A 11 mo	1
10	45	4	Alcohol	R	CC	1	HAT/biliary leak	A 11 mo	2§
11	57	4	Alc + HCV	R	CC	2	Biliary leak	A 11 mo	1
12	61	4	PBC	R	CC	1	Biliary leak	A 10 mo	1
13	47	4	Alcohol	R	CC	1	—	A 10 mo	1
14	57	4	Alcohol	R	CC	1	—	A 10 mo	1
15	43	3	Alcohol	R	CC	2	HA dissection	A 9 mo	1
16	45	4	Alcohol	R	CC	2	—	A 8 mo	1
17	1.5	2	BA	L	CJ	1	—	A 8 mo	1
18	45	4	PSC	R	CJ	2	Segment 4 necrosis	D 8 mo Sepsis	—
19	38	3	Alcohol	R	CC	2	Biliary stenosis	A 8 mo	1
20	39	—	FHF	R‡	CC	2	HAT	D 1 mo MOF	—
21	43	4	Alcohol	R	CC	1	—	D 13 mo CMV	—
22	33	4	Amyloid	R	CC	2	—	A 7 mo	1
23	23	—	FHF	R	CJ	2	—	A 4 mo	3
24	38	4	Amyloid	R	CC	1	—	A 3 mo	1
25	56	2	Alcohol	R	CC	2	—	A 3 mo	1
26	40	1	AI	R‡	CC	2	Hemoperitoneum	D 1 mo MOF	—
27	52	3	HBV	R‡	CC	1	HA stenosis	A 1 mo	1

UNOS = Unit Network for Organ Sharing; L/R = left/right split liver graft; Amyloid = amyloid neuropathy; SBC = secondary biliary cirrhosis; HCV = hepatitis C virus; Crypto = cryptogenic cirrhosis; PBC = primary biliary cirrhosis; BA = biliary atresia; PSC = primary sclerosing cholangitis; FHF = fulminant hepatic failure; AI = autoimmune hepatitis; HBV = hepatitis B virus; CJ = choledocojejunostomy; CC = choledococholedocostomy; PNF = primary nonfunction; HAT = hepatic artery thrombosis; HA = hepatic artery; A = alive; D = deceased; MOF = multiple organ failure; CMV = cytomegalovirus.

* UNOS classification: 4 = at home; 3 = frequent hospital visits; 2 = hospitalized; 1 = in intensive care.

† Patient's status at follow-up; 1 = at home; 2 = frequent hospital visits; 3 = hospitalized; 4 = in intensive care.

‡ Graft received.

§ Awaiting retransplantation.

4. The hepatic veins were separated, the left hepatic vein remaining with the left graft, whereas the right and the middle hepatic veins remaining in all cases with the right graft in continuity with the inferior vena cava. This was performed after resection of the caudate lobe, allowing easier division of the left hepatic vein.
5. The liver was divided through the middle of segment 4. This was done with a simple scalpel blade to obtain a flat raw surface. Sutures were applied to all visible vessels. Figure 1 is a schematic representation of the basic steps of the splitting procedure.
6. Five milliliters of fibrin glue (Tissucol, Immunofrance, Orly, France) was applied on the raw surfaces. This was reinforced by a collagen mesh (Hemostagene, Sarback-LTM, Suresnes, France) and by a polyglactin 910 mesh (Vicryl, Ethicon, Neully sur Seine, France) sutured to the liver capsule. When necessary, arterial and venous grafts from the donor were used to increase the length of the vessels for anastomosis.

At the end of the procedure, the two grafts obtained were weighted. The whole procedure of graft preparation required 2 to 3 hours. The graft to be sent to an outside center was always prepared first to reduce cold ischemia time.

Management of Vascular Variations

Anatomic variations of donor hepatic arteries encountered and the methods of arterial division in each case are summarized in Figure 2.

Table 2. MORPHOLOGICAL, OPERATIVE DATA, AND RESULTS OF SPLIT-LIVER TRANSPLANTATION

	All Recipients (n = 27)	Recipients of Right Grafts (n = 21)	Recipients of Left Grafts (n = 6)	p
Body weight (kg)	61.3 ± 19.3	67.7 ± 15.2	39 ± 15.8	S
Whole liver weight (g)	1781 ± 228	—	—	—
Graft weight (g)	—	1145 ± 187	482 ± 145	S
Donor/recipient weight ratio	—	1.8 ± 0.38	2.71 ± 2.23	S
Graft/recipient weight ratio (%)	—	1.69 ± 0.42	1.47 ± 0.68	NS
Ideal liver weight* (g)	1169 ± 229	1247 ± 133	895 ± 294	S
Graft/ideal liver weight ratio (%)	—	93.4 ± 21.4	58.6 ± 15.1	S
Cold ischemia time (min)	634 ± 125	645 ± 27	593 ± 48.5	NS
Intraoperative blood transfusion†	10.5 ± 7.4	11.7 ± 1.6	6.3 ± 2.5	NS
Transfusion after unclamping†	4 ± 3.4	4.8 ± 3.4	1.0 ± 0.8	S
Patient survival 1 yr‡ (%)	79.4 ± 8.3	72.4 ± 10.7	100	NS
Graft survival 1 yr‡ (%)	78.5 ± 8.6	76 ± 10.6	83.3 ± 15.2	NS

p = p value (recipients of right *vs.* left grafts. S = significant ($p < 0.05$); NS = not significant.
* Ideal liver weight (g) = 706.2 × body surface area (m^2) + 2.4.[41]
† Units of packed blood cells.
‡ Actuarial Kaplan–Meier.

For the seventeen grafts (14 left and 3 right grafts) sent to other units, the celiac axis and the portal trunk were left with the graft in 14 (82%) and 12 cases (71%), respectively. All four grafts we received (marked with an asterisk on Table 1) were right SLG, of which three were with the right branch of the hepatic artery and one was with the right hepatic artery on a patch of superior mesenteric artery. All four were with the right branch of the portal vein.

Recipient Operation and Postoperative Care

The operation on the first recipient, usually the one receiving the right graft, was started as soon as the harvesting surgeon had assessed the quality of the liver in the donor and found it suitable for transplantation. The operation on the second recipient, when performed at our

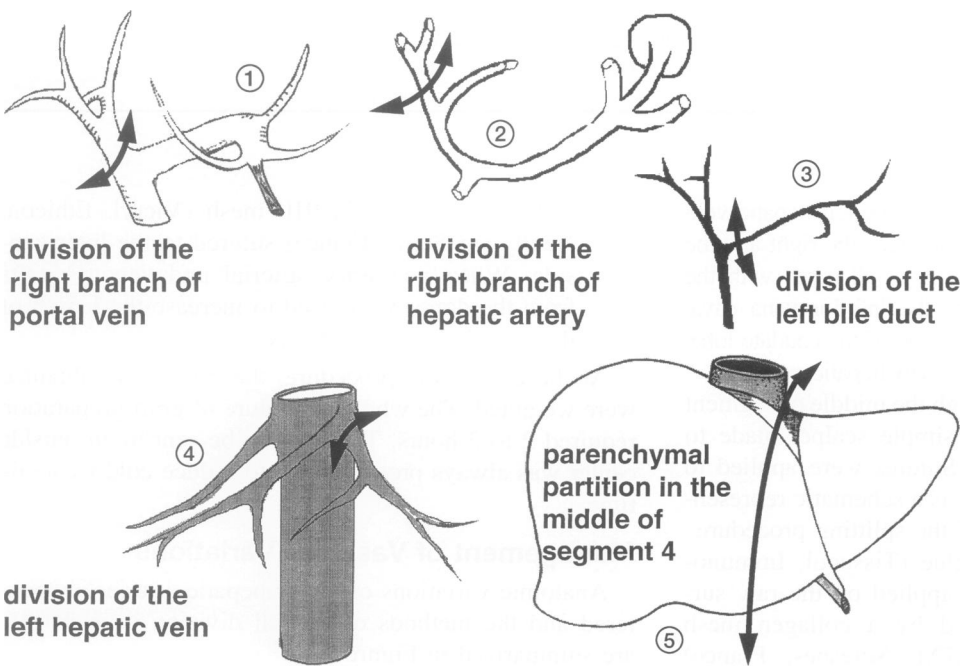

Figure 1. Schematic representation of the basic steps of the splitting procedure.

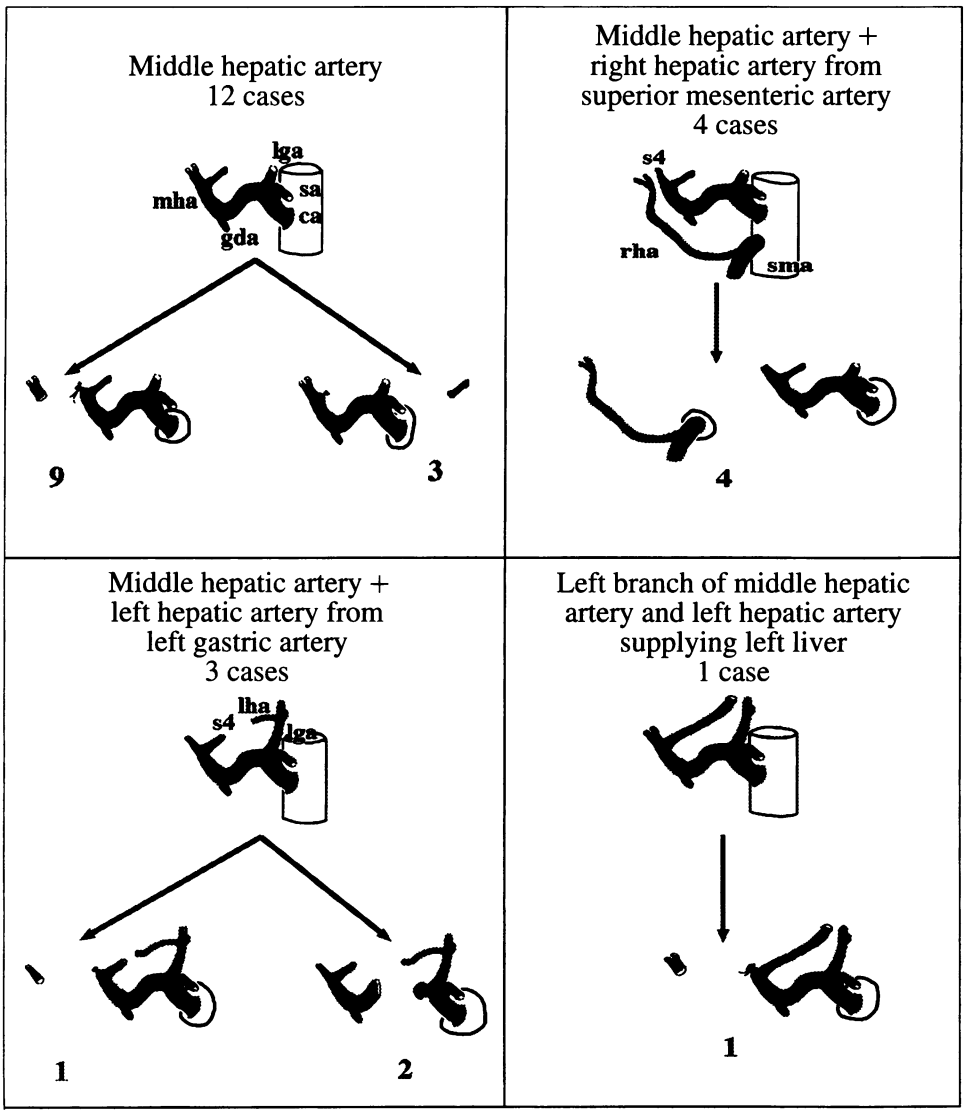

Figure 2. Schematic representation of the variations of the arterial supply of donor livers and of the type of arterial division in each case (20 splits performed in our center).

Abbreviations: ca: celiac axis; lga: left gastric artery; sa: splenic artery; gda: gastroduodenal artery; mha: middle hepatic artery; sma: superior mesenteric artery; rha: right hepatic artery; lha: left hepatic artery, s: segment.

center, was started as soon as arteriography and cholangiography had confirmed the anatomic feasibility of the splitting procedure.

The technique of LT with a split graft has been described previously.[2-5] In recipients of a right graft, the inferior vena cava was preserved in all cases, as this lessens graft manipulation and shortens the time of organ rewarming before declamping the portal vein.[6] For left grafts, implantation of the left hepatic vein on the native inferior vena cava was performed using various venoplasty techniques as described by Emond et al.[7] To prevent venous kinking, attention was paid to leaving the left hepatic vein short and to securing the position of the graft by suturing the falciform ligament to the diaphragm.

Postoperative care included a daily Doppler ultrasound examination while the patient was in the intensive care unit, then weekly until discharge from hospital. Anticoagulation with heparin, aiming at a partial thromboplastin time of 1.5 to 2.0 times controls, was started unless spontaneous partial thromboplastin time was more than 35 seconds or platelets were lower than 30.000/mL. Heparin anticoagulation was maintained until hospital discharge, and aspirin 250 mg/day was given thereafter.

Organization of the Splitting Procedure

From January 1, 1995, we decided to consider for splitting all organs from suitable donors that were allocated to our unit by the French Organ Sharing Organization and of proposing one of the split grafts back to the Organization for finding an appropriate recipient.

Data Analysis

Results are given as mean plus or minus standard deviation. Comparison of continuous variables between right and left SLG was done with Student's t test (unpaired). The p values < 0.05 were considered statistically significant. Patient and graft survival rates were calculated using the Kaplan–Meier method.

RESULTS

Mortality and Early Graft Failure

Regarding operative mortality, two patients (8%) died in the 2 months after transplantation. The first patient (patient 20) was transplanted for fulminant hepatitis of unknown cause. After the operation, an acute necrotizing pancreatitis, a thrombosis of the hepatic artery that was desobstructed successfully, and multiple organ failure with diffuse sepsis developed in the patient, eventually leading to her death on day 33. Postmortem examination results showed multiple peripancreatic abscesses. The second patient (patient 26) was a 35-kg woman with terminal autoimmune cirrhosis in the United Network for Organ Sharing (UNOS) 1 category. Generalized sepsis developed in the patient, who died of multiple organ failure 1 month after transplantation.

Late mortality occurred in three patients (11%). One patient (patient 8) had terminal alcoholic cirrhosis and severe malnutrition and was in the UNOS 1 category (intensive care bound) because of renal failure. This patient died of sepsis and multiple organ failure 4 months after transplantation. Autopsy results showed patent biliary and vascular anastomoses. The other two patients died after hospital discharge: severe sepsis developed in one patient (patient 18) at 8 months while awaiting retransplantation for chronic rejection, and the other patient (patient 21) died of severe systemic cytomegalovirus disease 12 months after transplantation.

Early graft failure occurred in one patient (4%) (patient 2), who was transplanted for primary biliary cirrhosis with a left graft. This was the patient with the lowest ratio of graft-to-body weight in the series (0.87%). Liver failure developed in this patient immediately after surgery and the patient was retransplanted as an emergency on day 6 with a whole liver. The patient currently is alive with normal liver function 1 year after retransplantation.

Morbidity and Technical Complications

Thirteen technical complications occurred in 12 patients (48%). The main complications were arterial (four patients, 15%) and biliary (six patients, 22%). No complication concerning the portal vein or the caval drainage occurred in this series.

Arterial Complications Case Reports

Case 1 (Patient 10)

In this instance, the common hepatic artery of the graft was anastomosed to the left branch of the native proper hepatic artery. A choledococholedocostomy was performed on a T tube. A biliary leak developed from the raw surface of the graft and was drained percutaneously on day 49. Arterial thrombosis was diagnosed on day 63. Five months after LT, surgery was performed to optimize the drainage of the biliary fistula. At present, the patient is awaiting retransplantation for recurrent episodes of intrahepatic cholangitis and a biliary fistula 11 months after transplantation.

Case 2 (Patient 20)

This patient is already mentioned in the paragraph on mortality. The arterial anastomosis was done with an interposed arterial conduit between the right branch of the proper hepatic artery of the graft and the native supra celiac aorta. During surgery for acute necrotizing pancreatitis on day 15, partial thrombosis was discovered. The anastomosis was refashioned and remained patent until the death of the patient 33 days after transplantation.

Case 3 (Patient 15)

This patient was transplanted with a right graft. The arterial anastomosis was performed between the right branch of the proper hepatic artery of the graft and the native proper hepatic artery. Suspicion of partial thrombosis on Doppler ultrasound on day 14 was confirmed by arteriography the same day. Emergency reoperation disclosed a dissection of the recipient hepatic artery. Arterial reconstruction was performed using an arterial graft between the graft and the inframesenteric aorta. At present, the patient is alive with a patent artery on Doppler ultrasound and normal liver function test results 9 months after transplantation.

Case 4 (Patient 27)

This patient received a right SLG vascularized by a right hepatic artery on a patch of superior mesenteric artery anastomosed to the common hepatic artery of the recipient. A long postanastomotic stenosis was suspected on Doppler ultrasound and confirmed at arteriography. Urgent repair was carried out with resection of the stenosis and interposition of an autologous saphenous vein graft. Doppler ultrasound examination is normal 2 months after the repair.

Biliary Complications Case Reports

Case 1 (Patient 5)

This patient received a left graft for secondary biliary cirrhosis. Biliary reconstruction was done with a choledocojejunostomy on a Roux-en-Y loop. A biliary leak developed in the patient from the raw surface, which was drained percutaneously on day 23 and stopped spontaneously, allowing removal of the drain on day 41. At present, the patient has normal liver function and Doppler ultrasound examination 11 months after transplantation.

Case 2 (Patient 10)

This patient received a right graft with a choledococholedocostomy. A biliary fistula from the graft raw surface was drained percutaneously on day 18, and the patient was operated on on day 24 to optimize the drainage. The drain was removed 4 months after transplantation. At present, the patient is alive with normal Doppler ultrasound examination and bilirubin levels as well as elevated transaminase and γ-glutamyltransferase due to nonspecific hepatitis 10 months after transplantation.

Case 3 (Patient 11)

This patient received a right graft and a kidney. The biliary anastomosis was a choledococholedocostomy on a T tube. A radiologic leak from the anastomosis was diagnosed at routine cholangiography on the postoperative day 26. Arteriography findings were normal. The fistula healed spontaneously, and the patient has normal liver function test and Doppler ultrasound 11 months after transplantation.

Case 4 (Patient 10)

This is the patient with intrahepatic cholangitis already discussed in the paragraph on arterial complications.

Case 5 (Patient 7)

This patient received a left graft for amyloid polyneuropathy with a choledocojejunostomy on a Roux-en-Y loop. Stenosis of the biliary anastomosis was suspected on ultrasound examination and confirmed by percutaneous cholangiography 4 months after transplantation. Percutaneous dilatation and stenting of the stenosis with a plastic tube was performed successfully. The drain was removed 2 months later, and the patient has normal liver function test and Doppler ultrasound 11 months after transplantation.

Case 6 (Patient 19)

This patient received a right SLG with a choledococholedocostomy. Stenosis of the anastomosis was diagnosed at routine ultrasound 2 months after transplantation. Percutaneous dilatation and stenting were performed. The stent was removed after 2 months, and the patient has normal ultrasound and liver function tests 8 months after transplantation.

Other Complications

Bleeding occurred in one patient (4%) (patient 26). Reoperation on day 5 showed the origin of the bleeding from a diaphragmatic artery. Segment 4 necrosis occurred in 1 patient (4%) needing necrosectomy (patient 18). Histologically proven acute rejection occurred in 37% of patients. Chronic rejection occurred in one patient (patient 18), who died awaiting retransplantation.

Survival

Patient survival (Kaplan–Meier) for the entire series at 1 year is 79.4 $\pm$ 5.8%, and graft survival is 78.5 $\pm$ 8.6%. Patient and graft survival rates were comparable for right and left SLTs.

Outcome of the Splitting Policy

Of the 91 livers allocated to our unit, 8 were discarded because of massive steatosis, leaving 83 transplantable organs. Donor and recipient conditions were judged favorable for liver splitting in 41 instances (49%), generating the offer of an SLG. The offer was not taken up in 16 patients (38%) because no partner center could be found and the double transplantation could not be carried out in our unit (no suitable second recipient or staff shortage). After initial acceptance of the split on 25 patients, the offer was withdrawn by us for 5 patients (20%): during retrieval because the left lobe was too small (2 patients), or moderate steatosis (1 patient), and after retrieval in 2 patients because no agreement could be found with the partner team on the vascular division. All livers withdrawn from splitting were transplanted as whole organs. Overall, 111 transplantation procedures were done with 87 livers in our and in partner units, representing an increase in the amount of available organs of 28% (24/87).

DISCUSSION

Our series shows that, despite its complexity, SLTs can offer patient and graft survival rates comparable to that of transplantation with a whole organ.[8] This confirms the most recent experience of SLT in other centers, which is undoubtedly more favorable than the earlier results, including our own, with this procedure (Table 3).[5,9–13]

These results have been obtained by the rule of not cumulating the risks in three main areas, namely: 1) the

Table 3. RESULTS OF SPLIT-LIVER TRANSPLANTATION IN LARGE REPORTED SERIES

Series (reference)	No. of Patients	No. of Grafts	Patient Survival (%)†	Graft Survival (%)†
Emond et al.[5]	18	18	60	52
Shaw et al.[9]	10	10	50	50
DeVille de Goyet et al.[10]	23	25	78	68
Houssin et al.[12]	16	16	75	69
Sloof et al.[11]	15	15	73	67
European Split Liver Registry*[13]	95	98	Elective, 85 Urgent, 63	Elective, 76 Urgent, 57
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1987–1994 (unpublished)	18	18	Elective, 63 Urgent, 14	Elective, 54 Urgent, 0
1995 (present series)	27	27	79.4	78.5

* Split-liver transplantations performed in nine European centers from 1988 to 1993 (including the series published by Houssin, De Ville De Goyet, and Sloof).
† Patient and graft survival are at 1 year for all series and at 6 months for the European Split Liver Registry.

quality of the donor and of the organ, 2) the anatomic suitability of the graft, and 3) the choice of the recipient.

Only good quality organs were used, excluding from splitting any marginal donor. Selection was done on the basis of donor age, hemodynamic conditions, and liver function tests. We had planned to resort liberally to frozen section examination, but this was necessary only in one instance, showing moderate steatosis and making us abandon the splitting procedure in favor of whole organ LT.

The anatomic background for SLG has been studied extensively.[14–18] In practice, anatomic limitations are rare and will be encountered mainly concerning the size of the left lobe (segments 2 and 3) and the arterial configuration of the graft. In our experience (and in a preliminary anatomic study of 32 cases), the "nonsplittable" liver will occur even less often than the "ideally splittable" liver with a separate hepatic artery for each graft. Some anatomic variants, however, such as a separate artery for segment 4, technically are more demanding and may represent an additional risk not worth taking when the transplantation procedure or the postoperative course is anticipated to be difficult. We did not meet any biliary or venous abnormalities formally contraindicating splitting in our series.

Concerning the selection of recipients, the SLT technique is probably best reserved for elective procedures in patients in stable clinical conditions (UNOS classes 2–4). This lesson has been learned from the poor results of our previous experience in SLT for emergency transplantations or retransplantations (Table 3). The rule of choosing good recipients can be bent, because of pressing clinical reasons, and indeed it was for some of our patients, but a higher risk must be accepted. In our series, the three deaths before discharge occurred in two patients UNOS class 1 and in a patient with fulminant hepatitis. The reasons underlying this fact are not yet clear. It is our impression, however, that recovery of normal hepatic function is slower with SLG and could involve a period of regeneration of liver tissue in the graft that patients with diminished reserve may not afford.

The respect of a minimal graft to patient weight ratio also is part of the selection of recipients[19]: the only case of early graft failure, leading to retransplantation, occurred in the patient with the lowest graft-to-patient-weight ratio (0.87%). After this case, we have respected the cutoff level of 1%, which has, however, allowed us to transplant successfully a left graft into adults of small body build in four instances.

If the respect of these simple rules has allowed results comparable to whole LT in terms of patient and graft survival, the complications of SLT are still too frequent. They are, however, probably related to technical factors and should be correctable as experience is gained with the procedure.

Complications

Vascular Complications

The rates of arterial occlusion in the literature range from 0% to 6% in adults[20–23] and from 3.2% to 16.7% in children (2.8%–11.4% for reduced-size liver grafts).[20–22, 24–28] Arterial complications in our patients (15%) were thus in the upper range of what is currently accepted. The application of microsurgical techniques to the SLT procedure should optimize the results as reported for living-related LT.[29] We advise anticoagulation and active monitoring of arterial patency by repeated Doppler ultrasound with arterial salvage if required, as this was successful in all three cases where it was attempted. Portal

vein complications were not a problem in our experience, despite the fact that the portal trunk was not available in the majority of cases. Venous outflow obstruction for left SLG did not occur using the venoplasty techniques.[7]

Biliary Complications

Biliary complications occurred in 22% of our patients. In published series, they range from 12.5% to 19.5% in adults[20,30,31] and from 5% to 22% in children (5%–13% in reduced-size liver grafts).[21,24,26,28,31] From our experience, biliary complications can be of two types. The most benign are leaks from the raw surface. They occurred in three cases, resolved with percutaneous drainage and since we have used the technique of injecting UW solution into the bile ducts to look for small trickles, this complication has disappeared. Potentially more troublesome are the problems concerning the biliary anastomosis. Leaks at this level will heal spontaneously in the absence of ischemia or distal obstruction. Stenosis may be a more difficult problem to solve. It occurred in two cases in our series, one on a choledocojejunostomy and one on a choledococholedocostomy. Both were treated successfully by percutaneous balloon dilatation and temporary stenting. It is possible that the application of microsurgical techniques to the biliary reconstruction will lessen the incidence of this complication. Other points that may be relevant to its prevention are as follows: 1) to limit the dissection of the left hepatic duct and of the hilar plate to a minimum, 2) to stent the anastomosis as reported in living-related LT,[32] 3) to construct the anastomosis on a Roux-en-Y loop on the right side too, to benefit from the healthier vascular supply of the intrahepatic right duct, and 4) to further reduce the cold ischemia time by the technique of *in situ* splitting in the cadaveric donor.[33] Preliminary results with this procedure have indeed shown a very low incidence of biliary problems (Broelsch, personal communication, 1996).

Bleeding

Once a feared complication of the SLG procedure, it has been nearly abolished by better management of the raw surface and by consistently keeping the middle hepatic vein with the right graft not to obstruct venous outflow from segments 5 and 8. Bleeding from the raw surface was expectably more important from the right, given its larger area, but blood loss was in fact not higher than in patients receiving a whole liver during the same year.

Impact of the Policy of Intention to Split

In the period under study, the number of transplantable grafts was increased by 28% if we include the transplantations performed in partner centers. Pediatric LT represents 10% to 15% of all cases of LT in most countries, and if it is confirmed that splitting can be safely applied to at least 20% of transplantation procedures, this technique could virtually abolish graft shortage and waiting list mortality in children. Given the improving results of SLT, we believe that, whenever possible, this technique should be offered before living-related LT for elective procedures and in countries where cadaveric donors are available. Also, because of the problem of organ shortage in the adult population, reduced-size LT[24,28,34–40] should be considered only when SLT cannot be done. The logistic effort involved in performing the partition of the organ and the two SLT recipient procedures in the same center is major, and it is not, in our opinion, the most rational way to go. In the future, it is hoped that, as confidence is gained in the technique, nearby centers will be able to organize patient coupling prospectively. This may be encouraged by a policy of organ allocation to a center, as it is the case in France, or to a pair of centers, rather than to a patient on a nominal basis.

CONCLUSION

Our results show that SLT is at the dawn of becoming as successful as whole LT and that it can be safely performed by a dedicated team, potentially providing a reliable expansion of organ supply of approximately 30%. The still-too-high incidence of complications probably can decrease as experience is gained in case selection and surgical technique.

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Discussion

DR. JACQUES BAULIEUX (Lyon, France): Thank you Dr. Azoulay for this exciting communication. I have a great interest in the split for the adult. Can you give me some explanations on the technique and on the results? What about the etiology and the pathology of the patients? Did you perform the two liver transplants in your unit?

DR. CHRISTOPH BROELSCH (Hamburg, Germany): Thank you Dr. Azoulay. Congratulations for these results. It is another epochal paper coming from the Paul Brousse Hospital, because it will change the face of cadaveric liver transplantation in the future quite significantly and it comes along at the same time where we have just recently published our results of *in situ* split-liver transplantation at the American Surgical Association forcing the Transplant Community in Europe to think more about the possibilities of splitting. You quite rightly mentioned the history of the reduced size and the splits, and it is something to say in consolation of our oncologic surgical colleagues, because it is exactly what we have learned from liver tumor surgery that we are now able to apply to transplantation. The reason why this has not been applied so frequently in the past actually has been that the results of the splits thus far had remained inferior compared with those of a normal full-size transplantation. You mentioned our results in the series from Chicago from 1989 to 1990, and there were a number of complications with the graft itself: segment 4 ischemia, multiple biliary complica-