Logistics and Technique for Combined Hepatic–Intestinal Retrieval

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During a 13-month period, *en bloc* liver–small bowel cadaveric grafts were procured for seven children and one adult. All liver grafts functioned immediately, and all but one of the recipient patients recovered. Return of absorptive small bowel function was slow, but the integrity of the bacterial intestinal barrier was not disrupted. The described technique allows the procurement of other abdominothoracic organs, with the exception of the whole pancreas.

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S INCE 1987,[1] OPERATIONS DERIVED from an experimental multivisceral transplant procedure[2,3] have been used with increasing success to treat combined liver and intestinal failure.[4-6] In this report, we provide further details about donor selection and preparation, retrieval technique, preservation, and allograft quality in a series of eight consecutive liver–small bowel transplantations.

Methods

Case Material

Recipient ages ranged from 7 months to 26 years, with a median of 2.5 years. The cadaveric donors were 8 days to 21 years of age. They were ABO identical with the recipients, hemodynamically stable, on minimal or no intravenous doses of vasopressors, and with normal liver function tests. Two of the eight liver–intestine grafts were from a cross-match–positive donor. Donors were selected who were smaller in weight than the proposed recipient in all except one case, to ensure proper fit of the transplanted organs without the need for tight abdominal wound closure.

Donor Preparation

Although it could not always be completed, an attempt always was made to flush the intestinal tract with polyethylene glycol-electrolyte solution (Golytely) at 10 to 30 mL/minute (0.6 to 1.8 L/hour). After lavage, an antibiotic preparation was infused into the intestine every 4 hours. Each donor was given intravenous ampicillin and cefotaxime immediately after acceptance into donorship and at the time of operation. To minimize the cold ischemia time of the allograft, the recipient operation was begun on notification that the donor team had begun their operation and had found the organs and circumstances of procurement to be satisfactory.

Donor Surgical Technique

Isolation of the liver and small bowel in continuity with their central vascular structures, cooling of the composite graft, and its removal and preservation involve distinct stages.

Laparotomy and hepatic hilar dissection. The abdomen is opened through a cruciate incision. The liver is mobilized by dividing its ligaments. The common bile duct is transected and the bile is washed out. After division of the right gastric and gastroduodenal arteries, the underlying portal vein is exposed. The left gastric and splenic arteries are ligated at the celiac axis, preserving an accessory left hepatic artery if one is found. Then, the celiac trunk is dissected to the aorta. An extended Kocher maneuver completes the initial stage of the operation (Fig. 1).

Isolation of the intestinal component. The ascending colon is freed from its retroperitoneal fusion, and the ves-
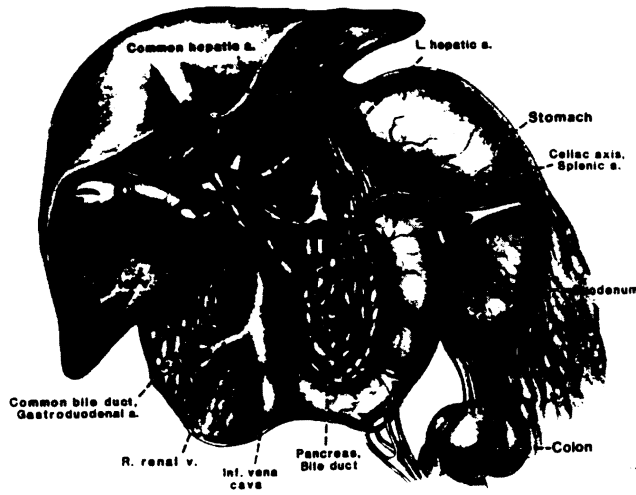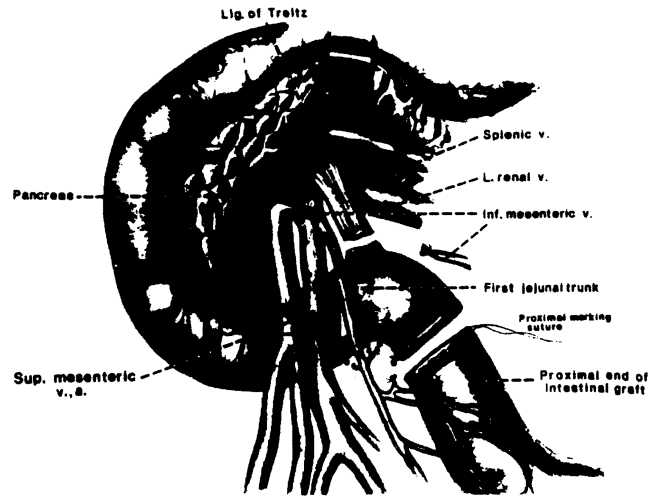
FIG. 1. Exposure of the hepatic hilum.

FIG. 3. Preparation of the proximal jejunum and mesentery.

sels within the mesentery of the terminal ileum and right colon are divided, sparing the ileal branches of the ileocolic artery (Fig. 2). Division of the ileum at the ileocecal valve is deferred as long as possible to allow spontaneous passage of intestinal contents into the colon throughout the dissection. The ascending and transverse colons are now retracted to the left. The proximal jejunum is transected close to the ligament of Treitz, and the highest jejunal arcades are dissected, taking care not to damage the blood supply to the proximal end of the intestinal graft. Marking of this end with a long suture facilitates bowel orientation at the time of implantation (Fig. 3).

Exposure of axial vessels of the composite graft. The central blood vessels of the graft are still overlaid by the pylorus. colon. and pancreas. The colon is eliminated as an impediment by opening the gastrocolic ligament, di-

viding the transverse mesocolon, including the middle colic vessels, near its root and rotating the right and transverse colons to the left and out of the field.

Now, the portal and superior mesenteric veins are exposed by transecting the pylorus and neck of the pancreas (Fig. 4). Stripping the pancreas and duodenum from the specimen requires ligation of numerous small venous tributaries entering the lateral and posterior walls of the superior mesenteric vein and arteries emanating from the superior mesenteric artery. It is imperative during this stripping to look for a replaced right hepatic artery from the superior mesenteric artery and to conserve it if it is found (Fig. 4 inset). If circumstances dictate, this removal of the duodenum and pancreas can be done on the back table as described previously.[3] and this is the preferable
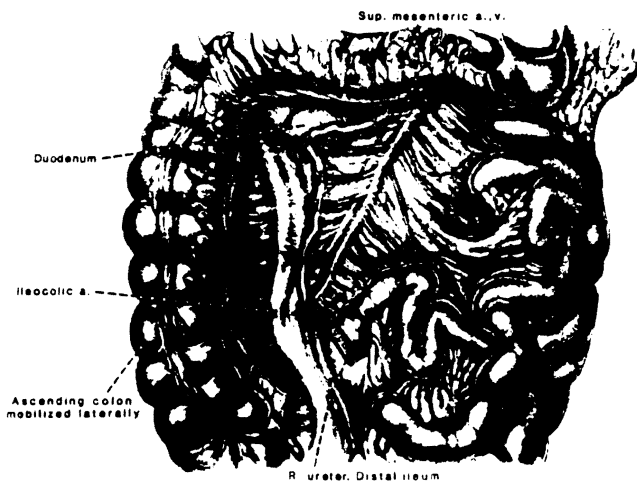

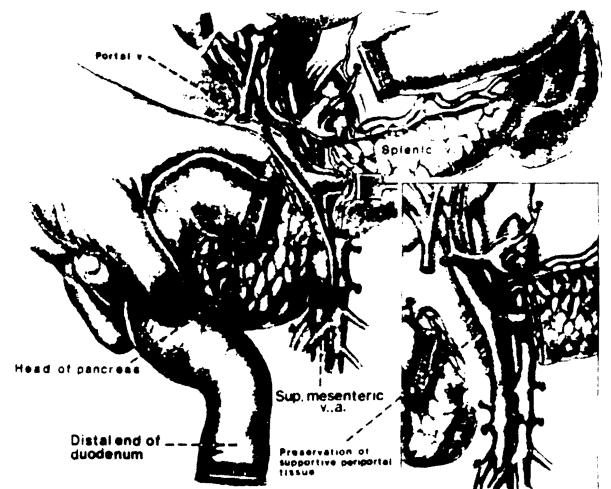FIG. 2. Preparation of the distal ileum and mesentery.

FIG. 4. Exposure of the axial vessels of the composite graft. Inset: Preservation of supportive periportal tissue.

option if the donor is unstable or if the other procurement teams must proceed quickly.

Cooling and en bloc *removal.* The technique is a modification of the so-called "flexible" technique,[7,8] with which chilled fluids are infused into the arterial blood supply of the organs to be procured through a cannula in the distal aorta, which is placed after systemic heparinization. Before this step, the supraceliac aorta is encircled for cross-clamping at the appropriate later time. For portal venous infusion, a venous cannula is placed in the splenic vein and advanced through its confluence with the superior mesenteric vein into the portal vein. By using a generous (>1.5 cm) splenic vein stump, a branch point is left that can later be clamped separately and anastomosed to the recipient portal vein without interruption of the venous outflow from the intestinal allograft.

The previously encircled proximal aorta is cross-clamped, and simultaneous aortic and portal cooling is begun. The venous outflow is vented in the usual way by transecting the inferior vena cava above and below the liver.[7,8] Cooling without overperfusion of the intestine is the objective. Based on earlier experience with the organ cluster grafts,[3] in which overperfusion may have resulted in duodenopancreatic complications, we limit the total amount of cold perfusate to 1 liter for the aorta and 1 liter for the portal vein in adults, 300 mL each for the aorta and portal vein in the newborn, and a proportionately calculated quantity in intermediate-sized donors. If the liver does not feel cold after this limited infusion, additional portal fluid can be directed and confined to the liver by finger compression of the portal vein just below the tip of the catheter.[3] There should be no concern if the intestine does not feel cold, providing it is blanched. Because the small bowel is a hollow organ, it will cool more rapidly in the ice bath, which is its destination, than a solid organ.
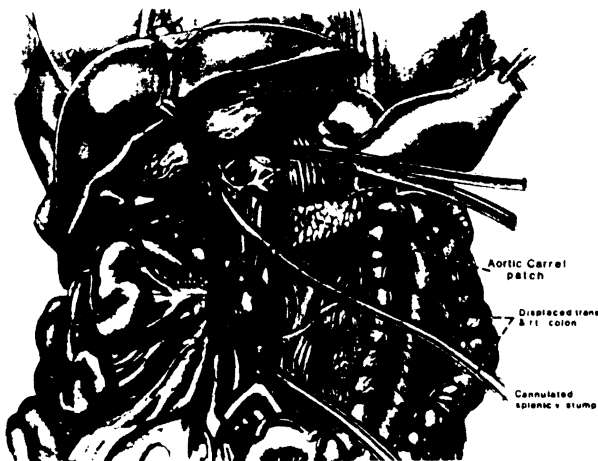

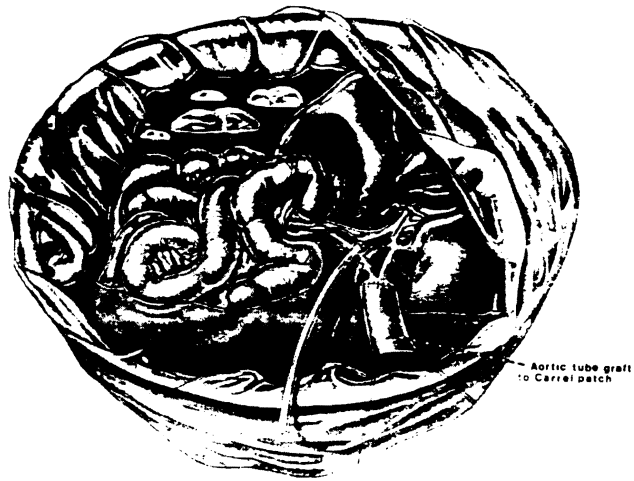FIG. 5. Cold perfusion of *in situ* specimen.

FIG. 6. Liver–small intestinal graft with vascular connections.

Severance from the donor aorta of the double arterial stem of the graft is the crucial final step and can ruin the graft if improperly done. In addition to obtaining a usable arterial pedicle for the liver–intestinal graft, the blood supply to the kidneys that are left behind can be damaged. The superior mesenteric and renal arteries can be defined by light traction on the small bowel and kidneys. The origin of these vessels must be looked for internally, from within the aorta as a Carrel patch is fashioned containing the origins of the celiac axis and superior mesenteric artery. The right renal artery usually is only one or 2 mm from the right margin of the Carrel patch (Fig. 5).

The remainder of the procurement is identical to the standard multiple organ procedures.[7,8] The total operative time averages 2½ hours. With the abdominal viscera out of the way, the chilled *in situ* kidneys are now removed at the same time as the thoracic team completes its work. The excised liver—small bowel graft is placed first in an ice basin and then in a plastic bag containing cold UW solution, packed in ice for transportation. No effort is made to wash out the intestine, which was stapled shut at its upper and lower ends at the appropriate stages of the dissection. Whatever enteric contents are entrapped remain throughout with the specimen until its transplantation to the recipient.

Back table procedure. Back at the recipient hospital, recipient surgeons confer about the donor and final details of the graft preparation. The suprahepatic and infrahepatic vena cava are fashioned in the same way as for liver transplantation.[7,8] Dissection of the celiac axis is carried distally to at least the splenic artery. Dissection of the superior mesenteric artery for a similar length prevents distortion or twisting of this vessel. As periadventitial connective tissue and ganglionic tissue are removed in the process (Fig. 6), small arterial and lymphatic vessels are ligated to prevent later bleeding or lymphorrhea. The Carrel patch

TABLE 1. *Indices of Allograft Preservation*

| Patient | Before Transplant | | After Transplant | | | | |
| | Total Bilirubin (mg/dL) | Cold Ischemia (hr) | Peak Liver Chemistry (Week 1) | | | Small Bowel Biopsy Ischemic Injury |
			Total Bilirubin (mg/dL)	SGPT (IU/L)	SGOT (IU/L)	
1	15.1	8.9	1.7	153	114	—
2	18.1	7.7	6.3	781	694	—
3	13.1	2.9	3.2	324	142	—
4	44.0	10.6	7.1	306	62	+ (8 days)
5	30.9	7	8.1	118	65	—
6	15.2	7.5	5.0	436	277	—
7	48.6	7.5	6.4	414	179	—
8	9.2	8.2	5.0	176	158	—

of the graft can be given length by anastomosing it to a donor aortic conduit (Fig. 6). The numerous alternative means of arterializing these grafts have been described elsewhere.[3]

At all phases of the donor and recipient operations, the portal vein uniting the liver and intestine is vulnerable to stretching and distortion. The hazard to this vital anatomic link can be lessened by avoiding overdissection of the periportal tissues, particularly those posterior to the portal vein, which should be left essentially untouched.

Results

Cold ischemic times averaged 7.5 hours (range, 2.9 to 10.6) (Table 1). After revascularization, the livers were soft and pink and promptly produced bile. In the small bowel, pulsations were immediately present at the mesenteric border, whereas peristalsis and intraluminal mucous production was evident within 15 minutes after reperfusion. Edema was not detectable in the bowel wall or

mesentery. In recipient 8, whose body weight was less than the donor, the organs were too large and abdominal wall closure had to be done in stages.

All liver grafts functioned immediately with serum bilirubin and transaminase levels peaking on the first postoperative day (Table 1) and falling rapidly thereafter to normal levels. Prothrombin times normalized by the second postoperative day.

The intestinal graft stomas used for postoperative decompression were not discernibly different than healthy stomas in nontransplant patients. The mucosa was pink, moist, well vascularized, and without edema. In most cases, there was a high stomal output of clear watery fluid during the first postoperative week. The histopathologic studies of only one graft showed significant preservation injury (Table 1) (Fig. 7). None of the biopsies obtained in the first postoperative week had histologic evidence of submucosal bacterial invasion. Blood cultures were negative during this time.
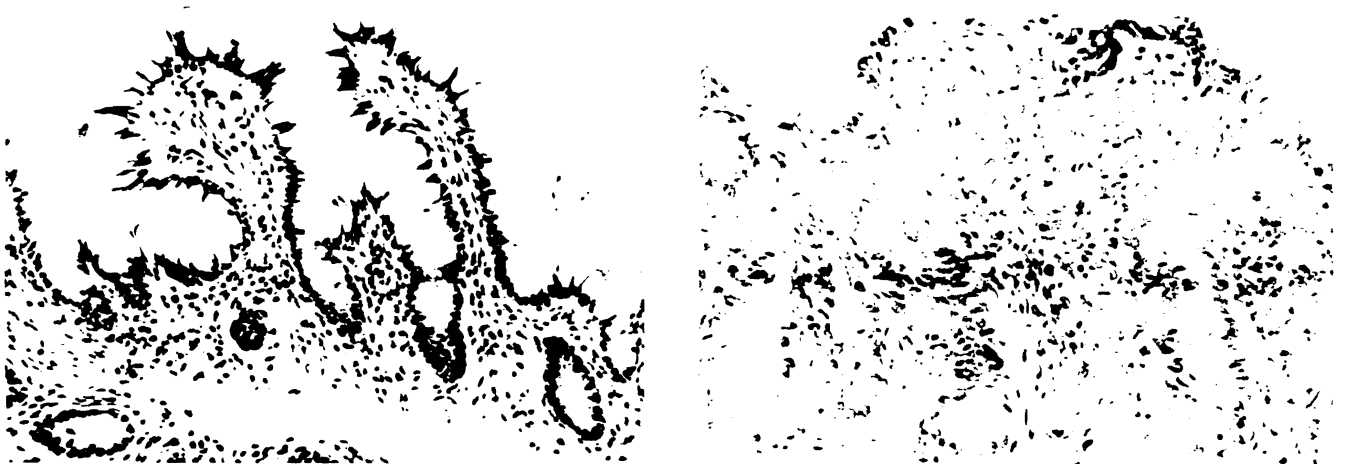

FIG. 7. Histologic monitoring of preservation injury of the intestinal graft: (A, left) Endoscopic biopsy 10 days after transplantation with intact mucosal architecture (H&E ×480). (B, right) Preservation injury 8 days after surgery with scattered capillary microthrombosis (arrow), partial distortion of the villous architecture, neutrophilic infiltration, and focal deposition of granulation tissue in the lamina propria (H&E ×480).

Recovery of intestinal graft motility was clinically, radiologically, and endoscopically apparent 1 to 2 weeks after transplantation. No morbidity related to ischemic injury of the organs was encountered. Seven of eight patients are alive 131 to 542 days after engraftment (mean, 308 ± 180). The only death was caused by a leak at the upper intestinal anastomosis and subsequent graft-*versus*-host disease.

Discussion

Although the safety and efficacy of isolated human small intestinal allografts has been demonstrated,[9] there is a subpopulation of patients with the short gut syndrome maintained on total parenteral nutrition who have met our entry criteria because they have developed cholestasis, steatosis, periportal inflammation, fibrosis, and finally cirrhosis. In one series[10] of such patients there was an inexorable progression of liver histology, biochemistry, and clinical measurements from normal to the death of the patients within 1 year after elevation of the liver function tests.

Our technique of liver–small intestinal procurement for such patients is an extension of the standard flexible method.[7,8] It can be performed in conjunction with heart, lung, and kidney retrieval with expectation of good primary function of all organs. Although whole-organ pancreas retrieval is precluded, pancreatic islets can be salvaged. The liver–intestine grafts were of high quality. Although motility and nutritional functions were slow to resume, the microscopic absence of submucosal bacterial invasion and negative surveillance blood cultures during the first week ruled out clinically significant intestinal translocation episodes.

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