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Significance of Blood Flow Measurement in Clinical Liver Transplantation

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VASCULAR complications are not uncommon after orthotopic liver transplantation (OLTx).[1,2] In order to further improve the outcome of OLTx, intra- and postoperative adjunctive measures will be required to further improve such problems as hepatic artery thrombosis. Since the first successful measurement in 1945 by Bradley and others[3] with a dye clearance method using bromosulphthalein, various methods have been advocated for the accurate measurement of blood flow to the human liver.[4] Of these, the electromagnetic flowmeter technique has emerged to be one of the most reliable, and allows the direct measurement of flow through the hepatic artery (HA) and the portal vein (PV) independently.[4] The purpose of this study was to clarify the importance of blood flow measurements during or after OLTx.

PATIENTS AND METHODS

Between July 1, 1987 and February 18, 1988, 230 patients underwent 272 OLTx at the Presbyterian Unversity Hospital and Children's Hospital of Pittsburgh. Their ages varied from 6 months to 72 years old with a mean of 35.9 years; 125 were male (54.3%). During this eight month period, hepatic blood flows were measured in 51 liver allografts of 42 patients after OLTx (18.8%). Of these, 35 grafts in 28 pediatric patients underwent elective flow measurements, and 11 grafts in ten adult and one pediatric patient underwent emergency blood flow measurements. None of the patients were hemodynamically unstable at the time of flow measurement.

Blood Flow Measurement

Blood flows in the HA and PV were measured with a square-wave electromagnetic flowmeter, Cliniflow II®, Model FM701D (Carolina Medical Electronics, Inc., King, North Carolina). Probes which fit the vessels snugly were selected for the measurement. A zero flow reference was obtained by placing the probes in an isolated ground in a plastic beaker filled with normal saline. At the time of flow measurement, the heart rate, blood pressure, central venous pressure, urine output, the dose of vasopressors and, when available, pulmonary artery pressure and cardiac output were recorded.

RESULTS

Elective Blood Flow Measurement

Of the 35 grafts in the 28 pediatric patients who underwent elective flow measurements, six (21.4%) had HA flows of less than 60 mL/min. Table 1 lists the flow data of these six patients. Of these six, five patients (83.3%) developed HA thrombosis; four with complete and one with partial thrombosis. Three of these grafts in three patients (10.7%) demonstrated abnormally low HA flows in the presence of good pulsation of the HA (Cases 2, 3, 4). Cases 2 and 3 received no additional definitive procedures, with an assumption that there was flowmeter malfunction. In both cases, HA thrombosis was confirmed immediately postoperatively. In Case 4, HA thrombosis was confirmed intraoperatively by taking down the HA anastomosis. Replacement of the donor celiac axis and common hepatic artery with an interposition arterial graft (donor iliac artery) improved the flow to 50 mL/min. However, this patient also went on to develop HA thrombosis postoperatively.

Table 1. Flow Data among Pediatric Patients Who Exhibited Abnormally Low Flow with Good Pulsation of the Hepatic Artery

Case	Age/Sex	Liver Disease	Flow (ml/min) HA	Flow (ml/min) PV	Outcome
1	10 mo/M	CBA	50	—	HAT, required OLTx II
2	17 mo/F	CBA	0	530	HAT, alive and well
3	36 mo/F	Alagille	35	380	intraop. HAT of right branch, died during OLTx II
4	23 mo/F	CBA	0	1100	intraop HARec for HAT,
			(50)*	—	recurrent HAT, OLTx II
5	18 mo/F	CBA	30	—	HAT, required OLTx II
6	7 mo/M	CBA	50	200	HA patent, alive and well

( )* – flow data after hepatic artery reconstruction; HA – hepatic artery; PV – portal vein; CBA – congenital biliary atresia; HAT – hepatic artery thrombosis; OLTx II – second orthotopic liver transplantation; HARec – hepatic artery reconstruction.

Emergency Blood Flow Measurement

As shown in Table 2, 11 patients underwent emergency flow measurements. Indications were intraoperative or postoperative HA thrombosis in five (45.5%) and clinical impression of poor HA flow in six patients (54.5%). Among the five patients who underwent flow measurements for intraoperative or postoperative HA thromboses, Case 10 underwent a composite HA reconstruction, in which an aortohepatic interposition graft was anastomosed to the donor proper hepatic artery, and the recipient aberrant right hepatic artery was anastomosed to the donor aberrant right hepatic artery. Of the six patients who underwent flow measurements for poor inflow, three of these patients (50%) underwent a definitive procedure to increase inflow; 1) aortohe-

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Table 2. Flow Data among Patients Who Underwent Emergency Blood Flow Measurement

Case	Age/Sex	Indication	Flow (ml/min) HA	Flow (ml/min) PV	Outcome
1	36/F	AHIG for poor inflow	190	—	HA patent, alive and well
2	63/F	SA ligation for poor inflow	200 650*	1800 2100*	HA patent, alive and well
3	57/M	HARec with recipient RHA for poor inflow	150 320*	2400 1800*	HA patent, alive and well
4	50/M	weak HA pulse	600	—	HA patent, alive and well
5	39/F	weak RHA pulse	400† 115‡	—	HA patent, alive and well
6	39/M	weak HA pulse	300	—	PGNFN with HAT, required OLTx II
7	29/M	AHIG after intraop. HAT	210*	1500*	HA patent, alive and well
8	19/F	Revision of AHIG after intraop. HAT	900*	1000*	died of ruptured aortic pseudoaneurysm
9	21/M	Revision of AHIG for intraop. HAT	70 120*	850 —	HAT, required OLTx II
10	60/F	composite HARec after intraop. HAT	200*† 180*‡	—	HA patent, alive and well
11	2/M	AHIG after postop. HAT	45*	—	HAT, alive and well

*flows after hepatic artery reconstruction; †flows in the proper hepatic artery; ‡flows in the right hepatic artery; HA - hepatic artery; PV - portal vein; AHIG - aortohepatic interposition graft; SA - splenic artery; HARec - hepatic artery reconstruction; RHA - right hepatic artery; PGNFN - primary graft non-function; OLTx II - second orthotopic liver transplantation; HAT - hepatic artery thrombosis.

patic interpositon graft (Case 1), 2) splenic artery ligation (Case 2) and 3) conversion of the inflow vessel to the recipient aberrant right hepatic artery (Case 3). The other three patients (50%) demonstrated adequate HA flow by flowmeter. Of these 11 patients, HA in nine patients (75%) remained patent, whereas three patients (25%) in whom HA had flows of 120, 300 and 45 mL/min, developed HA thrombosis. In case 6, HA thrombosis was found at the time of retransplantation for primary graft nonfunction at seven days after the inital OLTx.

DISCUSSION

Of the various vascular complications during or following OLTx, HA thrombosis represents one of the most significant and devastating complications, which has been attributed in large part to technical difficulties, which include anatomical variation, the deep location of the vessels as well as the caliber of the anastomosis.[5,6] The present study clearly demonstrates that routine measurement of blood flow in pediatric OLTx can be extremely helpful, since the flow determinations can alert the surgeon to an unrecognized HA thrombosis or to an abnormally low HA flow. This occurred in six out of 28 children (21.4%) in this study.

The results from this study further emphasize that palpation of the HA after HA anastomosis is not necessarily a reliable method to examine HA patency or flow, and that strong pulsatile flow from the amputated distal donor splenic artery merely suggests good inflow to that point, and does not necessarily verify the presence of distal arterial patency. The other contribution of blood flow measurements after OLTx is the acquisition of objective data on hepatic arterial flow following reconstruction of the HA for HA thrombosis. Although our experience in the measurement of blood flow after such arterial revision has been limited, low HA flow after the revision may be associated with recurrent HA thrombosis.

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