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Echo-Doppler Evaluation of Reverse Flow Sign in the Intrahepatic Portal Branches After Surgery

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Objective
The authors evaluated the clinical significance of the development of reversed portal flow after abdominal surgery other than portosystemic shunt procedure.

Summary Background Data
There have been several reports in regard to reversed portal flow demonstrated by pulsed Doppler ultrasonography, most of which were related to portal hypertension. To the authors' knowledge, this is the first report in which reversed portal flow also is present in patients who have undergone abdominal surgery other than portosystemic shunt procedure.

Methods
Preoperative and postoperative pulsed Doppler ultrasonographic examinations were performed in 126 patients who underwent abdominal surgery. Postoperatively, the portal flow direction was assessed in the right portal branch or the umbilical portion of the left portal branch.

Results
Of the 126 patients, reversed portal flow developed in 10 after surgery; 9 of them died of liver failure.

Conclusions
The postoperative development of reversed portal flow is considered to have grave prognostic significance, indicating that the degree of postoperative liver damage is extremely critical.

It is well known that portal flow direction can easily be altered when the gradient of portal venous pressure is reversed, because the portal venous system is a circulatory system without valves. There have been many reports of hepatofugal flow in the portal vein under various conditions.[1–11] In the course of our observations of postoperative changes in portal hemodynamics using pulsed Doppler ultrasonography, we encountered ten patients in whom the portal flow direction changed from hepatopetal to hepatofugal after abdominal surgery other than portosystemic shunt procedures. Critical liver dysfunction developed subsequently in all except one. As far as

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Table 1. CHARACTERISTICS, DIAGNOSIS, AND OPERATIVE PROCEDURES IN THE 126 PATIENTS STUDIED

Age (range)	60.2 ± 9.8 yrs (31–83 yrs*)
Sex (M/F)	90/36
Liver cirrhosis (with/without)	58/68
Diagnosis (no. of patients)	
Primary liver cancer	(73)
Esophageal varix	(13)
Gastric cancer	(11)
Esophageal cancer	(7)
Colorectal cancer	(6)
Pancreatic cancer	(5)
Chronic pancreatitis	(3)
Cholelithiasis	(2)
Metastatic liver cancer	(2)
The others	(4)
Operative procedures (no. of patients)	
Hepatectomy	(75)
Gastrectomy	(10)
Esophageal transection	(8)
Esophagectomy	(7)
Pancreatoduodenectomy	(6)
Colorectal resection	(6)
Hassab's operation	(5)
Distal pancreatectomy	(3)
Cholecystectomy	(2)
The others	(4)

* Mean ± standard deviation.

we know, there has been no report of similar cases. Therefore, the hepatofugal portal flow observed in patients after abdominal surgery other than portosystemic shunt procedures may have an entirely different significance from that in the types of cases previously reported.

We describe the characteristic hepatofugal portal flow in the ten patients and discuss the clinical significance of the development of this alteration after abdominal surgery other than portosystemic shunt procedures.

MATERIALS AND METHODS

Preoperative and postoperative pulsed Doppler ultrasonographic examinations were performed in 126 patients who underwent abdominal surgery other than portosystemic shunt procedure (Table 1). Fifty-eight of the patients had liver cirrhosis, the diagnosis of which was based on the histologic findings for the liver; in the other 68 patients, liver cirrhosis was excluded, based on the intraoperative macroscopic findings or evaluation of the liver biopsy specimen. In all of the patients, the preoperative serum total bilirubin value was below 2.0 mg/dL.

Portal blood flow measurements were performed on all of the patients on the day before surgery, and in most of them, 1, 2, 3, 5, and 7 days after surgery, using a system in which an ultrasonic convex scanner with a 3.5-MHz transducer is combined with a pulsed Doppler apparatus (Aloka SSD-680 or SSD-2000, Aloka, Tokyo, Japan). When hyperbilirubinemia (serum total bilirubin > 2.0 mg/dL) was found more than 7 days after surgery,

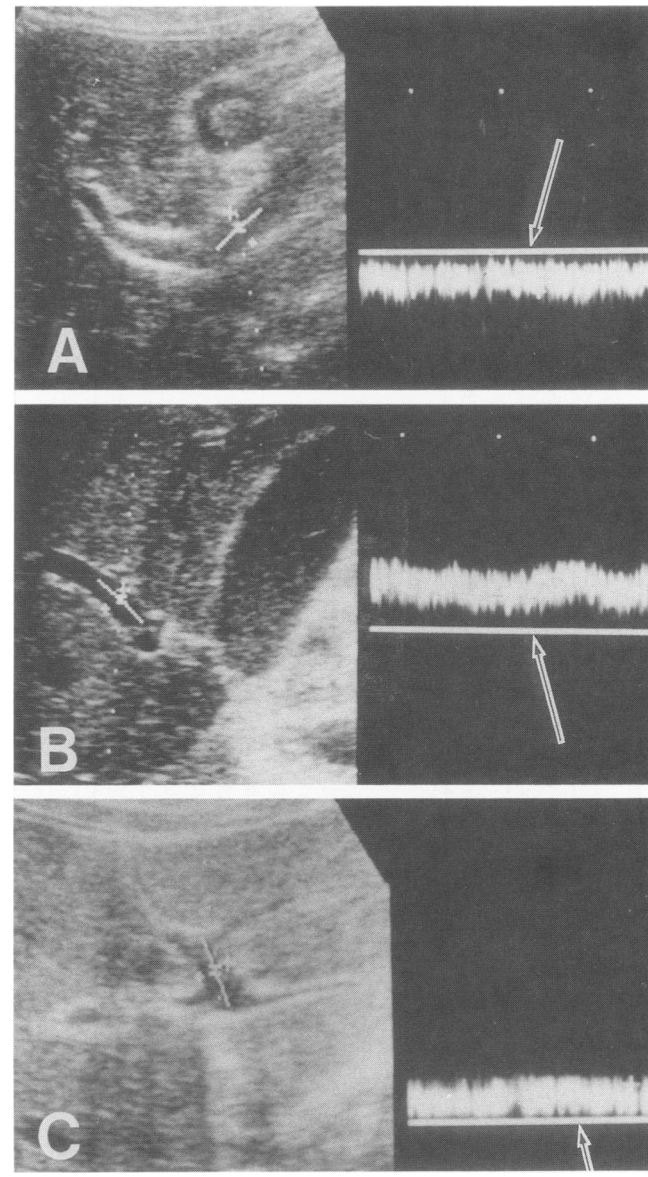

Figure 1. The method of preoperative assessment with duplex Doppler sonogram of the portal venous system is illustrated. (A) The sample volume is placed in the main portal vein. The Doppler shift is displayed below the zero line (arrow) because the flow is moving away from the source of the Doppler beam (*i.e.*, normal flow toward the liver). On positioning of the sample volume in the right portal branch (B) and in the umbilical portion of the left portal branch (C), the Doppler shift in both appears positive (above the zero line, arrow), indicating that the flow is moving toward the source of the Doppler beam (*i.e.*, normal hepatopetal flow).

Table 2. CLINICAL PROFILES OF THE 10 PATIENTS WHO DEVELOPED REVERSED PORTAL FLOW (RPF)

Patient	Age (yrs)	Sex	LC	Diagnosis	Operation Performed	Postoperative Complication	Site Assessed	POD	Outcome
1	70	F	–	Pancreatic cancer	PD	Hemorrhage, Abscess	UP	1	Died 37 days after RPF was first noted.
2	75	M	–	Pancreatic cancer	PD	Hemorrhage, Abscess	RB	25	Died 42 days after RPF was first noted.
3	71	F	–	Pancreatic cancer	PD	Abscess	RB	91	Died 3 days after RPF was first noted.
4	68	M	+	Gastric cancer	Gastrectomy	—	RB	7	Died 23 days after RPF was first noted.
5	49	F	+	Esophageal varix	Esophageal transection	—	RB	1	Discharged after recovery from hyperbilirubinemia
6	64	F	+	Esophageal varix	Esophageal transection	Hemorrhage	RB	25	Died 4 days after RPF was first noted.
7	45	M	+	Esophageal varix	Hassab's operation	Renal dysfunction	RB	109	Died 2 days after RPF was first noted.
8	58	M	+	HCC	Partial resection of the liver	Hemorrhage	RB	6	Died 4 days after RPF was first noted.
9	62	F	+	HCC	Right lobectomy of the liver	Hemorrhage	UP	11	Died 5 days after RPF was first noted
10	60	M	+	HCC	Right lobectomy of the liver	Hemorrhage	UP	5 and 14	Died 13 days after RPF was first noted.

LC = liver cirrhosis; POD = postoperative day that reversed portal flow was noted; PD = pancreatoduodenectomy; UP = umbilical portion of the left portal branch; RB = right portal branch; HCC = hepatocellular carcinoma.

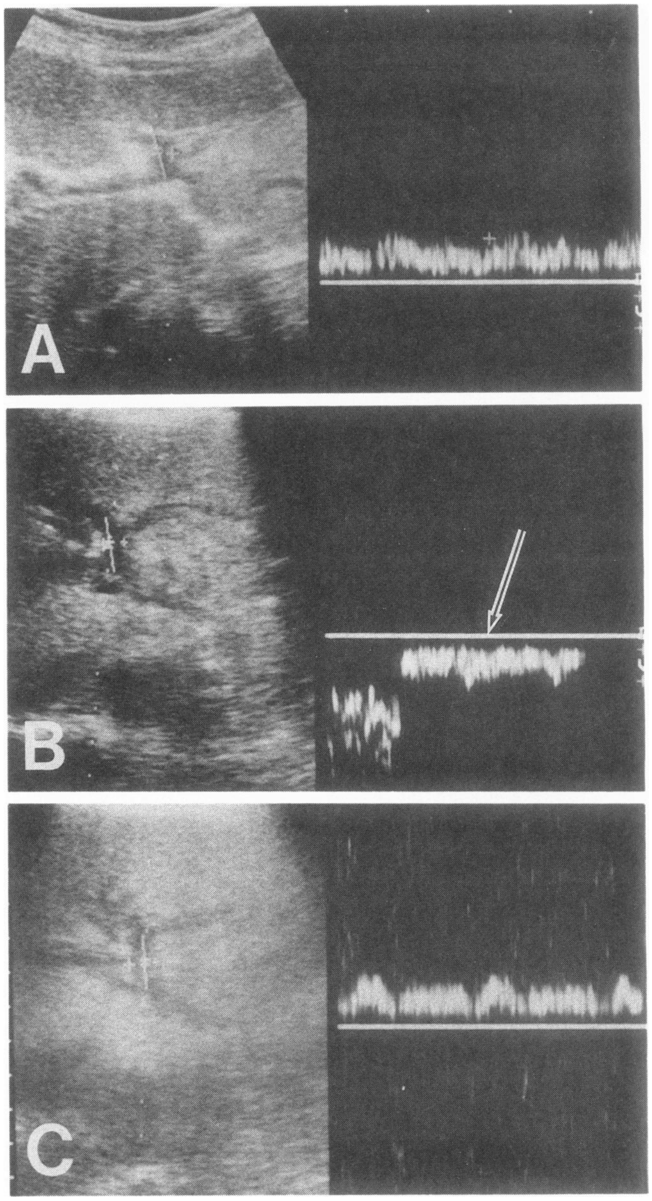

Figure 2. Changes in portal flow direction in patient 1 are demonstrated. (A) The preoperative flow direction in the umbilical portion of left portal branch was hepatopetal. (B) The Doppler shift is displayed below the zero line (arrow) at the time of intra-abdominal hemorrhage because the flow is moving away from the source of the Doppler beam (*i.e.*, reversed hepatofugal flow). (C) The direction of flow recovered to hepatopetal after the hemorrhage was controlled.

examinations were conducted intermittently thereafter. The blood flow direction was assessed preoperatively in the main portal vein, the intrahepatic right portal branch, and the umbilical portion of the left portal branch (Fig. 1). Postoperative assessments of the flow direction were made mainly in the right portal branch, because this branch can be visualized easily via the intercostal approach when a patient holds a normal

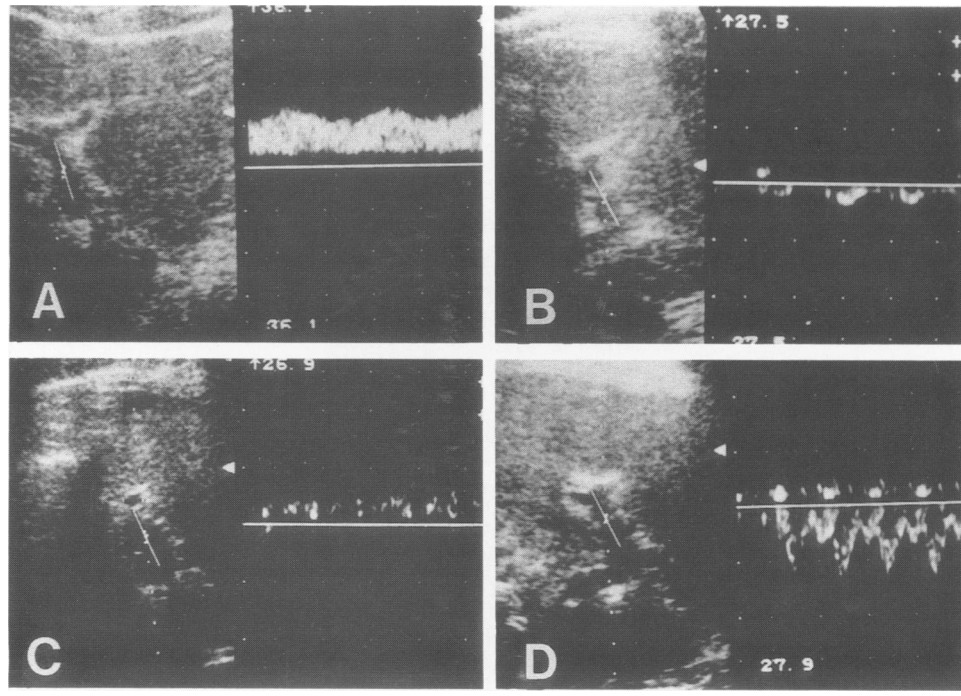

Figure 3. Changes in portal flow direction in patient 10 are demonstrated. (A) The preoperative portal flow in the umbilical portion of the left portal branch was hepatopetal. (B) The flow direction changed to hepatofugal in the absence of any specific incidents on the fourth postoperative day when encephalopathy developed in the patient. The flow direction recovered to hepatopetal spontaneously (C), although it reversed again, showing pulsatile waveform (D).

breath.[12] The assessments were made in the umbilical portion of the left portal branch, in the event that the right portal branch could not be visualized or when right lobectomy of the liver had been performed. Pulsed Doppler signals were obtained from a 2-mm sample volume located at the center of each vessel. When the signals obtained indicated hepatofugal flow, the sample volume was relocated to several different places in the same vessel to confirm the direction of the flow.

RESULTS

Preoperative observations of the portal flow direction in each vessel revealed hepatopetal flow in all of the patients. Postoperative hyperbilirubinemia (serum total bilirubin value > 2.0 mg/dL) was seen in 59 patients; severe liver dysfunction (serum total bilirubin value > 5.0 mg/dL) developed in 15 of these 59 patients. Hepatofugal portal flow was observed in ten of the patients, all of whom had postoperative hyperbilirubinemia. Severe liver dysfunction developed in all except one (patient 5). The clinical profiles of the ten patients in whom reversed portal flow developed are summarized in Table 2. Seven of them had liver cirrhosis, and the other three had a history of obstructive jaundice caused by carcinoma of the pancreatic head. Six of them had postoperative hemorrhage. Renal dysfunction developed in patient 7 before liver failure. All three patients who underwent pancreatoduodenectomies showed accompanying intra-abdominal abscess due to leakage of pancreatojejunostomies. Generalized sepsis developed in two patients (patients 1 and 2). None of the other patients (including patient 3) showed septic signs or symptoms in their postoperative course. In patients 1 and 2, the hepatofugal portal flow was noted during massive intra-abdominal hemorrhage, and recovery to hepatopetal flow was seen after the hemorrhage was controlled (Fig. 2). The hepatofugal portal flow in patient 5 and the first episode in patient 10, which developed during transitory encephalopathy, occurred independently of hemorrhage, and each had spontaneous recovery to hepatopetal flow (Fig. 3). In the other episodes of hepatofugal flow, including the second episode in patient 10, no recovery to hepatopetal flow was seen (Fig. 4). All of the patients except patient 5 died of liver failure.

DISCUSSION

The development of the pulsed Doppler ultrasonography has prompted noninvasive and physiologic studies of portal hemodynamics in various liver diseases, and there have been several reports in regard to hepatofugal flow in the portal venous system, most of them related to portal hypertension.[13–19] Several groups of investigators have reported that hepatofugal portal flow is observed frequently in patients who have undergone portosystemic shunt procedures.[20–22] To our knowledge, this is the first report that hepatofugal flow in the intrahepatic

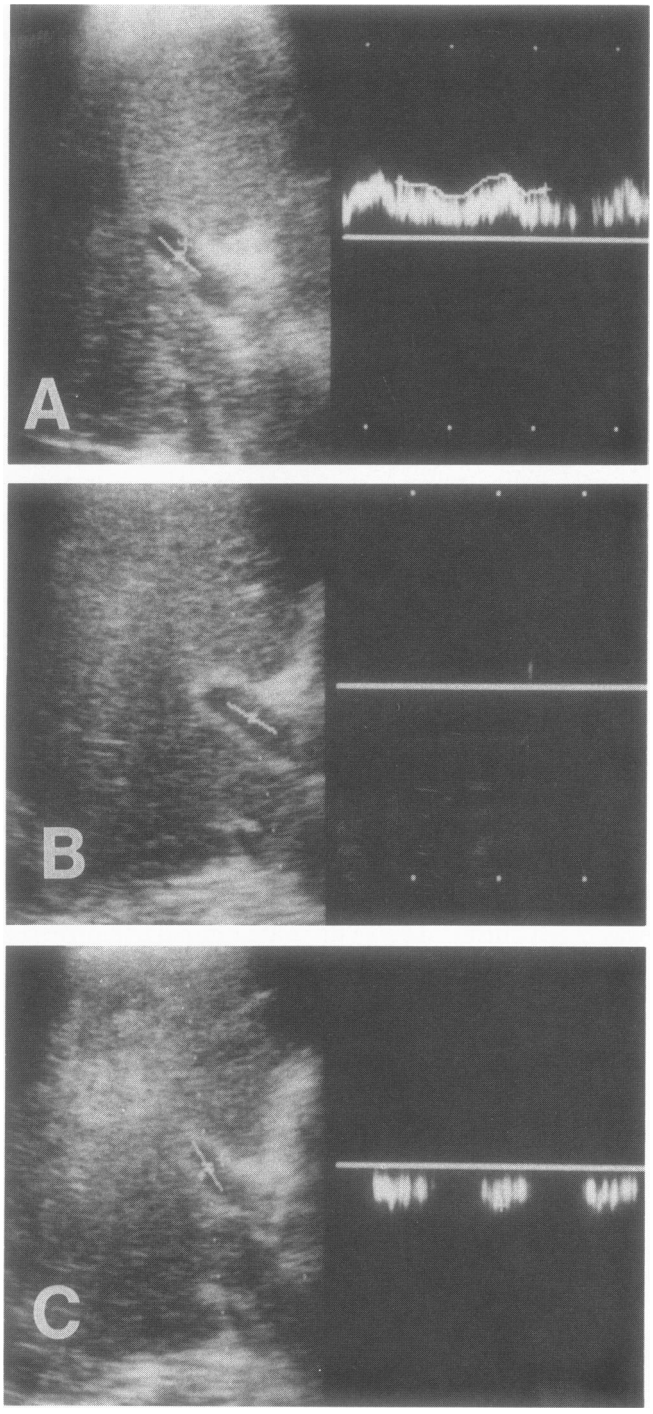

Figure 4. Changes in portal flow direction in patient 8 are demonstrated. The postoperative portal flow in the right branch was hepatopetal initially (A), but subsequently, Doppler signals could no longer be obtained (B). The flow reversed on the fifth postoperative day, and the direction did not recover to hepatopetal flow (C).

portal vein also is present frequently in patients who have undergone abdominal surgery other than portosystemic shunt procedures.

Seven of the ten affected patients in our study had liver cirrhosis, and the other three had preoperative history of obstructive jaundice. Each patient, therefore, might have had some degree of portal hypertension preoperatively. Suspected mechanisms of the development of the reversed portal flow after the surgery include intraoperatively or postoperatively sustained liver damage induced by various complications, such as intraoperative or postoperative hemorrhage or infection, with increase of the portal venous pressure, as well as decrease of portal inflow induced by peripheral circulatory failure or the increase of the shunting flow into the systemic circulation, resulting in the reverse of the gradient of the portal venous pressure. The reversed portal flow in some patients reverted to the normal direction (in patients 1, 2, and 5, and the first episode in patient 10), but was irreversible in others (patients 3, 4, 6, 7, 8, and 9, and the second episode in patient 10). Thus, the complicated mechanisms involved in the development of reversed portal flow are either reversible or irreversible.

Arterioportal shunting has been observed angiographically in a wide variety of pathologic conditions.[23–25] Thus, it is reasonable to suppose that the component of the reversed flow in the intrahepatic portal vein may be the flow through the arterioportal communications. Two routes have been recognized angiographically. The classic route is that via the hepatic sinusoids (trans-sinusoidal), resulting in retrograde hepatofugal flow in the portal branches; however, a transvasal route also has been recognized more recently, in which portal flow is reported to often remain hepatopetal.[26] In patient 3, the latter type of arterioportal anastomosis was demonstrated by color Doppler flow imaging; the portal flow in the peripheral portion of the anastomosis was hepatopetal and pulsatile in its waveform. Conversely, in the proximal portion of the same site, the portal flow was hepatofugal and almost constant in its waveform (Fig. 5). In the other patients, no direct arterioportal anastomosis could be detected ultrasonographically, and the route in most may have been trans-sinusoidal.

Much attention focuses on the hemodynamics in the portal trunk or the hepatic vein when hepatofugal flow appears in the intrahepatic portal vein. Unfortunately, postoperative observations of the portal trunk could not be performed in any of our patients because there were various restrictions on its delineation after surgery. A surprising observation was that the flow direction in the middle hepatic vein in patient 2 also was reversed at the time of hemorrhage, and it recovered normally after the hemorrhage was controlled (Figs. 6 and 7).

The waveform of the reversed portal flow was constant in most of the patients, but in patient 5 and in the second episode in patient 10, it was pulsatile. On the basis of the

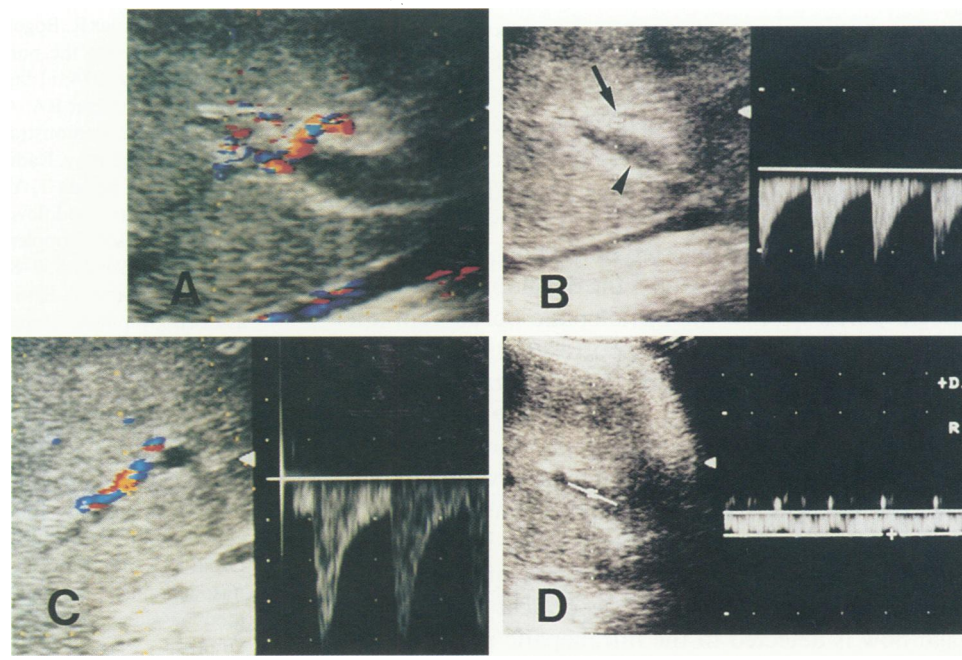

Figure 5. A transvasal arterioportal shunting in patient 3 is demonstrated by color Doppler imaging (A). Spectral Doppler analysis of the vessel (arrow) penetrating the wall of the right portal branch (arrowheads) revealed an arterial signal (B). The portal flow in the peripheral region of the anastomosis was hepatopetal and pulsatile in its waveform (C). In contrast, the portal flow proximal to the anastomosis was hepatofugal and almost constant in its waveform (D).

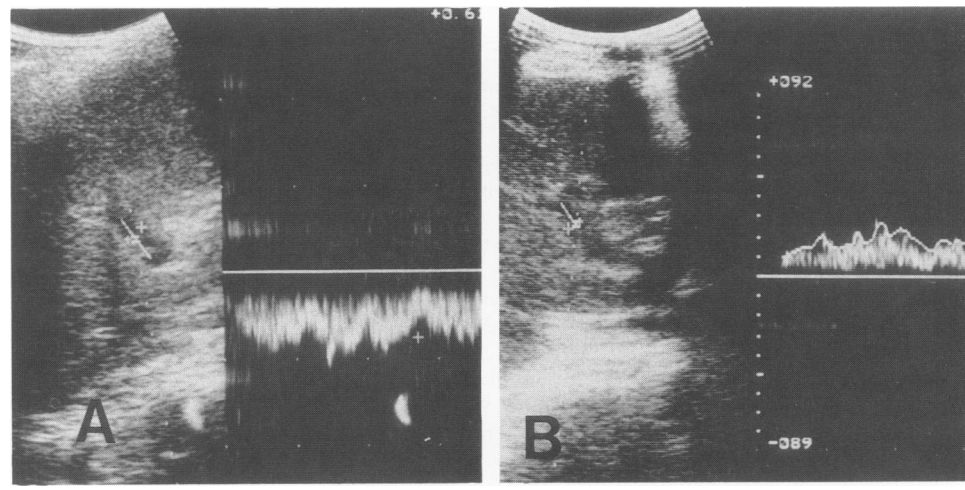

Figure 6. The flow in the right portal branch in patient 2 is hepatofugal during postoperative intra-abdominal hemorrhage (A), but recovery to hepatopetal flow is seen after the hemorrhage has been controlled (B).

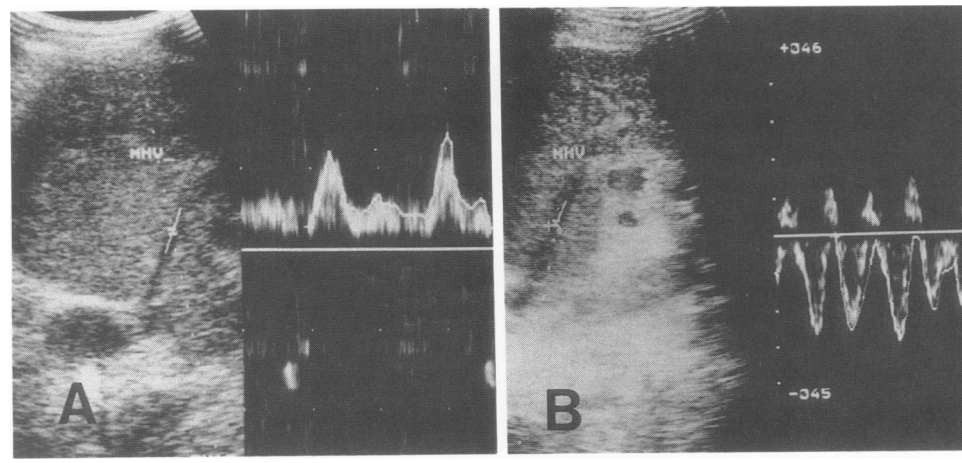

Figure 7. Doppler signals from the middle hepatic vein in patient 2 are demonstrated. Spectral Doppler analysis in the middle hepatic vein when intra-abdominal hemorrhage developed in the patient, which revealed blood flow toward to the source of the Doppler beam, indicating that the blood in the middle hepatic vein was flowing away from the inferior vena cava (A). After the hemorrhage was controlled, the blood flow direction recovered to normal (toward the inferior vena cava) (B).

current study alone, it cannot be determined what caused the differences in the waveform of the hepatofugal portal flow.

Hepatofugal flow in the portal venous system has been reported by many investigators, and its relation to encephalopathy and the stage of the liver cirrhosis has been mentioned in several reports.[13,16,21] The prognostic value of the development of reversed portal flow, however, still remains unclear. In our study, the development of hepatofugal portal flow in the intrahepatic portal vein after abdominal surgery other than portosystemic shunt procedure indicated more marked postoperative progression of portal hypertension and the existence of the decrease of portal inflow, resulting in poor prognosis.

Pulsed Doppler ultrasonographic observation of postoperative changes in intrahepatic portal hemodynamics is easy and noninvasive. We believe that it can provide useful information regarding the degree of liver damage after surgery, which apparently is critical when hepatofugal flow is detected in the intrahepatic portal vein by pulsed Doppler ultrasonography.

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