Dynamic studies on portal haemodynamics by scintiphotosplenoportography: flow patterns of portal circulation

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SUMMARY Scintiphotosplenoportography (SSP) was performed in 190 instances in 161 patients. No significant complications, such as severe pain or splenic haemorrhage, were encountered in any of the patients studied. Flow patterns of SSP were classified into nine groups according to the direction of collateral flow. Hepatopetal collateral flow was frequently observed in pancreatic cancer. In portal hypertension, cephalic collateral flow was more frequently observed than caudal flow. In detecting oesophageal varices, both SSP and endoscopy were performed in 81 patients. In four out of 46 patients with cephalic flow, oesophageal varices could not be observed by endoscopy. Conversely, in three out of 44 patients with oesophageal varices, SSP failed to show cephalic flow. The combined use of SSP and endoscopy would therefore provide more useful information in the management of patients with portal hypertension.

We have recently reported on the new technique of scintiphotosplenoportography (SSP), which permits clear visualisation of the portal venous system by combining splenoportography and scintillation scanning (Kashiwagi *et al.*, 1974). The resolution of SSP was inferior to that of radiographic splenoportography, but it was expected that the hazard of splenic haemorrhage might be reduced and that data gathered through the use of SSP might reflect more accurately the functional state of portal circulation than those derived by conventional angiography (Zimmon, 1974).

In this paper, we would like to report the results of analysis of our personal experience at Osaka University Hospital with 190 SSP investigations in 161 patients, focusing especially on the flow pattern of portal circulation and its clinical significance.

Methods

SSP was carried out in 161 patients with various disorders, as listed in Table 1. The diagnoses of chronic hepatitis and liver cirrhosis were all based on the evidence of liver biopsy. The diagnosis of

idiopathic portal hypertension was established by the presence of non-cirrhotic portal fibrosis, normal or near normal hepatic function, and splenomegaly. The diagnoses of carcinoma of the liver or the pancreas were confirmed by angiography, examination at laparotomy, or necropsy. The miscellaneous group was composed of patients without liver diseases. One or more repeat examinations were done in 23 patients, so that 190 examinations were performed. Informed consent was obtained from all patients.

With a patient lying in the supine position, the scintillation camera was positioned closely over the upper abdominal area. The site of introduction of the needle for splenic puncture was determined by percussion. The needle used for splenic puncture was 23 gauge in diameter and 60 mm in length. The needle was attached to a three-way stop cock, which also held a syringe with ¹³³Xe or ^{99m}TcO₄⁻ in saline solution and a syringe with saline solution alone. Percutaneous splenic puncture was usually performed through the eighth or ninth intercostal space in the left mid- or posterior axillary line. Confirmation as to whether the tip of the needle was precisely placed in the splenic sinusoids or not was made by aspirating blood into the syringe with saline solution. Injection of less than 2 ml (5 to 20 mCi) of ¹³³Xe or ^{99m}TcO₄⁻ in saline solution was made into the spleen. Local

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Fig. 1 Diagram of portal circulation patterns obtained by scintiphotosplenoportography. Scintiphotosplenoportograms in 161 patients can be classified in nine flow patterns.

anaesthesia of the injection site was not required, as the needle for splenic puncture was fine and the injection time was short. The scintillation cameras employed were a Picker Dynacamera, Hitachi RC-IC-1205, and Toshiba GCA-202. These cameras were equipped with a data processing system. Images were recorded on video or magnetic tapes, and, afterwards, serial scintiphotos were obtained with Polaroid camera by replay of tapes. When the examination was completed, the patient was instructed to stay in bed for five hours.

Contraindications were ascites, thrombocytopenia less than 50 000, and/or low prothrombin activity less than 50%.

Endoscopic examination of the oesophagus was carried out in 81 patients, before or after SSP was done.

Results

According to the flow patterns of portal circulation obtained by SSP, images were classified into three groups (I, II, and III), and then each group was subdivided into three subgroups (a, b, and c) as shown in Fig. 1. A representative case of each group is shown for comparison of patterns (Figs. 2-4). Group I has no portosystemic collaterals (Fig. 2). Among this group, group Ia shows the normal course

Fig. 2 Typical case presentation of group I, in which no portosystemic collaterals are visualised. The normal course of portal circulation progressing through splenic vein, portal vein and liver is observed (Ia). The tortuous splenic vein is demonstrated (Ib). The splenic vein is not clearly visualised and hepatopetal collaterals are observed (Ic). SP: spleen. SV: splenic vein. PV: portal vein. C: hepatopetal collaterals.

of portal circulation, while group Ib shows the tortuous splenic vein. Group Ic demonstrates the hepatopetal collaterals. Group II has portosystemic collaterals and the flow to the liver (Fig. 3). Group III represents the complete diversion of splenic flow through the portosystemic collaterals and no liver image (Fig. 4). Group II and III were subdivided according to the direction of collateral flow. The direction of collateral flow was defined as follows. Reversed circulation into the connecting vessels between the portal venous system and the superior vena cava, such as the backflow into coronary or short gastric vein, was regarded as cephalic direction. Portal diversion through connecting vessels between the portal venous system and the inferior vena cava, such as the backflow into the mesenteric, left renal, or umbilical vein, was regarded as caudal direction. In subgroup a, b, and c, the direction of collateral flow was cephalic, both cephalic and caudal, and caudal respectively.

The distribution of flow patterns is shown in Fig. 1. The normal portal circulation pattern (group Ia) was

Fig. 3 Typical case presentation of group II, in which portosystemic collaterals are visualised and the flow to the liver is also demonstrated. Cephalic collaterals (coronary vein and oesophageal varices) are clearly visualised (IIa). Collaterals in both cephalic and caudal directions are observed (IIb). Caudal collateral (umbilical vein) is demonstrated (IIc). SP: spleen. SV: splenic vein. PV: portal vein. CV: coronary vein. EV: oesophageal varices. C: caudal collaterals. UV: umbilical vein.

frequently observed (36.0%). Among the groups with portosystemic collaterals (group II and III), group IIa was observed in 23.0%, and group IIIa in 6.2%. Groups with caudal directional collateral flow were infrequently observed (group IIb; 3.7%, group IIc; 2.5%, group IIIb; 0.6%, group IIIc; 1.9%). Repeated examinations were investigated in 23 patients and the same portal circulation patterns were obtained.

Table 1 shows flow patterns of portal circulation in various diseases. In 62 patients with chronic hepatitis, 54 patients belonged to group I (87.1%) and the remaining eight patients belonged to group II and III (12.9%). In liver cirrhosis, 13 out of 56 patients belonged to group I (23.2%). Among these, only four patients belonged to group Ia (7.1%). Forty patients had cephalic directional collateral flow and belonged to group IIa, b, or IIIa, b (71.4%).

Fig. 4 Typical case presentation of group III, in which diversion of injection through portosystemic collaterals takes place and no liver image is obtained. All the bolus reaches the heart via cephalic collaterals (coronary vein and oesophageal varices) (IIIa). The bolus diverts the two directional collaterals of cephalic and caudal directions and the inflow to the heart is observed (IIIb). The inflow to the heart via caudal collaterals and inferior vena cava is clearly visualised (IIIc). SP: spleen. SV: splenic vein. CV: coronary vein. EV: oesophageal varices. HT: heart. C: caudal collaterals. IVC: inferior vena cava.

Three patients belonged to group IIc or IIIc. In patients with idiopathic portal hypertension, group Ia was not observed. One patient with carcinoma of the liver belonged to group IIa; this patient had clumps of tumour cells obstructing the main right portal branch. Four out of nine patients with carcinoma of the pancreas belonged to group Ic and one patient belonged to group IIIc. In 17 patients with miscellaneous disorders, four patients belonged to group Ib. These patients had splenomegaly due to hematological disorders.

Table 2 shows the correlation between oesophageal varices by endoscopic examination and flow patterns of portal circulation by SSP. In three patients belonging to group Ib, oesophageal varices were clearly observed by endoscopic examination. Conversely, in four patients belonging to group IIa and IIIa, oesophageal varices were not observed by endoscopic examination. In group IIc and IIIc, no patient had obvious oesophageal varices. In group IIb and IIIb, all except one patient had obvious oesophageal varices.

A few patients noted transient abdominal pain associated with the examination.

Discussion

The examination of the portal circulation's flow pattern is very important to the physicians who are responsible for the management of patients with various liver diseases, especially those with portal hypertension. If a patient has collateral flow escaping the portal circulation through the oesophageal plexus, oesophageal varices are developed and variceal haemorrhage may take place. On the other hand, in a patient who has any portosystemic collaterals

Table 1 Flow patterns of portal circulation by scintiphotosplenoportography

Diagnosis	No. of patients	I			II			III		
		a	b	c	a	b	c	a	b	c
Chronic hepatitis	62	38	16		4		2	2		
Liver cirrhosis	56	4	9		28	6	1	5	1	2
Idiopathic portal hypertension	11		3				1	3		
Carcinoma of liver	6		5		1					
Carcinoma of pancreas	9	3	1	4						1
Miscellaneous	17	13	4							
Total	161	58	38	4	37	6	4	10	1	3

Table 2 Correlation between findings of oesophageal varices by endoscopic examination and flow patterns of portal circulation by scintiphotosplenoportography

Findings of varices	I			II			III			Total
	a	b	c	a	b	c	a	b	c	
*		3		30	5		5	1		44
†	2	4			1	2				9
-	12	9	1	3		1	1		1	28
Total	14	16	1	33	6	3	6	1	1	81

*Oesophageal varices were obviously observed.
 †Oesophageal varices were doubtfully observed.
 -Oesophageal varices were not observed.

other than the oesophageal plexus, the development of such dangerous varices may be reduced or prevented, although these collaterals decrease the hepatic blood flow and may cause hepatic insufficiency or encephalopathy. For investigating such abnormalities of portal circulation, radiographic splenoportography has been considered to be a valuable and standard diagnostic technique. However, this technique carries the risk of causing severe splenic haemorrhage, so that it is important to find a more suitable method for evaluating the portal venous system. We have recently developed the technique of SSP, which has several distinct advantages compared with conventional radiographic splenoportography (Kashiwagi *et al.*, 1974, 1975, 1978).

In this investigation using this new technique, flow patterns of portal circulation have been studied in various disorders. Flow patterns in SSP were classified into nine groups and were analysed. Group Ia is considered to be the normal portal circulation pattern. Splenic vein tortuosity was frequently observed in portal hypertension, so that group Ib was distinguished from group Ia. Group Ic represents the existence of hepatopetal collateral flow which often occurs in stenosis or obstruction of the splenic vein. This group was frequently observed in patients with carcinoma of the pancreas. Therefore, SSP seems to be useful for pathophysiological diagnosis of carcinoma of the pancreas. Group IIa was most frequently observed in patients with portosystemic collaterals. Group IIb and IIc were infrequently observed. This tendency was similar in group III. This result indicates that caudal directional collateral flow rarely occurs as compared with cephalic flow, although the reason for this is unknown. In radiographic splenoportography, Jackson (1963) has classified flow patterns into five classes and reported that caudal directional collateral flow was observed in 55 out of 124 patients with liver cirrhosis (44.4%). It appears that the demonstration of caudal collateral flow occurs more frequently by splenoportography than SSP. This difference may be due to the fact that, in splenoportography, extensive filling of the portal venous tributaries might occur against the natural flow direction because of larger injection. Fourteen out of 61 patients with portosystemic collaterals belonged to group III (23.0%). The failure to visualise the portal vein observed in group III does not always indicate its occlusion or reverse flow. In one case belonging to group IIIa, radiographic splenoportography clearly demonstrated the portal vein with intrahepatic branches. As is the case in radiographic splenoportography (Burchell *et al.*, 1965), the failure to show a patent portal vein might result from diversion of the injection into porto-

systemic collaterals.

On the other hand, the determination of splenic pulp pressure may be as important as visualisation of portosystemic collaterals. Unfortunately, we did not measure the splenic pulp pressure in this investigation because of the danger of the additional risk of severe splenic haemorrhage, and so the relationship between the splenic pulp pressure and the various patterns of portal circulation could not be discussed.

In recent years, the diagnosis of oesophageal varices has been made by endoscopic examination. However, it is very important to investigate oesophageal varices from the haemodynamic point of view, as varices are developed by disturbance of the portal circulation. In this study, oesophageal varices have been investigated both by endoscopic examination and SSP in 81 patients. As shown in Table 2, in detecting oesophageal varices, discrepancies existed between morphological findings by endoscopy and haemodynamic findings by SSP. In three out of 44 patients with oesophageal varices proved by endoscopic examination, SSP failed to show the cephalic collateral flow (6.8%). Such a phenomenon has been also observed in radiographic splenoportography (Greene *et al.*, 1965). Various factors such as the patient's position, flow characteristics of the portal circulation, and holding the breath during the procedure might be implicated. Conversely, in four out of 46 patients with cephalic collateral flow, oesophageal varices could not be observed by endoscopic examination (8.7%). This may be explained by the fact that SSP demonstrates both intramural and para-oesophageal collaterals, whereas endoscopy demonstrates only intramural collaterals. In a small number of cases of group IIc and IIIC, oesophageal varices were not obvious on endoscopic examination, although these cases had advanced liver cirrhosis. In such cases, caudal directional collateral flow may prevent the development of oesophageal varices. Additional accumulation and following up of patients would be necessary to elucidate this point. These results suggest that, in the management of patients with portal hypertension, especially those in whom surgery is contemplated, SSP and endoscopy combined would enable physicians to extract more useful information than either technique on its own.

Therefore, SSP appears to be a clinically useful diagnostic tool, as it provides, easily and safely, accurate information about the functional state of the portal circulation.

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