Hepatic Distribution of Blood Flow from the Superior or Inferior Mesenteric Vein Mapped by Portal Scintigraphy with Iodine-123-Iodoamphetamine

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We previously reported the clinical meaning of measurements of the relative contributions of the superior and inferior mesenteric veins with [^{123}I]iodoamphetamine after oral (in an enteric capsule) and rectal administration. The same method was used to map blood flow in the liver from both of these veins in 82 subjects, 31 with chronic hepatitis and 51 with cirrhosis. **Methods:** Three hours after administration of a capsule containing 22.8 MBq of [^{123}I]iodoamphetamine, data showing hepatic blood flow from the superior mesenteric vein were collected for 10 min. Next, 111 MBq of [^{123}I]iodoamphetamine was administered rectally and data showing hepatic blood flow from the inferior mesenteric vein were collected for 30 min. Shunt indices from the superior and inferior mesenteric veins were calculated from these data. **Results:** In patients with chronic hepatitis, blood from the superior mesenteric vein flowed into the right lobe or both lobes, but, in some patients with cirrhosis, blood from this vein flowed into the left lobe. In some patients with chronic hepatitis, blood from the inferior mesenteric vein flowed into the left lobe, but, in most patients with cirrhosis, the liver was not visualized during this examination and evaluation was not possible. Of the 53 patients in whom blood flow from both veins could be evaluated, 47 had blood from the two veins mixed to some extent in the liver and 6 had portal streamlining, with blood from the superior mesenteric vein going to the right lobe and blood from the inferior mesenteric vein going to the left lobe. **Conclusion:** These results suggest that blood flow in the superior and inferior mesenteric veins can be found mixed in the liver in most subjects with liver disease.

Key Words: portal streamlining; iodine-123-iodoamphetamine; per-rectal portal scintigraphy

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The inferior mesenteric vein (IMV) and the superior mesenteric vein (SMV) unite to form the portal vein. In some canine studies, starting with the study of Serege (*1*), portal streamlining, in which blood from these portal branches does not mix within the portal vein, was found (*2*). That is, blood flowing in the IMV joins that in the splenic vein to supply the left lobe of the liver, and blood flowing in the SMV supplies the right lobe. Another study (*3*) in dogs did not show streamlining. It is generally believed that such streamlining does occur in most healthy human subjects, and clinical evidence suggesting such streamlining has been found. Amebic ulceration of the colon most frequently involves the cecum (*4*). Amebae are carried by the portal vein to the liver, where they produce abscesses. Solitary abscesses occur in the right lobe in about 90% of patients with hepatic involvement (*5,6*). Seventy percent of hydatid liver cysts are in the right lobe (*7*). In both diseases, the predilection for the right lobe may have resulted from streamlining of flow from the SMV.

We previously described the clinical meaning of findings obtained when the relative contribution of the SMV and IMV is measured with simultaneous administration of [^{123}I]iodoamphetamine (IMP) given orally in an enteric capsule and given rectally (*8*). Here, we used the same method to map blood flow in the liver from these two veins.

METHODS

Subjects

We studied 7 healthy volunteers and 82 patients with liver disease, which was diagnosed by examination of liver specimens obtained by laparoscopy or needle biopsy under ultrasonic guidance. Results of the histological examination, which was based on internationally established criteria (*9*), showed that there were 8 patients with chronic persistent hepatitis, 23 patients with chronic aggressive hepatitis, and 51 patients with cirrhosis of the liver. All subjects gave informed consent.

Imaging Protocol

Subjects fasted after dinner the evening before the test and also took laxatives. A capsule containing 22.8 MBq [^{123}I]IMP was taken before breakfast, and the test was performed 3 hr later. The capsule dissolves at pH > 5.7. The subjects lay supine and a polyethylene tube was inserted into the rectum. The camera was positioned over the subject's abdomen so that the field of view included the lungs and liver. Data from the first 10 min of the test were gathered by a data-processing apparatus for radiological data, and a summed image was displayed in color. The region of interest in the liver was outlined with reference to a previously acquired ^{99m}Tc-phytate scintigram. During this same 10-min period, time-activity curves for the liver and lungs were made. The portal shunt index through the small intestine (through the SMV) was calculated by:

$$\text{Shunt index through the SMV} = \frac{\text{Count for lungs}}{\text{Count for lungs} + \text{count for liver}} \times 100\%$$

with the counts for the lungs and liver in equilibrium.

Iodine-123-IMP (111 MBq) with 15 ml of air was injected into the upper rectum through the tube. Time-activity curves for the liver and lungs were produced on the same data-processing apparatus for 30 min starting at the time of the injection. The data during this time were corrected by subtraction of the values recorded in the 30-sec period immediately before injection and a summed image was displayed in color. The ratio of the liver and lung counts was unchanged after at least 20 min had passed, so we used the following expression:

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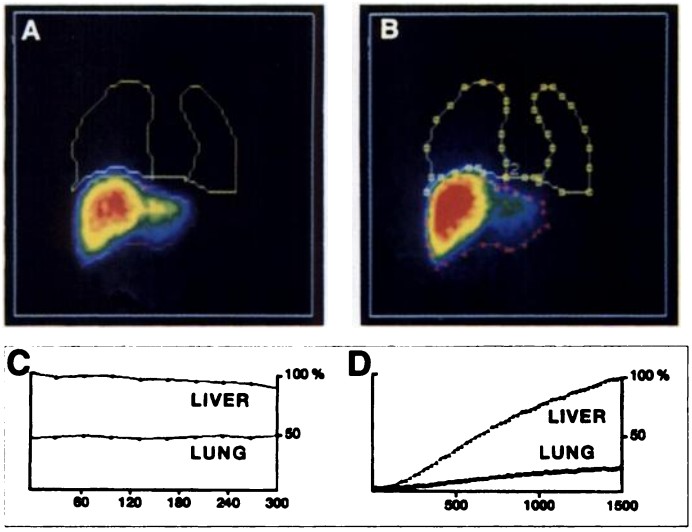

FIGURE 1. Blood from the SMV and IMV supplying the right lobe of the liver. (A) Ten-minute color image for the liver (red) and lungs (yellow) after oral administration of [^{123}I]IMP (Patient 1; SI-S, 30%). (B) Thirty-minute color image obtained after per-rectal administration of [^{123}I]IMP (Patient 1; SI-I, 21%). (C, D) Time-activity curves for A and B, respectively.

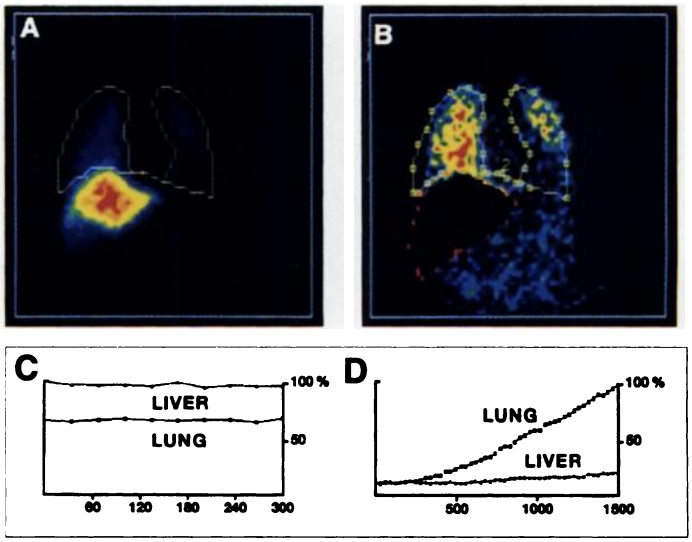

FIGURE 3. Blood from the SMV supplying the left lobe of the liver; that from the IMV is not detected in the liver. (A) Ten-minute color image for the liver (red) and lungs (yellow) after oral administration of [^{123}I]IMP (Patient 3; SI-S, 37%). (B) Thirty-minute color image obtained after per-rectal administration of [^{123}I]IMP (Patient 3; SI-I, 86%). (C, D) Time-activity curves for A and B, respectively.

$$\frac{\text{Count for lungs at 20–30 min}}{(\text{Count for lungs} + \text{count for liver}) \text{ at 20–30 min}} \times 100\%$$

as the portal shunt index through the rectum (through the IMV) (*8*).

Statistical Analysis

Results are expressed as medians with 25th and 75th percentiles. The significance of differences between the means was evaluated by the Mann-Whitney U-test (two-tailed). Differences with probability values of less than 0.05 were considered to be significant.

RESULTS

The three most common patterns of blood flow are described as follows.

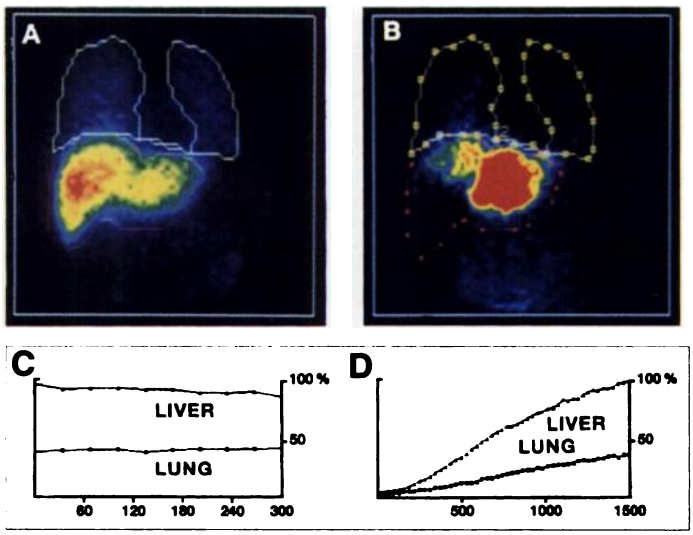

FIGURE 2. Blood from the SMV supplying the right lobe of the liver and that from the IMV supplying the left lobe. (A) Ten-minute color image for the liver (red) and lungs (yellow) after oral administration of [^{123}I]IMP (Patient 2; SI-S, 26%). (B) Thirty-minute color image obtained after per-rectal administration of [^{123}I]IMP (Patient 2; SI-I, 34%). (C, D) Time-activity curves for A and B, respectively.

Patient 1. In a 55-yr-old woman with chronic aggressive hepatitis, the blood flow from both the SMV and the IMV supplied the right lobe of the liver. The portal shunt index through the SMV (SI-S) was 30% and that through the IMV (SI-I) was 21% (Fig. 1).

Patient 2. In a 62-yr-old man with cirrhosis, the blood flow from the SMV supplied the right lobe of the liver and that from the IMV supplied the left lobe. The SI-S was 26% and the SI-I was 34% (Fig. 2).

Patient 3. In a 64-yr-old woman with cirrhosis, the blood flow from the SMV supplied the left lobe of the liver, but blood flow from the IMV was not found in the liver. The SI-S was 37% and the SI-I was 86% (Fig. 3).

In the 31 patients with chronic hepatitis, blood from the SMV supplied the right lobe in 18 patients and both lobes in 13 patients (Table 1); the SMV did not supply the left lobe in any of these patients. In the 51 patients with cirrhosis, however, the SMV supplied the left lobe in 12 (24%). When the blood flow from the IMV was being tested, the liver was not visualized in 29 (57%) patients with cirrhosis; only the lungs appeared (Table 2). When those patients were not considered, however, no significant difference was seen between the patterns in chronic hepatitis or cirrhosis.

TABLE 1
Liver Blood Distribution from the Superior Mesenteric Vein in Study Subjects

Subjects	No (%) with blood flow from SMV supplying: Right lobe	Both lobes	Left lobe	Total
Controls	3 (43)	4 (57)	0 (0)	7
Patients with CH	18 (58)	13 (42)	0 (0)	31
Patients with cirrhosis	20 (39)	19 (37)	12 (24)	51

CH = chronic hepatitis.

TABLE 2
Liver Blood Distribution from the Inferior Mesenteric Vein in Study Subjects

Subjects	No. (%) with blood from IMV supplying				
	Right lobe	Both lobes	Left lobe	Lungs	Total
Controls	3 (43)	4 (57)	0 (0)	0 (0)	7
Patients with CH	13 (42)	12 (39)	6 (19)	0 (0)	31
Patients with cirrhosis*	10 (20)	9 (18)	3 (6)	29 (57)	51

*Total does not equal 100% because of rounding off.
CH = chronic hepatitis.

TABLE 5
Relationship of Blood Distribution Patterns from Inferior Mesenteric Vein with Laboratory Test Results

IMV to	Albumin (g/dl)	PT (%)	Platelets (/mm³)	ALT (IU/L)
Right lobe	3.8 (3.6, 4.0)	88 (82, 94)	15.7 (10.6, 19.2)	153 (68, 213)
Both lobes	4.0 (3.6, 4.2)	100 (90, 103)	16.4 (11.5, 19.6)	86 (42, 171)
Left lobe	3.9 (3.8, 4.2)	94 (72, 104)	14.6 (10.7, 17.2)	105 (50, 229)
Lung	3.3 (3.0, 3.5)*	75 (62, 88)*	10.1 (6.9, 13.6)*	88 (43, 136)

*$p < 0.001$ compared with values in all three rows above, Mann-Whitney U-test.
PT = prothrombin time; ALT = alanine aminotransferase. The results are expressed as medians (25th and 75th percentiles).

There were six patients in whom streamlining (blood from the SMV supplying the right lobe and blood from the IMV supplying the left lobe) was seen (Table 3). This group comprised 11% of the 53 patients in whom blood distribution from both the SMV and IMV could be evaluated. There were no patients with reversed streamlining.

The median albumin concentration, prothrombin time and platelet count of patients whose blood distribution from the SMV was to the left lobe of the liver were lower than these medians of the patients whose blood distribution from the SMV was to the right lobe or to both lobes ($p < 0.05$; Table 4). The mean albumin concentration, prothrombin time and platelet count of patients whose blood distribution from the IMV was to the lungs were lower than the means of the patients whose blood distribution from the IMV was to the right lobe, the left lobe or both lobes ($p < 0.001$; Table 5).

TABLE 3
Liver Blood Distribution from the Superior and Inferior Mesenteric Veins

*	No. (%) with blood from IMV supplying				
	Right lobe	Both lobes	Left lobe	Lungs	Total
Right lobe	18 (47)	4 (11)	6 (16)	10 (26)	38
Both lobes	5 (16)	15 (47)	2 (6)	10 (31)	32
Left lobe	0 (0)	2 (17)	1 (8)	9 (75)	12

* Rows show no. (%) with blood from SMV supplying regions indicated.

TABLE 4
Relationship of Blood Distribution Patterns from the Superior Mesenteric Vein and Laboratory Test Results

SMV to	Albumin (g/dl)	PT (%)	Platelets (/mm³)	ALT (IU/liter)
Right lobe	3.8 (3.4, 4.0)	88 (75, 95)	14.1 (10.2, 18.4)	117 (68, 207)
Both lobes	3.8 (3.3, 4.0)	93 (78, 101)	14.8 (9.9, 18.4)	83 (35, 178)
Left lobe	3.3 (2.9, 3.6)*	75 (66, 89)*	9.8 (7.3, 12.4)*	91 (44, 114)

*$p < 0.05$ compared with values in both rows above, Mann-Whitney U-test.
PT = prothrombin time; ALT = alanine aminotransferase. The results are expressed as medians (25th and 75th percentiles).

The median SI-S (25th and 75th percentiles) was 19.5% (11.7, 26.0) when the SMV supplied the right lobe, 21.0% (7.3, 34.1) when the SMV supplied both lobes and 33.5% (26.6, 39.4) when the SMV supplied the left lobe (Fig. 4). This third SI-S was significantly higher than the first and second SI-S.

The median SI-I (25th and 75th percentiles) was 16.0% (8.0, 45.7) when the IMV supplied the right lobe, 15.0% (8.0, 56.5) when the IMV supplied both lobes and 15.0% (13.1, 39.7) when the IMV supplied the left lobe (Fig. 5); the differences were not significant. As expected, the SI-I was high when the IMV supplied the lungs alone.

DISCUSSION

In 1901, Serege (*1*) reported injecting India ink into the portal branches of dogs, finding that splenic blood supplied the left lobe of the liver, with mesenteric blood supplying the right lobe. Hahn et al. (*2*) injected radioactive phosphoric acid into portal branches of dogs and found streamlining of blood flow in the splenic vein to the left lobe and in the mesenteric vein to the right lobe. They suggested that the movement of tumor emboli might be affected by this pattern of flow and observed that primary intestinal malignancies result in liver metastases mainly in the right lobe.

Atkinson et al. (*10*) found that streamlining might be present at the start of the portal vein but suggested that the separate channels mixed before the liver was reached. The high-pressure

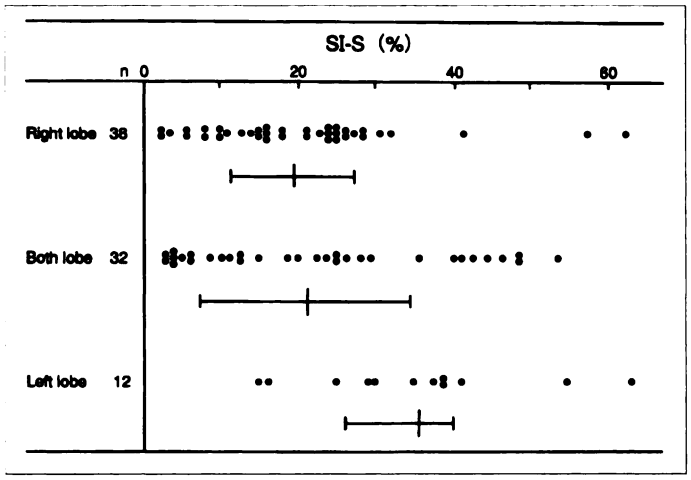

FIGURE 4. Intrahepatic blood flow distribution from the SMV and SI-S. The SI-S, when the SMV supplied the left lobe, was higher than when it supplied the right lobe or both lobes ($p < 0.01$).

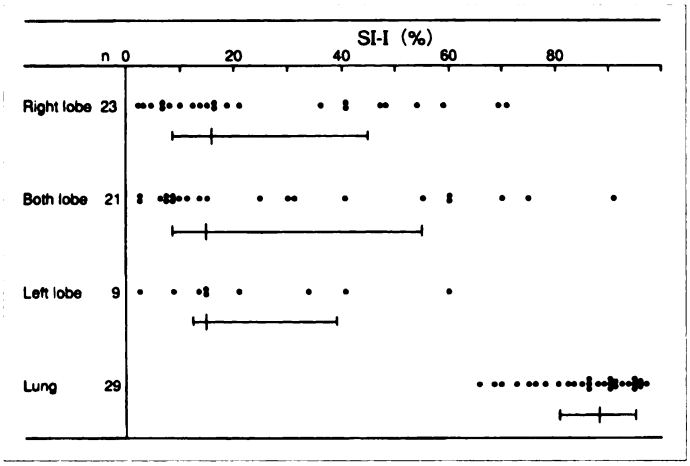

FIGURE 5. Intrahepatic blood flow distribution from the IMV and SI-I. The SI-I, when the IMV supplied the right lobe, the left lobe and both lobes was not significantly different. When the IMV supplied the lungs only, the SI-I was higher than SI-Is in the other three groups ($p < 0.0001$).

injection of a considerable volume is done during portography, which may increase flow volume and velocity, diminish streamlining and cause filling of the portal venous bed (*10,11*). Gates and Dore (*12*) injected ^{198}Au-labeled colloid into a mesenteric vein and found that blood flow in the portal vein moves to the right lobe when injection is into a subdivision of the SMV. They injected small volumes slowly to prevent the problems that arose in earlier studies.

Kashiwagi et al. (*13*) did similar research by injecting a small amount of ^{133}Xe into the spleen. They found that portal blood was not evenly mixed when tracked to the liver. Their study design enabled them to observe the dynamics of portal blood flow under almost physiological conditions, since the small amount of isotope used does not require high pressure when injected.

Per-rectal portal scintigraphy has been used to measure the portal circulation with a radionuclide, and studies have shown its clinical usefulness (*14–17*). Per-rectal portal scintigraphy allows a visual grasp of the state of portal hypertension. In many subjects with this condition, however, the radionuclide does not flow into the portal system due to increased resistance in the liver. It flows instead into the inferior vena cava through collateral routes. Visualization of the route of portal blood flow is difficult in such patients, and evaluation of hemodynamic abnormalities is not easy.

Measurement of the blood flow of the SMV is essential for the evaluation of portal circulation. Portal blood flow consists mainly of blood flow of the SMV and that of the splenic vein, including that of the IMV. The ratio of the two in healthy subjects is about 1:1 (*18,19*). The hemodynamics of the IMV can be evaluated by the conventional per-rectal method, but the approach through the small intestine allows evaluation of the hemodynamics of the SMV. The combination of results by these two methods would give more accurate information than the use of data from either method alone.

Iodine-123-IMP is small enough to be absorbed readily by the gut, and it is carried through the portal system into the liver. In dogs, more than 90% of IMP injected directly into the portal vein is taken up by the liver (*20*). The shunt fraction calculated from counts obtained after injection of IMP or macroaggregated albumin are highly correlated (*20*), so IMP is suitable in this examination.

We previously established a method for evaluation of portal circulation from the IMV and SMV by simultaneous injection of IMP orally and rectally (*8*). In this study, we used this method to study the distribution of portal blood flow within the liver under nearly physiological conditions. Our study showed that the blood flow from the SMV did not supply the right lobe in all patients and that blood flow from the IMV did not necessarily supply the left lobe. Streamlined flow was found in only six patients (11%). One possible explanation might be variation in the branching of the blood vessels: the IMV does not join with the splenic vein in all subjects but may join with the SMV or with the site where the splenic vein joins the SMV. The blood flow from the SMV did not supply the left lobe in any of the patients with chronic hepatitis, but it did in 12 (24%) of the patients with cirrhosis. In addition, in patients with cirrhosis, the portal blood flow was streamlined in a smaller proportion than in the patients with chronic hepatitis. The SI-S in the group in whom blood from the SMV supplied the left lobe was significantly higher than that in the group in whom blood from the SMV supplied the right lobe or both lobes. Portal blood flow seems to be more abnormal in cirrhosis than in chronic hepatitis because of intrahepatic or extrahepatic shunt formation and higher portal pressure.

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