Coincidence Positron Imaging of the Liver and Heart following Rectal Administration of ^{13}N -ammonia in Liver Cirrhosis[†]

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Rectal administration of ammonium salt as done in the rectal ammonia tolerance test, is followed by rapid absorption of ammonia, which is cleared by the normal liver in a single passage¹⁾. Therefore, ammonia concentration in blood should not rise appreciably in the hepatic vein and systemic arteries.

In the presence of porta-systematic collaterals, some of the absorbed ammonia will bypass the hepatic cells through intra-and/or extrahepatic shunts and go into systemic circulation, thus resulting in an elevation of arterial concentration of ammonia.

^{13}N -ammonia is a short-lived ($T_{1/2}=10$ min) cyclotron produced β^+ emitter.

We expected that sequential coincidence positron imaging of the liver and heart following rectal administration of ^{13}N -ammonia would be of diagnostic value in patients with liver cirrhosis or idiopathic portal hypertension.

Recently, Hazenberg, et al. reported on rectal ^{13}N -ammonia test (^{13}N -liver/heart ratio) by using a conventional Anger type γ -camera with a 1000 hole high energy collimator and a 4096 channel analyzer with a magnetic tape

recorder for body measurement^{2),3)}. Under these conditions, the spatial resolution of their detecting system, seems to be insufficient for the determination of ^{13}N -liver/heart ratio.

Unlike their instrumentation, we used a novel type positron camera which has enough spatial resolution for the same purpose.

1. Materials and Methods

1) Production of ^{13}N -labeled ammonia⁴⁾

Irradiation was carried out on the NIRS cyclotron. Distilled water was bombarded with a 20 μA external proton beam of 20 MeV.

The ^{13}N -containing solution was introduced into a reduction vessel containing Devarda's alloy and NaOH, and ^{13}N -labeled ammonia was isolated by distillation into a vessel containing 5 ml of a 0.9% $(\text{NH}_4)_2\text{CO}_3$ solution.

2) Apparatus⁵⁾

A new positron camera interfaced with an on-line computer system (TOSBAC 3400 model 31) consisting of a focal detector of hexagonal multi-crystal array and a conventional Anger-type γ -camera (TOSHIBA, GCA-202, delayed line type), was used for positron imaging of the liver and heart.

Some characteristics of the positron camera are; (1) maximum attainable high counting rate of about 2.55 kcps, (2) detec-

[†] ^{13}N -アンモニアの経直腸投与後の肝硬変患者の肝と心の同時計数陽電子イメージング。福田信男, 館野之男, 力武知之, 松本徹, 富谷武浩, 鈴木和年, 高圓博文*, 武者広隆*, 奥田邦雄*: 放射線医学総合研究所, 280 千葉市穴川4-9-1, * 千葉大学医学部第一内科, 280 千葉市亥鼻町1-8-1

Table 1 Wedged hepatic venous pressure (WHVP), portal venous pressure (PVP), percentage retention* of indocyanine green 15 min after i.v. injection ($ICG^{(R15)}$), and the heart/liver ratio of ^{15}N -activity per unit area 15 min after rectal administration of ^{15}N -ammonia (H/L_{15})

Name	Sex	Age	Clinical diagnosis	Grade of varices	Ascites	serum γ -globulin (%)	WHVP (mm H_2O)	PVP (mm H_2O)	$ICG^{(R15)}$ (%)	H/L_{15}
T. O.	F	68	Essential tremor	(-)	(-)	11.6				0.18
F. T.	M	35	Essential hypertension	(-)	(-)					0.43
B. Y.	M	70	Convalescent stage of acute hepatitis	(-)	(-)	15.5			16.0	0.2
H. I.	F	50	"	(-)	(-)	21.6			7.5	0.17
T. I.	F	46	Chronic hepatitis	(-)	(-)	18.0			5.0	0.40
I. S.	M	59	"	(-)	(-)	24.0			17.0	0.35
Y. S.	M	44	"	(-)	(-)	19.8			14.5	0.32
Y. K.	F	48	Liver cirrhosis	(III)	(±)	32.5	370		62.5	0.81
T. U.	M	45	"	(III)	(-)	31.8	330	340	30.0	0.66
M. S.	M	41	"	(+)	(-)	32.4	320		65.0	0.72
S. H.	M	42	"	(+)	(-)	21.6	280		34.0	0.53
T. N.	M	43	"	(+)	(+)		370		40.5	1.29
Y. N.	M	33	"	(+)	(+)	28.7	120	290	48.5	1.11
H. T.	M	49	"	(+)	(±)	33	380	402	21.0	1.12
T. Y.	F	46	"		(+)	35.2	400		59.0	0.88
M. N.	F	57	Idiopathic portal hypertension	(+)	(-)		205		27.5	0.90
M. H.	F	46	"	(+)	(-)	16.9	110	340	4.0	0.73
T. H.	M	35	"	(III)	(-)	17.9	130	410	8.0	0.70

tion efficiency of 0.6~0.9 dots/sec/ μCi , (3) spatial resolution of 6~9 mm(FWHM)(those figures depend on the distance from the collimator surface of the γ -camera to source), and (4) area of uniform sensitivity of about 20 cm in diameter at the depth of 20 cm from collimator surface.

3) Procedure

Fifteen-thirty mCi of ^{15}N -ammonia dissolved in 10 ml of a solution buffered at pH 8.1 (Na^+ : 130 mEq/l, K^+ : 20 mEq/l, Cl^- : 100 mEq/l, HCO_3^- : 50 mEq/l) was administered via a catheter into the rectum previously cleaned by enema. The localization of the liver and heart had previously been determined by ^{99m}Tc -phytate imaging and ^{99m}Tc -phytate angiography, respectively.

4) Patients (Table 1)

The control group (patient without varices and ascites) consisted of a patient with essential tremor, a patient with essential hypertension, three patients with chronic hepatitis and two patients in the convales-

cent stage of acute hepatitis. Eight patients with liver cirrhosis, and three patients with idiopathic portal hypertension were also studied.

2. Results

In all subjects, ^{15}N -radioactivity appeared in the liver in about 1 min after rectal administration of ^{15}N -ammonia.

In control subjects, ^{15}N -liver activity reached a maximum in about 20 min and then decreased gradually; the heart activity was much lower and increased gradually up to 50 min. A typical example of sequential positron imaging of the liver and heart in a control subjects (T.O.) is shown in Fig. 1A. ^{15}N -radioactivity clearly visualized the liver within 5 min after administration while it was difficult to discriminate the heart image.

In patients with liver cirrhosis expected to have porta-systemic collateral circulation, however, it was difficult to discriminate the faint liver image from the lung and the

heart image as shown in Fig. 1B. The liver activity in the patient with cirrhosis continued to increase following the rapid rise during the first 10 min. The radioactivity per unit area at 15 min after rectal administration of ^{13}N -ammonia are shown with the other data in Table 1.

3. Discussion

This work was undertaken to evaluate the relevance of sequential coincidence positron imaging of the liver and heart following rectal administration of ^{13}N -ammonia for the detection of porta-systemic collateral circulation. While conclusive comment is not yet in order because of inadequate case studies in the present work, the accumulation of ^{13}N -ammonia to the liver with cirrhosis was found to be much lower than that in the control without varices and ascites. It may be attributed to porta-systemic collateral cir-

culcation and decreased effective intrahepatic portal vascularity, as well as to reduced number of functioning hepatocytes in liver cirrhosis.

The heart activity in liver cirrhosis seems to be much higher than the control. It may represent accumulation of ^{13}N -ammonia by-passing the hepatocytes in the liver with cirrhosis to reach the cardiac muscle which is known to take up ammonia efficiently⁶.

In the evaluation of porta-systemic collateral circulation, determination of ^{13}N -heart/liver ratio overcomes difficulty associated with the variations in dosage and absorption in each patient. The observed increase in this ratio in cirrhosis may reflect the hepatofugal circulation and decreased intrahepatic portal vascularity, and decreased number of functioning hepatocytes, and have a significance different from that of dye retention tests.

Fig. 1 Sequential coincidence positron image of the liver and heart following rectal administration of ^{13}N -ammonia with $^{99\text{m}}\text{Tc}$ -phytate image and the illustration.

A. A patient (T.O.) with essential tremor.

B. A patient (Y.K.) with liver cirrhosis.

The present method is commendable for its non-invasiveness, quick radiation decay, and rapidity in having the results.

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