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# Exploring a technique for reducing the influence of scattered rays from surrounding organs to the heart during myocardial perfusion scintigraphy with technetium-99m sestamibi and technetium-99m tetrofosmin

Hajime MONZEN,* Masatake HARA,** Makoto HIRATA,* Akira NAKANISHI,* Makoto OGASAWARA,* Takatoshi SUZUKI,* Tamie SATO,** Hisashi SHIMOYAMA,** Futoshi TADEHARA,*** Kunihiko HIROSE** and Rumio YUKI*

**Department of Radiology, Otsu Red Cross Hospital*
***Department of Cardiology, Otsu Red Cross Hospital*
****Department of Internal Medicine, Kure Kyosai Hospital*

We have devised a new position (Monzen position) which can suppress the influence of scattered rays from surrounding organs (liver, etc.) when conducting myocardial imaging. Unlike the conventional techniques, which require a waiting period of 30–60 minutes before imaging can be started after the infusion of technetium-99m sestamibi or technetium-99m tetrofosmin, this position allows single-photon emission tomography to be started about 5–10 minutes after the infusion of the tracer. Therefore, with this technique the total time required for imaging is reduced and consequently the physical and mental burden of the patient is also reduced. Furthermore, the number of patients who can receive this test at any facility can be increased. This position may also be applicable in myocardial scintigraphy using some other tracers.

**Key words:** single-photon emission tomography, technetium-99m sestamibi, technetium-99m tetrofosmin, body position, scattered rays

## INTRODUCTION

IN JAPAN, tracers such as technetium-99m sestamibi ($^{99m}$Tc-MIBI), technetium-99m tetrofosmin ($^{99m}$Tc-TF), thallium-201 chloride ($^{201}$Tl), iodo-123 meta-iodobenzylguanidine ($^{123}$I-MIBG) and iodo-123 beta-methyl-iodophenyl pentadecanoic acid ($^{123}$I-BMIPP) have been clinically used in cardiac nuclear medicine studies. When $^{99m}$Tc or $^{123}$I is used for scintigraphy, evaluation of some areas of the heart such as the inferior wall and the apex cordis is sometimes hampered by factors such as scattered rays emitted from the tracer accumulated in the liver, gallbladder and other organs. It is known that during image reconstruction involving filtered back-projection (FBP), excessive accumulation of the tracer in the liver can lead to underestimation of myocardial radioactivity in the area close to the liver.[1] To avoid the influence of this radioactivity, imaging must be started after complete clearance of the tracer from the liver, thus extending the time needed for this test.[2] To overcome these problems, several methods of image reconstruction such as ordered subset expectation maximization (OSEM) have been developed and have been used at some facilities.[3–5] However, these methods have not yielded satisfactory results. In addition to these methods, another method has been devised, by which the patient ingests 16 oz (about 500 m*l*) of water immediately before the start of myocardial perfusion SPECT to inflate his/her stomach so that the liver can be displaced downwards and away from the visual field for evaluation of the heart.[6] Yet, in our experience, this method does not contribute to a satisfactory improvement of the image quality either. Still more, this method, which necessitates massive water ingestion by the patient, is risky for patients with heart failure or compromised cardiac function.[7]

Under these circumstances, we investigated a new position for patients on the gamma camera bed during

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For reprint contact: Hajime Monzen Ph.D., Department of Radiology, Otsu Red Cross Hospital, 1–1–35, Nagara, Otsu, Shiga 520–8511, JAPAN.

SPECT in which the distance between the liver and heart increases, minimizing the influence of the liver on myocardial SPECT. With the conventional techniques of myocardial SPECT, 30–60 minutes is required before imaging after intravenous infusion of $^{99m}$Tc-MIBI or $^{99m}$Tc-TF. In this new position, the waiting period can be shortened to about 5–10 minutes.

## METHODS

*Body position*

The patient is asked to lie in the supine position on the gamma camera bed, with the right arm placed along the body and the left arm raised high towards the head (a position resembling the posture taken by a backstroke swimmer). The buttocks are slid to the left edge of the gamma camera bed and the upper half of the body is curved to the right. We have named this position "Monzen position" (Photo 1).

*Apparatus*

A two-detector type PRISM-AXIS (Shimadzu, Kyoto, Japan) and a three-detector type PRISM-IRIX (Shimadzu, Kyoto, Japan) were used in combination with a Low Energy High Resolution parallel-hole collimator (LEHR-Par). Data on projected images were collected under the following conditions: (1) matrix 64 × 64, (2) internal angle of detector 78 degrees (only two detectors were used when a 3-detector type device was used), (3) angle of rotation 102 degrees, (4) either a combination of step angle 5.1 degrees/20 directions and collection time 25 sec/step (total testing time 9.9 min) or a combination of step angle 6.0 degrees/17 directions and collection time 37.5 sec/step (total testing time 13.1 min) (Fig. 1) and (5) energy window 140 keV ± 15%.

Data thus collected were processed using an Odyssey LX (Picker International, Inc., Bedford Heights, OH). Data were pre-processed with a Butterworth Filter (Order 8.0, Cut-off 0.12–0.20). A Ramp Filter was employed for image reconstruction. Reconstructed images with a slice thickness of 6.28 mm were obtained with FBP. We did not incorporate Chang's correction for attenuation or similar correction.

*Phantom study*

To investigate the influence of high tracer accumulation in the liver on imaging of the heart, we evaluated the influence of varying degrees of overlaps between the upper edge of the liver and the lower edge of the heart on reconstructed images, using a heart/liver phantom (HR-2, myocardial volume 124.3 m*l*, Kyotokagaku Co., Ltd., Kyoto, Japan).

A 2 m*l* defect chip was inserted into the side wall to simulate a defect. In view of the previous reports that about 2% of the administered tracer accumulates in the myocardium,[8,9] we assumed the clinical dose level to be 200 MBq and infused about 4 MBq (30 kBq/m*l*) of the tracer into the myocardial phantom. Because the liver/heart ratio in clinical cases is about 1.5–15, we adopted the ratio of 6 (intermediate between 1.5 and 15) and set the tracer level in the liver at 180 kBq/m*l*, equivalent to 6 times the level in the myocardial phantom.

Planar and SPECT imagings were performed under two settings. Under setting 1, the lower edge of the heart and the upper edge of the liver were placed horizontal to the body axis. Under setting 2, the heart position was deviated by 5 mm in the upward direction as compared to that in setting 1. Planar images were compared using profile curves, while SPECT images were compared visually.

*Clinical study*

Between October 13, 2005 and January 13, 2006, seventy-four patients (mean age: 63.4 ± 8.9 years) underwent myocardial perfusion scintigraphy in our hospital under the diagnosis of suspected angina pectoris, old myocardial infarction or cardiomyopathy. The tracer used was $^{99m}$Tc-MIBI in 31 patients and $^{99m}$Tc-TF in 43 patients. In 35 of these 74 patients, imaging was conducted with the patient in the conventional position (raising both arms during imaging) and the Monzen position. These 35 patients were the subjects of this study. Planar imaging was conducted as follows. First, imaging was conducted according to the conventional position, beginning 10 minutes after intravenous infusion of $^{99m}$Tc-MIBI or $^{99m}$Tc-TF (pre-set time: 1 min). This was followed by imaging in the Monzen position (pre-set time: 1 min). A profile curve was depicted for the range corresponding to the visual field of the heart to be reconstructed, and the radioactivity in the heart was compared with that in the liver. SPECT imaging was performed after planar imaging (first in the Monzen position for 10 minutes and then in the conventional position for 10 minutes).

*Magnetic resonance imaging (MRI)*

In 10 volunteers, the abdomen was imaged in both the conventional position and the Monzen position to examine the anatomical relationship of the liver with the heart. Imaging conditions to measure the heart-liver distance, Sequence: B-TFE, TR: 2.9 ms, TE: 1.5 ms, FA: 80, slice: 20 slices, thickness: 7 mm/0.7 mm, gap, FOV: 500 mm, Matrix 256 × 256, scanning time: 20 sec, NSA: 1, Coil: Q-body. Coronal images perpendicular to the axis of the system were taken.

*Method of measurement with MRI*

(a) Conventional position

Imaging under the above-mentioned conditions, with both arms kept raised. On the cross-section in which the left part of the heart is located lowest along the Y-axis, a line horizontal to the X-axis and perpendicular to the Y-Z axis was drawn over the right lung-diaphragma region. Then, the distance from this line to the myocardium

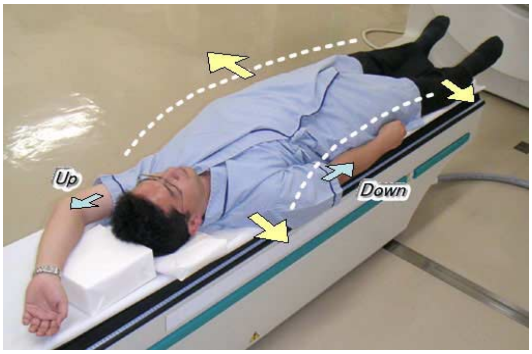


**Photo 1** Monzen position. This position is characterized by the slight curving of the body to the right.

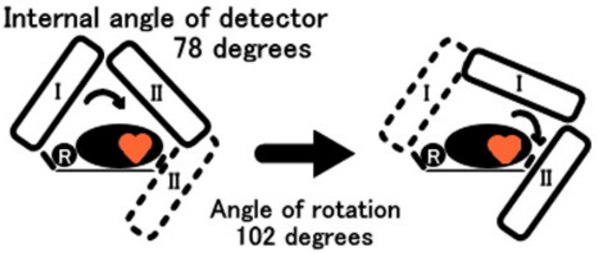


**Fig. 1** Data collection for 180 degrees with a two-detector system. Imaging is not affected even when the right arm is not raised.

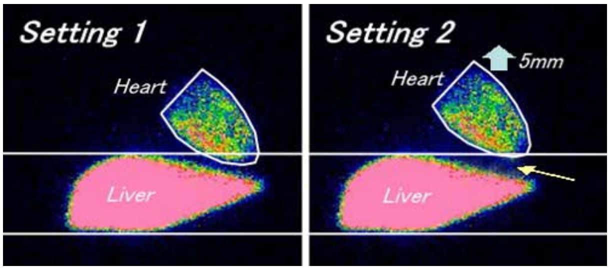


**Fig. 2** Phantom study. A: The lower edge of the heart is at the same level as the upper edge of the liver. B: The heart appears 5 mm upwards from its location in position A. (FWHM 6.68 mm, FWTM 12.98 mm, 100 mm in air gap)

located lowest along the Y-axis was measured within the same cross-section. Overlapping was marked “+” and absence of overlapping was marked “–”.

(b) Monzen position

The right arm was kept down, the left arm was raised, and the buttocks were placed near the left end of the bed. The method of measurement was the same as the one used with the conventional position.

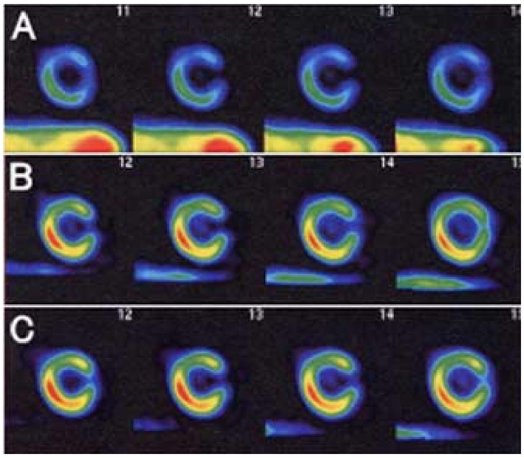


**Fig. 3** SPECT images obtained in the positions shown in Figure 2. A, Position A in Figure 2: Truncation (–). B, Position A in Figure 2: Truncation (+). C, Position B in Figure 2: Truncation (–).

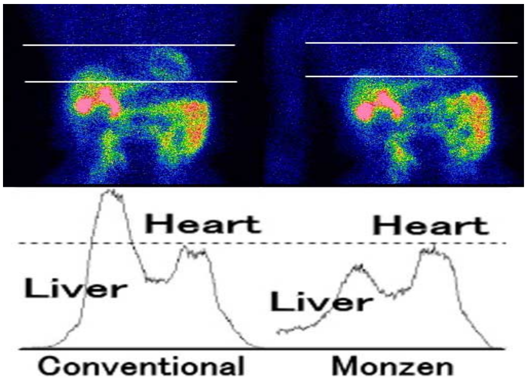


**Fig. 4** Curves prepared from planar images. While the conventional body position displayed a high count, Monzen body position provided a low count. That difference in counts indicates the increased distance between liver and heart.

## RESULTS

*Phantom study*

As shown in Figure 2 (planar images), the phantom study was performed under two settings: (A) 0 mm in the vertical direction (Setting 1: *left*) and (B) 5 mm in the vertical direction (Setting 2: *right*). The presence/absence of overlaps of the upper edge of the liver with the lower edge of the heart is clearly visible. Figure 3 shows the SPECT images in these cases. Figure 3A corresponds to Setting 1, i.e., the image reconstructed with the ordinary method. The quality of the heart image was low under the influence of the tracer in the liver. Figure 3B is an image obtained by vertical reconstruction by means of truncation and masking of the tracer accumulated in the liver under Setting 1. Figure 3C is a reconstructed image of higher quality obtained under Setting 2, in which the influence from the tracer in the liver was minimal because the vertical distance between the heart and liver was as large as 5 mm.

*Clinical study*

Figure 4 shows the curves prepared from the planar images of a patient in whom this position proved useful.

With the conventional position (Fig. 4A), a high level of tracer accumulation in the liver overlapped with the heart on the reconstructed image, and caused an artifact. With the Monzen position (Fig. 4B), there was no overlap of the liver with the heart, except for minimal contamination by the scattered rays from the liver. Furthermore, the gall-bladder with high trace accumulation was shifted downwards in the Monzen position, thus yielding an artifact-free reconstructed image.

Figure 5 shows images reconstructed from SPECT data collected in the Monzen position (*upper*) and the conventional position (*lower*). Imaging in the Monzen position was performed at an early point of time when the influence of the scattered rays from the liver seemed to be large.

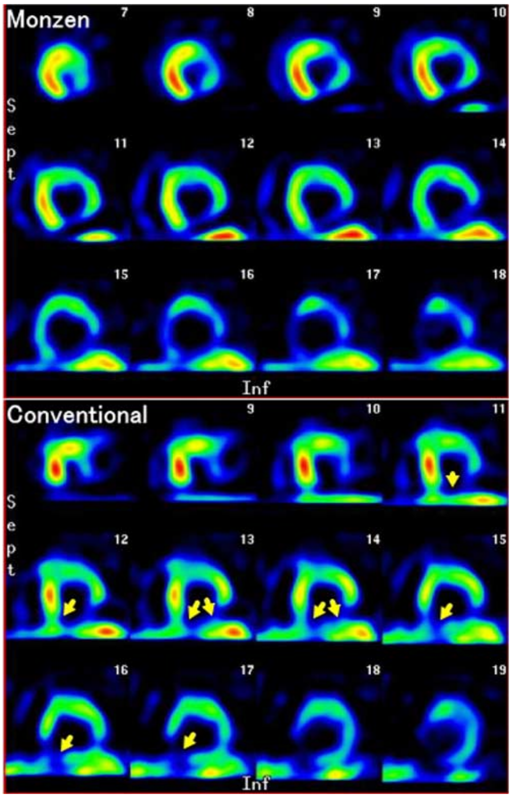


**Fig. 5** Images reconstructed from SPECT data collected in the Monzen and conventional positions. *upper:* Monzen position. *lower:* Conventional position. Diagnosis of the inferior wall and apex cordis impossible in conventional position (*arrow*).

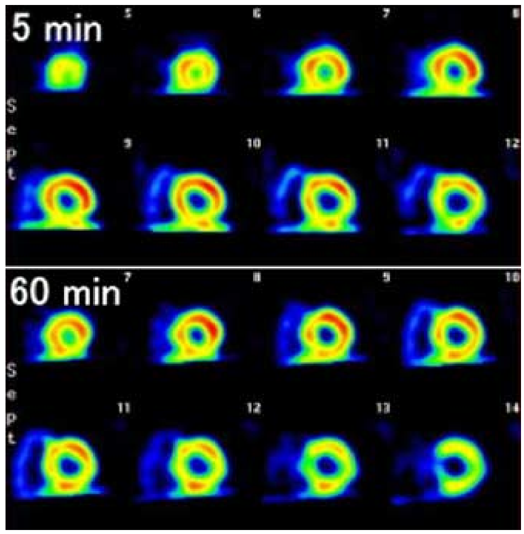


**Fig. 6** Images taken in the Monzen position. *Upper:* 5 minutes after the intravenous infusion of a technetium preparation. *Lower:* One hour after the intravenous infusion of a technetium preparation.

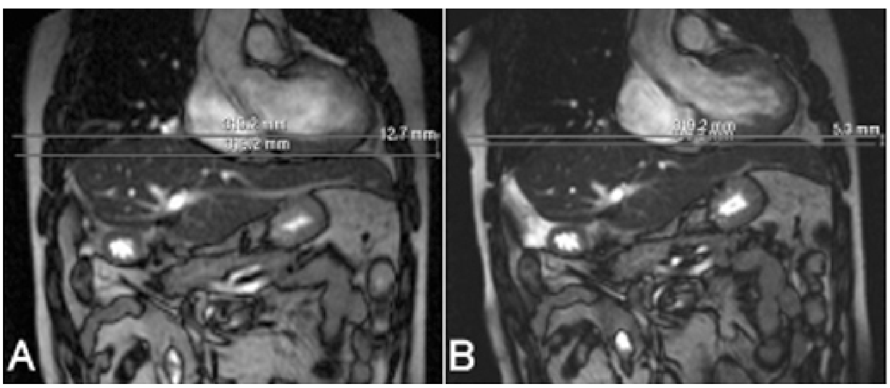


**Fig. 7** MRI coronal imaging. Reduced overlap of the heart and liver. A: Conventional position. B: Monzen position. As shown above, Monzen body position in Figure 7-B lessened the distance between liver and heart from 5.3 mm to 12.7 mm in comparison with the conventional body position in Figure 7-A. The Gallbladder tended to follow liver as liver moved away from the heart in Monzen position.

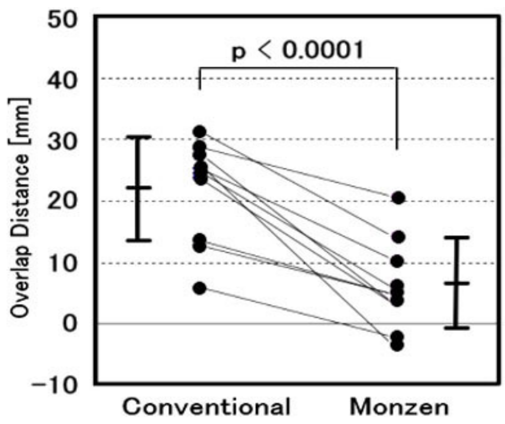


**Fig. 8** Comparison of overlap distance between liver and heart in MRI images with conventional position vs. Monzen position. Statistical analyses were performed using the Student's t-test.

Imaging with the conventional position was performed immediately after imaging with the Monzen method. On the image obtained with the Monzen method, the liver is clearly discernable from the heart. Adequate evaluation was possible using the image taken with the Monzen position even when the time elapsed after the intravenous injection of the tracer was shortened. With the conventional position, however, the influence of trace accumulation in the liver, gallbladder, etc. was important even at 20 minutes or more after the intravenous dosing of the tracer, and there was a large overlap of the upper edge of the liver on the lower edge of the heart, making adequate evaluation.

Figure 6 shows images taken in the Monzen position in another patient 5 minutes and one hour after the intravenous infusion of a technetium preparation. The tracer had already been incorporated into the myocardium at 5 minutes, yielding an artifact-free image. This allows us to conclude that there is no clinical problem in starting imaging 5 minutes after the intravenous infusion of the technetium preparation. Besides, in other patients the artifact due to tracer accumulation in the liver was reduced or absent. When myocardial perfusion scintigraphy was performed in the conventional position, the images obtained often did not allow adequate evaluation. With the new position we have devised, evaluation was impossible in only 2 of the 74 patients, i.e., in only 2 patients who were not in the correct Monzen position.

*MRI study*

Figure 7 shows MRI images. With the conventional position, the extent of overlap of the lower edge of the heart with the upper edge of the liver in 10 healthy volunteers was 21.86 ± 8.22 mm. In the Monzen position, it was markedly smaller (6.45 ± 7.18 mm, $p < 0.0001$), as shown in Figure 8.

## DISCUSSION

The 180-degree data collection can be affected by absorption of deeper tissues, resulting in a decrease of radioactivity from the anterior wall to the septum. The images thus obtained have disadvantages such as distortion towards the center of the reconstructed area. In the case of 360-degree data collection, the resolution might decrease due to absorption by the bed during imaging of the dorsal side and due to the large distance between the patient and detector.[10,11]

The Monzen position can overcome these shortcomings. In the case of 180-degree data collection in the Monzen position, the influence of the tracer accumulation in the liver, gallbladder, etc., was minimal, and contrast of the images was improved, yielding high quality images with high sharpness and other advantages which allowed adequate evaluation.

When this position and imaging technique were employed, the distance between the heart and liver was large and the gallbladder was located low, decreasing the influence of the rays scattered from the liver, etc. to the myocardium. This method is simple and noninvasive; there is no particular limitation in the scope of facilities and patients for whom this method is applicable. Since the Monzen position involves 180-degree data collection, it does not necessitate that both arms be raised during imaging. The subjects of this study reported that it was easy for them to raise only one arm during the study.

With conventional positions of myocardial imaging using $^{99m}$Tc-MIBI or $^{99m}$Tc-TF, a waiting period of 30–60 minutes is needed to ensure complete clearance of the tracer from the liver, gallbladder, etc. With the Monzen position, the waiting time can be shortened to 5–10 minutes. The total time required for stress myocardial scintigraphy was 3–4 hours with conventional positions. Our technique is expected to shorten this period to 1 hour. The Monzen position seems to be applicable not only to myocardial perfusion SPECT with $^{99m}$Tc-MIBI or $^{99m}$Tc-TF but also to myocardial function SPECT using $^{123}$I-MIBG, $^{123}$I-BMIPP, etc. Thus, this new technique seems to be very useful.

## CONCLUSIONS

A new position for patients undergoing myocardial perfusion SPECT with $^{99m}$Tc tracers was investigated. This position ensures separation of the heart from the liver during imaging, unlike the conventional positions which require the patient to raise both arms during the procedure.

This technique is expected to reduce the influence of the scattered rays (due to tracer accumulation in the liver or gallbladder) on the heart, leading to higher image quality, not only in myocardial perfusion scintigraphy with $^{99m}$Tc preparations but also in myocardial tests using other tracers (e.g., $^{123}$I preparations).

With this technique the waiting time until clearance of the tracer from the liver is shortened, and therefore the total time required for the test is reduced.

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