Advanced Technologies of Cardiovascular Nuclear Medicine and Their Evaluation in Clinical Practice

Hajime Murata, M.D., Masahiro Iio, M.D.
and Hinako Toyama, M.D.

Currently available advanced methods of cardiovascular nuclear medicine for the diagnosis of ischemic heart disease were studied. The methods included the multigate method by a large capacity gamma camera-computer (128 KW memory with multilayer disc) system which made it possible to acquire the data of either the first pass study or the equilibrium study in "image mode". Analyzed data were displayed on a color CRT using our moving image system (MIS) and dynamic image thus obtained serve to help for the high sensitive observation of the regional wall motion as well as the global function of the ventricles.

Myocardial tomography by a 7 pinhole collimator designed by us was also reported. The myocardial tomogram obtained was proven to show more sensitivity than two dimensional myocardial scan by the conventional collimator to detect smaller lesion and the lesions at the inferior or posterior wall of the left ventricle.

The cardiovascular nuclear medicine with recent advanced technologies was thought to be sensitive and useful method for the diagnosis of the ventricular performance and the myocardial ischemia.

In the past several years, technology of cardiovascular nuclear medicine has developed strikingly especially in the field of diagnosis of ischemic heart disease. This achievement mainly came from the development of the gate method which based on the introduction and combination of ever-growing computer technology and advanced high speed gamma camera. The application of Thallium chloride for myocardial imaging was the another meritorious technique for the current cardiovascular nuclear medicine.

Key Word:
Multigate method
First pass method
Equilibrium method
Bilateral collimator
7 pinhole collimator tomography

Authors introduced a large scale gamma camera-computer system two years ago and have succeeded to develop the real time gate method. Based on five years' experiences using 32 KW computer-gamma camera system, present system has expanded 128 KW memory in CPU and has high speed multi-layer magnetic disc so that analysis of gate study is made almost in real time. Increased memory in the system also facilitated the function of refresh memory which produce moving image of the heart on the color CRT in almost real time using the moving image system (MIS) developed by authors. We have also evaluated the function of two important collimator devices such as 1) bilateral collimator for simultaneous visualization of two directional images of the heart and 2) Kirch's 7 pinhole collimator to construct three dimensional image

Department of Nuclear Medicine and Radiological Sciences, Tokyo Metropolitan Geriatric Hospital
Address: 35-2 Sakae-cho, Itabashi-ku, Tokyo 173, Japan


71
of the heart.

Based on these technical improvement authors tried to evaluate the clinical usefulness of these methods especially on the diagnosis of ischemic heart disease.

METHOD

1. Large scale gamma camera-computer system suitable for cardiovascular nuclear medicine

Fig. 1 indicated the block diagram of the gamma camera-computer system recently developed in our laboratory. This system has NOVA-03 with 128 KW memory in CPU. The system also has multi-layer high speed magnetic disc with 24 MW memory. These increased memory capacity serve as a plenty of buffer memory for input of the data and as refresh memory for out put of the data. The system made it possible to acquire the data rapidly of the order of 10 msec in “image mode” as much as 2000 frames and to analyze the data immediately after data acquisition in real time.

2. Moving image system

In order to detect regional wall motion of the ventricle, authors have developed the moving image system (MIS). Processed sequential images stored in the disc are transferred into refresh memory in CPU and dynamic moving image of the heart is displayed on a color CRT using MIS. In MIS random access memory for color table is included. Therefore, it is optional to select different color table and even to select limited color level from among 16 color levels permitting easier edge detection of the ventricle to observe regional wall motion.

3. Collimators

Fig. 2 showed the schema of the bilateral collimator used in this study. This collimator consists of two arrays of parallel holes which are slanted at $+30^\circ$ and $-30^\circ$ to the vertical line. Therefore, when the collimator is placed horizontally on the anterior thorax of the patient, cardiac images of two directions, right anterior oblique (RAO) $30^\circ$ and left anterior oblique (LAO) $30^\circ$, can be obtained simultaneously. According to Kirch’s collimator, authors have designed a 7 pinhole collimator to obtain the reconstructed three dimensional image of the myocardium (Fig. 3). The resolution and clinical usefulness of the collimator on the diagnosis of ischemic heart disease were evaluated.

4. Modes of analysis of cardiac function

(a) First pass study

Increased CPU memory and high speed disc in the present system made it possible to acquire the series of data of first pass method in image mode into disc. Twenty mCi of $^{99m}$Tc was injected into antecubital vein and gamma camera was directed to the patient’s heart from RAO 30° projection with conventional collimator or from anterior projection with the bilateral collimator, respectively. R wave of patient’s ECG was used as gate signal and sequential data of 40 msec interval were acquired in image mode. Then the sequential data for each four beats from the peak time of the right and left low frequency radiocardiogram were selected for multigate processing.

(b) Equilibrium study

Following to the first pass study, after the injected radionuclides labelled the patient's red blood cells and became equilibrated with the total body blood, equilibrium study was performed. In this study gamma camera was directed to the patient from various projections such as anterior, LAO 30°, LAO 40°, LAO 60° and left lateral projections. Using multigate method sequential data of 40 msec interval were acquired for 300–600 beats in the memory of CPU.

(c) Analysis of global function of the left ventricle by variable ROI (regions of interest) method

On the sequential gated cardiac images, ventricular edges were usually predetermined (fixed ROI method). In this study authors developed and evaluated the value of variable ROI method which was performed by approximation with Tschebyscheff's formula and by differentiation of the profile curves of the radius from the center of the ventricle. Then ventricular volume curve, dV/dt and ventricular ejection fraction were obtained both by fixed ROI method and variable ROI method.

(d) Detection method of the regional wall motion of the ventricle

Abnormal wall motion was detected on the moving image of the ventricular contour on a color CRT.

(e) Myocardial images by Thallium were analyzed both by conventional collimator and 7 pinhole collimator. Clinical value and limitation of these method were evaluated.

RESULT

1. First pass study with the bilateral collimator

Fig. 4 showed the right cardiac pool images from RAO 30° and LAO 30° projections at end-diastole in a normal subject. The images were taken by the first pass method with the bilateral
collimator. Right ventricular ejection fraction in this case was calculated as 48%. On the display of the cardiac contours, two curved lines indicated at end-diastole and end-systole, and normal contraction of the right ventricle was demonstrated clearly (Fig. 5).

Fig. 6 showed the left cardiac images at end-diastole from two projections in the same case described above. Left ventricular ejection fraction was calculated to be 65%. Left ventricular edge images from the two projections made it possible to observe the regional wall motion of anterior and posterior basal segments, anterior wall, apex, inferior wall, posterior wall, septum and lateral wall of the left ventricle (Fig. 7).

Fig. 8 showed the comparison of the radioactivities in the ventricles measured by this system from RAO 30° and LAO 30°. No marked difference was observed in these activities from the right ventricle between RAO and LAO projections. However, the activity of the left ventricle from RAO was found to be remarkably small compared with LAO projection and approximately 30% decrease was noted in all studies. Main cause of the difference in the activities of the left ventricle from the two projections was thought to be absorption of the activity in the left ventricle by the blood in the right ventricle.

2. Equilibrium study

Fig. 9 showed the cardiac images at end-diastole obtained by the equilibrium study with multigate method in a normal subject. In the equilibrium image the left and right ventricles were separately observed only in LAO projection, and the two ventricles could not be visual-

![Graph showing intraventricular radioactivities measured from RAO and LAO projections.](#)
3. Comparison of the first pass and equilibrium

Fig.9. Cardiac pool images obtained with the equilibrium method.
upper left: anterior projection, upper center: LAO 30° projection, upper right:
LAO 45° projection, lower left: LAO 60° projection, lower center: left lateral
projection.

Fig.10. Left ventricular volume curves and dV/dt curves obtained with the first pass method and the equilibrium method in a normal subject.

Fig.11. Comparison of left ventricular ejection fractions obtained by the two methods in 28 cases.

methods

Left ventricular volume curves and dV/dt curves in a normal subject by the first pass method and the equilibrium method were showed in Fig. 10. Good agreement of the two methods was observed.

Left ventricular ejection fractions obtained by the first pass and equilibrium methods were
compared in 28 cases with and without cardiac disease. There was a significant correlation with $r = 0.922$ between the two methods (Fig. 11).

4. Myocardial tomography

Resolution of the 7 pinhole collimator designed by authors was indicated in Fig. 12. In the figure the values of full width half maximum (FWHM) were showed at the various distances from the collimator surface. The FWHMs were estimated in the pinholes of theoretical 0 mm, 3.0 mm and 5.5 mm in diameter. Calculated value of FWHM was the smallest in the pinholes of theoretical 0 mm and was the largest in the holes of 5.5 mm in diameter. FWHM of larger distance from the collimator showed larger value. Measured FWHMs were similar to the calculated FWHMs in the holes of both 3.0 and 5.5 mm in diameter.

One representative case was presented to show the value of this new collimator. Eighty nine years old male. ECG of this case suggested the presence of old anteroseptal wall infarction. Fig. 13 indicated conventional Thallium myocardial scan obtained with parallel hole collimator. Thallium uptake showed some decrease at the anteroseptal wall, however, presence of transmural infarction could not be diagnosed in this scan. On the myocardial tomography obtained in LAO 60° projection by 7 pinhole collimator, distinct defect was identified in the anteroseptal wall of the left ventricle (Fig. 14). Fig. 15 showed myocardial tomography of this case in RAO 30° with 30° tilting cephalad. Thallium defect was demonstrated clearly at the anterior wall and anterior portion of the intraventricular

Fig.13. Conventional thallium myocardial scan.
upper left: anterior
upper right: LAO 30°
lower left: LAO 60°
lower right: left lateral projection

Fig.14. Myocardial tomogram obtained in LAO 60° by 7 pinhole collimator in the same cases described above.
- upper left: 5 cm
- upper right: 6 cm
- lower left: 7 cm
- lower right: 8 cm from the chest wall

Fig.15. Myocardial tomogram obtained in RAO 30° with 30° tilting cephalad.
- upper left: 5 cm
- upper right: 6 cm
- lower left: 7 cm
- lower right: 8 cm from the chest wall

septum.

DISCUSSION

The patients with ischemic heart disease are increasing in number in this country and the need for diagnostic method which is able to obtain more precise data of the disease is growing. Cardiovascular nuclear medicine techniques as was reported in this paper have made it possible to obtain the informations of the global and regional functions of the ventricle and of the myocardium noninvasively.

In order to examine the ventricular function, it is necessary to obtain two kinds of informations, the pumping function of the ventricle and the myocardial perfusion. Concerning to the pumping function of the left ventricle, the first pass study and the equilibrium study by the gate method were useful to detect the global function and the regional wall motion of the ventricle.

Characteristics of the two methods were summarized in Table I. The main advantage of the first pass method was to be able to visualize separately the left and right ventricles. Therefore, the observation of the regional wall motion of the left ventricle was possible in RAO projection which made it easier to detect the abnormal motion of the anterior and inferior walls. More-

<table>
<thead>
<tr>
<th>TABLE I COMPARISON OF FIRST PASS METHOD AND EQUILIBRIUM METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separation of right and left ventricles</td>
</tr>
<tr>
<td>Repeated studies</td>
</tr>
<tr>
<td>Good</td>
</tr>
<tr>
<td>Has limitation</td>
</tr>
<tr>
<td>Analysis of global function</td>
</tr>
<tr>
<td>Observation of regional wall motion</td>
</tr>
<tr>
<td>Possible</td>
</tr>
<tr>
<td>Possible</td>
</tr>
<tr>
<td>Analysis of global function</td>
</tr>
<tr>
<td>Observation of regional wall motion</td>
</tr>
<tr>
<td>Possible</td>
</tr>
<tr>
<td>Good</td>
</tr>
<tr>
<td>Has limitation</td>
</tr>
</tbody>
</table>

Japanese Circulation Journal Vol. 43, January 1981
over, the first pass method made it easier to observe the right ventricular wall motion as well as to calculate right ventricular ejection fraction. On the other hand, the equilibrium method had the advantage to obtain the data with good statistics because it was possible to acquire the data for as many as necessary. Therefore, left ventricular global function could be obtained with high quality by this method such as LV volume curve and dV/dt. The equilibrium method also could perform repeated studies. For these reasons the equilibrium method was suitable for the observation of the left ventricular performance at rest and during exercise. However, there was limitation to observe the wall motion of anterior, inferior and posterior wall of the left ventricle in the equilibrium method.

Since the two methods had different merits respectively, the first pass study should be followed by the equilibrium study and informations should be obtained as many as possible by a single administration of the radionuclide. The display of cardiac moving image by MIS was sensitive method for the detection of the abnormal wall motion of the ischemic heart disease.

The seemingly luxury of our system will be compensated by the almost real time capability of the data processing which serve for the busy and emergency activities of the cardiac laboratories.

Thallium chloride for myocardial imaging has been a useful tool on the diagnosis of the myocardial ischemia. However, two dimensional image of the myocardium taken by the conventional collimator has drawbacks as to the detection of smaller lesion and the lesion of inferior or posterior wall. In the past several years tomographic methods for myocardial imaging has been developed such as emission computed tomography and single photon computed tomography. Myocardial imaging by 7 pinhole collimator introduced by Kirch and evaluated in this study is a kind of computed tomography and this method is the simplest and the most inexpensive method for myocardial tomography. The data obtained by the 7 pinhole collimator revealed the usefulness for the detection of the site and size of ischemic lesion and also made the gate analysis possible. However, the limitation lies on the detection of myocardial ischemia even by the tomography because myocardium to back ground ratio of Thallium is relatively low. The development of the radio-pharmaceutical which is more specific to myocardium will remain as a subject for the further study.

REFERENCES