Evaluation of Cardiac Function in Myocardial Infarction Patients by ECG ^{99m}Tc -MIBI Gated SPECT Using a Three-dimensional Perfusion/Motion Map Procedure

Masahiro NOMURA, MD, Yutaka NAKAYA,¹ MD,
Tomomi NADA, MD, Hitoshi MIYAJIMA, MD,
Yuki KONDO, MD, Ken SAITO, MD,
and Susumu ITO, MD

SUMMARY

Three-dimensional (3D) radionuclear myocardial imaging has improved the evaluation of left ventricular wall motion. However, there have been no studies evaluating left ventricular function using 3D-perfusion/motion map techniques. We hypothesized that the 3D-perfusion/motion map could accurately evaluate left ventricular wall motion even in patients with a history of myocardial infarction. Electrocardiogram (ECG)-gated single photon emission computed tomography (SPECT) using ^{99m}Tc -methoxy isobutyl isonitrile (MIBI) was performed in 20 patients with a history of myocardial infarction who underwent left ventriculography. Myocardial imaging data were collected during ECG-gated SPECT using a 3-headed gamma camera. Reconstructed 3D SPECT images were oriented to correspond to standard left ventriculography views (right anterior oblique and left anterior oblique projections), and the shortening fraction (SF) was calculated using the center line method. The SF and left ventricular ejection fraction from 3D SPECT images were compared with those determined by left ventriculography. There was a significant correlation between left ventriculography and the 3D-perfusion/motion map procedure in determining SF for all regions of the left ventricle except the anterobasal and posterior segments by using the Bland and Altman method. The 3D-perfusion/motion map procedure offers the advantage that the influences of contraction-related myocardial torsion and three-dimensional compression are minimized. In addition, this method facilitates evaluation of images from nonstandard projections. We conclude that this method may be useful for evaluating left ventricular function. (*Jpn Heart J* 1999; 40: 413-425)

Key words: 3D-perfusion/motion map, SPECT, ^{99m}Tc -methoxy isobutyl isonitrile, Shortening fraction

From the Second Department of Internal Medicine, and ¹Department of Nutrition, University of Tokushima, Tokushima, Japan.

Address for correspondence: Masahiro Nomura, MD, Second Department of Internal Medicine, School of Medicine, University of Tokushima, 2-50 Kuramoto-cho, Tokushima 770-8503, Japan.

Received for publication May 18, 1999.

Revised and accepted July 5, 1999.

THREE-dimensional (3D) radionuclear myocardial imaging has improved the evaluation of left ventricular function.¹⁾ Three-headed cameras can complete 360° scans within a short period of time. Moreover, images with a high degree of spatial resolution can be obtained because gamma cameras follow a noncircular orbit that fits the individual contours of the body.²⁾ A 3-headed type SPECT device (PRISM 3000, PICKER/Shimadzu), is capable of rapid data collection and the production of a 3D-representation of the myocardium in a few minutes. The 3D-myocardial images obtained using this device permit an objective evaluation of myocardial ischemia and/or infarction in any direction.²⁾

This method is expected to yield more information concerning cardiac wall motion. However, there have been no studies evaluating left ventricular function using 3D-perfusion/motion map techniques. In the present study, electrocardiogram (ECG)-gated single photon emission computed tomography (SPECT) using ^{99m}Tc-methoxy isobutyl isonitrile (MIBI) was performed in patients with old myocardial infarctions to evaluate left ventricular function using the 3D-perfusion/motion map technique. In order to determine the usefulness of this procedure, results were compared with those obtained from left ventriculography.

METHODS

Patients: Twenty consecutive patients with a history of myocardial infarction who underwent left ventriculography and ECG-gated SPECT were included in the study (12 men and 8 women; mean age: 64.8 ± 8.5 years). Patients with cardiac failure who could not remain in the supine position, patients with atrial fibrillation for whom it was difficult to perform ECG-gated SPECT and patients who had frequent extrasystoles were excluded from the study. Written informed consent was obtained from all patients for study enrollment. The study was performed in accordance with protocols approved by the Committee on Human Rights in Research of the University of Tokushima.

The diagnosis of myocardial infarction was based on history, electrocardiographic findings, serum creatine kinase activity, echocardiographic findings and cardiac catheterization findings. Infarction had occurred in the anterior wall in 9 patients, the inferior wall in 6 patients, and the lateral wall in 3 patients. Two patients had suffered non-Q wave infarctions.

Left ventriculogram: Left ventriculography was performed with biplane imaging using a 6 F pigtail catheter. Images were obtained in 2 projections, 30° right anterior oblique (RAO) and 60° left anterior oblique (LAO). Meglumine diatrizoate (40 to 50 ml) was infused as contrast at a rate of 12 ml/sec. The images were recorded on 35-mm cine film at 30 frames/sec.

Left ventricular end-systolic and end-diastolic endocardial contours from

Figure 1. Center line method of analyzing left ventricular wall motion in the RAO and LAO views (Sheehan *et al.*³⁻⁵⁾)

left ventriculographs were traced from normal, non-postpremature sinus beat images. Left ventricular wall motion was evaluated according to the center line method described by Sheehan *et al.*³⁻⁵⁾ Briefly, the end-diastolic and end-systolic contours were traced from the frames of the left ventriculogram (LVG) from RAO and LAO views by visual inspection. A center line was constructed by the computer midway between the end-diastolic and end-systolic contours (Figure 1). One hundred equidistant chords were drawn perpendicular to the center line, extending from the end-diastolic to the systolic contour. The length of each cord corresponded to the motion of the corresponding points on the left ventricular contour. To adjust for differences in heart size, the shortening fraction (SF) at each cord was calculated using the following formula.

$$SF = (\text{chord length/end-diastolic perimeter}) \times 100 (\%)$$

ECG-gated MIBI myocardial scintigraphy: Patients received 740 MBq (20 mCi) of ^{99m}Tc-MIBI intravenously for rest imaging. Patients were given 200 ml of milk 30 minutes after injection in order to facilitate tracer clearance from the gall bladder. ECG-gated SPECT imaging began one hour after traces injection with the patient in the supine position. A 3-head rotating gamma camera (PRISM 3000, PICKER/Shimadzu) was used. The camera was equipped with a low-energy, all-purpose collimator and interfaced to a computer (ODYSSEY, Shimadzu Corp., Kyoto, Japan). The SPECT acquisitions were performed for 30 seconds with a 15% energy window using 72 image stops (5° step). When cardiac gating was used, 8 frames/cardiac cycle were acquired in a 64 × 64 matrix. Myocardial scintigraphy was performed within an average of 1 week of left ventriculography.

Mean values for the SFs were obtained from the RAO and LAO views from chord numbers 1 to 20, 21 to 40, 41 to 60, 61 to 80 and 81 to 100, and 1 to 50 and 51 to 100, respectively (Figure 1). In the present study, each mean SF

value was used to evaluate wall motion for segment 1 (anterobasal), segment 2 (anterolateral), segment 3 (apical), segment 4 (diaphragmatic), segment 5 (posterobasal), segment 6 (septal) and segment 7 (posterior) defined in the AHA classification system.⁶⁾

3D-perfusion/motion map technique: The ECG-gated SPECT data were reconstructed using a 3D-perfusion/motion map program (PICKER)^{7,8)} and a data processing computer (ODYSSEY). The outline of the left ventricular wall was imaged by the relaxation labelling method. In this method, initial values were approximated and then converged to the best fit. The heart was modeled in two parts (i.e., apical region and the remainder of the left ventricle). The left ventricular apical region was modeled as a hemisphere (apical cap) and the remainder of the left ventricle was modeled as a cylinder according to the method of Garcia *et al.*¹⁾ That is, the left ventricular wall, remodeled into a cylinder and an apical cap, was divided into 24 portions along the circumference and into 12 portions along the major axis. Changes in the count from the heart axis (on the long axis view) to the myocardium were analyzed, in order to depict the frame of the cardiac lumen. One cardiac cycle was divided into 8 time frames, and the wall motion within the left side of the heart was represented in four dimensions (3 dimensions plus time) on the 3D-image. This 3D-reconstruction technique required approximately 10 minutes. Myocardial scintigraphic findings on 3D-perfusion/motion maps were evaluated by three cardiologists without prior knowledge of the contrast left ventriculography results.

We compared the mean SFs from 3D-perfusion/motion maps (SF_{3D}) and those from contrast left ventriculogram (SF_{LVG}) for RAO and LAO projections by regression analysis and the Bland and Altman method.⁹⁾

Comparison of left ventricular ejection fraction determined by left ventriculography and myocardial scintigraphy: On 3D-perfusion/motion maps, the ejection fraction was calculated from the relative volume by determining the number of pixels within the left ventricular lumen on end-diastolic and end-systolic images. The relative end-diastolic and end-systolic volumes, calculated from 3D-perfusion/motion map images, were used to calculate the left ventricular ejection fraction (EF_{3D}). The ejection fractions determined by left ventriculography (EF_{LVG}) and EF_{3D} were then compared by regression analysis and the Bland and Altman method.⁹⁾

RESULTS

Evaluation of the RAO image using the 3D-perfusion/motion map procedure: Figure 2 shows representative end-diastolic (A) and end-systolic (B) 3D-perfusion/motion map images from a patient with an old myocardial infarction

Figure 2. Regional wall motion analysis in a 57-year-old patient with a history of myocardial infarction based on 3D-perfusion/motion map imaging in the RAO view. **A, B:** End-diastolic (A) and end-systolic (B) 3D-perfusion/motion map images. **C:** Traced end-diastolic and end-systolic contours. **D:** Shortening fraction for each chord number.

and a stenosis in the left anterior descending coronary artery (AHA classification, segment 7) confirmed by coronary angiography. In the reconstructed 3D SPECT image, the apical wall was represented in green, suggesting that this area had reduced $^{99m}\text{Tc-MIBI}$ accumulation and ischemic and/or infarction-related changes. As shown in Figure 2C, the left ventricular endocardial contour at end-diastole and end-systole were traced. The SF for each chord number determined by the centerline method are depicted in Figure 2D. The SF was decreased in chord numbers 40 to 50. Left ventricular wall motion was reduced in the areas with decreased $^{99m}\text{Tc-MIBI}$ accumulation shown in Figures 2A and 2B. The segmented wall motion for each chord determined by left ventriculography is shown for this patient in Figure 3. The SFs determined by ventriculography were

Figure 3. Regional wall motion analysis based on left ventriculography in the RAO view (from the same patient as in Figure 2). **A:** End-diastolic and end-systolic left ventricular endocardial contours with a centerline constructed midway between the two contours. **B:** Shortening fraction for each chord number.

similar to those determined by 3D-perfusion/motion mapping.

The comparison between SFs for each myocardial segment (segments 1–5) determined by left ventriculography and 3D-perfusion/motion mapping by using regression analysis is shown in Figure 4A. There was a significant correlation between the two methods except for determinations made in the anterobasal segment (segment 1).

Moreover, comparison of these techniques by the method of Altman and Bland⁹ is shown in Figure 4B. Mean bias ($SF_{LVG} - SF_{3D}$) was not significantly different from zero (95% confidence interval) except for the anterobasal segment (segment 1).

Evaluation of the LAO image using the 3D-perfusion/motion map procedure: Figure 5 shows representative end-diastolic (A) and end-systolic (B) 3D-perfusion/motion map images from a patient with an old myocardial infarction and a stenosis in the left anterior descending coronary artery (AHA classification, segment 6). In the reconstructed 3D SPECT image, there was reduced ^{99m}Tc -MIBI accumulation and ischemic and/or infarction-related changes in the septal region. The left ventricular endocardial contours at end-diastole and end-systole are shown in Figure 6C. The SF for each chord is depicted in Figure 6D. The SF was decreased in chord numbers 1 to 50. Left ventricular wall motion was reduced in the areas with decreased ^{99m}Tc -MIBI accumulation (Figures 6A and 6B). The segmental wall motion for each chord for this patient (Figure 6) was similar to those shown in Figure 6D.

Figure 7A illustrates the SFs for each myocardial segment determined by

Figure 4. Comparison between shortening fractions determined by left ventriculography (LVG) and the 3D-perfusion/motion map (3D) procedure for each myocardial segment using regression analysis (A) and the Bland and Altman method (B). SF_{LVG} = shortening fraction determined by LVG; SF_{3D} = shortening fraction determined by 3D.

left ventriculography or 3D-perfusion/motion mapping. Significant correlations between SFs determined by the two methods were found for segments 5 and 6 by using regression analysis.

Moreover, comparison of these techniques by the method of Altman and Bland⁹ is shown in Figure 7B. Mean bias ($SF_{LVG} - SF_{3D}$) was not significantly different from zero (95% confidence interval) except for the posterior segment

Figure 5. Regional wall motion analysis in a 64-year-old patient with a history of myocardial infarction based on 3D-perfusion/motion map imaging in the LAO view. **A, B:** End-diastolic (A) and end-systolic (B) 3D-perfusion/motion map images. **C:** Traced end-diastolic and end-systolic contours. **D:** Shortening fraction for each chord number.

(segment 7).

Comparison of the left ventricular ejection fractions determined by 3D-perfusion/motion mapping and left ventriculography: The left ventricular ejection fraction (LVEF) calculated by left ventriculography (X) was compared to the LVEF calculated by 3D-perfusion/motion mapping (Y). There was a good linear correlation between the two methods in determining LVEF ($Y = 0.74X + 13.8$, $r = 0.73$, $p = 0.002$) in Figure 8A. Moreover, comparison of these techniques by the method of Altman and Bland⁹ is shown in Figure 8B. Mean bias ($EF_{LVG} - EF_{3D}$) was $-0.80 \pm 8.7\%$ and not significantly different from

Figure 6. Regional wall motion analysis based on left ventriculography in the RAO view (from the same patient as in Figure 5). **A:** End-diastolic and end-systolic left ventricular endocardial contours with a centerline constructed midway between the two contours. **B:** Shortening fraction for each chord number.

Figure 7. Comparison between shortening fractions determined by left ventriculography (LVG) and the 3D-perfusion/motion map (3D) procedure for each myocardial segment using regression analysis (A) and the Bland and Altman method (B). SF_{LVG} = shortening fraction determined by LVG; SF_{3D} = shortening fraction determined by 3D.

Figure 8. Comparison between left ventricular ejection fraction determined by left ventriculography (LVG) and the 3D-perfusion/motion map (3D) procedure using regression analysis (A) and the Bland and Altman method (B). EF_{LVG} = left ventricular ejection fraction determined by LVG; EF_{3D} = left ventricular ejection fraction determined by 3D.

zero (95% confidence interval - 18.2 to +16.6%).

DISCUSSION

ECG-gated cardiac pool scintigraphy with technetium-99m-labeled agents has been used to evaluate left ventricular function based on the first pass

method.¹⁰⁻¹²⁾ However, wall motion for the entire left ventricle cannot be evaluated because imaging is performed in only one plane. ^{99m}Tc-MIBI offers several advantages as an agent to assess left ventricular function. First, the short half-life of Tc-99m (6 hours) allows the administration of a much greater dose of radioactivity. Second, the energy emission of Tc-99m (140 keV) permits imaging with a standard gamma camera. As a result, ECG-gated myocardial SPECT imaging with ^{99m}Tc-MIBI allows simultaneous evaluation of myocardial blood flow and left ventricular function.¹³⁻²⁴⁾

ECG-gated 3D SPECT imaging may facilitate the evaluation of left ventricular wall motion. However, none of the previous studies have compared the results obtained from 3D SPECT with those from left ventriculography. This is the first study to perform such a comparison.

Two methods have been reported to evaluate cardiac function with ECG-gated myocardial SPECT imaging. One method evaluates the rate of change in local wall thickness with respect to left ventricular contraction (increase in count density).^{25,26)} The other method estimates ventricular wall motion using end-diastolic and end-systolic images.

It has been reported that the majority of ^{99m}Tc-MIBI binds to the mitochondria of myocardial cells.²⁷⁾ This characteristic is utilized for the evaluation of left ventricular function based on changes in local wall thickness measured by ECG-gated SPECT.^{24,25)} However, the increase in count density may reflect not only an increase in left ventricular wall thickness and a reduction in the longitudinal length²⁸⁾ but also an increase in both myocardial torsion and three-dimensional compression caused by cardiac contraction. Kubota *et al.*²⁹⁾ have demonstrated a strong correlation between left ventricular function and changes in count density considering the myocardial torsion. However, torsion occurs along the left ventricular longitudinal axis and the horizontal axis. Therefore, it is difficult to estimate torsion accurately.²⁹⁾ In the 3D-perfusion/motion map procedure used in the present study, left ventricular wall motion is evaluated by three-dimensional analysis. In this model, the influences of myocardial torsion can be taken into account.

The uptake of ^{99m}Tc-MIBI is reduced in the infarcted myocardium, making it difficult to evaluate wall motion accurately. Because the 3D-perfusion/motion map method is capable of estimating myocardial blood flow based on the uptake grade of ^{99m}Tc-MIBI, reduced ^{99m}Tc-MIBI uptake in the infarcted myocardium can be detected, which permits an evaluation of wall motion in the infarcted site.

There was a significant correlation between the 3D-perfusion/motion map evaluation and the left ventriculographic evaluation of left ventricular wall motion in all segments except the anterobasal and posterolateral segments by using the Bland and Altman method.⁹⁾ This discrepancy may exist because the left

ventricular basal region of SPECT images is inadequately recognized by the 3D-perfusion/motion map program. Respiration-related artifacts may also be responsible for the discrepancy. Moreover, there is a possibility that a true end-systolic image of left ventricle was not detected because only 8 frames/cardiac cycle were acquired using the 3D-perfusion/motion map method in the present study. This might also be the reason why we could not obtain a good correlation between the 3D-perfusion/motion map and the left ventriculographic methods.

In conclusion, wall motion and left ventricular ejection fraction evaluated by the 3D-perfusion/motion mapping procedure correlated well with the results of left ventriculography. In addition, this method may facilitate the evaluation of cardiac function in patients who cannot receive contrast dye. Furthermore, this method can evaluate wall motion in any orientation.

REFERENCES

1. Garcia EV, Cooke D, Van Train KF, *et al.* Technical aspects of myocardial SPECT imaging with technetium-99m sestamibi. *Am J Cardiol* 1990; 66: 23E-31E.
2. Yamazaki J, Kabano T, Uchi T, *et al.* The usefulness of three dimensional imaging of the myocardium using three heads SPECT camera (PRISM-3000). *Kaku-Igaku* 1993; 30: 95-105.
3. Sheehan FH, Stewart DK, Dodge HT, Mitten S, Bolson EL, Brown BG. Variability in the measurement of regional ventricular wall motion from contrast angiograms. *Circulation* 1983; 68: 550-9.
4. Sheehan FH, Bolson EL, Dodge HT, Mathey DG, Schofer J, Woo HW. Advantages and applications of the centerline method for characterizing regional ventricular function. *Circulation* 1986; 74: 293-305.
5. Sheehan FH, Schofer J, Mathey DG, *et al.* Measurement of regional wall motion from biplane contrast ventriculograms: a comparison of the 30 degree right anterior oblique and 60 degree left anterior oblique projections in patients with acute myocardial infarction. *Circulation* 1986; 74: 796-804.
6. AHA Committee Report. A reporting system on patients evaluated for coronary artery disease (News from the American Heart Association). *Circulation* 1975; 51: 5-40.
7. Faber TL, Stokely EM, Peshock RM, Corbett JR. A model-based four dimensional left ventricular surface detector. *IEEE Trans Med Imaging* 1991; 10: 321-9.
8. Rosenfeld, Hummel RA, Zucker SW. Labelling by relaxation operation. *IEEE Trans on System Man and Cybernetics* 1976; 6: 420-33.
9. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; 1: 307-10.
10. Sporn V, Perez Balino N, Holman BL, *et al.* Simultaneous measurement of ventricular function and myocardial perfusion using the technetium-99m isonitriles. *Clinical Nucl Med* 1988; 13: 77-81.
11. Baillet GY, Mena IG, Kuperus JH, Robertson JM, French WJ. Simultaneous technetium-99m MIBI angiography and myocardial perfusion imaging. *J Nucl Med* 1989; 30: 38-44.
12. Borges Neto S, Coleman RE, Jones RH. Perfusion and function at rest treadmill exercise using technetium-99m-sestamibi: comparison of one- and two-day protocols in normal volunteers. *J Nucl Med* 1990; 31: 1128-32.
13. Najm YC, Timmis AD, Maisey MN, *et al.* The evaluation of ventricular function using gated myocardial imaging with Tc-99m MIBI. *Eur Heart J* 1989; 10: 142-8.
14. Borger Neto S, Coleman RE, Potts JM, Jones RH. Combined exercise radionuclide angiocardigraphy and single photon emission computed tomography perfusion studies for assessment of coronary artery disease. *Semin Nucl Med* 1991; 21: 223-9.
15. Villanueva Meyer J, Mena I, Narahara KA. Simultaneous assessment of left ventricular wall motion

and myocardial perfusion with technetium-99m-methoxy isobutyl isonitrile at stress and rest in patients with angina: comparison with thallium-201 SPECT. *J Nucl Med* 1990; 31: 457-63.

16. Neglia D, Parodi O, Marzullo P, *et al.* Behavior of right and left ventricles during episodes of variant angina in relation to the site of coronary vasospasm. *Circulation* 1990; 81: 567-77.
17. Verzijlbergen JF, Cramer MJ, Niemeyer MG, Ascoop CA, van der Wall EE, Pauwels EK. ECG-gated and static technetium-99m SESTAMIBI planar myocardial perfusion imaging: a comparison with thallium-201 and study of observer variabilities. *Am J Physiol Imaging* 1990; 5: 60-7.
18. Grucker D, Florentz P, Oswald T, Chambron J. Myocardial gated tomoscintigraphy with 99mTc-methoxy-isobutyl-isonitrile (MIBI): regional and temporal activity curve analysis. *Nucl Med Comm* 1989; 10: 723-32.
19. Berman DS, Kiat H, Friedman JD, *et al.* Separate acquisition rest thallium-201/stress technetium-99m sestamibi dual isotope myocardial perfusion single photon emission computed tomography. *J Am Coll Cardiol* 1993; 22: 1455-64.
20. Taillefer R, Gagnon A, Laflamme L, Gregoire J, Leveille J, Phaneuf DC. Same day injection of Tc-99m methoxy isobutyl isonitrile (hexamibi) for myocardial tomographic imaging: comparison between rest-stress and stress-rest injection sequences. *Eur J Nucl Med* 1989; 15: 113-7.
21. Taillefer R, Dupras G, Sporn V, *et al.* Myocardial perfusion imaging with a new radiotracer, technetium-99m-hexamibi (methoxy isobutyl isonitrile): comparison with thallium-201 imaging. *Clin Nucl Med* 1989; 14: 89-96.
22. Kahn JK, McGhie I, Akers MS, *et al.* Quantitative rotational tomography with 201Tl and 99mTc-2-methoxy-isobutyl-isonitrile. A direct comparison in normal individuals and patients with coronary artery disease. *Circulation* 1989; 79: 1282-93.
23. Kiat H, Maddahi J, Roy LT, *et al.* Comparison of technetium-99m methoxy isobutyl isonitrile and thallium 201 for evaluation of coronary artery disease by planar and tomographic methods. *Am Heart J* 1989; 117: 1-11.
24. Heo J, Kegel J, Iskandrian AS, Cave V, Iskandrian BB. Comparison of same-day protocols using technetium-99m-sestamibi myocardial imaging. *J Nucl Med* 1992; 33: 186-91.
25. Marcassa C, Marzull P, Parodi O, Sambuceti G, L'Abbate A. A new method for noninvasive quantitation of segmental myocardial wall thickening using technetium-99m 2-methoxy-isobutyl-isonitrile scintigraphy: results in normal subjects. *J Nuc Med* 1990; 31: 173-7.
26. Chua T, Kiat H, Germano G, *et al.* Gated Technetium-99m sestamibi for simultaneous assessment of stress myocardial perfusion, postexercise regional ventricular function and myocardial viability: correlation with echocardiography and rest thallium-201 scintigraphy. *J Am Coll Cardiol* 1994; 23: 1107-14.
27. Piwica Worms D, Kronauge JF, Chiu ML. Uptake and retention of hexakis (2-methoxyisobutyl isonitrile) technetium (I) in cultured chick myocardial cells: mitochondrial and plasma membrane potential dependence. *Circulation* 1990; 82: 1826-38.
28. Rogers WJ Jr, Shapiro EP, Weiss JL, *et al.* Quantification of and correction for left ventricular systolic long-axis shortening by magnetic resonance tissue tagging and slice isolation. *Circulation* 1991; 84: 721-31.
29. Kumita S, Kumazaki T. Assessment of left ventricular function with ^{99m}Tc-MIBI gated myocardial SPECT using 3 head rotating gamma camera. *Kaku Igaku* 1994; 31: 43-52.