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Regional Myocardial Perfusion Abnormality Demonstrated by Intra-arterial Digital Subtraction Angiogram at Capillary Phase
A Comparison of DSA with Left Ventriculography and Thallium-201 Myocardial Scintigraphy

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Intra-arterial digital subtraction angiogram により描出された毛細管相における心筋灌流異常
左室造影および^{201}T1心筋シンチグラムとの比較

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心電図同期 digital subtraction angiography（DSA）に，選択的冠状動脈造影を適用し，動脈相，毛細管相，静脈相に対応する心筋血液灌流画像を得た．心筋梗塞例では，毛細管相の画像において梗塞部位に明らかな灌流欠損が認められた．本研究では，この灌流欠損部位の広がりを^{201}T1心筋シンチグラム，左室造影像と対比し，その臨床的意義を検討した．対象は，前壁心筋梗塞9例，健常例8例である．DSAにより示された灌流欠損部位は，^{201}Tl心筋シンチグラムで示されたそれより狭くなる傾向を示した．一方，左室造影で示された壁運動異常領域は，DSAで描出された灌流欠損領域よりも広範であった．しかし，顕著な壁運動異常領域は，DSAで描出された灌流欠損領域と良く一致していた．前壁心筋梗塞例において，DSAの毛細管相画像で描出された灌流欠損領域は，重度な虚血領域に対応する可能性が示唆された．

Introduction

The assessment of regional myocardial perfusion is very important for the diagnosis and treatment of

ischemic heart disease. At present, there are seven established methods for the evaluation of regional myocardial perfusion in man. They are: thallium-201 myocardial scintigraphy, inert gas clearance technique[1)2)], myocardial perfusion scintigraphy with macroaggregates of albumin[3)], positron emission computed tomography[4)5)], digital subtraction angiography (DSA)[6)~13)], two-dimensional echocardiography[14)15)], and X-ray computed tomography[16)]. Thallium-201 myocardial scintigraphy is the most popular method in daily practice. However, recent advances in DSA have made it possible to analyze regional myocardial perfusion rapidly and clearly. DSA demonstrates images not only at the arterial phase but also at both the capillary and venous phases. In cases of old myocardial infarction, the infarcted region was shown as a low density image corresponding to the poorly perfused area using DSA, as it was with thallium-201 myocardial scintigram[7)12)13)]. In the current study, regional myocardial perfusion abnormality is evaluated at the capillary phase. And the regions of perfusion abnormality shown by DSA are compared with those determined by thallium-201 myocardial scintigraphy and left ventriculography in order to assess its clinical validity.

Methods and Materials

(1) Patients

DSA examinations were performed on nine patients with old anterior myocardial infarction and eight control subjects. The nine patients consisted of seven men and two women aged from 36 to 63 years old (52 ± 8.4 years old, mean ± SD). Angiograms of 8 patients showed severe stenosis (more than 90%) and the other showed no stenosis in the left coronary arteries. The marked collateral vessels were not observed in all cases. The control subjects consisted of six men and two women aged from 44 to 68 years old (57 ± 7.3 years old, mean ± SD). All control subjects gave normal coronary arteriograms and normal left ventricular wall motion, but had a history of chest pain.

(2) Data acquisition and image formation

The DSA system for this study consisted of a commercial cineangiographic system (KXO-1250, Toshiba) with a 9 inch image intensifier and a special data acquisition system[6)7)8)]. X-ray TV images were recorded sequentially with the ECG signal at the TV rate (30 frames/sec). X-ray TV images were logarithmically amplified and digitized by a 8 bit AD converter into 512 × 512 pixel matrices with 8 bits depth. Image processing was performed on a minicomputer (YHP 1000F) with an image processing terminal display (Graphica I5048). Subtraction was performed sequentially between mask imags and enhanced images in the same cardiac phase corresponded by simultaneously recorded ECG signal. Sequential DSA images at end-diastolic phase were obtained from this record for the following analysis. The image, at which myocardial wall was enhanced remarkably by the contrast material, was selected as the image at the capillary phase. This image was compared with the thallium-201 myocardial scintigram and the left ventriculogram.

(3) Comparison of the DSA image at the capillary phase with the left ventriculogram and the thallium-201 myocardial scintigram

The left ventriculogram was performed at the same position as selective coronary arteriography (30 degree right anterior oblique). Forty ml of 76% Urografin was injected into the left ventricle. Regional wall motion was semi-quantitatively categorized by two experienced observers as normal, hypokinesis, severe hypokinesis, akinesis, or dyskinesis. Severe hypokinesis means almost akinesis. Wall motion was evaluated in six areas as illustrated in Fig. 1.

Thallium-201 myocardial scintigrams taken by a PHO/GAMMA LFOV scintillation camera with a MEP collimeter, were obtained from the anterior, 45 degree left anterior oblique, and left lateral views. Thallium-201 was injected intravenously in a dose of 2 mCi at rest. The regions of perfusion defect were

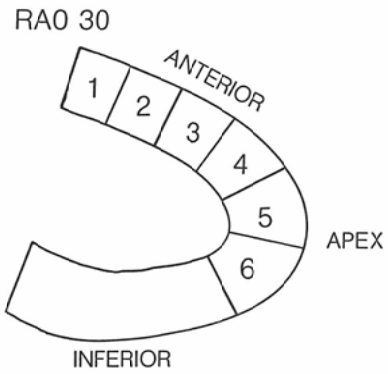

Fig. 1 Schematic diagram of myocardial segments defined for analyzing procedure.

determined at the three views.

A Chi-square test was used to confirm the differences between the DSA image, the thallium-201 myocardial scintigram and the left ventriculogram.

Results

DSA images of the old myocardial infarction are shown in Fig. 2. The DSA image at the arterial phase demonstrates the complete obstruction of the left anterior descending coronary artery (LAD) as did

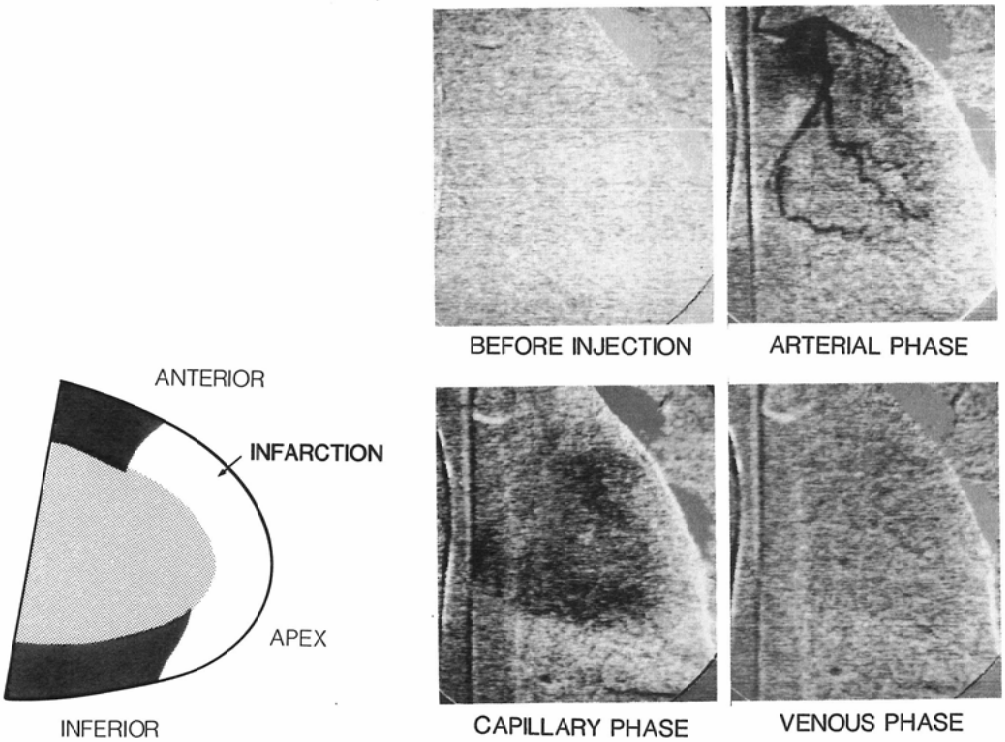

Fig. 2 DSA images in the case of old anterior myocardial infarction.
Perfusion defects were shown at capillary phase on the anterior wall and at apex. The left shows a schematic representation of the infarcted regions.

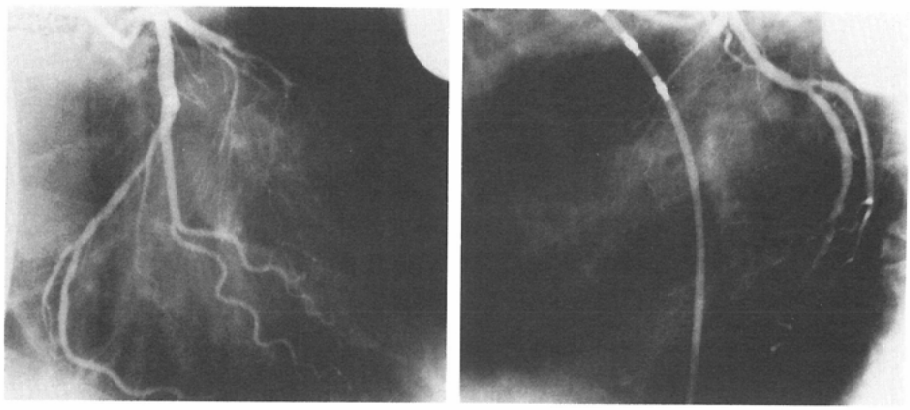

Fig. 3 Conventional cine angiogram of left coronary artery of the case shown by Fig. 2. Complete obstruction of LAD was shown.

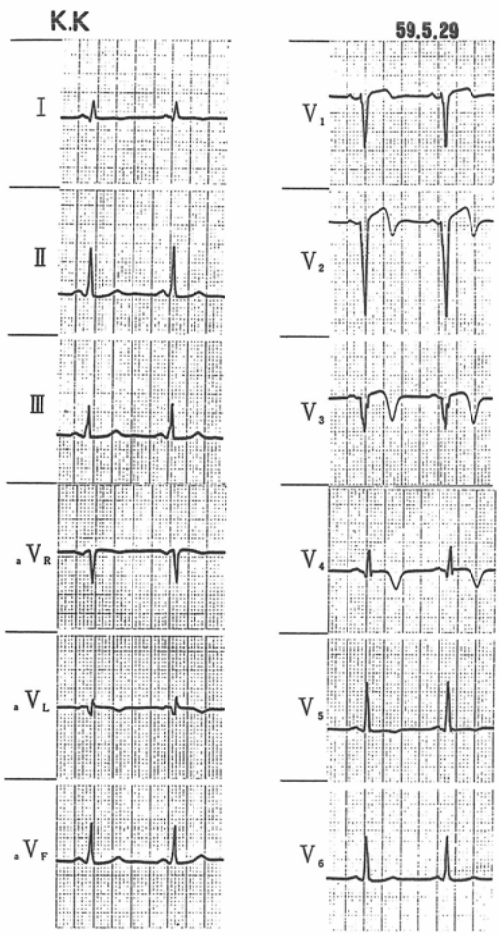

Fig. 4 ECG for the case of Fig. 2. QS pattern was shown in V1-3. Coronary T was shown in V2-4.

conventional coronary arteriogram (Fig. 3). Furthermore, the DSA image at the capillary phase demonstrates perfusion defects on the anterior wall and at the apex. The ECG findings of this case indicate, anteroseptal myocardial infarction (Fig. 4). The left ventriculogram of the same case shows akinesis at the apex and on the anterior wall, and hypokinesis near the anterobasal wall (Fig. 5). The thallium-201 myocardial scintigram demonstrates perfusion defect on the apical and anteroapical wall (Fig. 6). Fig 7 shows the results of the comparison between the DSA image, the thallium-201 myocardial scintigram and the left ventriculogram for the case shown in Fig. 2. The regions with abnormal wall motion are tended to be wider than the abnormal regions estimated from the DSA images and thallium-201 myocardial scintigrams. But the abnormal regions determined by the thallium-201 myocardial scintigram were narrower than those from the DSA images.

The eight control subjects did not show any abnormality either in the wall motion or in the thallium-201 myocardial scintigram. Fifty-four regions in a total of 9 patients with anterior old myocardial infarction were examined (Table 1 and Fig. 8). Table 1 shows the number of abnormal regions revealed by

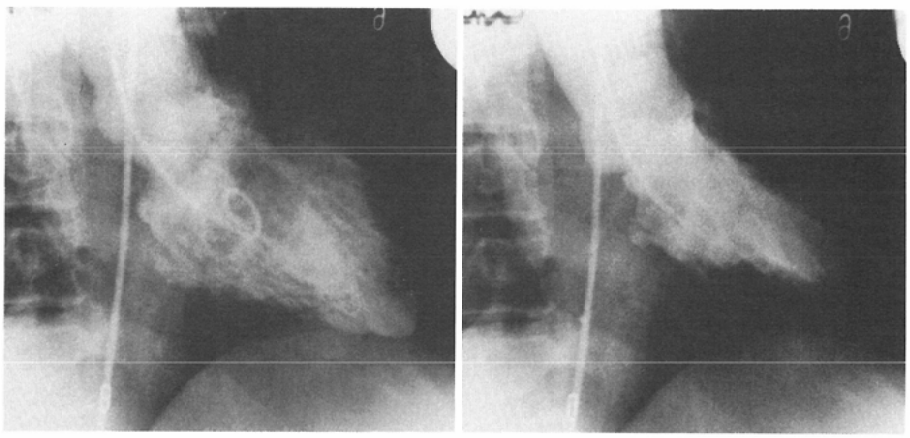

Fig. 5　Left ventriculogram of the same case as Fig. 2.
Akinesis at the apex and on the anterior wall.

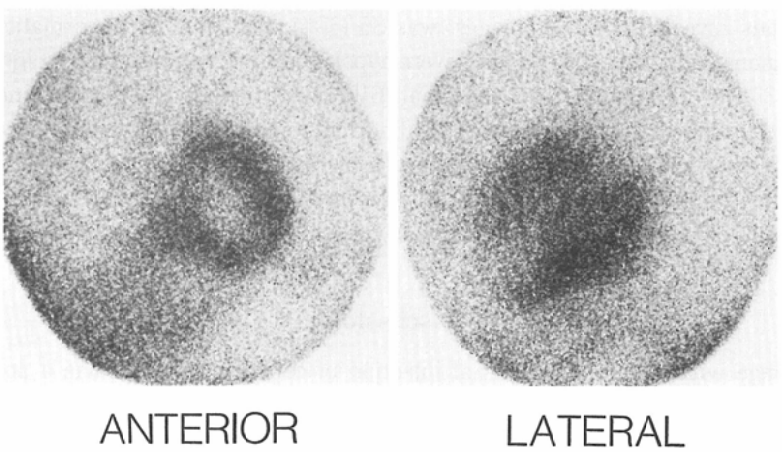

Fig. 6　Thallium-201-myocardial scintigram in the same case as Fig.2.

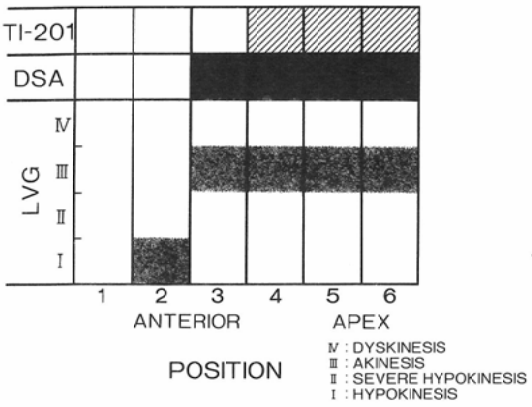

Fig. 7 Comparison of detectability of abnormal regions of left ventricular wall by three different modalities in the case shown in Fig. 2.
Thallium-201: Perfusion defect
DSA: Perfusion defect
LVG: Wall motion abnormality

Table 1 Number of abnormal regions detected by three procedures for the cases of anterior myocardial infarction.

Methodology \ Patient number	1	2	3	4	5	6	7	8	9
Thallium-201 myocardial scintigram	3	3	4	2	4	4	3	3	0
DSA	4	4	5	4	5	5	3	5	1
Left ventriculogram									
Dyskinesis			2		2				
Akinesis	4	4		3	4	6	4	4	
Severe hypokinesis			6	1					
Hypokinesis	1	1		1			1	1	1

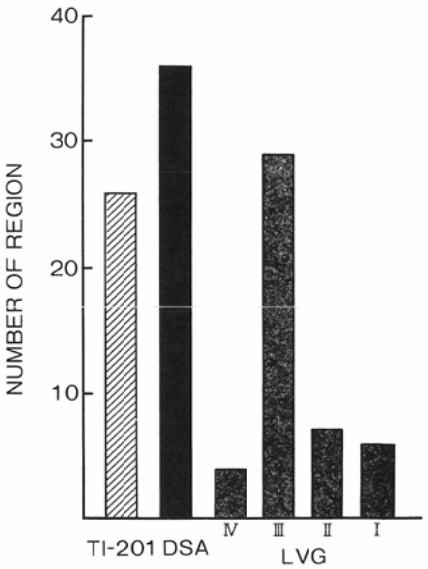

Fig. 8 Comparison of number of detected regions by three analyzing procedures in 9 cases of old anterior myocardial infarction.

DSA at the capillary phase, thallium-201 myocardial scintigraphy and left ventriculography. The number of abnormal regions revealed by DSA images, was 36 (67%). Wall motion abnormality was shown as dyskinesis in 4 regions, akinesis in 29 regions, severe hypokinesis in 7 regions and hypokinesis in 6 regions. Thus, a total of 85% of all regions were abnormal (61% of all regions showed dyskinesis or akinesis). Thallium-201 myocardial scintigraphy showed 26 abnormal regions (48%). The total number of abnormal regions demonstrated by left ventriculography, was much greater than that shown by DSA at the capillary phase ($p<0.05$). On the other hand, thallium-201 myocardial scintigraphy, seemed to show a smaller number of abnormal regions than DSA at the capillary phase, although the difference was not statistically significant.

Discussion

The DSA image with a coronary arterial injection of contrast material has a powerful ability to demonstrate not only the condition of the major branches of the coronary arteries, but also the regional distribution of myocardial perfusions at the small artery or capillary level. Actually, the DSA images did not show abnormal myocardial perfusion in the normal cases, whereas decreased myocardial perfusion has

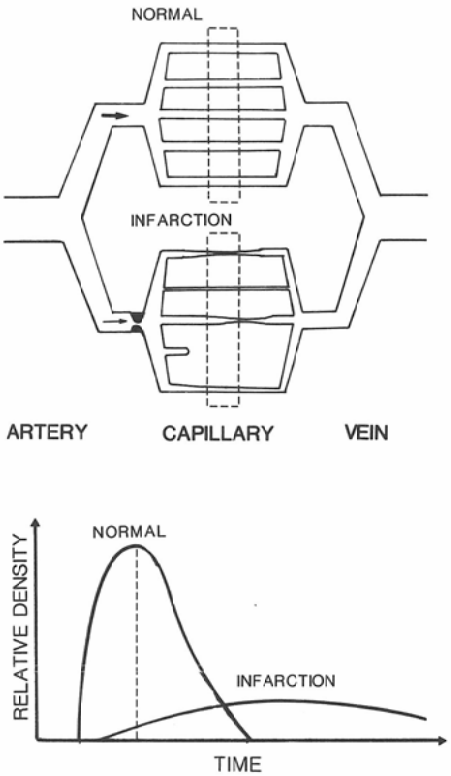

Fig. 9 Schematic model of the regional myocardium, and its time density curve.
Densitometry was performed in the dotted regions.

been shown at infarcted regions in the case of myocardial infarction[8)12)]. This decrease in myocardial perfusion might be caused by volume decrease in the vascular bed, arrival time delay of the contrast material caused by arterial stenosis and increased flow impedence in regional vessels due to pathological changes (Fig. 9).

The abnormal regions shown by the DSA images at the capillary phase corresponded well to the regions of severe wall motion abnormality shown by the left ventriculogram. So in these regions, myocardial cells might be replaced by fibrotic cells. The thallium-201 myocardial scintigram also showed the same defect in this region. Kozuka et al. reported that a good correlation was obtained between DSA images and thallium-201 myocardial scintigrams especially in the anterolateral wall[13)]. Similarly good correspondence was also revealed by the present study, but in this case the area of perfusion defect detected by the scintigram tended to be narrower than that detected by the DSA image. This must be explained as follows. The significance of the perfusion defect demonstrated by DSA is not the same as that by thallium-201 myocardial scintigraphy. The DSA image at the capillary phase may mainly describe the volume of the regional vascular bed, whereas the thallium-201 myocardial scintigram at rest may show the number of myocardial cells. The distribution of the thallous ion (Tl^{+}) is primarily intracellular and has been shown to be similar to that of the potassium ion in its concentration in the heart[17)]. However, a slight discrepancy still existed between the DSA image at the capillary phase and the thallium-201 myocardial scintigram. This may be due to the following factors:

1) The jeopardized ischemic zone shown by DSA may have viable myocardial cells, because our

previous study with circumferential analysis showed a gradual density decrease at these zones[8].

2) A poor spacial resolution of the scintigram.

3) A motion-blurred image.

4) A geometrical mismatch between the image of DSA and the thallium-201 myocardial scintigram.

The abnormal regions shown by severe abnormal wall motion corresponded well to those shown by the DSA image, except in size. The abnormal regions detected by left ventriculogram showed much broader area than those by DSA image. This over-estimation of the abnormal wall motion area might be due to passive alternation of motion of the normally perfused area by the severe dyskinesis of the adjacent ischemic myocardium[18].

Thus the regions of myocardial perfusion defect shown by DSA at the capillary phase, might describe the severe ischemic region clearly and exactly in the case of old anterior myocardial infarction.

Conclusions

In the case of anterior myocardial infarction, the DSA image at the capillary phase demonstrated the perfusion defect at the infarcted regions very well. The abnormal regions demonstrated by DSA were well correlated with both those demonstrated by thallium-201 myocardial scintigraphy, and the severe wall motion abnormality area. So the regions of perfusion defect revealed by DSA images at the capillary phase seem to describe the severely damaged region of the myocardium exactly.

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