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Myocardial perfusion assessed by digital subtraction angiography

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Summary

Perfusion of each myocardial portion in ischemic heart disease was assessed by digital subtraction angiography (DSA). There were 45 cases of ischemic heart disease and five normal controls. The contrast medium was 40 m*l* 76% Urografin which was injected into the central vein at a rate of 16 m*l*/sec using a 5F thin-wall catheter. A myocardial image was extracted, and a time-density curve for the corresponding portion was obtained. In the normal controls, the density was maximum in systole with a gradual decrease in diastole. In all myocardial infarction cases, the wave pattern disappeared. In the group whose infarcted areas were small (26 of the 45 cases), 22 (85% of the 26 cases) exhibited slowly increasing pattern. In the group whose infarcted areas were large (19 of the 45 cases), 15 cases (79%) had plateau type pattern. Observations of the perfusion of the myocardium using DSA facilitated quantitative diagnoses of the infarcted areas and forecasts of myocardial viability.

Key words

Digital subtraction angiography　Ischemic heart disease　Myocardial perfusion

Introduction

Digital subtraction angiography (DSA) is a relatively new diagnostic modality developed in the latter half of the 1970's. Its use has spread rapidly during the last several years, presumably because of its ease of operation, relative noninvasiveness, modest cost, and markedly improved image quality[1~3]. DSA makes particularly good use of the novel features of cardiac function diagnosis by nuclear medicine and it provides excellent resolution through its radiographic technique[2~10]. This is a report of observations of myocardial perfusion in each myocardial portion in patients with ischemic heart disease utilizing DSA.

Materials and methods

The subjects were 45 patients of ischemic heart disease (32 men, 13 women), whose ages ranged

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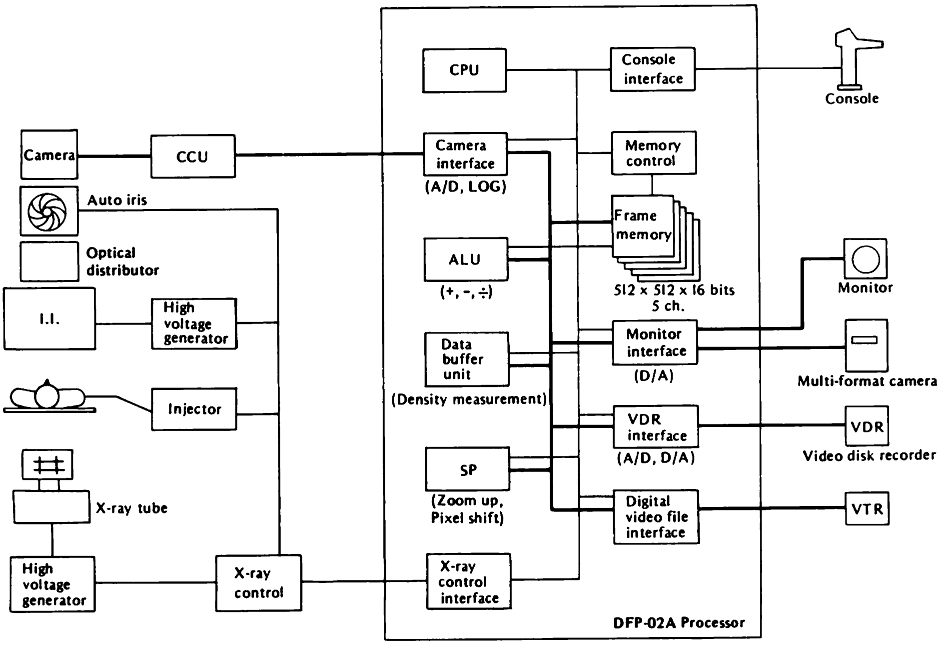


Fig. 1. Basic block diagram of the Toshiba DFP-02A digital fluorography system.
—— deta line ; —— signal line.

from 40 to 73 and averaged 50.2±6.4 years. The controls were five cases of hypertension (three men and two women, whose ages ranged from 35 to 45 and averaged 42±2.5 years). The ischemic heart disease included seven acute myocardial infarction (AMI), 24 old myocardial infarction (OMI), two combined acute and old myocardial infarction, and 12 combined acute myocardial infarction and angina pectoris. All cases received cardiac catheterization and angiography, myocardial scintigraphy and CT.

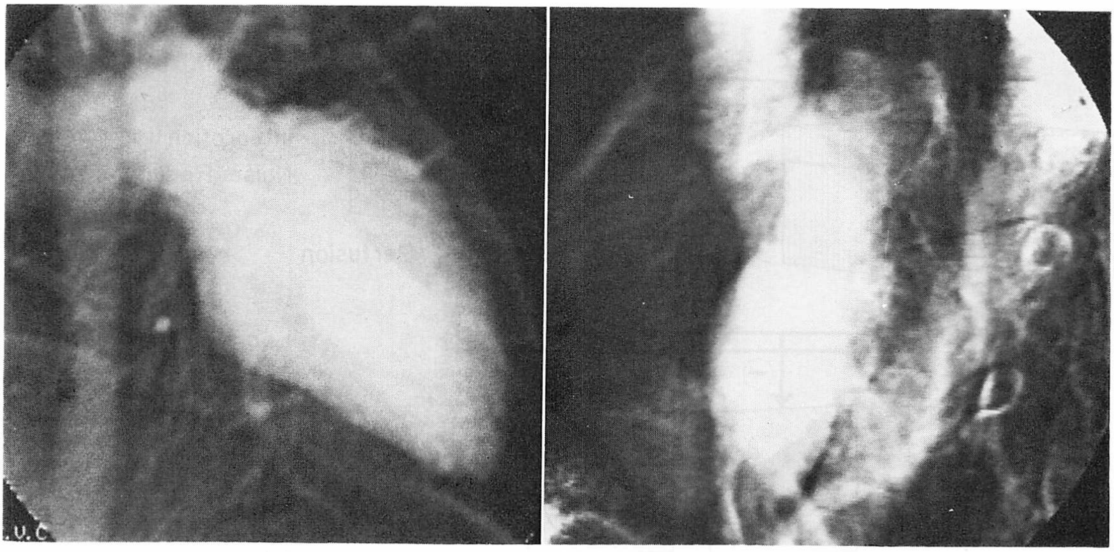
Four subtraction models were available, but only the super-pulse image mode with 30 frames/sec, a pulse width of 10 msec, and its time interval difference (TID) mode were used for the examination of patient group.

Data processing was performed using a 10-bit, 10 MHz, analog-to-digital (A/D) converter with a frame memory capacity of 512×512×16 bits and an 8-bit digital-to-analog (D/A) converter to provide a 256-level gray scale. The data were processed using a densitometer, facilitating measurement of the average contrast levels of the regions of interest (ROI). The X-ray tube focal spots were 0.6 mm and 1.2 mm, and the image intensifier was of the metal fiber type.

Fig. 1 is a block diagram of this system, the Toshiba Digiformer X (Model DFP-02A). Using an A/D converter, a set of analog data was digitized to 512×512 pixels, 10 bits, 1,024 levels per frame. This digital signal was further processed by logarithmic amplification, then fed into the computer memory.

An antihistamine was first administered intramuscularly. A 5F, 65 cm thin wall catheter with side holes was introduced through an antecubital vein. Its tip was advanced into the superior vena cava or right atrium. Then, 35 to 40 m*l* (0.7 to 0.8 m*l*/kg) 76% Urografin were injected each time, not exceeding 50 m*l* in the total amount, at a rate of 16 m*l*/sec.

For radiography 1) 30-degree right anterior oblique, 2) 70-degree left anterior oblique with 15-degree caudo-cranial tilt, 3) hepato-clavicular (four chamber) and 4) left lateral projections were used. Projections 1) and 2) were most



(A) (B)

Fig. 2. Left ventriculograms obtained from a patient with hypertension.

These frames are obtained after a central intravenous injection of 40 m*l* 76% Urografin. X-ray exposure projections used are 30-degree anterior oblique (A), and 70-degree left anterior oblique and 15-degree caudo-cranial tilting (B).

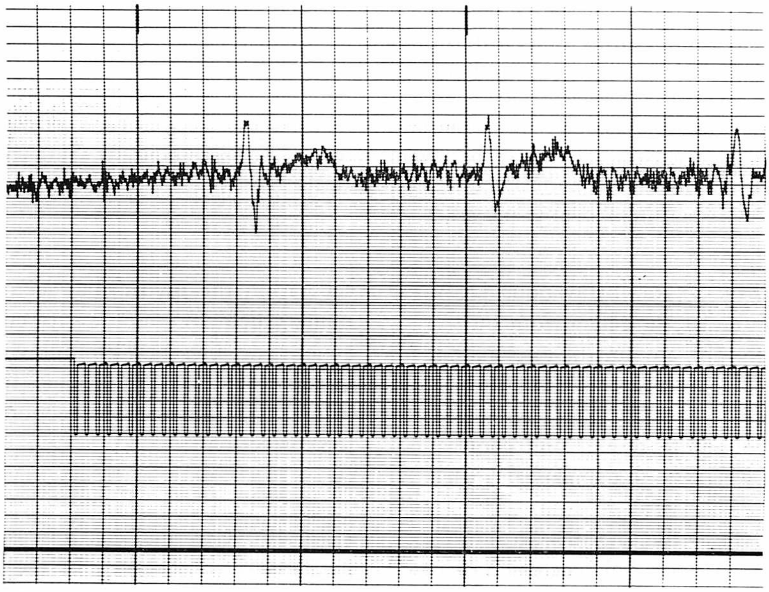


Fig. 3. Signals of X-ray exposure and ECG.

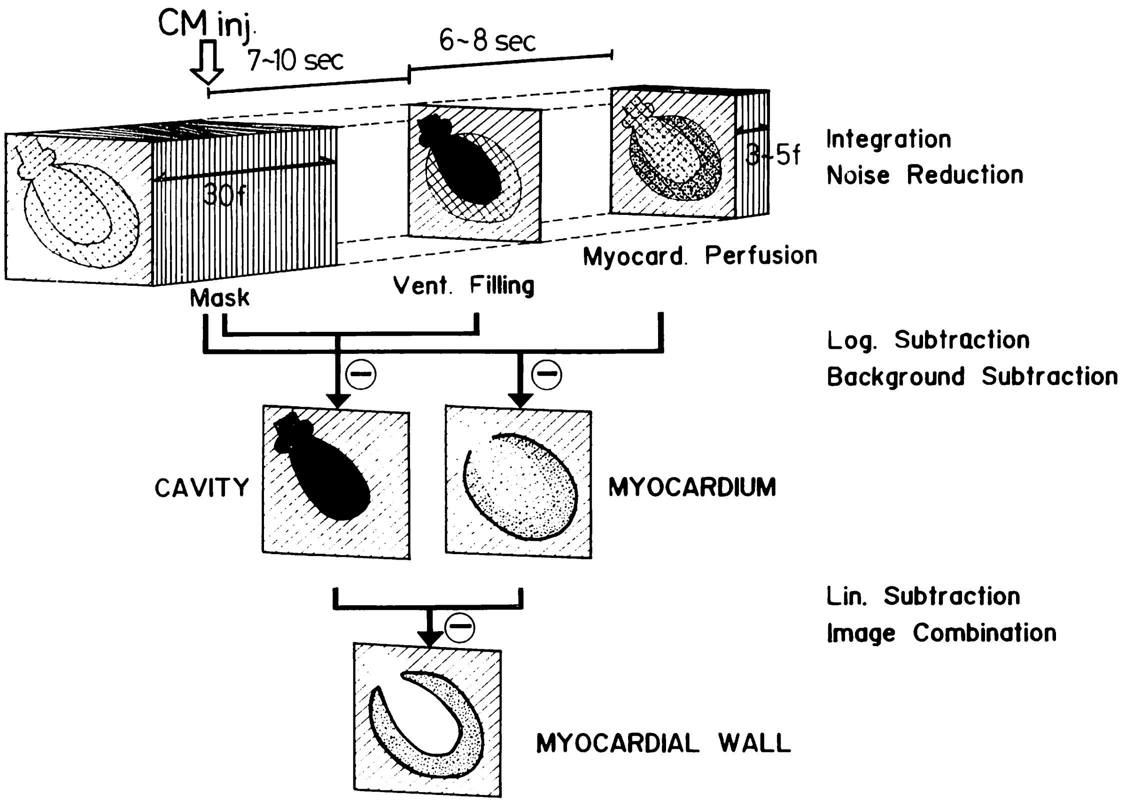


Fig. 4. Method of obtaining myocardial images.

Seven to ten seconds after contrast medium is injected into the central vein, an image of the filled ventricle is obtained. Then, 6 to 8 seconds later, the periodic image of myocardial perfusion is obtained. Some 3 to 5 image frames obtained in this period are integrated for the purpose of noisere duction. Then, the background is deleted in such a way that the mask images are logarithmically subtracted from the filled ventricle and myocardial perfusion images. It is furthermore possible to define the myocardial wall by linearly subtracting these two images.

frequently used (**Fig. 2**) for intravenous DSA, since superimposition of the left atrium on the left ventricle lessens the amount of information about the left ventricle. Thus, the tilt projection, 2) is necessary.

The ECG, radiographic signals and contrast medium injection were simultaneously recorded (**Fig. 3**).

The method of the extracting myocardium is shown in **Fig. 4**. Myocardial perfusion was measured under static and dynamic conditions. The extracted myocardial region was enhanced using a band window mode (**Fig. 5**). ROI was set within the myocardial section and the pulmonary field. A time-density curve in ROI was generated. The background value in the pulmonary field was subtracted from the density value of the myocardial section for each frame, for correction.

Results

In all five normal control cases, normal wave patterns were observed in the myocardial sections surrounding the left ventricular cavities as shown in **Fig. 6**. The normal wave patterns reached maximum in systole and decreased

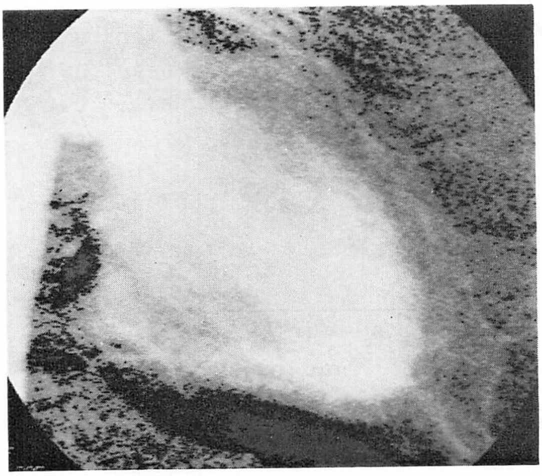


Fig. 5. The extracted myocardial region enhanced by using a band window mode.

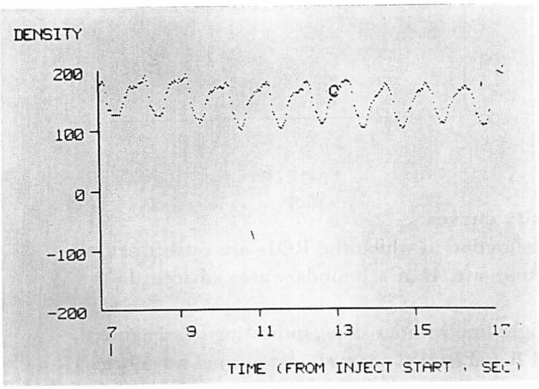


Fig. 6. Normal wave pattern obtained from a patient with hypertension.

gradually in diastole, as observed in the segment near the cardiac base (Seg. 1 and Seg. 2 of the American Heart Association categorization). Near the cardiac apex (in Seg. 3) the wave patterns showed delays in the cardiac phase.

In the time-density curve for the myocardial infarction portion, a normal wave pattern was not observed in any case. The irregular curves were classified in two groups: 1) a curve which showed a gradual rise (26 of 45 cases) (**Fig. 7**), and 2) a curve which formed a plateau (19 of 45 cases) (**Fig. 8**).

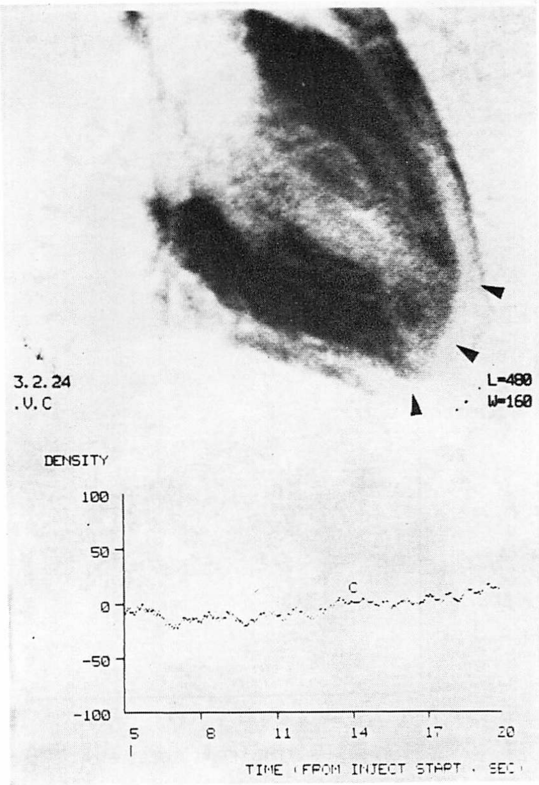


Fig. 7. Time-density curve obtained in a patient with small myocardial infarction located at the left ventricular apex.

Time-density curve shows a gradually rising density that does not form a normal wave pattern.

Arrowheads: akinetic region.

Fig. 9 shows the trend of the time-density curve of all 45 cases of infarction, assuming that the akinetic or dyskinetic region, where the ROI is centered, is the infarcted area. Of the 45 cases, 26 had infarcted area small enough to cover the only one segment in the American Heart Association categorization, and 22 of these showed a gradually rising density curve without normal wave pattern, and four showed even flat density curve after the background was subtracted. Remaining 19 cases had larger infarction containing two or more segments in the American Heart Association categorization, and four of them showed a rising density curve

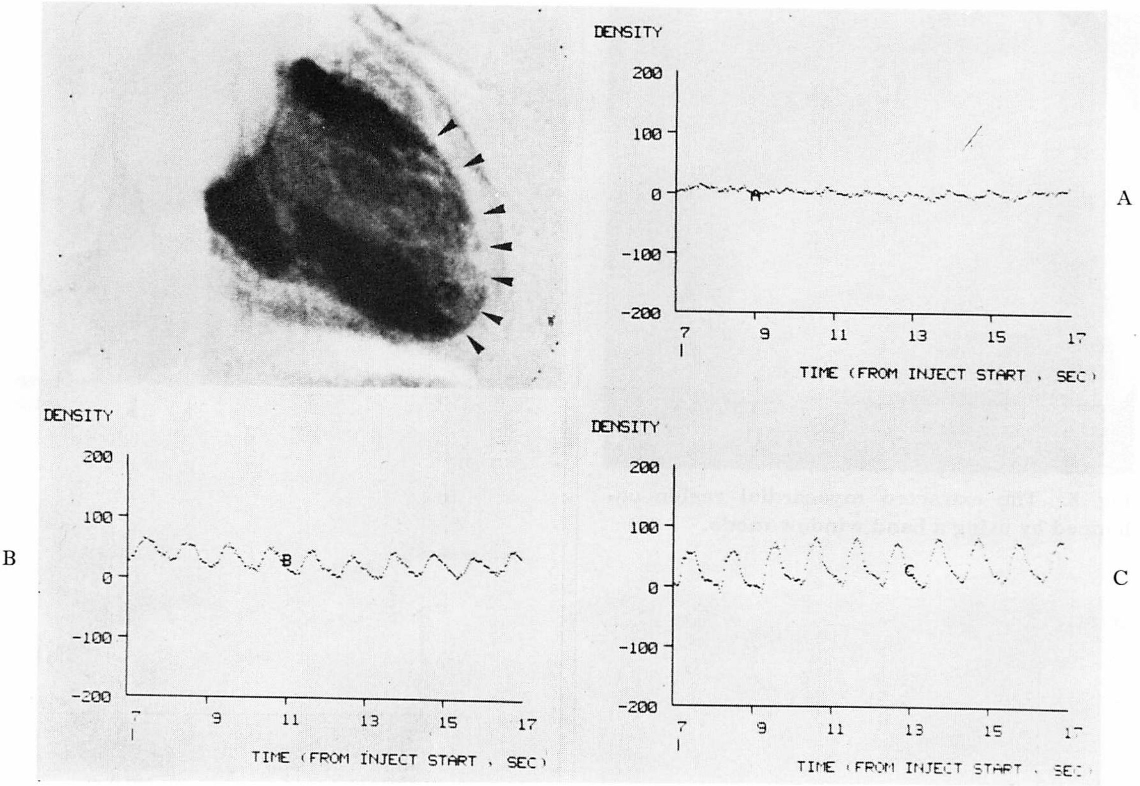


Fig. 8. Angiogram and three different time-density curves.

This figure shows a case of anteroseptal myocardial infarction in which the ROIs are established at 3 different places, A, B and C. A is located at the infarction site, B at a boundary area adjacent to the normally contracting area and C at the normal area.

The time-density curve of ROI A shows a nearly straight line without slope, indicating nearly absent blood flow in the infarcted area. On the other hand, ROI B and ROI C show almost normal waveforms.

and 15 showed a flat line.

Discussion

Due to the specificity of the coronary circulatory system and other factors, myocardial blood flow is very difficult to measure compared with blood flow in other organs. Under the present circumstances, there exists no satisfactory method for measuring the absolute value of the coronary blood flow in a non-invasive manner[11,12].

A less invasive procedure was attempted to observe the myocardial perfusion using DSA. With this method, there might be a problem as to where and how to establish the ROI for calculating the background count. Two factors affect the density of the myocardium; 1) the recirculated contrast medium causing superimposition on the left ventricular cavity in the 30-degree RAO projection, and 2) the contrast medium passing through the pulmonary vein. The former factor can be eliminated when the myocardial image is extracted just before the coronary sinus is opacified. *The latter factor has an important effect.* The effect of superimposition on the pulmonary vein was eliminated by subtracting the density from the course of the pulmonary vein (**Fig. 10**). In the fan-like zone converging from the lung periphery to the pulmonary venous trunk, ROI 1 was set in the

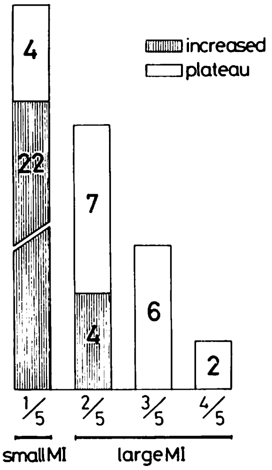


Fig. 9. Result of studying the trend of the time-density curve.

In the small myocardial infarction (MI) group, 22 of 26 (85%) cases show an increased density with time.

In the large MI group, only 4 of 19 (21%) show an increased pattern. The remainder, 15 of 19 (79%), revealed a plateau pattern.

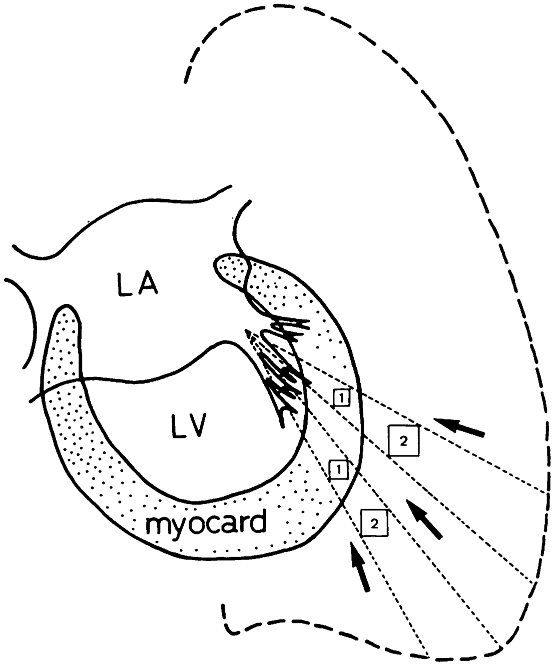


Fig. 10. Schematic interpretation of ROI setting.

Arrows reveal the direction of pulmonary venous return.

The fan-like area converging from the lung periphery to the pulmonary venous trunk is supposed. ROI 1 is set in the myocardium and ROI 2 in the pulmonary field.

LA = left atrium; LV = left ventricle; myocard = myocardium.

myocardium; ROI 2, in the lung periphery adjacent to the peripheral margin of the myocardium. The density of the myocardium was obtained by subtracting ROI 2 from ROI 1.

The difference in the amount of contrast medium reaching the wide and narrow infarcted areas could be observed. Thus, in most cases, the broad infarcted areas exhibited low density values, and the narrow infarcted areas exhibited high density values. However, no correlation was observed between the widths of infarcted areas and the times following the onsets of infarction.

By extracting cardiac images and describing their time-density curves, it was found that the widely infarcted areas did not show any changes in density, but in many instances, the narrow infarcted areas exhibited rises in density with time. These findings coincide with reports of observations made using X-ray CT$^{12)}$. These phenomena reflect the establishment of collateral circulations caused by fibrotic changes following infarction. As explained, DSA has clarified the perfusion status in the infarcted areas, disclosing the sites and extents of non-perfused myocardium.

This study did not consider the effects of scattered X-rays, which must be included for more accurate observation of the coronary blood flow. The amounts of contrast media were limited in DSA, so radiographs could not be obtained in various projections. This is a disadvantage of DSA, however, this study may be the first step in quantitative assessments of the extension of myocardial infarction based on the myocardial perfusion, and it may aid in assessments of myocardial viability.

Digital subtraction angiographyによる心機能解析：特に心筋灌流分布の評価

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Digital subtraction angiography (DSA)を用い，心筋各部の灌流状態を観察した．対象は虚血性心疾患45例，および正常対象群としての高血圧心5例である．造影剤は76% Diatrizoate 40mlで，5Fカテーテルを中心静脈にまで挿入し，16ml/秒で注入した．左心室が造影された後に得られる心筋濃染像を抽出し，心筋部の時間-濃度曲線を描かせた．

正常対象群では，収縮期に最高値となり，拡張期には緩慢に下降する曲線が得られたが，心筋梗塞例ではそれらの正常波形が全くみられなかった．また，限局性心筋梗塞群(45例中26例)では，22例(26例中85%)に不規則ながらも徐々に上昇するpatternが得られた．広汎梗塞群(45例中19例)では，15例(79%)に全く変化のないplateau型の濃度曲線が得られた．

DSAを用いて心筋灌流状態を観察することにより，梗塞部およびその周辺の心筋性状を知ることができると考えられた．

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