Echocardiography
Evaluation of the Tissue Character in Myocardium

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The present authors developed the method of ultrasono-cardiotomography in 1964. Since then evaluation of the anatomical structure and organic changes in heart tissues has been carried out noninvasively in our institute. In my presentation, emphasis will be laid on the usefulness and significance of ultrasono-cardiotomography for the detection and evaluation of changes in the tissue character of the myocardium.

Materials and Methods
Forty patients with myocardial hypertrophy or degeneration were investigated. These patients were selected from cases with valvular diseases, hypertension, hypertrophic or congestive cardiomypathy, myocardial infarction, endocarditis or endocardial fibroelastosis. Patients were subjected to routine physical and laboratory examinations, including ECG, X-ray examinations, cardiac catheterization etc. In order to confirm the diagnosis, the sections of specimens obtained at surgical operation, biopsy or at postmortem autopsy were examined in several cases. The findings thus obtained were compared with the findings on ultrasono-cardiotomography. The correlation between these two findings in myocardial infarction was investigated further by animal experiments.

The ultrasonic transducer used in this investigation had a concave disc with 2.25 MHz or 3.5 MHz in frequency. The transducer was 30 mm in diameter and 100 mm in its radius of curvature. The ultrasonic examinations were carried out by the transthoracic technique in a supine position. The intensity of the echoes in the abnormal tissue was measured by sensitivity graded tomogram pairs obtained by changing the gain of the receiving amplifier at intervals of 3 dB to 5 dB.

The cardiotomographic findings of the cases with abnormality in myocardial tissue are characterized as follows by three criteria:
First, based on the degree of the morphological changes, for instance the changes in wall thickness or deformation of the heart structure.
Second, based on the appearance of abnormal echoes and their distribution.
Third, based on the changes in the character of the echo especially the changes in echo intensity.

Morphological changes of the heart structure in cases with myocardial damage

In cases with myocardial abnormality, the changes in wall thickness and dimension of the ventricular cavities were observed as morphological changes. Fig. 1 shows a summary of the morphological changes. The changes in wall thickness can be classified into the following three types. They are:
Type I, associated with an increase in thickness;
Type II, in which the wall thickness has remained unchanged;
Type III, which is associated with a decrease in thickness;
The upper photograms of this figure show type I which is observed in hypertrophic car-
diomyopathy, the pictures in the middle show type II.

The left side picture in the middle shows a case of congestive cardiomyopathy and the right side picture shows a case of mitral regurgitation. The lower ones show type III which is associated with decreased thickness. The left side picture is a case of myocardial infarction and the right side one is a case of endocardial fibroelastosis.

Changes in the dimension of the ventricular cavities are also divided into three types. They are a narrow-space type, type with dilated space and a type with ordinary space. Obstructive cardiomyopathy belongs to the narrow-space type and congestive cardiomyopathy and endocardial fibroelastosis belong to the type with dilated space.

Appearance and distribution of abnormal echoes

Two kinds of echoes are found in this study. One is an echo which is the same as that observed usually in normal tissue but is remarkably increased in its intensity. The other is an echo which is not detected in normal tissue.

The abnormal echoes mentioned above are also classified into three types on the basis of the echo pattern and its distribution on the cardiomogram. As demonstrated in the upper photograph of the Fig. 2, the first type is a case with unusual increment in the intensity of the echo.
that is reflected from the endocardium and from the myocardial tissue in its vicinity. The left side tomogram shows a case of bacterial endocarditis and the right one shows a case of endocardial fibroelastosis. Both of them are associated with changes in the tissue character of the endocardium and its vicinity.

The second type is a case with a wide and intensified echo of the endocardium together with a fine nodular echo which is localized in the inner half of the myocardium adjacent to the endocardium, and is frequently observed in valvular diseases, hypertension and cardiomyopathy. The tomogram (middle left on this figure) shows a case of valvular disease and the right one shows a case of cardiomyopathy.

The third type has abnormal echoes throughout the myocardium. The lower tomograms of this figure demonstrate an echo of this type. The left side picture shows a case of obstructive hypertrophic cardiomyopathy and the right one shows a case of myocardial infarction. The white arrow indicates the abnormal echo.

The abnormal fine nodular echoes that are observed in the third type are classified into three types on the basis of the difference in their echo character as shown in the Fig. 3.

The first type shows a large nodular pattern as observed in the upper tomogram of this figure. This is an echo from a case of hypertension.

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The second type shows a medium-sized nodular pattern as observed in the picture in the middle. This picture shows an echo from a case of nonobstructive hypertrophic cardiomyopathy.

The third type shows a fine nodular pattern as observed in the lower tomogram of a case of IHSS.

The fine nodular echo as observed in the third type is recognized frequently in normal cases.

From these results, it is considered that the shape and distribution of the echo in the myocardium differ depending on the kind of heart disease and on the mechanism that is responsible for the tissue degeneration.

**Measurement of the echo character of abnormal echoes**

For the quantitative measurement of the intensity and the distribution of abnormal echoes, the sensitivity graded tomogram pair method was utilized.

As shown in Fig. 4, in normal cases, when the intensity of the echo from the pericardium is 0 dB, that from the endocardium is about 20 to 25 dB weaker than that of the pericardium. The echo from the myocardium is about 25 to 30 dB weaker than that from the pericardium.

Fig. 5 shows a case of endocardial fibroelastosis. A wide and strong echo is demonstrated in the endocardium. The intensity of this echo is
about 15 dB weaker than that of the pericardial echo and is about 5 to 10 dB stronger than that of the normal endocardial echo.

Fig. 6 demonstrates a case of aortic insufficiency. In this case, the abnormal echoes are distributed in the inner half of the myocardium adjacent to the endocardium. The endocardial echo appears in the range of 10 to 15 dB. The intensity of the abnormal nodular echo in the myocardium is about 5 dB weaker than that of the endocardial echo. However these abnormal echoes are about 5 to 10 dB stronger in intensity than the normal myocardial echo.

Fig. 7 shows tomogram pairs in a case of transmural myocardial infarction which was produced in an animal experiment. The intensity of the abnormal band-shaped echo in the myocardium is nearly of the same intensity as that of the pericardial echo. The intensity of these abnormal echoes produced by scar tissue or marked increment of the fibrous tissue in the myocardium are about 20 to 30 dB stronger than that of the normal myocardial echo.

The nodular or fine nodular echoes caused by the degeneration or moderate increment of the fibrous tissue in the myocardium are about 5 to 10 dB stronger in intensity than the normal myocardial echo.

These results indicate that strong abnormal echoes appear when organic changes occur in the myocardium. Thus it was found that the sensitivity-graded tomogram pair method is useful for the evaluation of the quality of the myocardial tissue.

Correlation between the echo pattern and actual changes of the tissue character

A correlation between the echo pattern demonstrated on the cardiotomogram and actual changes of the tissue character in the myocardium were demonstrated in Fig. 8. Case I is a case of non-obstructive hypertrophic cardiomyopathy. Large nodular and massive echoes in the myocardium and wide strong echoes in the endo-
Fig. 5. Sensitivity graded tomogram pairs in a case of endocardial fibroelastosis.

cardium at the area indicated by the white arrow on the tomogram are recognized.

Case II is a case of obstructive hypertrophic cardiomyopathy. As shown in the cardiotomograms, numerous medium and fine nodular echoes which shown a reticular pattern are observed in the myocardial area of the left ventricular wall. Actual histological findings of the specimen obtained at autopsy are demonstrated in the right side pictures. These sections were stained by the technique of Masson’s trichrom stain, so the areas that are stained blue indicate the presence of tissue degeneration or fibrous tissue.

Thick fibrous tissues are observed at the area which is demonstrated by a wide intensive echo. Degeneration of the myocardium and increment of the fibrous tissues are demonstrated in the area of nodular or fine nodular echoes.

Case III is a case of anterior myocardial infarction in an experimental dog. As shown by the white arrow, scar tissue is found at the area of

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the narrow intensive nd band-shape echo.

In myocardial infarction, mild or moderately severe cases are only examined by ultrasono-
cardiogtomography and by UCG. These patients improve and thus no specimen is taken from them. On the contrary, in severe cases a sudden death frequently occurs before the detailed ultrasonic examination is carried out.

Therefore, it is difficult to collect the exact data of ultrasonic examination or a histological examination in various types of myocardial infarction. So, experiments were carried out by using dogs with various types of myocardial infarction.

Based on the results of the experiments, ultrasono-cardiogramographic findings were divided into the following two general types;

Type I: the echo of the ventricular wall becomes remarkably narrow in width. A strong cord-like pattern is observed everywhere as demonstrated on the left photogram in Fig. 9.

Type II: scattered large nodular echoes in the
localized area of the myocardium as shown in the right photogram of this figure.

Type I was recorded in a case of antero-septal infarction of the transmural type. A strong and band-shaped echo is demonstrated in the ventricular septum. Scar tissue is observed over a wide area corresponding to the changes observed in the excised heart. The ventricular septum is very thin. Type II of this figure was recorded in a case of posterior infarction. In this type, damage of the myocardium is of the transmural type, but small areas of localized necrosis are scattered throughout the myocardium. Large nodular echoes are found in the corresponding area of the myocardium as shown by the white arrow on the tomogram.

Fig. 7. Sensitivity graded tomogram pairs of the excised dog heart in a case of transmural myocardial infarction.

Fig. 10 shows mild cases of the type I and type II. Photogram III shows the same pattern as that in type I. But the area of the infarction is narrower than that in the figure 9. The case shown in the right photogram had subendo-cardial infarction. Nodular echoes can be found in a localized area of the myocardium adjacent to the endocardium.

The results obtained from humans and experimental dogs suggested that the changes in echo patterns in myocardial area are in good agreement with those in the actual tissue character. Thus it was found that the quality of myocardial tissue degeneration can be evaluated non-invasively by ultrasono-cardiotomography.

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Fig. 8. A correlation between the echo pattern on the cardiotomogram and actual changes of the tissue character in the myocardium.

Fig. 9. A correlation between the echo pattern on the cardiotomogram and actual changes of the tissue character in the myocardium of transmural myocardial infarction which was produced in an animal experiment.
CONCLUSION

From the facts mentioned so far, it can be concluded that the changes of the tissue character which appeared in the heart structure can be evaluated non-invasively by using ultrasonocardiotomography.

However, problems such as microscopic analysis of the acoustic character of the tissue and improvement of the resolution of the tomogram remain to be solved for their practical application. Further development, of course, in this field is anticipated.