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CLINICAL APPLICATIONS OF FETAL ECHOCARDIOGRAPHY

HIDEYO SHIMADA, MICHIKO TAKAHASHI,
SHIZUO KATAGIRI

Department of Medicine, Kitasato Institute Hospital, Tokyo, Japan

HIDEO KOBAYASHI

Department of Gynecology

KAZURU SAITO

Central Laboratory

Recent advances of echocardiography have made it possible to study cardiac anatomy and circulatory physiology of fetus.

We studied the foetal cardiac structures and physiology by cross-sectional and *M*-mode echocardiography in 200 fetuses at 32-40 weeks of gestation. Fetuses were reexamined within 2-5 days after birth to provide comparative data for assessment of circulatory changes at birth.

In these echocardiographic studies, we examined three cases with congenital cardiac malformations (DORV, TGA, and VSD). We diagnosed DORV before birth, when two great arteries rising from one single ventricle were observed. But TGA and VSD were only diagnosed after birth. Therefore, we concluded that this technique is useful to diagnose malformations of the cardiac chambers or correlations between the cardiac chambers and the two great arteries.

We also examined mitral valve diastolic descent rate (MVDDR), mitral valve excursion (MVE), tricuspid valve diastolic descent rate (TVDDR), tricuspid valve excursion (TVE) and aortic dimension (AOD).

In conclusion, fetal echocardiography may be applicable to diagnose cardiac malformations and also to evaluate cardiac functions before birth.

1. Introduction

Ultrasound technique has made it possible to analyse the physiological states of the various organs of the human body. In the field of cardiology, many new approaches have been tried, and nowadays the ultrasound technique is believed to be an indispensable method for the diagnosis of heart and the great vessels.

Especially, the recent advances in the cross-sectional echocardiography and Doppler method enabled us to record the states of the fetal heart and to analyse the fetal cardiac anatomy and physiology.

The present study explains the technique to record fetal echocardiogram and its clinical applications based on our experiences over the past 3 years.

2. Method

Three-hundred and twenty-five fetuses of healthy mothers, varying 30 to 40 weeks of gestation were selected for this study.

Cross-sectional and *M*-mode echocardiography were used for recording in all cases. In our first attempt, we failed to obtain good tracings in 1/3 of the cases, but we tried again within the same week on the failed cases. Finally, from 85 per cent of all the cases, we could get enough information to evaluate the foetal heart.

Ten cases from which clear four chamber view tracings could be obtained, went to Doppler study.

Fetuses were re-examined within 4 to 7 days after birth, to provide comparative data for the assessment of circulatory changes at birth.

A Toshiba SSH 11 real-time, phased-array ultrasonic sector scanner with a hand-controlled 2.4 MHz transducer, was used to perform cross-sectional and *M*-mode echocardiography.

Pulsed Doppler examinations were performed with a Doppler flowmeter combined with the echocardiograph systems.

The most important thing to get a good fetal echocardiograms is the transducer positions.

When the fetus is in the right occipito-anterior position or left occipito-anterior position, echocardiograms can be obtained from maternal right or left flank, respectively (position *A* in Fig. 1).

From this position, the ultrasonic beam passes through the fetal heart via the fetal spine and fetal lung. Therefore, the sector images of te fetal heart along its mirror imaged long axis view can be obtained (Fig. 2). It is especially easy to estimate the orientation of the fetus and fetal heart in this position.

A long axis view tracing, a short axis view tracing and a four chamber view tracing can be obtained, when the transducer is placed on the maternal naval region, as shown in position B in Fig. 1. But it is rather difficult to determine the transducer position to get stable tracings.

We proceeded with Doppler examinations as soon as a clear four chamber view tracing had been obtained. The sampling site of the left side of the heart was the left ventricular outflow tract just below the mitral valve, and the right side of the heart, it was the right ventricular outflow tract just below the tricuspid valve.

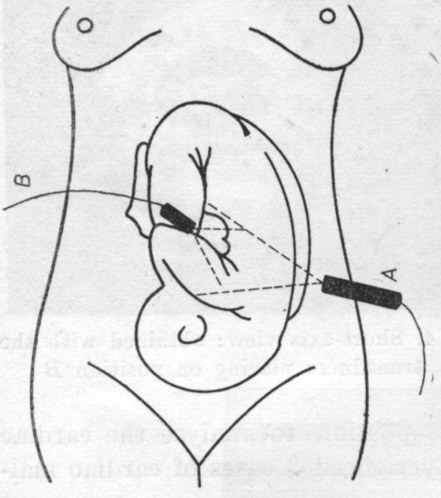

Fig. 1. Two standard transducer positions: A — transducer is placed in maternal flank; B — transducer is placed in maternal navel region.

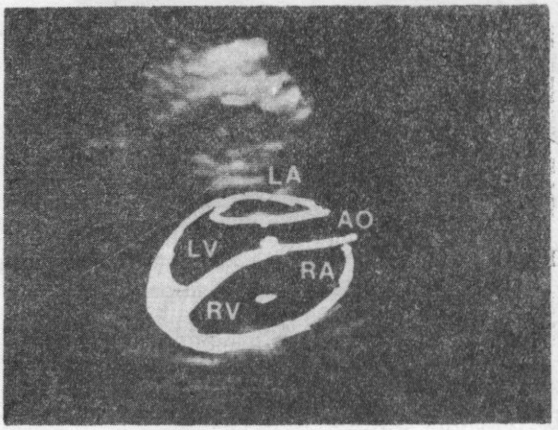

Fig. 2. Long-axis view: obtained with the transducer placing on position A.

The flow velocity was calculated by using the formula as follows.

$$v = \frac{f_2 C}{2 f_0 \cos\theta},$$

where v — maximum velocity, f_2 — frequency shift, f_0 — transducer frequency, θ — angle between ultrasound beam and velocity.

3. Results

1. Normal cross-sectional echocardiogram of the fetus

Fig. 2 shows a long axis view tracing obtained from the material flank (position A in Fig. 1). Instead of the usual long axis view pattern obtained from the chest wall, a mirror imaged pattern was detected through the echocardiogram.

Fig. 3 shows a long axis view tracing obtained from the material naval region (position *B* in Fig. 1). The pattern is quite similar to that of the one obtained from the chest wall.

Fig. 4 is a short axis view tracing and Fig. 5 is a four chamber view tracing. These echocardiogram patterns are quite similar to those obtained from the chest wall.

Fig. 3. Long-axis view: obtained with the transducer placing on position *B*

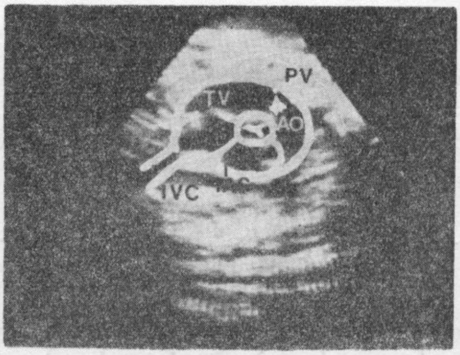

Fig. 4. Short-axis view: obtained with the transducer placing on position *B*

By utilizing these echocardiograms, it is possible to analyse the cardiac anatomy to a certain extent. We already experienced 3 cases of cardiac malformations among 325 cases.

2. Abnormal cross-sectional echocardiogram of fetus

As mentioned above, we experienced 3 cases of cardiac malformations. These are DORV, VSD and TGA. We diagnosed DORV before birth, but we could not make diagnosis of VSD and TGA before birth.

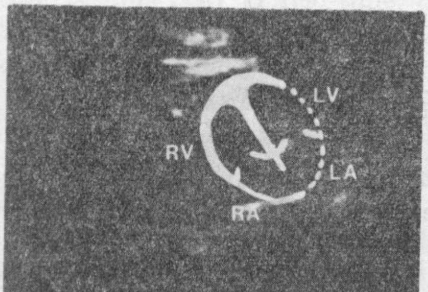

Fig. 5. Four-chamber view: obtained with the transucer placing on position *B*

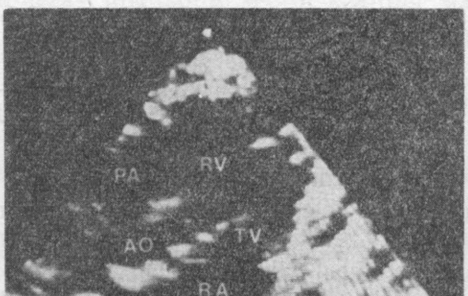

Fig. 6. Double outlet right ventricle. The view obtained with transducer placing on position *B*. Two great arteries which arise from the single ventricle are displayed to the left of the image

Fig. 6 is the cross-sectional echocardiogram of the fetus with DORV. It shows a quite abnormal findings, i.e. two great arteries arise from the single ventricle which has coase trabeculations.

This finding suggests a case of either DORV or single ventricle.

The fetus was born at 40 weeks as a girl weighing 3040 grams, but cyanosis was not observed at birth. At one month of age, the girl began to experience cyanosis by crying. At this point catheterization and angiography were performed and DORV was diagnosed. Cyanosis and dyspnea developed gradually and she died at the age of 2 months. Autopsy revealed DORV, polysplenia and dextrocardia.

3. Normal M-mode echocardiogram of the fetus

M-mode echocardiograms are also recordable from various places in fetal heart.

Fig. 7 is a mitral valve echocardiogram pattern obtained from the image in Fig. 2. The mitral valve pattern shows a mirror image from the pattern obtained from the chest wall, i.e. as shown in the figure, the anterior leaflet of the mitral valve moves posteriorly during the diastolic phase.

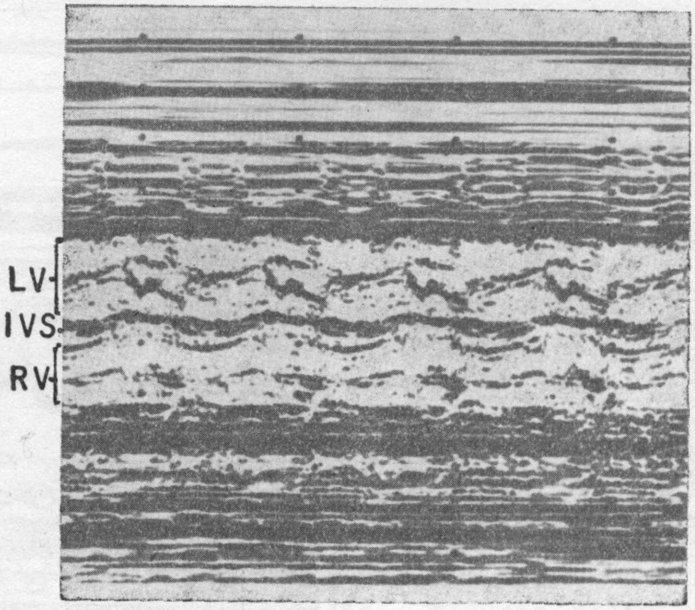

Fig. 7. A mitral valve echocardiogram pattern obtained from the image in Fig. 2

Fig. 8 is an aortic valve pattern obtained from the same image. The top of the panel is the left atrium and the bottom is the right ventricle, and the middle part is the aorta. The aortic valve moves posteriorly during the systolic phase.

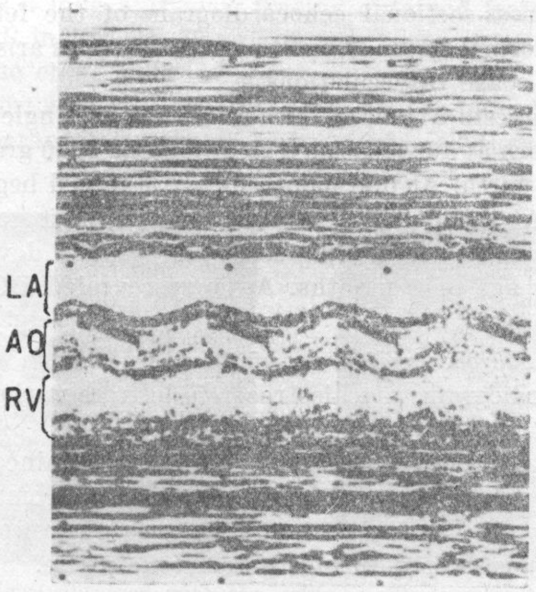

Fig. 8. An aortic valve pattern obtained from the image in Fig. 2

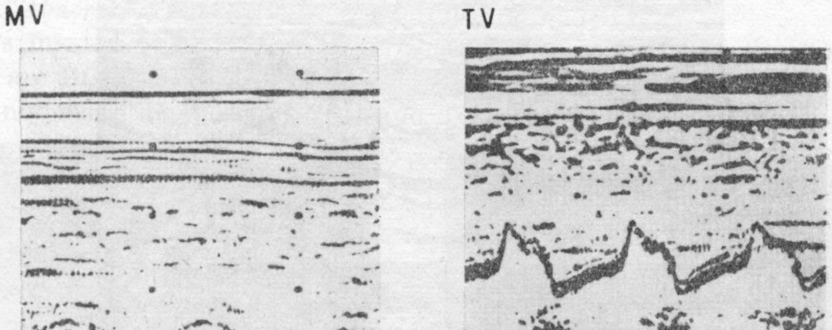

Fig. 9. Echocardiogram patterns of mitral valve and tricuspid valve

Fig. 9 shows echocardiogram patterns of the mitral valve and the tricuspid valve. These are quite similar to the pattern obtained from the chest wall.

Fig. 10 shows the echocardiogram pattern of the aortic and pulmonary valves. The aortic valve pattern here is quite similar to that of the usual pattern, but the pulmonary valve pattern is lacking an *a* dip, probably due to pulmonary hypertension.

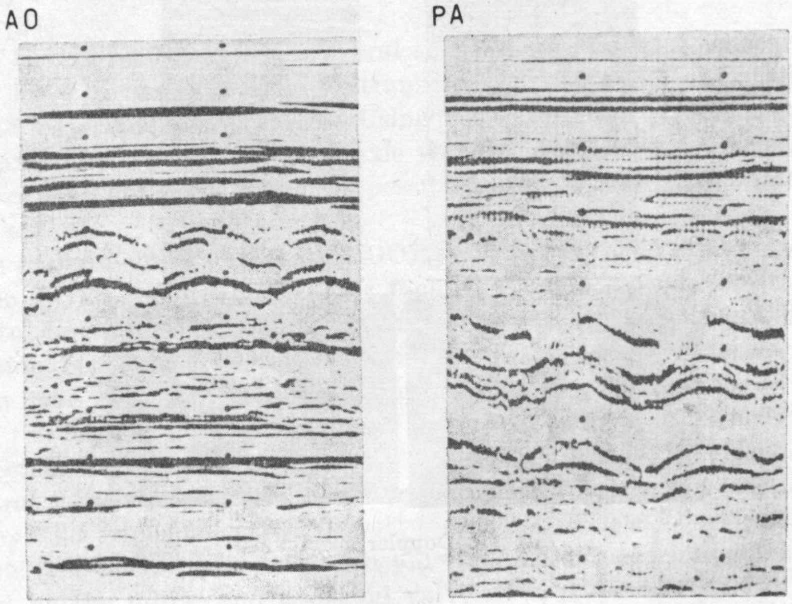

Fig. 10. An echocardiogram pattern of the aortic and pulmonary valves

4. Normal values of the M-mode echocardiogram of the fetus

The normal values of the fetal *M*-mode echocardiograms were calculated from the above mentioned figures.

The normal data of the fetuses are described in Table 1.

Table 1

Specification	Before birth [mm]	After birth [mm]
MVDDR	43.1 ± 12.4	54.3 ± 7.7
MVE	7.3 ± 0.9	9.5 ± 1.1
TVDDR	49.7 ± 12.8	57.9 ± 9.1
TVE	8.1 ± 1.1	11.1 ± 1.1
AOD	8.8 ± 0.9	11.5 ± 1.0

5. Flow velocity patterns of fetal heart

Doppler spectrum of the mitral and tricuspid valves is shown in Fig. 11. The tricuspid valve flow shows much higher spectrum than that of the mitral

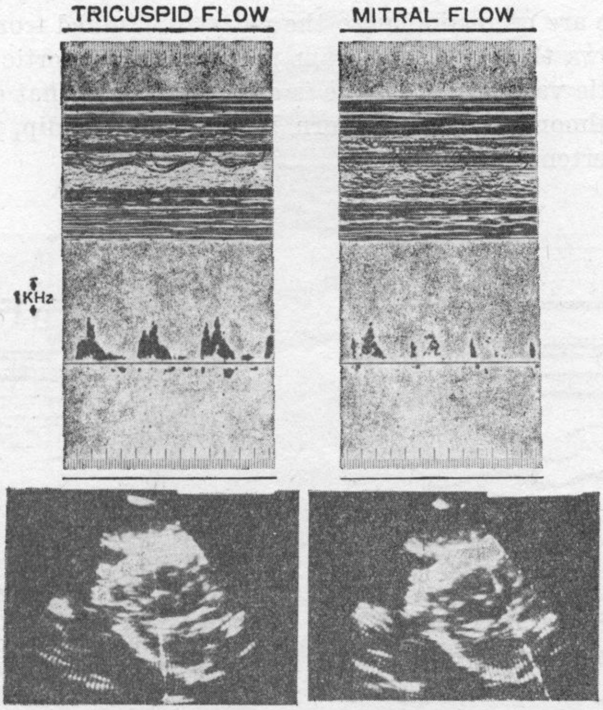

Fig. 11. Doppler spectrum

Fig. 12. Comparison between mitral flow velocity and tricuspid flow velocity in fetus

valve flow. On the bases of these patterns, the flow velocity of the mitral and tricuspid valves was calculated. Fig. 12 shows the result. The flow velocity ratio between the mitral and tricuspid valves is 1.0 to 1.3 (mean value is 1.12).

4. Discussion

Only a few studies have been reported in the field of the fetal echocardiography [2].

We have already reported several times about the fetal echocardiography and we have deviced "standard" transducer positions [3], i.e. the maternal flank and maternal naval positions. Using these "standard" transducer positions, a long axis view tracing, a short axis view tracing and a four chamber view tracing can be obtained, and it is possible to analyse cardiac anatomies to a certain extent.

We experimented on cases of DORV, VSD and TGA, but we could only diagnose DORV before birth. This fact may suggest that this technique is useful to diagnose the extreme cardiac malformations of chambers and the correlation between the cardiac chambers and the great arteries.

We have also tried to analyse the physiology of fetuses.

At the fetal stage, since lungs do not work, pulmonary circulation cannot be detected. Therefore, the blood stream through the foramen ovale supplies the mitral valve flow, and the blood stream through the ductus arteriosus is supplied by the tricuspid valve flow.

Since the mitral valve and tricuspid valve DDR and excursion are strongly affected by the mitral and tricuspid valve flow, respectively, it is possible to estimate the circulatory changes at birth, when the mitral valve and tricuspid valve DDR and excursion of the fetus are compared with those of a new born baby.

As shown in Table 1, the increased ratio of the mitral valve DDR and excursion is almost equal to that of tricuspid DDR and excursion. These facts may suggest that the blood flow through the foramen ovale and through the ductus arteriosus is nearly equal.

In order to confirm the hypotesis, Doppler method was performed.

The blood flow ejected from the left ventricle can be detected by measuring the aortic flow. Similarly, the blood flow ejected from the right ventricle can be detected by measuring the pulmonary flow. But it is very difficult to determine the sampling site of the aorta and pulmonary arteries by the Doppler flow meter, on the fetal echocardiogram.

We used the left ventriclar outflow tract just below the mitral valve and the right ventricular outflow tract just below the tricuspid valve as a sampling site for the Doppler flow meter. As mentioned above, mitral valve flow is nearly equal to the blood flow through the foramen ovale, and the tricuspid flow is nearly equal to that of the ductus arteriosus.

As shown in Fig. 12, the flow velocity ratio between the mitral and tricuspid valves was 1.12 (mean). Therefore, when the left ventricle ejects 1, the right ventricle ejects 1.12.

There has been no report about the fetal cardiac circulations in the human heart. The only report by RUDOLPH and HEYMANN [1], based on animal experiments, describes that the left ventricle ejects only 1/3 of the total cardiac output. But our data suggest that about 1/2 of the total cardiac output is ejected from the left ventricle before birth.

5. Conclusions

The technique to record the fetal echocardiograms and its results have been explained. The fetal echocardiography may be applicable to diagnose cardiac malformations and also to evaluate cardiac functions before birth.

References

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