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CONTRAST DOPPLER ECHOCARDIOGRAPHY

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A new technique in the scope of cardiac ultrasound — "contrast Doppler echocardiography" — is introduced and its first clinical applications are presented. The presence of contrast material within the right heart cavities following the peripheral vein injection is easily recognized by characteristic Doppler signal changes. This knowledge was used to detect a small amount of contrast passing through atrial (ASD) or ventricular septal defect (VSD) towards the left heart cavities despite the dominant left-to-right shunting. The high sensitivity of contrast Doppler in those conditions was presented by correct diagnosis of 10 ASD and 3 VSD. Besides that, the other application of this technique is in selected cases of tricuspid regurgitation.

Therefore, the combination of both pulsed Doppler and contrast echo-investigation seems to be advantageous in the diagnosis of the mentioned diseases. However, further research in this very specialized method is required.

1. Introduction

Both pulsed Doppler and contrast echocardiography are well established methods evaluating the character of blood flow within the heart and the great vessels. Recently, it has been shown that microbubbles are very good for Doppler studies [4], however, the clinical value of this technique still remains to be defined.

Contrast Doppler echocardiography (CDE) has been used in our laboratory since 1982 and here the first clinical experiences with the application of the method in some heart diseases are presented.

2. Material and methods

For the examination by CDE we selected the following groups of patients:

Group 1, atrial septal defect — ASD

10 patients with ASD proved by heart catheterization were studied. A catheter introduced into the right atrium passed through the defect to the left

atrium in all of them. Then, using a standard dye-dilution technique a left-to-right ($L-R$) shunt was demonstrated ranging between 20-80 per cent of total pulmonary blood flow (TPBF).

Group 2, tricuspid regurgitation — TR

The group comprised 11 patients — 9 with rheumatic mitral valve disease and relative tricuspid insufficiency, 1 with Ebstein's anomaly and 1 with advanced coronary heart disease with mitral and tricuspid regurgitation due to dilation of both ventricles. TR was positive on right ventriculograms in 4 patients, in the other 7 subjects clinical and pulsed Doppler findings suggested the presence of TR.

Group 3, ventricular septal defect — VSD

Only 3 patients were included in this group: 2 with congenital VSD proved by catheterization with existing L—R shunt of 69 and 17 per cent of TPBF, respectively, and 1 patient with acquired ASD due to the muscular septum rupture in acute myocardial infarction. The last diagnosis was confirmed at autopsy.

3. Contrast Doppler echocardiography — CDE

A one-dimensional ATL 500 A Pulsed Doppler system was used to detect the passage of contrast material within the heart cavities or the great vessels. Contrast echocardiography was performed according to the recommendations of ROELANDT [7]. As the contrast we used 5—15 ml of aereated saline or 5 per cent dextrose injected via a teflon cannula introduced into the antecubital vein of the left arm. The Doppler measurement and recording started simultaneously with the injection of the contrast medium.

In agreement with the recent report of GOLDBERG *et al.* [4], we observed the characteristic changes of Doppler output due to the passage of microbubbles through the sample volume. An audible flow signal was altered to a very typical high-pitched crackling sound whenever the microbubbles acted as ultrasonic reflectors. The character of this sound is so specific that according to our experience it cannot be mistaken for Doppler reflections from red blood cells or heart structures. Another pattern seen on the graphical Doppler display was a marked rise in the signal strength indicator followed by an obvious dispersion of the time interval histogram (TIH) dots indicating the turbulent flow. However, both of the latter events following the rapid injection are partly due to the actual and temporary flow increase. Therefore, we consider only the presence of all the mentioned Doppler abnormalities necessary for true microbubble detection.

The simultaneously recorded M-mode tracing allowed us to observe the presence of the contrast within the heart cavities, correct localization of Doppler sample volume and timing of Doppler signal changes.

4. Results and discussion

Atrial septal defect — ASD

The alterations of the Doppler signal as described above were distinctly observed in all of the 10 patients investigated. Doppler sampling performed within the left atrial outflow tract, i.e. under the echo of the anterior mitral leaflet, indicated an abnormal passage of isolated microbubbles (Fig. 1). Our

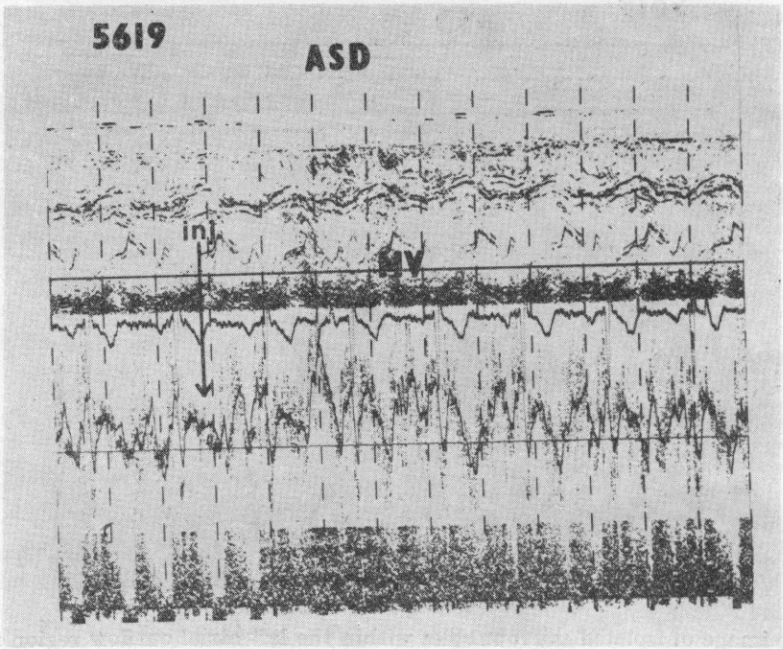

Fig. 1. Atrial septal defect. After the contrast injection the contrast appears within the right ventricle and some isolated microbubbles passing through the mitral orifice cause the turbulence pattern on TIH (the dispersion of the dots along the mean velocity curve) and a marked rise in the signal strength indicator (bottom). The sample volume (a solid line in *M*-mode tracing) is inserted into the mitral orifice (MV)

results support some previous studies dealing with contrast echocardiography in cases with dominant $L-R$ atrial shunts [1-3, 5, 6, 8]. However, single contrast echocardiography detected some isolated microbubbles only in 7 of our 10 patients (Fig. 2). Therefore, we believe that the CDE findings yield more impressive and convincing results than a single one dimensional echocardiography. The enhanced sensitivity of CDE makes it a method of the first choice in direct non-invasive ASD detection. The other advantage of CDE seems to be the possibility of reducing the number of contrast injections to obtain the positive result.

To evaluate the specificity of CDE in ASD, we examined another group of 10 patients with various rheumatic valve diseases but without any evidence of ASD. The only observed abnormality following the contrast injection in 6 of them was a temporary increase in the Doppler flow signal within the left heart cavities, with no audible signal indicating the presence of microbubbles. We are convinced that there exists no possibility of false positive findings for an experienced Doppler investigator excluding the occurrence of spontaneous contrast.

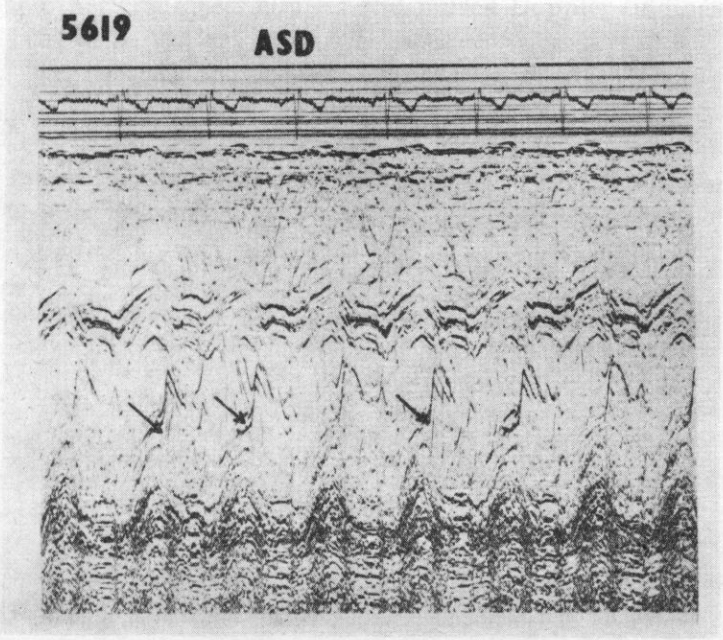

Fig. 2. The image of isolated microbubbles within the left atrial outflow region in *M*-mode recording (arrow indicates the microbubbles)

Besides the patients with ASD, one subject with patent foramen ovale (PFO) and haemodynamically insignificant $L-R$ shunt of 9 per cent of TPBF showed a negative CDE finding. Nevertheless, we must stress that we did not use the Valsalva maneuver to increase the right atrial pressure and thus reverse the direction of the shunt flow. Perhaps, in such cases this provocation is valuable and should be recommended [5].

Tricuspid regurgitation — TR

In our study we used two different positions of the Doppler sample volume to detect regurgitant microbubbles in tricuspid insufficiency.

The first sampling was performed within the right atrial outflow tract, i.e. under the echo of the anterior tricuspid leaflet. This approach yielded truly positive results in all of the 11 successive patients. After the contrast injection

a very strong and typically modified Doppler signal was detected in this region during systole (Fig. 3). In fact, the finding resembles closely the conventional Doppler abnormality in this condition, but it is much more pronounced and convincing.

The other Doppler sampling was done within the inferior vena cava (VCI). Using only *M*-mode echocardiography in the subcostal approach, successful imaging of the VCI was possible in 5 of 11 cases. Every successful positive

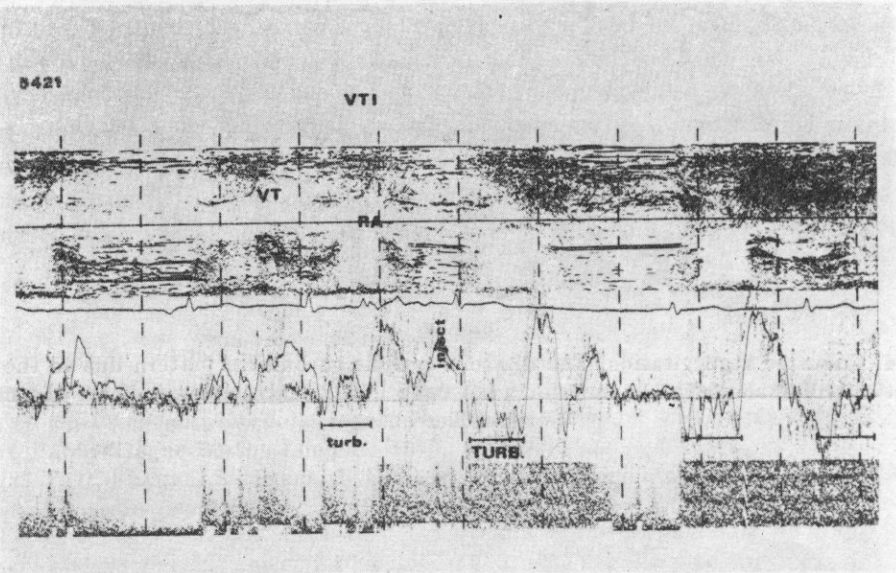

Fig. 3. Tricuspid regurgitation (VTI). The typical Doppler changes due to the regurgitant microbubbles towards the right atrial outflow tract-RA (sample volume under the echo of anterior tricuspid leaflet VT)

finding presented itself as Doppler signal change during several successive systoles (Fig. 4). Although the microbubbles were recorded in *M*-mode recording in all positive investigations, the Doppler signals of the present contrast lasted markedly longer than its visualization. Sometimes the Doppler sampling helped us to recognize the VCI more easily than *M*-mode echocardiography did.

With respect to the high sensitivity of CDE in TR, we would recommend this technique as a selective procedure only in cases with non-convincing Doppler or contrast findings.

Ventricular septal defect — VSD

Our experience with VSD to data is limited to a very small number of examined patients — 2 with congenital VSD and 1 subject with muscular septum rupture due to an acute myocardial infarction. In all the three cases the CDE investigation revealed the abnormal passage of isolated microbubbles from

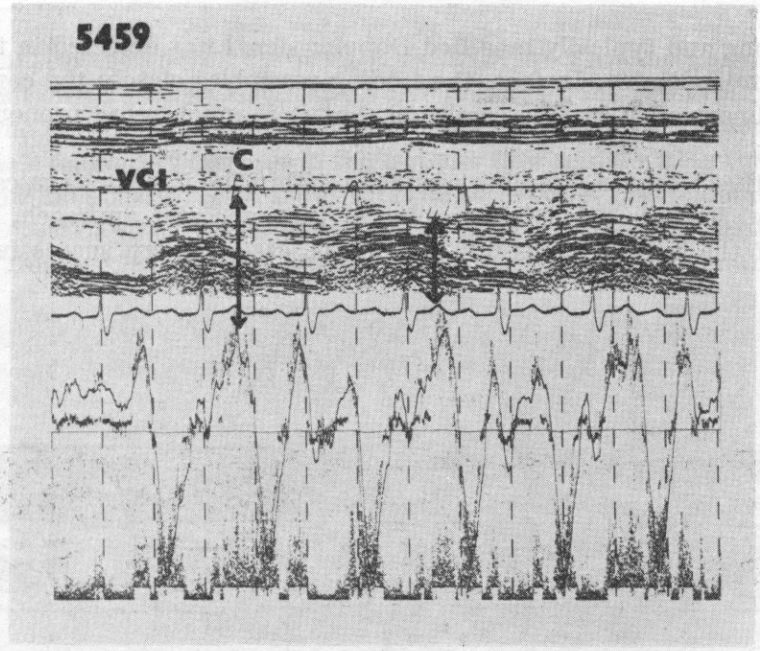

Fig. 4. Tricuspid regurgitation. The diastolic-systolic turbulence pattern due to the regurgitant microbubbles into the inferior vena cava (VCI). The arrows indicate the moment of Doppler changes

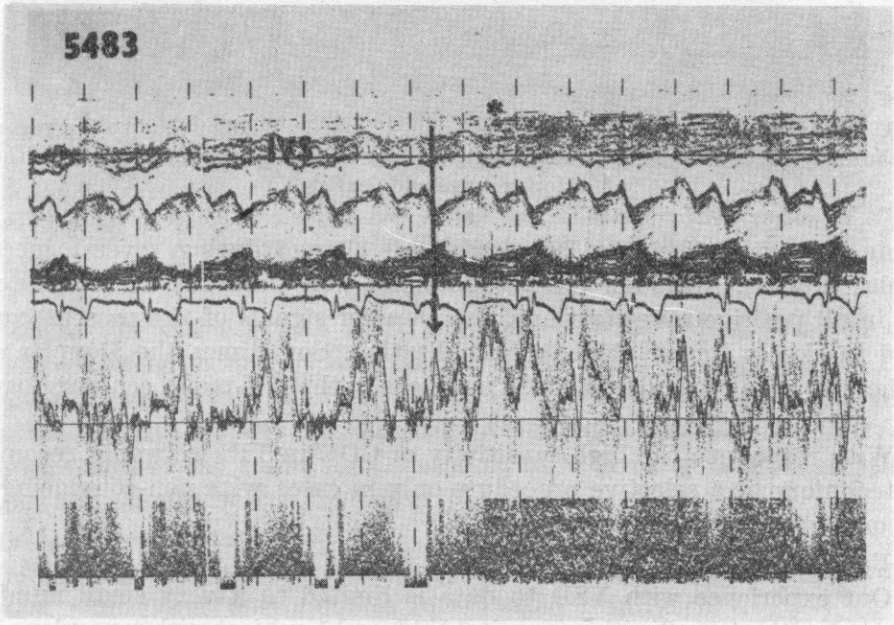

Fig. 5. Ventricular septal defect. The Doppler tracing changes due to the microbubbles entering the left ventricular outflow tract (see arrow). Doppler sampling performed in the left ventricular outflow tract, close to the left septal border. (IVS... septum, asterisk indicates the contrast within the right ventricle)

the right ventricle towards the left ventricular outflow tract that cannot be observed in healthy persons (Fig. 5). Despite a dominant $L-R$ shunt our results indicate the presence of a small interventricular $R-L$ shunt that might probably be facilitated by the turbulence of shunt flow.

The diagnosis of VSD by M-mode echocardiography is extremely difficult, if ever possible, and completion of the examination by pulsed Doppler increases the sensitivity to approximately 50 per cent, according to our experience in adults. Therefore, any other non-invasive approach to detect this condition is valuable. From this point of view, our results would be promising; nevertheless, they would need further verification.

In conclusion we dare say that the CDE combines the advantages of both pulsed Doppler and contrast echocardiography with encouraging results in the detection of atrial and ventricular $L-R$ shunts and tricuspid regurgitation. We believe that this completely new application of cardiac ultrasound will become a selective procedure in every well established echo-laboratory.

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