Non-invasive diagnosis of mitral regurgitation by Doppler echocardiography*

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SUMMARY The value of Doppler echocardiography for the non-invasive diagnosis of mitral regurgitation was studied blindly in 161 consecutive invasively investigated adult patients. Regurgitation was graded from 0 to 3 at selective left ventricular angiography. The Doppler echocardiographic examination was considered to be positive when a disturbed systolic flow was found within the left atrium behind the aorta or the anterior leaflet of the mitral valve. The test was considered to be negative in the absence of a regurgitant jet. The level of the signal to noise ratio was checked by the recording of the ventricular filling flow. The study was performed in 131 cases from the left side of the sternum and in 101 cases from the apex. There were no false positives and thus the specificity was 100 per cent. The 20 false negatives were all in patients with grade 1 regurgitation. Thus only some (33%) instances of mild regurgitation were misdiagnosed, and the sensitivity for moderate to severe mitral regurgitation was 100 per cent.

The clinical diagnosis of isolated mitral regurgitation is usually simple, but it can be difficult in the presence of other lesions or of prosthetic structures producing murmurs. Among the methods of non-invasive exploration, echocardiography provides only inconstant and indirect evidence and the phonomechanogram can produce incorrect results. This means that, even today, diagnosis in certain cases can only be made by angiography, so it is important to develop a reliable non-invasive method for the assessment of mitral regurgitation.

The principle of the pulsed Doppler velocimeter, the limitations of this technique, and the equipment used have already been described in other reports.¹⁻⁴

Doppler echocardiography has already been proposed in this context,^{3 5-8} but available studies are either fragmentary,^{3 6 8} or relate to children only.⁷ The purpose of the present work was therefore to evaluate the sensitivity and specificity of this method in adults.

Methods of examination

Two methods were used. One is based on conventional echocardiographic technique, from the

left edge of the sternum, and the other involves an apical approach.

PARASTERNAL APPROACH (Fig. 1)

The patient is placed in a supine or left lateral position. The transducer is located on the third or fourth intercostal space. The aorta and mitral valve are identified by echo. The measurement volume is placed in the left atrium, behind the posterior wall of the aorta or the anterior leaflet of the mitral valve. It is advisable to start the screening using a thick measurement volume, subsequently proceeding with a thin volume. The surface of the mitral orifice is explored by displacement of the transducer and electronic gate, looking for a systolic jet. Fig. 2 shows an example where the septum, anterior leaflet of the mitral valve, and posterior wall of the left atrium are easily distinguishable. The two continuous black lines indicate the position of the measurement volume. It will be noted that the diastolic inlet flow is not clearly recorded, though pronounced systolic regurgitation exists.

APICAL APPROACH (Fig. 3)

This is similar in principle to that used for exploration of mitral stenosis. The patient is positioned on his left side, and the transducer is located at the apex beat, identified by palpation.

The ultrasound beam is oriented so as to display

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Fig. 1 Illustration of the parasternal approach with the probe in the third intercostal space and the measuring volume within the left atrium (see text).

the anterior leaflet of the mitral valve. The measurement volume is located behind the systolic position of this leaflet.

It should be noted, however, that the measurement volume should be placed behind the mitral valve in the systolic configuration, as opposed to the diastolic, namely in a considerably more posterior position than that used for recording the diastolic inlet flow, for detection of regurgitation. It is important to obtain a position in the left atrium, and not in the left ventricle, and this is achieved by means of echocardiographic identification, making it possible to distinguish the left atrial posterior wall, which is fine and relatively stable. Once the correct position has been secured, careful movement of the transducer can be used to explore the mitral annulus in the search for turbulent flow.

FLOW ANALYSIS

With the two approaches, the rasping, turbulent surge characteristics of mitral regurgitation make it possible to distinguish the latter from left inlet flow from the pulmonary veins. According to the set of filters, only the systolic component of the latter is recorded, but in this case the flow is regular and without turbulence. With both techniques, diagnosis of a continent valve is based on the absence of regurgitant flow. It is therefore appropriate in all cases to check that the performance of the unit is sufficient to detect the presence of a possible jet, by recording the diastolic filling flow.

Subjects

These two methods were studied in patients who were to undergo catheterisation. Ultrasound exploration was carried out by a physician who had no

Fig. 2 Example of recording obtained using the parasternal approach (see text).

Fig. 3 Illustration of the apical approach. The probe is at the site of the apex beat (see text).

knowledge of the clinical and investigative data of the patients. Examinations were made of 161 consecutive patients, whose ages varied between 5 and 75 (mean: 40); 72 were male and 89 were female. One-hundred and thirty-one were studied by the parasternal approach, 101 by the apical approach, and 71 by both.

Regurgitation was assessed by means of selective left ventricular angiography, in the right anterior oblique projection, with injection of Renografin at a flow-rate of 50 ml in three seconds, with a frame speed of 50/second. A four-stage semiquantification technique was used as follows. 0: absence of re-

Table Comparison between Doppler echocardiography and angiography

		Angiographic grade			
		0	1	2	3
LSE	-	41	11	0	0
	+	0	32	36	11
Apical	-	31	9	0	0
	+	0	28	26	7

LSE: approach by left sternal edge.

Apical: approach by the apex.

Doppler +: presence of rasping systolic flow in left atrium.

Doppler -: absence of rasping systolic flow in left atrium, but signal to noise ratio validated by recording diastolic filling flow.

gurgitation; 1: slight regurgitation with no total opacification of the left atrium in any case; 2: regurgitation with total opacification of the atrium only after a number of systoles; and 3: severe regurgitation giving total opacification of the left atrium on the first systole.

Results

The results are given in the Table. It will be noted that there is no difference between the two approaches. There are no false positive results, and specificity is therefore 100 per cent. If mild regurgitation is excluded (grade 1), there are no false negative results, and sensitivity is also 100 per cent.

On the other hand, with mild regurgitation sensitivity is less good (74% for the parasternal approach, and 76% for the apical approach). These problems of the detection of mild regurgitation explain the sensitivity values for regurgitation of all severity, respectively 88 and 87 per cent.

Discussion

METHOD

The parasternal approach was the first to be described.⁵ It has advantages. The flows to be recorded are at moderate depth, and the size of the ultrasound window with this site makes it possible to vary the angles of incidence and to scan the surface of the mitral ring without difficulty. The widespread use of this site in echocardiography results in familiarity with the echo landmarks. Furthermore, this method can be used without difficulty on artificial valves. On the other hand, this approach has the drawback of providing an angle of incidence frequently close to the perpendicular to the flow, and thus unfavourable for Doppler measurement. Indeed, this makes it necessary to vary the angles of incidence before arriving at a negative conclusion.

The apical approach is more recent.⁶ Its advantages and disadvantages are in mirror image with those of the parasternal approach. The flows

to be recorded are further from the transducer, and therefore more difficult to measure. The possible range of angles of incidence is more restricted, and it is sometimes difficult to obtain a correct angle, and even harder to scan the mitral surface. In the case of an artificial valve, the multiple echoes from the prostheses make identification of the left atrium a delicate matter. On the other hand, a position parallel to the flow is more often obtained.

The very disturbed characteristics of the regurgitant flow make its measurement by Doppler effect difficult,⁹ particularly in cases where the signal to noise ratio is poor. The amplitude of the curves obtained, already substantially influenced by problems of angle, therefore has no significance in this case, even using the apical approach.

There is also the problem of pulmonary venous flow. Experiments with animals have shown that this flow has characteristics comparable with those of vena caval flow.¹⁰ There are two essential anterograde components, one systolic and clearly predominant, the other protodiastolic and mesodiastolic, and with much lower amplitude. These two components have low velocities, and are measured at great depth and at distinctly unfavourable incidence. It can easily be understood that with the use of filters, Doppler echocardiographic recording of these flows can give two separate components, or only one, quasi-exclusive systolic component.

Fig. 4 shows a typical example: the septum, mitral valve anterior leaflet root, and double posterior wall of the left atrium. This duplication is generally recognised as corresponding to the point of connection with a pulmonary vein.¹¹ The same essentially systolic flow can be recorded in front of this double wall, or between the two walls. In this

Fig. 4 Recording of a pulmonary vein flow. The sample volume indicated by the black arrow is positioned between the anterior and the posterior wall of the pulmonary vein. Only the systolic component of the flow is accurately recorded (see text).

particular case, the measurement volume is between the two walls.

RESULTS

With the parasternal approach, the mediocre sensitivity of detection of mild regurgitation can certainly be attributed to the fact that, irrespective of its size, very localised regurgitation can escape detection during scanning but it is more probable that the combined problems of incidence, signal to noise ratio, and the difficulty of measuring turbulent flow, intervene in this context. On the other hand, specificity is very good, contradicting a short summary published in 1974.¹² It appears difficult to accept the problems of sensitivity encountered in angiography, to explain these earlier results. The role of the pulmonary veins is probably of prime importance, but this was not mentioned.

The apical approach appeared of less value in a preliminary study,³ using the first prototype of the equipment. Since then progress has been made. Echocardiographic circuits with improved sensitivity make it possible to check more accurately that the measurement volume is correctly in the left atrium and not in the left ventricle. Progress with Doppler circuits, combined with improvements in transducer design, ensure substantially improved sensitivity characteristics. All this indicates to what extent the Doppler echocardiographic method is still in full development, and how necessary it is to take into account the characteristics of each instrument in order to obtain valid results from its use.

Some attempts at quantification of leaks have been published. Kalmanson *et al.*⁶ used a ratio between the area under the diastolic wave and one over the systolic wave, with presentation of anterograde flows as positive, and regurgitant flows as negative. This technique, however, has a number of difficulties. Firstly, simultaneous accurate recordings of diastolic flow and regurgitation are rarely obtained, and secondly, the mean regurgitation velocity is difficult to measure accurately because of its turbulent character. The different velocities measured are poor reflections of instantaneous flow rates, because of major variations in section areas. Finally, there is no reason why flow and regurgitation should be parallel. They are therefore viewed from difficult angles, and the ratio between them also depends on these angles.

An alternative approach⁸ consists in making a rough assessment of surge diameter and extension of the turbulence into the left atrium. This method suffers from limitations of M-mode identification, and remains, therefore, partially subjective. Further-

more, the equipment incorporates a threshold system, preventing measurement of frequencies in the interference produced by the transducer and electronic circuits. When the signal to noise ratio is mediocre (obese patient, excessive scan depth), the results depend substantially on adjusting the instrument. Thus we did not attempt to study this type of quantification, though our day-to-day practice with the thinner patients is in accord with the results that have been presented. The combined use of pulsed Doppler and cross-sectional echocardiography has been described recently,¹³ and seems to allow a more precise evaluation of the extension of the regurgitant flow within the left atrium but further studies are needed.

Finally, it should be noted that the two approaches can both be used on patients with artificial valves. Only the echocardiographic identification points are changed. In these cases, the parasternal approach is simpler, being less sensitive to multiple echoes or variations in ultrasound velocity introduced by prosthetic substances.

Conclusion

Doppler echocardiography can be used at present for the diagnosis of mitral regurgitation. Even highly localised and moderate leaks can give a clearly identifiable signal. Specificity is very good, if care is taken to differentiate correctly between mitral regurgitation and flows from the pulmonary veins. Sensitivity is also good when regurgitation is at least of moderate severity. With the current state of development of the equipment, only a few, highly discrete regurgitation jets escape detection. This method can also be applied in the case of artificial valves.

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References

- 1 Péronneau P, Hinglais J, Pellet M, Leger F. Vélomètre sanguin par effet Doppler à émission ultrasonore pulsée. *Onde Electrique*, 1970; **50**: 3-23.
- 2 Diebold B, Theroux P, Bourassa MG, Péronneau P, Guermonprez JL. Noninvasive assessment of aortocoronary bypass graft patency using pulsed Doppler echocardiography. *Am J Cardiol* 1979; **43**: 10-6.
- 3 Diebold B, Theroux P, Bourassa MG, et al. Non-invasive pulsed Doppler study of mitral stenosis and mitral regurgitation: preliminary study. *Br Heart J* 1979; **42**: 168-75.
- 4 Thuillez C, Thérout P, Bourassa MG, et al. Pulsed Doppler echocardiographic study of mitral stenosis. *Circulation* 1980; **61**: 381-7.
- 5 Johnson SL, Baker DW, Lute RA, Dodge HT. Doppler echocardiography: the localization of cardiac murmurs. *Circulation* 1973; **48**: 810-22.
- 6 Kalmanson D, Veyrat C, Bouchareine F, Degroote A. Non-invasive recording of mitral flow velocity patterns using pulsed Doppler echocardiography. *Br Heart J* 1977; **39**: 517.
- 7 Stevenson JG, Kawabori I, Guntheroth WG. Differentiation of ventricular septal defects from mitral regurgitation by pulsed Doppler echocardiography. *Circulation* 1977; **56**: 14-8.
- 8 Abbasi AS, Allen MW, de Cristofaro D, Ungar I. Detection and estimation of the degree of mitral regurgitation by range-gated pulsed Doppler echocardiography. *Circulation* 1980; **61**: 143-7.
- 9 Reneman RS, Spencer MP. Difficulties in processing of an analogue Doppler flow signal. In: Reneman RS, ed. *Cardiovascular applications of ultrasound*. Amsterdam: North Holland, 1974: 136-7.
- 10 Morgan BC, Abel FL, Mullins GL, Guntheroth WG. Flow patterns in cavae, pulmonary artery, pulmonary vein and aorta in intact dogs. *Am J Physiol* 1966; **210**: 903-9.
- 11 Nanda NC, Gramiak R. *Cardiac ultrasound*. In: Gramiak R and Waag RC, eds. St Louis: Mosby, 1975: 132.
- 12 Johnson SL, Baker DW, Lute RA, Murray JA. Detection of mitral regurgitation by Doppler echocardiography (abstract). *Am J Cardiol* 1974; **33**: 146.
- 13 Miyatake K, Kinoshita N, Nagata S, et al. Intracardiac flow pattern in mitral regurgitation studied with combined use of the ultrasonic pulsed Doppler technique and cross-sectional echocardiography. *Am J Cardiol* 1980; **45**: 155-62.

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