Non-invasive diagnosis and assessment of tricuspid regurgitation and stenosis using one and two dimensional echo-pulsed Doppler

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SUMMARY Twenty normal subjects and 82 patients with valvular heart disease, whose lesions were independently assessed either by cardiac catheterisation and/or at operation, were studied using the pulsed Doppler technique combined with either one or two dimensional echocardiography. Of these, 41 patients had tricuspid lesions, including 40 with regurgitation and nine with stenosis. The tricuspid analogue flow velocity trace and the Doppler frequency spectrum (time interval histogram) were recorded. Characteristic differences were found between the records from subjects with and without tricuspid lesions. In subjects with tricuspid regurgitation there was a systolic negative wave on the analogue velocity display and broadening of the time interval histogram. In subjects with tricuspid stenosis there was an abnormal pattern, and significantly increased duration of the diastolic wave on the analogue velocity trace, again with broadening of the time interval histogram. Sensitivity and specificity ranged between 85 and 95%. The calculated ratio between the measured amplitudes of the systolic and diastolic waves correlated well with independently performed grading of the regurgitation on a three point scale in 85% of cases. Grading of the severity of tricuspid stenosis on a three point scale based on studies of the diastolic Doppler velocity anomalies was the same in 85% of cases as the grading based on established invasive techniques. The addition of two dimensional echocardiography to the pulsed Doppler technique increased the sensitivity for mild lesions.

Invasive procedures do not solve all the diagnostic problems raised by tricuspid lesions,¹⁻⁵ in spite of some helpful contributions from dye dilution,² intracardiac phonocardiography,^{6,7} and angiography.⁸ Echocardiography,⁹⁻¹¹ even when combined with contrast injections for the study of tricuspid regurgitation,^{12,13} often lacks sensitivity and may give non-specific diagnostic information, since it relies on peripheral or indirect data, such as motion of the interventricular septum. As early as 1970, continuous wave Doppler provided information on systemic venous return and led to a new diagnostic method for the evaluation of tricuspid disease.¹⁴⁻¹⁶ The crucial advantage of pulsed Doppler, combined with either one dimensional¹⁷⁻²⁴ or two dimensional²⁵ echocardiography, is that it provides direct data from the site of the lesions. The present study was undertaken to evaluate the reliability of this new method when applied both to regurgitation and stenosis.

Subjects and methods

The study population included 20 normal subjects (12 women and eight men, mean age 28 years), and 82 patients (50 women and 32 men, mean age 38 years) in whom the presence of a tricuspid lesion was confirmed or ruled out using classical invasive procedures, that is right heart catheterisation (77 cases), with right ventricular angiography in 20 cases, intracardiac phonocardiography in seven cases, dye dilution curves in nine cases, and assessment of the tricuspid valve at the time of surgery in 38 cases. Diagnoses included mitral lesions, pure (45) or combined with aortic valve (22) and/or tricuspid valve (21) disease, isolated aortic valve lesions (14), acute tricuspid endocarditis (four), chronic endomyocardial fibrosis (five), mitral and tricuspid prolapse (four) and congenital heart disease (10). Forty-seven patients were in sinus rhythm and 35 in atrial fibrillation.

DIAGNOSIS OF TRICUSPID LESIONS

Tricuspid lesions were present in 41 patients consisting of 40 cases of regurgitation, eight of whom had associated stenosis, and one case of pure stenosis. With one exception the diagnosis was substantiated by at least two invasive procedures.

CLASSIFICATION OF TRICUSPID LESIONS

The severity of the tricuspid lesions was graded independently from the ultrasound findings on a three point scale, using the maximum information available in each case from cardiac catheterisation, pressure measurements, dye dilution, right ventricular angiography, and the surgical findings. This independent grading was grade 1 mild (19 lesions), grade 2 moderate (22 lesions), and grade 3 severe (eight lesions).

APPARATUS

We used an ATL* 3 MHz pulsed Doppler velocimeter, combined either with a one dimensional echocardiograph (ATL 500 A), or with a two dimensional 90° wide angle mechanical sector scanner (ATL 851). Each device uses a single transducer for both techniques. The diameter of the transducer is 1.2 cm for the ATL 500 A, and 2.5 for the ATL 851. According to the Doppler principle, the range gating system makes it possible to record the velocity of a small blood sample (2×4 mm) at any given location along the ultrasonic beam from 3 to 17 cm.²⁶ The output consists of three signals: (1) an audiosignal of the Doppler shift, (2) the time interval histogram, a form of spectral display of the Doppler signal, and (3) the analogue flow velocity trace. These two displays have been well described;²⁶ in brief, the time interval histogram is produced by measuring the interval between two successive zero crossings of the Doppler audiosignal; the instantaneous Doppler shift is defined as the reciprocal of this interval; a dot is printed on the strip chart paper at a distance from the zero line which is directly proportional to the Doppler shift frequency. The analogue flow velocity trace corresponds to the mean value of the Doppler frequency shift and is obtained by frequency-to-voltage conversion of the audiosignal using zero crossing detection technique; its polarity may be reversed by a switch on the recorder.

We also used two video monitors, one for the real time scanning, and the other for the Doppler display. Recordings were made on a Sony video tape recorder. Hard copies of real time imaging were obtained on a 4633 Tektronix recorder. Doppler analogue flow velocity traces, TM echocardiographic tracings, Doppler spectral displays, as well as simultaneous electrocardiograms lead II, and frequency selecting phonocar-

diagrams were recorded on an Irex I† fibreoptics recording system.

RECORDING METHOD

Tricuspid Doppler recordings were obtained by locating the transducer at the lower parasternal edge when using the one dimensional echo Doppler (37 cases).¹⁷ For two dimensional echo Doppler, we used the parasternal short axis (aortic valve and left ventricular level), apical four chambers, and subcostal views (45 cases), previously described for normal hearts.²⁵

In brief, two dimensional echo Doppler recordings always required successively: (1) dynamic scanner visualisation of the tricuspid valve, (2) location of the Doppler beam at the desired angle to the tricuspid valve, (3) adjustment of the Doppler gate to control the depth of the sample volume along that beam. This was achieved by obtaining a good two dimensional scan of the right heart cavities and of the tricuspid valve, and then the axis of the Doppler beam seen as a continuous white line was swept across the scan plane by moving a lever on the probe until it crossed the tricuspid valve at the desired angle. The Doppler gate, seen as a bright spot, was adjusted using a control on the probe. The image was then frozen while the apparatus was automatically switched to the Doppler system. When the characteristic Doppler sound was heard, the recording was made. We recorded several samples at the annulus: at least one at the centre of the annulus and one at the commissures.

VARIABLES STUDIED

The study involved the analysis of both the analogue and the spectral displays.

(1) Analogue flow velocity traces

These were examined for the presence or the absence of a systolic negative wave, its amplitude, duration, and spatial annular extension, and also for the diastolic pattern.

(a) When a negative wave was present, an index of its magnitude was calculated: the negative/positive (N/P) ratio. This was obtained for each recording in the following manner (Fig. 1): the amplitude of the negative wave was measured at two points in systole, the first (N1) 70 ms after the first heart sound, and the other (N2) 70 ms before the second heart sound as shown on the phonocardiogram. The maximum diastolic positive deflection (P) from the trace was measured and the mean of the ratios N1/P and N2/P was calculated; that is $\frac{N1/P + N2/P}{2}$. This value was

obtained for each recording. Where there were only two recordings, the mean of the two N/P values was

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Fig. 1 Schematic representation of the tricuspid flow velocity trace, with determination of the N/P ratio (systolic segment: full line, normal; thick dashed line, abnormal negative wave seen in patients with tricuspid regurgitation; V, analogue flow velocity trace; 0, zero line; LII, lead II of the electrocardiogram; PCG, phonocardiogram; S1 and S2, first and second heart sounds; IC, brief negative deflection caused by the isometric contraction; S, systolic segment; "D" and "A", early- and end-diastolic positive filling waves; N1 and N2, amplitude of the negative wave calculated in centimetres from the zero line; P, maximal amplitude of the positive diastolic wave calculated in centimetres from the zero line). The systolic negative depth is measured in two points of systole: -0.07 s after the end of the first heart sound (N1), and -0.07 s before the second sound (N2); it is then related to the amplitude of the "D" wave (P); the same manoeuvre is repeated on another blood velocity sample examined at the annulus, and the overall mean is calculated.

calculated. Where more than two recordings were available, the most disparate values of N/P were used to obtain the mean. Where one of these was zero, the other value was divided by two.

(b) The duration of the early diastolic filling wave (D) was measured for patients with atrial fibrillation. The time interval was corrected for heart rate by the Bazett²⁷ formula. The mean of values from five cardiac cycles was obtained for each recording.

(2) Frequency spectrum

This was examined for the presence or absence of a spectral broadening when the Doppler sample volume was at any point of the annulus or in the right atrium. Spectral broadening was considered abnormal when the dispersion of the dots was present on the time interval histogram according to the following criteria: (1) use of the minimal Doppler gain compatible with the recommended signal to noise ratio judged from the bottom trace on the monitor called "signal amplitude" (Fig. 2), (2) amplitude of the dispersion at least twice as wide as that seen on the spectrum for laminar flow in segments of the same cardiac cycle,

(3) duration of the disturbance equal to or greater than 0.10 s, and (4) absence or interference from any cardiac structure motion.

Analysis of the Doppler data was made without knowledge of the results of the invasive procedures. A statistical analysis of the results was performed using a Hewlett Packard 4815 with determination of: (1) the mean value and standard deviation for the duration of the diastolic filling (D) wave in cases of atrial fibrillation and for the N/P ratio in cases of regurgitation; (2) the significance of the differences found between different grades of severity for the latter, assessed using the Student test (t and P); (3) the linear regression equations between the calculated Doppler data and the haemodynamic variables.

Results

NORMAL SUBJECTS

Fig. 2 shows the normal pattern of the tricuspid flow velocity trace both for analogue and spectral display, using the two dimensional echo Doppler. Neither an abnormal spectral broadening nor a systolic negativity was noted during the cardiac cycle.

PATIENTS WITH TRICUSPID LESIONS

Diagnosis

(1) *Tricuspid regurgitation* (Figs. 3 and 4). The presence of an abnormal systolic negative wave and/or of a spectral broadening was noted in 41 patients. In 35 of these patients, tricuspid regurgitation was proven (sensitivity: 87%, and specificity: 85%). Five false negative diagnoses were found in patients with mild regurgitation, four of whom were studied with one dimensional echo Doppler only. False positive diagnoses were equally common using the two echo procedures.

(2) *Tricuspid stenosis* (Fig. 5). In 10 cases, diastolic abnormalities were found on the velocity recordings where the corresponding Doppler sound was higher pitched; with the Doppler sample at one or several points of the annulus, the "D" summit of the analogue trace was cut off and replaced by an indented horizontal plateau or gently ascending slope with broadening of the corresponding part of the spectrum. In six patients with atrial fibrillation, a significant increase in duration of the "D" wave was noted (Table 1 and Fig. 6). Of these 10 cases, tricuspid stenosis was confirmed in eight cases by the invasive data: the ninth case of proven stenosis was not found by Doppler (sensitivity: 88%, specificity: 97%). In one false positive case, external compression of the tricuspid annulus caused by a huge left atrium was found during operation. Fig. 7 illustrates the overall results (sensitivity, specificity, predictive value, and accuracy of the method).

Fig. 2 Normal subject: tricuspid flow velocity trace obtained using two dimensional echo Doppler (d, Doppler beam; T, tricuspid valve; G, Doppler gate; RA, right atrium; LV, left ventricle; ECHO, TM echocardiographic visualisation; S, frequency spectrum (time interval histogram); sig. amp., signal amplitude; other abbreviations as in Fig. 1). Here, two different approaches are used to visualise the tricuspid valve: (A) on the left, using the apical four chamber view, (B) on the right, using the left ventricular short axis view; the Doppler gate (seen as a white point) has been moved along the Doppler beam (seen as a white line) to the level of the tricuspid valve: the characteristic normal tricuspid flow velocity pattern is displayed, both on the spectrum (bottom left and middle) and on the analogue (bottom right). Four segments are shown: the "ic" deflection lined up with the first sound; the "S" segment near to the zero line because of the absence of forward flow in systole and the two positive waves of forward flow, the early diastolic "D", and the end-diastolic "A" related to atrial contribution to the ventricular filling. Note the smooth pattern of the diastolic summits, and the absence of any noticeable spectral broadening. In A, the gate was intentionally located a little higher than the annulus to show the effects of the valvular motion on the spectrum: brief transient dispersion of the dots is elicited, without pathological significance.

Assessment of severity of lesions

(1) *Tricuspid regurgitation* (Fig. 8 and Table 2). A significant increase in the N/P ratio between each grade of severity was found. Satisfactory grading of severity was obtained from Doppler data in 85% of cases, with two underestimations and one overestimation.

(2) *Tricuspid stenosis*. The assessment of the severity was satisfactorily obtained in 87% of cases, with one overestimation. The indented pattern was found at the commissures in two mild lesions out of three, and spread nearer to the centre in the five cases of

moderate stenoses. No satisfactory recording could be obtained in diastole in one case of severe stenosis.

Correlations between N/P ratio, diastolic filling wave duration, and haemodynamic variables (Tables 1 and 2) No significant difference between the three grades of severity was found for the mean value of the "v" wave, the mean right atrial pressure, or the systolic right ventricular pressure. No satisfactory linear correlation was found between those variables and the measurements performed on Doppler data.

Fig. 3 Chronic endomyocardial fibrosis with severe tricuspid regurgitation (same abbreviations as in Fig. 2, ao, aortic valvular area). (1) Four chamber view: the gate is located at the level of the tricuspid valve and the bottom panel shows a conspicuous negative S wave (thick arrow). (2) Left ventricular short axis view: the spectral curve at the bottom is abnormal in systole, showing pronounced and prolonged broadening with presence of backward flow (small arrows). (3) Aortic valvular area short axis view: the abnormal systolic negative wave is also displayed using this approach. No normal systolic pattern could be recorded in this case of severe regurgitation resulting from annular dilatation.

PATIENTS WITHOUT TRICUSPID LESIONS

With the exception of the false Doppler diagnoses already mentioned the recordings were similar to those of normals. Disappearance of the "A" wave was observed in cases of atrial fibrillation; the "D" wave was normal in these patients (Fig. 9).

Discussion

The comments will be focused on (1) the technical limitations of the pulsed Doppler technique, (2) the recall of the respective advantages of one and two dimensional echo Doppler, (3) the results for regurgitation, and (4) stenosis.

(1) TECHNICAL LIMITATIONS

Though the empirical relations between the velocity traces obtained and the flow disturbances of tricuspid valve disease cannot be disputed, and the shapes of the velocity traces both in normal subjects and in those with tricuspid valve disease are similar to those

recorded using continuous wave Doppler catheters¹ and electromagnetic flowmeters,²⁸ there are technical limitations of the technique which put some constraints on the interpretation of these velocity traces. (1) Absolute velocities cannot be calculated since the angle θ between the ultrasound beam and blood flow direction is unknown, and neither the time interval histogram nor the analogue velocity display are calibrated. (2) Pulsed Doppler imposes a conflict between the use of high pulse repetition frequency for the measurement of high velocities and the lower pulse repetition frequency required for recordings at any depth, the so-called "Nyquist limit". (3) Spectral broadening on the time interval histogram, commonly accepted as an indication of turbulence in the sample volume, may also arise if the Nyquist limit is exceeded and is very susceptible to observer control.

Some of these limitations are less serious for tricuspid valve disease than for mitral valve disease, since the tricuspid valve is closer to the chest wall and the blood velocities tend to be lower.

Fig. 4

Fig. 4 Moderate tricuspid regurgitation: tricuspid versus caval detection for the diagnosis of the regurgitation (same abbreviations as in previous figures, SBC, subcostal approach; IVC, inferior vena cava). On the left, four chamber view, the gate is located at the tricuspid valve: signs of tricuspid regurgitation are elicited on the Doppler displays at the bottom (thick arrow lining with the systolic negative wave). On the right, the gate is moved towards the vena cava, using the subcostal approach: the regurgitation is missed since there is a normal pattern of the systolic part of the caval flow velocity.

Fig. 5 Pulsed Doppler recordings in tricuspid stenosis (same abbreviations as before, M, mitral valve; TIH, time interval histogram). This figure shows two recordings at the tricuspid valve: in 1 (top left panel), the gate has been located at the centre of the tricuspid orifice (indicated by 1 on the scanner view in the middle panel): though some indentations may be seen on the analogue trace, the general normal diastolic pattern is recognisable with the separate "D" and "A" waves. In 2 (top right panel) the gate has been located next to the commissural area (indicated by 2 on the scanner view in the middle panel): a typical stenosed indented pattern is recorded with progressive ascent toward the end of the diastole (oblique arrows). This patient had a mild pure stenosis with a pressure gradient of 3 mmHg. This figure shows the need for several Doppler recordings at a given orifice, in order not to miss a mild lesion.

Fig. 5

Table 1 Duration of filling "D" wave in patients with atrial fibrillation with and without tricuspid disease

	Patients without tricuspid disease	Patients with tricuspid regurgitation	Patients with tricuspid stenosis
No. of subjects	12	12	6
Duration of filling "D" wave (c)*	0.29 ± 0.04	0.33 ± 0.06**	0.51 ± 0.06***

Correlation between mean right atrial pressure/DFW: $y = 17.92.x + 1.46$ $r = 0.41$.

*Duration of filling "D" wave (c), with correction for heart rate, expressed in seconds.

*** $p < 0.001$; ** $p < 0.05$.

Note: Significant increase in duration of forward flow in cases of organic stenosis obvious in spite of the limited number of stenotic cases and of the discrete character of the stenosis in a third of the cases. No satisfactory linear correlation appears between this duration and the value of the mean of the right atrial pressure.

Fig. 6 Duration of the filling wave in patients with and without tricuspid lesion and with atrial fibrillation (TL=0, patients without tricuspid lesions; TR, tricuspid regurgitation; TS, tricuspid stenosis; DFWc, duration of the diastolic filling wave "D", with correction for heart rate). The mean values (horizontal bars) and the standard deviations (vertical bars) are indicated, and also the individual values. A significant increase of the duration of the "D" wave was observed in patients with stenoses.

One of our criteria for the assessment of a disturbed spectrum needs some comment: the reference to a normal segment in the cardiac cycle could be inadequate when combined lesions are present, but, in our experience, it was always possible to find a normal segment for comparison in such cases.

(2) TWO DIMENSIONAL ECHO DOPPLER VERSUS ONE DIMENSIONAL ECHO DOPPLER

The placement of the sample volume was much easier

with the two dimensional echo which enabled a more accurate investigation of the annulus and of the commissures. This fact probably explains the lower rate of false negative results for the diagnosis of mild regurgitation when using this apparatus. On the other hand, the signal to noise ratio was less good for the Doppler, and the probe less handy in this equipment than in the one dimensional device.

(3) RESULTS FOR TRICUSPID REGURGITATION

Fig. 4 illustrates the need for recording direct data on tricuspid flow disturbances for a reliable assessment of lesions. This requirement is fulfilled by the use of the pulsed Doppler technique. We have already mentioned the advantages of the use of the two dimensional equipment for avoiding false negative results

Fig. 7 Correlative data between pulsed Doppler echocardiography and invasive procedures for diagnosis of tricuspid lesions (TR, tricuspid regurgitation; TS, tricuspid stenosis; SE, sensitivity; SP, specificity; PV, predictive value; A, accuracy of the method; F+, false positive diagnoses using pulsed Doppler; F-, false negative diagnoses using pulsed Doppler; T+, true positive diagnoses using pulsed Doppler confirmed by invasive procedures; T-, true negative diagnoses using pulsed Doppler confirmed by invasive procedures; S, total successful diagnoses using pulsed Doppler; E, total wrong diagnoses using pulsed Doppler).

Table 2 Value of N/P ratio and of haemodynamic variables involved in correlative study for patients with tricuspid regurgitation

No. of patients (34) N/P	Tricuspid regurgitation			Correlation between N/P ratio and haemodynamic variables (n=28)	
	Grade 1 (9) 0.21±0.11	Grade 2 (19) 0.44±0.15 *	Grade 3 (6) 0.75±0.11 **		
"v" wave	6±3	11±4	14±8	v wave=6.49 N/P+7.34	r=0.26
Mean right atrial pressure (mmHg)	7±3	9±3	10±4	Mean right atrial pressure (mmHg)=2.79 N/P+7.54	0.14
Right ventricular systolic pressure (mmHg)	39±13	45±16	45±31	Right ventricular systolic pressure= -4.49 N/P+43.82	0.02

N/P, ratio of amplitude of negative systolic wave, related to that of the diastolic positive wave.
 *p<0.01.
 **p<0.001.

Fig. 8 Semiquantitative assessment of severity of regurgitation using N/P ratio. Left column, overall mean (M) (horizontal bar) with the standard deviation (vertical bar) for the patients with tricuspid regurgitation (TR); second to fourth columns: mean values of the N/P ratio according to the grading of increasing severity (1 mild, 2 moderate, 3 severe); p, p values for each grade of severity; last column on the right: three patients were examined before (○) and after (●) removal of the tricuspid valve (Post-TR); the tricuspid removal was followed by a significant increase in the N/P ratio.

In spite of these advantages and resultant more accurate checking of the sample, the false positive percentage was equal for both types of equipment. Since there is no gold standard for evaluation of tricuspid regurgitation, one logical explanation for our findings of negative systolic velocity at the tricuspid annulus in some patients not diagnosed as having tricuspid regurgitation was that the Doppler technique is more sensitive and, therefore, superior to other techniques of tricuspid valve assessment. Among these, angiography appeared the most reliable, as we found only

one false positive Doppler diagnosis when this procedure was used for the correlative study.

The correlation of both displays (analogue and spectral) increased the diagnostic sensitivity; the reason was that some cases of mild regurgitation could only be shown on the spectrum and not on the analogue display, and, conversely, some cases of free regurgitation, described as "silent" during intracardiac phonocardiographic procedures,⁶ coexisted with apparently laminar flow. Two different procedures have been described to assess the severity of the tricuspid regurgitation: an index of systolic turbulence²³ and the calculation of the N/P ratio²²; in our experience, the characteristics in amplitude and duration of the spectral broadening appeared less reliable than the calculation of the N/P ratio, and were not taken into account for grading the severity. The evaluation of the severity therefore only relied, in the present study, on the measurement of the N/P ratio; we are aware that at least three factors prevent an accurate quantification of tricuspid regurgitation: (1) the somehow arbitrary selection of the two samples at the annulus, (2) the unknown angle θ which, moreover, could vary if the heart moves and if forward and reverse flow are not at 180° to each other, and (3) the variations in size of the tricuspid annulus during the cardiac cycle.²⁹ In spite of these limitations, our index proved to be clinically very useful for a semiquantitative evaluation of tricuspid regurgitation. Discrepancies in Doppler grading were generally related to unrepresentative samplings in the presence of low cardiac output leading to underestimation, or of exceptionally poor echo visualisation. The lack of satisfactory correlation between the N/P ratio and the haemodynamic variables may be explained by the presence of nearly normal pressures in several patients with significant lesions.

(4) RESULTS FOR TRICUSPID STENOSIS
 These preliminary results suggest high diagnostic reliability of the pulsed Doppler technique. In two cases, the Doppler technique appeared even more

Fig. 9 Tricuspid flow velocity recording in patient with atrial fibrillation but without tricuspid lesion (same abbreviations as in previous figures, MV, mitral valve; LA, left atrium; RV, right ventricle; TV, tricuspid valve). There is a disappearance of the "A" wave with an early diastolic "D" wave of normal duration. The systolic wave is normal. (Each vertical bar interval = 0.04 s.)

reliable than cardiac catheterisation since Doppler studies showed anomalies, diagnostic of tricuspid stenosis, where cardiac catheterisation disclosed no significant tricuspid pressure gradient; at operation, the valve was found to show commissural fusion and appeared typically stenosed. Severe tachyarrhythmia was the reason for a false negative result in one case where no adequate diastolic flow recording could be obtained. External compression of the orifice was found to have the same consequences upon flow as valvular stenosis and may, therefore, occasionally cause confusion.

The significantly increased duration of the early diastolic filling wave was a reliable and sensitive sign of stenosis in patients with atrial fibrillation, where the lack of "A" wave could make the pattern anomalies less obvious. This timing anomaly helped to avoid confusion with the increased diastolic flow component seen in patients with severe regurgitation, since there is no appreciable overlap between the respective values in both groups (Fig. 6). The evaluation of the severity was not based on the time interval histogram because of its limitations; a more quantitative approach may be expected from the use of Doppler real time spectral frequency analysers recently available. For instance, the analysers may perform the transform by numerous multiplications and additions of discrete Doppler time samples with frequency sweeps called "chirps" (Z chirp transform),³⁰ or may

use a digital fast Fourier transform.³¹ In our study, the assessment relied on a pattern recognition method taking into account the central and commissural velocity patterns which appeared clinically reliable. No relation between the duration of the filling wave and the severity of the stenosis could be established in our limited number of cases, and this needs further investigation.

Conclusion

Provided that some methodological rules are observed, the pulsed Doppler technique seems the most reliable non-invasive method so far developed for assessment of tricuspid lesions; its reliability was maintained even in patients with atrial fibrillation and heart failure, and was independent of the level of right ventricular pressure.

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