Aortic stenosis in adults
Non-invasive estimation of pressure differences by continuous wave Doppler echocardiography

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SUMMARY The peak and mean aortic transvalvar pressure differences measured invasively and non-invasively by continuous wave Doppler echocardiography were compared in 87 consecutive patients with aortic stenosis. The mean values were calculated from the maximal velocities of the aortic jet recorded with a spectral display of the Doppler frequency shifts and by applying a modified Bernoulli equation. Technically satisfactory velocity curves for estimating the mean pressure differences could not be obtained in three patients and invasive measurements were not obtained in two. In all patients the peak transvalvar pressure difference was calculated since the aortic jet was identified non-invasively. The peak and mean pressure differences measured invasively and non-invasively correlated well—with only minor underestimation of the pressure differences measured with the Doppler technique—regardless of age, sex, and the presence or absence of aortic valvar regurgitation, or other valvar lesions.

With a systematic search for the highest velocities in the aortic jet and with on line spectral analysis of the Doppler frequencies the peak and the mean aortic pressure differences can be determined non-invasively with a high degree of precision in almost all patients.

The ability to measure pressure differences correctly and repeatedly by continuous wave Doppler echocardiography has been achieved in mitral and pulmonary valve stenosis as well as in aortic stenosis in children and young adults.[1-8] In older patients with aortic stenosis, however, the technique used initially showed significant underestimation of the pressure differences in some subjects.[3 5 6] Since left heart catheterisation is not completely without risk and is not suitable for repeated use during long term follow up, a reliable non-invasive technique for measuring the pressure differences in aortic stenosis would be useful.

On line spectral analysis of the Doppler frequencies provides better and more reliable data on the pressure differences in aortic stenosis in adults than can be obtained with the maximum frequency estimators used earlier. With spectral analysis the high frequencies in the Doppler signal can be distinguished more easily when the signal to noise ratio is low. In particular, the often weak Doppler signals with few high frequencies in some of the older patients with aortic stenosis can now be recorded.

The present prospective study aimed to assess the accuracy of continuous wave Doppler echocardiography in measuring the pressure differences in aortic stenosis in adults, using on line spectral analysis of the Doppler signal. The data obtained non-invasively were compared with invasive measurements in a consecutive series of patients.

Patients and methods

From November 1981 to February 1984, 88 patients were diagnosed as having aortic stenosis which was the main reason for referral for cardiac catheterisation; all 88 patients participated in the study. One patient had clinically deteriorated during the study period and underwent second catheterisation. Thus the total study comprised 89 examinations. Only patients in whom adequate recordings could be

obtained both invasively and non-invasively were included in the various comparisons. The aortic jet could be identified in all patients. In two patients attempts to perform retrograde catheterisation of the aortic valve failed and transseptal catheterisation was not performed. The peak pressure difference could therefore be compared in only 87 patients. The age range was from 27 to 77 (mean 62·3) years; 38 patients were women and 49 men (Table). Twenty-four had aortic stenosis only, 24 had aortic stenosis combined with mild aortic incompetence, 39 had aortic stenosis and moderate or severe aortic incompetence, and 21 had one or more additional valvar abnormalities.

The mean pressure difference could be compared in only 84 patients since the maximal velocities from the Doppler recordings could not be traced reliably throughout the whole of systole in three patients.

All patients were in a clinically stable condition during the studies. All invasive studies were performed after standard premedication with aprobarbital 100 mg orally; otherwise medication was similar in the two studies.

INVASIVE MEASUREMENTS
In all patients combined right and left heart catheterisation was performed via a femoral approach using a standard Seldinger technique. Pressures were recorded using liquid filled catheters and Elema-Siemens transducers E 033E and a Mingograph 82 recorder. The pressures were recorded during withdrawal of the catheter from the left ventricle to the ascending aorta. The pressure difference between the left ventricle and the aorta was measured by superimposing the aortic curve on the left ventricular curve. The catheter was withdrawn only during a period of stable heart rate. Pressure curves from premature beats and the two following beats were disregarded. Three different pressure differences were measured (Fig. 1).

The peak to peak pressure difference was taken as the difference between the peak of the left ventricular curve and the peak of the aortic curve.

The peak pressure difference was calculated as the maximal instantaneous difference between the left ventricular and the aortic pressure curves. This pressure difference equals that calculated from the highest systolic velocities recorded with the Doppler method.

The mean pressure difference was obtained by planimetry of the area between the two pressure curves.

Results are expressed as mean (SD) values obtained from three consecutive beats in each subject.

Table *Peak and mean aortic valve pressure (mm Hg) gradients measured by the Doppler technique (D) and at cardiac catheterisation (C) in patients according to age and sex and to presence of aortic stenosis (AS) only or accompanied by various degrees of aortic incompetence (AI) or other valvar lesions or both. Values are mean(SD)*

|	AS only			AS with mild AI			AS with moderate or severe AI			AS with other valvar lesions			Totals		
	C	D	No of patients	C	D	No of patients	C	D	No of patients	C	D	No of patients	C	D	No of patients
Peak values															
Age <50 years:															
Women	—	—	0	68	62	1	125 (41)	128 (27)	2	—	—	0	106 (44)	106 (43)	3
Men	112	89	1	160	147	1	69 (14)	69 (20)	4	64	68	1	91 (39)	85 (35)	6
Age ≥50 years:															
Women	73 (36)	70 (34)	14	103 (29)	94 (28)	15	87 (27)	82 (28)	6	87 (24)	80 (20)	11	88 (34)	82 (32)	35
Men	94 (47)	83 (45)	9	85 (50)	74 (44)	7	102 (37)	98 (38)	27	100 (43)	92 (42)	9	97 (41)	91 (40)	43
All ages:															
Women	73 (36)	70 (34)	14	101 (30)	92 (28)	16	97 (33)	94 (33)	8	87 (24)	80 (20)	11	90 (34)	84 (32)	38
Men	96 (45)	84 (42)	10	95 (54)	83 (48)	8	97 (37)	94 (36)	31	97 (48)	90 (41)	10	97 (41)	90 (39)	49
Totals	83 (41)	76 (38)	24	99 (38)	89 (35)	24	97 (35)	94 (35)	39	92 (37)	85 (31)	21	94 (38)	88 (36)	87
Mean values															
Age <50 years:															
Women	—	—	0	45	43	1	90 (37)	96 (23)	2	—	—	0	75 (37)	78 (35)	3
Men	86	61	1	120	100	1	47 (10)	49 (16)	4	44	45	1	66 (32)	60 (24)	6
Age ≥50 years:															
Women	52 (29)	47 (25)	14	75 (20)	66 (22)	14	62 (19)	56 (23)	5	67 (20)	56 (15)	9	63 (25)	57 (24)	33
Men	63 (36)	56 (31)	9	60 (36)	54 (35)	7	69 (27)	66 (26)	26	69 (34)	63 (30)	9	66 (30)	62 (29)	42
All ages:															
Women	52 (29)	47 (25)	14	73 (20)	65 (22)	15	70 (25)	67 (29)	7	67 (20)	56 (15)	9	64 (26)	58 (26)	36
Men	65 (35)	56 (30)	10	68 (40)	59 (36)	8	66 (26)	64 (26)	30	66 (33)	62 (29)	10	66 (30)	61 (28)	48
Total	58 (32)	51 (27)	24	71 (28)	63 (27)	23	67 (25)	64 (26)	37	67 (27)	59 (23)	19	65 (28)	60 (27)	84
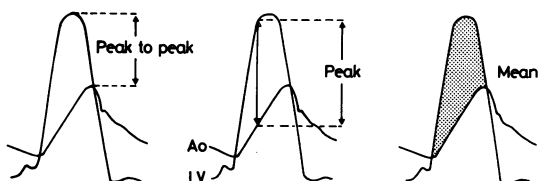
Fig. 1 *Schematic drawing of the pressure differences between the pressure curves of the left ventricle (LV) and of the ascending aorta (Ao) in patients with aortic stenosis.*

DOPPLER MEASUREMENTS

The ultrasound recordings were made with two different combined pulsed and continuous wave Doppler instruments. One (PEDOF, Vingmed A/S, Norway; Irex IIIB, Irex Co, New Jersey, USA) was

used with or without imaging while the other (ALFRED, Vingmed A/S, Norway) could be used alone. Although the ALFRED system is able to emit ultrasound in the range of 1–10 MHz, only 2 MHz was used since this is the frequency emitted by the PEDOF system. All velocities from the aortic jet were recorded in the continuous mode. This mode has no range resolution but it is able to record the very high blood velocities often present in the jets in aortic stenosis. To determine whether the increase in velocity occurred at, below, or above the aortic valve the level of the increase in velocity was identified using the pulsed mode. In this mode the velocities can be measured at selected depths (from 1 to 12 cm or 1 to 15 cm) and with slightly different sample volumes (of 7 or 5 mm in diameter and 7 or 5–10 mm in length) for the two instruments
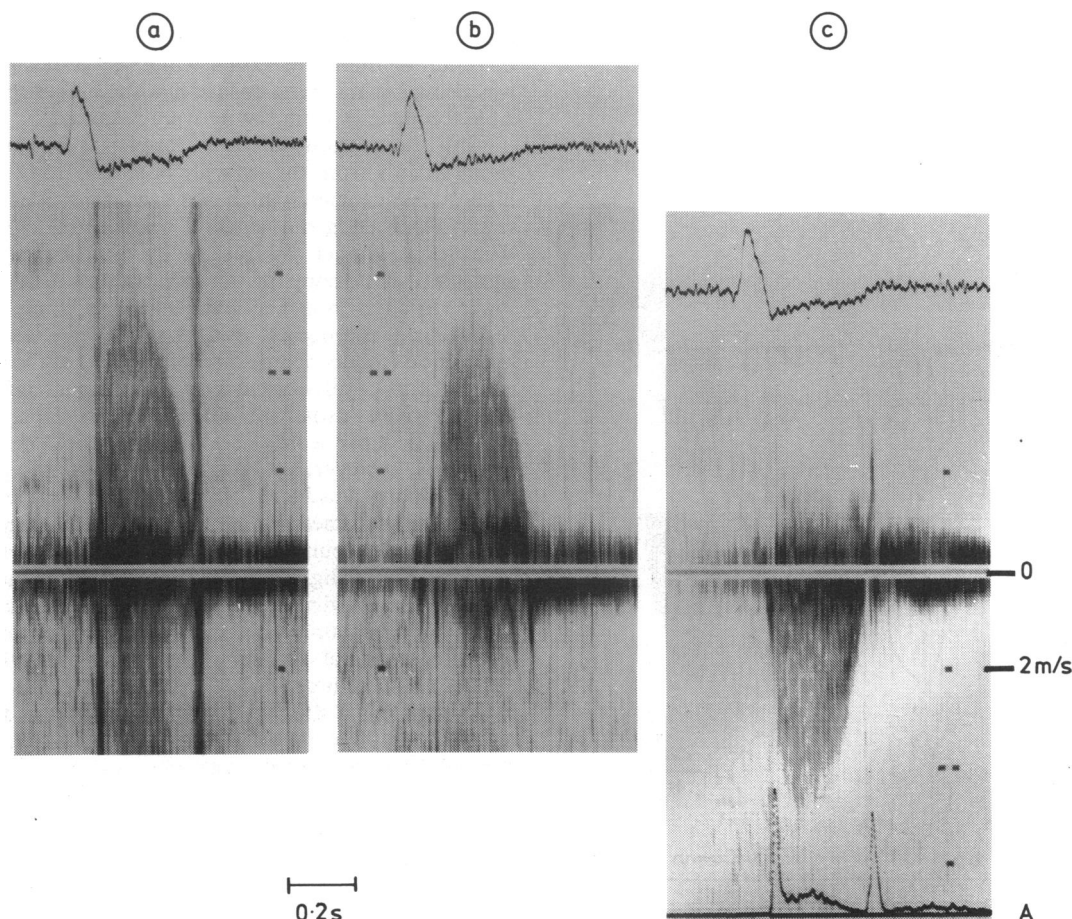

Fig. 2 *Spectral display of continuous wave Doppler signals from the velocities in the aortic jet recorded from the (a) parasternal, (b) suprasternal, and (c) apical transducer positions. The maximal velocities are found at the outer border of the spectral curves. The curve from the parasternal region contains most of the highest velocities and gives the highest pressure difference. The amplitude (A) tracing of the Doppler signal shows aortic valve opening and closure.*

respectively. The limits for the maximal velocities that can be measured in the pulsed mode are slightly higher with the ALFRED instrument because of continuous variable pulse repetition rates for the different depths. Although the velocity limits can be further increased by using range ambiguity and special spectral analysis of the Doppler frequencies,[9 10] this may be time consuming and the highest velocities often present in aortic jets can be more easily recorded using the continuous mode.

Spectral analysis of the Doppler signals was performed with a Chirp Z transform (Daisy, Vingmed A/S, Norway) printed out on thermic photoprinters. The amplitude of the Doppler signal may be recorded separately.

Velocity
The velocities (V) of blood flow can be calculated according to the Doppler equation (1):

$$V = f_d \times c/2f_0 \times \cos \alpha$$

where f_d is the Doppler shift (the difference in frequency between the emitted ultrasound (f_0) and the ultrasound reflected from the blood), c is the veloc-

Fig. 3 *(a) Spectral display of continuous wave Doppler signals from the velocities of the aortic jet recorded from the cardiac apex. (b) Schematic drawings of the curves for the instantaneous peak pressure difference with the equations for the calculation of the peak (△ p peak) and the mean (△ p mean) pressure difference (in mm Hg).*

ity of the sound in blood, and α is the angle between the emitted ultrasound beam and the direction of the blood flow studied. The maximal frequency shifts—namely, highest frequencies—are found at the outer border of the spectral curve (Fig. 2). Since the Doppler equation shows that the true velocities are recorded when the angle between the ultrasound beam and the velocities is zero (cos α = 1), attempts were made to minimise this angle. A thorough search was, therefore, made in all transducer positions used for recording aortic jet velocities—from the apex, the suprasternal notch, and along the entire right and left sternal border—in all patients. The search from the right sternal border was made with the patient in the right lateral position and from the apex in the left lateral position. From these sites a further search was made using the frequencies in the audiosignal from the Doppler shifts. The transducer was moved around in these areas and the direction of the beam varied while the audiosignal was being listened to to ensure that the highest possible frequencies from the jet were recorded.

With the continuous wave Doppler technique a signal mainly from the jet will contain more of the highest frequencies, which are seen as a concentrated band along the edges of the spectral curve. With less of the jet within the ultrasound beam the signal will have fewer of the high and more of the lower velocities from beside the jet. To facilitate the recording of the highest frequencies a filter with a high cutoff frequency was often used. To help localise the aortic valve area a cross sectional echocardiogram was usually obtained before the Doppler study. The final search for the maximal Doppler shifts was, however, always carried out with a separate Doppler transducer. No attempt was made to correct for presumed differences between the direction of the ultrasound beam and the direction of the aortic jet. Since slight movements of the transducer or underlying cardiac structures or both often make it difficult to obtain a consecutive series of optimal recordings several recordings were made during periods of stable heart rate; if premature beats were present these and the two following beats were disregarded. In five patients with atrial fibrillation intervals of similar length were used and RR intervals of 700–900 ms were preferred. The maximal velocities were measured from the outer zone of the spectral curves.
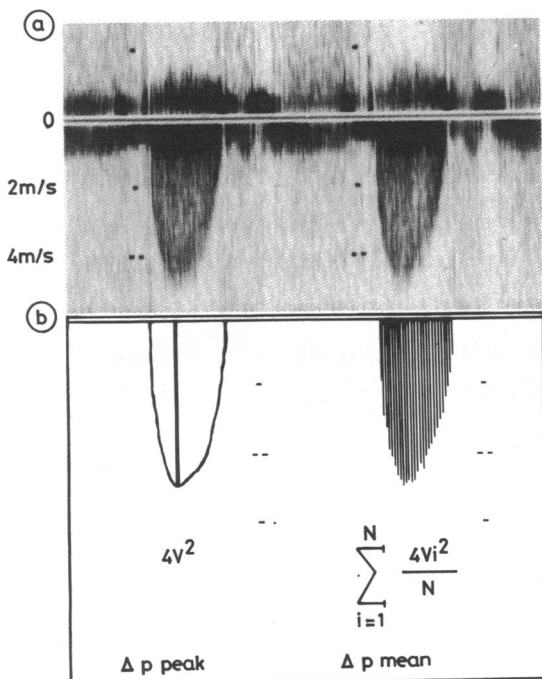
Calculation of pressure differences
As shown in previous studies,[1 2] the pressure difference across the valvar obstruction can be calculated from the maximal velocities of the jet recorded by applying the following modified Bernoulli equation (2): $P_1 - P_2 = 4(V_{max})^2$ where the maximal veloc-

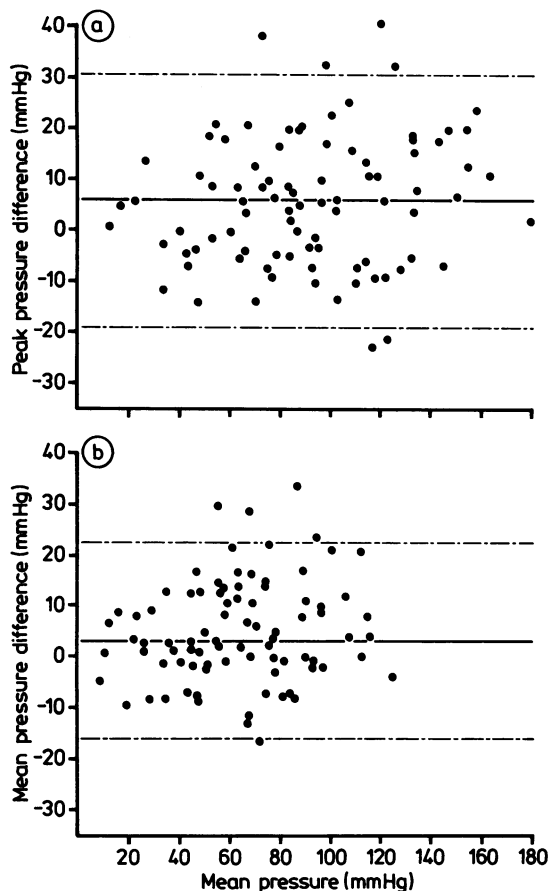ities (V_{max}) are given in m/s and the pressure difference (P_1-P_2) in mm Hg. In this formula the velocities proximal to the obstruction are ignored. The error introduced is minimal when there is no increase in velocity in the left ventricular outflow tract. If the velocities below the valve are significantly increased the formula (3): $P_1-P_2 = 4(V_2^2-V_1^2)$ has to be used to avoid overestimation of the pressure difference across the valve. This formula was not applied in the study since none of these patients has additional subvalvar obstruction.

A peak to peak pressure difference cannot be measured with the Doppler method since the velocities recorded from the aortic jet reflect the instantaneous peak pressure difference during systole, whereas the peaks of the pressure curves in the left ventricle and the ascending aorta occur at different times in systole. *The peak pressure difference* across the valve was calculated from the highest velocities recorded during systole using formula (2) as shown in Fig. 3 and expressed as the mean of three optimal beats. *The mean pressure difference* was calculated from instantaneous peak pressure differences measured at equal intervals of 20 ms along the spectral curve and expressed as the mean of three beats.

In all patients the Doppler measurements preceded the invasive studies. The Doppler study was generally performed one day before catheterisation, although in a few patients the non-invasive study preceded catheterisation by two (n = 6) or three (n = 3) days. In four patients the Doppler study was repeated during the pressure recording at catheterisation.

Results

The aortic jet could be identified and recorded in all patients, and Fig. 4 shows the peak and mean pres-

Fig. 4 *Relation of (a) peak and (b) mean pressure difference by the Doppler technique and cardiac catheterisation to the mean pressure by both techniques. —, mean; ——, 2 SD.*

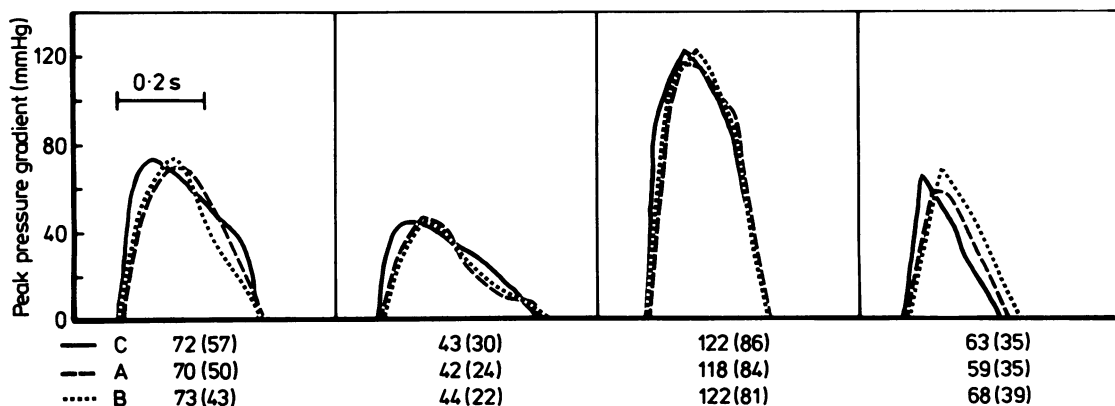|					
—	C	72 (57)	43 (30)	122 (86)	63 (35)
——	A	70 (50)	42 (24)	118 (84)	59 (35)
.....	B	73 (43)	44 (22)	122 (81)	68 (39)

Fig. 5 *Instantaneous peak (mean) pressure differences in four different patients measured at cardiac catheterisation (C) during Doppler studies recorded simultaneously with (A) or the day before (B) catheterisation.*
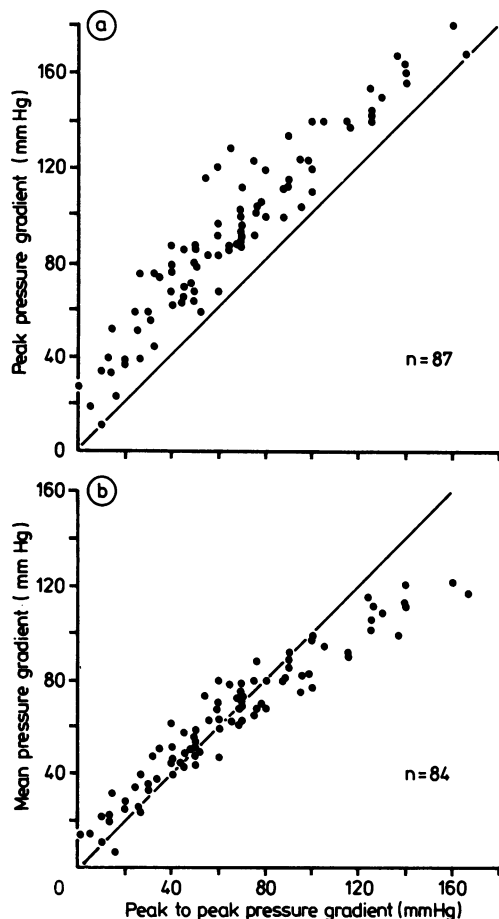
Fig. 6 *Relation between (a) the peak to peak and the peak pressure differences and (b) the peak to peak and the mean pressure differences, all measured at catheterisation.*

sure differences measured with the Doppler and invasive technique. There is generally a slight systematic underestimation of both pressure differences with the Doppler method. Nevertheless, the underestimation was >20 mm Hg in only nine and seven patients or >30 mm Hg in only four and one for peak and mean pressure differences respectively. These patients all had very high peak pressure differences.

The Table shows the data from Fig. 4 *a* and *b* in relation to age, sex, presence or absence of aortic incompetence, and presence or absence of other valvar abnormalities. The Doppler technique accurately predicted the pressure difference regardless of age, sex, and of other valvar abnormalities. These findings were also true of patients of ≥70 years

(n = 22) (detailed data not shown). The correlation for the mean pressure difference was almost identical to that for the peak pressure difference, and there was a similar slight systemic underestimation by the Doppler technique.

Figure 5 shows the instantaneous peak pressure difference throughout systole measured simultaneously with the Doppler and the invasive techniques. Figure 5 also shows the pressure difference calculated from the spectral curves of Doppler recordings obtained the day before cardiac catheterisation. The pressure curves were almost identical.

Figure 6 shows the relation between the peak to peak pressure differences and the peak or the mean pressure differences all recorded invasively. In most cases the peak to peak pressure difference was close to the mean pressure difference, although in some cases there was considerable discrepancy between the two measurements. The peak pressure difference was consistently higher than the peak to peak pressure difference.

Discussion

The present study shows that a velocity recording from the aortic jet can be obtained in all patients with aortic stenosis and that this is achieved regardless of the age of the patient. This is in contrast to our initial experience where we failed to identify the aortic jet.[3] Although the initial studies showed good agreement between the pressure differences obtained with the Doppler technique and from invasive measurements in children and young adults,[4] the agreement was less good among older patients, the pressure differences being severely underestimated in some.[3] Later studies have confirmed the good results in children,[7] whereas the results in adults have been more variable,[5 6 11 12] although in studies in which spectral analysis of the Doppler signal was also applied the results were better.[11 12] The present data indicate that a good estimate of the pressure difference in aortic stenosis can regularly be obtained regardless of the age of the patient. The results are equally good whether or not aortic regurgitation of any severity or other valvar lesions are present.

The two main reasons for the improved accuracy of the non-invasive measurements are most likely to be *(a)* the improvement in equipment, which includes on line spectral analysis of the Doppler signals, and *(b)* our modification of currently applied techniques. With the spectral display, the distribution of the frequencies in the Doppler signal is well shown, and this allows discrimination between optimal and suboptimal signals. Weak high frequency

signals are more easily recorded with this technique than with a maximal frequency estimator, which is disturbed by noise in the presence of weak signals when the signal to noise ratio is low. In some of the older patients with aortic stenosis the Doppler signals are weak and in others the signals may contain relatively few of the highest frequencies. In both instances the highest frequencies may be recorded with spectral analysis but not with a maximum frequency estimator.

The other reason for the improved results is probably the extensive search for the best signals from the aortic jet. In earlier studies mainly the suprasternal notch and the right sternal border were searched since these were most often the best locations to be used in younger patients. In the present study a routine search was made in all patients from the apical area, the suprasternal notch, and the parasternal region even if a good signal was obtained in the area first searched. In some of these patients the highest velocities could be recorded even from distant sites, such as a high midaxillary position. Even if these areas are searched carefully this search should not take more than 15–20 minutes even in difficult cases. Figure 2 shows the recording of an aortic jet from three different sites. Since there is a squared relation between the velocities and the pressure difference even small differences between highest velocities measured in the same patient become important. To avoid underestimation the highest velocities must always be recorded.

To help in the initial search for the aortic valve area, especially from the apex, cross sectional echocardiogram may be obtained before or simultaneously with the Doppler study. The finding and recording of the highest velocities are, however, best performed without simultaneous imaging. For the right sternal border and the suprasternal notch imaging is less important, even if the ascending aorta and the valve area can be well visualised from the right sternal border.

UNDERESTIMATION OF THE PRESSURE DIFFERENCE

Some underestimation of the pressure difference obtained with the continuous wave Doppler technique would be expected since the angle in the Doppler equation has been ignored and an angle close enough to zero may not be achieved. In this respect the underestimation of the pressure difference in this study is surprisingly small. One reason is probably the search from widely different angles. In some patients, however, almost equally high velocities may be recorded from quite different directions. One possible reason for this is the dispersion of the jet velocities. With the pulsed Doppler technique it has been shown that the jet velocities extend for several centimetres beyond the valvar obstruction.[13] With some dispersion of the jet the highest velocities may be recorded from different directions, and this could increase the likelihood of obtaining a sufficiently small angle to some of the highest velocities.

While the presence of too great an angle between the ultrasound beam and the blood velocities may be the main reason for underestimating the pressure difference with the Doppler technique, other possible factors are the lack of enough high frequencies in the Doppler signal and the influence of viscous losses and inertia that is ignored in the simplified Bernoulli equation. A certain number of the highest frequencies have to be present in the signal for these to be recorded, and in this respect the spectral analysis is far more sensitive than the frequency estimator. Doppler signals with too few of the highest frequencies on the spectral display gradually fade out without showing a clear outline to the curve. Such curves were considered to be inadequate and were not used for calculations in the present study. With small adjustments of the transducer direction more of the higher velocities can usually be obtained and clearly recorded. With such signals the use of filters that remove most of the lower frequencies may help in recording the highest frequencies.

Viscous losses are also ignored in the formula used for calculating the pressure difference. From experimental studies[1 14] this does not seem to be of importance with the orifice sizes present in aortic stenosis. The tendency to greater underestimation of the higher pressure difference might be explained in this way, but it is more likely to be due to the squared relation between velocity and pressure difference in the formula. The same angle error will, at a higher velocity, cause a greater underestimation of the pressure difference.

Simultaneous recording of velocity and pressure with catheter tip transducers has shown a delay in the velocity recording compared with the pressure curve, which is ascribed to inertia.[15] In the present study this delay was neglible (Fig. 5). This was most likely to have been due to the delay caused by the fluid filled catheters and to less delay in the spectral analysis than in the analogue signals. The mean pressure difference can therefore be calculated from the velocity curves without more underestimation than that caused by underestimating the velocity.

OVERESTIMATION OF THE PRESSURE DIFFERENCE

The slight overestimation of the pressure difference in some of the patients might be more unexpected. There are, however, several possible reasons for a slight degree of overestimation. Since the studies

were not performed simultaneously in most patients some day to day variation due to changes in heart rate and cardiac output would be expected. The invasive procedures were performed after pre-medication, the non-invasive recordings without. On the other hand, all the patients were in a stable clinical condition and the heart rates were similar on the two occasions. Furthermore, in the four patients with simultaneous measurement the Doppler study performed the day before and the one performed during the catheterisation gave virtually identical results (Fig. 5). Nevertheless, some true difference in the pressure difference between the two recordings cannot be excluded among the patients in whom the measurements were not performed simultaneously.

Another factor that might introduce some over-estimation is that the flow velocity proximal to the obstruction was ignored when the pressure difference was calculated. The velocities of 0·7–1·0 m/s usually present in the left ventricular outflow tract in adults with aortic stenosis would lead to an overestimation of the peak pressure difference of only 2–4 mm Hg and of the mean pressure difference of 1 mm Hg if these are ignored. But with higher velocities below the valve, such as in patients with additional subvalvar obstruction or in some patients with aortic regurgitation, over-estimation by ignoring this factor becomes more pronounced and formula (3) should be used. The velocities below the valve were recorded in all the patients, and none had additional suvalvar obstruction.

A third possible reason is some degree of over-estimation of the velocities from the spectral curve due to the effect of the transit time.[16] This represents a random uncertainty in the estimation of the frequencies since the sampling of the frequencies has to be done over a very short time interval because of the rapid changes in velocity with time in pulsatile flow. Attempts to correct for an assumed angle between the ultrasound beam and the velocity may also lead to overestimations. Such corrections were not made in the present study.

When a higher pressure difference is recorded with the Doppler than with the invasive technique the latter difference may also be erroneous, because of excessive damping of the pressure curves or recording too far downstream from the aortic valve where some of the pressure difference may be regained. In this study care was taken to record the pressure in the ascending aorta only a short distance above the valve. Another factor that might influence the results at retrograde catheterisation is the possible effect of the catheter passing through a severely narrowed valve, since increases in arterial pressure on withdrawal of the catheter have been reported.[17]

In some studies apparent overestimations with the Doppler technique have not been true over-estimations but have resulted from the comparison of the peak instantaneous pressure difference using the Doppler technique with the peak to peak pressure difference at catheterisation[12] or from uncertainty about which pressure differences had been compared.[67] The peak instantaneous pressure difference is always higher than the difference between the peaks of the pressure curves from the left ventricle and the ascending aorta (Fig. 6). As shown in Figure 6 the peak to peak pressure difference used in some cardiac centres is, in most patients, more related to the mean than to the peak instantaneous pressure difference.

Obviously, much confusion occurs when the pressure differences obtained from Doppler recordings are evaluated. It is therefore important to note that the pressure differences most easily calculated from the peak value of the velocity curves represent the highest pressure difference occurring during systole. The peak to peak pressure difference from the invasively recorded pressure curves from the left ventricle and the ascending aorta represents the pressure difference between the peaks of the two curves occurring at different times during systole. The best estimate of the degree of obstruction is, however, given by the mean systolic pressure difference and is the pressure difference that should be preferred for both techniques.

DOPPLER AND CROSS SECTIONAL IMAGING
Cross sectional echocardiography performed either before or simultaneously with the Doppler study may shorten the time needed for orientation, especially from the apical region. In the present study the Doppler signal was recorded using a separate Doppler transducer in all the patients. This usually gave a better signal, and in some patients higher velocities could be recorded, probably both because of the higher sensitivity and because of the better access with the smaller separate Doppler transducer.

It is usually easy to identify the signal from the aortic jet, but other systolic jets may have similar directions. These jets are distinguished from aortic jets by observing their timing and duration, and either by recording the electrocardiogram and a phonocardiogram together with the velocities or by comparing flow across the various valves together with the valve movements. The valve movements can be identified from the amplitude of the Doppler signal. Mitral regurgitation is the most frequent differential diagnosis and is easily distinguished since the jet is of longer duration and is continuous with forward mitral flow.

PULSED VS CONTINUOUS WAVE DOPPLER

Since higher velocities may be recorded in the pulsed mode, the better signal to noise ratio in this mode might be an advantage. In children a good correlation between invasive measurements and those using pulsed Doppler with high pulse repetition rates has been reported.[10] Our experience so far in adults has been that the pulsed mode is less practical and more time consuming and does not improve the results.

CLINICAL IMPLICATIONS

The pressure difference represents one important variable in the assessment of aortic stenosis. The present study shows that provided a careful search is made to ensure that the highest velocities of the aortic jet are always recorded and provided that a spectral display of the Doppler frequencies is performed, the Doppler technique is an accurate method of measuring the aortic valvar pressure difference noninvasively. This technique is valuable in the diagnosis and in the further follow up of patients with aortic stenosis. In particular, it rapidly identifies patients in whom an indication for surgery is present or who should be further evaluated invasively. In older patients in particular, in several cases recently the high pressure difference measured with the Doppler technique was the only clue to the severity of the aortic stenosis.

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