

Transmitral velocities measured by pulsed Doppler in healthy volunteers: effects of acute changes in blood pressure and heart rate

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SUMMARY The effect of a two minute cold pressor test on transmitral velocities measured by pulsed Doppler was studied in 11 healthy volunteers. Blood pressure increased significantly during cold immersion but peak atrial and peak early diastolic transmitral velocities and their ratio (A:E) were unchanged. There was no correlation between changes in Doppler variables and changes in calculated mean arterial blood pressure during the test. Heart rate changes were variable and not related to changes in blood pressure. In individual people the change in pulse interval during cold immersion was significantly and inversely correlated with the change in the A:E ratio.

The large acute increase in arterial pressure seen during the cold pressor test in normal volunteers had no consistent effect on the transmitral velocity profile although small changes in heart rate were associated with large changes in A:E ratio. The effect of small changes in heart rate may be of considerable importance in determining transmitral velocity profiles. Thus in clinical and experimental studies in which the heart rate is not controlled, Doppler data on transmitral flow should be interpreted with caution.

Alterations in transmitral velocities measured by Doppler, particularly the ratio of peak atrial to peak early diastolic flow (A:E ratio), have been attributed to abnormal left ventricular relaxation.^{1,2} Pulsed Doppler echocardiography has been widely used to examine left ventricular diastolic function in people with hypertension,³ hypertrophic cardiomyopathy,⁴ and ischaemic heart disease.⁵

Recently it has been recognised that factors other than myocardial disease, including age,^{6,7} left ventricular preload,⁸ end diastolic pressure,⁹ and Doppler sample site¹⁰ may alter transmitral flow measurements.

Two studies of invasive measurements of haemodynamic variables in dogs suggested that the rate of left ventricular relaxation may be partly determined by left ventricular afterload.^{11,12} There are no data on the effect of acute changes in afterload on transmitral velocity measured by Doppler in healthy people.

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We examined the effect of a standard cold pressor test, which produces large changes in blood pressure, and thus afterload,¹³ on transmitral velocity in healthy volunteers.

Patients and methods

We studied 11 untreated, healthy volunteers (eight men, three women, mean (SD) age of 34.4 (5.9) years, range 24 to 44 years). They had no history of hypertension, cardiovascular disease, or excessive alcohol consumption.

PROTOCOL

All measurements were made in a quiet laboratory with a constant ambient temperature of 21°C. Volunteers were positioned in a left lateral semirecumbent position and this was adjusted until optimal Doppler recordings were obtained: thereafter the volunteers' position was not changed. After they had rested for 10 minutes they immersed their right hands in melting ice for two minutes. Blood pressure was recorded indirectly with a standard mercury sphygmomanometer and heart rate was measured from the electrocardiogram. The mean blood pres-

sure was calculated as diastolic pressure plus one third of the pulse pressure.

DOPPLER RECORDING AND ANALYSIS

Pulsed Doppler examinations of transmitral flow were recorded continuously on videotape throughout the cold pressor test on a Dasonics CV 400 ultrasound system with a transducer emission frequency of 3.0 MHz. The Doppler sample volume was placed, without angle correction, in the mitral valve funnel just to the left ventricular side of the mitral annulus and with the ultrasound beam as parallel as possible to left ventricular inflow.

We analysed the Doppler profiles recorded immediately before the cold pressor test, at one and two minutes during the test, and one minute after the test. Peak early diastolic velocity (E), peak atrial velocity (A), their ratio (A:E), and the corresponding pulse intervals (RR) were averaged over five consecutive cardiac cycles.

Data were expressed as mean (SD). Formal tests of statistical significance were obtained by standard methods of analysis of variance and linear regression analysis. Statistical significance is reported for p values of < 0.05.

Table 1 Peak atrial (A) and early (E) diastolic velocities, their ratio (A:E), pulse interval (RR), and mean blood pressure (MBP) measured before, after one and two minutes of a cold pressor test, and one minute after the end of the test

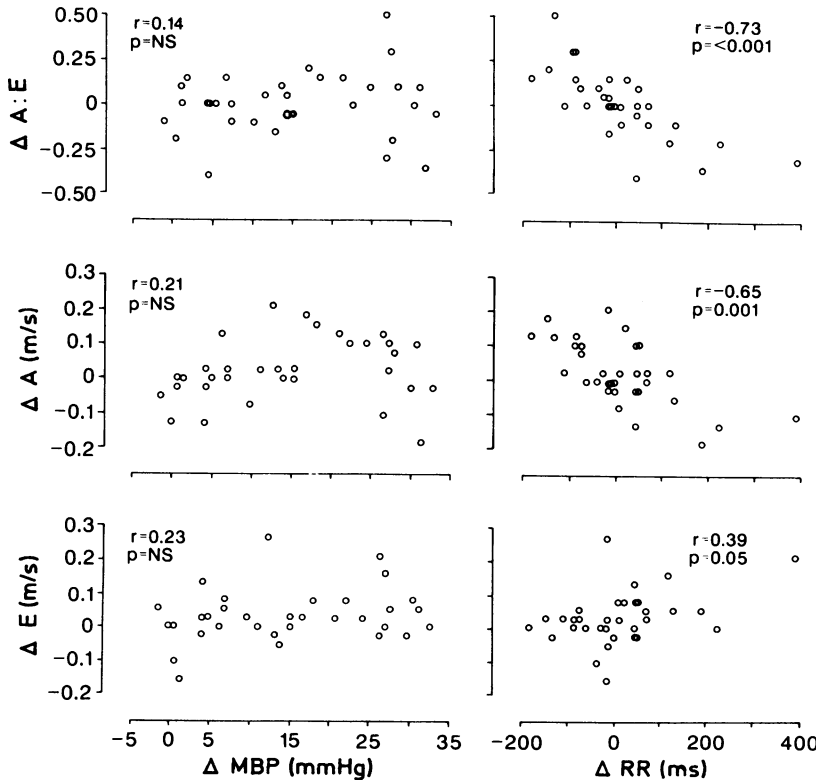
	A (m/s)	E (m/s)	A:E	RR (ms)	MBP (mm Hg)
Before	0.42 (0.02)	0.62 (0.04)	0.72 (0.08)	872 (48)	81 (2)
1 min	0.46 (0.03)	0.62 (0.04)	0.79 (0.10)	857 (46)	101 (3)*
2 min	0.45 (0.03)	0.66 (0.04)	0.79 (0.11)	901 (52)	102 (3)*
After	0.42 (0.04)	0.66 (0.03)	0.65 (0.08)	899 (32)	86 (3)

*p < 0.001 compared with values before test.

Results

HAEMODYNAMIC EFFECTS OF THE COLD PRESSOR TEST

Mean arterial blood pressure increased by approximately 20 mm Hg (p < 0.001) during the cold pressor test (table) and returned to pretest values within one minute of the removal of the hand from the ice. Heart rate did not change significantly during the cold pressor test and we found no relation between changes in heart rate and blood pressure.



Relations between individual changes from baseline of mean blood pressure (MBP) and pulse interval (RR) and individual changes in peak early (E) and atrial (A) diastolic transmitral velocities and their ratio (A:E) during (1 and 2 minutes) and after (1 minute) the cold pressor test in eleven healthy individuals.

DOPPLER VARIABLES AND THEIR RELATION TO BLOOD PRESSURE

There were no significant changes in peak atrial velocity (A), peak early diastolic velocity (E), or A:E ratio at any stage of the cold pressor test despite a 20 mm Hg increase in mean arterial pressure. The changes in mean arterial blood pressure within individuals did not correlate with changes in A, E, or A:E (figure).

DOPPLER VARIABLES AND THEIR RELATION TO HEART RATE

Though heart rate did not change during or after the cold pressor test in the group as a whole, the heart rate increased in some individuals and decreased in others. Changes in A:E within each individual correlated significantly with the change in RR (figure). This correlation was mainly the result of an inverse relation between changes in RR and in peak atrial velocity (A), though a less striking, but still statistically significant, positive correlation was noted between changes in RR and in peak early diastolic velocity.

Discussion

This study shows that transmitral velocity measured by Doppler is not affected by large changes in arterial pressure but it is considerably affected by small changes in heart rate.

The cold pressor test reliably increases blood pressure with small or inconsistent effects on other relevant haemodynamic variables.¹³ We used the cold pressor test to assess the effects of acute changes in blood pressure on transmitral velocities measured by Doppler. Analysis of transmitral flow by Doppler has been advocated as a method for examining left ventricular diastolic function¹² and animal experiments have suggested that the rate of left ventricular relaxation may be partly determined by afterload.^{11,12} The original purpose of this study was to examine the effects of changes in blood pressure on Doppler variables in order to determine whether such changes need to be taken into account when serial Doppler examinations are interpreted.

Because we were unable directly to measure changes in central haemodynamic variables in this non-invasive study we cannot exclude changes in preload in our study group, but earlier work suggests that changes in preload are likely to be small.¹³ Because the experiment was performed in conscious people, a direct effect of increased afterload on left ventricular relaxation (and thus Doppler transmitral velocity) may have been opposed by reflex effects. Whatever the mechanism, we found no consistent relation between large acute changes in blood pressure and

changes in Doppler variables, suggesting that changes in afterload can be ignored in an interpretation of Doppler measures of mitral flow. Our data do not exclude the possibility of a small effect of blood pressure variation on Doppler variables, but any such effect would be of little importance in practice. Further studies are required before conclusions can be drawn about the effects of acute changes in blood pressure in patients with cardiovascular disease.

We found that the peak velocity of the atrial component of diastolic flow was inversely related to the pulse interval within individuals. Our data suggest that a small change in heart rate from 70 to 80 beats/min would increase the ratio of peak atrial to peak early diastolic transmitral velocity (A:E) by approximately 30%. Other studies that have specifically examined the effects of changes in heart rate on transmitral velocities measured by Doppler have shown similarly pronounced effects of heart rate. Gillam *et al* using programmed pacing showed a tenfold change in E:A ratio as heart rate was changed from 60 to 100 beats/min.¹⁴ Parker *et al* using atropine showed a similar dependency of A:E on heart rate.¹⁵ This relation between changes in heart rate and in peak atrial velocity and A:E ratio may be of considerable clinical and experimental importance. Reliable correction for changes in heart rate between sequential studies will not be possible until the precise relation between heart rate and transmitral flow is fully established. There are many published reports of changes in A:E after procedures such as coronary angioplasty,^{16,17} head up tilting,¹⁸ and administration of vasoactive drugs.^{8,19} The results of such studies may not be valid if the heart rate changed between the Doppler examinations.

Serial measurements of transmitral velocity profiles are not significantly affected by large changes in blood pressure in healthy volunteers. In clinical and experimental studies in which the heart rate changes, Doppler data on transmitral velocity should be interpreted with caution.

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