Clinical Studies

Analysis of Left Atrioventricular Plane Movement during Diastole in Ischemic Heart Disease

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SUMMARY

The aim of the present study was to investigate the properties of diastolic left atrioventricular plane displacement (AVPD) in coronary artery disease (CAD) patients. In 125 patients (mean age 58.7 ± 13.7) with CAD and in 51 age-matched healthy subjects, a complete transthoracic echocardiographic study was performed. The AVPD was recorded by M-mode echocardiography, from apical four and two chamber views at four sites corresponding to the septal, lateral, anterior and inferior walls of the left ventricle. Mean AVPD in early diastole (E-AVPD), mean AVPD from atrial systole (A-AVPD) and the ratio A-AVPD/E-AVPD were determined. In normal subjects, such as in 35 patients without left ventricular segmental wall motion abnormalities (SWMA), stepwise multiple regression analysis showed none of these factors to be significantly related to E-AVPD or A-AVPD. Aging was correlated negatively to the E-AVPD/A-AVPD ratio (p<0.05). In 90 patients with left ventricular SWMA, stepwise multiple regression analysis showed that indices of left ventricular systolic function correlated positively to E-AVPD (p<0.001) and A-AVPD (p<0.001). The E-AVPD/A-AVPD ratio was correlated to left ventricular ejection fraction and heart rate (p<0.005). Mean E-AVPD was significantly lower in CAD patients than in normal subjects (p<0.001), while A-AVPD was higher in patients without left ventricular SWMA in comparison to normal subjects (p=0.02). Also, mean A-AVPD/E-AVPD was higher in CAD patients than in the control group (p<0.001). Mean E-AVPD/A-AVPD was correlated to the E/A ratio of transmitral flow in CAD patients with (r=0.669) and without (r=0.771) SWMA.

The E-AVPD and A-AVPD in CAD patients with SWMA is reduced according to the deterioration of left ventricular systolic function. The atrial contribution to the longitudinal distension of the left ventricle is increased in...
CAD patients. In CAD patients, especially those without left ventricular SWMA, the E-AVPD/A-AVPD ratio has a good correlation to left ventricular filling behavior. (Jpn Heart J 36: 545–556, 1995)

**Key words:** Atrioventricular plane Diastolic function Coronary artery disease

The size and motion of the mitral annulus has been studied extensively with the expectation of providing important hemodynamic information.\(^1,2\) Several investigators have shown that atrioventricular plane displacement (AVPD) during systole reflects left ventricular systolic function.\(^3-6\) Recently, diastolic atrioventricular plane motion has been studied to assess left ventricular diastolic function in healthy subjects.\(^7\)

The purpose of this study was to investigate properties of diastolic AVPD in patients with coronary artery disease.

**MATERIALS AND METHODS**

One hundred and twenty-five patients with exertional angina pectoris, in sinus rhythm, were studied. The diagnosis of coronary artery disease was confirmed by selective coronary arteriography. Clinical information and results of cardiac catheterization are listed in Table I. Patients having congenital or valvu-
lar heart disease, arrhythmias, left ventricular hypertrophy, echocardiographic features of left ventricular aneurysm and technically inadequate echocardiogram, were excluded from the study. Fifty-one healthy age-matched subjects without history of cardiac or other diseases, and with a normal physical examination, exercise tolerance and echocardiogram, were also included in the study as the control group.

**Echocardiography:** Complete echocardiographic-Doppler studies were obtained just prior to cardiac catheterization using a Hewlett-Packard ultrasonic instrument (Model 77020 AC) and a 2.5 MHz focused transducer. The subjects were examined in the partial left lateral decubitus position. Before the echo examination blood pressure was measured with a mercury sphygmomanometer.

Echocardiographic techniques and measurements of cardiac dimensions were obtained according to the instructions of the American Society of Echocardiography.9,10 Recordings of the AVPD during the cardiac cycle were obtained with the M-mode cursor directed from apical views during expiration.

![Echocardiogram Image](image)

**Figure 1.** M-Mode recording of left atrioventricular plane displacement (AVPD) in early diastole (E-AVPD) and that due to atrial systole (A-AVPD).
Initially, the M-mode cursor was oriented towards the right septal margin of the left atrioventricular plane and then toward its lateral margin from the apical four-chamber view. Consequently, the M-mode cursor was placed at the anterior and inferior borders of the left atrioventricular plane in the apical two chamber view.

On each side the echocardiographic beam was oriented in a way to be perpendicular to the motion of the left atrioventricular plane. Using the leading edge of the echoes, the AVPD during early diastole (E-AVPD) and the AVPD during atrial systole (A-AVPD) were measured (Figure 1). The ratio E-AVPD/A-AVPD was calculated. A mean value of measurements of five consecutive cardiac cycles was used from the above reported four sites. The diagnosis of the left ventricular segmental wall motion abnormalities (SWMA) was determined visually by two independent echocardiography specialists. Differences of opinion were resolved by consensus.

Pulsed Doppler transmitral inflow velocities were recorded between the tips of the mitral leaflets from the apical four-chamber view during expiration and read by another investigator who did not know the previous echocardiographic results. Early mitral flow peak velocity (E) and the peak velocity of late mitral flow (A) were measured from the velocity tracing.

**Cardiac catheterization:** Immediately after the echocardiographic Doppler study, all patients underwent cardiac catheterization, without any change in their medications.

Left ventricular diastolic pressures were recorded using a 7F fluid-filled

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<th>Table II. Comparison of Characteristics of Coronary Artery Disease Patients with or without Segmental Wall Motion Abnormalities of the Left Ventricle</th>
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<tr>
<td><strong>Healthy subjects</strong></td>
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<td>(n = 51)</td>
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<tr>
<td>HR (beats/min)</td>
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<tr>
<td>Age (years)</td>
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<td>SBP (mmHg)</td>
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<td>DBP (mmHg)</td>
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<td>CO (l/min)</td>
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<td>EDP (mmHg)</td>
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<td>EF (%)</td>
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</table>

CAD = coronary artery disease; SWMA = segmental wall motion abnormalities; HR = heart rate; SBP = systolic blood pressure; DBP = diastolic blood pressure; EDD = end-diastolic diameter of the left ventricle (LV); ESD = end-systolic diameter of the LV; LA = left atrium; E = early mitral flow peak velocity; A = peak velocity of late mitral flow; CO = cardiac output; EDP = end-diastolic pressure; EF = ejection fraction of the LV.
Cordis pigtail catheter connected to a SensoNor 840 pressure transducer. Left ventricular end-diastolic pressure was measured as the point on the diastolic wave form coincident with the onset of the QRS complex on the electrocardiogram. Measurements were made over a respiratory cycle and averaged.

Left ventriculography was performed with a rapid injection of 35 to 50 ml of Iopamiron in a 30° right anterior oblique projection. The left ventricular volumes and ejection fraction were determined from the 30° right anterior oblique angiogram.¹¹

Selective coronary arteriography was performed in all patients. Coronary artery disease was defined as narrowing of at least 50% of one or more major

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<th>Table III.</th>
<th>Results of Stepwise Multiple Regression Analysis in Normal Subjects (n=51) and in Patients Without (n=35) and with (n=90) Left Ventricular Segmental Wall Motion Abnormalities</th>
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<tbody>
<tr>
<td></td>
<td>Normal subjects</td>
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<td>Variables</td>
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<tr>
<td>E-AVPD</td>
<td>Age</td>
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<td>A-AVPD</td>
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<tr>
<td>R² = 0.24, F (1.16) = 6.50, p &lt; 0.05</td>
<td>R² = 0.36, F (1.20) = 13.1, p = 0.0017</td>
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<td>E-AVPD</td>
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<td>A-AVPD</td>
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<tr>
<td>R² = 0.57, F (3.49) = 23.86, p &lt; 0.001</td>
<td>R² = 0.24, F (2.50) = 9.00, p &lt; 0.001</td>
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<tr>
<td>E-AVPD</td>
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<td>A-AVPD</td>
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<td>R² = 0.21, F (2.50) = 2.9, p &lt; 0.005</td>
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**E-AVPD** = early diastolic atrioventricular plane displacement; **A-AVPD** = late atrioventricular plane displacement; **SWMA** = segmental wall motion abnormalities; **EF** = left ventricular ejection fraction; **CO** = cardiac output; **LVEDD** = left ventricular end-diastolic diameter; **LVESD** = left ventricular end-systolic diameter.
Statistical analysis: Results are given as mean ±SD. Comparisons are made using Student’s t-test. Correlation between two different parameters was evaluated by linear regression analysis. Also, one-way ANOVA test and stepwise multiple regression analysis were used.

In order to test the reproducibility of the AVPD, 40 subjects (15 normal subjects and 25 patients) were studied twice by two other independent investigators. One investigator was quite familiar with the recording of AVPD while the second one was less experienced with that technique. Intraobserver and interobserver variability was estimated to be insignificant using analysis of variance. The intraobserver variabilities in measuring E-AVPD and A-AVPD were 4.9% and 5.3% while the interobserver variabilities were 6.3% and 6.8%, respectively.

RESULTS

The differences in basic clinical and echocardiographic Doppler and hemodynamic data between patients with or without SWMA of the left ventricle and healthy subjects are listed in Table II.

Determinant factors of E-AVPD, A-AVPD and of the E-AVPD/A-AVPD ratio were evaluated by stepwise multiple regression analysis in normal subjects and in patients without or with SWMA of the left ventricle. The determinant

| Table IV. Atrioventricular Plane Motion during Early Diastole (E-AVPD), due to Left Atrial Systole (A-AVPD) and Their Ratio (A-AVPD/E-AVPD) in Patients with CAD and Normal Subjects |
|-----------------|-----------------|-----------------|
|                 | E-AVPD (mean)   | A-AVPD (mean)   | A-AVPD/E-AVPD (mean) |
| Group 1         |                 |                 |                        |
| Normal subjects | 10.4±1.8        | 5.85±1.32       | 0.565±0.18             |
| Group 2         |                 |                 |                        |
| Patients with SWMA | 7.4±2.1   | 5.8±1.1         | 0.765±0.21             |
| Group 3         |                 |                 |                        |
| Patients without SWMA | 9±1.8     | 6.4±0.76        | 0.70±0.18              |
| ρ Value         |                 |                 |                        |
| Group 1 vs 2    | <0.001          | =0.02           | <0.001                  |
| Group 1 vs 3    |                 |                 | Group 1 vs 2           |
| Group 2 vs 3    |                 |                 | Group 1 vs 3           |

CAD = coronary artery disease; SWMA = segmental wall motion abnormalities.
Figure 2. Correlation between ratio of left atrioventricular plane displacement in early diastole (E-AVPD) to atrioventricular plane displacement due to atrial systole (A-AVPD) and E/A ratio of transmitral flow in normal subjects (upper panel), in coronary artery disease patients without (middle panel) and with segmental wall motion abnormalities of the left ventricle (lower panel).
factors evaluated in normal subjects were: age, heart rate, systolic and diastolic blood pressure, left ventricular end-diastolic diameter, diameter of the left atrium and the difference between left ventricular end-systolic and end-diastolic diameters. In coronary artery disease patients cardiac output, left ventricular ejection fraction and the left ventricular end-diastolic pressure were also evaluated.

In patients without SWMA of the left ventricle, a stepwise multiple regression analysis did not show any significant contribution of any of the above mentioned factors, apart from age, in predicting E-AVPD, A-AVPD and E-AVPD/A-AVPD. Aging exhibited a significant negative correlation only for the E-AVPD/A-AVPD ratio (Table III).

In patients with SWMA a stepwise multiple regression analysis showed that the difference between end-systolic and end-diastolic diameter, left ventricular ejection fraction and cardiac output were significantly correlated to E-AVPD. The two last variables were also correlated to A-AVPD. Left ventricular ejection fraction and heart rate correlated significantly to the E-AVPD/A-AVPD ratio (Table III).

The mean E-AVPD and A-AVPD and their ratio in normal subjects and in patients with coronary artery disease, with or without SWMA of the left ventricle, are shown in Table IV. The mean E-AVPD was significantly lower in patients with coronary artery disease with or without SWMA, than in normal subjects. Between patients with or without SWMA there was a significant difference in this parameter. The mean A-AVPD was significantly increased in patients without SWMA compared to normal subjects. Consequently, the mean A-AVPD/E-AVPD ratio was significantly greater in patients with coronary artery disease with or without SWMA, than in healthy controls. Between patients with or without segmental wall abnormalities there was no significant difference in the A-AVPD/E-AVPD ratio.

There was a significant linear correlation (Figure 2) between mean E-AVPD/A-AVPD and the E/A ratio of transmitral flow in normal subjects ($r = 0.805, \ p < 0.001$), in coronary artery disease patients with ($r = 0.669, \ p < 0.001$) or without ($r = 0.771, \ p < 0.01$) SWMA of the left ventricle.

**DISCUSSION**

The left ventricle contracts in the direction of its short, as well as its long axis.\(^{12}\) In systole, contraction of the longitudinal fibers of the left ventricle produces longitudinal shortening of this structure, as well as descent of the left atrioventricular plane toward the relatively immobile cardiac apex.\(^{13-15}\) During diastole, the left atrioventricular plane ascends towards the atrial roof during early diastole and atrial systole, with a pause during mid-diastole.\(^{7,15}\)
During early diastole the upward movement of the left atrioventricular plane takes place in the face of increasing blood flow velocity across the mitral valve. Such an acceleration implies a positive pressure difference from the left atrium to left ventricle. Thus, the motion of the left atrioventricular plane toward the atrial roof must be a result of a greater force, which is likely to be the result of elastic recoil arising from compression of the left ventricular myocardium or stretching of the left atrial myocardium during ventricular systole. Elastic recoil of the left ventricle is the main mechanism of the displacement but many other factors influence the process, including change in diastolic intracellular calcium, heart rotation, movement in the thorax, tension from adjacent organs such as the aortic arch, vena cava, and so on.

Alam et al., by calculating the ratio of motion of the atrioventricular plane caused by left systole to the total diastolic displacement in a series of healthy persons, proposed that this ratio could be used as a parameter for the assessment of diastolic function, considering that it represents the contribution of atrial systole to left ventricular filling. Recently, identical findings were confirmed in hypertensive patients with normal systolic function.

In this study we investigated factors that could influence the motion of left atrioventricular plane displacement in normal and in coronary artery disease subjects.

At first, in patients with coronary artery disease without SWMA of the left ventricle none of the factors examined were found to be related to E-AVPD or A-AVPD. However, in patients with left ventricular SWMA it was shown that E-AVPD was affected by left ventricular ejection fraction, cardiac output, and the difference between end-systolic and end-diastolic diameter of the left ventricle, which expresses left ventricular systolic function. Previous studies have shown that the phase of early left ventricular diastolic filling is influenced by left ventricular systolic function, which is related to early diastolic behavior through the elastic recoil of the left ventricle. The reduced left ventricular systolic function must have an influence on left ventricular elastic recoil, which, as has already been mentioned, is probably due the early diastolic motion of the mitral annulus.

In coronary artery disease patients with SWMA, the deterioration of left ventricular systolic function was also found to be significantly correlated with reduction of the A-AVPD. In this subgroup of patients with reduced systolic function, left ventricular remodelling after myocardial infarction may also be associated with significant abnormalities of diastolic function. The fibrous maturation within an infarcted area results overall in a left ventricle with poor compliance. A stiffer left ventricle imposes a higher left atrial afterload, resulting in a shift in left ventricular filling during early diastole and in a reduced active left
atrial emptying, which is reflected in the late atrioventricular plane displacement. Also, reduced active left atrial emptying may be due to decreased atrial contractility.\(^{21}\)

Compared to healthy subjects, patients with coronary artery disease, were found to have a higher A-AVPD/E-AVPD as a result of the reduction of E-AVPD with unchanged or increased A-AVPD. This means an increased relative atrial contribution to the left ventricular longitudinal distension in coronary artery disease patients. A similar finding has also been reported by other investigators\(^{22}\) who demonstrated that the percentage of left atrial contribution to left ventricular filling is increased in patients with coronary artery disease.

In the present study, in coronary disease patients as well as in healthy subjects, a significant correlation between the E-AVPD/A-AVPD ratio and the E/A ratio of transmitral flow was found, which indicates that the diastolic movement of the mitral annulus reflects the left ventricular filling. The E/A ratio of transmitral flow is the most popular method for clinical detection of left ventricular diastolic dysfunction.\(^{21}\) The correlation between the E-AVPD/A-AVPD ratio and the E/A ratio of transmitral flow was weaker in patients with SWMA. This probably is due to the fact that this subgroup of patients had a definitely smaller left ventricular ejection fraction and cardiac output compared to patients without SWMA, and as is well known, early atrioventricular plane displacement (E-AVPD) is determined by left ventricular systolic function. Another reason may be the existence of variable atrial contractile function in coronary artery disease patients with SWMA.

The echocardiographic assessment of atrioventricular plane motion during diastole has the advantage of low interobserver and intraobserver variability and could be applied in a clinical setting where only two-dimensional but not Doppler echocardiographic equipment is available at bedside. The E-AVPD/A-AVPD ratio is a good indicator of left ventricular filling in coronary artery disease patients without SWMA of the left ventricle, in whom, as in healthy subjects, it is related only to aging. In this subgroup of coronary artery disease patients the noninfarcted or those not exposed to severe ischemia of the cardiac muscle may behave normally. Aging has the same effect on diastolic performance in these patients as in normal subjects. Aging alters left ventricular diastolic function by reducing the rate and extent of the rapid filling phase, related to increased regional asynchrony\(^{23}\) and also by decreasing left ventricular compliance with a concomitant compensatory increase of left atrial emptying.\(^{24}\) The result of these mechanisms is probably reflected by the increase of the A-AVPD/E-AVPD ratio with aging in normal subjects and in patients with coronary artery disease without SWMA of the left ventricle.

In coronary artery disease patients with left ventricular SWMA it is difficult
to conclude that E-AVPD/A-AVPD is a good indicator of left ventricular filling because it is not independent of systolic function and heart rate. However, not only E-AVPD/A-AVPD, but any diastolic functional indicator is influenced by systolic function and heart rate in the in vivo measurement of cardiac function including end-diastolic pressure, time constant of isovolumic pressure decline, \(-dP/dt\), pressure half time, end-diastolic pressure volume relation and Doppler measurement of A/E ratio of transmitral flow.\(^{21}\) It is necessary to remember that it is difficult to completely separate left ventricular systolic and diastolic functional indices even in very carefully conducted experimental studies. Taking that into account, it is very important to recognize this limitation in diastolic functional evaluation by E-AVPD/A-AVPD.

**Limitations of the study:** One of the limitations of our study is that the echo study and the catheterization were not made simultaneously. The measurement of left ventricular end-diastolic pressure would have been more precise if a microtype catheter had been used.

**In conclusion:** The E-AVPD and A-AVPD in CAD patients with SWMA is reduced according to the deterioration of left ventricular systolic function. The atrial contribution to the longitudinal distension of the left ventricle is increased in CAD patients. In CAD patients, especially without left ventricular SWMA, the E-AVPD/A-AVPD ratio has a good correlation to left ventricular filling behavior.

**REFERENCES**