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Annulus Paradoxus

Transmitral Flow Velocity to Mitral Annular Velocity Ratio Is Inversely Proportional to Pulmonary Capillary Wedge Pressure in Patients With Constrictive Pericarditis

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Background—The early diastolic velocity of the mitral annulus (E') is reduced in patients with diastolic dysfunction and increased filling pressures. Because transmitral inflow early velocity (E) increases progressively with higher filling pressures, E/E' has been shown to have a strong positive relationship with pulmonary capillary wedge pressure (PCWP) and left ventricular end-diastolic pressure. However, previous studies have primarily involved patients without a pericardial abnormality. In constrictive pericarditis (CP), E' is not reduced, despite increased filling pressures. This study evaluated the relationship between E/E' and PCWP in patients with CP.

Methods and Results—We studied 10 patients (8 men; mean age, 64 ± 7 years) with surgically confirmed CP. Doppler echocardiography was performed to measure early and late diastolic transmitral flow velocities. Tissue Doppler echocardiography was performed to measure E' . PCWP was measured with right heart catheterization. All patients were in sinus rhythm. Mean E and E' were 91 ± 15 cm/s and 11 ± 4 cm/s, respectively. Mean PCWP was 25 ± 6 mm Hg. E' was positively correlated with PCWP ($r=0.69$, $P=0.027$). There was a significant inverse correlation between E/E' and PCWP ($r=-0.74$, $P=0.014$). Despite high left ventricular filling pressures, E/E' (mean, 9 ± 4) was <15 in all but 1 patient.

Conclusions—Paradoxical to the positive correlation between E/E' and PCWP in patients with myocardial disease, an inverse relationship was found in patients with CP. (*Circulation*. 2001;104:976-978.)

Key Words: pericarditis ■ pressure ■ mitral valve

Recent observations suggested that mitral annular velocity (E'), as measured by tissue Doppler echocardiography, in patients with systolic dysfunction or primary myocardial disease behaves as a preload-independent index of left ventricular (LV) relaxation¹ and that the ratio of transmitral flow velocity (E) to E' is a predictor of LV filling pressures.²⁻⁴ In patients with constrictive pericarditis (CP), however, E' is usually well preserved, despite increased filling pressures,⁵ possibly due to a greater contribution by the longitudinal movement of the left ventricle for diastolic filling and normal LV relaxation. The purpose of the present study was to evaluate the relationship between E/E' and LV filling pressures in patients with CP.

Methods

Patients

We studied 10 patients (8 men; mean age, 64 ± 7 years; range, 54 to 72 years) with surgically confirmed CP. CP was caused by previous coronary artery bypass operation in 4 patients and was idiopathic in the other 6 patients. The interval between cardiac catheterization and echocardiography was 6 ± 7 days. In 7 patients, it was ≤ 3 days (Table). This study was approved by the Institutional Review Board.

Two-Dimensional and Doppler Echocardiography

Two-dimensional and Doppler echocardiographic examinations were performed in a standard manner with a commercially available cardiac ultrasound unit. A pulsed-wave Doppler study of mitral inflow velocity was performed with simultaneous respiratory recording from a nasal thermistor, as described previously (Figure 1).^{6,7} The first cardiac cycles in which filling and ejection occurred in their entirety during a particular respiratory phase (either inspiration or expiration) were analyzed. Three respiratory cycles were analyzed for each patient. For tissue Doppler echocardiography measurements, the specialized pulsed-wave Doppler mode for tissue velocity was used, and the Nyquist limit was adjusted to a range of 15 to 20 cm/s. Gains were minimized to allow for a clear tissue signal with minimal background noise. From the apical 4-chamber view, a 2- to 5-mm sample volume was placed at the septal corner of the mitral annulus to record annular velocities (Figure 1). All Doppler velocities were recorded with a chart recorder at a sweep speed of 50 or 100 mm/s.

Cardiac Catheterization

Right and left heart catheterization was performed to measure pulmonary artery or capillary wedge pressure (PCWP) and LV diastolic pressure. A 6-F, balloon-tipped, flow-directed pulmonary arterial catheter was placed through a femoral vein into the pulmonary artery under fluoroscopic guidance. With the balloon inflated,

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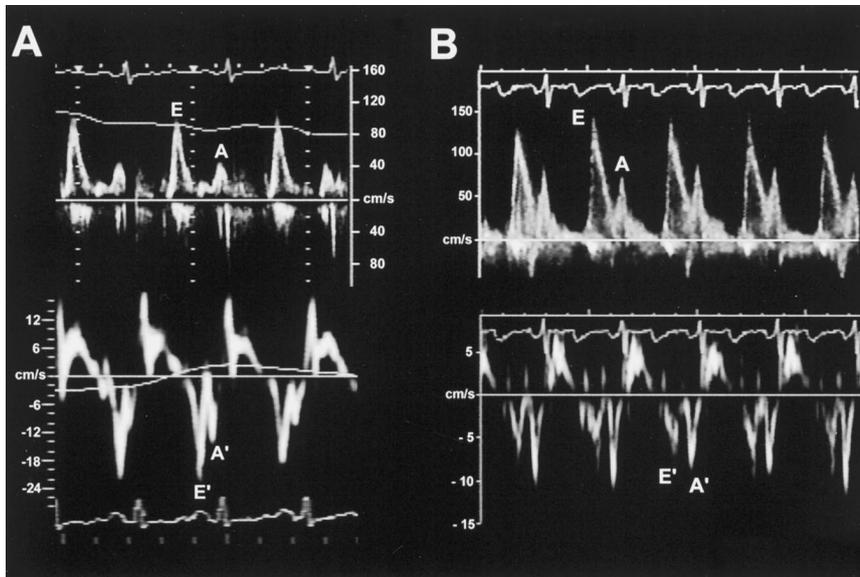


Figure 1. Early diastolic mitral inflow (E) and annular velocities in 2 separate patients. A, 56-year-old man with CP. Note that E is ≈ 100 cm/s and E' is 20 cm/s. PCWP was 31 mm Hg, and E/E' was 5. B, 54-year-old man with CP. PCWP was 18 mm Hg, and E/E' was 17. A indicates late filling velocity; A', late diastolic annular velocity.

the catheter was advanced into the pulmonary capillary wedge position, which was confirmed fluoroscopically by the presence of characteristic pressure waveforms and by a saturation of $>95\%$. LV pressure was recorded with a 7-F, high-fidelity, manometer-tipped catheter (Millar Instruments, Inc), as described previously.⁸ LV end-diastolic pressure (LVEDP) was measured from the LV pressure tracing at the point just before the onset of an increase in LV systolic pressure. Averaged values of ≥ 3 consecutive beats were used for statistical analysis.

Results

The cardiac rhythm was sinus in all patients. Clinical and hemodynamic data of the study patients are listed in the Table. The mean mitral flow velocity was 73 ± 22 cm/s (range, 50 to 120 cm/s) with inspiration and 91 ± 15 cm/s (range, 80 to 130 cm/s) with expiration. The mean change in E from inspiration to expiration was $30 \pm 22\%$ (range, 8% to 60%). Mean E' was 11 ± 4 cm/s (range, 7 to 21 cm/s). PCWP and LVEDP were 25 ± 6 and 27 ± 6 mm Hg, respectively. E' was positively correlated with PCWP ($r=0.69$, $P=0.027$) and LVEDP ($r=0.69$, $P=0.029$). Consequently, there was a significant inverse correlation between E/E' and PCWP ($r=-0.74$, $P=0.014$; Figure 2) and LVEDP ($r=-0.76$,

$P=0.011$). Despite high LV filling pressures, E/E' (mean, 9 ± 4) was <15 in all but 1 patient. Tissue Doppler echocardiography was repeated after pericardiectomy in 3 patients. E' decreased from 12 to 8 cm/s on average after pericardiectomy in these patients.

Discussion

The principal finding of this study is the inverse correlation between E/E' and LV filling pressures in patients with CP. This is in contrast to the positive correlation between E/E' and LV filling pressures in patients without a pericardial abnormality. Hence, the term "annulus paradoxus" is proposed to describe the paradoxical behavior of the mitral annulus in CP.

The assessment of LV filling pressure is clinically important in patients with established heart disease and usually requires invasive hemodynamic measurement. Several non-invasive Doppler echocardiographic indices that use conventional mitral inflow parameters have been proposed to estimate LV filling pressure.⁹⁻¹¹ Because E is directly influenced by left atrial pressure and inversely altered by changes in the

Clinical and Hemodynamic Data for 10 Patients With CP

| Case | Sex | Age, y | Cause | Time Between Echo and Catheterization, d | E/E' | PCWP, mm Hg | τ , ms |
|------|-----|--------|------------|--|------|-------------|-------------|
| 1 | M | 69 | S/P CABG | 16 | 10 | 23 | 59 |
| 2 | M | 72 | S/P CABG | 1 | 5 | 31 | 53 |
| 3 | M | 63 | Idiopathic | 1 | 11 | 24 | ... |
| 4 | M | 59 | Idiopathic | 19 | 7 | 22 | 75 |
| 5 | M | 63 | S/P CABG | 13 | 10 | 18 | 69 |
| 6 | M | 54 | S/P CABG | 3 | 17 | 18 | 39 |
| 7 | F | 72 | Idiopathic | 2 | 11 | 21 | 57 |
| 8 | M | 56 | Idiopathic | 2 | 4 | 31 | 48 |
| 9 | F | 58 | Idiopathic | 2 | 6 | 34 | ... |
| 10 | M | 69 | Idiopathic | 2 | 9 | 30 | ... |

Echo indicates echocardiography; F, female; M, male; S/P CABG, status post coronary artery bypass grafting; and τ , time constant of relaxation.

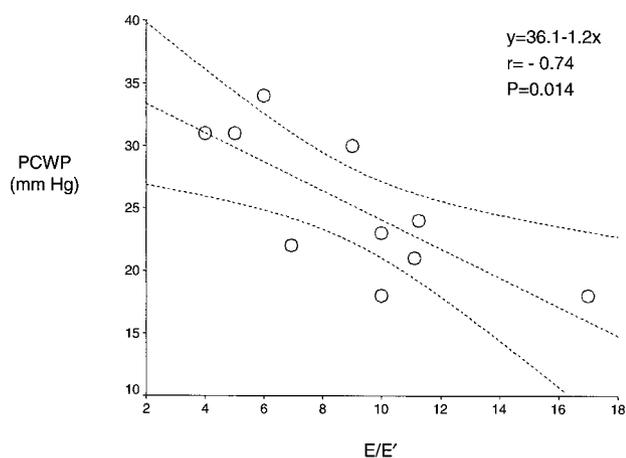


Figure 2. Correlation between E/E' and PCWP.

time constant of relaxation, an increase in left atrial pressure can override the effects of impaired relaxation.

Recently, combining E with E' has been proposed as a tool for assessing LV filling pressures. Several investigators have shown that the E/E' ratio is valid for determining LV filling pressures by offsetting the effects of relaxation on E in estimating filling pressures. Nagueh et al validated the relationship between E/E' and PCWP in patients with either impaired or pseudonormal relaxation² or with sinus tachycardia.³ Ommen et al⁴ found that an E/E' >15 identified increased LV filling pressure. In addition, they showed that E/E' provided better estimates of LV filling pressures than pulmonary venous flow pattern or the Valsalva maneuver. However, these studies did not include patients with CP.

In CP, E' is usually well preserved or even accentuated, despite increased filling pressures, and the finding of preserved E' has been suggested as being clinically useful for distinguishing CP from restrictive cardiomyopathy.⁵ In this study, a significant inverse correlation was found between E/E' and LV filling pressures in patients with CP, which is the inverse of the correlation shown in patients with a primary myocardial disease. The plausible explanation for this finding is the exaggerated longitudinal motion of the mitral annulus, despite high filling pressures in patients with CP, because the lateral expansion of the entire heart is limited by the constricting pericardium. The more severe constriction with a higher filling pressure, the more accentuated is the longitudinal motion of the mitral annulus. This explanation can be supported by the finding that E' was decreased after pericardiectomy in all 3 patients who had a repeat measurement of E' postoperatively. In addition, normal relaxation and a small LV cavity with good systolic function may result in increased longitudinal excursion and E'.

In this study, E' was measured from the septal annulus because its velocity is less influenced by the pericardium. E' from the lateral annulus is usually higher than that of the septal annulus in patients without pericardial abnormality. However, it is potentially affected by the calcification or adhesion of the pericardium in patients with CP.¹²

Study Limitations

The major limitation of this study is that echocardiographic measurement of E and E' and cardiac catheterization were not performed simultaneously. Therefore, there was a delay in the measurement of intracardiac pressures and PCWP from the measurement of E and E'. However, all patients were in a chronic state, and there was no change in their medications and clinical conditions between echocardiography and cardiac catheterization.

Conclusion

In patients with CP, E/E' is inversely correlated with PCWP, paradoxical to the positive correlation found in patients with a primary myocardial disease. The term "annulus paradoxus" is proposed to describe this unique relationship in patients with CP.

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