Accurate Determination of Mitral Regurgitation by Assessing its Influence on the Combined Diastolic Mitral and Pulmonary Venous Flow: Just ‘Looking Twice’

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Aims: To assess the diagnostic accuracy of combined transmitral E wave velocity and reversed systolic pulmonary venous flow for the quantification of mitral regurgitation severity.

Methods and results: Measuring forward and total left ventricular stroke volume, mitral regurgitation severity was assessed quantitatively by calculating the regurgitant fraction in 106 consecutive patients with pure mitral regurgitation. According to the regurgitant fraction, the optimal E wave velocity for accurate distinction of mild to moderate and more than moderate mitral regurgitation was chosen by calculating the receiver-operating characteristic plot. Severe mitral regurgitation was defined by reversed systolic pulmonary venous flow.

Combining transmitral E wave velocity and reversed systolic pulmonary venous flow had an overall accuracy of 78% (95% CI 70–86%) for classification of mitral regurgitation severity. E wave velocity >1·0 ms⁻¹ predicted more than moderate mitral regurgitation with 78% sensitivity (95% CI 69–86%) and 90% specificity (95% CI 82–95%), resulting in a positive likelihood ratio of 8·1 (95% CI 5–15) and negative likelihood ratio of 0·25 (95% CI 0·18–0·35). For reversed systolic pulmonary venous flow in the presence of increased E wave velocity, the sensitivity and specificity to detect severe mitral regurgitation was 78% (95% CI 69–86%) and 97% (95% CI 92–99%) with the corresponding positive and negative likelihood ratio of 29 (95% CI 11–96) and 0·22 (95% CI 0·14–0·31). Test accuracy was independent of systolic function in a multivariate regression analysis.

Conclusions: ‘Looking twice’, once at the transmitral E wave velocity and once at pulmonary venous flow in patients with mitral regurgitation, allows accurate determination of moderately severe and severe mitral regurgitation.

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Key Words: mitral valve insufficiency; Doppler; echocardiography; diastole; pulmonary circulation.

Introduction

Mitral regurgitation is a common valvular heart disease. Its accurate quantification is important, since it influences clinical management (i.e. cardiac surgery or conservative treatment)[1–3]. Since severity of regurgitation does not necessarily correlate with severity of symptoms[4], echocardiography is a decisive tool for further invasive evaluation in preparation for valve replacement. However, accurate echocardiographic quantification of mitral regurgitation has many pitfalls[5], and an easy-to-handle but accurate approach covering all degrees of regurgitation is still missing from clinical routine. Quantification of mitral regurgitation using continuous, more accurate variables (i.e. regurgitant fraction[6] or the regurgitant orifice area[7]), is time consuming and therefore often avoided in clinical routine. Qualitative characterization of mitral regurgitation (i.e. using the spatial distribution of the regurgitant colour flow Doppler jet[8] or its morphology at the orifice[9]) is observer dependent, and does not allow...
patients to be placed accurately into three or more mitral regurgitation-categories. As an alternative, severity of mitral regurgitation can be quantified by assessing its haemodynamic consequences on flow velocity profiles in cardiovascular structures adjacent to the regurgitant jet (i.e. left atrium and pulmonary veins). Recently, the feasibility of this concept has been shown regarding the haemodynamic consequences of mitral regurgitation on mitral inflow and pulmonary venous flow. Increased E wave velocity of the mitral inflow reflects the haemodynamic atrial burden by the mitral regurgitation volume and is a sensitive marker of severe mitral regurgitation. A cut-off value for E wave velocity of >1.2 ms\(^{-1}\) has been shown to detect moderately severe or severe mitral regurgitation with a sensitivity of 86%\(^{10}\). Systolic pulmonary venous flow reversal (Fig. 1) is a very specific (96%), but weakly sensitive marker (52%) of severe mitral regurgitation\(^{12}\). Accordingly, looking first at mitral inflow with its high sensitivity for excluding more than moderate mitral regurgitation, and second at pulmonary venous flow with its excellent specificity for confirming severe mitral regurgitation, has the potential of an easy and accurate method assessing moderately severe and severe mitral regurgitation. Therefore, the purpose of this study was to verify these theoretical considerations in clinical routine, and to assess the overall accuracy of this combination of two diagnostic tests for the classification of mitral regurgitation.

Two-dimensional Doppler Echocardiography

All patients underwent routine M-mode and two-dimensional Doppler echocardiography, using commercially available instruments with 2-0-, 2-5-, or 3-5-MHz transducer (Acuson XP 128, Acuson Aspen, Acuson Sequoia C256, Mountainview, CA, U.S.A.), partially including the option for second harmonic imaging (Acuson Aspen and Sequoia C256, Mountainview, CA, U.S.A.). Patients were examined in the left supine position. Left ventricular M-mode measurements for calculation of left ventricular mass were performed according to the recommendations of the American Society of Echocardiography\(^{13}\). Left ventricular mass was calculated using the formula of Penn, adapted by Devereux et al.\(^{14}\). Left ventricular end-diastolic and end-systolic volumes were measured as

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**Methods**

**Study Patients**

One hundred and six patients with pure mitral regurgitation were included into this prospective study. All patients gave informed consent to participate.

Inclusion criteria were: (1) pure, at least mild mitral regurgitation, (2) sinus rhythm with heart rate <100 beats/min, (3) sufficient image quality for measurement of left ventricular outflow tract diameter in the parasternal long axis view and left ventricular end-diastolic and end-systolic volumes in the apical four- and two-chamber view, and (4) sufficient quality of diastolic mitral and pulmonary venous flow signals. Exclusion criteria were: (1) more than mild aortic regurgitation, (2) concomitant mitral or aortic stenosis, (3) left ventricular ejection fraction (EF) <30%, and (4) the presence of atrial fibrillation, atrial flutter or sinus tachycardia >100 beats/min.

The study cohort was divided into three groups according to the mitral regurgitant fraction determined by two-dimensional echocardiographic left ventricular planimetry (providing total stroke volume) and by the echocardiographic Doppler-derived calculation of the forward stroke volume across the left ventricular outflow tract\(^{6}\). This method is subsequently called the standard method. The three study groups were mild/moderate mitral regurgitation (regurgitant fraction <35%; n=52), moderately severe mitral regurgitation (regurgitant fraction \(\geq 35%\); n=22) and severe mitral regurgitation (regurgitant fraction \(\geq 50%\); n=32).
Mitral and Pulmonary Venous Flow in Mitral Regurgitation

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regurgitant fraction = (total stroke volume – stroke volume across the aortic valve) / total stroke volume

For Doppler examination of the mitral inflow, the sample volume of the pulsed wave Doppler was positioned at the tips of the mitral leaflets in the apical four-chamber view. Measurements included peak E wave velocity (ms⁻¹), peak A wave velocity (ms⁻¹), E wave deceleration time (ms), isovolumetric relaxation time (ms) and A wave duration (ms). At least three cardiac cycles were measured and averaged for each variable. For Doppler examination of pulmonary venous flow, attention was paid to position the sample volume of the pulsed wave Doppler at least 1 cm within the right upper pulmonary vein in order to avoid Doppler signals originating from the regurgitant jet moving along the atrial wall. At least three cardiac cycles were measured and averaged for systolic and diastolic flow time integral of the spectrum (VTIₛ and VTI₅), and pulmonary venous flow A wave duration (ms). If systolic forward flow was followed by reversed systolic flow, the difference was measured to give total systolic flow (VTIₛ). Thus, a negative VTIₛ indicates predominantly reversed systolic pulmonary venous flow. Flow reversal was defined as a ratio of systolic to diastolic pulmonary venous flow velocity time integral (VTIₛ/VTI₅) < 0.

Results

Patient Characteristics

Comparing the patients in the three categories of mitral regurgitation severity, no differences in age, heart rate and blood pressure were found. The frequency of mitral valve prolapse as cause of mitral regurgitation increased with severity of mitral regurgitation. The percentage of male gender was significantly higher in the group with severe mitral regurgitation (Table 1).

Doppler Echocardiographic Data

Left ventricular end-diastolic diameter and left ventricular end-systolic volume were largest in the group with severe mitral regurgitation (Table 2). Analysis of mitral inflow parameters showed that E/A ratio and E wave velocity increased with increasing severity of mitral regurgitation. Isovolumetric relaxation time, E wave deceleration time and A wave duration decreased, indicating a tendency to restrictive left ventricular filling patterns. In pulmonary venous flow velocity spectra, VTIₛ alone, as well as the systolic to diastolic ratio (VTIₛ/VTI₅) decreased significantly in all categories of mitral regurgitation, but were negative only in severe mitral regurgitation. No relation with mitral regurgitation severity was found for the pulmonary venous flow A wave duration and VTI₅ alone (Table 2). In a linear regression model, E wave velocity correlated moderately well, (regurgitant fraction = 0.01 E wave velocity + 0.7; r² = 0.34, P < 0.001) (Fig. 2), but best of all mitral inflow parameters with mitral regurgitant fraction (Table 3). In a linear regression model of the pulmonary venous flow parameters, pulmonary venous flow VTIₛ/VTI₅ ratio correlated best (regurgitant fraction = -0.02 pulmonary venous flow VTIₛ/VTI₅ + 1.1; r² = 0.45, P < 0.001) (Fig. 3) with mitral regurgitation severity as assessed by regurgitant fraction (Table 3). In a multiple regression model with regurgitant fraction and left ventricular-EF < 45% as dummy variable, a significant correlation with impaired left ventricular systolic function was found for
Table 1. Patient characteristics.

<table>
<thead>
<tr>
<th></th>
<th>Mild or moderate MR (RF &lt;35%)</th>
<th>Moderately severe MR (RF 35–49%)</th>
<th>Severe MR (RF ≥50%)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>52</td>
<td>22</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>64 (15)</td>
<td>63 (11)</td>
<td>63 (15)</td>
<td>NS</td>
</tr>
<tr>
<td>Male gender (%)</td>
<td>67 (35/52)</td>
<td>45 (10/22)</td>
<td>81 (26/32)</td>
<td>0.02</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>72 (19)</td>
<td>80 (18)</td>
<td>77 (17)</td>
<td>NS</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>133 (23)</td>
<td>130 (22)</td>
<td>121 (23)</td>
<td>NS</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>75 (12)</td>
<td>76 (9)</td>
<td>74 (15)</td>
<td>NS</td>
</tr>
<tr>
<td>Mitral valve prolapse (%)</td>
<td>8 (4/52)</td>
<td>18 (4/22)</td>
<td>41 (13/32)†</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Values are mean (SD). *P<0.01 vs moderately severe mitral regurgitation. †P<0.001 vs mild or moderate mitral regurgitation. Abbreviations: MR, mitral regurgitation; NS, not significant; RF, regurgitant fraction.

Table 2. Echocardiographic data.

<table>
<thead>
<tr>
<th></th>
<th>Mild or moderate MR (RF &lt;35%)</th>
<th>Moderately severe MR (RF 35–49%)</th>
<th>Severe MR (RF ≥50%)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>52</td>
<td>22</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>RF (%)</td>
<td>17 (14)</td>
<td>43 (5)</td>
<td>57 (6)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>End-diastolic LV diameter (mm)</td>
<td>54 (7)</td>
<td>58 (9)</td>
<td>61 (7)‡</td>
<td>0.007</td>
</tr>
<tr>
<td>Stroke volume (ml)</td>
<td>77 (24)</td>
<td>78 (25)</td>
<td>92 (25)†</td>
<td>0.02</td>
</tr>
<tr>
<td>LV hypertrophy (%)</td>
<td>65 (34/52)</td>
<td>72 (16/22)</td>
<td>72 (23/32)</td>
<td>NS</td>
</tr>
<tr>
<td>LV ejection fraction (%)</td>
<td>56 (14)</td>
<td>50 (13)</td>
<td>56 (15)</td>
<td>NS</td>
</tr>
<tr>
<td>E wave velocity (ms⁻¹)</td>
<td>0.8 (0.2)</td>
<td>1.0 (0.2)</td>
<td>1.3 (0.2)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>A wave duration (ms)</td>
<td>0.7 (0.3)</td>
<td>0.6 (0.3)</td>
<td>0.6 (0.3)</td>
<td>NS</td>
</tr>
<tr>
<td>E/A ratio</td>
<td>1.3 (0.6)</td>
<td>1.9 (1.0)</td>
<td>2.6 (1)</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>E wave deceleration time (ms)</td>
<td>199 (63)</td>
<td>178 (62)</td>
<td>160 (45)†</td>
<td>0.01</td>
</tr>
<tr>
<td>Isovolumetric relaxation time (ms)</td>
<td>85 (24)</td>
<td>84 (16)</td>
<td>67 (17)‡</td>
<td>0.002</td>
</tr>
<tr>
<td>A wave duration (ms)</td>
<td>155 (19)</td>
<td>152 (23)</td>
<td>143 (21)†</td>
<td>0.03</td>
</tr>
<tr>
<td>PVF VTI_{L} (cm)</td>
<td>0.12 (0.08)</td>
<td>0.06 (0.06)</td>
<td>0.10 (0.15)</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>PVF s velocity (ms⁻¹)</td>
<td>0.45 (0.15)</td>
<td>0.22 (0.34)</td>
<td>0.30 (0.29)</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>PVF VTI_{L} (cm)</td>
<td>0.15 (0.07)</td>
<td>0.14 (0.05)‡</td>
<td>0.22 (0.19)†</td>
<td>0.01</td>
</tr>
<tr>
<td>PVF d velocity (ms⁻¹)</td>
<td>0.58 (0.19)</td>
<td>0.68 (0.25)</td>
<td>0.76 (0.26)‡</td>
<td>0.004</td>
</tr>
<tr>
<td>PVF VTI/VTI_{L}</td>
<td>0.81 (0.33)</td>
<td>0.53 (0.46)</td>
<td>0.44 (0.38)‡</td>
<td>&lt;0.001‡</td>
</tr>
<tr>
<td>PVF A wave duration (ms)</td>
<td>150 (19)</td>
<td>151 (20)</td>
<td>146 (19)</td>
<td>NS</td>
</tr>
</tbody>
</table>

Values are mean (SD). *P<0.01 among all groups. †P<0.05 vs mild or moderate mitral regurgitation. ‡P<0.05 among all groups. §P<0.05 vs severe mitral regurgitation. LV hypertrophy was defined as left ventricular mass index >109 gm⁻² for women and left ventricular mass index >134 gm⁻² for men. Abbreviations: d, diastolic; LV, left ventricular; MR, mitral regurgitation; NS, not significant; RF, regurgitant fraction; s, systolic; VTI, velocity time integral.

E/A ratio and E wave deceleration time, but not for E wave velocity alone or pulmonary venous flow VTI/VTI_s ratio (Table 3).

**Mitral E Wave Cut-off and Reversed Systolic Pulmonary Venous Flow**

According to the receiver-operating characteristic plot, a cut-off velocity of >1.0 ms⁻¹ for E wave was accurate distinguishing between mild/moderate and moderately severe or severe mitral regurgitation. For distinction between moderately severe and severe mitral regurgitation, reversed systolic pulmonary venous flow in the presence of E wave velocity >1.0 ms⁻¹ was demanded.

**Validation of the ‘Looking Twice’ Approach**

Assuming an E wave velocity >1.0 ms⁻¹ and reversed systolic pulmonary venous flow as one diagnostic test for the distinction of mild/moderate, moderately severe and severe mitral regurgitation, validation in 106 consecutive patients showed that the finding of E wave velocity >1.0 ms⁻¹ increased the likelihood of having moderately severe or severe mitral regurgitation eight-fold (95% CI 5.0–14.9). The additional observation of reversed systolic pulmonary venous flow increased the odds of dealing with severe mitral regurgitation 29-fold (95% CI 96) (Table 4). On the other hand, due to only moderate sensitivity of E wave velocity and reversed
systolic pulmonary venous flow, the absence of these findings did not entirely rule out severe mitral regurgitation (Table 4). Misclassification of mitral regurgitation severity occurred in 23 cases (22%, 95% CI 1–31%). Mitral regurgitation was underestimated by one degree in 13 cases. In three patients severe mitral regurgitation, according to the standard method, was classified as only mild/moderate according to mitral inflow and pulmonary venous flow. In all three patients, left ventricular systolic function was impaired (EF <45%) and mitral inflow patterns indicated restrictive left ventricular filling. Overestimation of mitral regurgitation severity occurred in seven cases, but never more than one degree.

Inter-observer Agreement of the ‘Looking Twice’ Approach

The inter-observer evaluation of the qualitative grade of mitral regurgitation severity using the combined Doppler method showed a concordance of 0.98.

Table 3. Regression analysis between Doppler data and regurgitant fraction.

<table>
<thead>
<tr>
<th></th>
<th>$r^2$</th>
<th>Slope</th>
<th>Intercept</th>
<th>EFdependent†</th>
</tr>
</thead>
<tbody>
<tr>
<td>E wave velocity</td>
<td>0.34</td>
<td>0.01</td>
<td>0.7</td>
<td>No</td>
</tr>
<tr>
<td>E/A ratio</td>
<td>0.17</td>
<td>0.02</td>
<td>1.1</td>
<td>Yes</td>
</tr>
<tr>
<td>E wave deceleration time</td>
<td>0.06</td>
<td>-0.68</td>
<td>206</td>
<td>Yes</td>
</tr>
<tr>
<td>Isovolumetric relaxation time</td>
<td>0.07</td>
<td>-0.27</td>
<td>89</td>
<td>No</td>
</tr>
<tr>
<td>A wave duration</td>
<td>0.07</td>
<td>-0.26</td>
<td>160</td>
<td>No</td>
</tr>
<tr>
<td>PVF peak s velocity</td>
<td>0.42</td>
<td>-0.01</td>
<td>0.6</td>
<td>No</td>
</tr>
<tr>
<td>PVF VTI /VTId</td>
<td>0.45</td>
<td>-0.02</td>
<td>1.1</td>
<td>No</td>
</tr>
</tbody>
</table>

*P<0.05 for all regression analysis. †A dependence of the Doppler variable from EF was postulated if its unexplained variation in a multiple regression model using a dummy variable for EF<45% as predictor variable was significantly reduced. Abbreviations: d, diastolic; EF, ejection fraction; PVF, pulmonary venous flow; s, systolic; VTI, velocity time integral.

Figure 2. Correlation between mitral E wave velocity and mitral regurgitant fraction determined by the quantitative Doppler method. Dark shaded areas represent false positive (upper left hand area) or false negative (lower right hand area).

Figure 3. Correlation between pulmonary venous VTI; VTI, and mitral regurgitation fraction determined by the quantitative Doppler method. Dark shaded areas represent either false positive (lower hand area) or false negative (upper hand area). Abbreviations: VTI/VTId; systolic to diastolic velocity time integral.

Discussion

Assessing the haemodynamic consequences of mitral regurgitation on both the flow velocity profile of mitral inflow and pulmonary venous flow by transthoracic echocardiography is an accurate and simple method to classify mitral regurgitation severity. It combines the advantage of a sensitive marker (i.e. early peak velocity of mitral inflow) to rule out more than moderate mitral regurgitation, with a highly specific marker (i.e. reversed systolic pulmonary venous flow) to detect severe mitral regurgitation.

Mitral Inflow in Mitral Regurgitation

Doppler measurement of mitral inflow has gained wide interest predominantly for non-invasive evaluation of diastolic left ventricular filling[18]. The confounding effects of left ventricular filling pressure, age, ventricular and atrial function have been extensively studied and must be accounted for in the interpretation of diastolic
The haemodynamic effects of mitral regurgitation on mitral inflow Doppler patterns in addition to diastolic ventricular function are less well studied. Recent evidence in patients with sinus rhythm has shown, that the burden of the regurgitant volume on the left atrium predominantly alters peak velocity of early passive left ventricular filling\(^\text{[10,29]}\). The rate and proportion of early left ventricular filling is augmented due to changes in the gradient between the left atrium and the left ventricular\(^\text{[21]}\).

In this study, similar findings were obtained: although significant changes were found between the three categories of mitral regurgitation for most of the mitral inflow parameters (Table 2), E wave velocity correlated best with regurgitant fraction in the linear regression model (Table 3). In a multivariate regression model, confounding effects of impaired left ventricular function (i.e. left ventricular EF 30–45%) on E wave velocity in the presence of mitral regurgitation could be excluded, but a significant correlation of systolic dysfunction was found for E/A-ratio and E wave deceleration time, also in the presence of mitral regurgitation (Table 3).

These findings are in agreement with a recent study\(^\text{[20]}\) in patients with severe mitral regurgitation and impaired left ventricular function which has documented a reduction of A wave velocity and E wave deceleration time when compared with patients with severe mitral regurgitation and normal systolic left ventricular function. Restrictive left ventricular filling patterns in patients without mitral regurgitation and with severe diastolic dysfunction are mainly due to a decrease in A wave velocity and shortening of E wave deceleration time. E wave velocity is only increased to a lesser extent\(^\text{[22,23]}\). Even in patients with a mean pulmonary capillary wedge pressure >35 mmHg, E wave velocity rarely exceeds 1 ms\(^{-1}\)\(^\text{[23]}\). The assumption, that a cut-off value of 1·0 ms\(^{-1}\) for E wave velocity can only be reached by a certain amount of regurgitant volume, seems therefore to be valid even in patients with high left ventricular filling pressures due to impaired left ventricular systolic function.

An effect of heart rate and age on E wave velocity could be excluded, as in the study by Thomas and co-workers\(^\text{[10]}\).

**Pulmonary Venous Flow in Mitral Regurgitation**

Pulmonary venous flow is a result of the pressure difference between the left atrium and the pulmonary veins. It is mainly affected by left atrial pressure and its compliance, which itself is influenced by left ventricular systolic and diastolic function\(^\text{[24]}\). In severe mitral regurgitation, systolic reflux of blood into the pulmonary veins can be recorded by Doppler echocardiography as negative component of the systolic VTI (reversed flow)\(^\text{[25]}\). For optimal assessment of mitral regurgitation severity with transoesophageal or transthoracic echocardiography, the question has been raised as to whether the flow pattern in one pulmonary vein is representative for all pulmonary veins. Furthermore, in all studies investigating the diagnostic accuracy of reversed systolic for the detection of severe mitral regurgitation, an eccentric jet on colour Doppler flow mapping was more prevalent in the severe than in the other categories of mitral regurgitation\(^\text{[11,12,25-26]}\). Some reports\(^\text{[12,25]}\), including a recent study using magnetic resonance imaging to document the pulmonary venous flow pattern\(^\text{[25]}\) have shown reversed systolic pulmonary venous flow in severe mitral regurgitation to be independent of a possible entrance of an eccentric jet on colour Doppler flow mapping into the vein being investigated. A study by Klein et al.\(^\text{[11]}\) has suggested a dependence of pulmonary venous flow pattern of mitral regurgitation jet direction. Discrepancies between left and right upper pulmonary venous flow recordings were found in correlation with an eccentric anteromedial jet directed into the right upper pulmonary vein, whereby reversed systolic pulmonary venous flow was documented only there\(^\text{[11]}\). Conversely, independence of the jet direction might be explained by the fact that flow reversal is driven by the pressure gradient between the left atrium and the pulmonary veins, which is not solely represented by the spatial distribution of the regurgitant jet on colour Doppler flow mapping\(^\text{[26]}\).

Systolic flow reversal in a pulmonary venous flow is a highly specific marker for severe mitral regurgitation. The reported specificities exceed 95% in all Doppler
Mitral and Pulmonary Venous Flow in Mitral Regurgitation

Diagnostic Accuracy of Combined E Wave Velocity and Reversed Systolic Pulmonary Venous Flow

Combining two diagnostic tests to augment post-test probability assumes their independence. In the case of E wave velocity during early mitral inflow and reversed systolic pulmonary venous flow, the temporal separation of the two events minimizes their concordance for grading mitral regurgitation severity. Its combination provides a fast and accurate estimation of mitral regurgitation severity in most patients with sinus rhythm. Pulmonary venous flow can be sampled in >90% of cases during routine transthoracic echocardiography.[29] Overall, the combined method of transmitral E wave velocity and pulmonary venous flow-analysis was accurate in four of five cases and misclassification of more than one mitral regurgitation degree occurred in only 3% of the study population. In all these patients, left ventricular function was impaired and Doppler echocardiography revealed severely impaired diastolic function. As a consequence, the pressure difference between left atrium and left ventricular was probably to small for allowing E wave velocity to become >1 ms$^{-1}$. The major advantage of our approach is that it is fast and technically easy, but accurate estimate of regurgitation. Time consuming, but more detailed Doppler methods should only be performed when evidence for more than moderate mitral regurgitation is present. Mitral inflow and pulmonary venous flow may also give useful information about mitral regurgitation severity in selected cases, where the regurgitant jet or its origin cannot be adequately visualized (e.g. in the setting of acoustic shadowing after aortic valve replacement).

Limitations

The effect of atrial fibrillation on test accuracy was not addressed in this study. Because of reduced left ventricular filling in late diastole due to failing atrial contraction, passive mitral inflow during early diastole is probably increased and limits the usefulness of E wave velocity >1 ms$^{-1}$ for detecting more than moderate mitral regurgitation. In theory, reversed systolic pulmonary venous flow as sign of severe mitral regurgitation should not be affected by atrial fibrillation.

Although an effect of impaired left ventricular function on E wave velocity and systolic pulmonary venous flow was excluded (Table 3), sensitivity of our test may be reduced in patients with severely impaired diastolic function (most of the time due to systolic dysfunction). In addition, we did not study patients with EF <30%.

Using transthoracic echocardiography, most often only one pulmonary vein is sampled. As long as the issue of dependence of the investigated vein from jet direction has not been clearly addressed, an effect of the prevalence of eccentric mitral regurgitation on test accuracy cannot be excluded.

In the absence of a true ‘gold standard’ for quantification of mitral regurgitation, the performance of a comparative diagnostic test can only be estimated or calculated using Bayesian methods[8][9][30]. We employed a quantitative Doppler method as standard for mitral regurgitation severity which has gained wide acceptance and was also the method of choice in other studies[9][12].

Conclusions

Combining E wave velocity of mitral inflow and reversed systolic pulmonary venous flow is an easy and accurate way to quantify mitral regurgitation severity. For clinical routine, ‘looking twice’ offers a fast and accurate first assessment of mitral regurgitation severity and provides an important clue in the puzzle of grading mitral regurgitation severity by Doppler.

References


