Influence of the mechanism of regurgitation on the quantification of mitral regurgitation by the proximal flow convergence method and the jet area method

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In 84 patients mitral regurgitation was quantified by angiography. The mechanism of regurgitation was determined by echocardiography (organic, n=54, functional, n=30). The radii of the proximal isovelocity surface areas in the flow convergence region for 28 and 41 cm s⁻¹ blood flow velocity and the area and length of the regurgitant jet were measured using colour flow Doppler imaging. The radii of the proximal isovelocity surface areas correlated more closely with the angiographic grade than the jet parameters irrespective of the mechanism of regurgitation. In more than 90% of the patients, grades I—II mitral regurgitation were correctly differentiated from grades III—IV by means of the radii of the proximal isovelocity surface areas. Using the jet parameters, the differentiation was correct in 50-90% of the patients depending on the mechanism of regurgitation. The jet area method particularly failed to identify grades III—IV organic mitral regurgitation due to a high prevalence of eccentric jets in these patients.

It is concluded that the proximal flow convergence method was suitable for the quantification of mitral regurgitation irrespective of the mechanism of mitral regurgitation. On the other hand, the value of the jet area method depended largely on the regurgitation mechanism.

(Key Words: Mitral regurgitation, colour flow Doppler imaging, proximal flow convergence region, proximal isovelocity surface area, regurgitant jet area.)

Introduction

Determination of the severity of mitral regurgitation is a prerequisite for adequate treatment of patients with this valvular dysfunction. Since it remains problematic to classify the severity of mitral regurgitation by means of clinical criteria, colour Doppler echocardiography is routinely used for its non-invasive quantification. It is controversial, however, which is the best method for the quantification of mitral regurgitation since some investigations showed several limitations of the widely used spatial distribution of the regurgitant jet within the left atrium (jet area method). The existence of a region of flow convergence proximal to a restrictive orifice was demonstrated by means of colour flow Doppler imaging in recent studies. The extension of this flow convergence region was proved to be a reliable parameter for the quantification of mitral regurgitation (proximal flow convergence method). Moreover, the extent of the flow convergence region more closely correlated with the severity of mitral regurgitation than the jet area in the left atrium.

Enriquez-Sarano et al. pointed out, however, that the accuracy of the jet area method for the assessment of the severity of mitral regurgitation depends on the mechanism of regurgitation as well as on the eccentricity of the regurgitant jet and it is of clinical significance in deciding in which subset of patients colour flow Doppler imaging may be used quantitatively or not. Therefore, in this study the value of the proximal flow convergence method and of the jet area method for the quantification of mitral regurgitation was compared with regard to the mechanism of regurgitation and the eccentricity of the regurgitant jet using angiographic grading as the reference method.

Methods

Patients

The study group consisted of 84 consecutive patients (46 men, 38 women) with mitral regurgitation found by...
colour and CW-Doppler echocardiography and verified by angiography. The mean age was 63 ± 10 years (range 25–78 years). Fifty-two patients were in sinus rhythm, 32 patients in atrial fibrillation.

Out of these 84 patients, 54 suffered from organic mitral valve disease: valve sclerosis with or without annular calcification in 24, a prolapse of the anterior valve leaflet in seven, a prolapse of the posterior valve leaflet in 14, a flail leaflet in six and no clearly definable lesion in three patients. All three patients had normal left ventricular function, no left ventricular hypertrophy and coronary heart disease was excluded during cardiac catheterization. A minor lesion of the mitral valve was assumed, but not detected by echocardiography. Fourteen of the 54 patients had associated mitral stenosis. Eight patients had concomitant coronary artery disease or aortic valve failure, while function and size of the left ventricle were normal.

In 30 patients (coronary artery disease in 19, aortic valve disease in eight and dilated cardiomyopathy in three) the cause of mitral regurgitation was functional with a structurally normal mitral valve while left ventricular function was depressed. All patients gave informed consent.

**Colour Doppler examination**

All patients were examined in a lateral recumbent position from the apical view by the same experienced investigator with a commercially available system (Toshiba SSH 160A, Toshiba Corp., Tokyo, Japan) operating with a 2-5 MHz transducer. Colour flow Doppler imaging was performed in the velocity-mode, using a 30° sector angle, at a pulse repetition frequency of 3 kHz. Wall filter was adjusted at 600 Hz. A scanning rate of 13 frames s⁻¹ was obtained. Optimal gain setting was defined as the maximal gain level possible without introduction of signals outside of flow areas. All quantitative measurements as described below were performed during the examination as an average from at least five beats using the cineloop-mode. Images were additionally recorded on videotape. An electrocardiogram was recorded simultaneously. The echocardiographic examination was performed before cardiac catheterization with a time interval of up to 24 h in 92% and up to 48 h in 8% of our patients.

**Colour Doppler measurements**

*Proximal flow convergence method*

The isovelocity hemispheres, i.e. proximal isovelocity surface areas in the flow convergence region on the left ventricular side of the mitral valve were imaged for blood flow velocities of 28 and 41 cm s⁻¹ by the corresponding first aliasing borders. This was obtained by zero-shifting which alters the colour reversal from blue to red/yellow for flow away from the transducer. The proximal isovelocity surface area-radius was defined as the maximum distance between the aliasing border and the regurgitant orifice measured parallel to the direction of the Doppler beam (mm). If it was not possible to locate exactly the regurgitant orifice, the level of the mitral valve leaflets during systole was defined as the reference. Frame-by-frame analysis was used to obtain the largest proximal isovelocity surface area-radius in every systole.

*Jet area method*

The regurgitant jet area within the left atrium was imaged in the apical four- and two-chamber view (Fig. 1). The view with the larger jet area was selected for further analysis. The jet area was defined as the varianced and aliased signals surrounded by contiguous non-disturbed velocities coded in blue. As for the proximal isovelocity surface area-radius, the largest jet area in every systole was obtained reviewing frame by frame. The area of the left atrium was traced from a representative frame from the same view during the same portion of systole. The areas of the jet and of the left atrium were measured for planimetry. According to Enriquez-Sarano et al. jets were classified as eccentric if they were in close contact with one of the mitral valve leaflets behind the regurgitant orifice and remained in close contact with one of the left atrial walls. The central jets showed an initial direction into the cavity of the left atrium irrespective of whether the jet had contact with wall structures further down in the atrium or not. The jet length was defined as the maximum distance of the regurgitant signals from the mitral orifice. Jet area was expressed as an absolute value (cm²) as well as a percent of the left atrial area, and the jet length as an absolute value (cm).

In 35 randomly selected study patients echocardiographic data were re-examined by the same investigator from video tapes more than 6 months after the first echocardiographic examination. Additionally, a second investigator evaluated the proximal isovelocity surface area-radius independently from the jet parameters in these patients on two separate occasions.

**Cardiac catheterization**

Biplane left ventricular angiograms were performed in a 30° right anterior oblique and a 60° left anterior oblique view with injection of 35 ml SolutratB at 18 ml s⁻¹. The severity of mitral regurgitation was graded according to the criteria of Sellers et al. The angiograms were interpreted by two observers without knowledge of the results of the echocardiographic examination. Eighty-four patients who were equally classified by both observers as far as the angiographic grade of mitral regurgitation was concerned, were included in the study. (In the case of a further 20 patients, who were not included in the study, the grading of the two observers differed for one grade.)

Eur Heart J, Vol. 17, August 1996
Statistical analysis

Values are given as mean ± SD. Paired data were compared using the Wilcoxon signed rank test. Differences between unpaired data were assessed using the Wilcoxon–Mann–Whitney and the Kruskal–Wallis tests. The correlation between the angiographic grading and the colour Doppler measurements was calculated by the Spearman’s rank correlation method. Intra-observer and inter-observer variability were obtained by calculating coefficients of variation. A $P$ value of <0.05 was considered significant.

Results

Haemodynamic data

Heart rate during echocardiography was $72 ± 14 \text{ min}^{-1}$ and $71 ± 12 \text{ min}^{-1}$ during cardiac catheterization ($P$, ns). While systolic blood pressure did not differ significantly ($134 ± 20 \text{ mmHg}$ during echocardiography vs $135 ± 24 \text{ mmHg}$ during cardiac catheterization), diastolic blood pressure was higher during echocardiography ($74 ± 11$ vs $70 ± 11 \text{ mmHg}$, $P<0.01$). During catheterization there were no significant differences between patients with organic and patients with functional mitral regurgitation with regard to left ventricular systolic pressure ($139 ± 28$ vs $150 ± 32 \text{ mmHg}$) and pulmonary capillary wedge pressure ($19 ± 6$ vs $18 ± 8 \text{ mmHg}$).

Colour Doppler measurements

The proximal flow convergence region could not be imaged because of an overlap with the blood flow towards the left ventricular outflow tract in two of the 84 patients. One had a grade III mitral regurgitation and the other an additional aortic regurgitation. In a third patient the jet could not be visualized behind the highly structurally abnormal mitral valve leaflets.

The number of patients with organic and with functional mitral regurgitation with regard to the different angiographic grades are listed in Table 1. Almost all (93%) patients with a functional mechanism had grade I or II mitral regurgitation whereas in patients with organic mitral regurgitation there was an almost symmetrical distribution between the four angiographic grades. Furthermore, the numbers of eccentric and central jets are given for the different angiographic grades in organic and functional mitral regurgitation in Table 1 (it should be noted that most of the patients with severe mitral regurgitation, i.e. angiographic grade III or IV, showed an eccentric jet in the left atrium). Of the 27 patients with prolapse of a a leaflet or flail leaflet two
Table 1 Number of patients with organic and with functional mitral regurgitation

<table>
<thead>
<tr>
<th>Angiographic grade</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic</td>
<td>19 (9/10)</td>
<td>11 (6/5)</td>
<td>10 (0/10)</td>
<td>14 (2/12)</td>
</tr>
<tr>
<td>Functional</td>
<td>18 (16/2)</td>
<td>10 (8/2)</td>
<td>1 (1/0)</td>
<td>1 (0/1)</td>
</tr>
</tbody>
</table>

Organic: patients with organic mechanism of mitral regurgitation; Functional: patients with functional mechanism of mitral regurgitation. Numbers in brackets indicate the number of patients with a central jet (first number) and of patients with an eccentric jet (second number).

Table 2 Values of the different colour Doppler measurements for the angiographic grades I—IV of mitral regurgitation

<table>
<thead>
<tr>
<th>Angiographic grade</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>r_{28}</td>
<td>3.8 ± 2.0</td>
<td>6.7 ± 2.8</td>
<td>13.0 ± 4.8</td>
<td>21.6 ± 8.0</td>
<td>0.001</td>
</tr>
<tr>
<td>r_{41}</td>
<td>2.1 ± 1.9</td>
<td>4.8 ± 2.3</td>
<td>9.6 ± 3.4</td>
<td>15.6 ± 5.8</td>
<td>0.001</td>
</tr>
<tr>
<td>JA</td>
<td>3.9 ± 2.5</td>
<td>5.9 ± 2.3</td>
<td>4.6 ± 2.3</td>
<td>8.9 ± 5.5</td>
<td>0.001</td>
</tr>
<tr>
<td>JL</td>
<td>3.2 ± 1.1</td>
<td>4.2 ± 0.9</td>
<td>3.9 ± 1.5</td>
<td>5.0 ± 1.8</td>
<td>0.001</td>
</tr>
<tr>
<td>JA%</td>
<td>13 ± 8</td>
<td>18 ± 7</td>
<td>14 ± 7</td>
<td>25 ± 15</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Values are mean ± SD. r_{28}, proximal isovelocity surface area—radius for the flow velocity of 28 cm . s^{-1} (mm); r_{41}, proximal isovelocity surface area—radius for the flow velocity of 41 cm . s^{-1} (mm); JA, jet area (cm^2); JL, jet length (cm); JA%, relation of jet area to left atrial area (%). Values refer to the whole study group.

had grade I, three grade II, eight grade III and 14 grade IV mitral regurgitation.

The values of the proximal isovelocity surface area—radius for the flow velocities of 28 and 41 cm . s^{-1} and the values of the jet area, jet length, and relation of jet area to left atrial area are listed in Table 2 with regard to the different angiographic grades of mitral regurgitation for the whole study group.

The mean values of the proximal isovelocity surface area—radius for both velocities investigated and of the parameters derived from the regurgitant jet as well as the mean value of the angiographic grade are compared between the patients with organic and with functional mitral regurgitation in Table 3(a). The comparison of the Doppler parameters with regard to the eccentricity of regurgitant jet is provided in Table 3(b).

The rank correlation coefficients between the angiographic grade of mitral regurgitation and the measurements derived from colour Doppler flow imaging are listed for the whole study group and for the subgroups with organic and functional mitral regurgitation (Table 4, Figs 2 and 4). The rank correlation coefficients are further differentiated according to the jet morphology (eccentric or central) (Table 4, Figs 3, 5 and 6).

A correct differentiation of mild to moderate (grades I—II) from severe (grades III—IV) mitral regurgitation by the colour Doppler parameters depended on the mechanism of regurgitation and the jet morphology. The data are listed in Table 5.

Intra-observer variability

Coefficients of variation for the proximal isovelocity surface area—radius for a flow velocity of 28 cm . s^{-1} were 5.1%; for a flow velocity of 41 cm . s^{-1}, 5.9%; for the jet area, 8.2%; and for the jet length, 4.7%.

Inter-observer variability

Coefficients of variation for the proximal isovelocity surface area—radii were 9.1% (flow velocity 28 cm . s^{-1}) and 10.9% (flow velocity 41 cm . s^{-1}); for the jet area, 8.6%; and for the jet length, 6.4%.

Catheterization results

The severity of mitral regurgitation was determined by cardiac catheterization and classified as grade I in 37, grade II in 21, grade III in 11, and grade IV in 15 patients.

Discussion

The data of this study indicate that the proximal flow convergence method is more suitable for the determination of the severity of mitral regurgitation than the jet area method. This could be demonstrated for the whole study group and corresponded with data concerning native as well as prosthetic valves. As Enriquez-Sarano et al. pointed out, however, it is a matter of clinical significance which method for the quantification of mitral regurgitation provided reliable data in which subset of patients.

The proximal flow convergence method could reliably differentiate between mild to moderate and severe mitral regurgitation in all patients with organic mitral regurgitation. Proximal isovelocity surface area—radius and angiographic grade were closely correlated. The correlation coefficient was less in the subgroup of patients with organic mitral regurgitation and a centrally directed regurgitant jet probably due to the unequal distribution of the patients within the different angiographic grades. The proximal flow convergence method was little influenced by the structural alterations of the mitral valve, although the assumption of a hemispheric symmetry of the flow convergence region may not be valid and the location of the regurgitant orifice often remains elusive in the presence of irregular surroundings of the regurgitant orifice. The latter problem, however, is mainly present in patients with flail leaflet or prolapse of the mitral valve and severe mitral regurgitation resulting only in small errors when the large proximal isovelocity surface area—radii are measured. In two of our patients with grade III
Table 3 Values of the different colour Doppler measurements with regard to (a) the mechanism of mitral regurgitation and (b) the eccentricity of regurgitant jet

<table>
<thead>
<tr>
<th></th>
<th>( r_{28} )</th>
<th>( r_{41} )</th>
<th>JA</th>
<th>JL</th>
<th>JA%</th>
<th>AG</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic</td>
<td>11.0 ± 9.0*</td>
<td>7.9 ± 6.9*</td>
<td>5.5 ± 4.0</td>
<td>4.0 ± 1.6</td>
<td>16 ± 12</td>
<td>2.3 ± 1.2</td>
</tr>
<tr>
<td>Functional</td>
<td>5.4 ± 3.2*</td>
<td>3.6 ± 2.5*</td>
<td>5.2 ± 2.7</td>
<td>4.0 ± 1.1</td>
<td>18 ± 8</td>
<td>1.5 ± 0.7</td>
</tr>
<tr>
<td>(b)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eccentric</td>
<td>12.0 ± 9.4*</td>
<td>8.6 ± 7.0*</td>
<td>5.2 ± 3.3</td>
<td>4.0 ± 1.7</td>
<td>15 ± 9</td>
<td>2.6 ± 1.2</td>
</tr>
<tr>
<td>Central</td>
<td>5.8 ± 4.3*</td>
<td>4.0 ± 3.5*</td>
<td>5.6 ± 3.9</td>
<td>3.7 ± 1.1</td>
<td>18 ± 11</td>
<td>1.5 ± 0.8</td>
</tr>
</tbody>
</table>

Values are mean ± SD. Organic, patients with organic mechanism of mitral regurgitation; Functional, patients with functional mechanism of mitral regurgitation; Eccentric, patients with an eccentric regurgitant jet (independent of the mechanism of mitral regurgitation); Central, patients with a central regurgitant jet. \( r_{28} \), proximal isovelocity surface area-radius for the flow velocity of 28 cm \( \text{s}^{-1} \) (mm); \( r_{41} \), proximal isovelocity surface area-radius for the flow velocity of 41 cm \( \text{s}^{-1} \) (mm); JA, jet area (cm\(^2\)); JL, jet length (cm); JA%, relation of jet area to left atrial area (%); AG, angiographic grade. *Significant difference \((P<0.05)\).

Table 4 Rank correlation coefficients between the different colour Doppler measurements and angiographic grade with regard to the mechanism of mitral regurgitation and eccentricity of regurgitant jet

<table>
<thead>
<tr>
<th></th>
<th>( r_{28} )</th>
<th>( r_{41} )</th>
<th>JA</th>
<th>JL</th>
<th>JA%</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>c+e</td>
<td>0.80( \uparrow )</td>
<td>0.81( \uparrow )</td>
<td>0.42( \uparrow )</td>
<td>0.44( \uparrow )</td>
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<tr>
<td></td>
<td>c</td>
<td>0.68( \uparrow )</td>
<td>0.68( \uparrow )</td>
<td>0.49( \uparrow )</td>
<td>0.51( \uparrow )</td>
</tr>
<tr>
<td></td>
<td>e</td>
<td>0.81( \uparrow )</td>
<td>0.82( \uparrow )</td>
<td>0.49( \uparrow )</td>
<td>0.41( \uparrow )</td>
</tr>
<tr>
<td>Organic</td>
<td>c+e</td>
<td>0.83( \uparrow )</td>
<td>0.85( \uparrow )</td>
<td>0.53( \uparrow )</td>
<td>0.47( \uparrow )</td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>0.68( \uparrow )</td>
<td>0.69( \uparrow )</td>
<td>0.78( \uparrow )</td>
<td>0.65( \uparrow )</td>
</tr>
<tr>
<td></td>
<td>e</td>
<td>0.82( \uparrow )</td>
<td>0.83( \uparrow )</td>
<td>0.57( \uparrow )</td>
<td>0.49( \uparrow )</td>
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<tr>
<td>Functional</td>
<td>c+e</td>
<td>0.67( \uparrow )</td>
<td>0.67( \uparrow )</td>
<td>0.36( \uparrow )</td>
<td>0.38( \uparrow )</td>
</tr>
</tbody>
</table>

All, whole study group; Organic, patients with organic mechanism of mitral regurgitation; Functional, patients with functional mechanism of mitral regurgitation. \( r_{28} \), proximal isovelocity surface area-radius for the flow velocity of 28 cm \( \text{s}^{-1} \); \( r_{41} \), proximal isovelocity surface area-radius for the flow velocity of 41 cm \( \text{s}^{-1} \); JA, jet area, JL, jet length; JA%, relation of jet area to left atrial area. \( \uparrow \) \( P<0.05 \); \( \uparrow \uparrow \) \( P<0.01 \); \( \uparrow \uparrow \uparrow \) \( P<0.001 \).

In patients with organic mitral regurgitation an eccentric regurgitant jet was present in about 70%. The percentage was even higher in severe mitral regurgitation, which was usually associated with a prolapse or a flail leaflet of the mitral valve according to previously published data [12,13]. This means that the interaction of the regurgitant jet with the left atrial walls grossly influenced and limited the jet area in almost all patients with severe mitral regurgitation [12,13]. A jet area >7.6 cm\(^2\) indicated a mitral regurgitation of more than grade II in most cases, whereas a small jet area was often
found in mitral regurgitation of grade III or more. This did not allow a differentiation of mild to moderate from severe mitral regurgitation, which is of clinical importance. This fact, in particular, represents a major limitation of the jet area method, which was also observed in studies previously published.

In patients with organic mitral regurgitation and a centrally directed regurgitant jet, the jet area was related to the angiographic grade to a similar extent as the proximal isovelocity surface area-radius. In these patients the differentiation of mild to moderate from severe mitral regurgitation was possible by means of the jet area method. A good correlation between the severity of mitral regurgitation and the jet area was also observed in studies previously published. In functional mitral regurgitation the proximal isovelocity surface area-radius correlated more closely with the angiographic grade than the jet area according to the data in organic mitral regurgitation. The correlation, however, was poor for all colour Doppler parameters investigated. This seems to be in contradiction to previously published data as far as the jet area is concerned. The reason for our results was probably that the patients with functional mitral regurgitation were unequally distributed within the different angiographic grades and in almost all cases a mild to moderate regurgitation was present. This can also be inferred from the regurgitant fractions given by Enriquez-Sarano et al. for their patients with functional mitral regurgitation in comparison to regurgitant
fractions in severe mitral regurgitation reported by other authors\textsuperscript{11,12,22-23}. Obviously, this did not affect the results of Enriquez-Sarano \textit{et al}. as they used a quantitative Doppler method as the reference method for the quantification of mitral regurgitation\textsuperscript{1121}. Although the correlation between the angiographic grade and the proximal isovelocity surface area-radius was closer than between the angiographic grade and the jet area, mitral regurgitation was correctly classified as mild to moderate in most cases by the proximal flow convergence method as well as the jet area method. Hence, substantial advantage of the proximal flow convergence method could not be inferred from our data in functional mitral regurgitation.

If our patients were classified according to the direction of the regurgitant jet irrespective of the mechanisms of mitral regurgitation, the proximal flow convergence method allowed a reliable differentiation between grades I–II and grades III–IV mitral regurgitation in the patients with central and eccentric jets. Using the jet area method this differentiation was reliably achieved in the patients with a central jet, but was not possible in nearly 50% of the patients with an eccentric jet. The eccentricity of the regurgitant jet probably provides useful information in the clinical setting, which colour Doppler method may be used for quantification of mitral regurgitation in a given patient\textsuperscript{11}.

The value of the different colour Doppler methods for the quantification of mitral regurgitation with regard to the eccentricity of the regurgitant jet was roughly reflected by the correlation coefficients between the colour Doppler measurements and the angiographic grading. The correlation between the proximal flow convergence method as well as the jet area method and angiography was substantially affected by the distribution of the patients within the different angiographic grades. Because only three patients with a central jet had a grades III–IV mitral regurgitation, the correlation between the colour Doppler measurements and angiographic grading was mainly determined by the patients with grades I–II mitral regurgitation, who showed a broad overlap of the values for the proximal isovelocity surface area-radius and the jet parameters between grade I and grade II. Thus, correlation between all colour Doppler measurements and angiographic grading was weak. In the patients with eccentric jets there was a large subgroup with grades III–IV mitral regurgitation. These patients showed large proximal

\textbf{Figure 5} Comparison of the jet area in the left atrium with the angiographic grade of mitral regurgitation for the patients with central jets (a) and for the patients with eccentric jets (b). Solid line, cut-off value at 7.6 cm$^2$ for the differentiation of grades I–II from grades III–IV mitral regurgitation. $r_{Sp}$, Spearman’s rank correlation coefficient.

\textbf{Figure 6} Comparison of the jet area in the left atrium with the angiographic grade in patients with organic mitral regurgitation. The values are shown for patients with central jets (a) and with eccentric jets (b). Solid line, cut-off value at 7-6 cm$^2$ for the differentiation of grades I–II from grades III–IV mitral regurgitation. $r_{Sp}$, Spearman’s rank correlation coefficient.
observer variability revealed low values for the coefficients of variation for all colour Doppler parameters.

Our patients were investigated by angiography and Doppler echocardiography with a time interval of up to 24 h (in a few patients of up to 48 h). Altered loading conditions of the left ventricle might have occurred changing the severity of mitral regurgitation. The haemodynamic conditions with regard to blood pressure and heart rate, however, remained constant during both diagnostic procedures except for a slight decrease in diastolic blood pressure during catheterization in comparison to the echocardiographic examination.

The differentiation between organic and functional mitral regurgitation remains arbitrary in some patients. But only eight of our patients had a morphologically altered mitral valve as well as coronary heart disease or aortic valve failure. In all of these patients organic mitral regurgitation was assumed.

It has to be emphasized that there exist further relevant methodological problems of the proximal flow convergence method as well as of the jet area method, which are obviously independent of the morphology of the mitral valve or the mechanism of mitral regurgitation. These problems were not investigated in this study and were discussed in detail elsewhere.

### Limitations

The angiographic quantification of mitral regurgitation has methodological limitations. The subjective interpretation of the angiograms is one of the important problems. To overcome this problem only those patients who were equally classified by both observers with regard to angiographic grade were included in this study. Furthermore, the limited accuracy of the reference method as a semi-quantitative approach might have influenced our results. However, angiography is still an accepted and widely used method for the quantification of mitral regurgitation. The proximal isovelocity surface area-radial and the parameters derived from the regurgitant jet were determined by the same investigator. Therefore, it is possible that the results of both colour Doppler methods have influenced each other. But this study did not intend to compare the proximal flow convergence method and the jet area method directly. The value of both methods for the quantification of mitral regurgitation was evaluated with regard to angiographic grading; information unknown at the time of echocardiography. Furthermore, a second observer re-evaluated the proximal isovelocity surface area-radial independently from the jet parameters.

### References


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**Table 5 Correct differentiation between grades I-II and grades III-IV mitral regurgitation by the different colour Doppler measurements with regard to the mechanism of mitral regurgitation and eccentricity of regurgitant jet**

<table>
<thead>
<tr>
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<th>r41</th>
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<th>JL</th>
<th>JA%</th>
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<td>91</td>
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<td></td>
<td>c</td>
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</tbody>
</table>

Percentage of patients (%) with correct differentiation between grades I-II and grades III-IV mitral regurgitation. All, whole study group; Organic, patients with organic mechanism of mitral regurgitation; Functional, patients with functional mechanism of mitral regurgitation. r28, proximal isovelocity surface area-radius for the flow velocity of 28 cm . s⁻¹; r41, proximal isovelocity surface area-radius for the flow velocity of 41 cm . s⁻¹; JA, jet area; JL, jet length; JA% relation of jet area to left atrial area.


