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Pulmonic Regurgitation: Semiquantification

Kelly Axsom, MD, Muhamed Saric, MD, PhD

INTRODUCTION

Trivial or mild degrees of pulmonic regurgitation (PR) are common in the structurally normal heart, and the presence of pathologic PR is rare in adults. Some degree of PR is present in between 5% and 78% of echocardiograms of structurally normal hearts. Echocardiographic evaluation of the degree of PR is much less well defined than for the other heart valves and is either descriptive or semiquantitative. This is primarily due to the low prevalence of clinically severe PR. In one series, only 1.6% of all severe valvular regurgitation was due to PR.

PULMONIC REGURGITATION EVALUATION OVERVIEW

As with other valve lesions, assessment of PR includes three basic elements: (1) establishing the mechanism of PR; (2) determining the severity of PR; and (3) assessing the impact of PR on cardiac chambers, primarily the right ventricle (RV) and the pulmonary artery (PA). Severity of PR is best assessed by Doppler echocardiography, whereas the mechanism of PR and its impact on cardiac chambers is evaluated by two-dimensional (2D) and three-dimensional (3D) echocardiography.

The American College of Cardiology and the American Heart Association guidelines on valvular heart disease address the issue of PR only briefly. The American Society of Echocardiography recommendations for evaluation of severity of PR include evaluation of anatomical structure of the pulmonary valve, right ventricular size, color Doppler pulmonic regurgitant jet size, and spectral Doppler jet density, duration, and deceleration rate, as well as a comparison between pulmonic and systemic flow. Other parameters of PR severity include timing of tricuspid valve closure and pulmonary valve opening, holodiastolic flow reversal in the pulmonary artery, low peak velocity of the PR jet. A dedicated investigation carefully looking for these findings should be included in the evaluation of PR, especially if other echocardiographic evidence of severity is inconclusive.

REFERENCES

On TEE, the pulmonic valve and PA can be imaged at mid-esophageal and transgastric views using approximately a 60-degree acquisition angle. The short axis of the pulmonic valve can be obtained by 3D TTE and TEE imaging.

**TABLE 125-1 Markers of Severe Pulmonic Regurgitation**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Moderate to Severe PR</th>
<th>Severe PR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COLOR DOPPLER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jet length and area</td>
<td>Increased</td>
<td>May be short</td>
</tr>
<tr>
<td>Jet turbulence</td>
<td>Turbulent jet</td>
<td>Laminar jet</td>
</tr>
<tr>
<td>Vena contracta</td>
<td>Wide</td>
<td>Very wide</td>
</tr>
<tr>
<td>Jet density</td>
<td>Dense</td>
<td>Very dense</td>
</tr>
<tr>
<td>Deceleration slope</td>
<td>Short</td>
<td>Very short</td>
</tr>
<tr>
<td>Premature cessation of retrograde flow</td>
<td>May be absent</td>
<td>Typically present</td>
</tr>
<tr>
<td>To-and-fro flow</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td>Peak PR velocity</td>
<td>Normal</td>
<td>Low</td>
</tr>
<tr>
<td>Premature opening of pulmonic valve</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td>Premature closure of tricuspid valve</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td><strong>CW DOPPLER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regurgitant volume</td>
<td>&lt;60 mL/beat</td>
<td>&gt;60 mL/beat</td>
</tr>
<tr>
<td>Regurgitant fraction</td>
<td>&lt;50%</td>
<td>≥50%</td>
</tr>
<tr>
<td>Holodiastolic flow reversal in PA</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td><strong>PW DOPPLER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional signs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RV and PA size</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Mild to moderate PR*: On color Doppler, jet is small (arrow) and vena contracta at jet origin is narrow. On spectral Doppler, the slope of PR jet is relatively flat (arrow). (See accompanying Video 125-1.)  

*Mild to moderate PR*: On color Doppler, jet is small (arrow) and vena contracta at jet origin is narrow. On spectral Doppler, the slope of PR jet is relatively flat (arrow). (See accompanying Video 125-1.)  

*Severe PR*: On color Doppler, jet is large and turbulent (arrow), whereas on spectral Doppler the PR slope is steep (arrow). (See accompanying Video 125-2.)  

*Very severe PR*: On color Doppler, jet is laminar (arrow) and of short duration. On spectral Doppler there is low peak velocity of PR jet (yellow arrow) and there is premature opening of pulmonic valve with abnormal antegrade flow in late diastole. (See accompanying Video 125-3.)  

AV, Aortic valve; PA, pulmonary artery; RA, right atrium; RVOT, right ventricular outflow tract.

Color and spectral Doppler echocardiography are the primary means of quantifying the degree of PR. As with other valvular regurgitations, the severity of PR depends on the interplay among the regurgitant orifice size, the regurgitant volume, and the trans-valvular pressure gradient (the diastolic pressure gradient between the PA and the RV in the case of PR).

To a certain point, as the regurgitant volume and the severity of PR increase, so do the size and turbulence of the regurgitant jet. However, when the regurgitant orifice becomes very large, a rapid equalization of pressures may lead to a smaller and more laminar regurgitant jet that terminates prematurely (before the end of diastole). It is important to bear in mind that PR is not the only...
Historically, angiography has been the primary means of validating early diastolic jet (arrows). This is in contrast to less severe forms of PR, where the PR jet lasts throughout diastole. Color Doppler on transthoracic short-axis view at the level of the aortic valve demonstrates abnormal antegrade flow across the pulmonic valve at the time of atrial contraction indicative of premature pulmonic valve opening resulting from elevated right ventricular pressures in severe PR. Pulmonary artery on TEE spectral Doppler tracing demonstrates abnormal holodiastolic flow reversal (arrows) in the pulmonary artery indicative of severe PR.

Figure 125-2. Additional markers of severe pulmonic regurgitation. A, Color M mode demonstrates that pulmonic regurgitation (PR) jet terminates abnormally in early diastole (arrows). This is in contrast to less severe forms of PR, where the PR jet lasts throughout diastole. B, Color Doppler on parasternal short-axis view demonstrates the rapid deceleration of the PR jet. C, Transesophageal echocardiography (TEE) spectral Doppler trace demonstrates abnormal holodiastolic flow reversal (arrows) in the pulmonary artery indicative of severe PR.

Determinant of the rate of pressure equalization; rapid equalization of pressures may also be mediated by a low diastolic PA pressure and/or high RV diastolic pressure. Collectively, all these phenomena form the basis of the semiquantitative assessment by both color and spectral Doppler imaging.

Color Doppler

Color Doppler is the most widely accepted method for assessing PR. Typical PR jet is seen in the right ventricular outflow tract during diastole. PR jets in the normal heart are usually narrow or “spindle-like” and originate centrally from the pulmonary leaflet coaptation site.

Jet Length

Original studies suggested that a jet length less than 10 mm implies trivial regurgitation. Theoretically, a more severe PR should be associated with longer jets. However, jet length is not considered a reliable index of PR severity because abrupt cessation of diastolic flow in severe PR may lead to relatively short PR jets. Furthermore, the more severe the PR, the less likely it is that a full jet length can be appreciated on the parasternal TTE window.

Jet Area

Planimetry of the jet area indexed for body surface area has been shown to correlate well with angiographic grades of PR severity in patients with tetralogy of Fallot repair. However, there are no well-validated criteria on what jet area defines severe PR. Again it is important to emphasize that with very severe PR, when equalization of PA to RV gradient take place early in diastole, the color Doppler jet area can be small and brief; this seemingly paradoxical diminution of jet area size should not be misinterpreted as less than severe PR.

Turbulent Versus Laminar Regurgitant Jet

Lesser degrees of PR are typically characterized by turbulent jets. When PR is very severe and when there is rapid equalization of pressure across the pulmonic valve in diastole, the PR jet becomes more laminar. This seemingly paradoxical finding is an important semiquantitative marker of PR severity.

Vena Contracta

The use of vena contracta width for determining severity of regurgitation is generally reserved for the other valves and has not been validated for PR. Semiquantitatively, a wide vena contracta in the setting of brief and small color Doppler jet area supports the diagnosis of severe PR.

Continuous-Wave Spectral Doppler

Continuous-wave (CW) spectral Doppler of the PR jet should be attempted on all echocardiographic exams. Semiquantitative measures of PR severity include signal density, deceleration slope, and the timing of jet cessation.

Jet Density

Theoretically, a more severe PR should be associated with more dense spectral tracings. However, there is no accepted method for fully quantifying PR using spectral density.

Deceleration Slope

Rapid deceleration slope of the diastolic Doppler signal is only a rough estimate of PR severity because there are no well-validated deceleration cutoff values for various degrees of PR. Although severe PR leads to a rapid deceleration slope of the PR jet, not all instances of rapid deceleration slope are indicative of severe PR. This is because the deceleration slope depends on both the size of the regurgitant orifice and the diastolic PA-to-RV pressure gradient. Thus in patients with low PA diastolic pressures and/or elevated RV diastolic pressures, a rapid slope may be seen in the absence of severe PR.

Premature Cessation of Retrograde Flow

Severe PR is characterized by premature cessation of retrograde spectral Doppler flow; instead of end diastole, the flow ends in mid to late diastole. However, not all instances of premature PR jet cessation are indicative of severe PR, as the phenomenon may also be seen in patients with low PA diastolic pressures and/or elevated RV diastolic pressures in the absence of severe PR.

To-and-Fro Flow

In patients with very severe PR, there may be little net antegrade flow across the PV; the bulk of flow simply recirculates across the PV (retrograde in diastole, then antegrade in systole). This gives
rise to a characteristic sinusoid “to-and-fro” velocity pattern on CW Doppler in patients with severe PR.

**Low Peak Pulmonic Regurgitation Velocity**

Another marker of severe PR is a low peak PR velocity. It is typically seen with the to-and-fro flow pattern just described.

**Premature Tricuspid and Pulmonic Valve Events**

Premature closure of the tricuspid valve and premature opening of the pulmonic valve are markers of severe PR seen on Doppler echocardiography and reflect elevated right ventricular pressures.

**Pulsed-Wave (PW) Spectral Doppler**

When the PR jet is not aliased, spectral PW Doppler recordings can be used to assess the severity of PR in the same manner as described for CW.

**Regurgitant Fraction by Pulmonic Valve Pulsed-Wave**

Spectral PW Doppler recordings can be used to roughly estimate the regurgitant fraction of PR by tracing retrograde and antegrade flow velocity profiles individually to obtain respective velocity time integrals (VTIs). Assuming a constant PV diameter in systole and diastole, a ratio of retrograde VTI (a measure of regurgitant volume) to antegrade VTI (a measure of total stroke volume) represents the regurgitant fraction. Theoretically, a ratio of 0.5 or more would indicate severe PR (i.e., a regurgitant fraction of ≥50%). However, there are no empirically validated cutoff values for grading PR severity using this method. Furthermore, this method cannot be used in patients with concomitant pulmonic stenosis because of poststenotic turbulence.

**Regurgitant Volume and Fraction by Comparing Pulmonic to Systemic Flow**

Systolic antegrade flow across the right ventricular outflow tract (RVOT) in a patient with PR represents the total stroke volume (TSV). If the patient has no significant aortic regurgitation and no shunt, then systolic antegrade flow across the left ventricular outflow tract (LVOT) represents the net stroke volume (NSV). The difference between TSV and NSV represents the regurgitant volume.

**Regurgitant Volume**

Regurgitant volume = TSV − NSV

**Regurgitant Fraction**

Regurgitant fraction = Regurgitant volume/TSV

Although these calculations are feasible, the cutoff values have not been validated for PR. The major limitation to this method is the frequent inability to measure the RVOT diameter accurately. It has been shown that regurgitant fraction calculation by echocardiography only moderately correlates with measurements obtained with cardiac MRI.

**Holodiastolic Flow Reversal in Pulmonary Artery**

Normally, the PW spectral Doppler profile in the pulmonary artery contains a large antegrade component in systole and a very small retrograde component confined to early diastole. As the severity of PR increases, so does the duration of retrograde flow in the pulmonary artery. In severe PR there is typically a holodiastolic flow reversal in the pulmonary artery spectral Doppler tracings. This is analogous to holodiastolic flow reversal in the thoracic and abdominal aorta in the setting of severe aortic regurgitation.

**M-Mode Echocardiography**

Many aspects of PR assessment by M-mode echocardiography have only historic value. However, with its excellent temporal resolution, M mode allows for very precise timing of cardiac events. For instance, one can easily demonstrate by color M mode the short, early diastolic nature of the jet in severe PR.

Moreover, recently a PR index by M-mode echocardiography (PRIME) to estimate the pulmonary regurgitation fraction (PRF) using a nonlinear regression was developed. M-mode tracings of the right pulmonary artery from the suprasternal notch are used to measure the maximal systolic and minimum diastolic dimensions. PRIME values of 1.21 or greater identified patients with a PRF of at least 25%. When compared with PRF calculated by cardiac MRI, this measurement was accurate. It remains unknown if this method can be replicated by other investigators.

**Impact of Pulmonic Regurgitation ON CARDIAC CHAMBERS**

Chronic PR is associated with PA and RV dilatation. PA dilatation may both lead to and be the result of severe PR. RV dilatation and interventricular septal flattening in diastole (a marker of RV volume overload) are nonspecific signs of severe chronic PR. Conversely, a normal RV size excludes severe chronic PR.

Please access ExpertConsult to view the corresponding videos for this chapter.

**REFERENCES**
