Aortic Valve Regurgitation
Joint Session with the ESC Working Group on Valvular Heart Disease

Evaluation of aortic regurgitation
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European Association of Echocardiography recommendations for the assessment of valvular regurgitation. Part 1: aortic and pulmonary regurgitation (native valve disease)

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Valvular regurgitation represents an important cause of cardiovascular morbidity and mortality. Echocardiography has become the primary non-invasive imaging method for the evaluation of valvular regurgitation. The echocardiographic assessment of valvular regurgitation should integrate quantification of the regurgitation, assessment of the valve anatomy, and function as well as the consequences of valvular disease on cardiac chambers. In clinical practice, the management of patients with valvular regurgitation thus largely integrates the results of echocardiography. It is crucial to provide standards that aim at establishing a baseline list of measurements to be performed when assessing regurgitation.

**Keywords**
- Valvular regurgitation
- Echocardiography
- Recommendations
- Aortic valve
- Pulmonary valve

**Valve assessment: recommendations**

1. TTE is recommended as the first-line imaging modality in valvular regurgitation.
2. TEE is advocated when TTE is of nondiagnostic value or when further diagnostic refinement is required.
3. 3D TEE or TTE is reasonable to provide additional information in patients with complex valve lesion.
4. TEE is not indicated in patients with a good-quality TTE except in the operating room when a valve surgery is performed.

**Key point**
Valve analysis should integrate the assessment of the aetiology, the lesion process, and the type of dysfunction.

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(2) TEE is advocated when TTE is of nondiagnostic value or when further diagnostic refinement is required.

(3) 3D TEE or TTE is reasonable to provide additional information in patients with complex valve lesion.

(4) TEE is not indicated in patients with a good-quality TTE except in the operating room when a valve surgery is performed.

(– If you want to discuss the problem with the cardiac surgeon, TEE will provide nearly always more informations about aortic valve morphology and aortic root dimension)
Just looking – qualitatively - at the cineloops ist not enough!
You have to quantify by measurements of
1. Left ventricular diameter
2. Left ventricular volumes
3. Left ventricular ejection fraction

LV size and function: recommendations
(1) Quantitative assessment of LV diameters, volumes, and ejection fraction is mandatory.
(2) 2D measurement of LV diameters is strongly advocated if the M-mode line cannot be placed perpendicular to the long axis of the LV.
(3) The 2D-based biplane summation method of disc is the recommended approach for the estimation of LV volumes and ejection fraction.
(4) 3D echo assessment of LV function is reasonable when possible.
(5) Contrast echo is indicated in patients with poor acoustic window.
(6) Qualitative assessment of LV function is not recommended.
Evaluation of aortic valve regurgitation:

If aortic valve regurgitation is more than mild, it is absolutely mandatory to check the left ventricular dimensions as well as the volumes.

In addition, if volume overload due to regurgitation is suspected both cavities – proximal and distal to the valve - have to be – quantitatively assessed: the left ventricle and the ascending aorta.
Aortic valve regurgitation: The evaluation should be systematically.

1. Description of morphology of the heart – especially the left ventricle and the ascending aorta
2. Description of the left ventricular function
3. Assessment of qualitative and quantitative parameters
   1. First target parameter: regurgitant fraction
   2. Second target parameter: planimetry of the regurgitant orifice
4. Secondary structural and functional findings
5. Special investigations like TEE and stress echocardiography

Key point
LV diameters, volumes, and ejection fraction should always be evaluated and reported. It is strongly recommended to index the LV diameters to the body surface area.
Standardized views for documentation and assessment for LV-function, standardized views also for the first documentation of the regurgitation
Key point
In patients with AR, careful aortic valve analysis is mandatory. The echo report should include information about the aetiology, the lesion process, and the type of dysfunction. The likelihood of valve repair should also be discussed in the case of pure AR.

(3) 3D TEE or TTE is reasonable to provide additional information in patients with complex valve lesion.
An “old“ approach for quantification of aortic valve regurgitation: determination of the ratio Vena contracta \( \frac{LVOT}{LVOT} \) – if ratio > 50% - severe regurgitation
Table 1  Functional classification of AR lesions

<table>
<thead>
<tr>
<th>Dysfunction</th>
<th>Echo findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>I: enlargement of the aortic root with normal cusps</td>
<td>Dilatation of any components of the aortic root (aortic annulus, sinuses of Valsalva, sinotubular junction)</td>
</tr>
<tr>
<td>Ila: cusp prolapse with eccentric AR jet</td>
<td>Complete eversion of a cusp into the LVOT in long-axis views</td>
</tr>
<tr>
<td>Cusp flail</td>
<td>Distal part of a cusp prolapsing into the LVOT (clear bending of the cusp body on long-axis views and presence of a small circular structure near the cusp free edge on short-axis views)</td>
</tr>
<tr>
<td>Partial cusp prolapse</td>
<td>Free edge of a cusp overriding the plane of aortic annulus with billowing of the entire cusp body into the LVOT (presence of a large circular or oval structure immediately beneath the valve on short-axis views)</td>
</tr>
<tr>
<td>Whole cusp prolapse</td>
<td>Presence of an eccentric AR jet without definite evidence of cusp prolapse</td>
</tr>
<tr>
<td>Iib: free edge fenestration with eccentric AR jet</td>
<td>Thickened and rigid valves with reduced motion</td>
</tr>
<tr>
<td>III: poor cusp quality or quantity</td>
<td>Tissue destruction (endocarditis)</td>
</tr>
<tr>
<td></td>
<td>Large calcification spots/extensive calcifications of all cusps interfering with cusp motion</td>
</tr>
</tbody>
</table>

Figure 5  Measurements of the aortic diameters. 1, valve annulus; 2, aortic sinuses; 3, sinotubular junction; 4, proximal ascending aorta.
In the case: bicuspid valve with annulus dilatation

Figure 4 Mechanisms of aortic regurgitation according to the Capentier functional classification. Type I, aortic annulus dilatation; Type IIa, prolapse of the left coronary cusp (arrow); Type III, rheumatic aortic valve disease with restricted cusp motion.
(4) TEE is not indicated in patients with a good-quality TTE except in the operating room when a valve surgery is performed.

I think, if you will discuss the problem with the cardiac surgeon, it is always better to have better information about valve morphology, coaptation distances and zones, aortic root dimension, and calcification near the coronary ostia by TEE.
Quantitative evaluation of aortic valve regurgitation:
Determination of regurgitant fraction
Severe aortic valve regurgitation – $RF_{AV} > 50\%$

$SV_{AV} - SV_{MV} \over SV_{AV}$

- $SV_{AV}$ = stroke volume, determined at the LVOT
- $SV_{MV}$ = stroke volume, determined at the mitral valve
- $(SV_{AV} - SV_{MV})$ = regurgitant volume at the aortic valve
- $RF_{AV}$ = regurgitant fraction

Normally it is too difficult to use this method in clinical practise (too many possibilities of errors)
Evaluation of aortic valve regurgitation

Options for quantification of regurgitant orifice

\[
\text{AV}_{RV} = (\text{SV}_{AV} - \text{SV}_{MV})
\]

Regurgitant volume at the aortic valve

\[
\text{RV} = \text{regurgitant volume}
\]

\[
\text{AV}_{RV} = \frac{\text{Regurgitant volume at the aortic valve}}{\text{VTI}_{AR}}
\]

\[
\text{ERO}_{AV} = \text{VTI}_{AR}
\]

Effective Regurgitant orifice

AR = Aortic valve regurgitation

\[
> 30\text{mm}^2 = \text{severe aortic valve regurgitation}
\]

The usage of this calculation depends on the quality and the correctness of the \(\text{AV}_{RV}\)-assessment.
The Pressure Half Time Method: Still useful, but there are limitations, e.g. concomitant valve diseases, flow conditions, and aortic dimensions.

Mild AR
- PHT > 550 msec
Moderate AR
- PHT (200) 300 – 550 msec
Severe AR
- < (200) 300 msec
The deceleration of the regurgitant flow in the cw-spectrum can estimate severity of aortic regurgitation. The longer the deceleration time (or PHT), the less severe the aortic regurgitation. If deceleration of the AR-signal will reach baseline at enddiastole, aortic enddiastolic is equal to left atrial pressure at enddiastolie – representing severe aortic regurgitation (example on the right side).
“Leipzig“-case in the recommendations

Similiar to the course of the deceleration of AR-signal the turbulences in severe Aortic regurgitation can be documented during the entire diastole using the colour M-Mode.

**Figure 7** (A) Colour Doppler showing a severe aortic regurgitation; (B) colour-coded M-mode depicting the time dependency of flow signal during the heart cycle.
The intensity of the cw-Doppler-spectrum is not recommended for semiquantification of the aortic regurgitation due to the following limitation. The intensity depends on the correctness of the angulation of the central regurgitant jet. If the probe angulation is not exactly within the jet during the entire diastole, the intensity represents not the flow within the jet anymore.
Wrong probe angulation is also the most frequent reason for overestimation of the severity of aortic valve regurgitation. If the angle between Doppler angulation and regurgitant jet is more than 30° and breathing artefact will display the jet out of the angulation, deceleration of the AR will be shortened and will counterfeit more severe regurgitation.

PHT-measurement o.k.? No
Estimation of the severity of valvular regurgitation: recommendations

1. The colour flow area of the regurgitant jet is not recommended to quantify the severity of valvular regurgitation.
2. Both the vena contracta measurement and the PISA method are the recommended approaches to evaluate the severity of regurgitation when feasible.
3. Adjunctive parameters should be used when there is discordance between the quantified degree of regurgitation and the clinical context.

Do not use colour flow area for quantification of the severity of valvular regurgitation: it is nonsense!
Key point
The colour flow area of the regurgitant jet is not recommended to quantify the severity of AR. The colour flow imaging should only be used for a visual assessment of AR. A more quantitative approach is required when more than a small central AR jet is observed.

Key point
The PISA method is acceptably reproducible in mitral regurgitation, TR, and AR. The following steps are recommended: (1) optimize the colour flow imaging (Variance OFF) with a small angle from an apical or parasternal window, (2) expand the image using zoom or regional extension selection, (3) shift the colour flow zero baseline towards the regurgitant jet direction to obtain a hemispheric PISA, (4) use the cine mode to select the most satisfactory hemispheric PISA, (5) display the colour Doppler off when necessary to visualize the regurgitant orifice, (6) measure the PISA radius using the first aliasing, and (7) measure the regurgitant velocity.

The PISA method has several advantages. Instrumental and haemodynamic factors do not seem to substantially influence flow quantification by this approach. The aetiology of regurgitation or the presence of concomitant valvular disease does not affect the regurgitant orifice area calculation. Although less accurate, this method can still be used in eccentric jet without significant distortion in the isovelocity contours.¹⁵
The vena contracta- and PISA-methods are only suitable in patients with aortic regurgitation, if proximal jet formation and proximal convergence zones are well documented. Otherwise both methods can cause severe overestimation of the AR severity. In these cases, the old fashion approach seems to be better.
How to decide about severity of aortic regurgitation due to indirect estimation?

Methods of „indirect“ quantification of the severity of aortic valve regurgitation:
1. Pressure half time-method – PHT
2. Vena contracta or proximal jet-width (or „old fashion“ – determination of the ratio Vena contracta / LVOT)
3. Regurgitant orifice (again„old fashion“– determination of the ratio proximal jet area /LVOT-area)
4. Subclavian- or aortic flow-profile

Key point
When feasible, the measurement of the vena contracta width is recommended to quantify AR. Intermediate vena contracta values (3–6 mm) need confirmation by a more quantitative method, when feasible. The vena contracta can often be obtained in eccentric jet. In the case of multiple jets, the respective values of vena contracta width are not additive. The assessment of the vena contracta by 3D echo is still reserved for research purposes.
33mm/17mm – ≈ 50%; Ratio > 50% = severe aortic valve regurgitation
The planimetry of the regurgitant orifice can be done using 2D- or 3D-TTE and TEE. The determination of area$_{LVOT}$/area$_{AR}$-ratio is more reliable than the diameter$_{LVOT}$/diameter$_{AR}$-ratio. Actually, there are many aspects to focus on the multidimensional approach for this assessment.
Key point

The measurement of the diastolic flow reversal in the descending aorta is recommended, when assessable. It should be considered as the strongest additional parameter for evaluating the severity of AR.

The flow profile within the proximal aorta and proximal great arteries, however, is influenced by the age-dependent „air chamber“-function of the aorta.

If the enddiastolic flow velocity in the descending aorta is more than 0.3m/sec, severe regurgitation can be assumed.
There are also very well established parameters for the flow velocities of the subclavian artery profile in the literature.

Numerical criteria for a severe aortic valve regurgitation:
1. $\frac{VTI_{\text{dia}}}{VTI_{\text{sys}}}>50\%$
2. $\frac{V_{\text{dia}}}{V_{\text{sys}}}>0.3$
3. $VTI_{\text{dia}}>25\,\text{cm}$

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Holodiastolic flow in the subclavian artery – at least moderate AR

### Table 1: Maximum diastolic velocity (D), diastolic velocity time integral (dVTI), the ratio of diastolic and systolic maximum velocities (D/S) and the ratio of diastolic and systolic Velocity Time Integrals (RF) in the subclavian artery velocity curve.

<table>
<thead>
<tr>
<th>Patients</th>
<th>D (cm/sec)</th>
<th>dVTI</th>
<th>D/S</th>
<th>RF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>-27±10</td>
<td>-15±14</td>
<td>0.1±0.09</td>
<td>14±12</td>
</tr>
<tr>
<td>AR 1+/2+</td>
<td>-25±7</td>
<td>-18±13</td>
<td>0.1±0.06</td>
<td>18±15</td>
</tr>
<tr>
<td>AR 3+/4+</td>
<td>-44±11</td>
<td>-90±30</td>
<td>0.52±0.1</td>
<td>75±19</td>
</tr>
</tbody>
</table>

Insignificant (1+/2+) versus significant forms of aortic regurgitation (3+/4+ AR) * $p<0.05$
Stress echocardiography is important in patients with asymptomatic chronic aortic regurgitation to detect early subclinical left ventricular dysfunction.

Physiologically left ventricle has to become smaller during stress – and longitudinal strain should be preserved.

Exercise echocardiography is useful in patients with severe AR and equivocal symptoms. It could also be useful in patients with borderline values in terms of LV ejection fraction (50–55%) or end-systolic diameter (closed to 50 mm or 25 mm/m²).
Determination of strain and twist will be very important as additional diagnostic features in the management of patients with aortic valve regurgitation.
Summary

Evaluation of aortic valve regurgitation

1. Quantitative assessment of left ventricular dimensions and volumes is mandatory in patients with AR.

2. The colour flow area is not anymore recommended for quantification of severity of AR.

3. If possible, regurgitant fraction and regurgitant orifice should be estimated by the PISA method.

4. Alternatively, the $a_{LVOT}/a_{AR}$-ratio can be determined.

5. Semiquantitativley, AR can be evaluated by PHT and flow profiles of the descending artery or subclavian artery.

6. For standardization subclavian artery profile offers advantages in comparison to the descening artery profile.
Thank You for Your Attention