GUIDELINES AND STANDARDS

Echocardiographic Assessment of Valve Stenosis: EAE/ASE Recommendations for Clinical Practice

Helmut Baumgartner, MD,† Judy Hung, MD,‡ Javier Bermejo, MD, PhD,†
John B. Chambers, MD,† Arturo Evangelista, MD,† Brian P. Griffin, MD,‡ Bernard Iung, MD,†
Catherine M. Otto, MD,‡ Patricia A. Pellikka, MD,‡ and Miguel Quiñones, MD‡

Baumgartner et al, Journal of the American Society of Echocardiography Volume 22 Number 1, January 2009
Aortic stenosis

Echocardiography has become the standard means for evaluation of aortic stenosis (AS) severity. Cardiac catheterization is no longer recommended except in rare cases when echocardiography is non-diagnostic or discrepant with clinical data.
AORTIC STENOSIS

A. Causes and Anatomic Presentation.

B. How to Assess Aortic Stenosis:
   - AS jet velocity.
   - Mean transaortic gradient.
   - Valve area by continuity equation.

C. How to Grade Aortic Stenosis.

D. Other findings: LVH, LV systolic dysfunction, AR, MVD, Ascending aorta & DSE.
A. Causes and Anatomic Presentation

Aortic stenosis aetiology: morphology of calcific AS, bicuspid valve, and rheumatic AS
(Adapted from C. Otto, Principles of Echocardiography, 2007)
Bicuspid Aortic Valve

- Fusion of right & left coronary cusps
- Associated with
  - Coarctation of aorta
  - Aortic root dilatation
  - Aortic dissection
Short axis of the aortic valve in zoom mode. The aortic valve appears to be trileaflet in the diastolic frame but is shown to be bicuspid with a raphe in systole.
B. How to Assess Aortic Stenosis: AS jet velocity

- CW Doppler
  - multiple acoustic windows in order to determine the highest velocity (apical and suprasternal or right parasternal most frequently yield the highest velocity)
  - colour Doppler is helpful to avoid recording the CWD signal of an eccentric mitral regurgitation (MR) jet
B. How to Assess Aortic Stenosis: mean pressure gradient

Continuous-wave Doppler of severe aortic stenosis jet showing measurement of maximum velocity and tracing of the velocity curve to calculate mean pressure gradient.
AORTIC STENOSIS

LEVEL OF STENOSIS

- VALVULAR
- SUPRAVALVULAR
- SUBVALVULAR
Supravalvular Aortic Stenosis

Brijesh Patel ET AL, J. Am. Coll. Cardiol. 2010;56;e13
SUBVALVULAR AORTIC STENOSIS

- Membraneous
- Fibromuscular ridge
- Tunnel-like
Subvalvular Aortic Stenosis

- moderate aortic stenosis (left) and dynamic outflow obstruction in hypertrophic cardiomyopathy (right).

- Note the different shapes of the velocity curves and the later maximum velocity with dynamic obstruction.
AVA by Continuity Equation

\[ A_2 = \frac{A_1 \cdot v_1}{v_2} \]
AVA by Continuity Equation

- **LVOT diameter** is measured in the parasternal long-axis view in mid-systole from the white-black interface of the septal endocardium to the anterior mitral leaflet, parallel to the aortic valve plane and within 0.5–1.0 cm of the valve orifice.
AVA by Continuity Equation

- **LVOT velocity** is measured from the apical approach.
- Using pulsed-Doppler, the sample volume (SV), with a length (or gate) of 3–5 mm, is positioned on the LV side of the aortic valve, just proximal to the region of flow acceleration into the jet. An optimal signal shows a smooth velocity curve.
- The VTI is measured by tracing the velocity.
AVA by Continuity Equation

The aortic valve area = \( (3.8 \text{cm}^2 \times 20 \text{ cm}) / 104 \text{ cm} = 0.7\text{cm}^2 \)

indicating critical aortic stenosis.
## C. How to Grade Aortic Stenosis

<table>
<thead>
<tr>
<th></th>
<th>MILD</th>
<th>MODERATE</th>
<th>SEVERE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic Jet velocity (m/s)</td>
<td>2.6-2.9</td>
<td>3.0-4.0</td>
<td>&gt; 4.0</td>
</tr>
<tr>
<td>Mean gradient (mmHg)</td>
<td>&lt; 20 (&lt;30&lt;sup&gt;a&lt;/sup&gt;)</td>
<td>20-40&lt;sup&gt;b&lt;/sup&gt; (30-50&lt;sup&gt;a&lt;/sup&gt;)</td>
<td>&gt;40&lt;sup&gt;b&lt;/sup&gt; (&gt; 50&lt;sup&gt;a&lt;/sup&gt;)</td>
</tr>
<tr>
<td>AVA (cm&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>&gt;1.5</td>
<td>1.0-1.5</td>
<td>&lt;1.0</td>
</tr>
</tbody>
</table>

<sup>a</sup> ESC Guidelines.
<sup>b</sup> AHA/ACC Guidelines
Low-flow low-gradient AS

**Definition:**
- Effective orifice area < 1.0 cm².
- LV ejection fraction < 40%; and
- Mean pressure gradient < 30–40 mmHg.

**DSE:** differentiate 2 clinical situations
- Severe AS causing LV systolic dysfunction.
- Moderate AS with another cause of LV dysfunction.
Mitral Stenosis: Role of Echocardiography

• Diagnosis of Mitral Stenosis
• Quantitation of stenosis severity.
  - mean gradient, mitral valve area.
• Assessment of valve anatomy.
• Other echo findings
  - pulmonary artery pressure
  - LA dilatation, thrombus.
  - assessment of concomitant valvular lesions
DIAGNOSIS OF MITRAL STENOSIS
Indices of mitral stenosis severity

• Mean gradient.
• MVA:
  1- Planimetry.
  2- Pressure half time (T_{1/2}).
  3- continuity equation.
  4- Proximal Isovelocity Surface Area method
Mean Pressure Gradient

- CW Doppler.
- Apical window.
- Colour Doppler to identify eccentric diastolic mitral jets.
- Trace the Doppler diastolic mitral flow.
- Average measurements if AF
Mean gradient, 20 mm Hg
Functional valve area, 0.5 cm²
MVA Planimetry

- Planimetry is considered as the reference measurement of MVA.
- 2D parasternal short-axis view.
- Determine the smallest orifice by scanning from apex to base.
- Lowest gain setting to visualize the whole mitral orifice.
MVA Planimetry

- obtained by direct tracing of the mitral orifice, including opened commissures.
- In mid-diastole (use cine-loop).
- Limitations: poor window, severe calcification.
Pressure Half Time (T_{1/2})

- T1/2 is defined as the time interval in msec between the maximum mitral gradient in early diastole and the time point where the gradient is half the maximum initial value.
- MVA is derived using the empirical formula: MVA=220 / T_{1/2}
Pressure Half Time ($T_{1/2}$)

The patient on the left reaches the pressure half-time in 241 ms (white arrow) and has a valve area of 0.9cm² (220/241). The patient on the right reaches the pressure half-time (white arrow) in 147 ms and has a valve area of 1.5cm² (220/147).
Pressure Half Time (T$_{1/2}$)

- Determination of Doppler pressure half-time (T$_{1/2}$) with a bimodal, non-linear decreasing slope of the E-wave. The deceleration slope should not be traced from the early part (left), but using the extrapolation of the linear mid-portion of the mitral velocity profile (right).
Percutaneous Balloon Mitral Valvuloplasty (PBMV)

- Percutaneous BMV is the procedure of choice in patients who have symptomatic, hemodynamically severe stenosis with an echocardiographic score of 8 or less and without left atrial thrombus.
- Echocardiography Plays a Major Role in Patient Selection for PBMV.
Indications for percutaneous valvuloplasty of MS

- **Class I**
  - Symptomatic patients (NYHA II, III, or IV), moderate or severe MS (MVA ≤ 1.5) and valve morphology favorable for percutaneous balloon valvotomy in the absence of left atrial thrombus or moderate to severe MR.
Assessment of mitral valve anatomy according to the Wilkins score

The total score is the sum of the four items and ranges between 4 and 16

<table>
<thead>
<tr>
<th>Grade</th>
<th>Mobility</th>
<th>Thickening</th>
<th>Calcification</th>
<th>Subvalvular Thickening</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Highly mobile valve with only leaflet tips restricted</td>
<td>Leaflets near normal in thickness (4-5 mm)</td>
<td>A single area of increased echo brightness</td>
<td>Minimal thickening just below the mitral leaflets</td>
</tr>
<tr>
<td>2</td>
<td>Leaflet mid and base portions have normal mobility</td>
<td>Midleaflets normal, considerable thickening of margins (5-8 mm)</td>
<td>Scattered areas of brightness confined to leaflet margins</td>
<td>Thickening of chordal structures extending to one-third of the chordal length</td>
</tr>
<tr>
<td>3</td>
<td>Valve continues to move forward in diastole, mainly from the base</td>
<td>Thickening extending through the entire leaflet (5-8 mm)</td>
<td>Brightness extending into the mid-portsions of the leaflets</td>
<td>Thickening extended to distal third of the chords</td>
</tr>
<tr>
<td>4</td>
<td>No or minimal forward movement of the leaflets in diastole</td>
<td>Considerable thickening of all leaflet tissue (&gt;8-10 mm)</td>
<td>Extensive brightness throughout much of the leaflet tissue</td>
<td>Extensive thickening and shortening of all chordal structures extending down to the papillary muscles</td>
</tr>
</tbody>
</table>
Determination of echocardiographic score (Wilkins’ Score)

<table>
<thead>
<tr>
<th>ECHOCARDIOGRAPHIC SCORE</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigidity</td>
<td>Mobile valve</td>
<td></td>
<td>Immobile valve</td>
<td></td>
</tr>
<tr>
<td>Thickening</td>
<td>Thin</td>
<td></td>
<td>Severely thickened</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>No bright echos</td>
<td></td>
<td>Multiple bright echo areas</td>
<td></td>
</tr>
<tr>
<td>Subvalvular apparatus</td>
<td>Sparse echos</td>
<td></td>
<td>Multiple thick chordae seen</td>
<td></td>
</tr>
</tbody>
</table>
Valve Area

- Normal  4 – 6 cm$^2$
- Mild     1.5 – 2.5 cm$^2$
- Moderate 1.0 – 1.5 cm$^2$
- Severe   <1.0 cm$^2$
How to Grade Mitral Stenosis

<table>
<thead>
<tr>
<th>Specific findings</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valve area (cm²)</td>
<td>&gt;1.5</td>
<td>1.0–1.5</td>
<td>&lt;1.0</td>
</tr>
<tr>
<td>Supportive findings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean gradient (mmHg)³</td>
<td>&lt;5</td>
<td>5–10</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Pulmonary artery pressure (mmHg)</td>
<td>&lt;30</td>
<td>30–50</td>
<td>&gt;50</td>
</tr>
</tbody>
</table>
Tricuspid Stenosis

- TS is rarely an isolated disorder; more often, it is accompanied by MS & TR.
- Parasternal right ventricular inflow view, parasternal short axis, apical four-chamber and subcostal four-chamber.
- Looks for valve thickening and/or calcification, restricted mobility with diastolic doming, reduced leaflet separation at peak opening, and right atrial enlargement.
How to Assess Tricuspid Stenosis

Planimetry \( \rightarrow \) is difficult and unreliable.

The evaluation of tricuspid valve stenosis with Doppler echocardiography is similar to the method described for mitral stenosis, although the constant of 190 has been proposed of the PHT method.

The hallmark of a stenotic valve is an increase in transvalvular velocity recorded by CWD.
How to grade Tricuspid Stenosis

Findings indicative of haemodynamically significant tricuspid stenosis

<table>
<thead>
<tr>
<th>Specific findings</th>
<th>Supportive findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean pressure gradient</td>
<td>Enlarged right atrium ≥ moderate</td>
</tr>
<tr>
<td>Inflow time–velocity integral</td>
<td>Dilated inferior vena cava</td>
</tr>
<tr>
<td>$T_{1/2}$</td>
<td></td>
</tr>
<tr>
<td>Valve area by continuity equation$^a$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 5 mmHg</td>
</tr>
<tr>
<td></td>
<td>&gt; 60 cm</td>
</tr>
<tr>
<td></td>
<td>≥ 190 ms</td>
</tr>
<tr>
<td></td>
<td>≤ 1 cm$^{2a}$</td>
</tr>
</tbody>
</table>

$^a$Stroke volume derived from left or right ventricular outflow. In the presence of more than mild TR, the derived valve area will be underestimated. Nevertheless, a value 1 cm$^2$ implies a significant haemodynamic burden imposed by the combined lesion.
Tricuspid Stenosis

TVI = 60 cm; mean grad = 9 mmHg
$P1/2t = 173 \text{ ms}$
Pulmonary stenosis

- Congenital anomaly, simple or part of complex.
- Parasternal short-axis view
- CW Doppler
- PW Doppler → site of stenosis.
- Muscular infundibular obstruction → late peaking systolic jet
Pulmonary stenosis
How to grade pulmonary stenosis

- Assessment of pulmonary stenosis severity is based mainly on the transpulmonary pressure gradient.
- Planimetry is not possible.
- Continuity equation or PISA → not validated in PS.

<table>
<thead>
<tr>
<th></th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak velocity (m/s)</td>
<td>&lt;3</td>
<td>3-4</td>
<td>&gt;4</td>
</tr>
<tr>
<td>Peak gradient (mmHg)</td>
<td>&lt;36</td>
<td>36-64</td>
<td>&gt;64</td>
</tr>
</tbody>
</table>
**PERCUTANEOUS BALLOON PULMONARY VALVULOPLASTY**

- Dome-shaped or dysplastic valve
- Size of pulmonary annulus → optimal balloon size.
- RV functions
• Echocardiography has become the key tool for the diagnosis and evaluation of valve disease, and is the primary non-invasive imaging method for valve stenosis assessment.

• Clinical decision-making is based on echocardiographic assessment of the severity of valve stenosis, so it is essential that standards be adopted to maintain accuracy and consistency across echocardiographic laboratories when assessing and reporting valve stenosis.
Take home massage

• It is essential in clinical practice to use an integrative approach when grading the severity of stenosis, combining all Doppler and 2D data, and not relying on one specific measurement.

• Finally, echocardiographic measurements of valve stenosis must be interpreted in the clinical context of the individual patient.
THANK YOU

SALAH ELTAHAN, MD
PROFESSOR OF CARDIOLOGY