Συστηματοποίηση, Λάθη και παγίδες στην ηχωκαρδιογραφική μελέτη των βαλβιδοπαθειών (Λήψη και ερμηνεία)

‘Μέθοδος και παγίδες στην ανεπάρκεια της αορτικής βαλβίδας’

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Επιμελήτρια Α’ Καρδιολογικής Κλινικής
ΓΝΑ ‘Γ. Γεννηματάς’
Disclosures: None
Echocardiographic evaluation of Aortic Regurgitation – integrated approach

a) Etiology/mechanism of AR
(feasibility of repair)

b) Severity of AR

c) Impact of AR on LV size/function

d) Clinical context

2D ECHO / Color Doppler

2D / Color Doppler / PWD, CWD

2D ECHO, contrast, 3D
Echocardiographic evaluation of Aortic Regurgitation – integrated approach

a) Etiology/mechanism of AR  
   (feasibility of repair)

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d) Clinical context
Clinical context

a) Symptoms and related clinical findings

b) Arterial blood pressure, heart rate

b) height, weight, body surface area
Etiology/mechanism of AR

a) Structure of cusps:
   thickening, calcification, vegetations

b) Motion of cusps:
   normal,
   prolapse/flail,
   restriction, malcoaptation

c) Annular size/dilatation of aortic root
## Etiology /mechanism of AR: Aortic Cusps

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Specific etiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congenital/leaflet abnormalities</td>
<td>Bicuspid, unicuspid, or quadricuspid aortic valve</td>
</tr>
<tr>
<td></td>
<td>Ventricular septal defect (i.e. supracristal (doubly committed) VSD with cusp prolapse)</td>
</tr>
<tr>
<td>Acquired leaflet abnormalities</td>
<td></td>
</tr>
</tbody>
</table>
Type IA           Type II A            Type III A          Type IB
Complete or incomplete raphe
symmetrical or asymmetrical
Etiology /mechanism of AR: Aortic Root

- Congenital/genetic aortic root abnormalities
- Acquired aortic root abnormalities

Marfan syndrome

Ehlers-Danlos syndrome

Takayasu's arteritis

Zoghbi WA et al. JASE 2017
Bekeredjian R et al. Circulation 2005
Types of Aortic Regurgitation according to cusp motion

Type I
Normal Cusp Motion with Aortic Dilation or Cusp Perforation

Type II
Cusp Prolapse

Type III
Cusp Restriction

Khoury El G et al. Curr Opin Cardiol 2005
Severity of AR

Doppler echocardiography:
*Qualitative and semi-quantitative parameters*

- **Color Doppler:**
  - Site of origin of regurgitation and direction of regurgitant jet
  - The 3 color Doppler components of the jet: flow convergence, vena contracta, jet area

- **CWD:**
  - Density of the jet velocity signal
  - Pressure half-time

- **PWD, color M-Mode:**
  - Flow reversal in descending and abdominal aorta
Severity of AR

Doppler echocardiography: 
Quantitative parameters

- Color Doppler / CWD:
  - PISA optimization for calculation of RVol and EROA

- PWD, CWD & 2D:
  Quantitative volumetric method
  - LVOT diameter, RVOT diameter, mitral annular diameter
  - corresponding pulsed Doppler for respective SV calculations and derivation of RVol and RF
  - EROA estimation by RVol/ CW AR- VTI
Impact of AR on LV size/function

Optimization of LV chamber quantitation and LV function evaluation:

- **contrast echo** when needed to avoid LV underestimation
- **3D echo as needed**, for more accurate assessment of **volumes and LVEF**
  - Parameters obtained by 3D echocardiography, tissue Doppler, and strain rate imaging may be useful mainly when the LVEF is < 55%, as **subtle LV dysfunction** can be obtained and can help in making the decision for surgery.

- **Indexing LV diameter for body surface area (BSA)** is recommended, especially in patients with small body size (BSA < 1.68 m²)
  - The small body size limitation is of particular concern in evaluating valve regurgitation in females, where normalizing measurements to body size may provide a more accurate assessment of outcomes

Other echo data to be acknowledged in order to avoid pitfalls in AR evaluation:

- **Concomitant valvular disease**
- **shunts**

Doppler echocardiography:

*Qualitative and semi-quantitative parameters*

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- **CWD:**
  - Density of the jet velocity signal
  - Pressure half-time

- **PWD, color M-Mode:**
  - Flow reversal in descending and abdominal aorta
Determine:
➢ Direction of the AR jet in the long-axis view (central or eccentric)
Determine:
➢ Origin of the jet in the short-axis view (central or commissural)
Colour flow Doppler:
the 3 components of the jet: flow convergence, vena contracta, jet area

At a Nyquist limit 50-60 cm/s
Colour flow Doppler: *regurgitant jet width / area*

<table>
<thead>
<tr>
<th>Modality</th>
<th>Optimization</th>
<th>Example</th>
<th>Advantages</th>
<th>Pitfalls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet width/LVOT diameter</td>
<td>• Long-axis view • Zoomed view • Imaging plane for optimal VC measurement may be different from PISA • Measure in LVOT within 1 cm of the VC</td>
<td></td>
<td>• Simple sensitive screen for AR • Rapid qualitative assessment</td>
<td>• Underestimates AR in eccentric jets • May overestimate AR in central jets as AR jet may expand unpredictably below the orifice • Is affected by the size of the LVOT</td>
</tr>
<tr>
<td>Jet area/LVOT area</td>
<td>• Short-axis view • Zoom view • Measure within 1 cm of the VC</td>
<td></td>
<td>• Estimate of regurgitant orifice area</td>
<td>• Direction and shape of jet may overestimate or underestimate jet area</td>
</tr>
</tbody>
</table>

Severe AR ≥ 65%

At a Nyquist limit 50-70 cm/s Color gain just below clutter-noise level
**Colour flow Doppler: Vena Contracta**

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</tr>
</thead>
<tbody>
<tr>
<td>Colour flow Doppler 2D</td>
<td><em>Vena Contracta</em></td>
<td><img src="image_url" alt="Image" /></td>
<td>- Surrogate for regurgitant orifice size</td>
<td>- Problematic in the presence of multiple jets or bicuspid valves</td>
</tr>
<tr>
<td></td>
<td>• Parasternal long-axis view</td>
<td></td>
<td>- May be used in eccentric jets</td>
<td>- Convergence zone needs to be visualized</td>
</tr>
<tr>
<td></td>
<td>• Zoomed view</td>
<td></td>
<td>- Independent of flow rate and driving pressure</td>
<td>- The direction of the jet (in relation to the insonation beam) will influence the appearance of the jet</td>
</tr>
<tr>
<td></td>
<td>• Imaging plane for optimal VC measurement may be different from that for PISA</td>
<td></td>
<td>- Less dependent on technical factors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Narrowest area of jet at or just apical to the valve</td>
<td></td>
<td>- Good at identifying mild or severe AR</td>
<td></td>
</tr>
</tbody>
</table>

Severe AR: Vena contracta > 6 mm

*Zoghbi WA et al. JASE 2017*
Doppler echocardiography:

*Qualitative and semi-quantitative parameters*

- **Color Doppler:**
  - Site of origin of regurgitation and direction of regurgitant jet
  - The 3 color Doppler components of the jet: flow convergence, vena contracta, jet area

- **CWD:**
  - Density of the jet velocity signal
  - Pressure half-time

- **PWD, color M-Mode:**
  - Flow reversal in descending and abdominal aorta
### CW Doppler: Density of the jet, Pressure Half Time (PHT)

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</thead>
<tbody>
<tr>
<td>Density of regurgitant jet</td>
<td>Align insonation beam with the flow</td>
<td><img src="image1.png" alt="Image" /></td>
<td>Simple</td>
<td>Qualitative</td>
</tr>
<tr>
<td></td>
<td>Adjust overall gain</td>
<td></td>
<td>Density is proportional to the number of red blood cells reflecting the signal</td>
<td>Perfectly central jets may appear denser than eccentric jets of higher severity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Faint or incomplete jet is compatible with mild or trace AR</td>
<td>Overlap between moderate and severe AR</td>
</tr>
<tr>
<td>Jet deceleration rate</td>
<td>Align insonation beam with the flow</td>
<td><img src="image2.png" alt="Image" /></td>
<td>Simple</td>
<td>Qualitative</td>
</tr>
<tr>
<td>(pressure half-time)</td>
<td>Usually best from apical windows</td>
<td></td>
<td>Specific sign of pressure relation between aorta and LV</td>
<td>Poor alignment of Doppler beam may result in lower pressure half-time</td>
</tr>
<tr>
<td></td>
<td>In eccentric jets, may be best from parasternal window, helped by color Doppler</td>
<td></td>
<td>If long, excludes severe AR</td>
<td>Affected by changes that modify LV-aorta pressure gradient (if short, implies significant AR or high LV filling pressure)</td>
</tr>
</tbody>
</table>

Mild AR: PHT > 500 ms
Severe AR: PHT < 200 ms

*Zoghbi WA et al. JASE 2017*
PHT can be increased due to:

- **Chronic AR with dilated LV and increased LV compliance**
  (PHT most reliable in the setting of acute AR
  - there may be triangular shaped CWD with linear deceleration slope from peak Vel to baseline)

- **Mitral stenosis**

PHT may be shortened due to:

- Other causes of **high LV filling pressure**
  (restrictive physiology, systolic and diastolic dysfunction, MR)

- Factors affecting **aortic diastolic pressure**:
  a. **Vasodilator therapy**
     (may shorten PHT even though AR fraction improves)
  a. **Sepsis**
  b. **Patent ductus arteriosus**
  c. **Dilated compliant aorta**
Severity of AR

Doppler echocardiography:  
*Qualitative and semi-quantitative parameters*

- **Color Doppler:**
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- **CWD:**
  - Density of the jet velocity signal
  - Pressure half-time

- **PWD, color M-Mode:**
  - Flow reversal in descending and abdominal aorta
PW Doppler: holodiastolic reversal in descending aorta in severe AR
PW Doppler:
Flow reversal in abdominal aorta
- more specific sign of severe AR
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</tr>
</thead>
<tbody>
<tr>
<td>Pulsed wave Doppler:</td>
<td>Align insonation beam with the flow in the proximal descending or abdominal</td>
<td><img src="image" alt="Diagram" /></td>
<td>• Simple supportive sign of severe AR</td>
<td>• Depends on compliance of the aorta; less reliable in older patients</td>
</tr>
<tr>
<td>Flow reversal in proximal</td>
<td>aorta</td>
<td></td>
<td>• More specific sign if seen in abdominal aorta</td>
<td>• Brief velocity reversal is normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Can be obtained with both TTE and TEE</td>
<td>• Can be present in arteriovenous fistula in upper extremity, ruptured</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>sinus of Valsalva or PDA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• May not be holodiastolic in acute AR</td>
</tr>
</tbody>
</table>

EDV > 20 cm/s

Zoghbi WA et al. JASE 2017
Doppler echocardiography: *Quantitative parameters*

- **Color Doppler /CWD:**
  - PISA optimization for calculation of $RVol$ and $EROA$

- **PWD, CWD & 2D:**
  - Quantitative volumetric method
  - LVOT diameter, RVOT diameter, mitral annular diameter
  - corresponding pulsed Doppler for respective SV calculations and derivation of $RVol$ and $RF$
  - EROA estimation by $RVol$/ CW AR- VTI
Colour flow Doppler / CWD:

PISA optimization for calculation of RVol & EROA

- ZOOM IN on LVOT in either PLAX or apical long-axis view
Quantitative Doppler: PISA (proximal isovelocity surface area) method

Zoghbi WA et al. JASE 2017
Quantitative Doppler: PISA (proximal isovelocity surface area) method

Flow Convergence Method

\[
\text{Reg Flow} = 2\pi r^2 \times \text{Va}
\]
\[
\text{EROA} = \frac{\text{Reg Flow}}{\text{PKV}}
\]
\[
\text{R Vol} = \text{EROA} \times \text{VTI}_{\text{Reg}}
\]

Zoghbi WA et al. JASE 2017
10% error in radius leads to 21% error in flow.
Isovelocity contour flattens as it approaches the orifice, underestimating flow.

Quantitative Doppler:

- ZOOM IN on LVOT in either PLAX or apical long-axis view.

Imaging from the right parasternal window may be helpful!!!

- Feasibility is limited by aortic valve calcifications.
- Not valid for multiple jets, less accurate in eccentric jets.
- Limited experience.
- Small errors in radius measurement can lead to substantial errors in EROA due to squaring of error.

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Quantitative Doppler: PISA (proximal isovelocity surface area) method

Ways about pitfalls:

- May add multiple EROAs
- Multiple measurements to reduce error
- If proximal structures distort contour, shift baseline downwards to reduce PISA radius
- 3D color flow for better assessment BUT lower spatial & temporal resolution

Keep in mind!!!:
EROA is peak Reg Flow divided by peak Vel obtained by CW Doppler (early diastole) - therefore, PISA radius should be measured in early diastole!

Zoghbi WA et al. JASE 2017
Doppler echocardiography: Quantitative parameters

- Color Doppler/ CWD:
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The volume of blood entering the LV via the MV, during diastole, should equal the volume leaving the LV via the LVOT, during systole (SV: stroke volume).

In AR, LVOT SV also comprises blood that has entered the LV via AR during diastole, that is Reg Vol. Therefore, in the absence of significant MR or a VSD:

The difference in SV represents the Reg Vol:

\[
\text{Reg Vol} = \text{SV LVOT} - \text{SV MV}
\]

Reg Fraction = (Reg Vol / SV LVOT) X 100%

EROA = Reg Vol / AR VTI
Quantitative volumetric method: regurgitant volume / fraction

Valid with multiple jets, eccentric jets

Not valid for combined MR-AR, unless pulmonic site is used
Quantitative volumetric method: regurgitant volume / fraction:

limitations - pitfalls

➢ Requires reference valve with no regurgitation (> mild)

➢ Cannot be used in presence of shunts (i.e. ASD, VSD)

➢ Sensitive to small measurement errors, esp. incorrect annulus measurements (diameters are squared in the equation)

➢ Requires multiple (4) measurements - technically challenging, introduces 4 possible errors

➢ Affected by sample volume location – mitral annulus, not tips

➢ Verify measurements by evaluating LV SV from LVEDV-LVESV
Additional testing with TEE and/or CMR is indicated when:

- Discordance between qualitative and quantitative parameters and/or clinical data
- Multiple valvular lesions or coexisting shunts
- When TTE is suboptimal and the mechanism of significant AR may not be identified (i.e. endocarditis, acute aortic dissection, isolated aortic root dilatation - 2D or 3D TEE)
- Bicuspid AV and suboptimal visualization of aortic root and ascending aorta (at least 4cm above AV)
- Special role of 2D and 3D TEE for pre-surgical evaluation or in the planning of transcatheter repair or replacement devices

Zoghbi WA et al. JASE 2017
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Zoghbi WA et al. JASE 2017
Phase-contrast CMR for assessment of AV flow:

- **Magnitude image:** provides anatomic location information
- **Phase image:** encodes velocity in each pixel

A flow-time curve is generated by integration of velocity and area data at each phase in the cardiac cycle. This can be used to compute forward and reverse flow. The reverse flow represents the directly measured volume of AR.

Zoghbi WA et al. JASE 2017
Evidence of increased LVEDP – acute severe AR:
- Premature closure of MV
- Premature opening of AV

PHT is more useful as a marker of severity, since LV compliance will not have adapted so quickly (there may be triangular shaped CWD with linear deceleration slope from peak Vel to baseline)
- Normal LV dimensions, often with vigorous LV function
- Other relevant pointers of acute onset: dissection, trauma, endocarditis

A high index of suspicion should be maintained, with a low threshold for performance of TEE.
Chronic Aortic Regurgitation by Doppler Echocardiography

Specific Criteria for Mild AR
- VC width < 0.3 cm
- Central Jet, width < 25% of LVOT
- Small or no flow convergence
- Soft or incomplete jet by CW
- PHT > 500 ms
- Normal LV size

(quantitation not needed)

Does AR meet specific criteria of mild or severe AR?

Intermediate Values:
AR Probably moderate

Perform quantitative methods whenever possible to refine assessment

Specific Criteria for Severe AR
- Flail Valve
- VC width > 0.6 cm
- Central Jet, width ≥ 65% of LVOT
- Large flow convergence
- PHT < 200 ms
- Prominent holodiastolic flow reversal in the descending aorta
- Enlarged LV with normal function

Mild AR
- RVol < 30 mL
- RF < 30%
- EROA <0.1 cm²
- AR Grade I

Moderate AR
- RVol 30-44 mL
- RF 30-39%
- EROA 0.10-0.19 cm²
- AR Grade II

Severe AR
- RVol 45-56 mL
- RF 40-49%
- EROA 0.20-0.29 cm²
- AR Grade III

Indeterminate AR
- Consider further testing: TEE or CMR for quantitation

- Poor TTE quality or low confidence in measured Doppler parameters
- Discordant quantitative and qualitative parameters and/or clinical data

* Beware of limitations of color flow assessment in eccentric AR jets; volumetric quantitation and integration of other parameters is advised.
Ευχαριστώ πολύ για την προσοχή σας !!!