ISCHEMIC MR

Interpretating the ECHO-findings

P.GIANNAKOPOULO
CARDIOLOGIST, CONSULTANT
“G.PAPANIKOLAOU” GH THESSALONIKI
Nothing to declare
Prevalence of Mitral Regurgitation (MR)

- **Framingham study**: **mild MR 19%** in asymptomatic men and women

- **Severe MR**: 0.2-1.9% of the general population (depending on the study)
Mitral Regurgitation Etiologies

Degenerative MR
- Also known as primary or organic MR
- Usually caused by an anatomic defect of one or more structures comprising the mitral valve apparatus—the annulus, the leaflets, the chordae tendineae, and the papillary muscles

Functional MR
- Also known as secondary MR
- Results from left ventricular (LV) dysfunction and dilation, which causes otherwise normal valve components to fail and results in MR

See Important Safety Information Referenced Within
Etiology of Mitral Regurgitation

- Ischemic mitral regurgitation—27%
- Endocarditis—5%
- Rheumatic valve disease—1%
- Other—2%
- Degenerative mitral disease (MVP)—65%

Waller BF et al: Clin Cardiol 17:395, 1994
Frequency of MR in HF pts

90% of pts with NYHA III-IV, 50% Moderate/Severe MR

Heart failure clinic, EF≤35%, Class III-IV

- Retrospective 1996-2001
- Echo reports Quantitative MR

- Mild: 31.9%
- Mild-Moderate: 11.8%
- Moderate: 21.9%
- Moderate-Severe: 12.5%
- Severe: 4.3%
- 0-Trace: 10.4%

N = 558

Patel JB- J Cardiac Failure 10:285, 2004
Definition of Ishemic MR

Pathophysiological triad

- Described by Dr. Alain Carpentier.
- Understanding of mitral valve pathology.

Pathophysiological Triad

<table>
<thead>
<tr>
<th>Etiology</th>
<th>The cause of the disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesions</td>
<td>Results from the disease</td>
</tr>
<tr>
<td>Dysfunctions</td>
<td>Results from the lesions</td>
</tr>
</tbody>
</table>

- Long term prognosis depends upon etiology, treatment strategy depends on dysfunction, surgical management depends upon lesion.

Causes of CIMR

- **Tethering of Mitral leaflets**
- LV dilatation
- PM displacement/discoordination
- Annular dilatation/dysfunction
- Insufficient LV-generated closing forces
- Global LV/PM dyssynchrony
Left, Mitral balance of forces.
Carpentier Classification of Mitral Regurgitation

**PRIMARY MR**
- Type I: Normal leaflet motion
- Type II: Increased leaflet motion
- Type IIa: Restricted leaflet motion (systole and diastole)
- Type IIb: Restricted leaflet motion (systole)

**SECONDARY MR**

### Mitral Regurgitation

<table>
<thead>
<tr>
<th>Type</th>
<th>Leaflet motion and annulus findings</th>
<th>Lesion</th>
<th>Aetiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Normal</td>
<td>Leaflet perforation</td>
<td>Endocarditis</td>
</tr>
<tr>
<td>IIa</td>
<td>Normal and dilated annulus</td>
<td>Annular dilatation</td>
<td>Ischaemic MR + significant LV dysfunction</td>
</tr>
<tr>
<td>IIb</td>
<td>Excessive prolapse</td>
<td>Chord elongation or rupture (flail leaflets)</td>
<td>Myxomatous/degenerative disease</td>
</tr>
<tr>
<td>IIa</td>
<td>Normal and dilated annulus</td>
<td>Papillary muscle elongation or rupture</td>
<td>Ischaemic cardiomyopathy</td>
</tr>
<tr>
<td>IIIa</td>
<td>Restricted (diastole and systole)</td>
<td>Leaflet thickening/retraction</td>
<td>Endocarditis</td>
</tr>
<tr>
<td>IIIa</td>
<td>Normal and dilated annulus</td>
<td>Leaflet thickening/retraction</td>
<td>Ischaemic cardiomyopathy</td>
</tr>
<tr>
<td>IIIb</td>
<td>Restricted (systole)</td>
<td>LV dilatation</td>
<td>Rheumatic heart disease</td>
</tr>
<tr>
<td>IIIb</td>
<td>Dilated and restricted (systole)</td>
<td>Papillary muscle displacement</td>
<td>Inflammatory</td>
</tr>
</tbody>
</table>

**Key:** LV = left ventricle; MR = mitral regurgitation

- Leaflet perforation
- Cordal elongation or rupture
- Rheumatic disease
- Ischaemic or non-ischaemic LV remodeling
- Annular dilation
Degenerative or primary MR –
disease of the Mitral apparatus
(e.g. FED/Barlow causing prolapse)

Functional/ischemic or secondary MR –
disease of the LV with secondary MV closure impairment

IMR

Disease of the Left Ventricle NOT the Mitral Valve

FMR

Normal LV

Dilated LV tethering one or both leaflets
Issues to address with echo in patients with MR

- What is the mechanism of the MR?
- How severe is the MR?
- What is the LV size and function?
- Are symptoms present?
- Is the valve repairable?
- If surgery is indicated, is there a surgeon available that can guarantee a successful repair?

www.escardio.org/EAE
Echo assessment of CIMR

- Confirm underlying Chronic Ischemic Heart Disease
- Severity of MR
- Exclude pathology in leaflets and chordae
- Assess LV and PM displacement

Phenotype of MR: *Symmetric* or *Asymmetric*
Echo assessment of CIMR

- LV function
- LV ejection fraction
- LV dimensions
- LV WMA
- Pulmonary Hypertension
Mitral Regurgitation

**Qualitative**
1. Valve morphology
2. Color flow imaging
3. CW doppler

**Semi quantitative**
1. PW doppler
2. Pulmonary venous flow
3. Vena contracta

**Quantitative**
1. Doppler volumetric method
2. PISA
Echocardiographic criteria for the definition of severe valve regurgitation: an integrative approach *(continued)*

(Adapted from Lancellotti et al.)

<table>
<thead>
<tr>
<th>Qualitative</th>
<th>Mitral regurgitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valve morphology</td>
<td>Flail leaflet/ruptured papillary muscle/large coaptation defect</td>
</tr>
<tr>
<td>Colour flow regurgitant jet</td>
<td>Very large central jet or eccentric jet adhering, swirling, and reaching the posterior wall of the LA</td>
</tr>
<tr>
<td>CW signal of regurgitant jet</td>
<td>Dense/triangular</td>
</tr>
<tr>
<td>Other</td>
<td>Large flow convergence zone</td>
</tr>
</tbody>
</table>
Echo assessment of CIMR

- **Distal jet area:**
  
  Jet/LA area > 40% = Severe MR

  **Advantage:** rapid, straightforward method, especially for centrally directed jets

  **Disadvantage:** varies with loading conditions (e.g., BP), technical factors (machine gain, frequency settings), underestimation of eccentric jets.

*Key point*

The colour flow area of the regurgitant jet is not recommended to quantify the severity of MR. The colour flow imaging should only be used for diagnosing MR. A more quantitative approach is required when more than a small central MR jet is observed.
Echo assessment of CIMR

**CW doppler**

- Qualitative approach to evaluate MR severity.
- Useful adjunct to other quantitative measurements.
- Adequate alignment of the beam with MR jet profile is crucial for an accurate representation of MR severity.
- Difficult to obtain in eccentric jet.

<table>
<thead>
<tr>
<th>Soft density, incomplete envelope</th>
<th>mild</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense signal with triangular shape</td>
<td>severe</td>
</tr>
</tbody>
</table>

Figure 24: Three examples of various degrees of mitral regurgitation (MR); mild (A), moderate (B), and severe (C) are provided. The regurgitant jet as well as the mitral E wave velocity increase with the severity of MR. In severe MR, the continuous wave Doppler signal of the regurgitant jet is truncated, triangular and intense. Notching of the continuous wave envelope (cut-off sign) can occur in severe MR. TVI, time-velocity integral.
Mitral Regurgitation

Semi quantitative
1. Vena contracta
2. PW doppler
3. Pulmonary venous flow
Echocardiographic criteria for the definition of severe valve regurgitation: an integrative approach *(continued)*

(Adapted from Lancellotti et al.)

<table>
<thead>
<tr>
<th>Semiquantitative</th>
<th>Mitral regurgitation</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Vena contracta</em> width (mm)</td>
<td>≥7 (&gt;8 for biplane)</td>
</tr>
<tr>
<td>Upstream vein flow</td>
<td>Systolic pulmonary vein flow reversal</td>
</tr>
<tr>
<td>Inflow</td>
<td>E-wave dominant ≥1.5 m/s</td>
</tr>
<tr>
<td>Other</td>
<td>TVI mitral/TVI aortic &gt;1.4</td>
</tr>
</tbody>
</table>
**Echo assessment of CIMR**

**Vena contracta width**

- Easy and quick method
- Relatively independent of hemodynamic factors.
- Limited by its narrow range.
- Image optimization needed
- Zoom mode with narrow sector and plane perpendicular to the jet is essential to improve spatial and temporal resolution.
- 2 chamber view (commissural view) is parallel to the mitral leaflet coaptation line, even mild degrees of functional regurgitation can appear to show a wide VC(not recommended)

<table>
<thead>
<tr>
<th>Vena Contracta Width</th>
<th>Mild MR</th>
<th>Moderate MR</th>
<th>Severe MR</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3 cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.3 – 0.7 cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 0.7 cm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Key point**

When feasible, the measurement of vena contracta is recommended to quantify MR. Intermediate vena contracta values (3–7 mm) need confirmation by a more quantitative method, when feasible. The vena contracta can often be obtained in eccentric jet. In case of multiple jets, the respective values of the vena contracta width are not additive. The assessment of the vena contracta by 3D echo is still reserved for research purposes.
Echo assessment of CIMR

Mitral inflow pattern

- Qualitative and complementary approach to MR severity.
- Semiquantitative
- Mitral to aortic time velocity integral (TVI) ratio of the pulsed wave doppler profile of mitral and aortic valves could be used to quantify isolated organic MR.
- A ratio greater than 1.4 suggests severe MR.
- < 1.0 mild MR.
- A wave dominant excludes severe MR.
- E wave >1.5 cm/sec – severe MR
- Influenced by LA Pressure and LV relaxation.
- Not accurate in Atrial Fibrillation
Echo assessment of CIMR

- PULMONARY VEINS

EAE guidelines for evaluation of VHD

Key point
Both the pulsed Doppler mitral to aortic TVI ratio and the systolic pulmonary flow reversal are specific for severe MR. They represent the strongest additional parameters for evaluating MR severity.

2010

<table>
<thead>
<tr>
<th>Systolic dominance</th>
<th>mild MR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic flow reversal</td>
<td>severe MR</td>
</tr>
</tbody>
</table>

Influenced by LA pressure and LV relaxation
Not accurate in atrial fibrillation

Figure 25 (A) Normal pulmonary vein flow pattern; (B) blunt forward systolic pulmonary vein flow in a patient with moderate mitral regurgitation (MR); (C) reversed systolic pulmonary flow in a patient with severe MR. S, systolic wave; D, diastolic wave.
Echocardiographic criteria for the definition of severe valve regurgitation: an integrative approach (continued)

(Adapted from Lancellotti et al.)

<table>
<thead>
<tr>
<th>Quantitative</th>
<th>Mitral regurgitation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
<td></td>
</tr>
<tr>
<td>EROA (mm²)</td>
<td>≥40</td>
</tr>
<tr>
<td>Regurgitant volume (mL/beat)</td>
<td>≥60</td>
</tr>
<tr>
<td>+ enlargement of cardiac chambers/vessels</td>
<td>LV, LA</td>
</tr>
<tr>
<td><strong>Secondary</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥20</td>
</tr>
<tr>
<td></td>
<td>≥30</td>
</tr>
</tbody>
</table>
Echo assessment of CIMR

Quantitative approaches

- Effective Regurgitant Orifice Area (EROA)
- Regurgitant volume
- Regurgitant fraction

*Useful to define the intermediate degrees of MR.*

---

**Figure 23** 3D shape of the flow convergence in functional (A) (hemielliptic) and organic mitral regurgitation (B) (hemispheric).

---

- European recommendations for MR quantification have taken into account the different characteristics of primary and secondary MR.
- **EROA**

<table>
<thead>
<tr>
<th>40 mm²</th>
<th>Primary MR</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 mm²</td>
<td>Secondary MR</td>
</tr>
</tbody>
</table>

Echo assessment of CIMR

2D Proximal Isovelocity Surface Area

- **Current recommended quantitative approach.**
- Qualitatively, presence of flow convergence at a Nyquist limit of approximately 50 - 60 cm/sec (routine examination) would suggest significant MR.
- PISA calculations are based on following parameters.

\[
\text{EROA} = 2\pi r^2 \times \frac{\text{V}a}{\text{Peak MRV(CW)}}
\]

- **EROA** = effective regurgitant orifice area
- **V}a = aliasing velocity

\[
\text{RV (cc)} = \text{EROA} \times \text{TVI MR (cm)}
\]

- **RV** = regurgitant volume
- **TVI = MV** time–velocity integral

- PISA method assumes that the EROA is constant throughout systole and is hemispheric in shape.
- PISA based methods tend to be more accurate for organic than for functional MR.
- PISA radius is constant in patients with organic rheumatic MR, increases progressively along the systole period in patients with mitral valve prolapse.
- In functional MR, an early peak is followed by a progressive midsystolic decrease, sometimes with another late systolic peak (bimodal pattern).

**Key point**

When feasible, the PISA method is highly recommended to quantify the severity of MR. It can be used in both central and eccentric jets. An EROA $\geq$ 40 mm$^2$ or a RVol $\geq$ 60 mL indicates severe organic MR. In functional ischaemic MR, an EROA $\geq$ 20 mm$^2$ or a RVol $\geq$ 30 mL identifies a subset of patients at increased risk of cardiovascular events.
Echo assessment of CIMR

Quantitative volumetric methods

- Pulse wave doppler is used.
- Flow rates and stroke volumes

\[ SV = TVI \text{ annulus} \times CSA \text{ annulus} \]

- **MR volume = Mitral inflow – aortic outflow**
- Mitral inflow volume = TVI × CSA (mitral annulus)
- Aortic outflow = TVI × CSA (LVOT)
- TVI at the level of mitral annular plane, as this is where the cross-sectional area is measured.
- Cross sectional area of mitral annulus is *assumed to be circular* and calculated as \( \pi r^2 \), where \( r \) is the diameter measured in the apical chamber view divided by 2.
- Anatomically mitral annulus is *D shaped*, more like an *ellipse* rather than a circle.
- Circular assumption is reasonable for who have developed at least moderate MR (annular dilation)
- *Ellipse - \( \pi ab \)* - diameters measured in A2C, A4C views.
- *This method assumes there is no aortic regurgitation*.
- In that case, pulmonary outflow can be used, assuming no pulmonary regurgitation.

Important note: The Doppler volumetric method is a time-consuming approach that is not recommended as a first line method to quantify MR severity.
Comparison of Transesophageal and Transthoracic Echo cardiographic Measurements of Mechanism and Severity of Mitral Regurgitation in Ischemic Cardiomyopathy (from the STITCH Trial)
Paul A. Grayburn, Eric J. Velazquez, MD, Jae K. Oh, MD
## Echo assessment of CIMR

### New parameters

- Asystolic tissue Doppler velocity measured at the lateral annulus $< 10.5 \text{ cm/s}$ has been shown to identify subclinical LV dysfunction and to predict post-operative LV dysfunction in patients with asymptomatic organic MR.
- Strain imaging allows a more accurate estimation of myocardial contractility than tissue Doppler velocities.

### Strain Imaging

- It is not influenced by translation or pathologic tethering to adjacent myocardial segments, which affect myocardial velocity measurements.
- In MR, strain has been shown to decrease even before LV ESD exceeds 45 mm.
- A resting longitudinal strain rate value $<1.07/s$ (average of 12 basal and mid segments) is associated with the absence of contractile reserve during exercise and thus with subclinical latent LV dysfunction.
- By using the 2D speckle tracking imaging (an angle independent method), a *global longitudinal strain* $<18.1\%$ has been associated with postoperative LV dysfunction.
- Practically, the incremental value of tissue Doppler and strain imaging for identifying latent LV dysfunction remains to be determined.
Echo assessment of CIMR

Sphericity index

LV Sphericity Index
To assess changes in LV shape, the sphericity index was calculated at end-diastole and end-systole as the volume of the LV divided by the volume of a sphere with a diameter equal to the LV longest axis (measured in the apical view). As this ratio increases and approaches 1, the ventricle becomes more spherical. The sphericity index is a surrogate measure of the degree of leaflet tethering because the more spherical the LV becomes, the greater the degree of papillary muscle displacement that exerts tethering on the leaflets.
Assessment of mitral valvular deformation and global and regional left ventricular remodeling in patients with secondary mitral regurgitation.


Copyright © American Heart Association, Inc. All rights reserved.
Echo assessment of CIMR

3D Echocardiography

- Better definition of mitral morphology
- Pathological changes
- Improves the characterization of mitral regurgitant jets.
- Spatially visualize the shape, size, orientation of MR jets in real time, thus enhancing the accuracy of quantification of MR severity.

3D PISA

- True proximal flow convergence region is rather more hemielliptical than hemispheric
- Yoesty and colleagues – calculation of EROA by 3D can greatly improve the accuracy of 2D based PISA assessment.
- Underestimation can be significantly corrected.

Limitations

- Low temporal resolution.
- “Volume” or “voxel” rates in real time is low even with small angles of view.
- Stitching artifacts (AF).
- Color doppler gain (effect on size, no effect on area)
- Instantaneous ROA should be integrated throughout systole (midsystole)
Three-dimensional \textbf{(3D) reconstruction of the mitral annulus} in secondary mitral regurgitation with measurements of the anteroposterior (A) and intercommissural (B) diameters, anterior (C) and posterior (D) leaflet surfaces, and dynamics of the mitral annulus (E).


Copyright © American Heart Association, Inc. All rights reserved.
Three-dimensional (3D) transesophageal echocardiography (TEE) to guide mitral valve annuloplasty in secondary mitral regurgitation (SMR).
Dynamic Ischaemic Mitral Regurgitation and the Role of Stress Echocardiography

Raluka Dulgheru, Julien Magne, Patrizio Lancellotti, and Luc A Pierard

IMR+Exercise stress-echo

- Pts with LV dysfunction and disproportional symptoms
- Pts with acute pulmonary oedema (without obvious cause)
- Unmask pts at high risk of mortality and HF (changes in ERO area >13mm²)
- Before CABG: in moderate MR
- After CABG: persistence of Pulmonary Hypertension and absence of functional class improvement
Key point

Exercise echocardiography is useful in patients with functional ischaemic MR and chronic LV systolic dysfunction to unmask the dynamic behaviour of MR. Patients with an increase in EROA by $\geq 13 \text{ mm}^2$ are patients at increased risk of cardiovascular events. In these patients, exercise echocardiography also helps to identify the presence and extent of viable myocardium at jeopardy.
Recommendations for the echocardiographic assessment of native valvular regurgitation: an executive summary from the European Association of Cardiovascular Imaging

Sequential evaluation

Table 2 Unfavourable TTE characteristics for mitral valve repair in functional mitral regurgitation

- Mitral valve deformation
- Coaptation distance \( \geq 1 \text{ cm} \)
- Tenting area \( > 2.5 - 3 \text{ cm}^2 \)
- Complex jets
- Posterolateral angle \( > 45^\circ \)
- Local LV remodelling
- Interpapillary muscle distance \( > 20 \text{ mm} \)
- Posterior papillary-fibrosa distance \( > 40 \text{ mm} \)
- Lateral wall motion abnormality
- Global LV remodelling
- EDD \( > 65 \text{ mm} \), ESD \( > 51 \text{ mm} \) (ESV \( > 140 \text{ mL} \))
- Systolic sphericity index \( > 0.7 \)

EDD, end-diastolic diameter; ESD, end-systolic diameter; ESV, end-systolic volume; LV, left ventricle.
Integrated approach to MR grading

MR Color Flow imaging
- Appears to be mild
- Central Jet
  - No PISA seen
  - Jet Area < 4.0 cm²
  - Or <20% LA area
  - CWD not intense
- Vena Contracta
  - >0.7cm
  - Central
  - PISA RV and ROA
- <0.3cm
  - Eccentric
  - Pulse Doppler RV and ROA
- Jet Direction
- Severe MR
- Mild MR

From Otto, Textbook of Clinical Echocardiography. Elsevier Inc. 2004
Take home message:

- **Echocardiography** is an important diagnostic tool in the evaluation of **Ischemic Mitral Regurgitation**

- Effective guide during interventions and during follow-up
THANK YOU FOR YOUR ATTENTION