Mitral regurgitation
MR is a very common valve disease

General population 1.7% moderate/severe MR
>75 years old 9.3% moderate/severe MR
ECHO in Mitral Regurgitation

BASICS: Valve anatomy
BASICS in valve anatomy: VALVES

ANTERIOR leaflet
1/3 of the ring
strong anatomical support

POSTERIOR leaflet
2/3 of the ring
weak anatomical support
more related to LV stress
BASICS in valve anatomy: VALVES

KEY: structures near Appendage or Aorta are Anterior

KEY: number 1 is always up in the top
BASICS in valve anatomy: ANNULUS

D shaped structure

Highest point is anterior

Lowest points are the commissures

Saddle-shaped
BASICS in valve anatomy: CHORDAE

- RCS
- NCS
- LCS
- Membranous septum
- Trigone
- Aortomitral curtain
- Basal chordae
- Intermediate chordae
- Marginal chordae
- Atrioventricular joint
- Zone of coaptation
ECHO in Mitral Regurgitation

BASICS in valve anatomy: PAPILLARY

CX-OM1
D1
AL
PM
RCA - IVP
D1
Echocardiographist TASK LIST in MR

- Location of MV disease
- Mechanism of the MR
- Evaluation of severity
- Consequences of MR
- Feasibility of MV repair
Location of MV disease

The echocardiographic view
Location of MV disease

The surgical view

Try to speak the same language
Location of MV disease: 2D TEE

You are the observer. You are IN the left atrium looking to MV plane.
2D TEE: 0º orientation
2D TEE: 0° orientation
2D TEE: 60° orientation
2D TEE: 60° orientation
2D TEE: 135° orientation
ECHO in Mitral Regurgitation

2D TEE: Transgastric
Location of MV disease: 3D TEE
Location of MV disease: 3D TEE
Echocardiographist TASK LIST in MR

- Location of MV disease
- Mechanism of the MR
- Evaluation of severity
- Consequences of MR
- Feasibility of MV repair
# Mechanisms of MV regurgitation

**The Carpentier classification**

<table>
<thead>
<tr>
<th>Type</th>
<th>Leaflet motion</th>
<th>Valve pathology</th>
<th>Prolapse or Flail</th>
<th>Leaflet thickening</th>
<th>Functional or Organic MR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ia</td>
<td>Normal</td>
<td>Annular dilatation</td>
<td></td>
<td></td>
<td>functional or organic</td>
</tr>
<tr>
<td>Ib</td>
<td></td>
<td>Leaflet defect</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IIA</td>
<td>Increased</td>
<td>Chordal elongation</td>
<td>Prolapse</td>
<td>not thickened (FED) or thickened (Barlow)</td>
<td>organic</td>
</tr>
<tr>
<td>IIB</td>
<td></td>
<td>Chordal rupture</td>
<td>Flail leaflet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IIc</td>
<td></td>
<td>Papillary muscle elongation</td>
<td>Prolapse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IId</td>
<td></td>
<td>Papillary muscle rupture</td>
<td>Flail leaflet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IIIa</td>
<td>Restricted</td>
<td>Commissural or chordal fusion or shortening</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IIIb</td>
<td></td>
<td>Leaflet tethering by LV dilatation</td>
<td></td>
<td></td>
<td>functional</td>
</tr>
</tbody>
</table>
## Type I: NORMAL valve motion

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Atrial view</th>
<th>Lesions</th>
<th>Etiology</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Atrial view" /></td>
<td><strong>Annular dilatation</strong></td>
<td>Ischemic HD</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Annular deformation</strong></td>
<td>MCD</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Leaflets perforation</strong></td>
<td>Endocarditis</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Cleft</strong></td>
<td>Congenital</td>
</tr>
</tbody>
</table>

Organic **OR** functional MR

Usually **central** MR jet
Type I: NORMAL valve motion

Annular dilatation
Type I: NORMAL valve motion

2/1 > 1.3

Diastole > 35mm

Annular dilatation
Type I: NORMAL valve motion

Valve perforation
Type I: NORMAL valve motion

Congenital cleft
**Type II: EXCESS valve motion**

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Atrial view</th>
<th>Lesions</th>
<th>Etiology</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Atrial view" /></td>
<td>Myxomatous degeneration</td>
<td>Degenerative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chordae elongation</td>
<td>Fibroelastic deficiencia Marfan Forme Fruste Barlow Endocarditis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chordae rupture</td>
<td>Rheumatic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Papillary elongation</td>
<td>Trauma</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Papillary rupture</td>
<td>Ischemic HD</td>
</tr>
</tbody>
</table>

**Eccentric MR jet**

directed to **opposite side** of the affected leaflet
Type II: EXCESS valve motion

P2 prolapse
Type II: EXCESS valve motion

Barlow disease
**Type III: RESTRICTED valve motion**

**IIIa: diastolic and systolic (retraction)**

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Atrial view</th>
<th>Lesions</th>
<th>Etiology</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Atrial view" /></td>
<td>Leaflets thickening&lt;br&gt;Leaflets retraction&lt;br&gt;Chordae thickening&lt;br&gt;Chordae retraction&lt;br&gt;Chordae fusion&lt;br&gt;Calcification&lt;br&gt;Commissures fusion&lt;br&gt;LV fibrosis</td>
<td><strong>Rheumatic</strong>&lt;br&gt;Carcinoid syndrome&lt;br&gt;Radiotherapy&lt;br&gt;Systemic lupus&lt;br&gt;Ergotamine&lt;br&gt;Hypereosinophilic synd&lt;br&gt;Mucopolysaccharidosis</td>
</tr>
</tbody>
</table>

**ORGANIC MR**

no predefined MR jet direction
Type III: RESTRICTED valve motion

IIla: Systolic and diastolic restriction
**Type III: RESTRICTED valve motion**
(tethering)

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Atrial view</th>
<th>Lesions</th>
<th>Etiology</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Atrial view" /></td>
<td>Tethering of leaflets</td>
<td>Ischemic HD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Papillary displacement</td>
<td>Dilated MCD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ventricular dilatation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ventricular aneurysm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ventricular fibrosis</td>
<td></td>
</tr>
</tbody>
</table>

**FUNCTIONAL MR**
Type III: RESTRICTED valve motion

IIIb: Symmetric systolic restriction

Central jet
Type III: RESTRICTED valve motion

IIIc Focal Tethering: Ischemic MR
Jet towards the same side of abnormal leaflet
Echocardiographist TASK LIST in MR

- Location of MV disease
- Mechanism of the MR
- Evaluation of severity
  - Regurgitant jet area
  - Jet width at vena contracta
  - Pulmonary vein flow
  - Regurgitant volume
  - Regurgitant fraction
  - PISA
  - 3D evaluation of jet
PRO

Fast and intuitive

CONs Doppler pattern affected by

- Technical factors: gain, settings, PRF…
- Direction of the jet (Coanda effect)
- Loading conditions

<table>
<thead>
<tr>
<th></th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet area</td>
<td>&lt; 4cm²</td>
<td>4 – 8 cm²</td>
<td>&gt; 8 cm²</td>
</tr>
<tr>
<td>Jet area/LAA</td>
<td>&lt;20%</td>
<td>20-40%</td>
<td>&gt;40%</td>
</tr>
</tbody>
</table>
Vena contracta width

Narrowest portion of MR jet width

**PRO** Fast and intuitive

**CONS** Doppler pattern affected by

- Technical factors: gain, settings, PRF...
- Lateral resolution
- Multiple jets
- Non circular orifice

<table>
<thead>
<tr>
<th></th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC width</td>
<td>&lt;0.3 cm</td>
<td>03-07 cm</td>
<td>≥0.7 cm</td>
</tr>
</tbody>
</table>
- Color settings are very important for measurement
  
  • Aliasing velocity of 50-60 cm/s
  • Adjust color gain to maximal without random color speckle
ECHO in Mitral Regurgitation

Pulmonary vein flow

Possible in ETT (RUPV)
easier with ETE

Systolic reversal = Severe MR
Volume study by Doppler

In case of valve regurgitation there is a **flow overload** in the abnormal valve.

The **difference** allow to measure the **regurgitant volume**.
Volume study by Doppler

Regurgitant volume = Total volume - Effective Volume

$$RV = (0.785 \times D^2 \times ITV_{disease}) - (0.785 \times D^2 \times ITV_{normal})$$
HOW TO... compute mitral reg volume

1. Mitral annulus diameter (Apical 4C – diastole)
2. Mitral Doppler TVI measurement
3. Mitral flow = $0.785 \times D^2_M \times TVI_M$
4. LVOT diameter (PLAX view)
5. LVOT aortic TVI measurement
6. Aortic flow = $0.785 \times D^2_{LVOT} \times TVI_{LVOT}$

MITRAL REGURGITANT VOLUME
Mitral flow – Aortic flow

MITRAL REGURGITANT FRACTION
Mitral regurgitant volume/ Mitral flow
## ECHO in Mitral Regurgitation

### Volume study by Doppler

<table>
<thead>
<tr>
<th>Regurgitation</th>
<th>Regurgitant volume</th>
<th>Regurgitant fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trivial</td>
<td>10-20 ml</td>
<td>10-20%</td>
</tr>
<tr>
<td>Mild</td>
<td>&lt;30 ml</td>
<td>&lt;30%</td>
</tr>
<tr>
<td>Moderate</td>
<td>30-60 ml</td>
<td>30-50%</td>
</tr>
<tr>
<td>Severe</td>
<td>&gt;60 ml</td>
<td>&gt;50%</td>
</tr>
</tbody>
</table>
ORE by volumetric method

Flow = Integral \times Area

Volume Regurgitant = \text{Integral of the regurgitation} \times \text{ERO}

\text{ERO} = \frac{\text{Volume Regurgitant}}{\text{Integral of the regurgitation}}
FLOW_{ERO} = FLOW_{hemisphere}

FLOW = 2\pi r^2 \times \text{Flow}_{velocity}

FLOW_{ERO} = ERO \times V_{MAX}^{\text{MR}}

FLOW_{hem} = 2\pi r^2 \times V_{\text{ALIASING}}

ERO = \frac{2\pi r^2 \times V_{\text{ALIASING}}}{V_{\text{MAX}}^{\text{MR}}}

PISA method
PISA method

Optimize 2D color (AP4c)

Adjust image to optimize PISA

ZOOM over mitral valve

Color flow baseline shift towards flow direction to increase e PISA (15-40 cm/s)

Measure PISA radius, MR VMAX and MR TVI

ERO = \frac{2\pi r^2 \times V_{\text{ALIASING}}}{V_{\text{MAX}} \text{MR}}

RV = ERO \times TVI

REGURGITATION
ECHO in Mitral Regurgitation

PISA FAST method

V_{aliasing}  
PISA radius (r)

MR Jet  
(assuming 500 cm/s)

V_{ALIASING} = 40 cm/s  
ERO = \frac{r_{PISA}^2}{2}
PISA method

PRO
- Less dependent of hemodynamic factors
- Associated valve disease does not affect calculation
- Etiology of MR does not affect calculation
- Can be used with eccentric jet

CONs
- Isovelocity surface is not always a hemisphere
3D evaluation of the jet

ERO direct measurement by vena contracta planimetry
3D PISA method

Exact flow convergence area measurement
The NEXT step
Echocardiographist TASK LIST in MR

- Location of MV disease
- Mechanism of the MR
- Evaluation of severity
- Consequences of MR
- Feasibility of MV repair
Consequences of MR

The echocardiographic assessment of functional mitral regurgitation

Simon Ray

**Table 2** Echo reporting in functional mitral regurgitation

<table>
<thead>
<tr>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left ventricle morphology and function</td>
</tr>
<tr>
<td>LV volumes, shape, and ejection fraction</td>
</tr>
<tr>
<td>Extent and localization of wall motion</td>
</tr>
<tr>
<td>abnormalities including thinning consistent</td>
</tr>
<tr>
<td>with scar</td>
</tr>
<tr>
<td>If indicated</td>
</tr>
<tr>
<td>Dyssynchrony</td>
</tr>
<tr>
<td>Contractile reserve for identification of</td>
</tr>
<tr>
<td>hibernating or stunned myocardium</td>
</tr>
<tr>
<td>Deformation imaging for identification of</td>
</tr>
<tr>
<td>hibernating or stunned myocardium</td>
</tr>
<tr>
<td>Other features</td>
</tr>
<tr>
<td>Left and right atrial size (volumes)</td>
</tr>
<tr>
<td>RV function</td>
</tr>
<tr>
<td>PA pressure</td>
</tr>
<tr>
<td>Severity of TR</td>
</tr>
</tbody>
</table>

European Journal of Echocardiography (2010) 11, i11-i17
Echocardiographist TASK LIST in MR

- Location of MV disease
- Mechanism of the MR
- Evaluation of severity
- Consequences of MR
- Feasibility of MV repair
ECHO in Mitral Regurgitation

Predictors of failed MV repair

Organic MR
- Severe central jet
- Annular dilatation > 50 mm
- Lesions in 3 or more segments
- Lesions of the anterior leaflet
- Severe calcification
- Scarcity of tissue in the leaflets
- Opposite dysfunction

Severe Central jet

Annular dilatation

> 50 mm

Extensive disease

Anterior Involvement

Severe calcification

Rev Esp Cardiol 2011; 64 (12): 1169-1181
### Predictors of failed MV repair

<table>
<thead>
<tr>
<th>Functional MR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coaptation distance $\geq 1$ cm</td>
</tr>
<tr>
<td>Tenting area $&gt;2.5$ cm$^2$</td>
</tr>
<tr>
<td>Posterolateral angle $&gt;45^\circ$</td>
</tr>
<tr>
<td>Interpapillary distance $&gt;20$ mm</td>
</tr>
<tr>
<td>Ventricular akinesia</td>
</tr>
<tr>
<td>EDD $&gt;65$ mm or ESD $&gt;51$ mm</td>
</tr>
<tr>
<td>Sphericity index $&gt;0.7$</td>
</tr>
</tbody>
</table>

- **Coaptation height**: $> 1$ cm
- **Tenting area**: $> 2.5$ cm$^2$
- **Posterolateral angle**: $> 45^\circ$
- **Severe LV dilatation**
- **Ventricular akinesia**
- **Marked sphericity**
When to look for an really expert surgical team

Table 2
Echocardiographic Pattern of Referral for Surgery to Optimize the Probability of Mitral Valve Repair (Approximate Stratification by Number of Cases per Year Performed by a Single Surgeon).

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Dysfunction</th>
<th>Calcification</th>
<th>Lesions</th>
<th>Probability of repair</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;50 cases/year</td>
</tr>
<tr>
<td>Fibroelastic</td>
<td>II</td>
<td>No/annular</td>
<td>Posterior localized prolapse (P2)</td>
<td>Feasible</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>No/annular</td>
<td>Anterior prolapse</td>
<td>Probable</td>
</tr>
<tr>
<td>Barlow</td>
<td>II</td>
<td>No/annular</td>
<td>Posterior localized prolapse (P2)</td>
<td>Feasible</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>No/annular</td>
<td>Prolapse of 3 or more segments</td>
<td>Probable</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>Leaflets</td>
<td>Prolapse of 3 or more segments</td>
<td>Improbable</td>
</tr>
<tr>
<td>Endocarditis</td>
<td>I</td>
<td>No</td>
<td>Perforation</td>
<td>Probable</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>No</td>
<td>Prolapse</td>
<td>Probable</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>No</td>
<td>Destructive lesions</td>
<td>Improbable</td>
</tr>
<tr>
<td>Rheumatic</td>
<td>IIIA</td>
<td>Annular</td>
<td>Malleable anterior leaflet</td>
<td>Probable</td>
</tr>
<tr>
<td></td>
<td>IIIA</td>
<td>Leaflets</td>
<td>(Rigid) calcified anterior leaflet</td>
<td>Improbable</td>
</tr>
<tr>
<td>(Functional) ischemic</td>
<td>I</td>
<td>No</td>
<td>Dilatation or annular deformation</td>
<td>Feasible</td>
</tr>
<tr>
<td></td>
<td>IIIIB</td>
<td>No</td>
<td>Tethering</td>
<td>Feasible</td>
</tr>
<tr>
<td></td>
<td>IIIIB</td>
<td>No</td>
<td>Predictors of repair failure</td>
<td>Improbable</td>
</tr>
</tbody>
</table>
Conclusions

Echocardiography is the basic tool for MR evaluation

- **Location** of the disease
- **Mechanism** of MR
- **Evaluation of severity**
- **Consequences** of MR

Evaluation of MR should be oriented towards therapy

- Try to speak the same language than surgeons
- Look for the possibility of valve repair
Special thanks to Dr. Bernard Cosyns for some of the images used in the presentation