3D Echo In The Assessment of Valve Morphology

- Raluca Dulgheru -
CHU Liege, Belgium
I, Raluca Dulgheru, DO NOT HAVE a financial interest/arrangement or affiliation with one or more organizations that could be perceived as a real or apparent conflict of interest in the context of the subject of this presentation.
“All directions” journey around the heart
Valves are inherently 3D structures

From Morphology to Dysfunction......

Disease/Etiology

SEE Morphology

Lesion

Dysfunction

Better understanding of valvular morphology (LESION) by 3DE

Better understanding of valve dysfunction

Potential benefits regarding valve repair procedures
3DE Advantages in Assessing Valve Morphology

- **MITRAL VALVE**
  - realistic representation
  - multiple orientations

- **AORTIC VALVE**
  - quantitative analysis (less/no geometrical assumption)
  - infinite possibility of cut planes (better understanding of valve morphology)

- **TRICUSPID VALVE**
  - improved assessment of valve dysfunction (stenosis/regurgitation)

- **PULMONIC VALVE**
3DE …not always as good as it sounds!

- **Sector Size**
- **Frame Rate**
- **Image Resolution**

3D Image quality depends on 2D Image quality

- Optimal sector size (see the valve, keep landmarks)
- Sufficient spatial resolution
- Adequate temporal resolution

3DE complements not replaces 2DE

Any valve morphology/dysfunction needs FIRST comprehensive 2DE evaluation, followed by 3DE
3DE Modalities for Valve Morphology Assessment

X-plane / Multiplane (bi and triplane views)

Reference plane

Lateral plane

Excellent frame rate

Color Doppler can be added

Multiple scanning planes no probe manipulation
3DE Modalities for Valve Morphology Assessment

X-plane / Multiplane (bi and triplane views)

Real time “narrow volume” – “In depth view” of the 2D image plane

Good frame rate
Best for guiding procedures
3DE Modalities for Valve Morphology Assessment

- **X-plane / Multiplane (bi and triplane views)**
- Real time “narrow volume” – “In depth view” of the 2D image plane, best for guiding procedures
- **Real time “3D Zoom”**

**Best for Valve Morphology**

- Good spatial resolution
- Satisfactory temporal resolution
3DE Modalities for Valve Anatomy Assessment

X-plane / Multiplane (bi and triplane views)

Real time “narrow volume” – “In depth view” of the 2D image plane, best for guiding procedures

Real time “3D Zoom” – best for Valve Morphology

Full Volume – largest sector available

Stitching together multiple smaller volumes, ECG gating

Excellent trade off (good spatial and temporal resolution), largest sector

Stitching artifacts: irregular HR, breathing
3DE Mitral Valve Morphology Assessment

- 3DE Image Acquisition -

Starts from 2D mid-oesophageal 4ch view

3D Full Volume

Optimize 2D image:
- Gain
- Sector width
- Sector depth

Full volume, breath holding

Starts from 2D bicommissural view

Lateral plane

Zoom 3D

Elevational plane

Zoom 3D volume

Aorta UP
3DE Mitral Valve Morphology Assessment

SURGEON’S view

LA appendage  Aorta

VENTRICULAR view
3DE Mitral Valve

Off line Multiplane review/Flexi-slice

Annulus

Leaflets

Subvalvular apparatus

Dynamic Interaction
The Mitral Valve - Annulus -

NON planar, saddle shape in normal subjects

Highest points

Lowest points

D shape when viewed from above, largest AL to PM commissures

Levine et al. Circulation 1989
The Mitral Valve - Annulus -

- Antero-posterior Diameter
- Intercommissural Diameter
- Mitral Annulus Perimeter
- Mitral Annulus Height
- Annulus Area In Projected Plane

No geometrical assumptions !!!!!
The Mitral Valve – Annulus size & shape -
- in secondary mitral regurgitation -

Watanabe et al. Circulation 2005
The Mitral Valve – Annulus size & shape -

- in primary mitral regurgitation Barlow’s disease and FED -

Mitral annulus area

- Controls
  - 7.5±2.1 cm²

- FED
  - 12±3.2 cm²

- Barlow’s
  - 15.4±3.8 cm²

p<0.05

Maffessanti et al. JASE 2011
The Mitral Valve – Annulus dynamics -

- change in mitral annulus area between diastole and systole -
- The SPHINCTER function of the mitral annulus -

~ 25% reduction in annular area with systole in normal subjects

Flachskampf et al. JASE 2000
3DE and MV Morphology - Leaflets -

- unique “en face” – Normal Mitral Valve

**ANTERIOR LEAFLET**
- trapezoid shape
- artificially divided into A1-A2-A3 scallops
- 1/3 of the annular circumference
- in continuity with NCC of the aortic valve (*intervalvular fibrosa*)

**POSTERIOR LEAFLET**
- crescentic shape
- 2 well defined indentations
- 3 individual scallops (P1-P2-P3)
- 2/3 of the annular circumference

**POSTERO-MEDIAL & ANTERO-LATERAL COMMISSURES**
3DE and MV Morphology - Leaflets -

- unique “en face” view -
Rapid and confident identification of the valve lesion

Leaflet perforation

Carpentier Type I

Complex Prolapse with Flail Leaflet
Barlow’s Disease

Carpentier Type II
3DE and MV Morphology - Leaflets -

- unique “en face” view -
Rapid and confident identification of the valve lesion

Higher accuracy than 2D TOE for:
- Cleft
- Leaflet perforation
- Commissural disease

Rapid localization of vegetation’s attachment point to the leaflets
Specific questions in Primary MR. Why move to 3D?

- Which scallop is affected? Surgeon’s view and MPR view
- Are the commissures involved? Surgeon’s view and MPR view
- Are there any calcifications? 2D better than 3D
- Is there lack of valve tissue? Extent? Surgeon’s view, off line analysis
- Is there any abnormality of the MV apparatus? 3D gives in one volume the dynamic relationship between MV leaflets and subvalvular apparatus
- Is there severe annular dilatation? Mitral Annulus Reconstruction – no geometrical assumptions
3DE MV Morphology in SMR

- LV dilation/remodeling
- Papillary muscles apical/outward displacement
- Tethering
- Restricted systolic leaflet motion
- Apical displacement of coaptation line & decreased coaptation surface
- Valve dysfunction
3DE MV Morphology in SMR “surgeon’s view”

“Funnel shape” MV

Symmetric tethering

Asymmetric tethering

Carpentier Type IIIb
3DE MV Morphology in MS

- unique “en face” / ventricular view -
Rapid and confident identification of the valve lesion

- Doming of the anterior valve leaflet in diastole
- Commissural/chordae fusion
- Posterior Leaflet systolic and diastolic restriction (shortened chordae)
- Non-planar mitral valve orifice

Assists patient’s selection for PMC

MV area by planimetry

Degree of commissural calcification (Suitability to PMC)

Careful search for Carpentier IIIa MR

Pliability of the AML
Accurate assessment of MA area by planimetry

3D TTE biplane:
- Good alignment
- Orthogonal plane in systole at leaflet opening site
- Advantage over 2DE, better control of the cutting plane orientation

MVA = 0.9cm²

3D TTE 1/multiple beat volume or 3D zoom mode:
- off line cropping of the volume
- smallest orifice is planimetered
- some vendors allow planimetry directly on the cropped volume
3DE - The Aortic Valve

**Drawbacks:**

**TOE:**
- Anterior position relative to probe
- Oblique incidence of US
- Thin cusps

**TEE:**
- Superior position relative to apex (best viewed in PSLA)
- Oblique incidence of US
- Thin cusps

**Image Acquisition:**

**Live 3D from mid-oesophageal short axis/3ch view**

**Full Volume**

**3D Zoom**

**Parasternal long axis:**
- Biplane
- Full Volume
Elegantly depicts AV leaflet morphology (bicuspid vs. tricuspid aortic valve)

- Advantages -

- Aortic view and ventricular view

Rapidly identifies abnormalities (masses attached to leaflets)

Fibroelasthoma

Functional AR

Singh et al. Echocardiography 2009
3DE - The Aortic Valve

- Improved assessment of AS severity (anatomic AVA) 3D TTE

Planimetry of the anatomic AVA

Biplane from PSLA

Anatomic AVA = 0.85 cm²

Still frame in mid-systole, cutting plane at the level of AV tips
3DE - The Aortic Valve

- Improved assessment of AS severity (anatomic AVA) 3D TOE -

Off line planimetry of the anatomic AVA

3D Zoom or Full Volume data set

Anatomic AVA = 1.35 cm²

Goland et al. Heart 2007

![Graph showing the relationship between Cath and RT3D](image)
3DE - The Aortic Valve

- Improved assessment of AS severity (effective AVA) -
- LVOT Geometry -

3 dimensional imaging techniques say : LVOT is NOT circular !!!!

Off line planimetry of the LVOT cross section without geometrical assumptions

CSA = 4.82 cm²

Khaw et al. Int J Cardiol 2009
3DE - The Tricuspid Valve

**Drawbacks:**

**TOE:**
- anterior position relative to probe
- oblique incidence of US
- thin cusps

**TEE:**
- retrosternal anterior position makes imaging of the lateral aspect of the valve difficult
- oblique incidence of US
- thin cusps

- **Image Acquisition**

- Full Volume from mid-oesophageal 4ch view

- Modified Apical View focused on the RV: Full Volume

- 3D Zoom Mode
3DE - The Tricuspid Valve

- Annular Morphology -
  - Complex oval, saddle shape
  - Non-planarity preserved through cardiac cycle, sphincter function
  - More circular and flattened in secondary TR

- Leaflets Morphology -
  - Leaflet restriction
  - Leaflet thickening
  - Prolapse
  - Perforations
  - Vegetations

Ton-Nu T et al. Circulation 2006
Conclusions

• Feasible and valuable in clinical practice, but needs training and experience

• For mitral and aortic valve morphology 3D TOE is preferred, especially when planning surgery

• Image quality is a trade off between sector size, temporal and spatial resolution

• Better understanding of valve dysfunction

• Helps in planning surgery

• Does not replace 2D echocardiography, but completes the study of valvular morphology