Quantification of Aortic Valve Stenosis using Transesophageal Real-Time 3D Echocardiographic Images

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Background

Aortic stenosis (AS) is the most common native valve disease. Its severity can be assessed by calculating **Aortic Valve Area** (AVA) using :

- catheter-based invasive measurements or
- echocardiography.

Echocardiographic methods to measure AVA include:

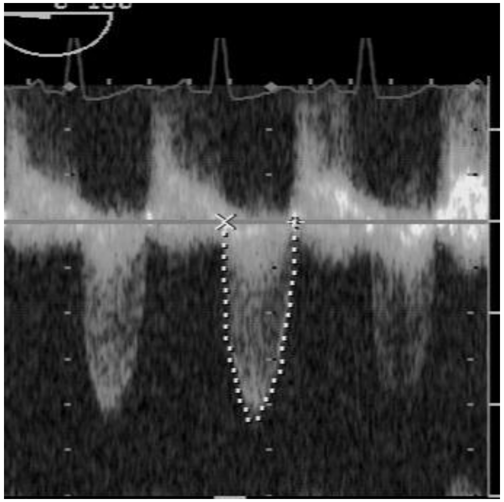
- 2D continuity equation
- Planimetry on 2D and reconstructed 3D Transesophageal Echocardiography

2D Continuity equation limitations

Geometrical assumption in 2D continuity equation:

$$AVA = \frac{Area_{LVOT} * VTI_{LVOT}}{VTI_{AV}} = \frac{(Diameter_{LVOT}^{2} * 0.7854) * VTI_{LVOT}}{VTI_{AV}}$$

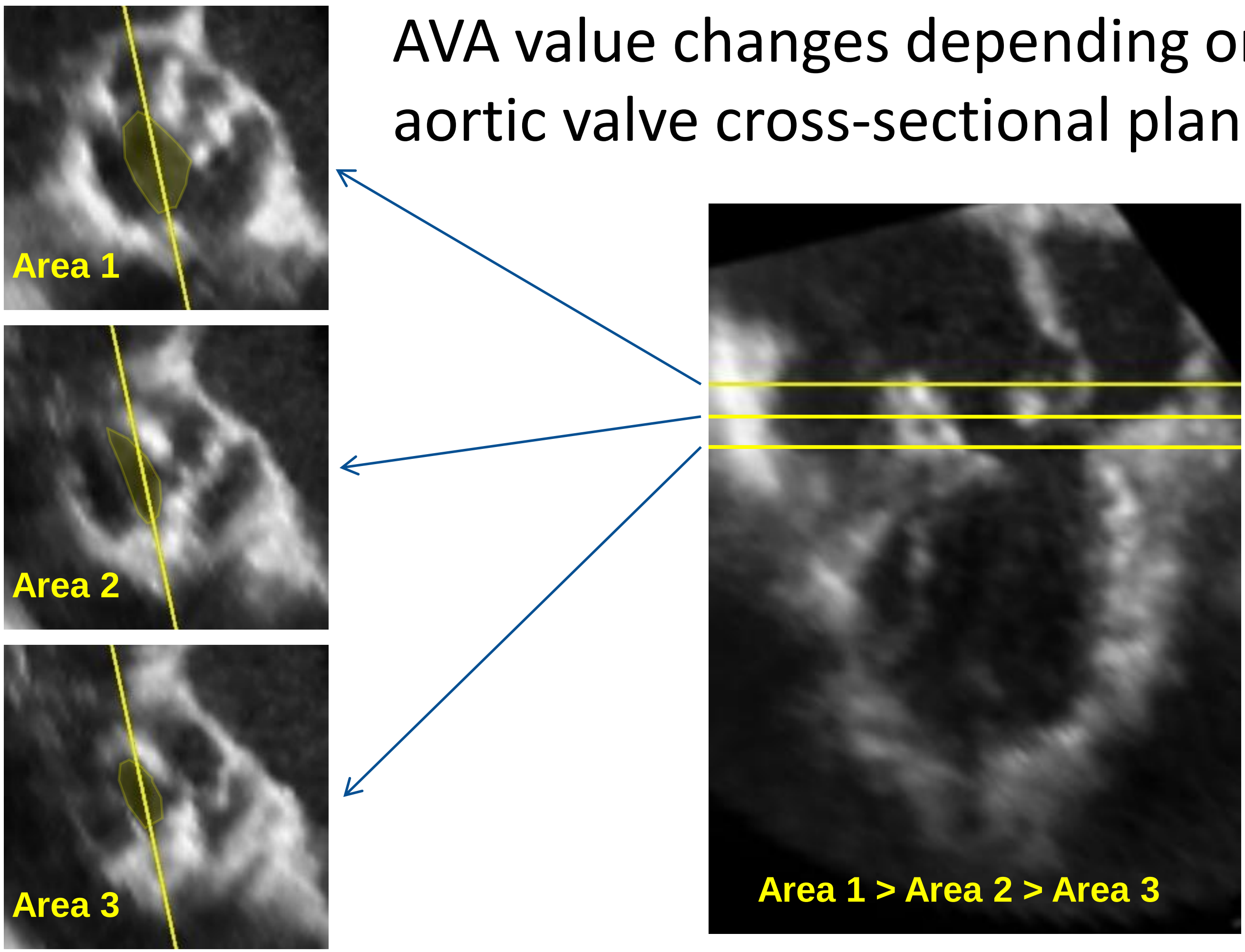
Left ventricular outflow tract cross-sectional area is hypothesized circular.



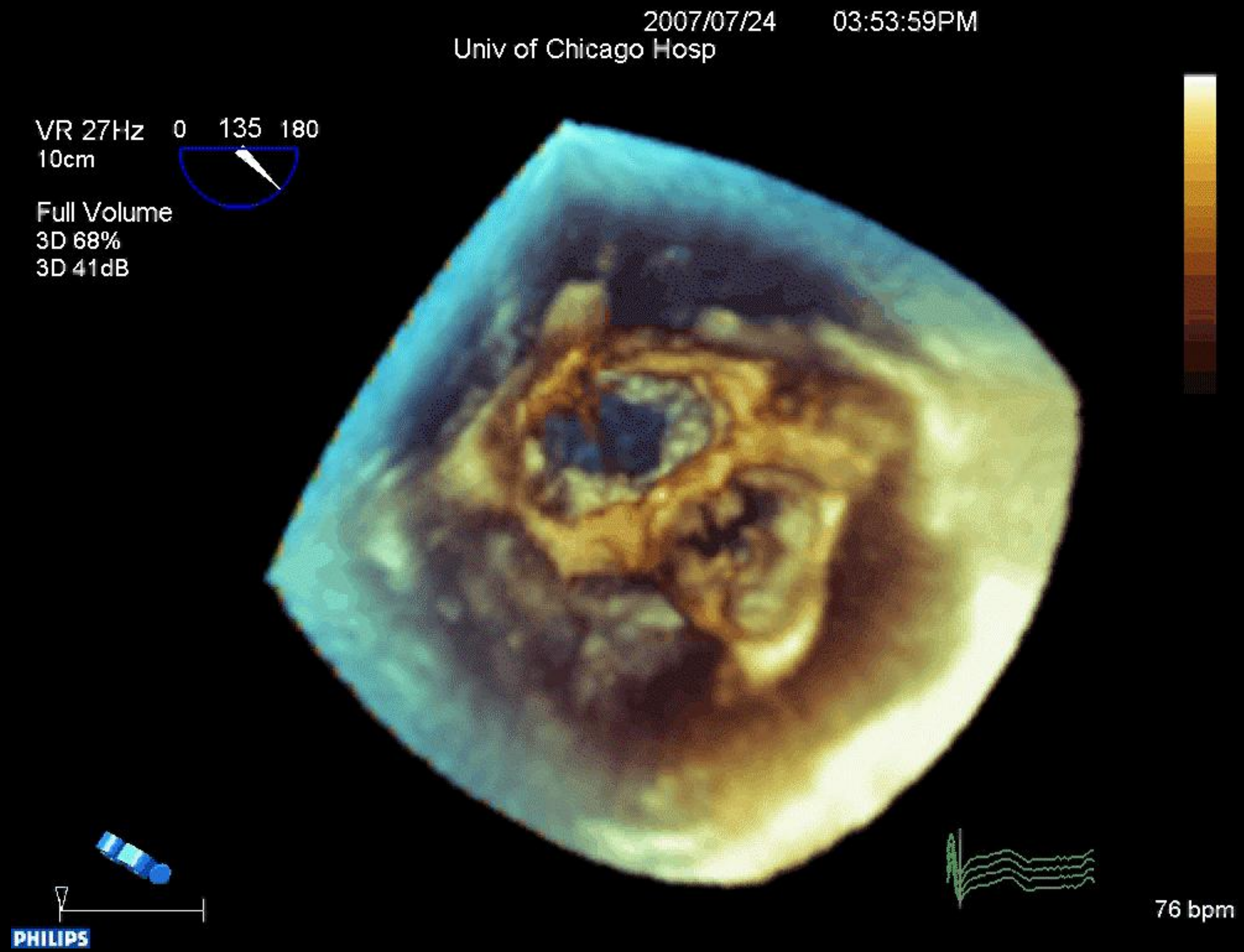
Velocities are computed using Doppler, thus these measurements are angle dependent.

Planimetry limitations

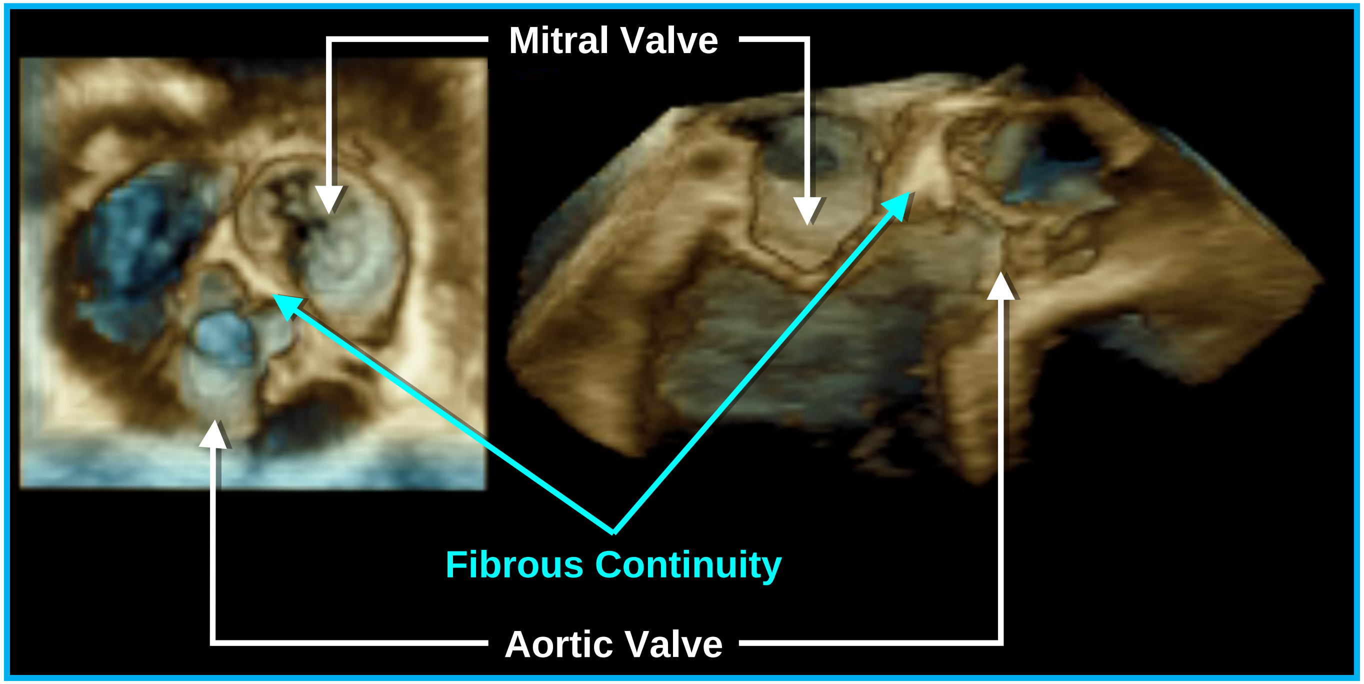
AVA value changes depending on selected aortic valve cross-sectional plane.



Real-time 3D mTEE



Aim



- The aim of this study was to present an **alternative semi-automatic non-invasive** method to estimate **AVA** in patients with AS using **new 3D matrix TEE imaging**
  - **without** geometrical assumption or continuity equation
  - **without** manual cross-sectional plane selection.

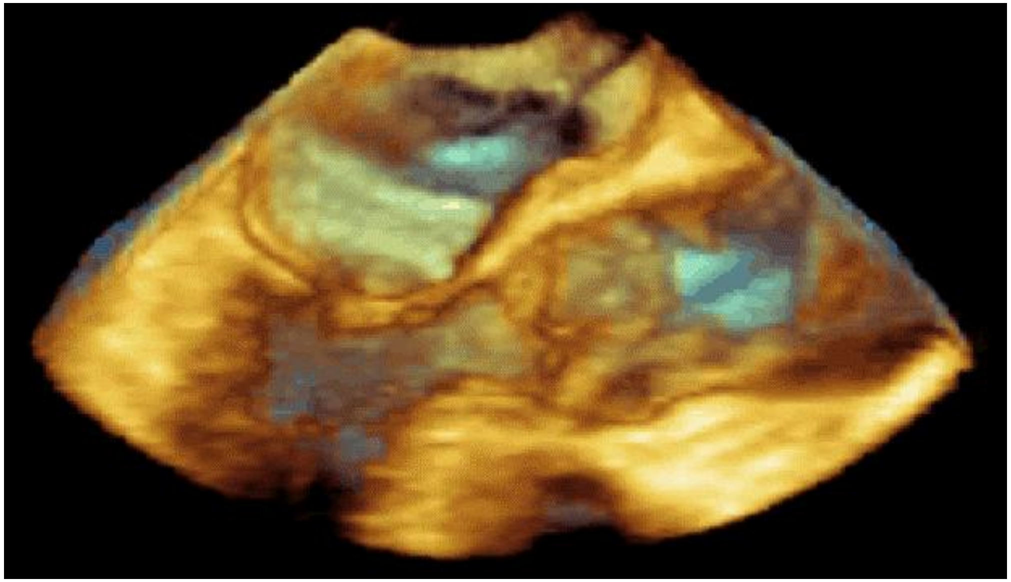
Methods

MTEE imaging (Phillips, iE33) was performed on:

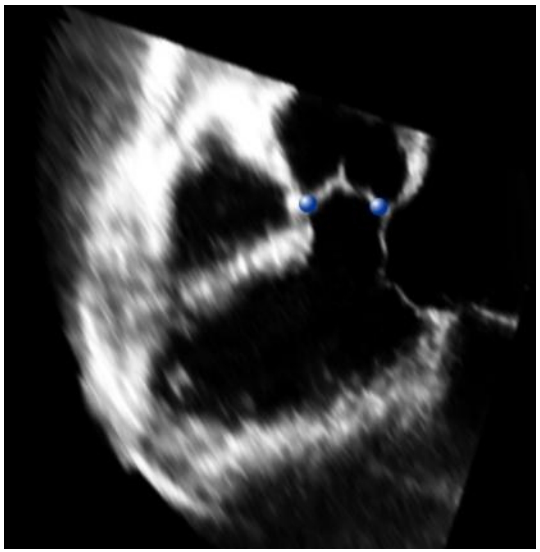
- **10 patients** with normal valves undergoing clinically indicated TEE
- **10 patients** with AS undergoing clinically indicated TEE

Data Acquisition

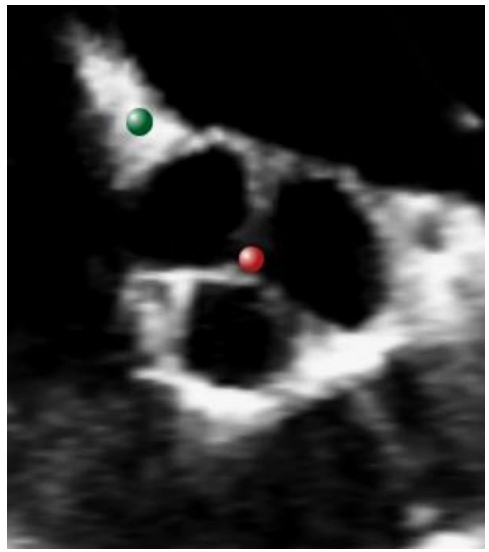
- The probe was positioned at the mid-esophageal level at a **120 tilt**
- Wide-angled acquisition mode
- ECG gating
- 7 narrow pyramidal scans



Aortic Annulus (AoA) detection



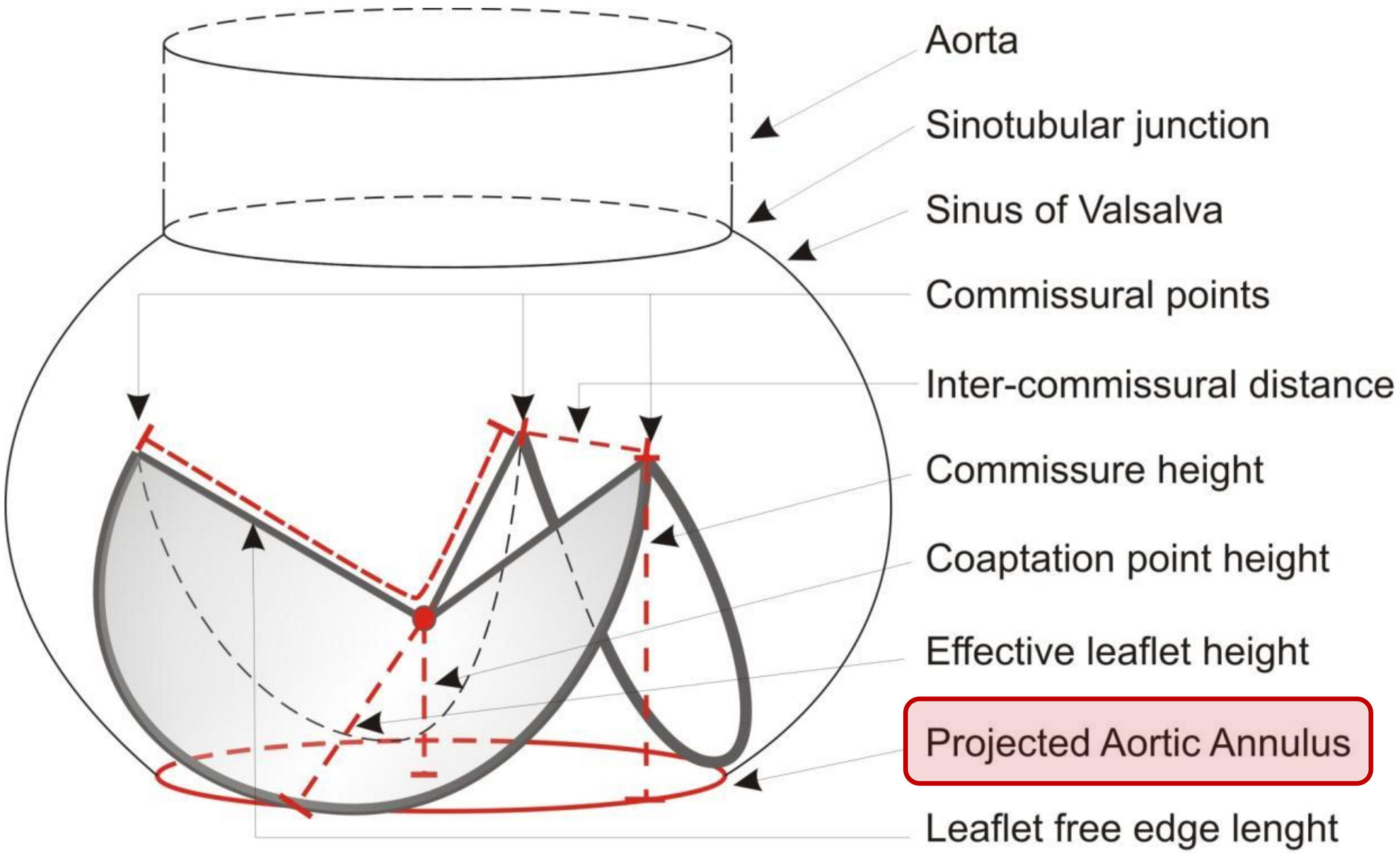
15 vertical cut planes passing through aortic valve axis (12   apart)



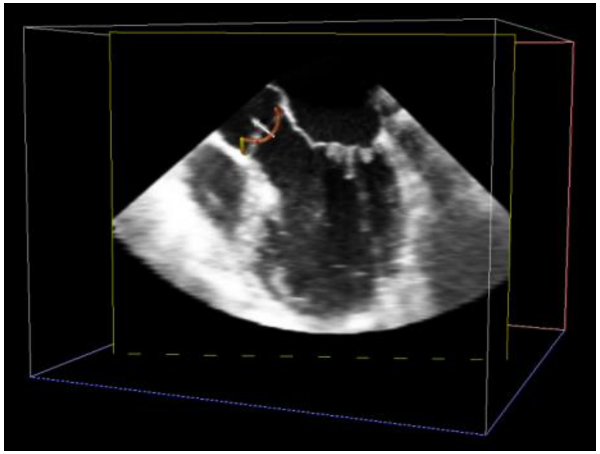
Inter-atrial septum and coaptation point as anatomical reference landmark

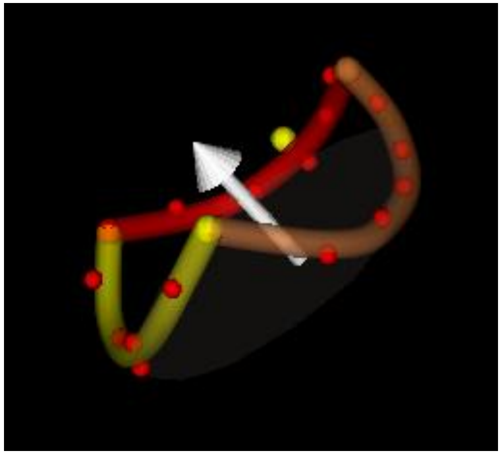
Aortic Annulus **3D reconstruction** and **Tracking** throughout cardiac cycle

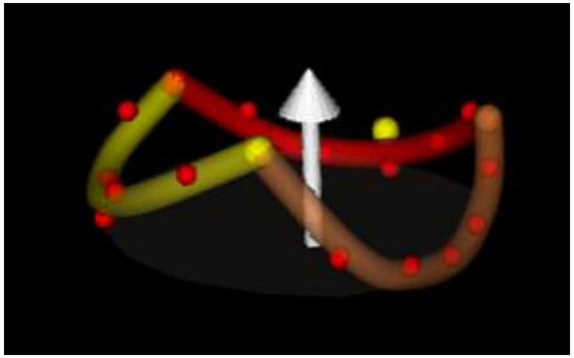
Aortic Annulus measurements



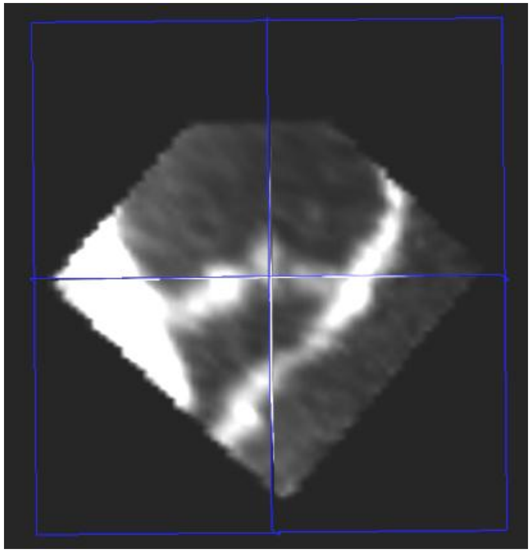
Maximum Intensity Projection





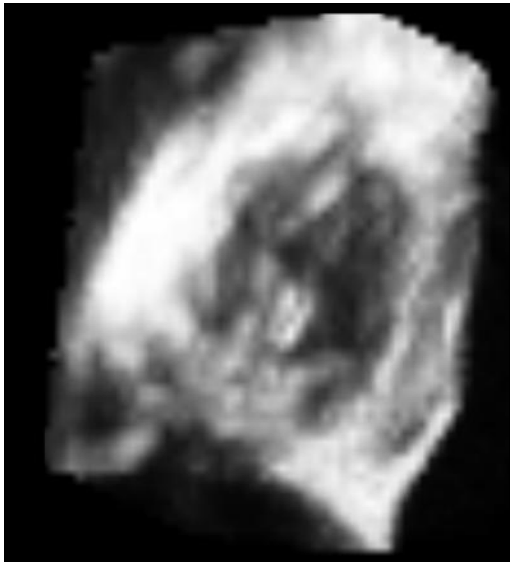


Aortic annulus is used to **crop** data and then to **rotate** it in aortic valve axis direction



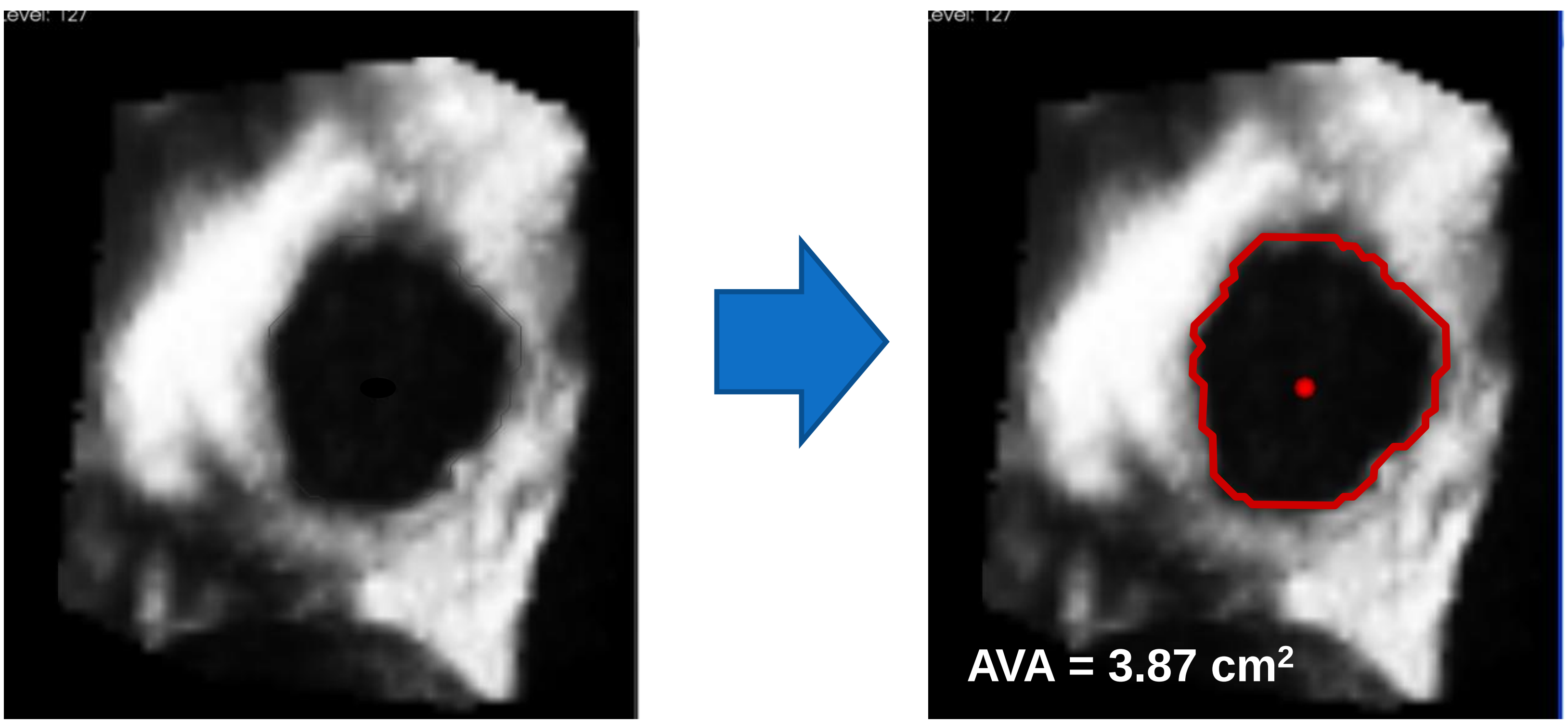
The result is a 3D Volume containing only aortic valve structures

Using this data a Maximum Intensity Projection (MIP) is computed



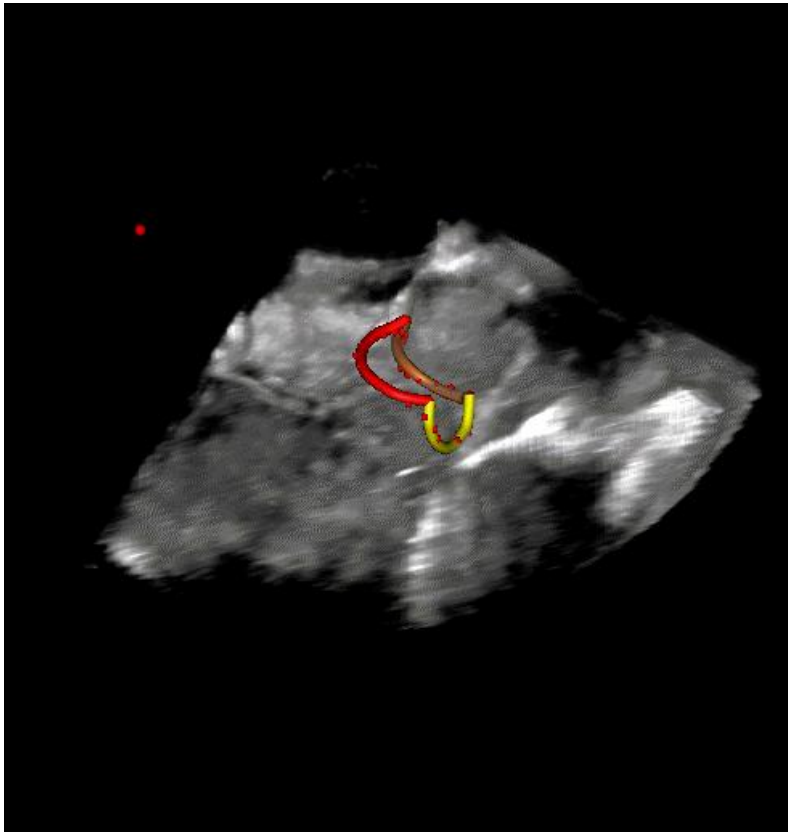
Aortic Valve Area measurement

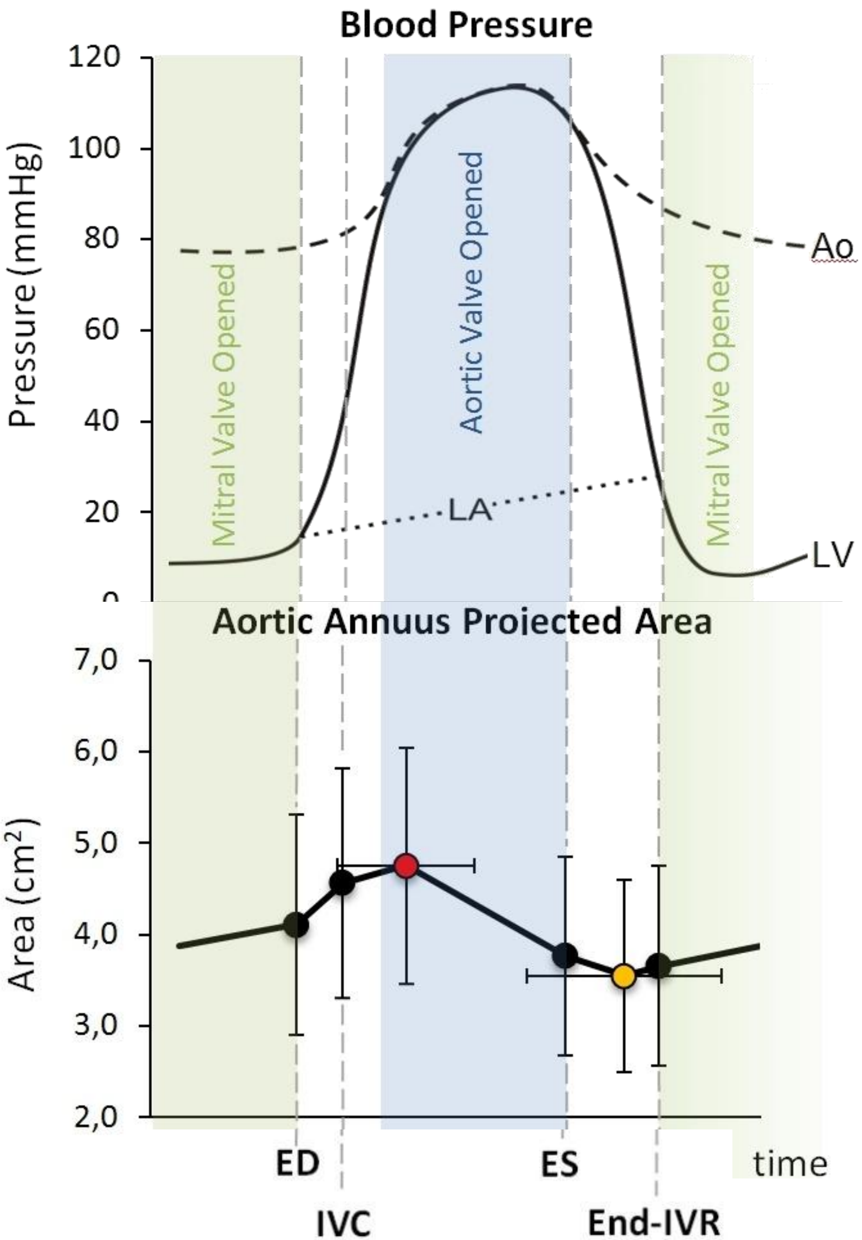
Finally the maximum intensity projection image is segmented in every frame in the cardiac cycle to obtain the area of aortic valve orifice



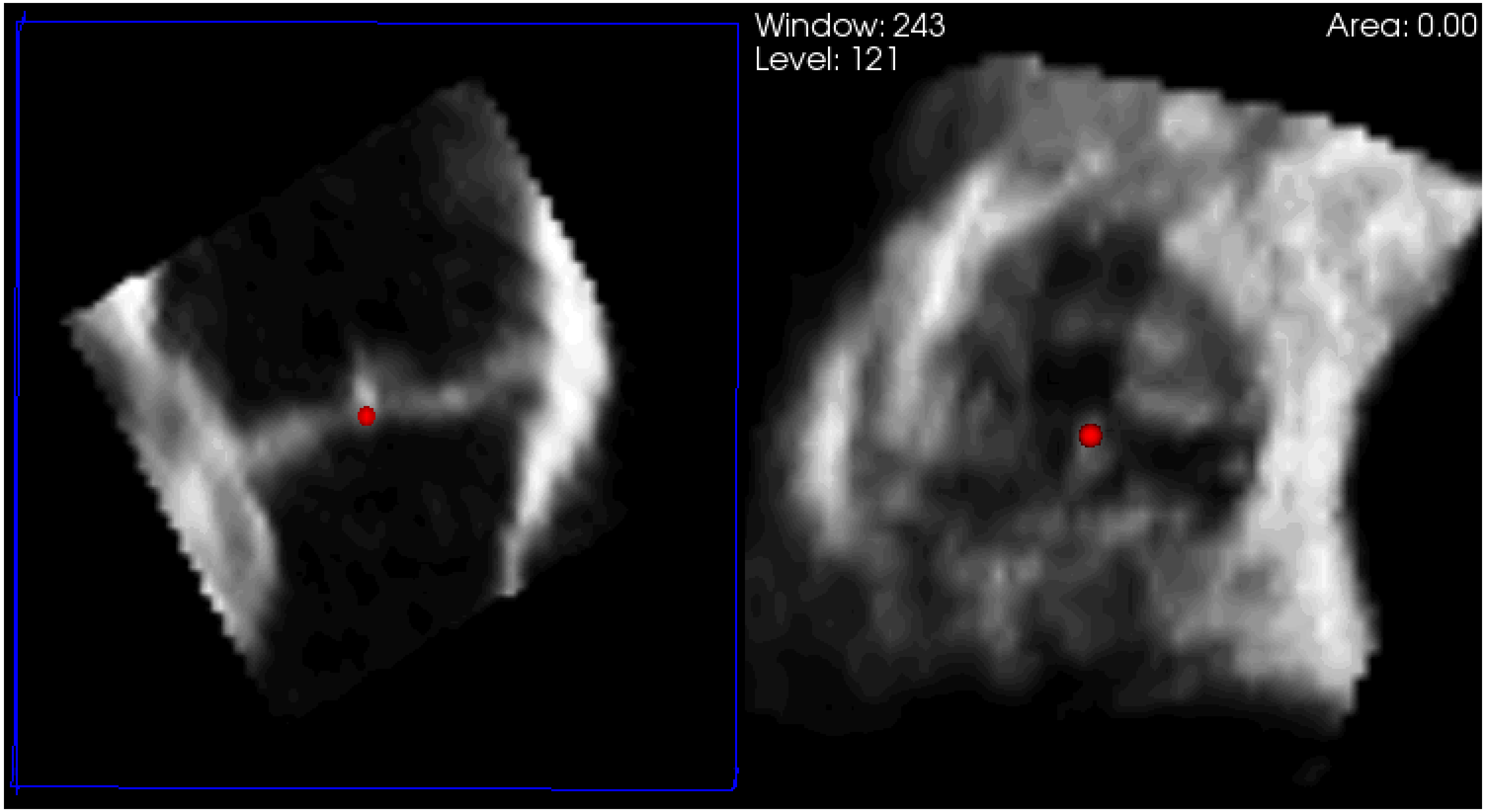
Results

Aortic annulus Projected Area

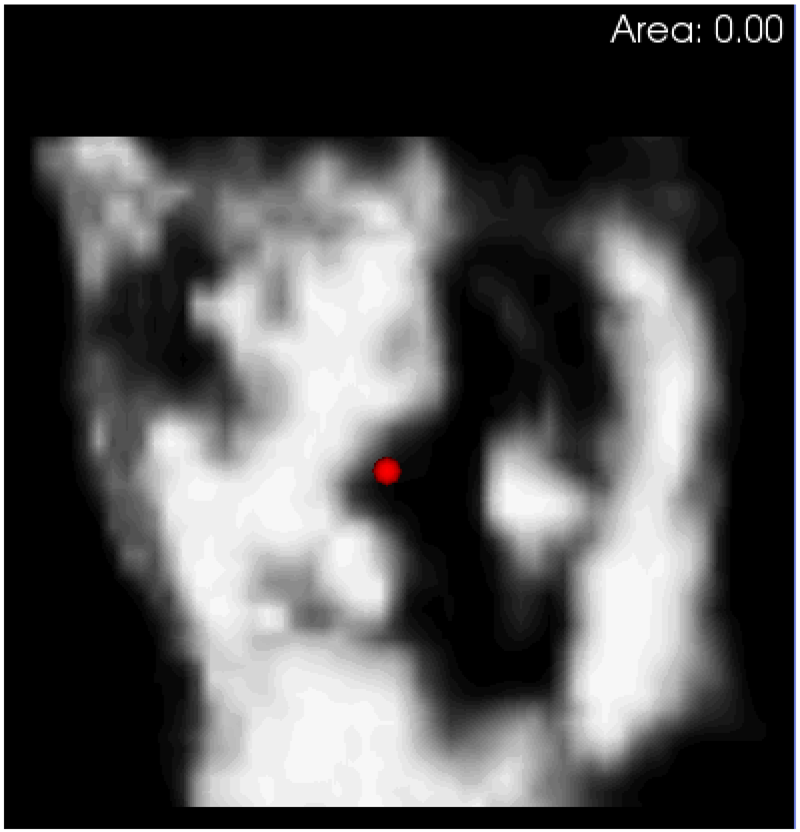


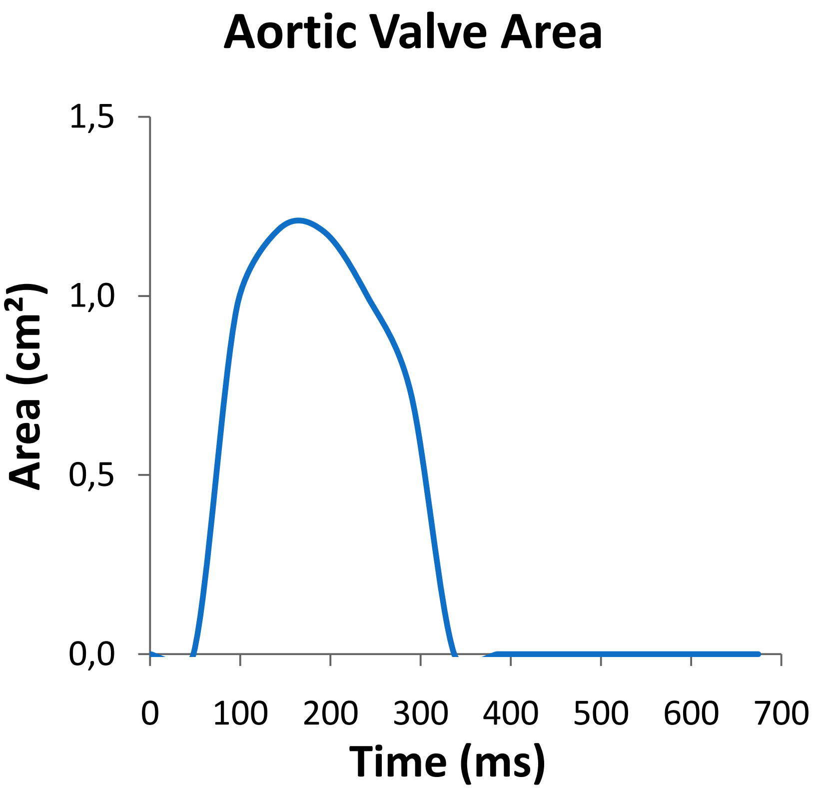


Results – Aortic Valve Area (Normal)



Results – Aortic Valve Area (AS)





Main quantitative results

Table 1. Measured parameters in normal (n=10) and AS (n=10) subjects

	AS	Normal	p value
Mean AVA during ejection (cm^2)	0.94 0.28	2.89 0.63	<0.001
AVA, 2D continuity equation (cm^2)	0.89 0.31	-	-
AVA/AoA area	25% 11%	69% 11%	<0.001

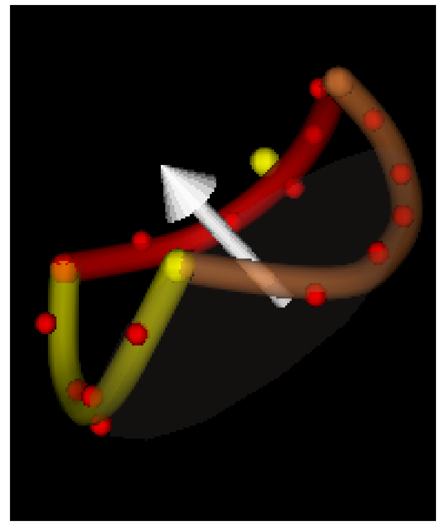
Good correlation (r=0.93) was found between AVA computed using 2D continuity equation and AVA computed using our method.

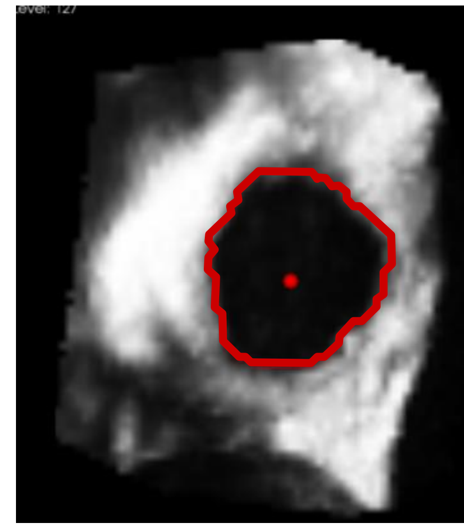
Aortic annulus ability to change dimension during cardiac cycle was severely reduced in AS subjects

AoA projected area and AVA are also strictly correlated. In case of AS, the ratio between AVA and AoA area is significantly reduced. This parameter reflects the ability of the AV to open and does not depend on AV size because it is normalized by AoA dimension.

Conclusions

- Our technique allows quantitative measurements of dynamic AV parameters in three dimensions, fully exploiting the 3D nature of the MTEE data.





- AoA was identified in 3D and projected AoA area was computed.
- AVA were automatically measured throughout the cardiac cycle without using geometrical assumptions or continuity equation.
- In conclusion, our methodology constitutes a new tool for objective assessment of the severity of AS.