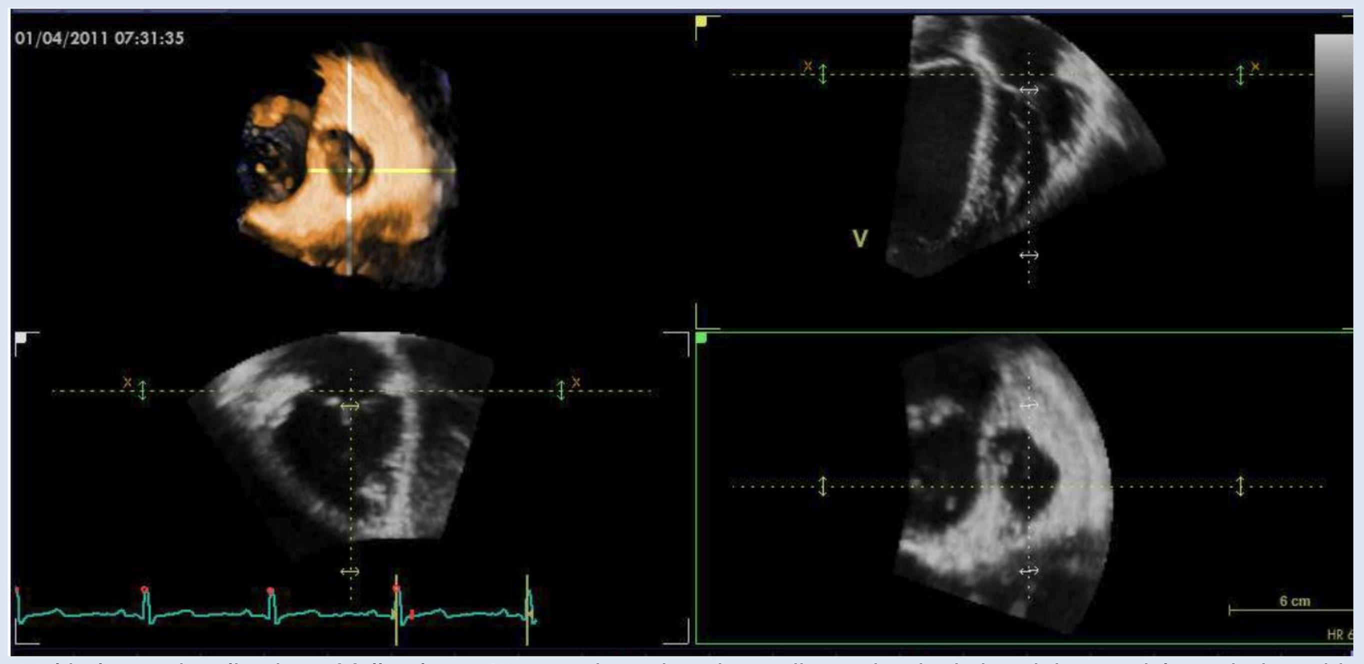
# A novel software tool to semi-automatically characterize tricuspid valve function and shape using trans-thoracic 3D echocardiography

*Federico Veronesi[1], Denisa Muraru[2], Karima Addetia[3], Cristiana Corsi[1], Claudio Lamberti[1], Roberto M Lang[3], Victor Mor-Avi[3], Luigi P Badano[2]*
*[1]DEI, Alma Mater Studiorum – Università di Bologna, Italy*
*[2]University of Padua, Department of Cardiac, Thoracic and Vascular Sciences, Padua, Italy*
*[3]University of Chicago Hospitals, Chicago, IL, USA*

## Background

Tricuspid valve assessment plays an important role in the diagnosis and management of a variety of cardiac disease states. Decision regarding when to surgically repair the tricuspid valve (TV), while operating on the mitral valve, is a topic of debate, and is frequently based solely on 2D measurement of TV diameters. In-depth morphological and functional characterization of patient TV will facilitate decision-making. Nowadays software tools allow for mitral valve detection and tracking, however because of the geometric and *a priori* knowledge included in these tools it is not possible to use them for TV. Moreover, TV is best visualized in apical thrans-thoracic acquisition and nowadays tools for valve analysis work with TEE 3D data,.




Multi-planar visualization of full volume 3D transthoracic echocardiography depicting right ventricle and tricuspid valve. On top left panel volume rendering is showed. Screen capture from commercially available 3D echocardiographic data analysis software.

## Aim

Consequently, we sought to develop a new software for 3D analysis of TV morphology from real-time 3D trans-thoracic echocardiography and to test it on several clinically relevant cases.

## Patient Population

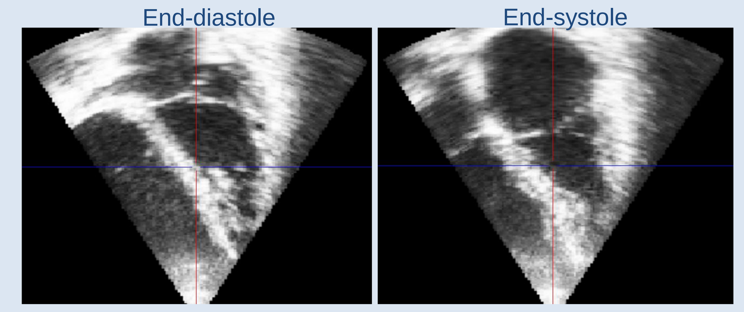
Real-time 3D transesophageal echocardiographic images were acquired using Philips iE33 with the matrix-array X7 probe on 30 patients including normal, pulmonary hypertension, flail leaflet (figure) and functional TR subjects. In order to test feasibility both zoomed and full volume acquisition were performed. For zoomed data, two consecutive beats, synchronized with ECG R-wave, were acquired using zoom mode in order to have maximal spatial resolution, to avoid stitch artifacts and to allow complete cardiac cycle acquisition. For full volume data, the acquisition was centered on right ventricle.

## Methods

We developed a software tool that in six steps guide the physician through the semi-automatic measurements of the complete TV structure in 3D and throughout cardiac cycle. User identifies TV annulus (TVA) points on rotated planes; to trace the 3D TVA smooth spline interpolation is used. The software automatically tracks TVA frame by frame through the cardiac cycle. On stabilized 3D dynamic TV view, manually identified commissures , coaptation and, in case of insufficiency, orifice border are used to automatically detect TV leaflets. Finally automatic computation of 3D parameters is performed.

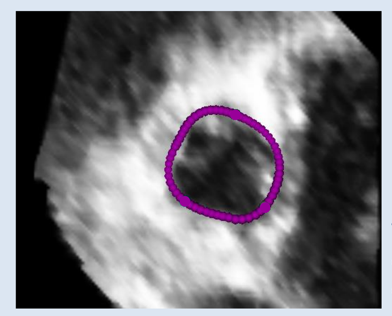
### Step 1

- Identification of end-diastolic and end-systolic frames.
- Identification of 2-chambers and 4 chambers view.




### Step 2

Computer assisted annulus delineation.

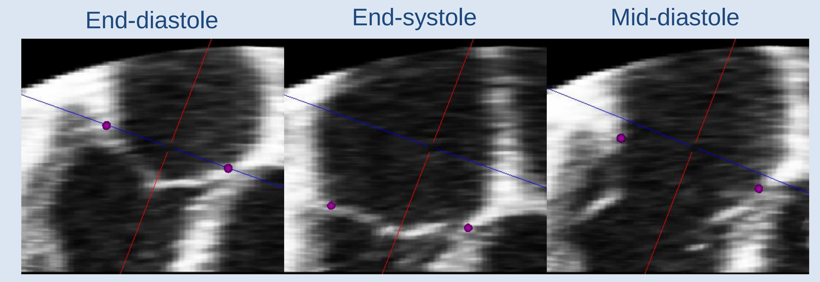


Tricuspid annulus super imposed on cross-sectional plane placed on valvular plane

The program traces an initial guess of the TA, centered on the intersection of the previously identified planes. The user has to move the points representing the intersection between 3D annulus and the cross sectional plane in the position corresponding to the anatomical tricuspid annulus. The procedure is repeated as many time as necessary on planes rotated around the TA center in steps of 30°. In order to allow for fast and consistent annulus delineation, TA points are interpolated in real time using smooth spline algorithm with variant weights.

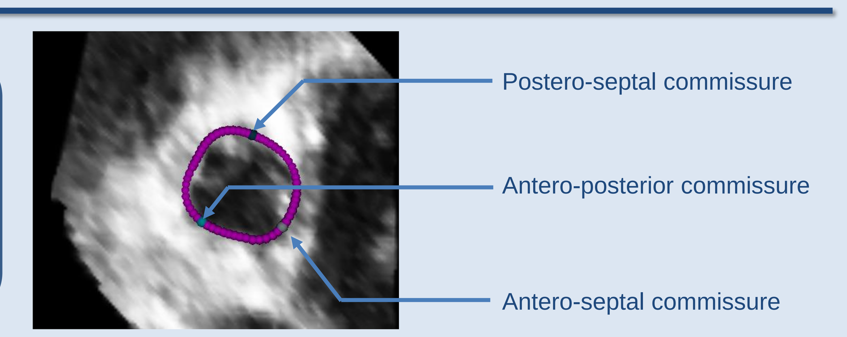
### Step 3

Annulus tracking. The software automatically tracks selected points throughout the cardiac cycle.



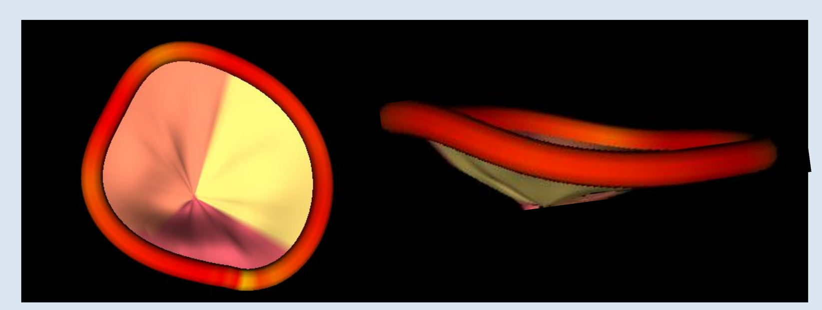

### Step 4

Commissures are manually identified on 'stabilized' short axis plane.




### Step 5

- Manual identification of coaptation point/orefice on short-axis cross-sectional plane.
- Automatic tracing of tricuspid leaflet using active contours



### Step 6

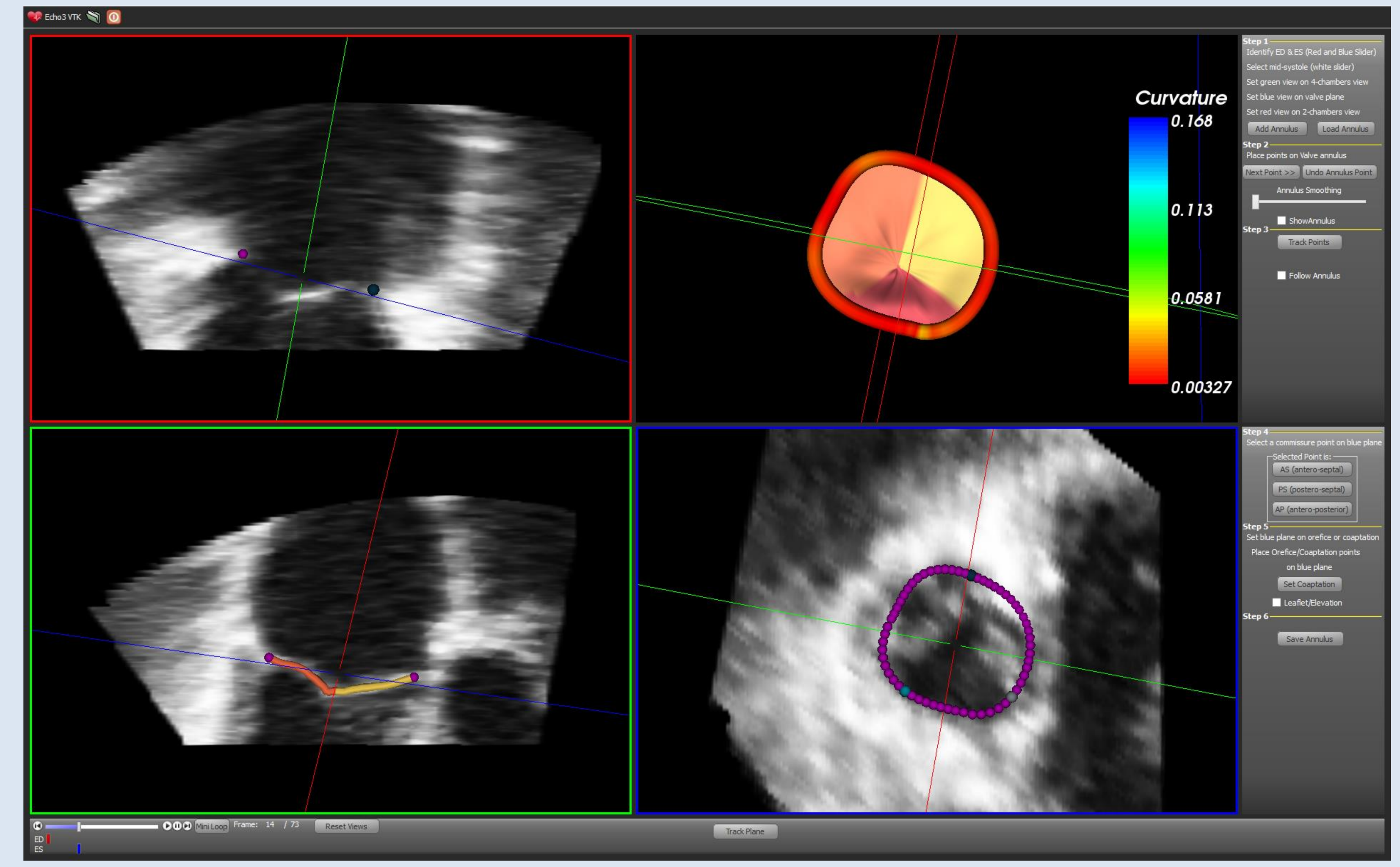
Save data and automatic computation of tricuspid valve measuremets.

At the time od saving the data, the software automatically compute several parameters describing TV morphology, TV dynamic behaviour and TV leaflet geometry.

## Results

Computed parameters included:

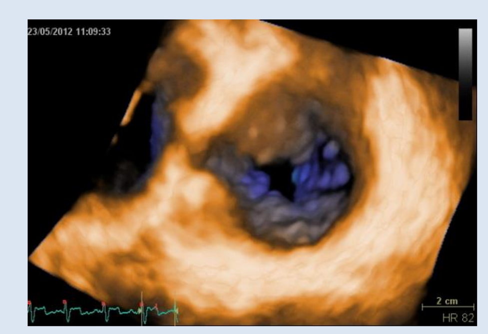
- maximum displacement(11.8±4.4mm);
- minimum TV area(8.1± 2.1cm²);
- ED TV Area(10.0 ± 2.3cm²);
- eccentricity(0.56±0.12);
- segment lengths(anterior:3.7±0.8, posterior:3.3±0.8, septal:3.3±0.5mm);
- leaflet angle(anterior:36±7°, posterior:43±11°, septal:45±10°);
- tenting volume(3.4±1.6ml).



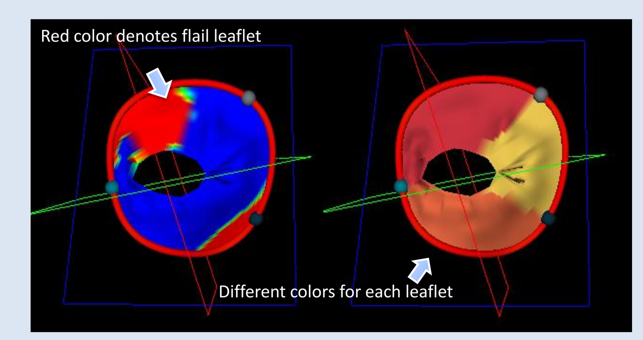

In this figure is presented the Graphic User Interface (GUI) of the tool developed. Using VTK and Qt open source C++ library:

- Top left: 2-chamber view. Top right: 3D visualization of the interpolated tricuspid annulus (TA). And tricuspid leaflet (Orange=Posterior, Red=Anterior and Yellow=Septal). Bottom left: 4-chambes view with superimposed the profile of septal and posterior leaflet. Bottom right: 2D slice on the TV plane with superimposed TA interpolation.
- Right bar: step-by-step guide to perform TA tracing.
- Bottom bar: frame controls (play, stop, etc.).

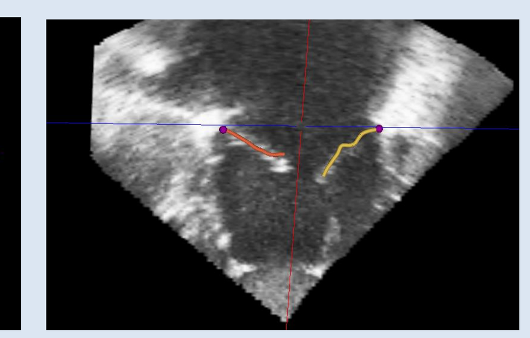
Example of TV analysis on a subject with severe tricuspid regurgitation and prolapsed leaflet.



Volume Rendering (Surgical View, GE)




3D TV computed by the software



Automatically traced leaflet

## Conclusions

Presented tool allow semi-automatically 3D quantification of TV through cardiac cycle supplying new morphological and functional indexes and potentially helping TV surgery decision-making and pre-operative virtual planning.