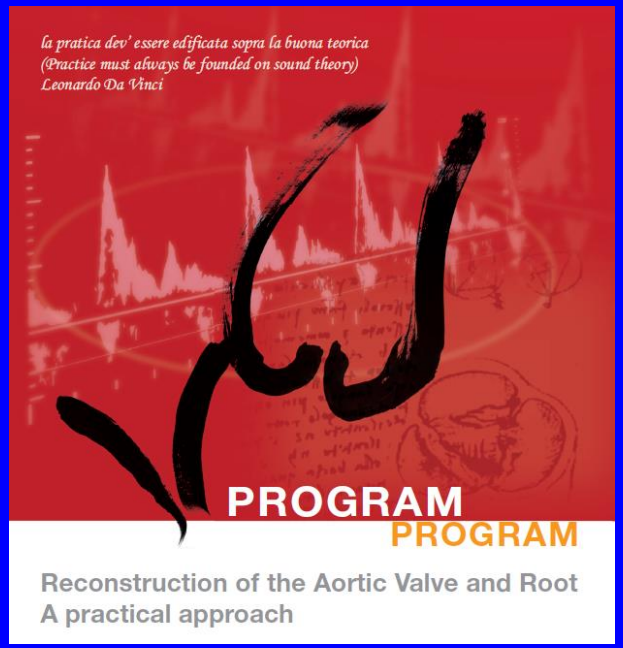
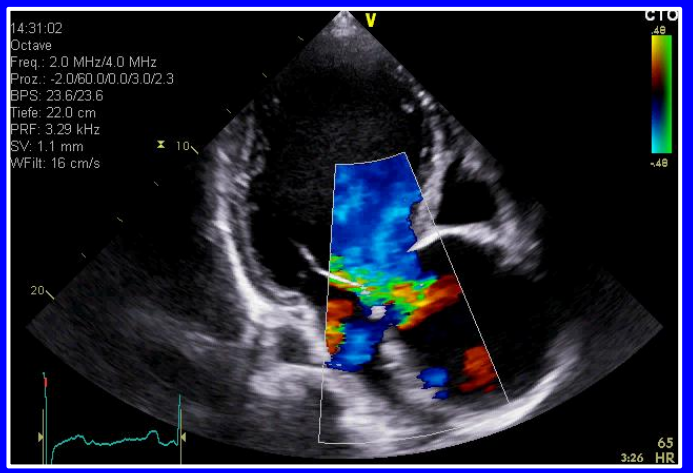
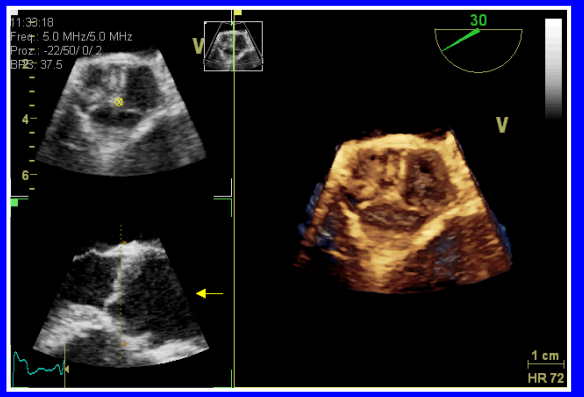
Reconstruction of the Aortic Valve and Root
A practical approach



A. Hagendorff: Multidimensional Echocardiography in Aortic Valve Repair

Thursday, 17th September 2015
14.00 – 14.30





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Universitätsklinikum Leipzig
Department für Innere Medizin, Neurologie und Dermatologie
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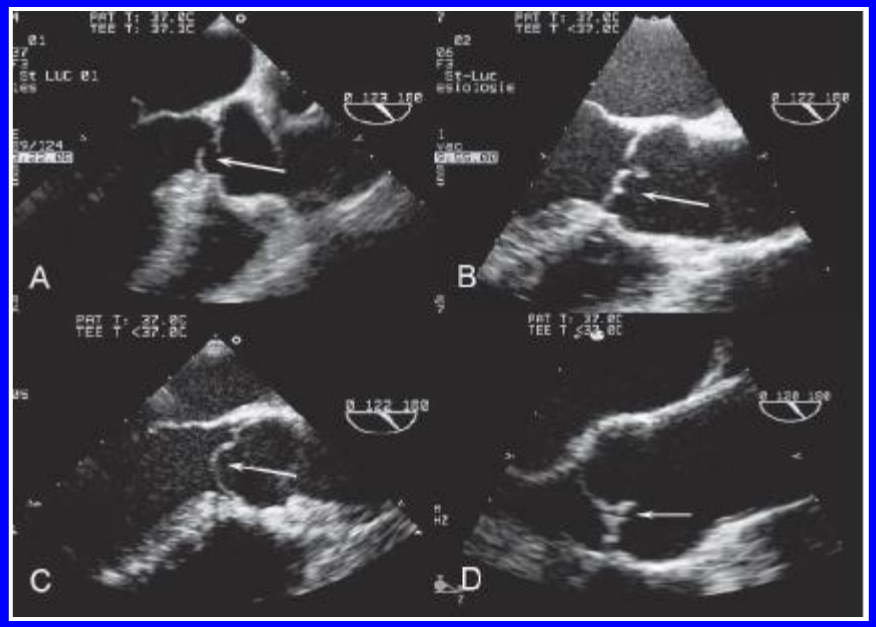
Reconstruction of the Aortic Valve and Root

Functional Anatomy of Aortic Regurgitation

Accuracy, Prediction of Surgical Repairability, and Outcome Implications of Transesophageal Echocardiography

Jean-Benoît le Polain de Waroux, MD*; Anne-Catherine Pouleur, MD*; Céline Goffinet, MD; David Vancraeynest, MD; Michel Van Dyck, MD; Annie Robert, PhD; Bernhard L. Gerber, MD, PhD; Agnès Pasquet, MD, PhD; Gébrine El Khoury, MD; Jean-Louis J. Vanoverschelde, MD, PhD

Circulation 2007; 116 [suppl I]: I264 – I269



The representation of imaging the aortic valve and aortic root by echocardiography in the literature.

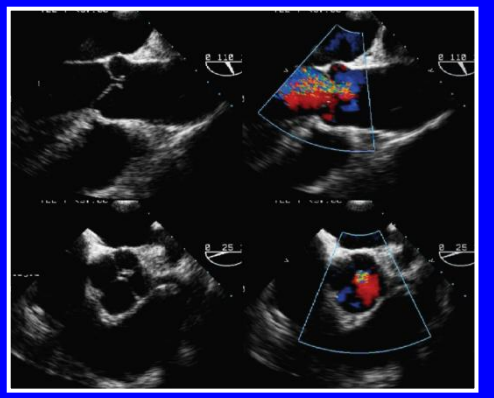
This figure (2007) seems to be not the actual standard of imaging in echocardiography in the present days.

Reconstruction of the Aortic Valve and Root

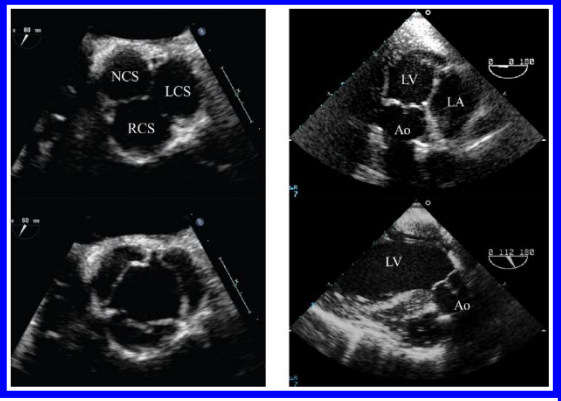
The role of echocardiography in aortic valve repair

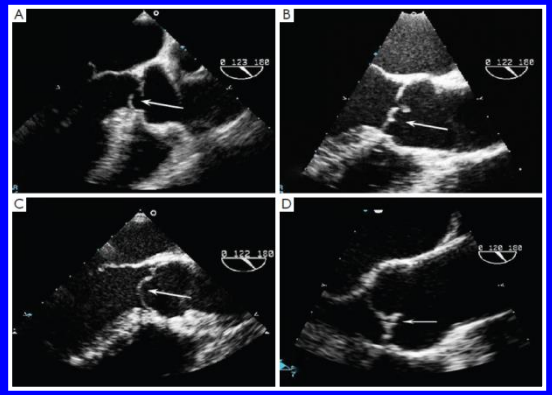
Jean-Louis Vanoverschelde, Michel van Dyck, Bernhard Gerber, David Vancraeynest, Julie Melchior, Christophe de Meester, Agnès Pasquet

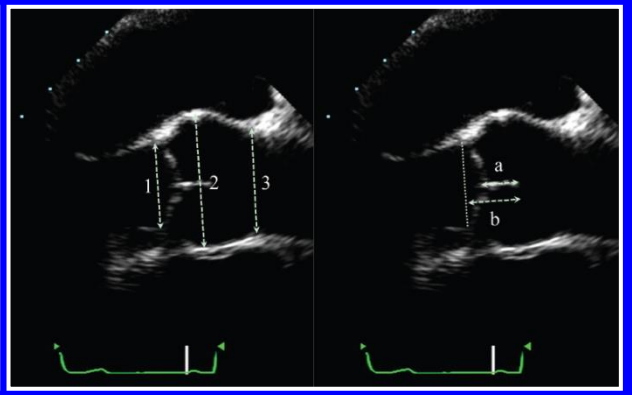
Ann Cardiothorac Surg 2013;2(1):65-72

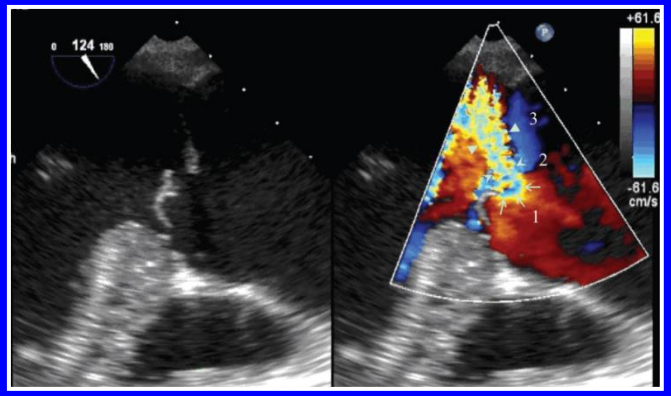


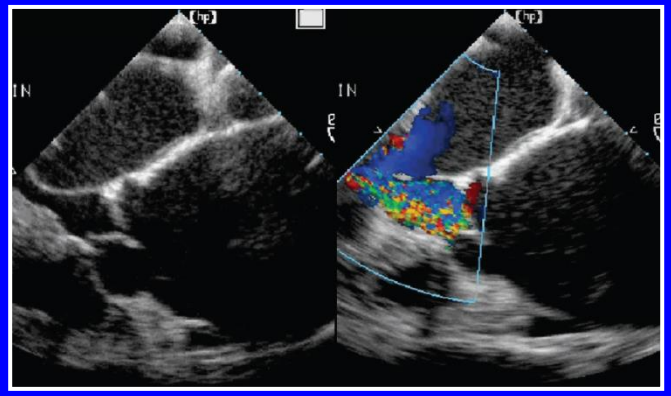
All figures in this paper of 2012 are still only 2D-echo images.



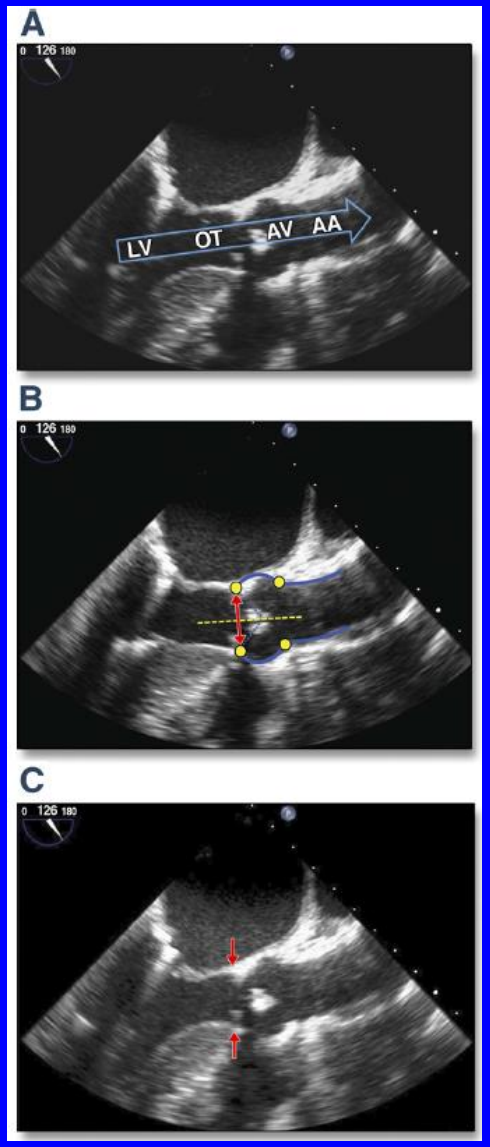








Reconstruction of the Aortic Valve and Root



STATE-OF-THE-ART PAPER
J Am Coll Cardiol Imag 2013; 6: 249-262

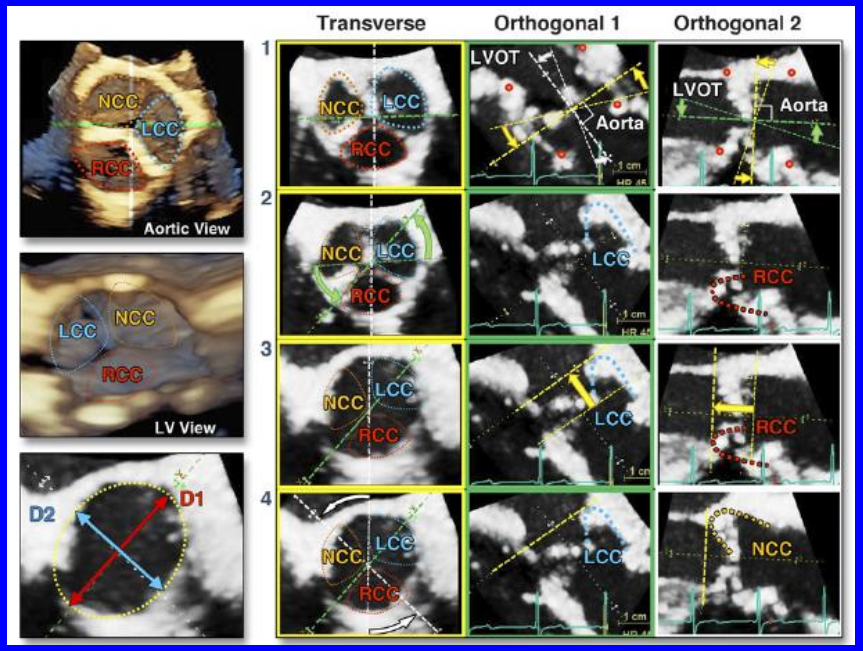
Standardized Imaging for Aortic Annular Sizing

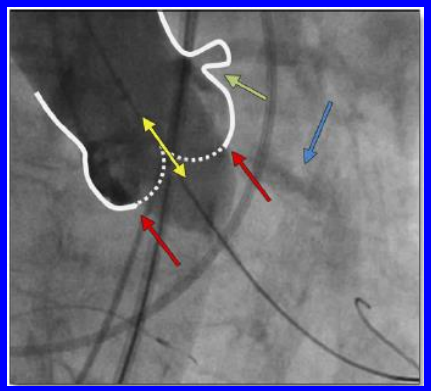
Implications for Transcatheter Valve Selection

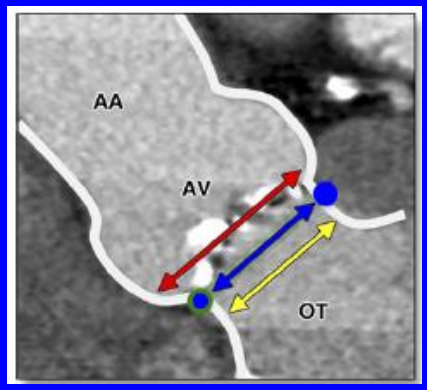
Albert M. Kasel, MD,* Salvatore Cassese, MD,* Sabine Bleiziffer, MD,†
Makoto Amaki, MD, PHD,‡ Rebecca T. Hahn, MD,§ Adnan Kastrati, MD,*
Partho P. Sengupta, MD‡

Multiple other figures are CT and angio images.

In 2013 only this 3D4D image is found in this standard imaging paper.



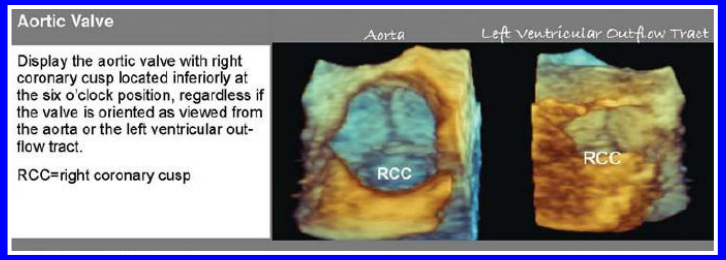


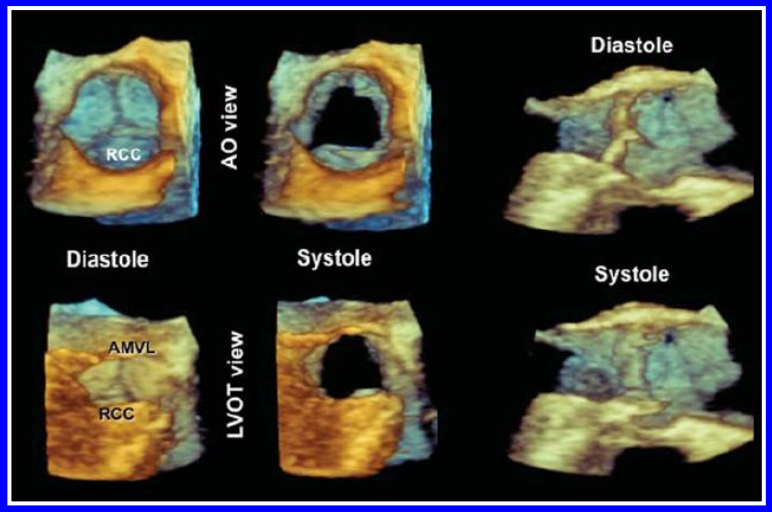


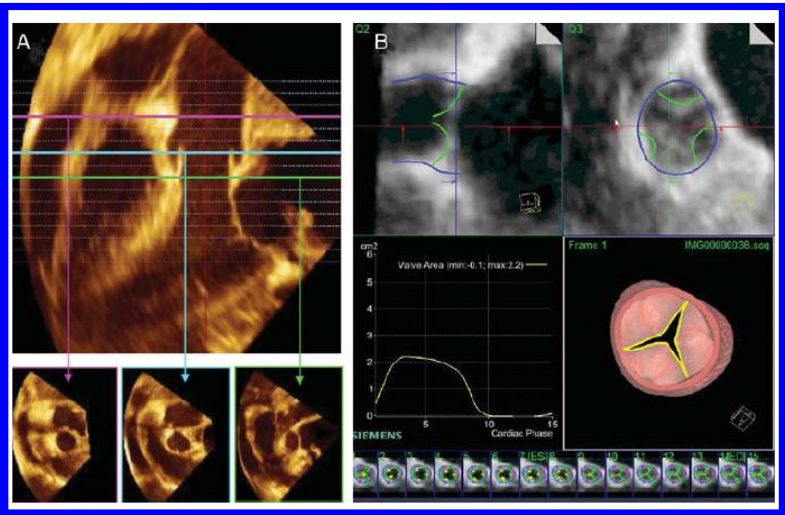
Reconstruction of the Aortic Valve and Root

EAE/ASE Recommendations for Image Acquisition and Display Using Three-Dimensional Echocardiography

Lang RM, Badano LP, Tsang W et al., Eur Heart J 2012; 13: 1-46







At least, in 2013 the 3D4D- echo technique for the aortic valve is fixed in the echo recommen-dations.

3D/4D-Echocardiography in Aortic Valve Repair

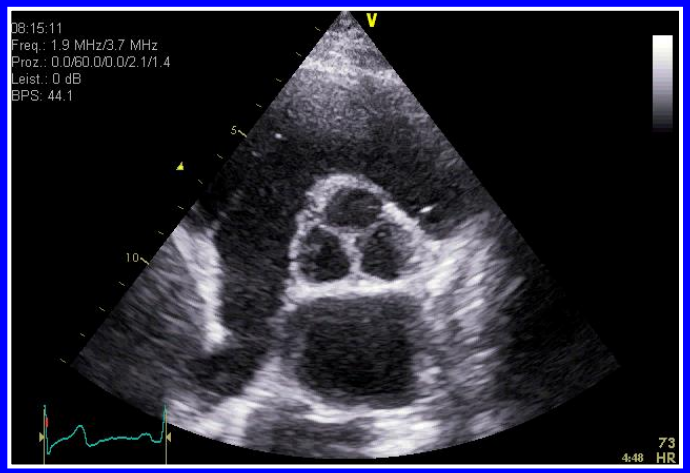
The key questions and challenges of echocardiography in aortic valve diseases

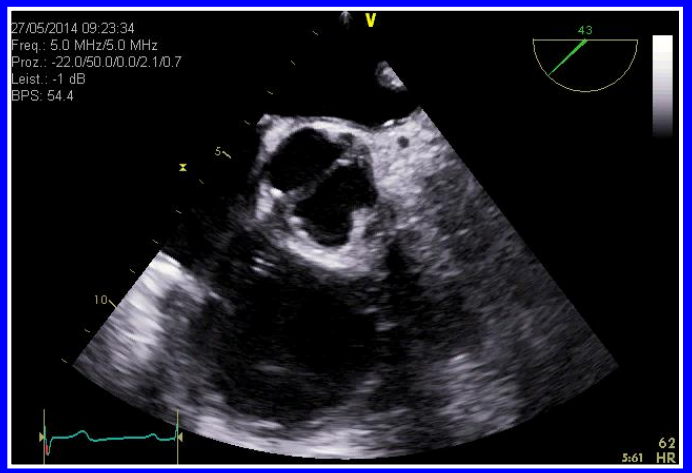
1. **The correct diagnosis of aortic valve disease**
2. The **complete** – convincing and objective (**and at least concise**) - documentation of the findings
   - Target parameter: the (indexed) geometric **orifice area** and effective orifice area in aortic valve stenosis
   - Target parameter: the **regurgitant fraction** and/or **efective regurgitant orrifice area** in aortic valve regurgitation
   - Morphological findings: **diameter of aortic annulus, root, sinutubular junction and ascending aorta**, geometry of the cardiac cavities, especially the left ventricle
   - Functional parameter: stroke volume, regurgitant volume (in addition - heart rate, blood pressure), pressure gradients, E/E`, sPAP, valvulo-arterial impedance, concomittant findings
3. Additional important findings
   - **Calcification of cusps and aortic root, number of cusps, localization of coronary ostia**

Reconstruction of the Aortic Valve and Root

The visualiztion of the aortic valve in sectional planes is important and excellent with modern ultrasound systems.
What is the added value of 3D/4D-echocardiography?

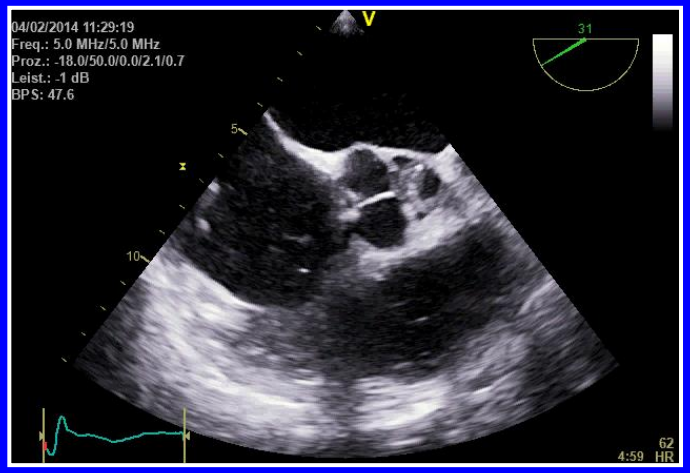
uni-cuspid

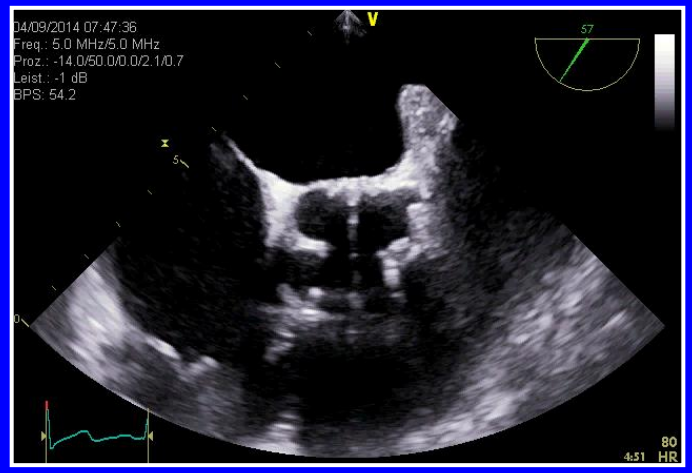




bi-cuspid

normal = tricuspid





quadri-cuspid

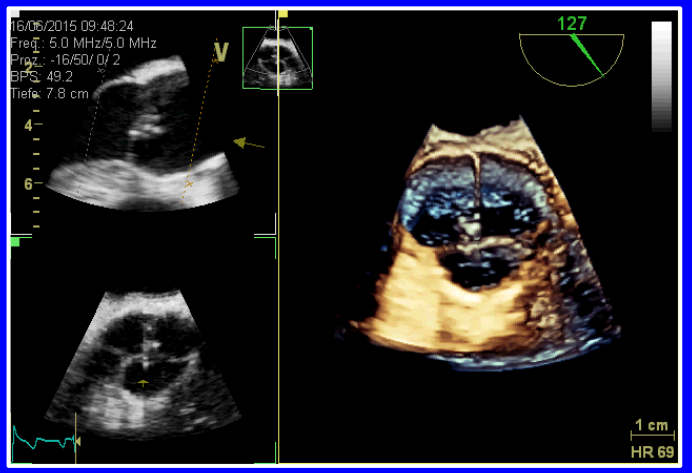
Reconstruction of the Aortic Valve and Root

There is a difference of transthoracic and transesophageal echocardiography: special practical aspects of 3D4D-imaging

- TTE is a more challenging task than TEE regarding the technical skill.
- In TTE frequencies are lower than TTE, thus spatial resolution is more limited.
- The higher the frequencies, the better the axial spatial resolution.
- The higher the frequencies, the less the penetration.
- Lateral resolution is affected by the frequency as well as by the band width of the transducer – normally in the higher regions of frequencies, but not at the highest – the lateral resolution is the best.

Why these informations are necessary?
– Of course to get the highest image quality, and at least, to get the best rendering in postprocessing software.

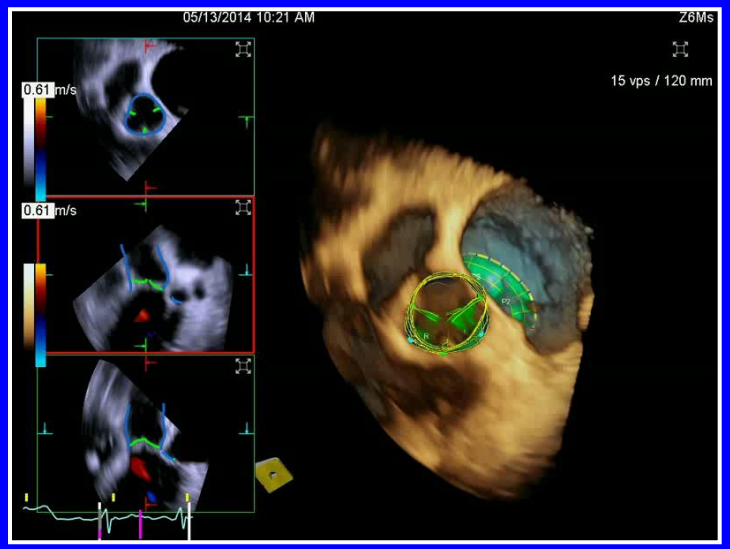
No excellent contours, no valid postprocession.

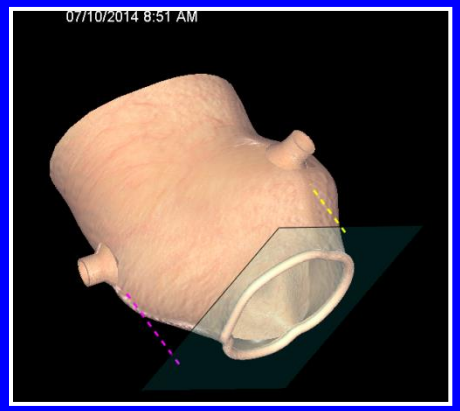


TEE after aortic valve repair: stitched data set

Reconstruction of the Aortic Valve and Root

Excellent image quality is the prerequisite for the correct diagnosis and the decision making due to the imaging pre-interventional procedures





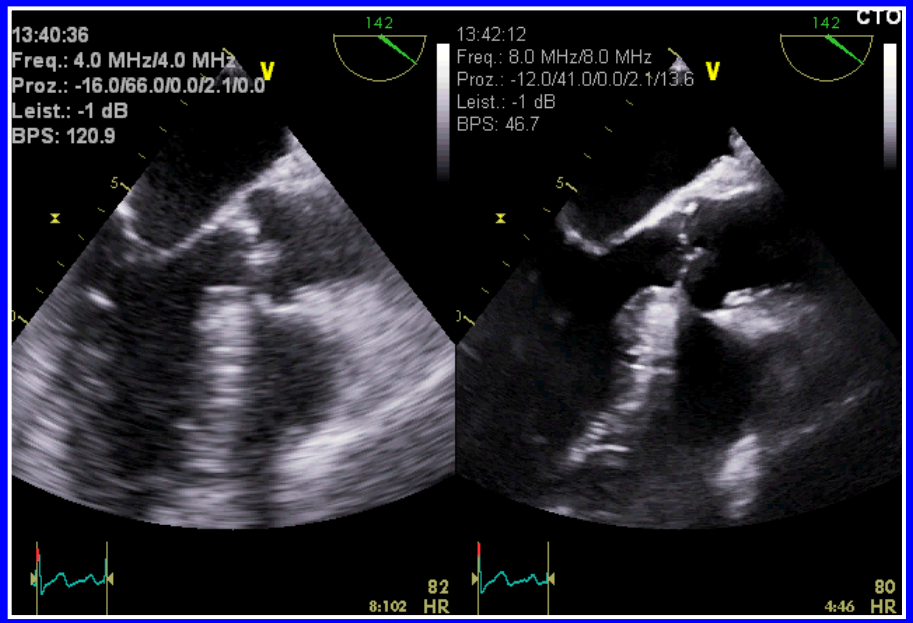
L Ostium Height	17.4	mm
R Ostium Height	22.5	mm

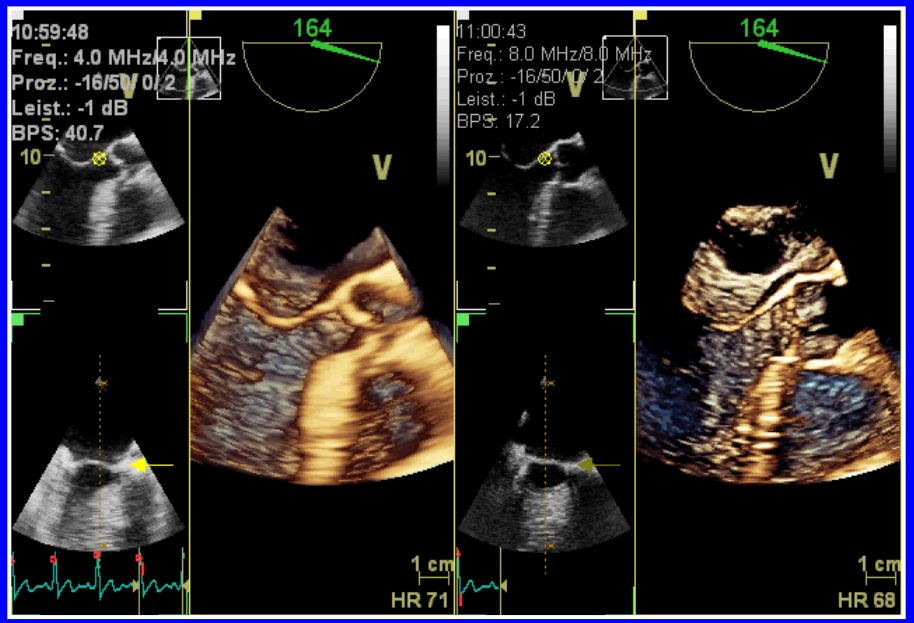
All parameters of aortic valve and aortic root dimensions, especially the distance between the aortic cusps / the aortic annulus and the coronary ostia can be easily measured within a 3D-TEE data set.

Reconstruction of the Aortic Valve and Root

Prerquisite for excellent image quality
in 2D as well as 3D/4D echocardiography:
knowledge about ultrasound physics and implementation of these aspects into the workflow by just technical knowledge about the buttons.
and in case of interventions and surgery – training for a fast workflow.

Then, detailed information about aortic valve and aortic root morphology is possible.
The spatial and temporal resolution of 3D TEE is at least comparable to cardiac-CT.

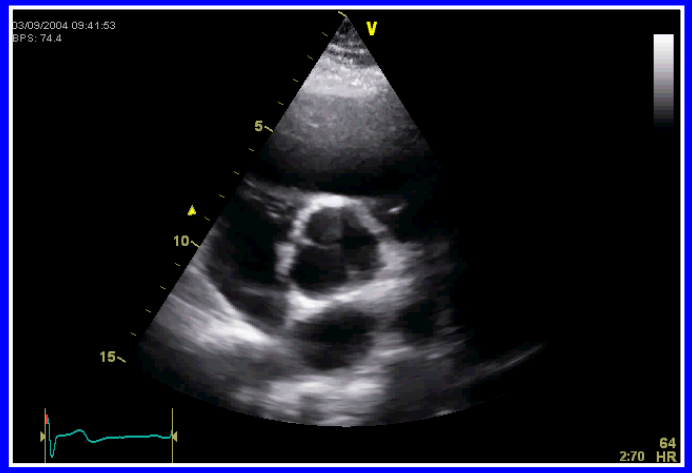


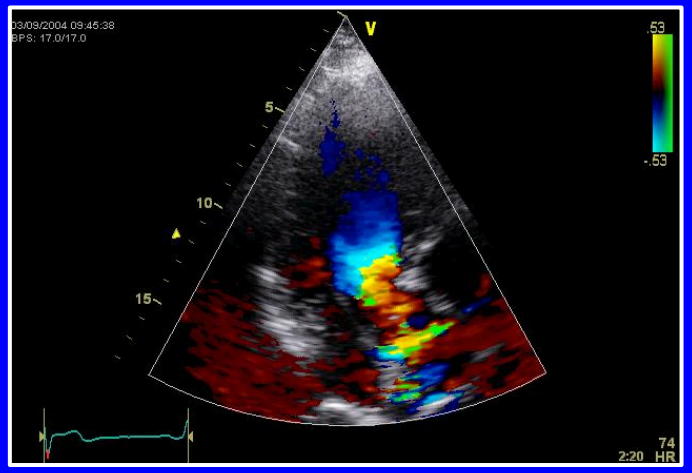
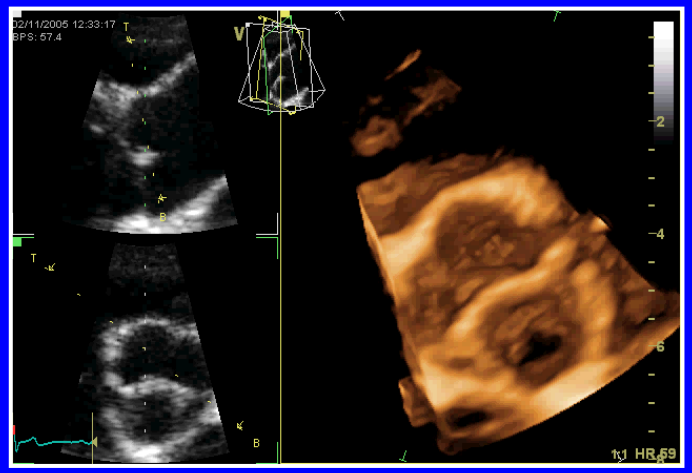


The same patients: „bad“ settings versus optimized settings in 2D and 3D-TEE.

Reconstruction of the Aortic Valve and Root

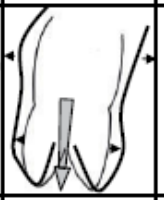
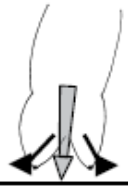
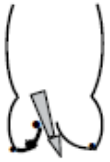
3D4D-TTE can be very helpful – and even sometimes better and sufficient in comparison to 3D4D TEE.
„old examples of 2005 with old machines“

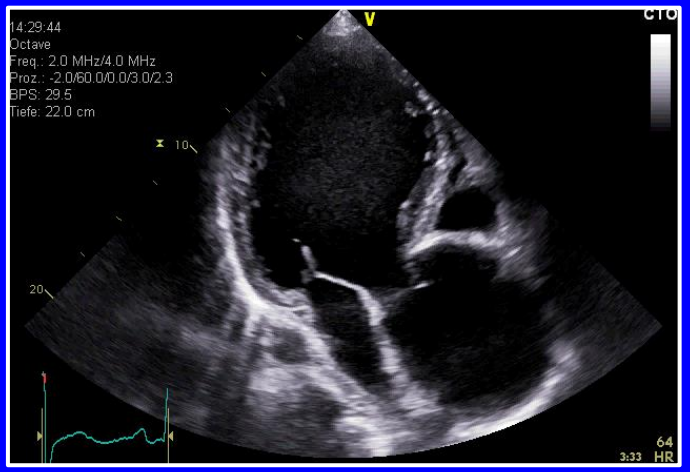


The additional value of information is obvious.
Surface imaging is a complete new modality than sectional scanning.

Reconstruction of the Aortic Valve and Root

AI Class	Type I Normal cusp motion with FAA dilatation or cusp perforation				Type II Cusp Prolapse	Type III Cusp Restriction
	Ia	Ib	Ic	Id		
Mechanism						
Repair Techniques (Primary)	STJ remodeling *Ascending aortic graft*	Aortic Valve sparing: *Reimplantation or Remodeling with SCA*	SCA	Patch Repair *Autologous or bovine pericardium*	Prolapse Repair *Plication* *Triangular resection* *Free margin Resuspension* *Patch*	Leaflet Repair *Shaving* *Decalcificatio* *Patch*
(Secondary)	SCA		STJ Annuloplasty	SCA	SCA	SCA



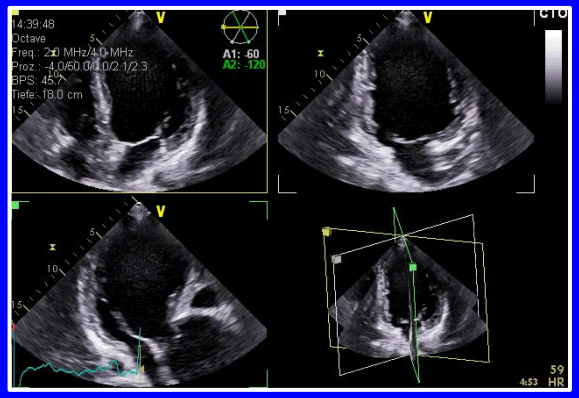
Example of 2D-imaging
Aortic regurgitation type Ia
FAA – functional aortic annulus;
STJ - sinotubular junction;
SCA - subcommissural anuloplasty

Conclusion: Aortic valve repair is an acceptable therapeutic option for patients with aortic insufficiency. This functional classification allows a systematic approach to the repair of AI and can help to predict the surgical techniques required as well as the durability of repair. Restrictive cusp motion (type III), due to fibrosis or calcification, is an important predictor for recurrent AI following AV repair.

Repair-oriented classification of aortic insufficiency: Impact on surgical techniques and clinical outcomes

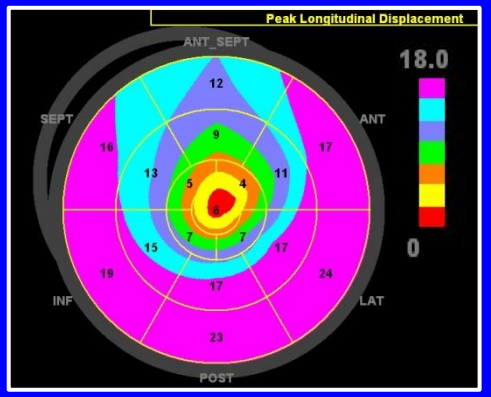
Munir Boodhwani, MD, MMSc, Laurent de Kerchove, MD, David Glineur, MD, Alain Poncelet, MD, Jean Rubay, MD, Parla Astarci, MD, Robert Verhelst, MD, Philippe Noirhomme, MD, and Gébrine El Khoury, MD

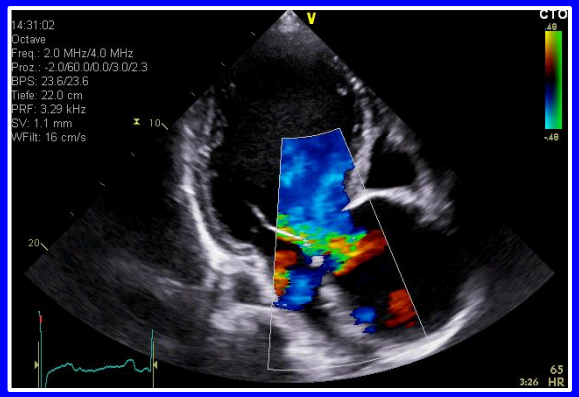
Reconstruction of the Aortic Valve and Root

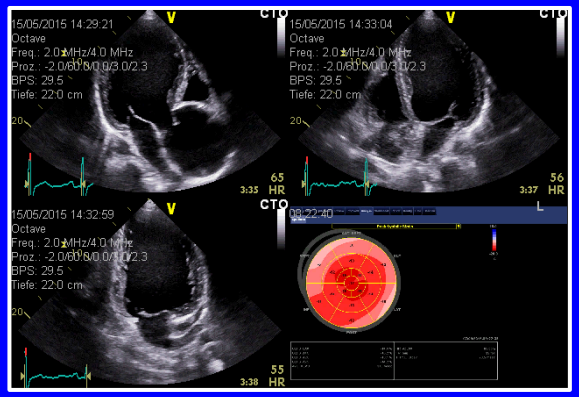


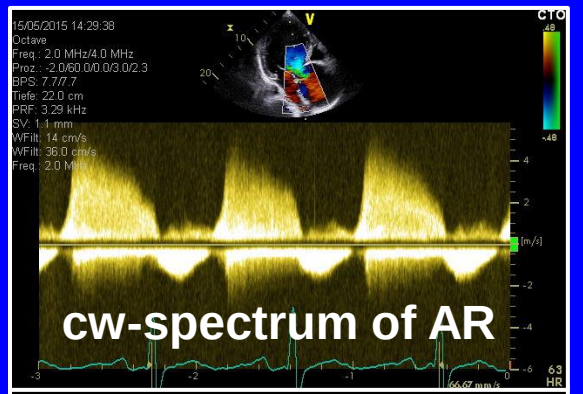
2D-TTE-imaging

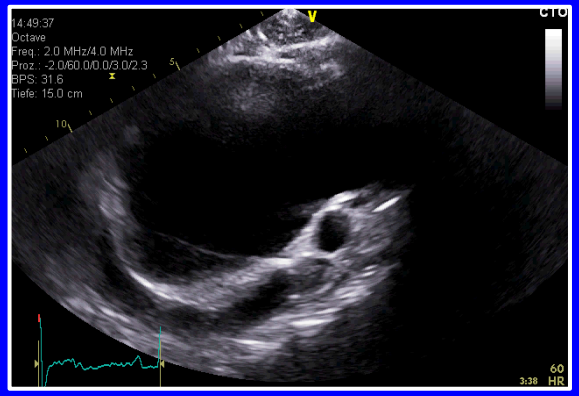
(triplane acquisition a
nd deformation imaging)
Visualisation of the aortic aneurysm
– funcional AR-anaylsis

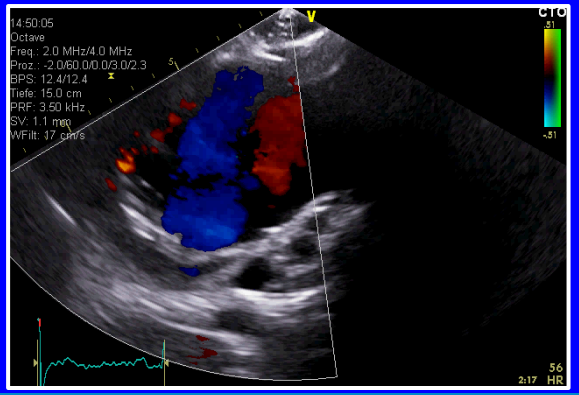


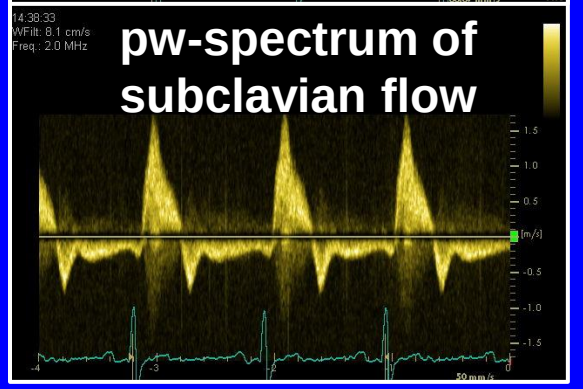








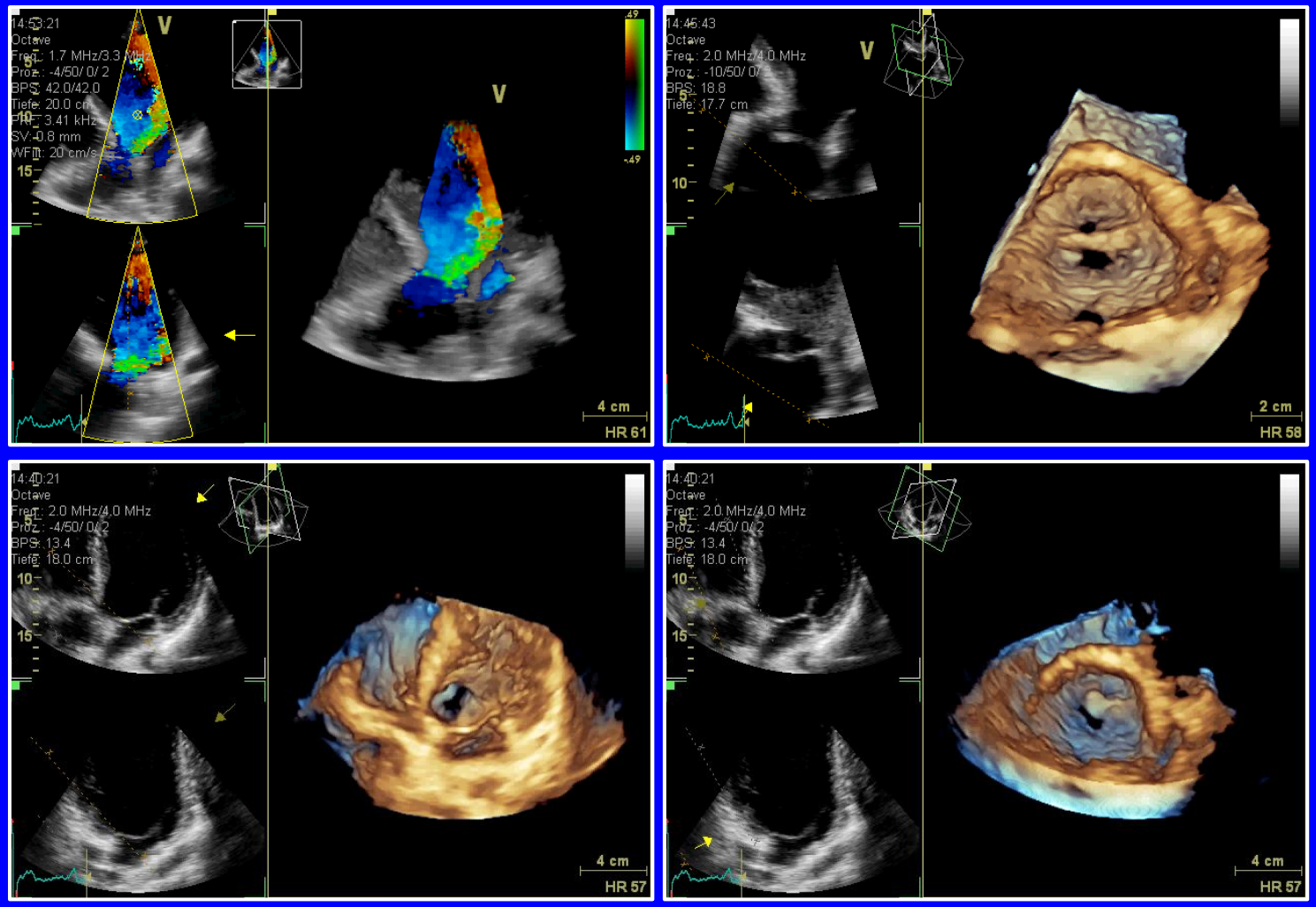




Reconstruction of the Aortic Valve and Root

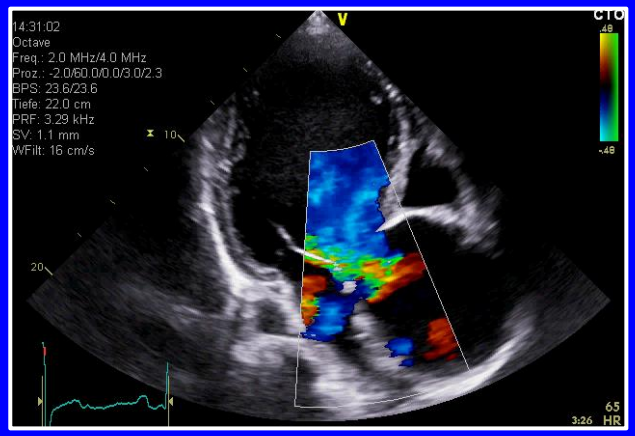
The added value of 3D/4D-TTE-imaging

imaging of regurgitant flow; surface morphology of aortiv valve and root

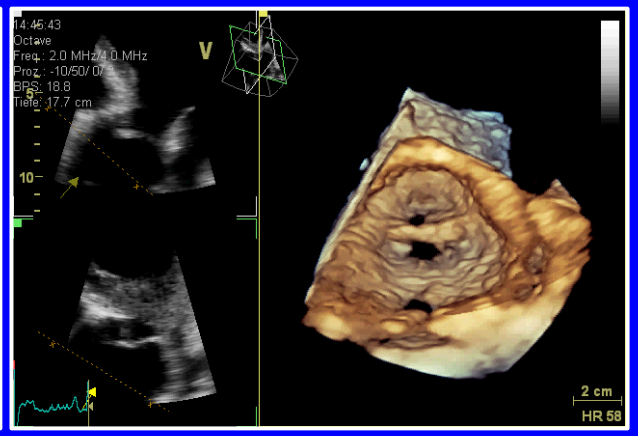


Reconstruction of the Aortic Valve and Root

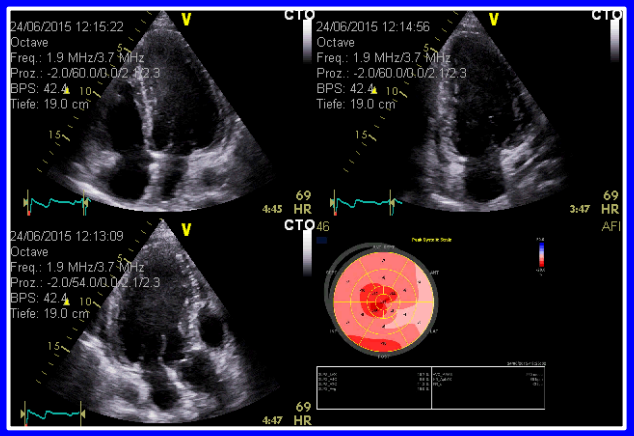
pre



pre

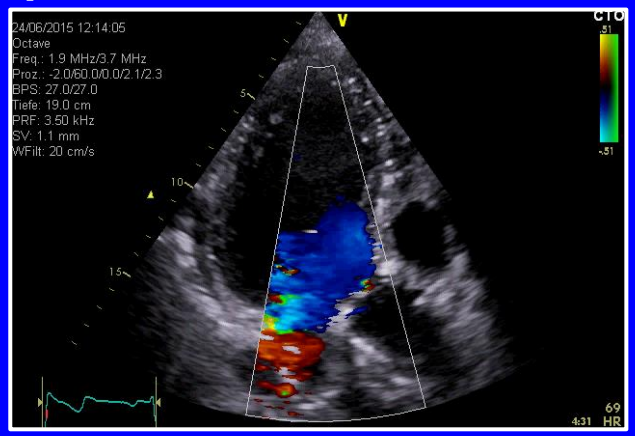


post

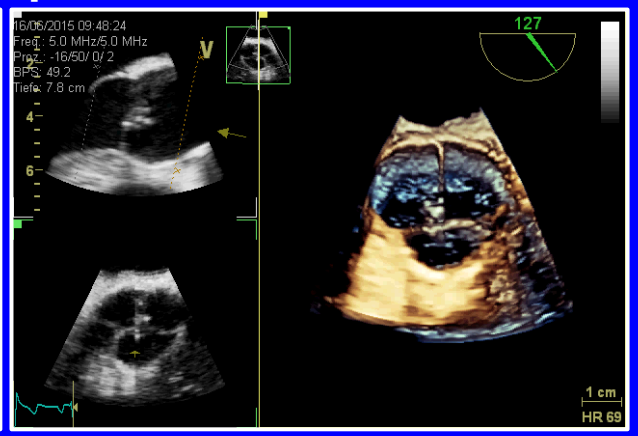


Comparison pre- and post-aortiv valve repair surgery

post



post



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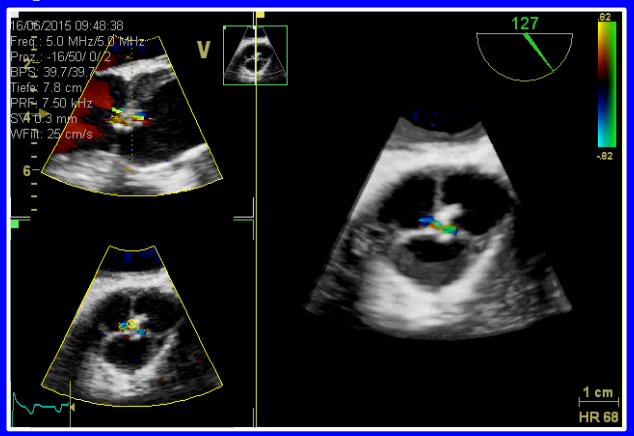
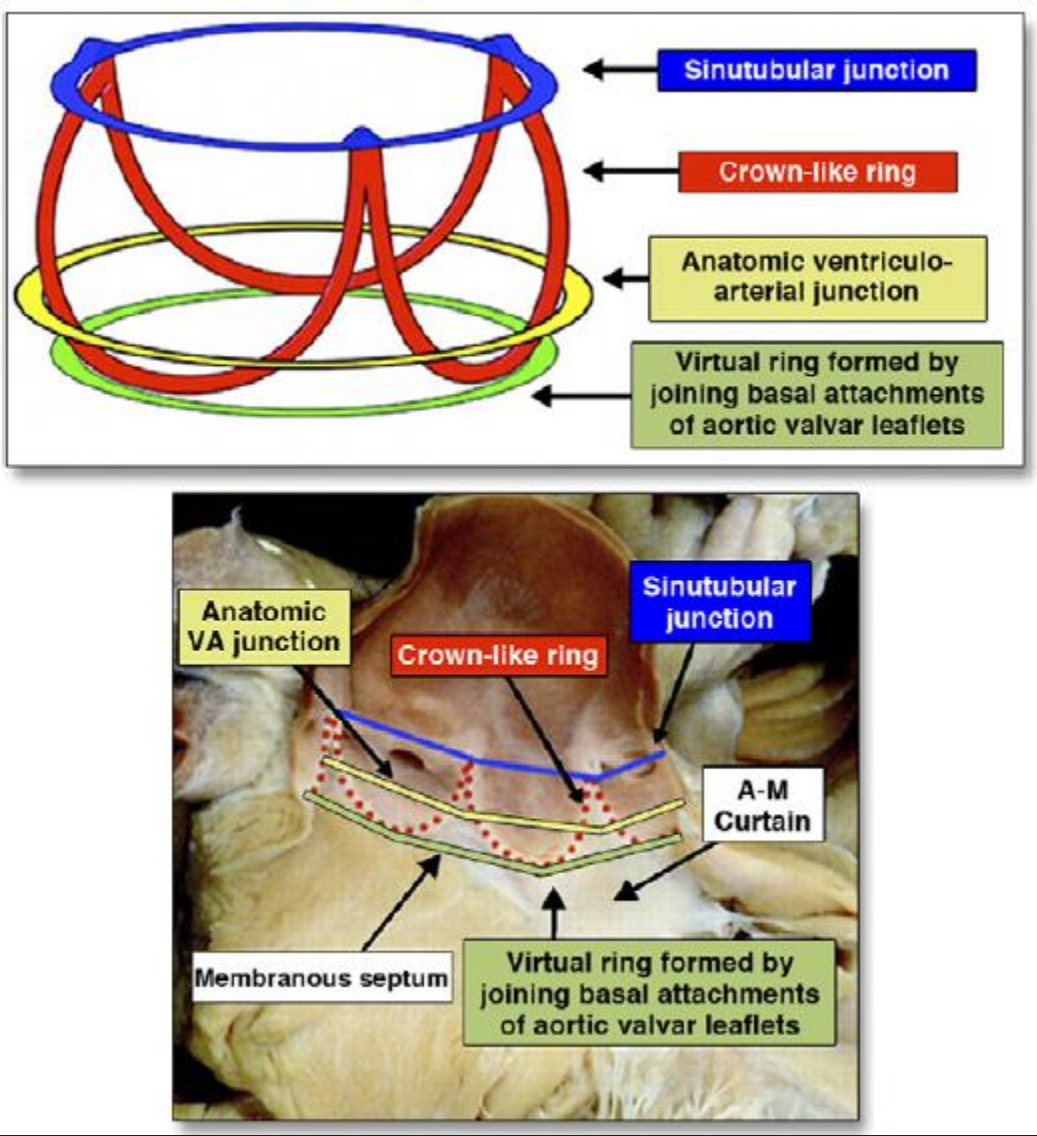


Reconstruction of the Aortic Valve and Root



Aortic Root Anatomy
(A) Diagram of aortic root anatomy showing coronet shape and location of various annular planes and coronary ostia relative to leaflet attachments. (B)
Imaging planes and leaflet attachments from (A) shown superimposed on postmortem specimen.
A-M aorto-mitral;
VA ventriculo-arterial.

according to Piazza N, de Jaegere P, Schultz C, Becker AE, Serruys PW, Anderson RH.
Anatomy of the aortic valvar complex and its implications for transcatheter implantation of the aortic
valve. Circ Cardiovasc Interv 2008;1: 74–81.

Reconstruction of the Aortic Valve and Root

Laurent de Kerchove, Gebrine El Khoury. Anatomy and pathophysiology of the ventriculo-aortic junction: implication in aortic valve repair surgery.
Ann Cardiothorac Surg 2013;2(1):57-64

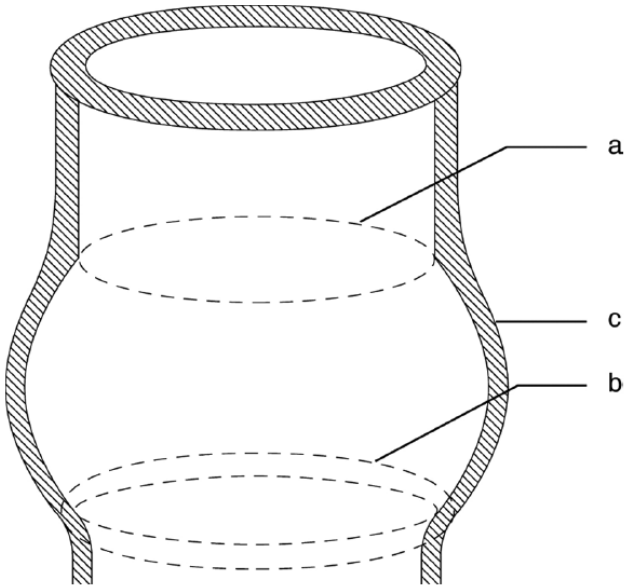
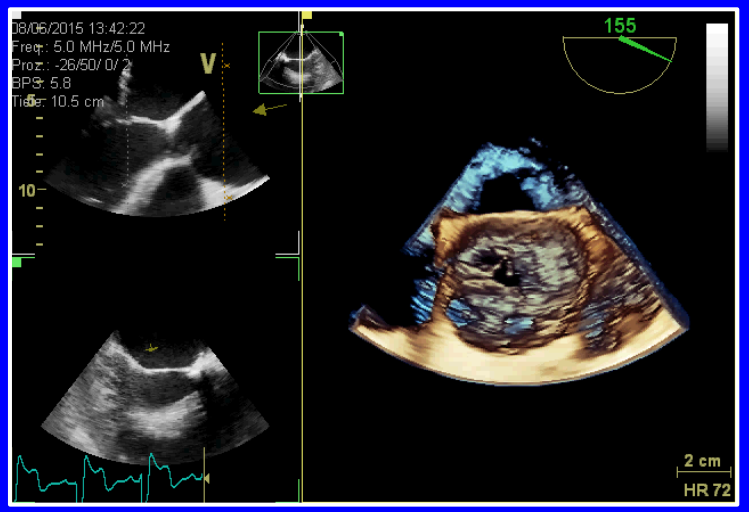
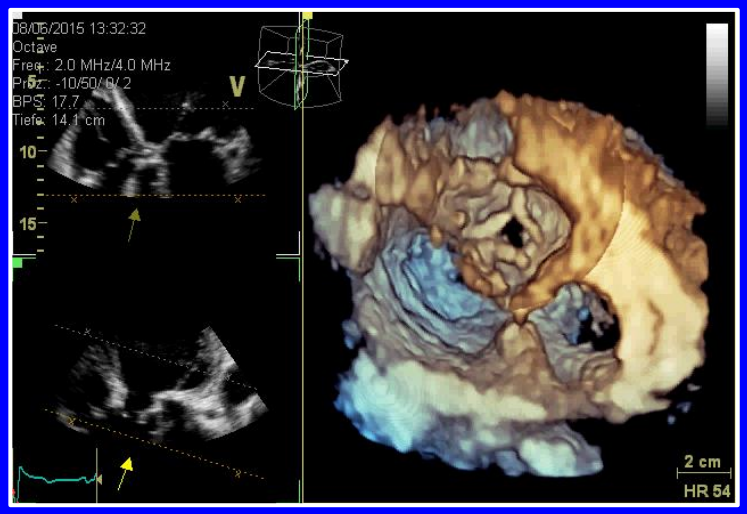


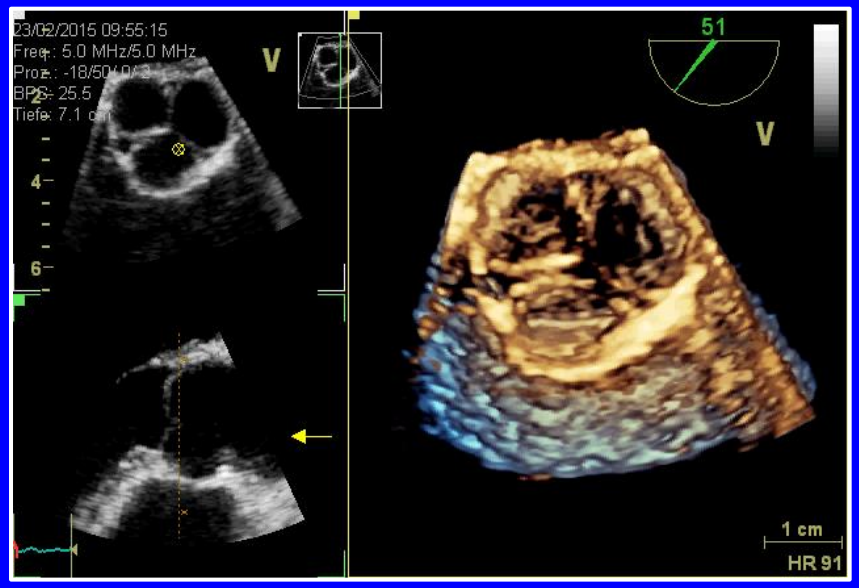
Figure 1 Diagrammatical representation of the aortic root. a. sinotubular junction; b. Ventriculo-aortic junction, also called basal ring or surgical annulus; c. the sinuses of Valsalva

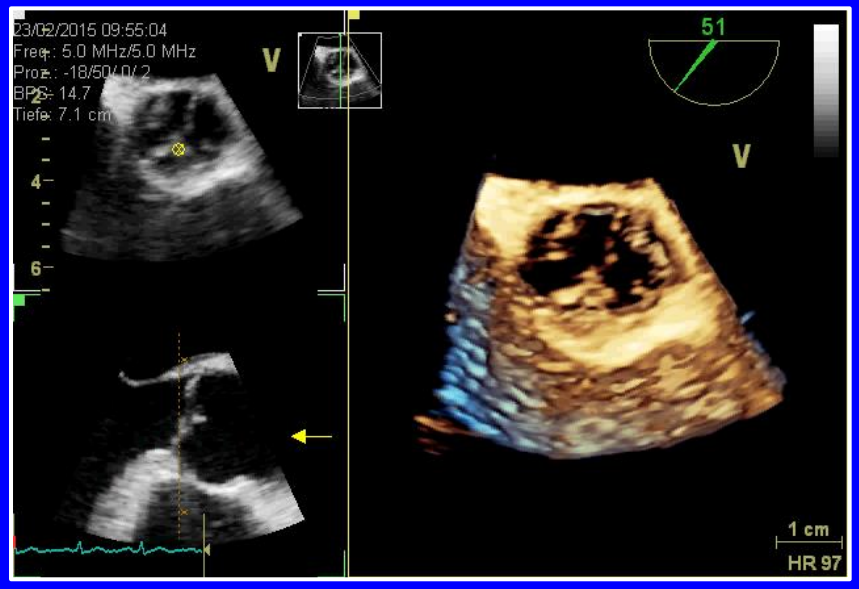


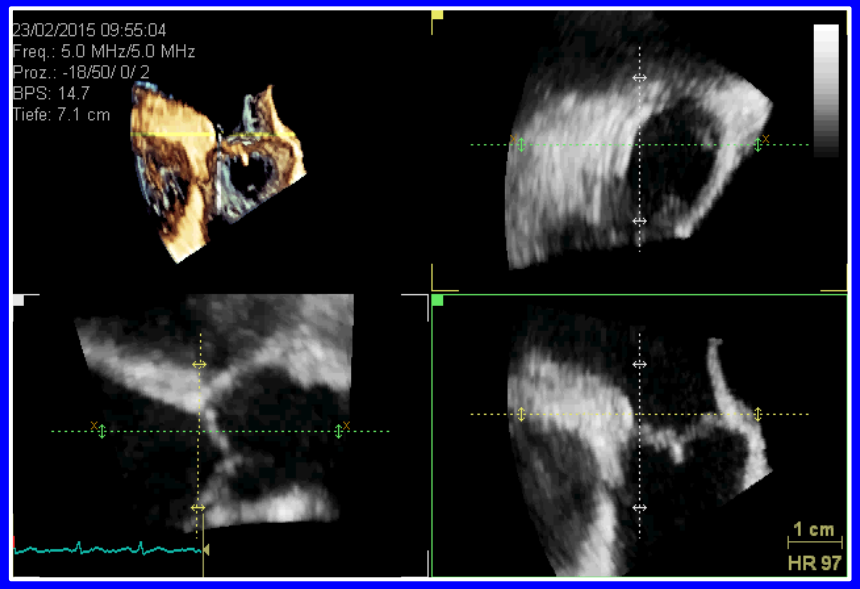


The anatomy of the aortic valve and the aortic root is complex. It can be better visualized multidimensional than in a two-dimensional image.

Reconstruction of the Aortic Valve and Root

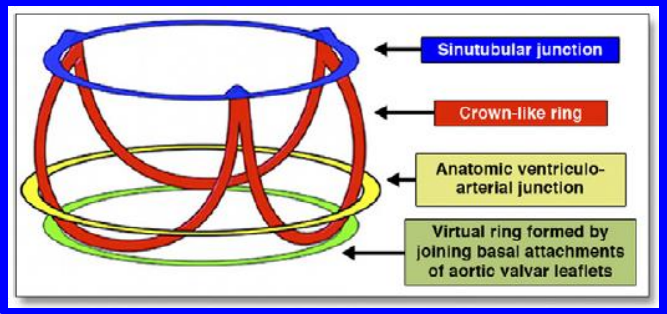






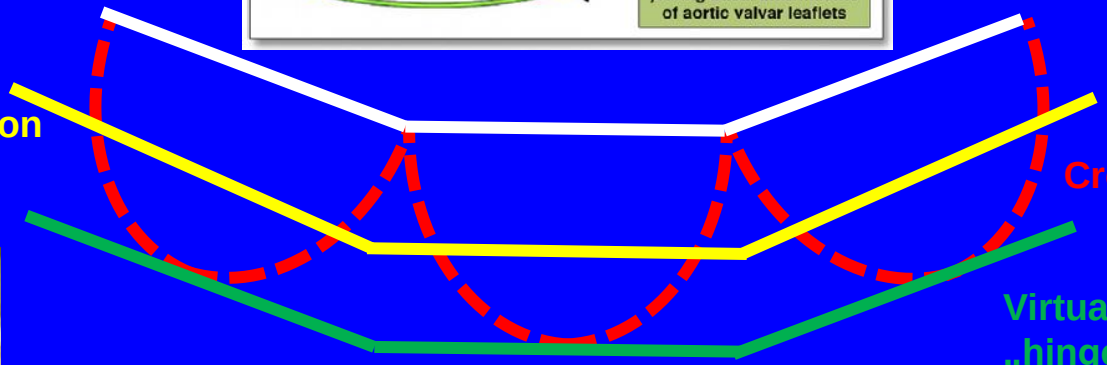
If the aortic annulus is visualized, the correct measurements of dimensions are not easy to understand.
The intersections of the commissures and the cusps with the sectional plane do not describe exactly the dimension of the virtual annulus at the hinge points of the cusps.

Reconstruction of the Aortic Valve and Root

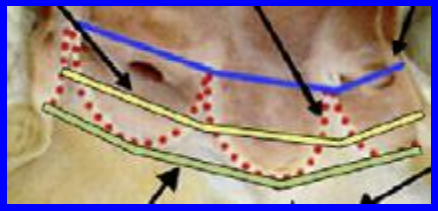


Sinutubular junction

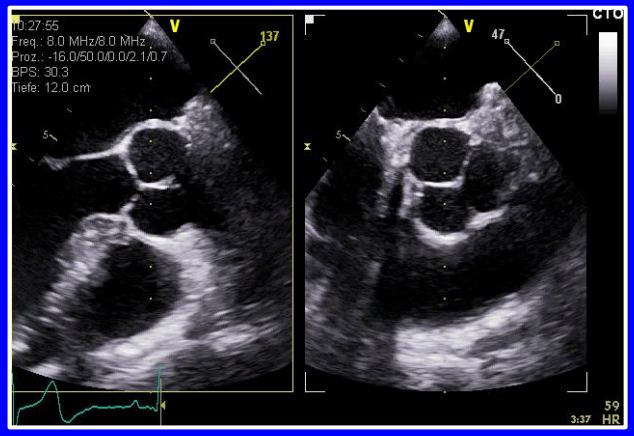
Anatomical ventriculo-arterial junction

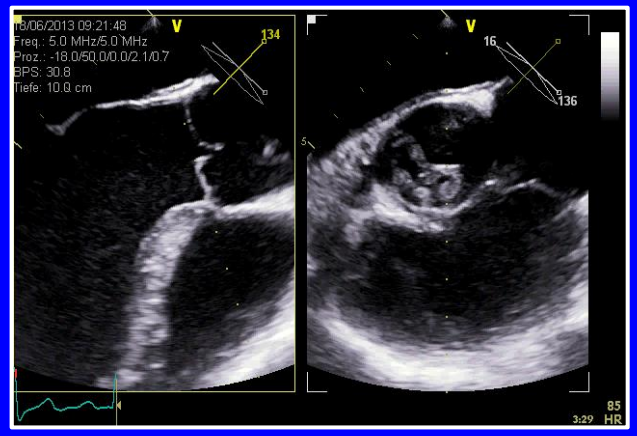


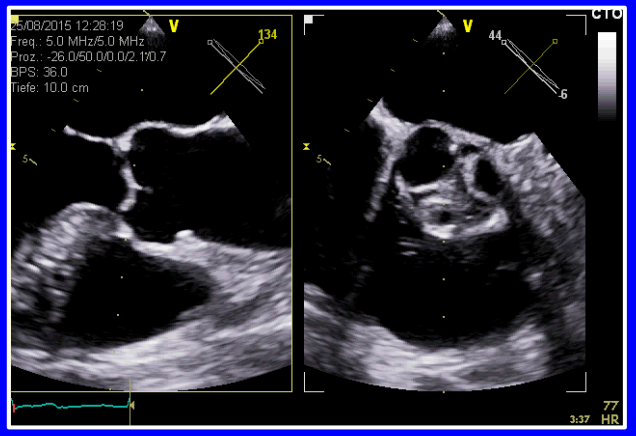
Crown-like ring



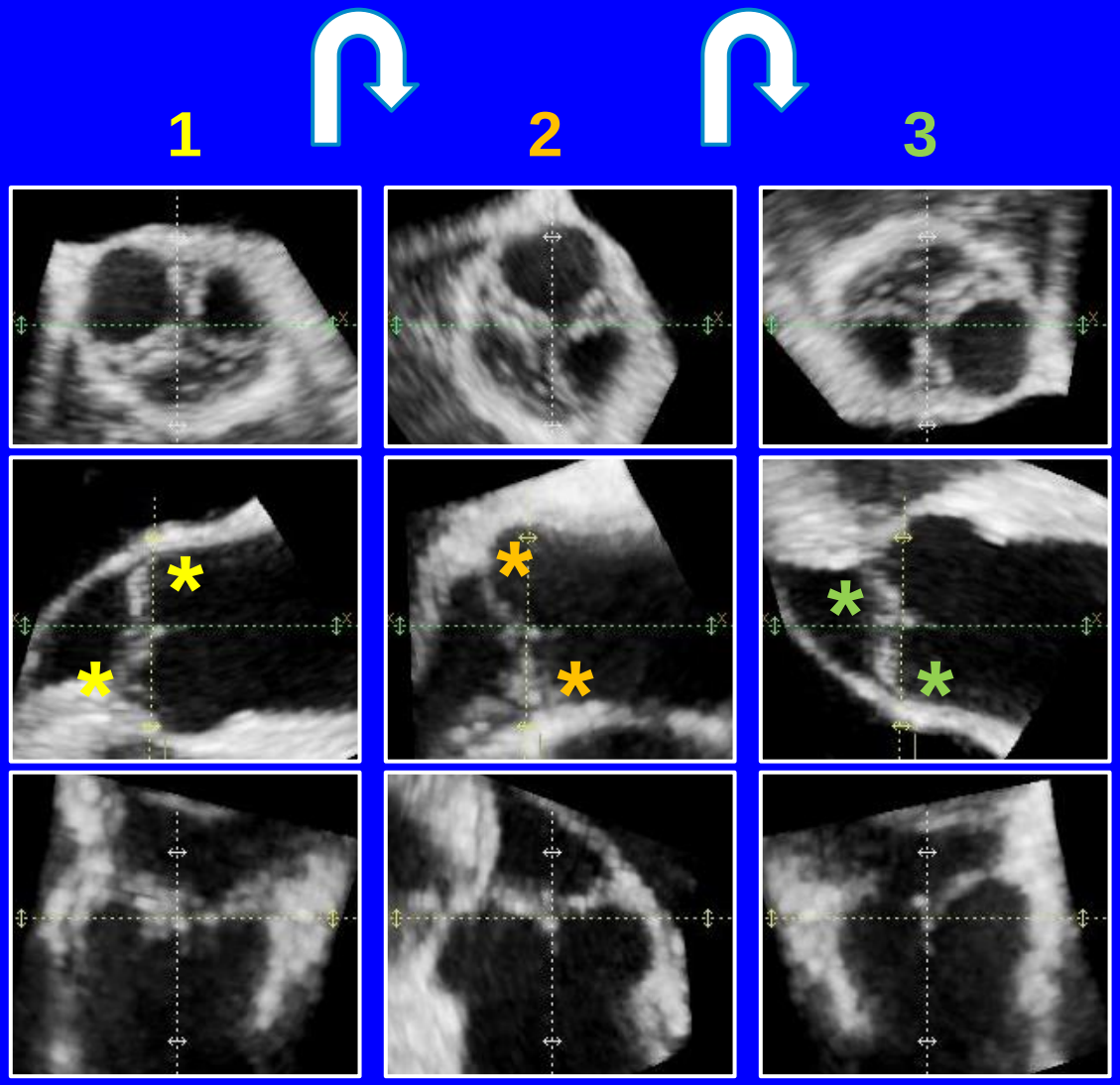
Virtual ring formed by the „hinge points“ of the aortic cusps

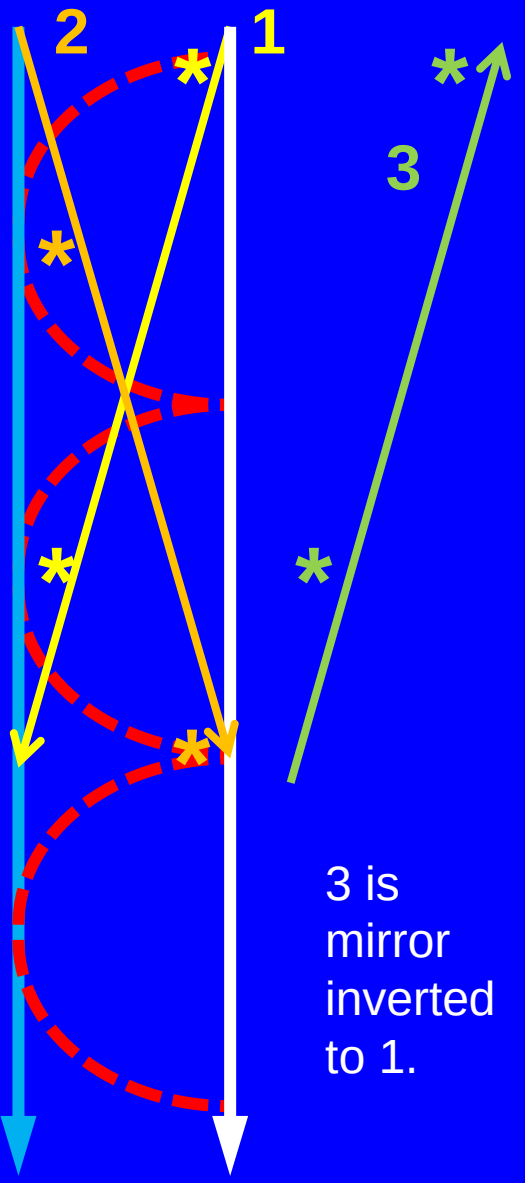






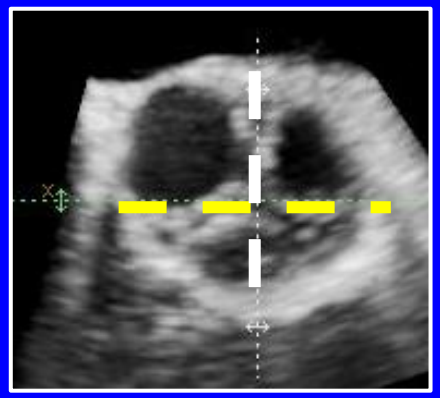
Reconstruction of the Aortic Valve and Root

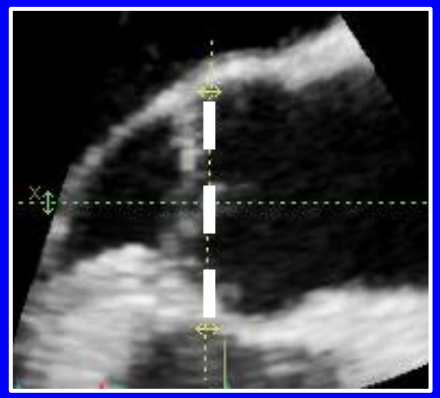


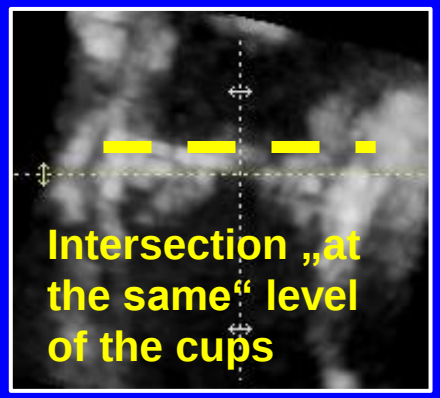


3 is mirror inverted to 1.

Reconstruction of the Aortic Valve and Root

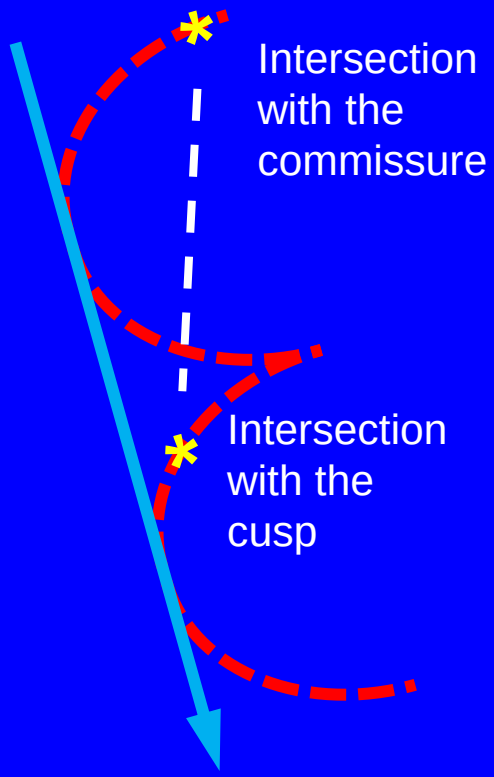




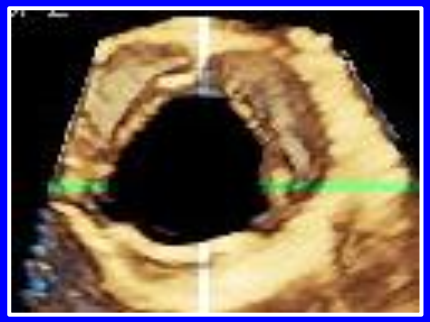


Diastole

Thus,
how to operate correctly?

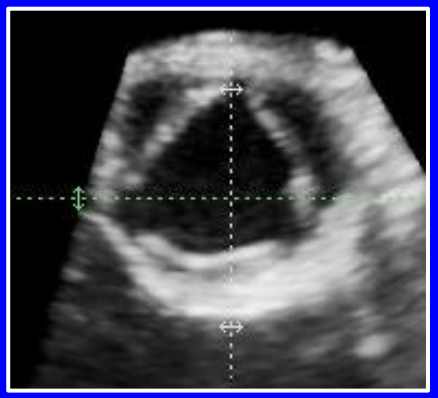


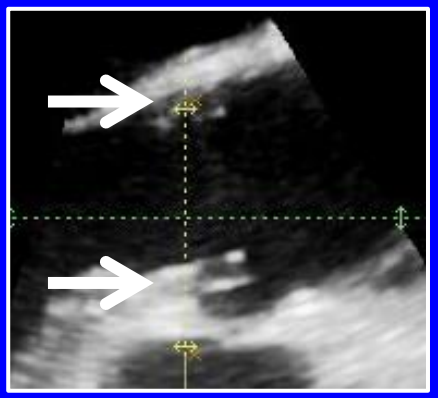
Systole

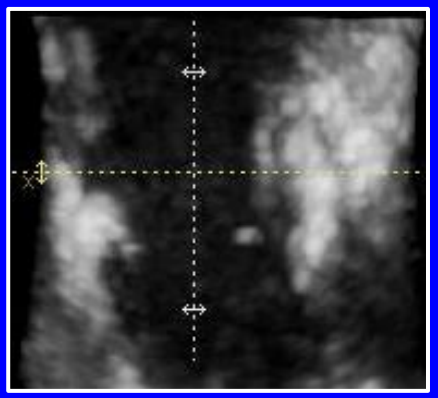


Intersection with the commissure

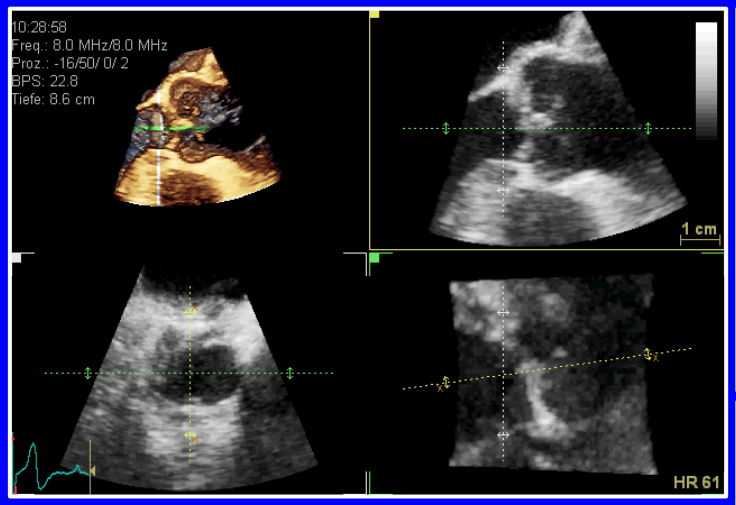
Intersection with the cusp

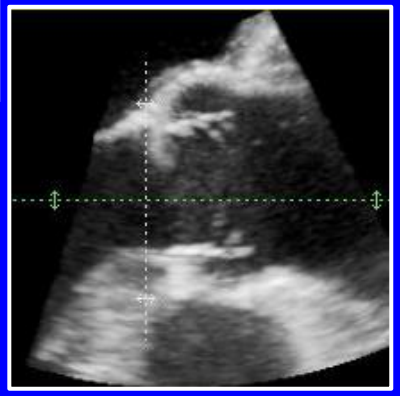


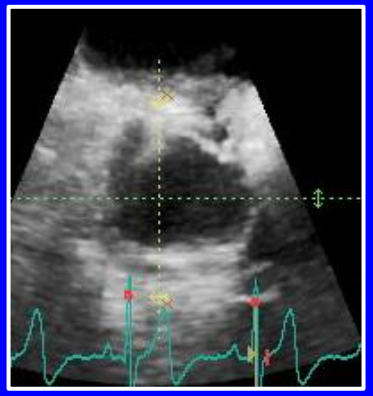


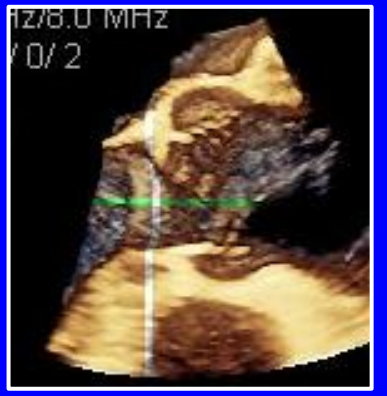


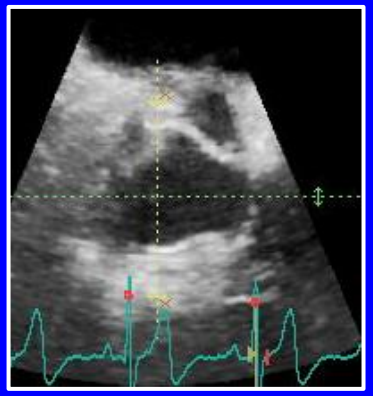
Reconstruction of the Aortic Valve and Root







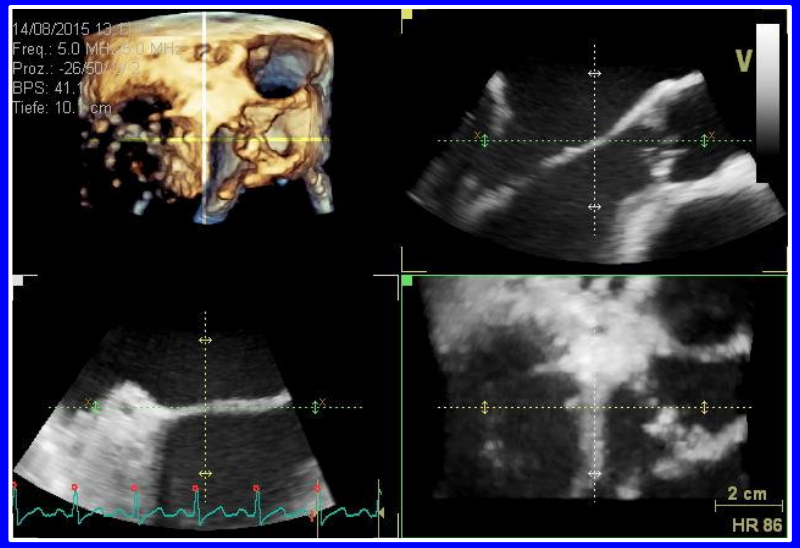


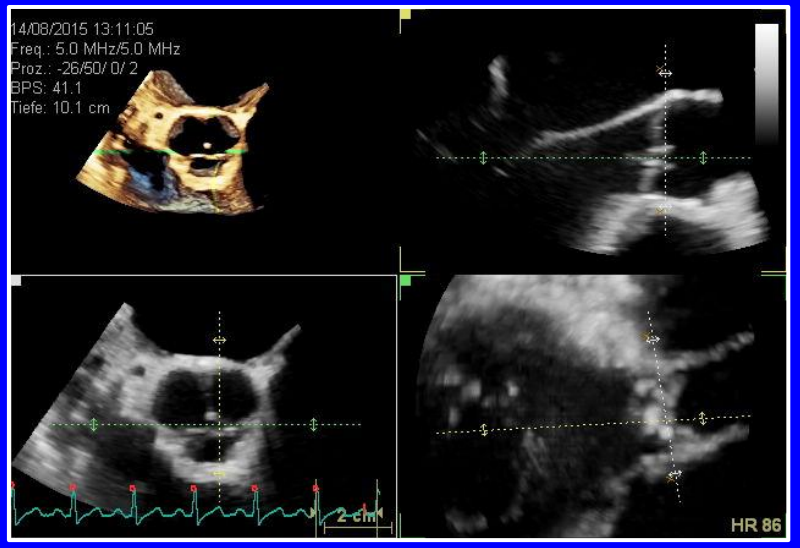


1. step: adjust the central axis of AV during diastole to label the perpendicular plane through the hinge points
2. step: go to systole to measure the widest expansion of the LVOT
3. step: adjust the annulus plane in the LAX view

Reconstruction of the Aortic Valve and Root

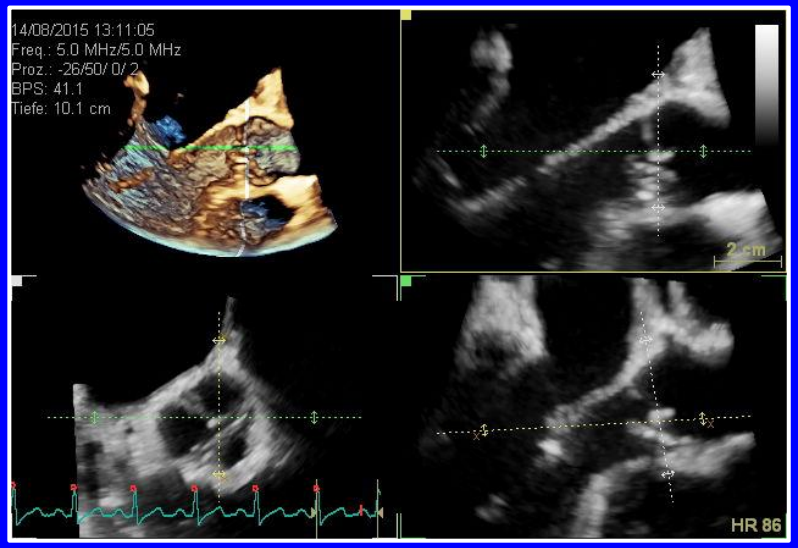
1





2

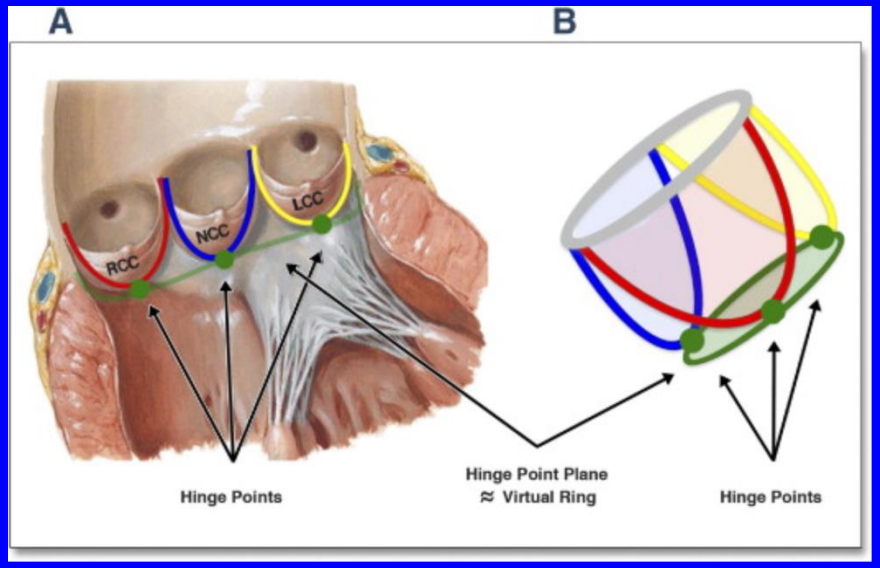
3

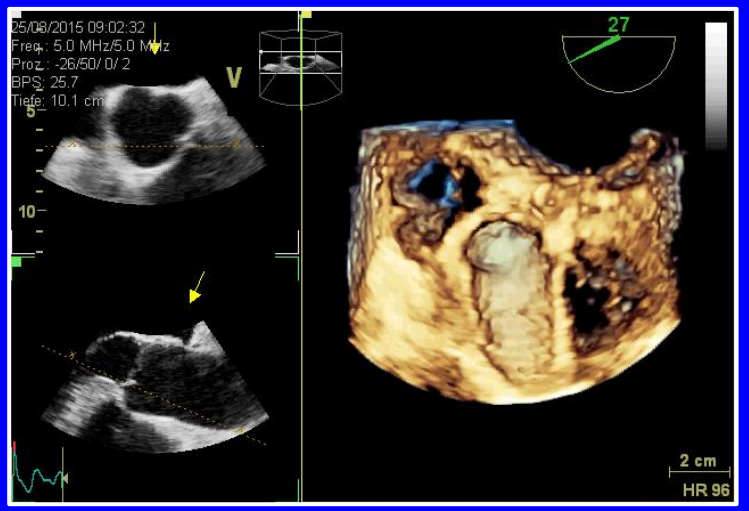


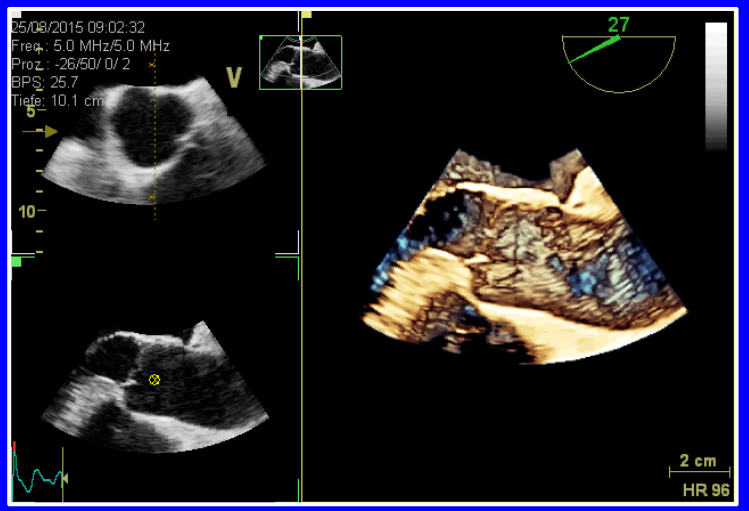
1. Acquire a ZOOM data set of the complete mitral and aortic valve
2. Adjust the central axis of the aortic root in the long axis
3. Adjust the central axis of the aortic root in the perpendicular axis
4. Adjust the short axis to the hindge points by translation during diastole
5. Rotate the short axis view to control the sectional short axis plane..

Reconstruction of the Aortic Valve and Root

aus: J Am Coll Cardiol Img. 2013;6(2):249-262. doi:10.1016/j.jcmg.2012.12.005
Standardized Imaging for Aortic Annular Sizing: Implications for Transcatheter Valve Selection







Normal Anatomy of the Aortic Annulus
The aortic annulus accounts for the tightest part of the aortic root (A) and is defined as a virtual ring (green line) with 3 anatomical anchor points at the nadir (green points) of each of the attachments of the 3 aortic leaflets (B). LCC = left coronary cusp; NCC = noncoronary cusp; RCC = right coronary cusp

Reconstruction of the Aortic Valve and Root

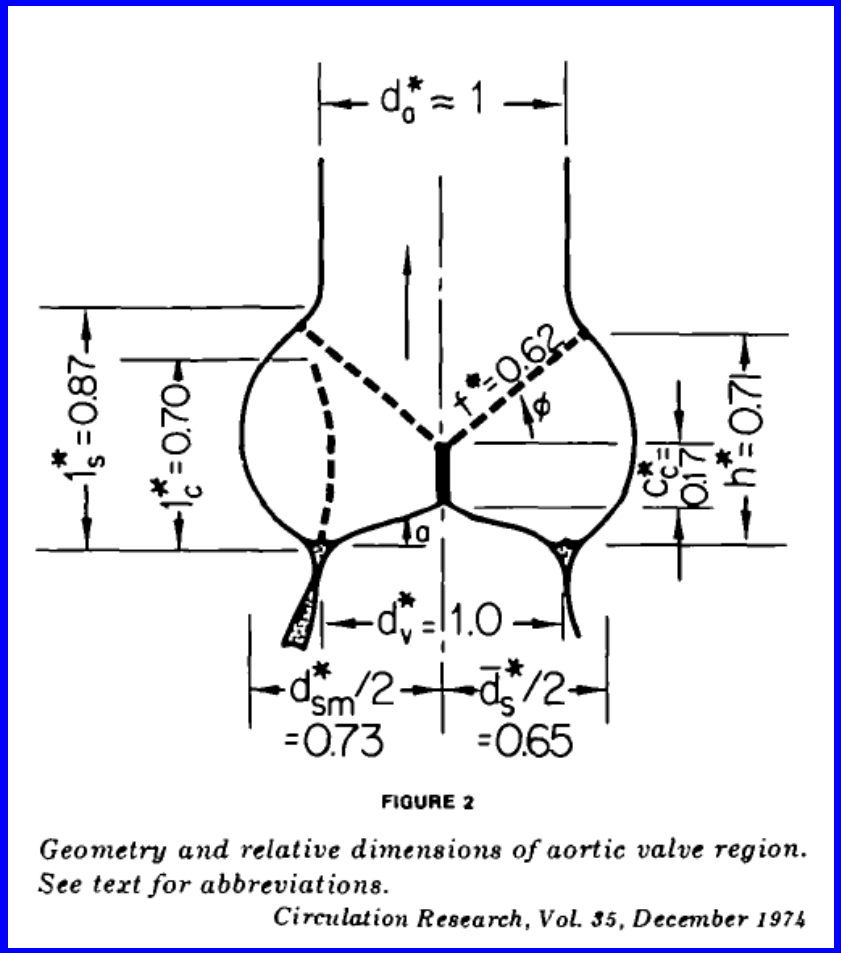
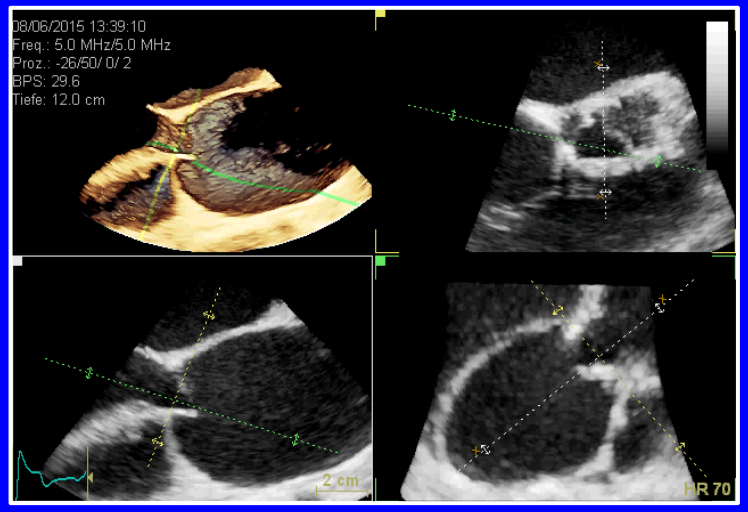
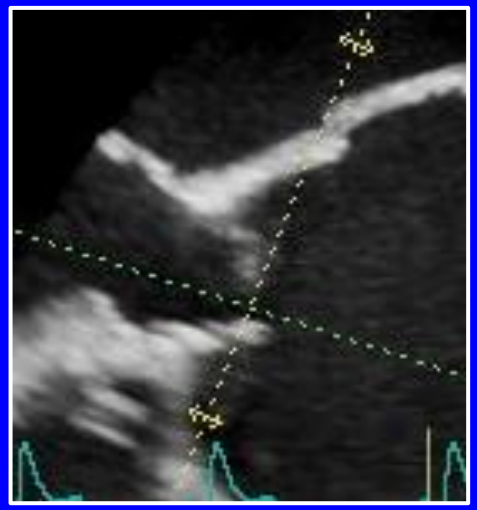


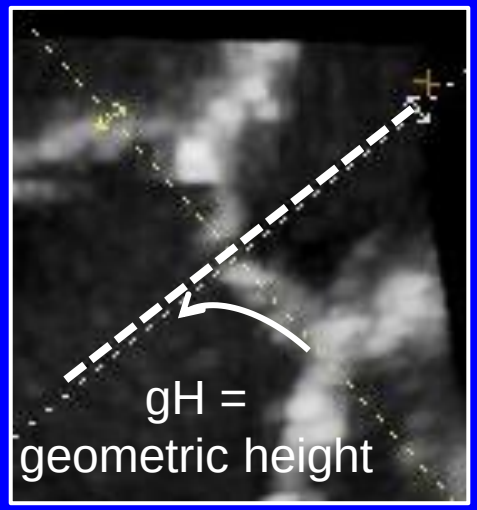
FIGURE 2

Geometry and relative dimensions of aortic valve region. See text for abbreviations.

Circulation Research, Vol. 35, December 1974



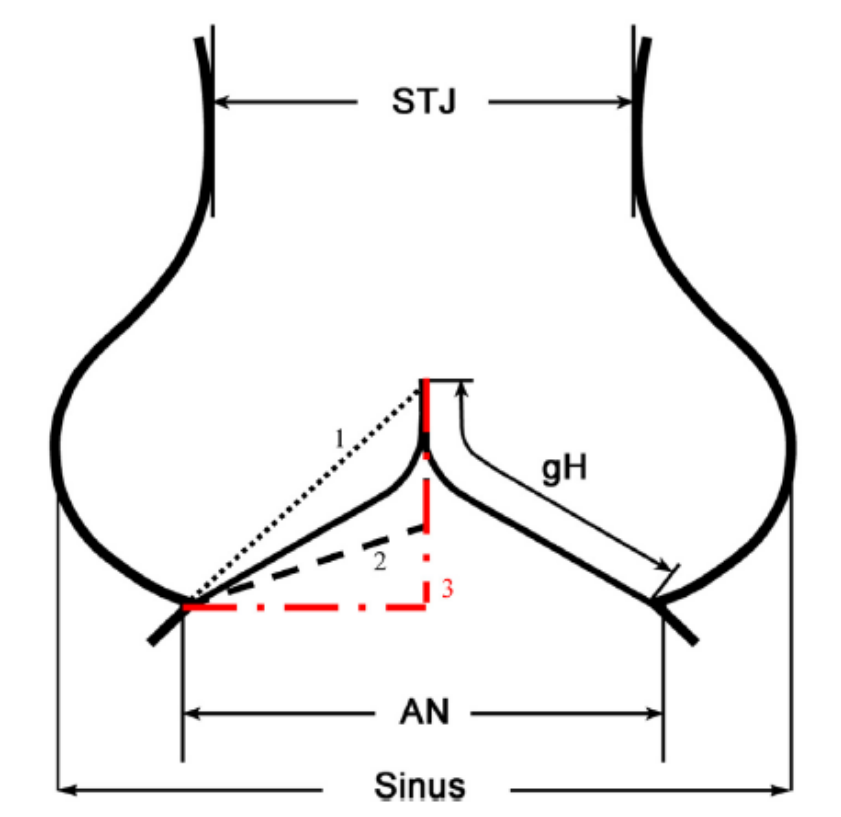


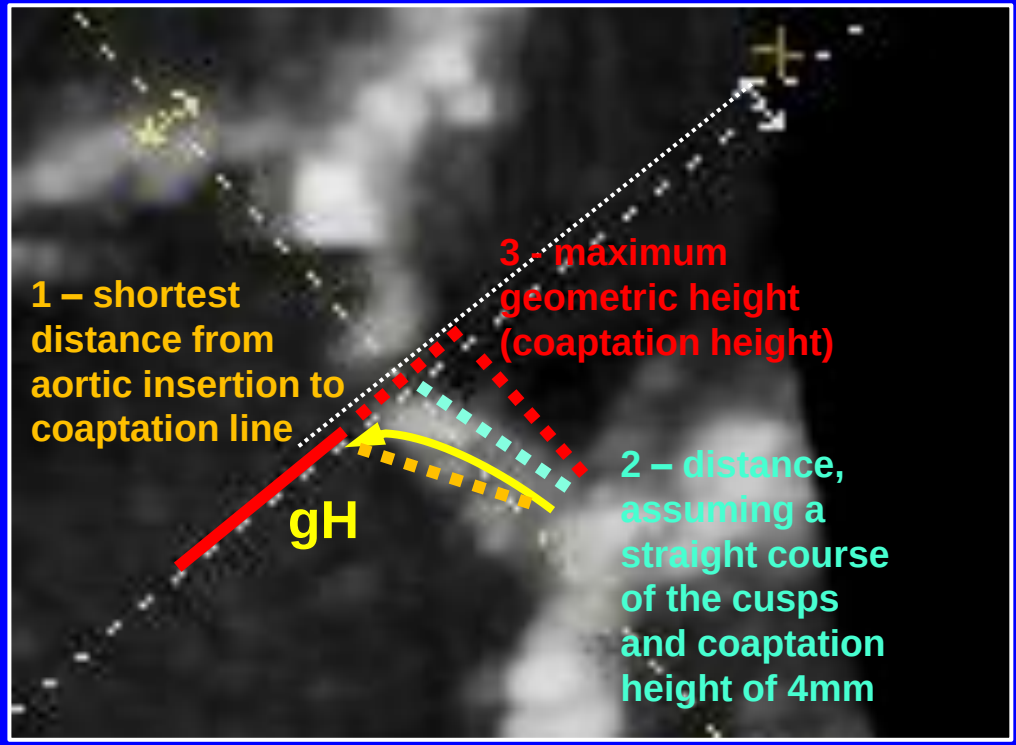


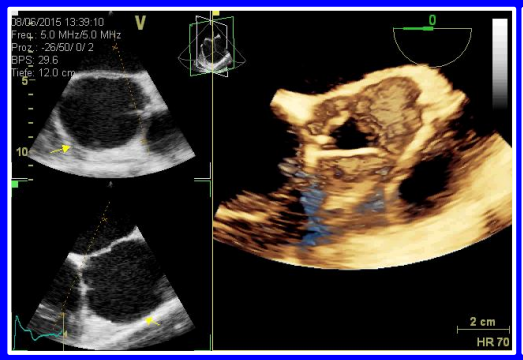
aus Swanson WM and Clark RE. Dimensions and Geometric Relationships of the Human Aortic Valve as a Function of Pressure. Circ Res 1974; 35: 871-882

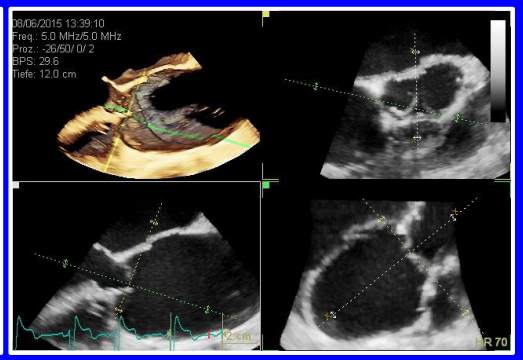
Reconstruction of the Aortic Valve and Root

The following measurements are possible (performed in special centers).







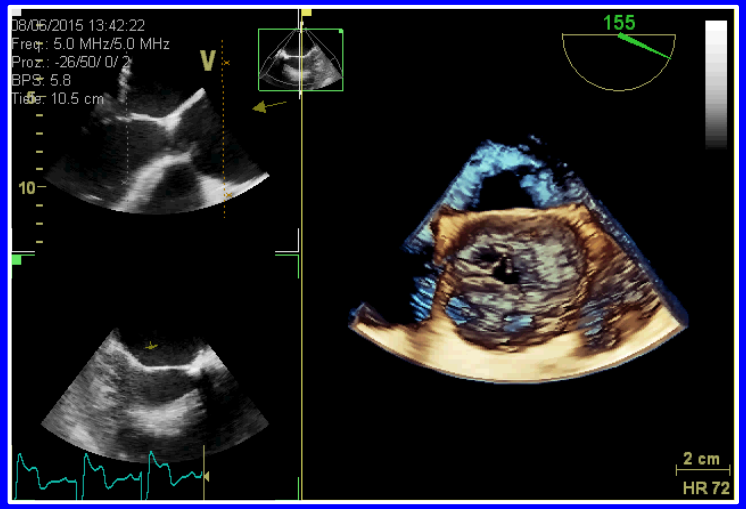


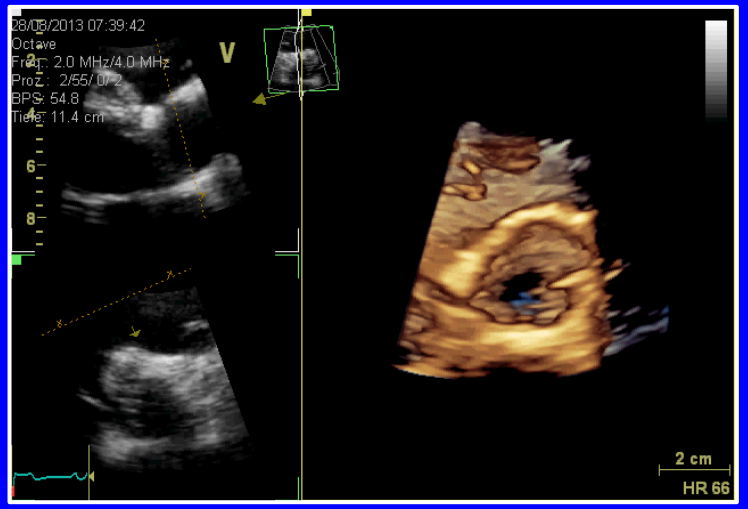
aus: Schäfers HJ, Schmied W, Marom G, Aicher D, Cusp height in aortic valves. The Journal of Thoracic and Cardiovascular Surgery 146; 2, 269-274 (2013

Reconstruction of the Aortic Valve and Root

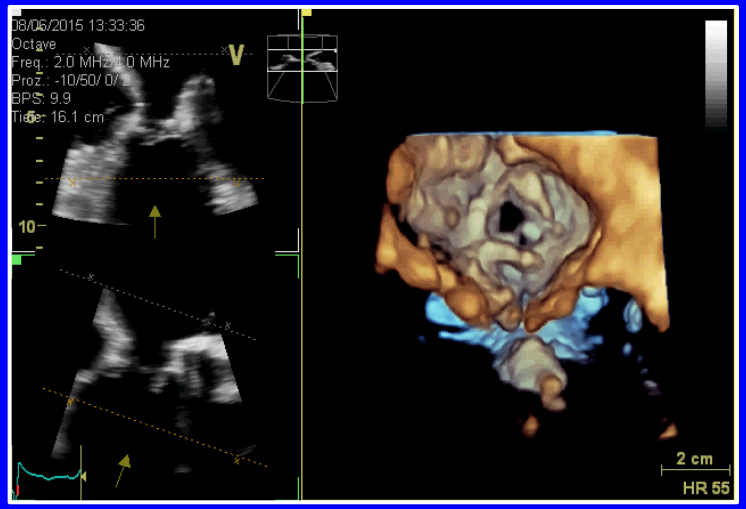
The 3D4D approach: use the best one.
The nearer approach – parasternal or TEE – is sometimes not the best.

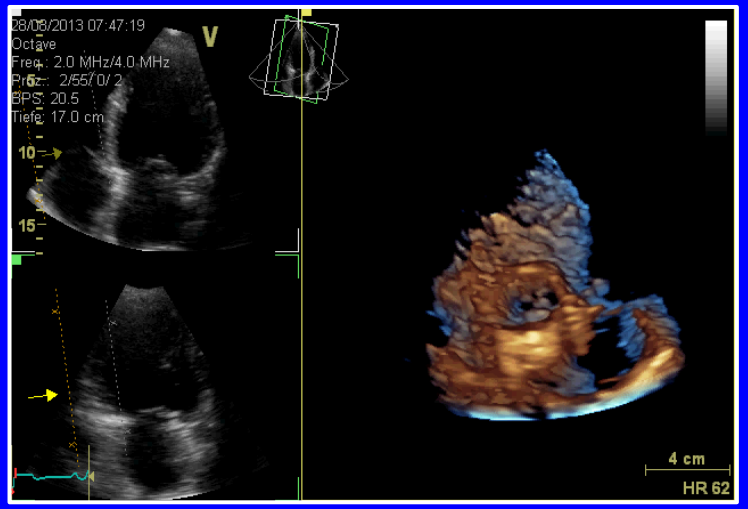
TEE





TTE apical



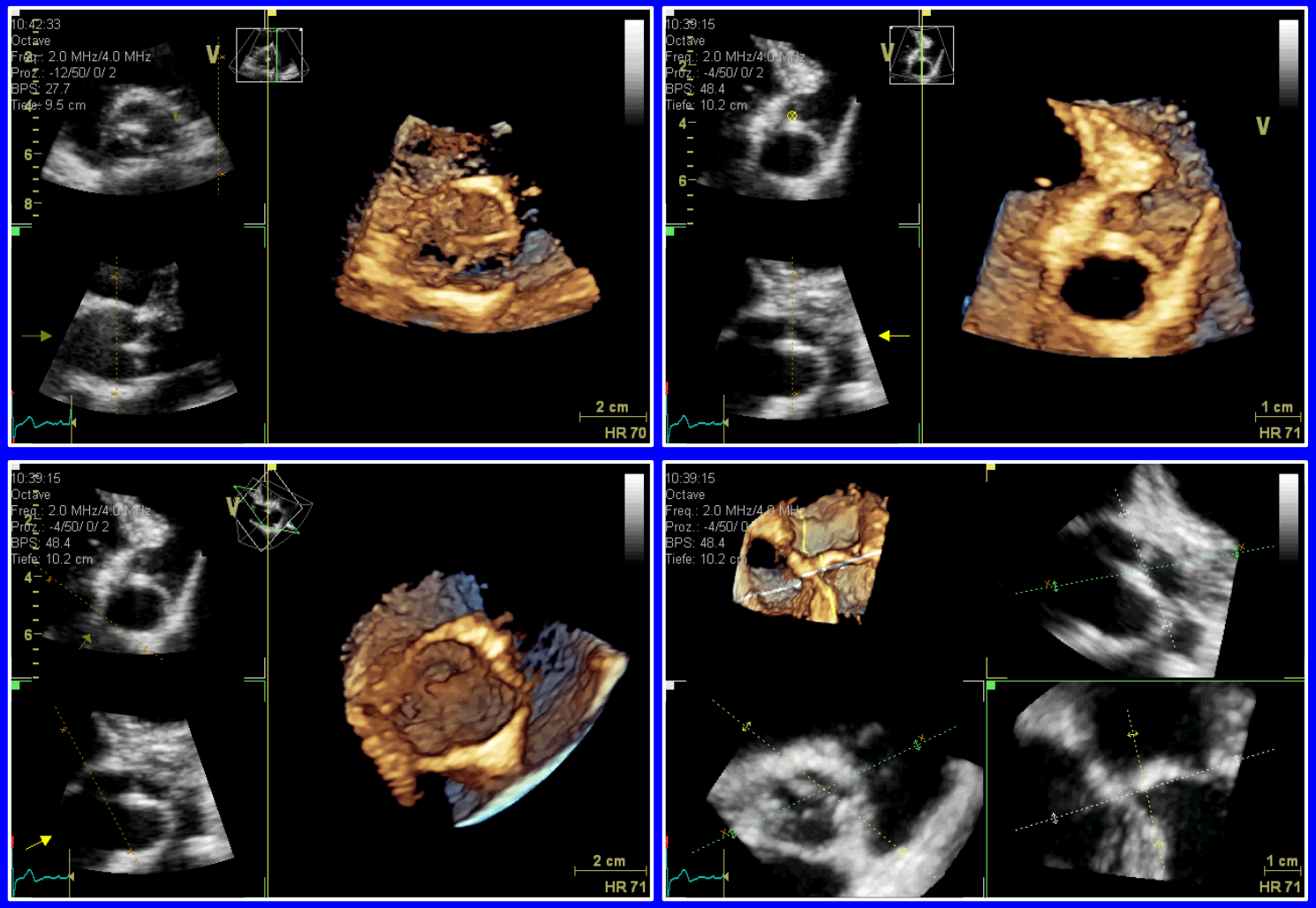


Use the approach with the best reflection speckles of the cusp to get their best visualisation.

TTE parasternal aersus apical

Reconstruction of the Aortic Valve and Root

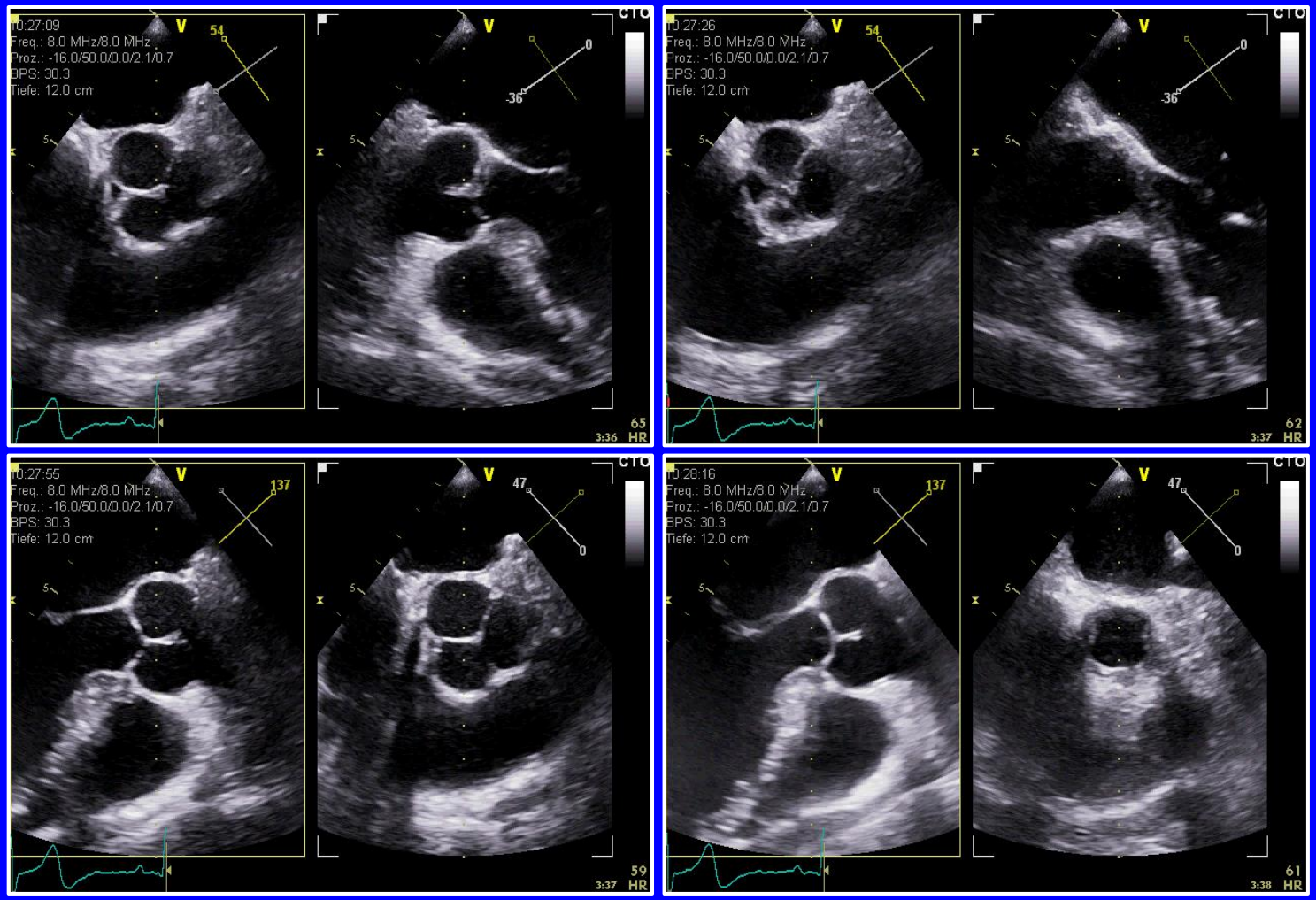
The 3D4D approach: use the best one.
The nearer approach – parasternal or TEE– is sometimes no the best.



Thera are more artifacts using the parasternal approach than using the apical approach. Postprocessing is easier using images with better rendering.

Reconstruction of the Aortic Valve and Root

The orientation of imaging in TTE and TEE
It is obvious – but sometimes not present.

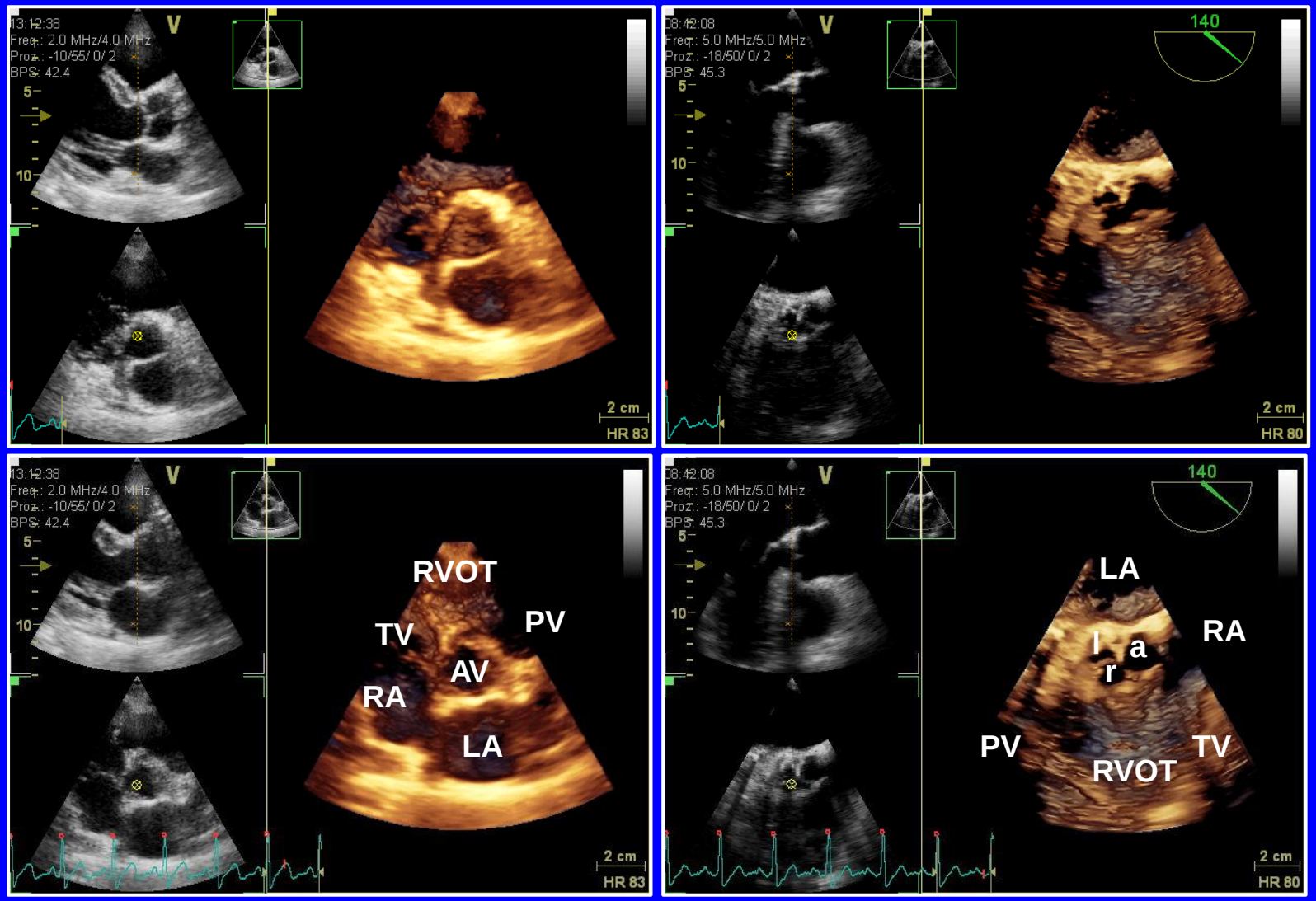


Biplane scanning: If the virtual annulus is perpendicular to the radial scanlines and the hindge points can be visualized in a short axis view. Primary scanning in the short axis view causes a mirror inverted long axis view, primary scanning in the long axis view causes a usual short axis view.

Reconstruction of the Aortic Valve and Root

Comparisons of views between TTE and TTE

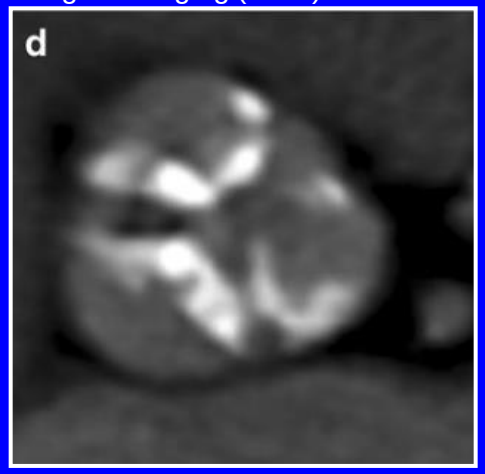
If the primary sectional plane is the long axis view in TTE, the 90° view is again with the blood stream in the LVOT. In TEE - if the primary sectional plane is the long axis view - the short axis view is again with the blood stream in the LVOT, but the view is mirror-inverted.

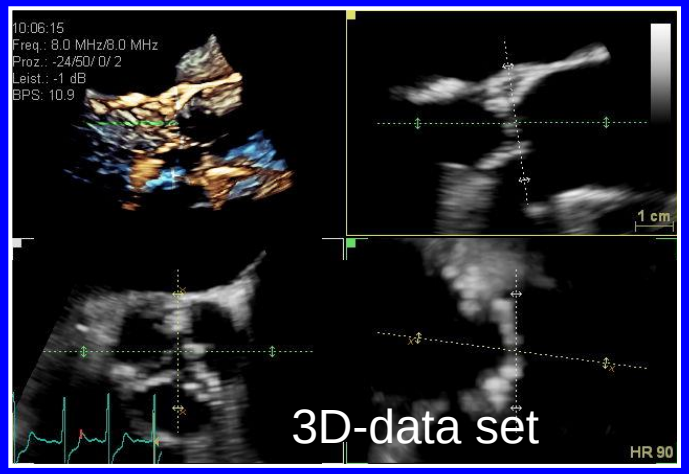


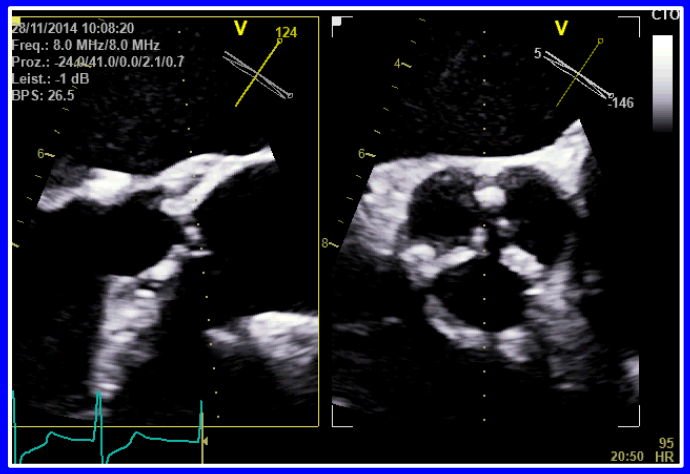
Reconstruction of the Aortic Valve and Root

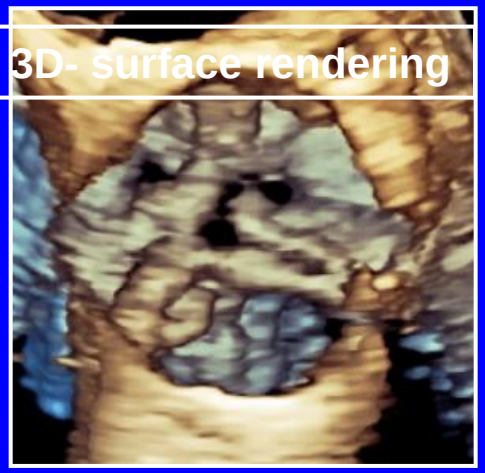
according to Rajiah P and SchoenhagenP.
The role of computed tomography in pre-procedural planning of cardiovascular surgery and intervention .
Insights Imaging (2013) 4:671–689

Morphology and calcification of aortic valve:
It can be assessed by echocardiography - however, echogeneity is not always the same thing. Stenotic orifice areas can normally well be determined by 2D- and 3D4D techniques.





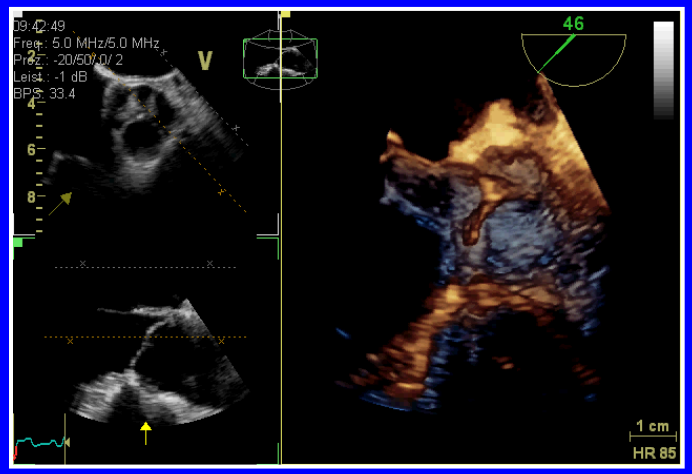


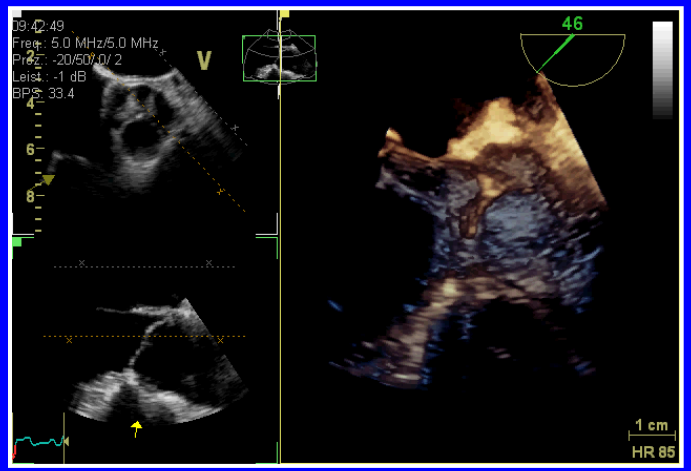


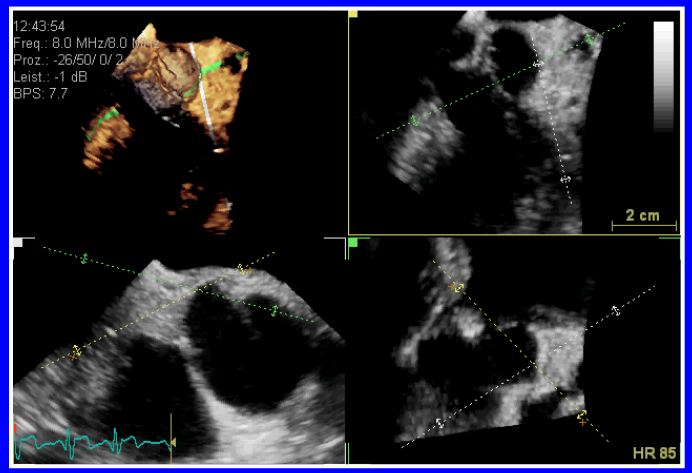
Biplane and 3D spatial resolution is sufficient and at least comparable to CT.

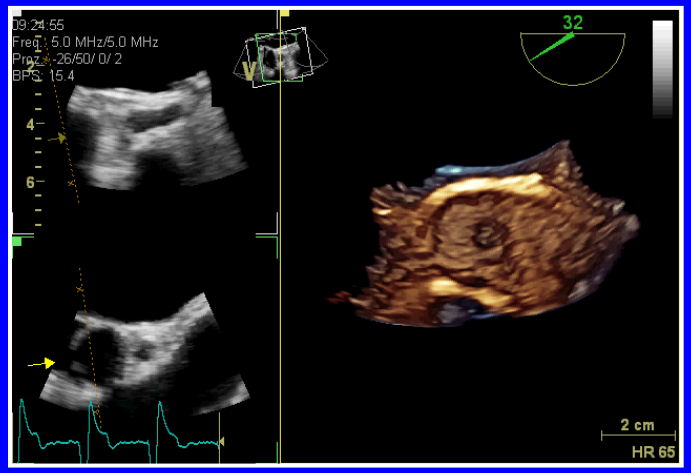
Reconstruction of the Aortic Valve and Root

The documentation of special cardiac structures: Anatmoy of coronary ostia and their relation to the aoric cusps







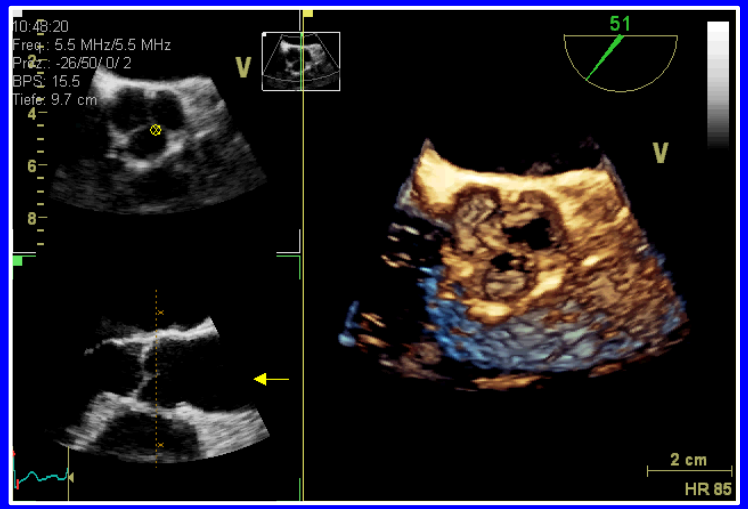


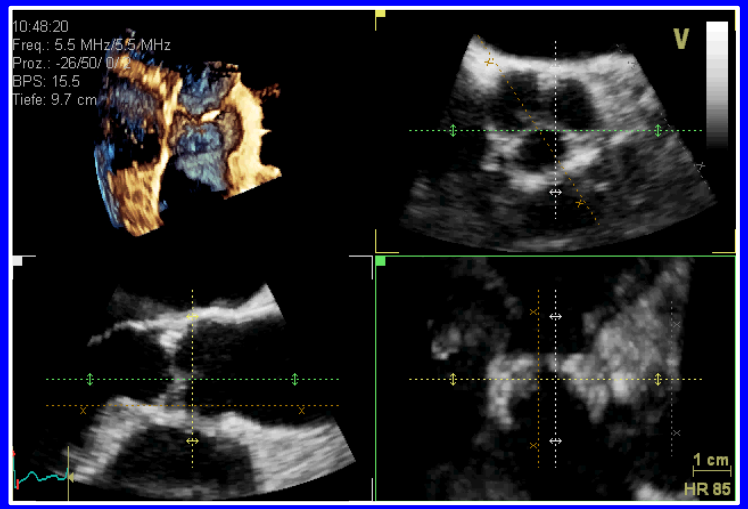
The distances between annulus and the coronary ostia as well as the lenght of the cusps can be easily measured using sectional planes within a 3D4D data set (furthermore the dynamic aspect of the ostial movement can be visualized and analyzed in 3D-TEE data sets.

Reconstruction of the Aortic Valve and Root

Visualization of coronary ostia by using FlexiSlice and 2-Click-Crop

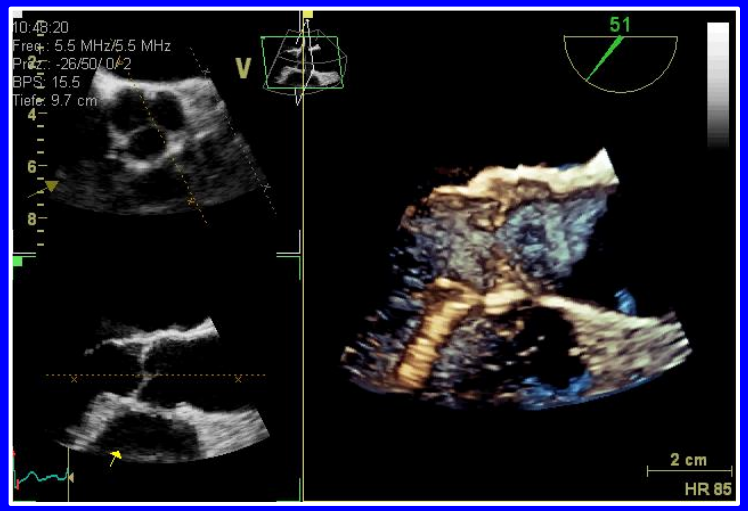
3D4D-data-set: short axis view aortic valve

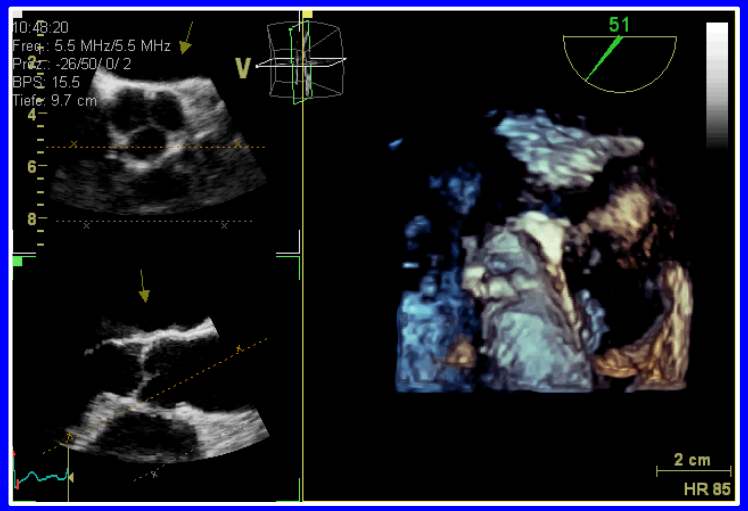




3D4D-data-set: Flexi-slice axis of the aortic valve

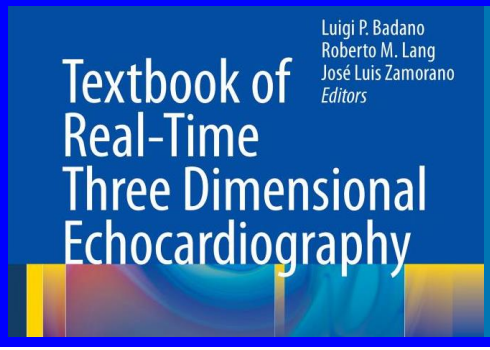
3D4D-data-set: long axis view ostium of the LCA





2-Click-Crop-view of the ostium of the RCA

Reconstruction of the Aortic Valve and Root

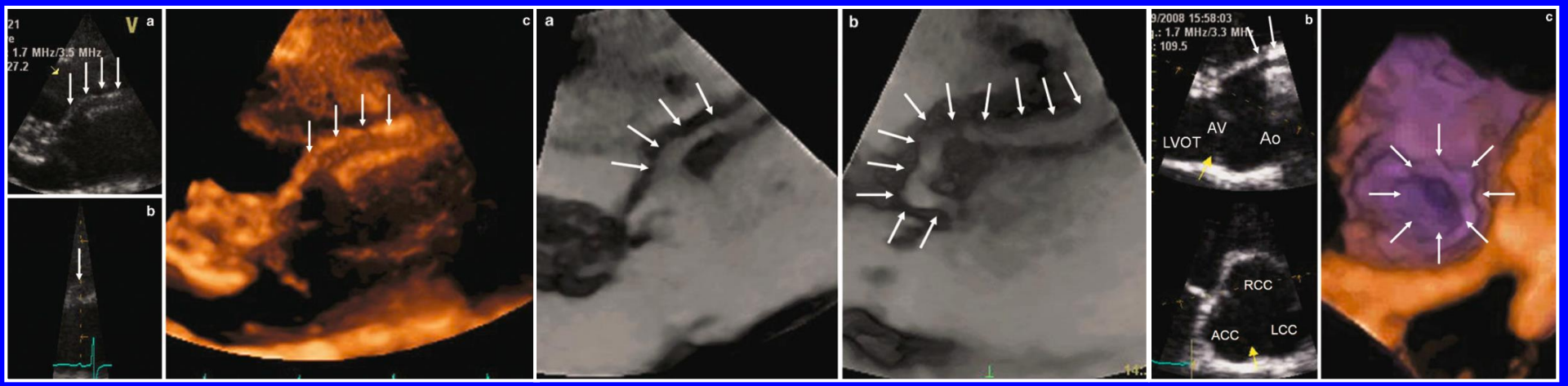


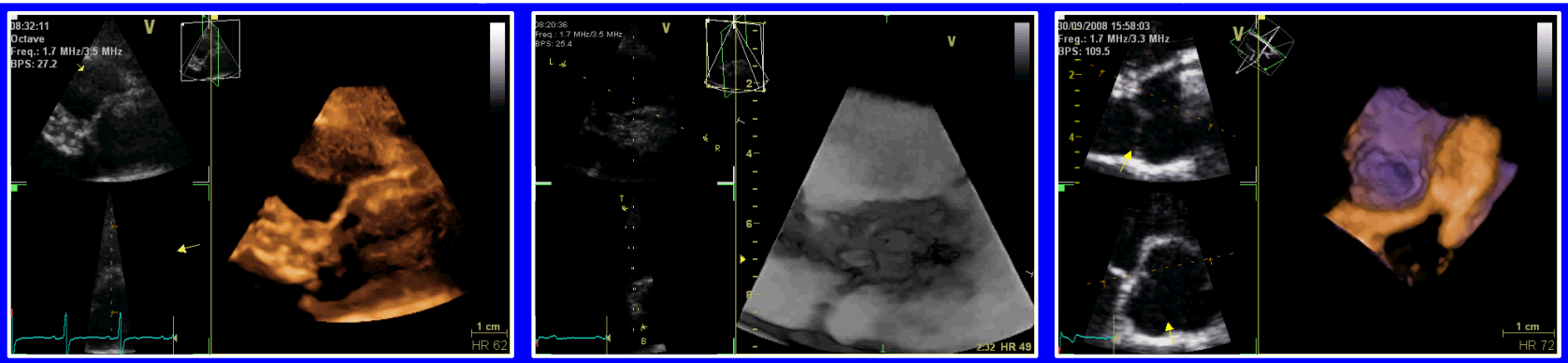
Visualization and Assessment of Coronary Arteries with Three Dimensional Echocardiography

16

Andreas Hagendorff

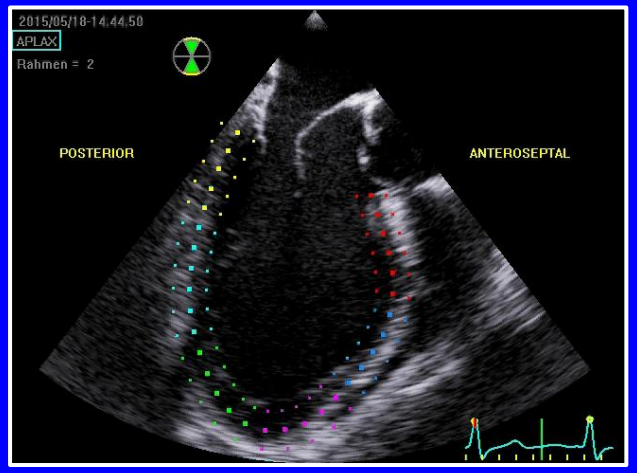
The proximal part of the right coronary artery is often well visible by 3D-TTE. Measurements of the cusps and aortic root dimensions can be performed.

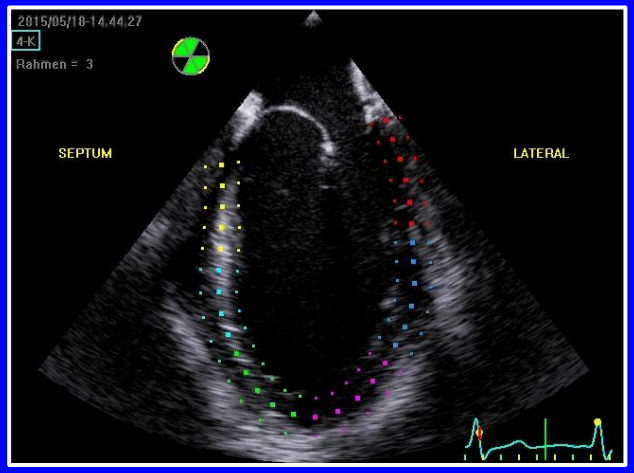


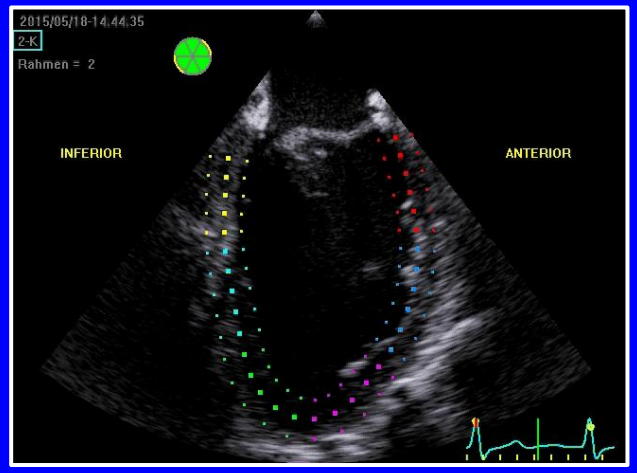


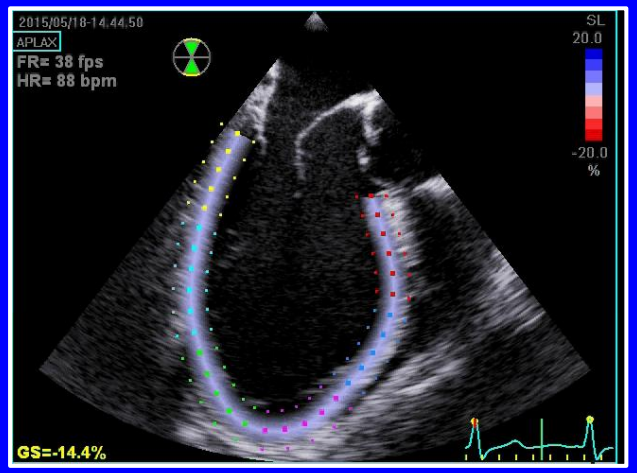
Reconstruction of the Aortic Valve and Root

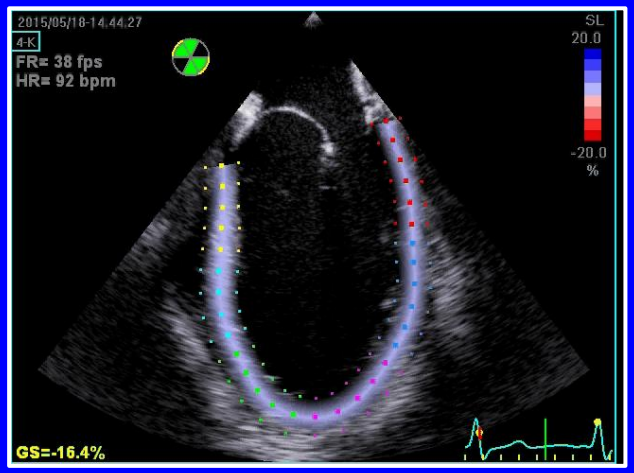
Aortic regurgitation Type Id: The assessment of left ventricular function by TEE „not very new“ – but still unknown: Analysis of deformation imaging in TEE

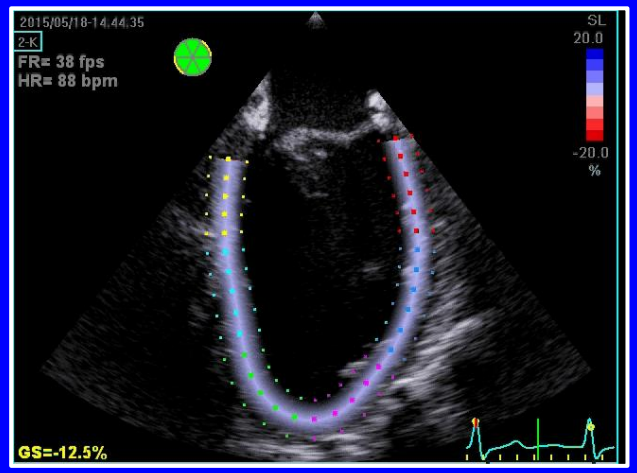






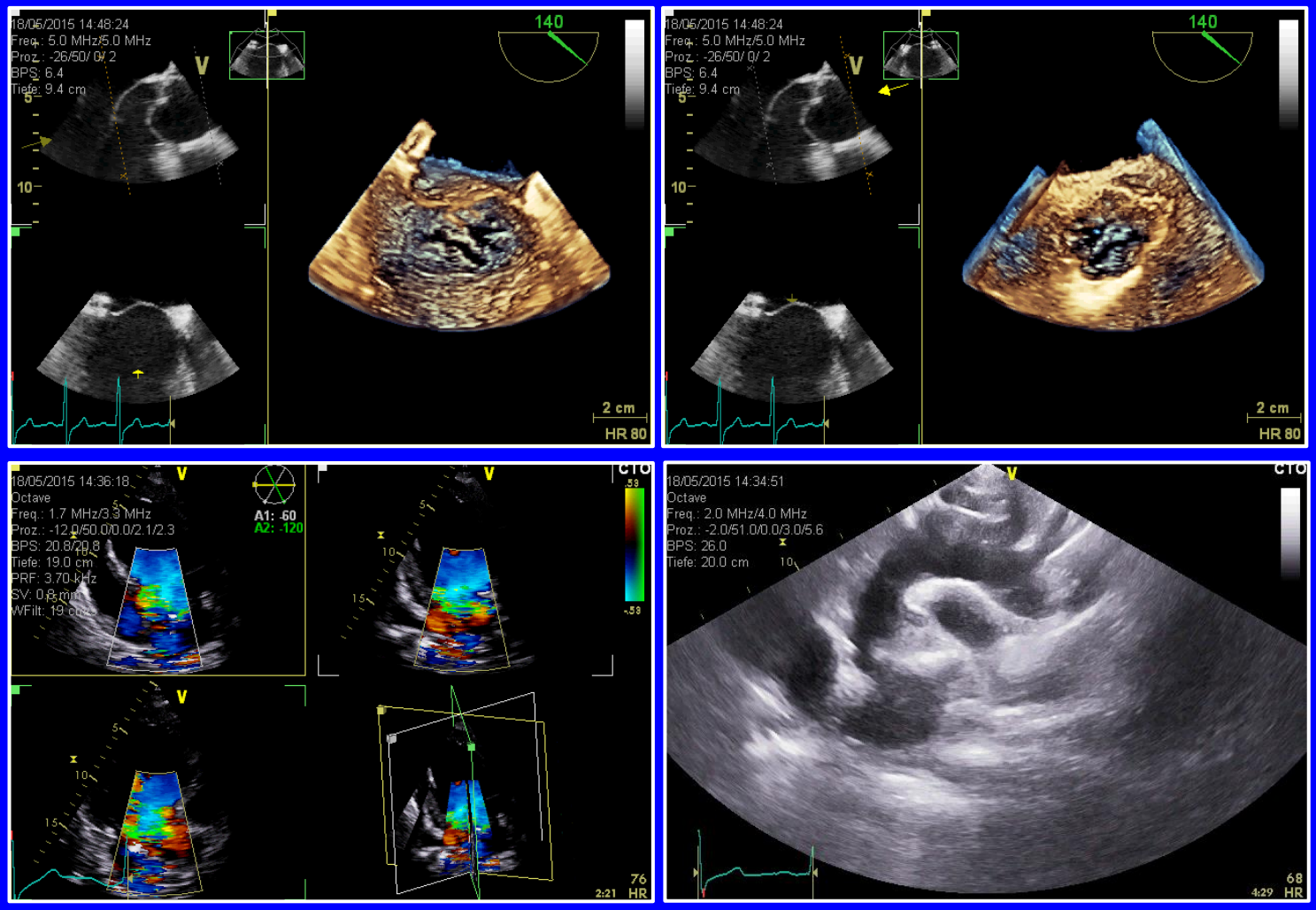






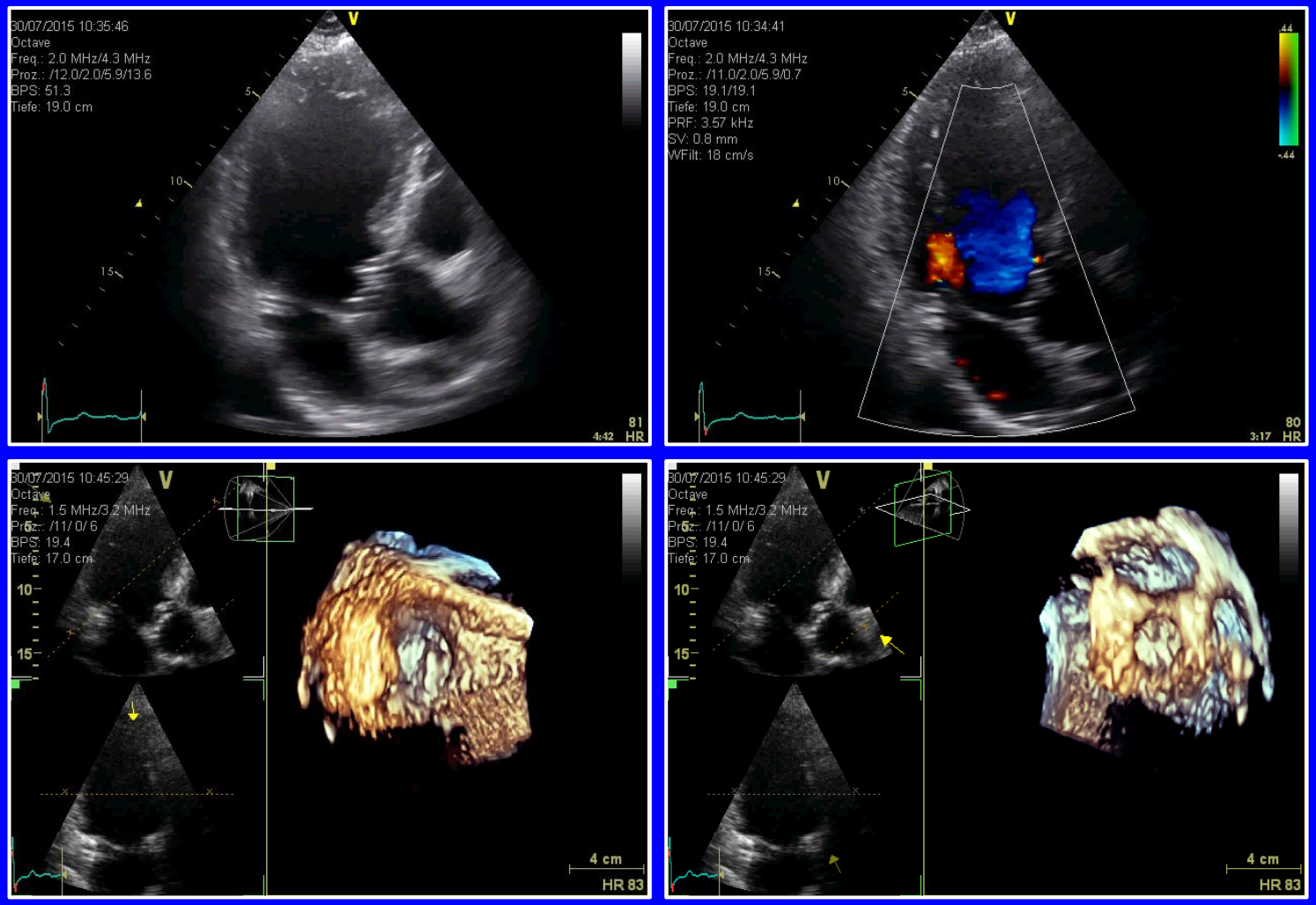
Reconstruction of the Aortic Valve and Root

Aortic regurgitation Type Id:
the pre-surgical state prior to aortic valve repaier



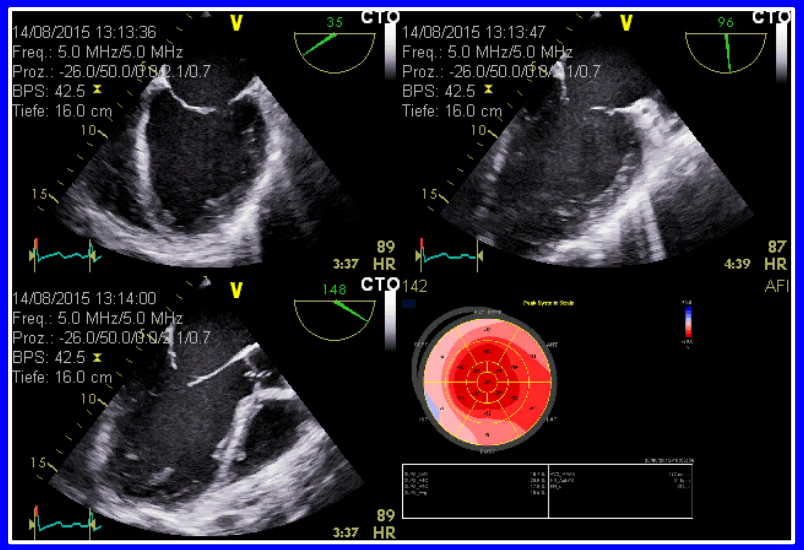
Reconstruction of the Aortic Valve and Root

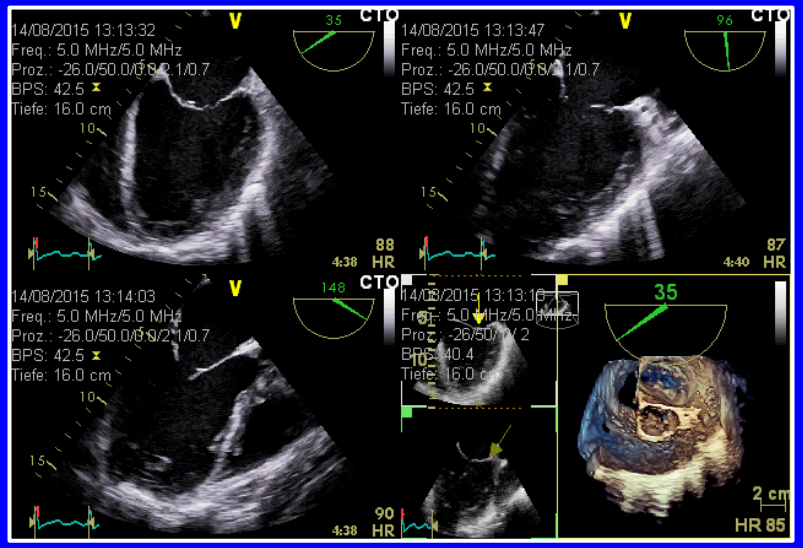
Aortic regurgitation Type Id:
the post-surgical state post to aortic valve repaier

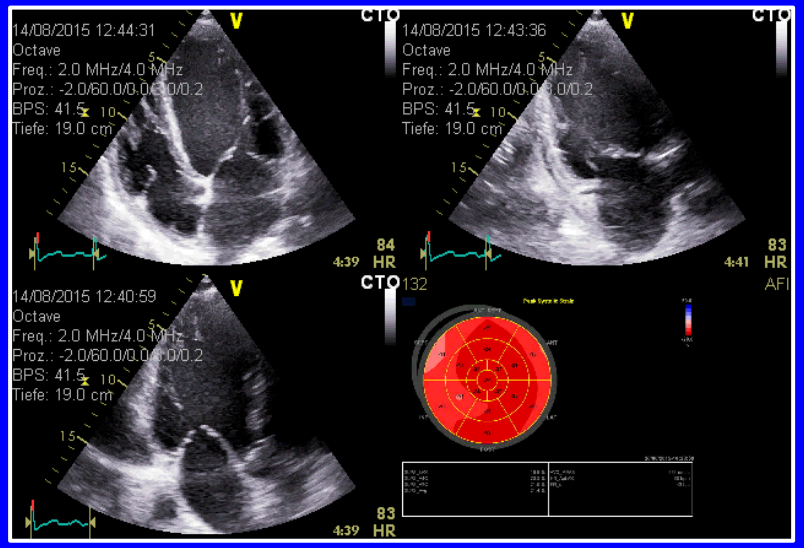


Reconstruction of the Aortic Valve and Root

There are differences in TTE and TEE speckle tracking – especially, if the sectional planes in TEE are not exactly standardized.

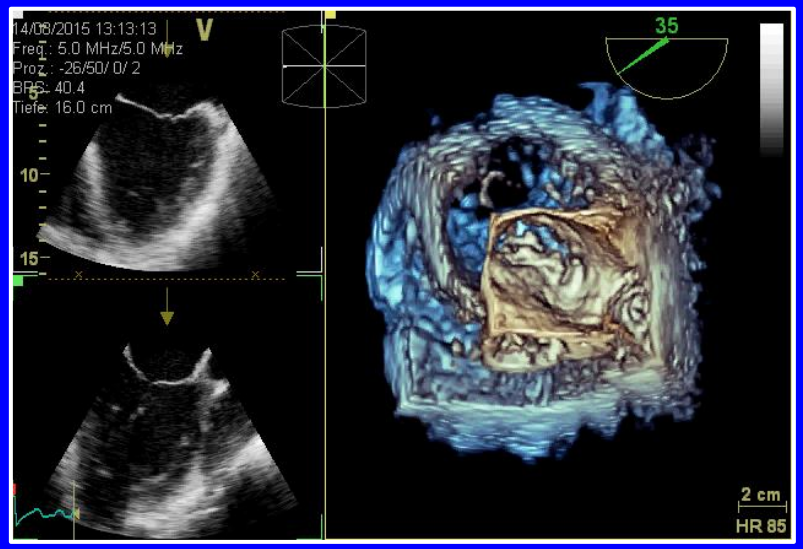


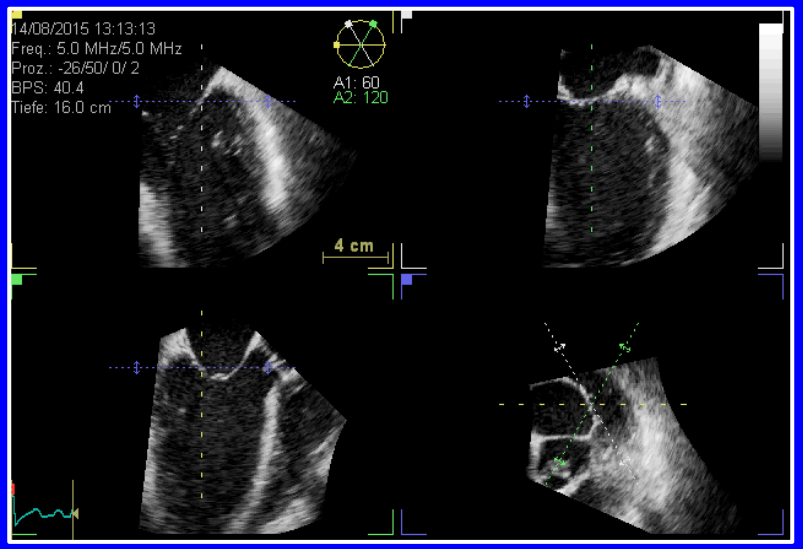


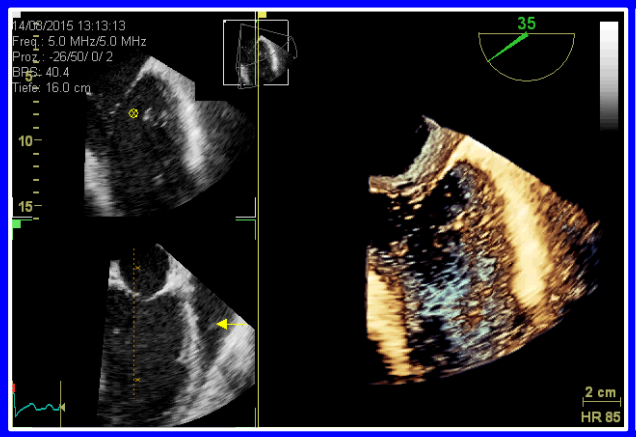


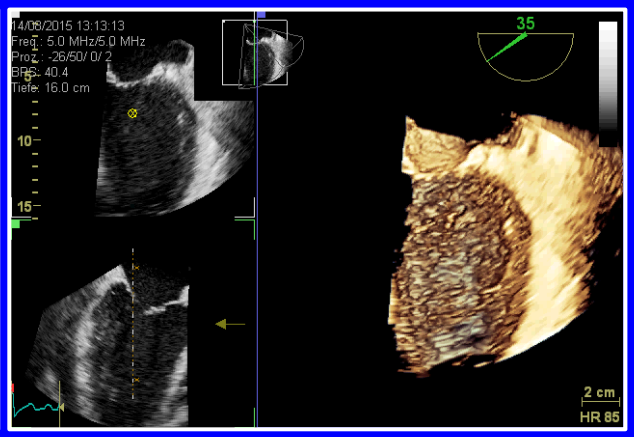
Reconstruction of the Aortic Valve and Root

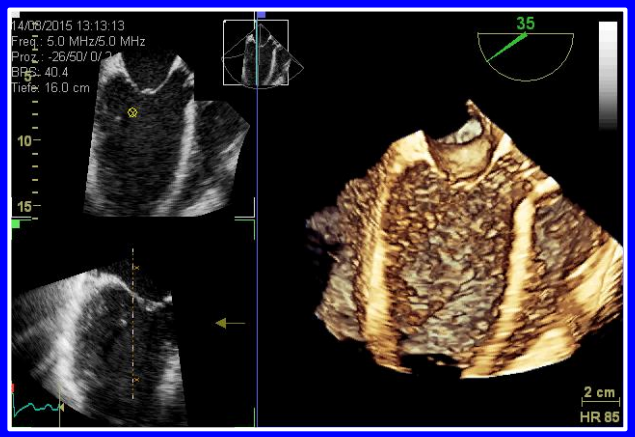
Standardization of sectional planes for conventional LV-function analysis by planimetry can be performed adjusting the planes in a complete 3D4D-TEE data set.







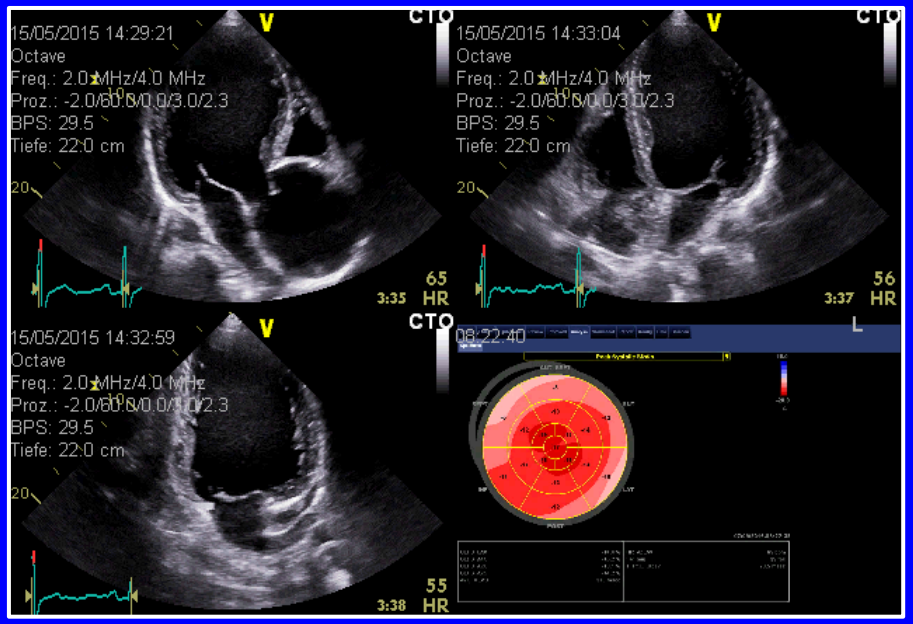




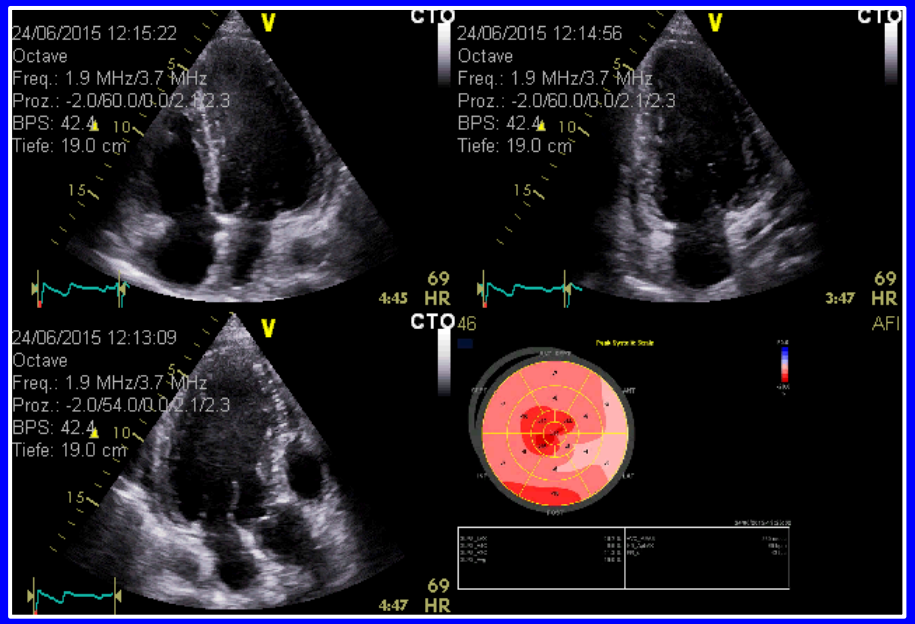
Reconstruction of the Aortic Valve and Root

Left ventricular function after aortic valve repair :
What is normal ?
What is a „normal“effect in excentric left ventricular hypertrophy due to volume overload?
What is the normal sequelae after surgical repair?
Can the reverse remodeling be monitored in the follow-up?
What is normal in the follow-up?

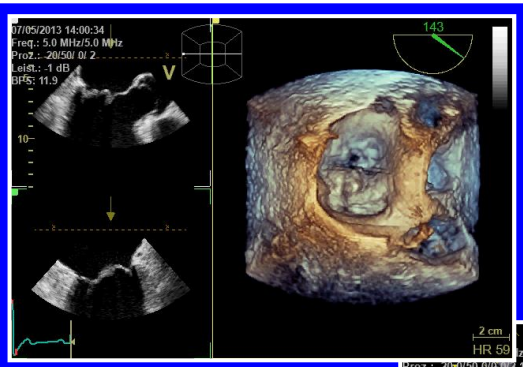
Global strain prior to surgery: -14.2%



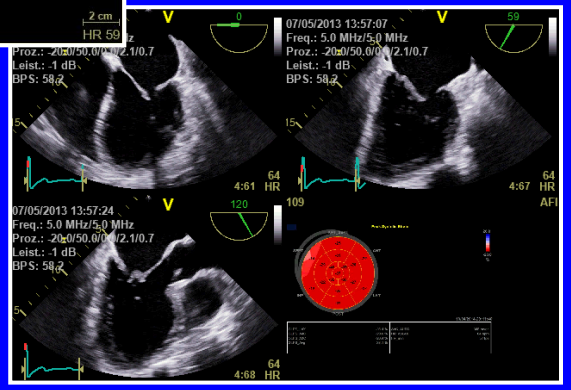
Global strain prior to surgery: -10.8%

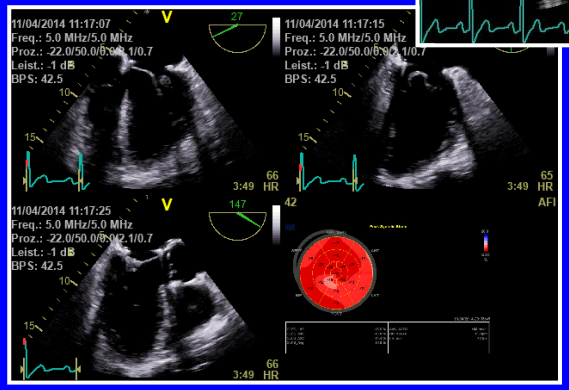


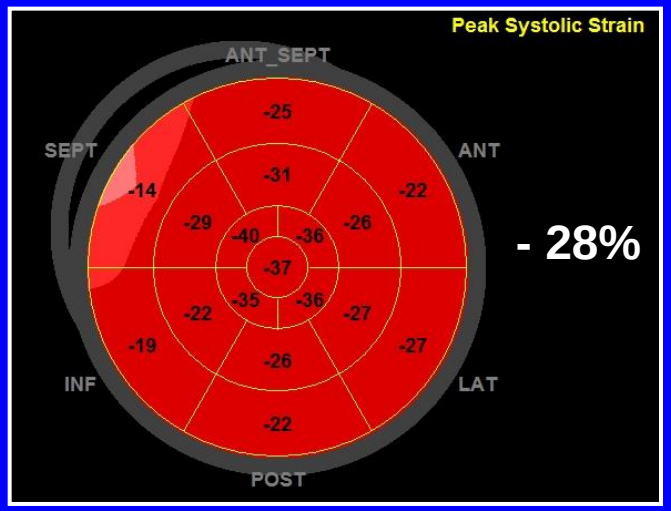
Reconstruction of the Aortic Valve and Root



Left ventricular function
after mitral valve annuloplasty:
What is normal ?
A global strain of -16%
one year after surgery?

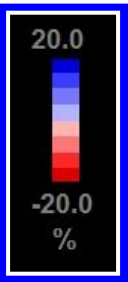






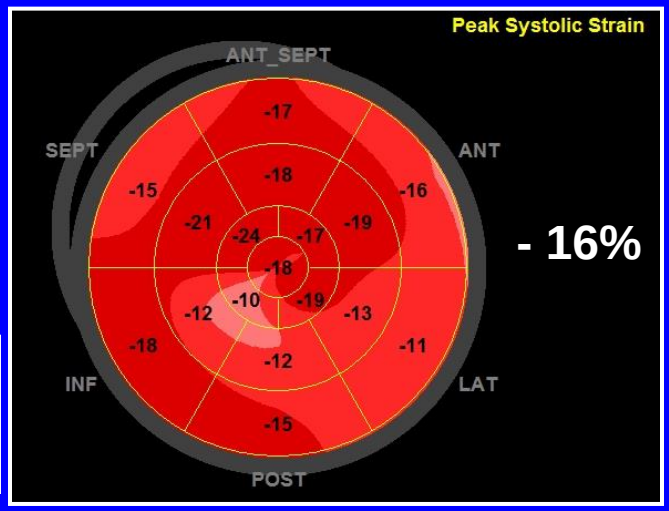
GLPS_LAX	-28.4 %
GLPS_A4C	-29.6 %
GLPS_A2C	-26.4 %
GLPS_Avg	-28.1 %

preoperative



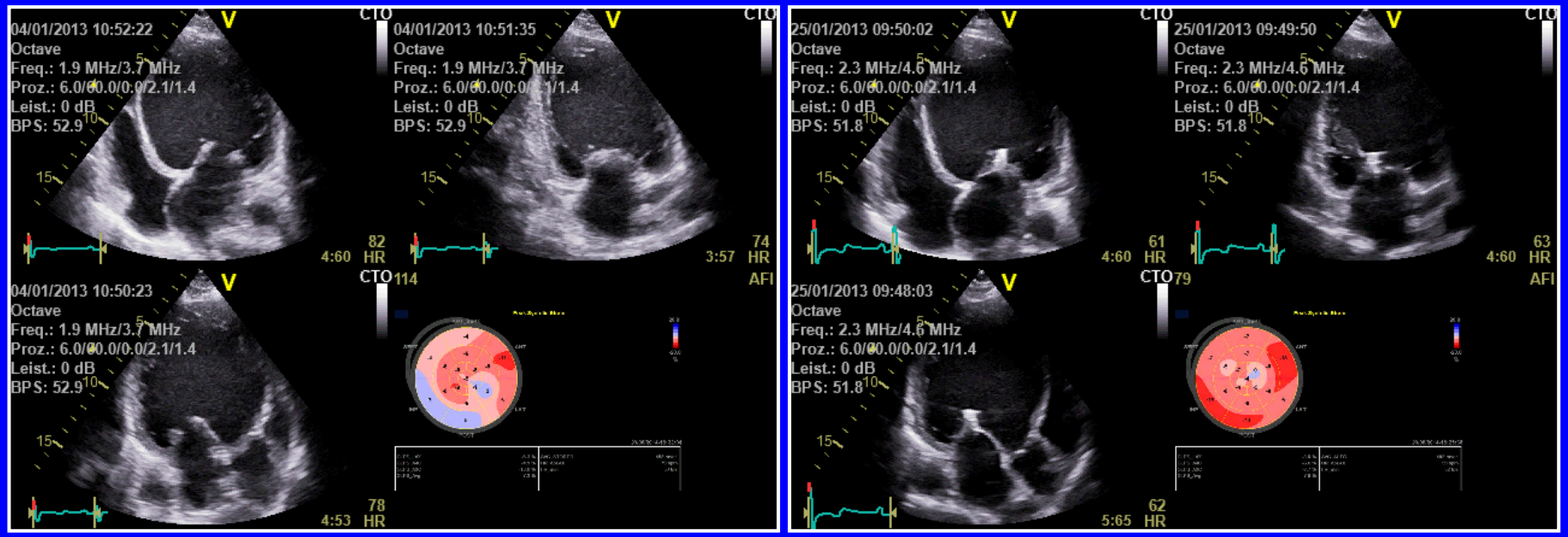
postoperative

GLPS_LAX	-15.6 %
GLPS_A4C	-18.0 %
GLPS_A2C	-14.4 %
GLPS_Avg	-16.0 %



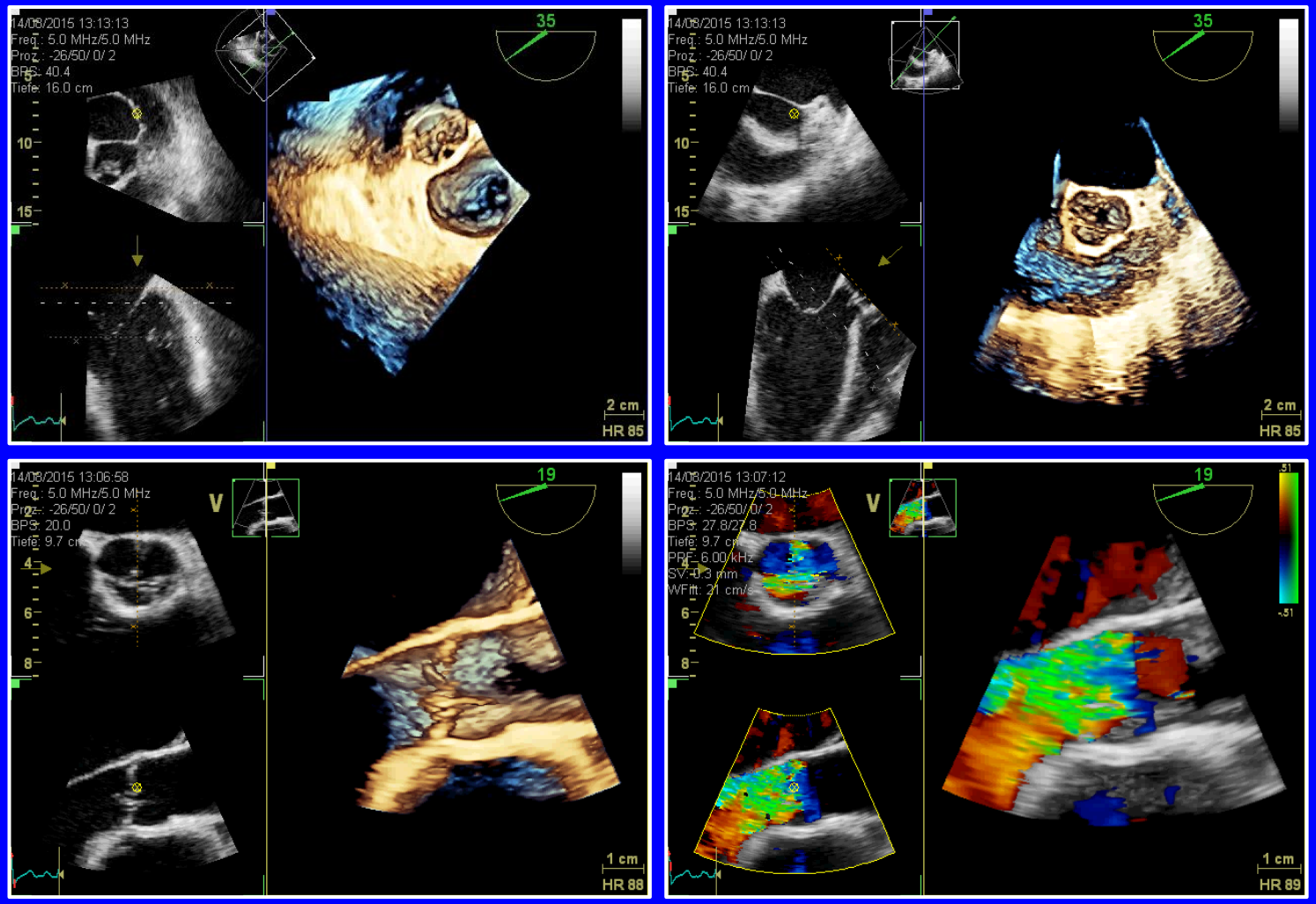
Reconstruction of the Aortic Valve and Root

Example:the monitoring of MitraClip-patients.
The acute effect of clipping can be monitored.
There is an improvement of left ventricular deformation, if the anterior-posterior diameter of the mitral annulus is reduced by the clipping procedure.



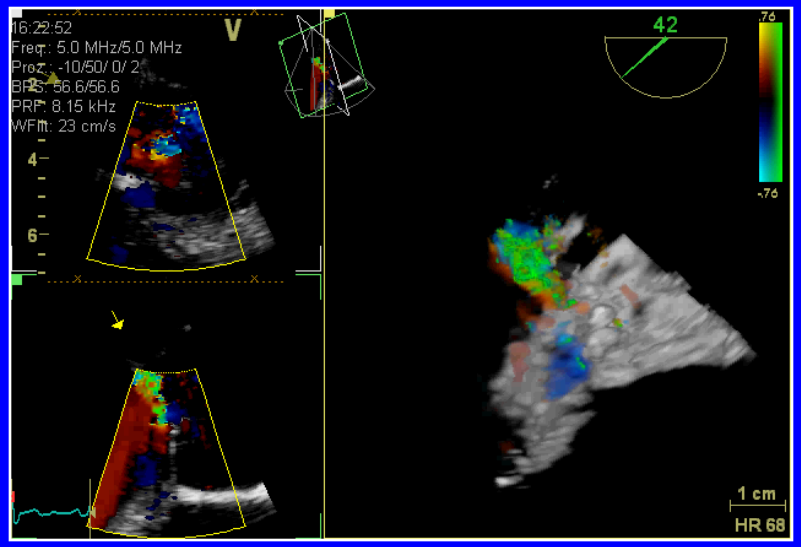
Reconstruction of the Aortic Valve and Root

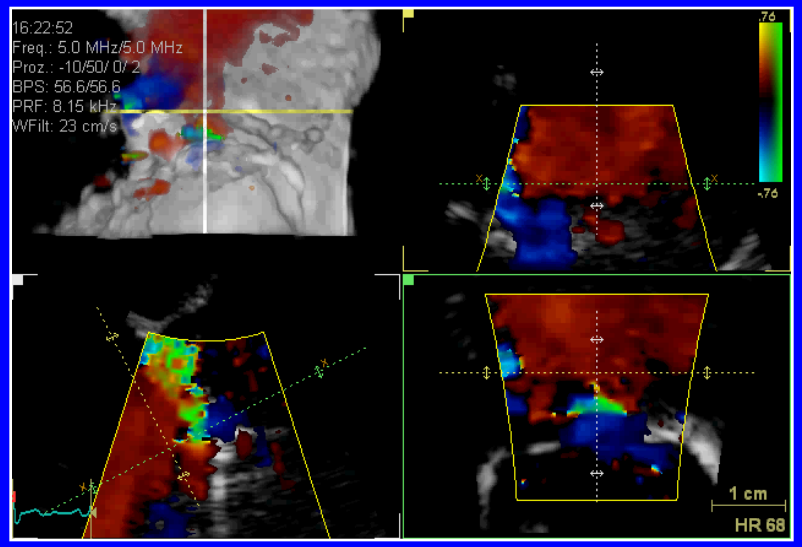
Navigation in the 3D4D-data set enables all views to the aortic valve (auto-alignement, 2-click-cropping and flip crop);
Estimation of effective regurgitant orifice by flexislice in a 3D4D color coded data set

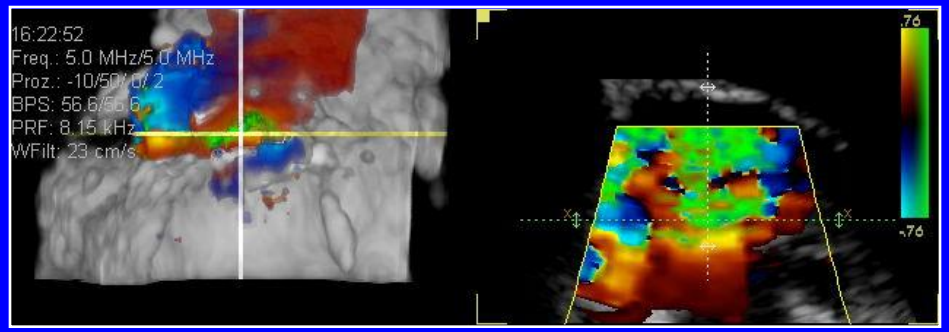


Reconstruction of the Aortic Valve and Root

Additional information and better diagnostic impact: Quantification of an excentric regurgitation in biscuspid aortic valve Case: ERO - 0.1-0.2 cm^2

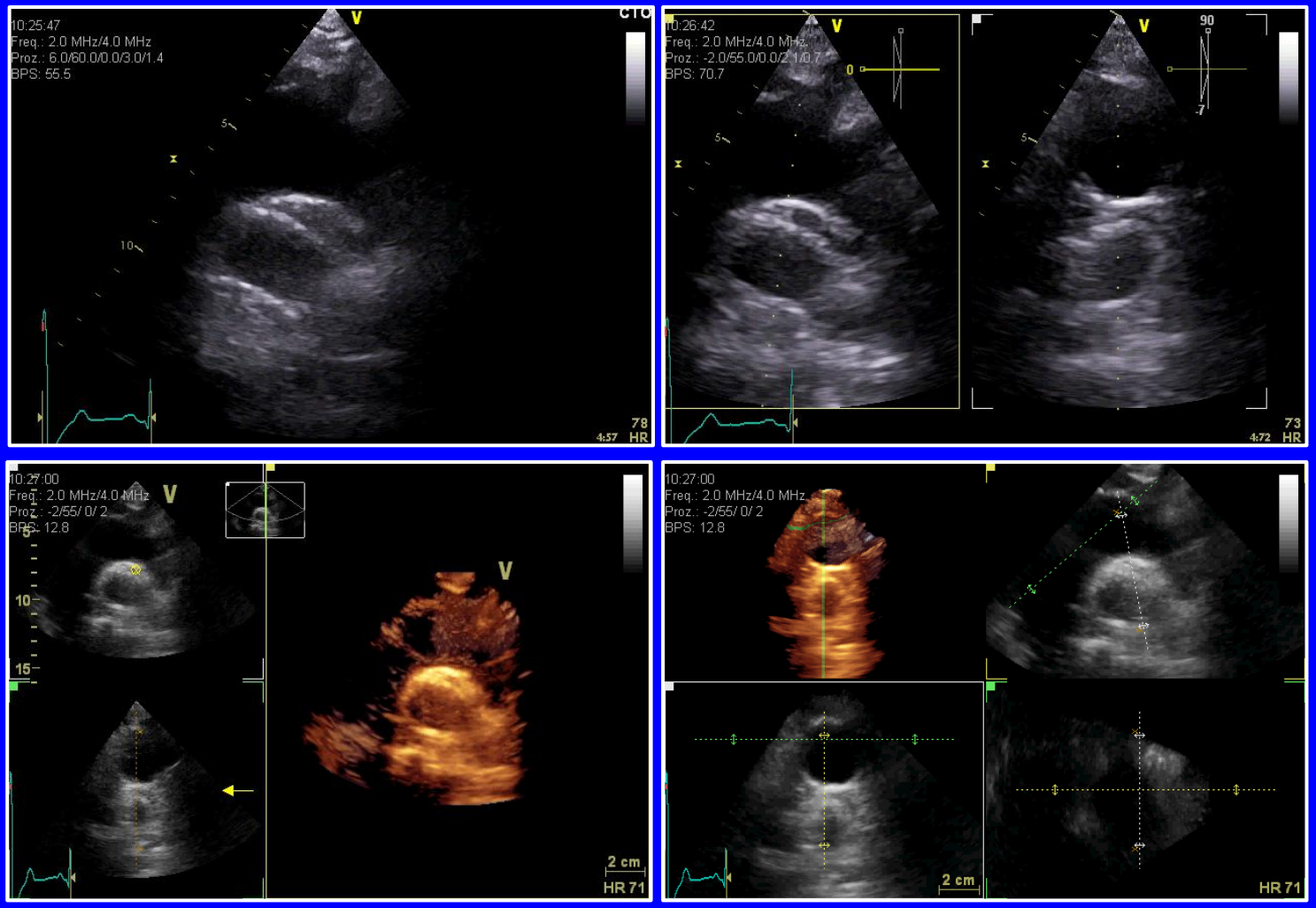






Reconstruction of the Aortic Valve and Root

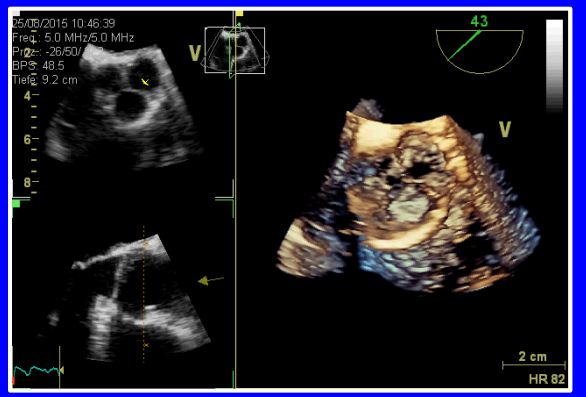
Multidimensional analysis of aortic arch: Objective measurements of aortic dimensions

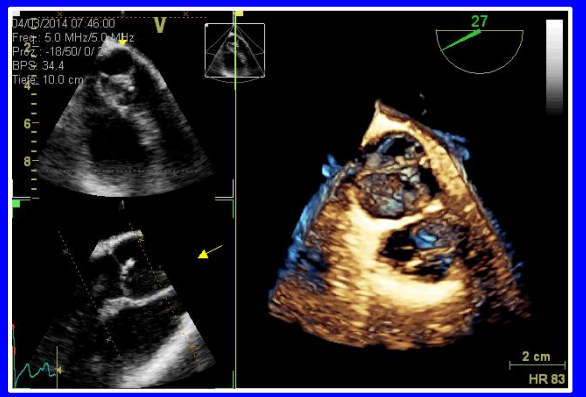


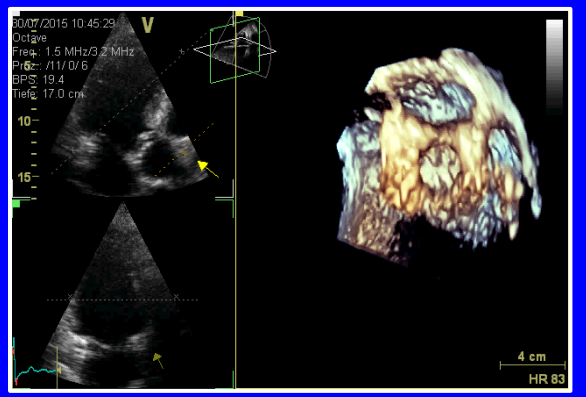
Reconstruction of the Aortic Valve and Root

Summary:

1. 3D4D echocardiography enables a completely new modality of imaging in echocardiography – the visualization of surfaces (endocardium and the cusps).
2. Biplane and triplane simultaneous sectional planes enables a better and more acurate standardization of imaging with improvement of measurements of anatomical structures.
3. Postprocessing in 3D4D data sets offers the possibility of new views (e.g. en-face view of the coronary ostia, etc.)
4. Especially for the decicion making and the planning of the surgical strategy 3D4D echocardiography can provide important informations.
5. The higher the image quality, the better the information.
6. Thus, training and expertise in 3D4D echocardiography is a prerequisite for a better diagnosis.







Reconstruction of the Aortic Valve and Root

Thank You for Your Attention