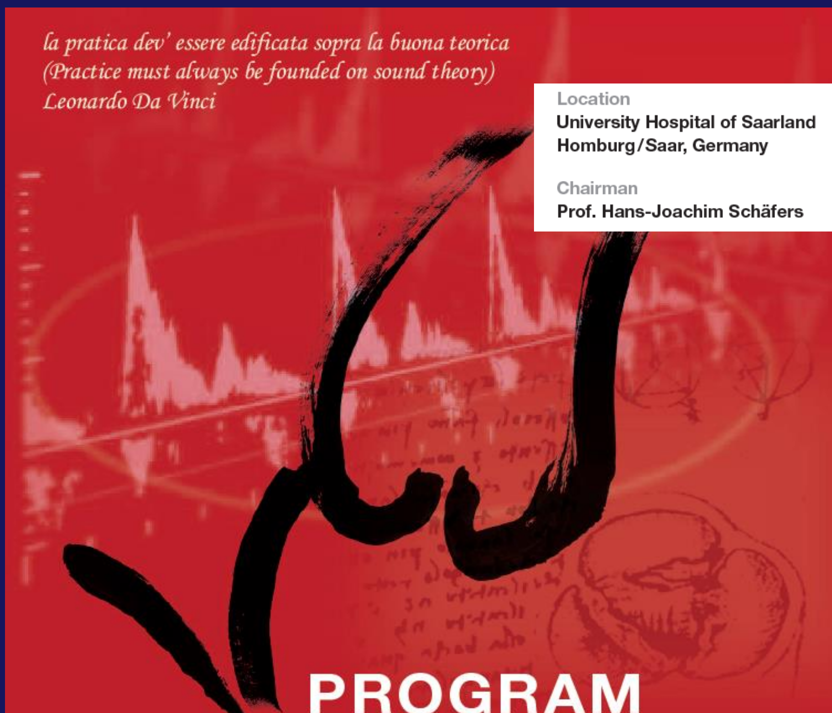
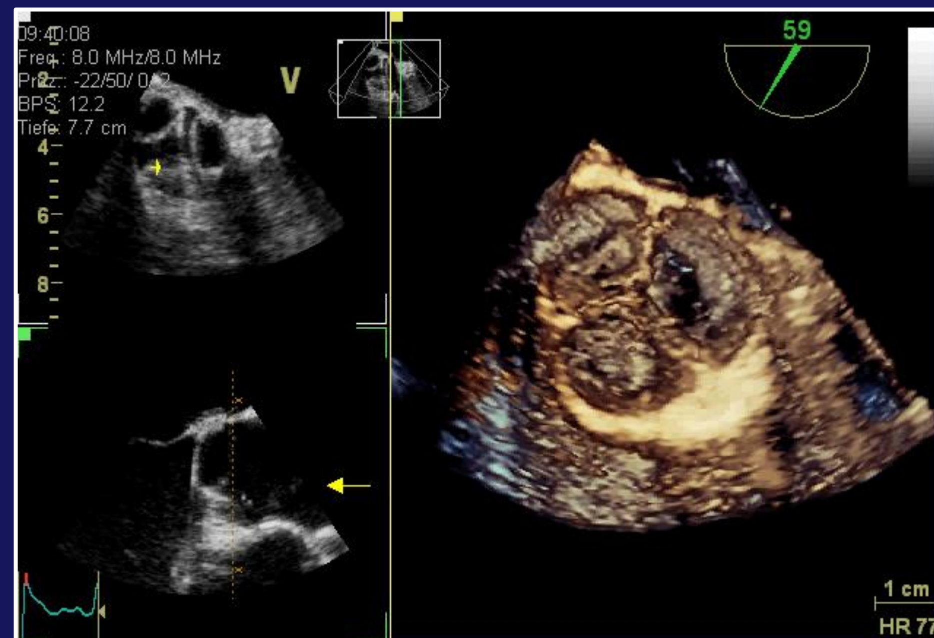
3D- and Multidimensional Echocardiography in Aortic Valve Repair



Thursday 15th September - 14.00



Practice must always be founded on sound theory.

Leonardo Da Vinci

EBAC

Declaration of Interests Policy and Rules

I declare for the last 3 years and the subsequent 12 month the following conflicts of interests:

Section I: Support for Research Activities - grant of the DEGUM
- no other financial research support

Section II: Support for Educational Activities - MIFO, GE Healthcare, Astra Zeneca, Servier, Novartis, Berlin-Chemie, Pfizer, Cardiac Dimension, Abbott, Bayer, Kelcon

Section III: Honorarium for Promotional Activities - none

Section IV: Personal Financial Interests in Vommercial Activities - none

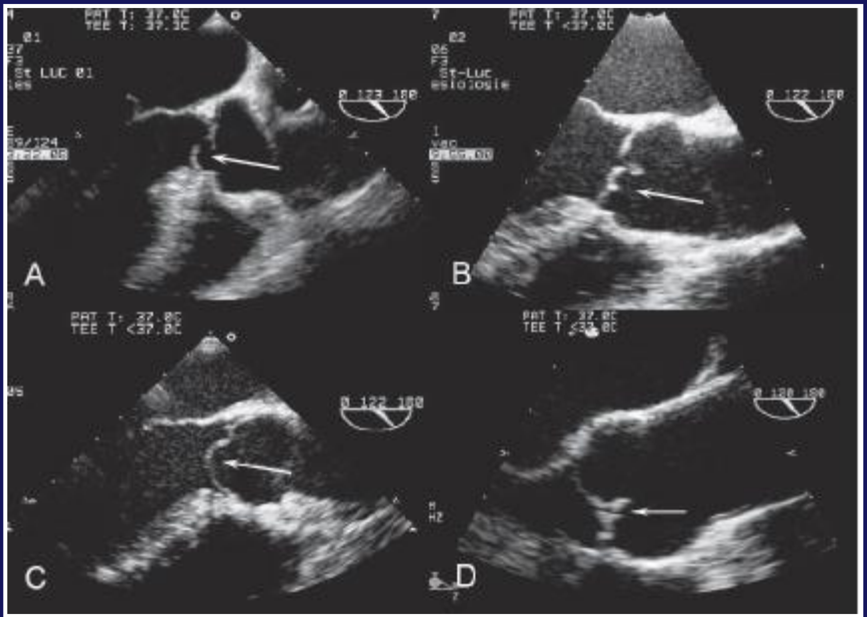
IB1; 2A11
Member of the German Society of Cardiology,
The German Society of Ultrasound, the German Society of Internal Medicine
and the European Society of Cardiology/Cardiovascular Imaging
Councillor of the EACVI Board

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.

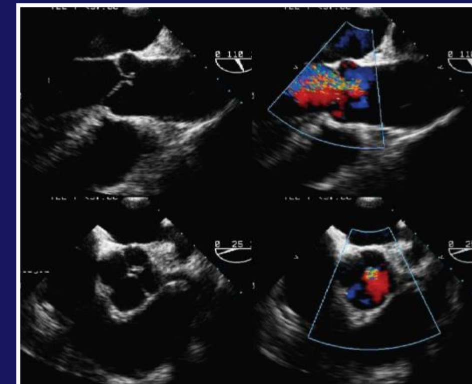
This figure (2007) does not represent the actual standard of echocardiography in the present days.

3D- and Multidimensional Echocardiography in Aortic Valve Repair

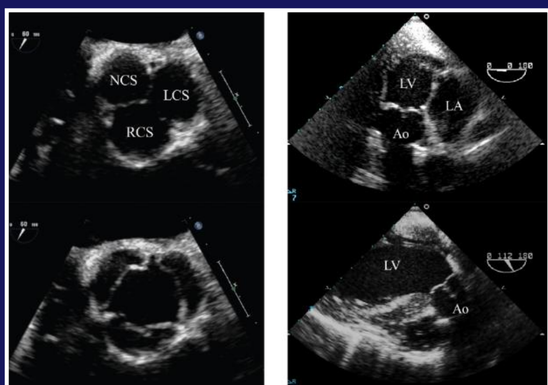
The role of echocardiography in aortic valve repair

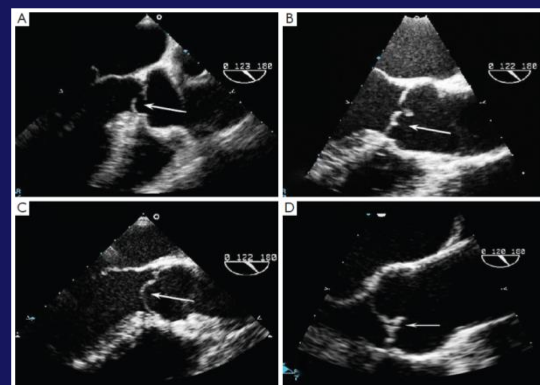
Jean-Louis Vanoverschelde, Michel van Dyck, Bernhard Gerber, David Vancraeynest, Julie Melchior, Christophe de Meester, Agnès Pasquet

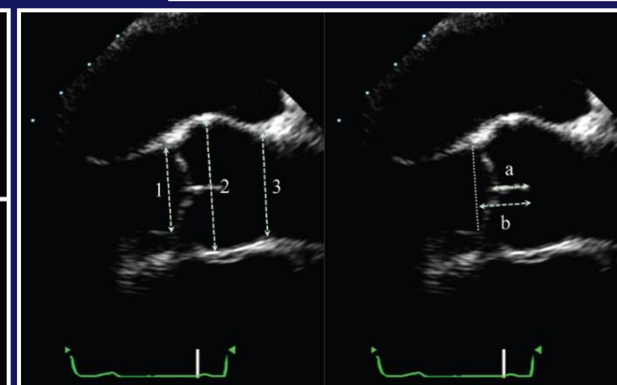
Ann Cardiothorac Surg 2013;2(1):65-72

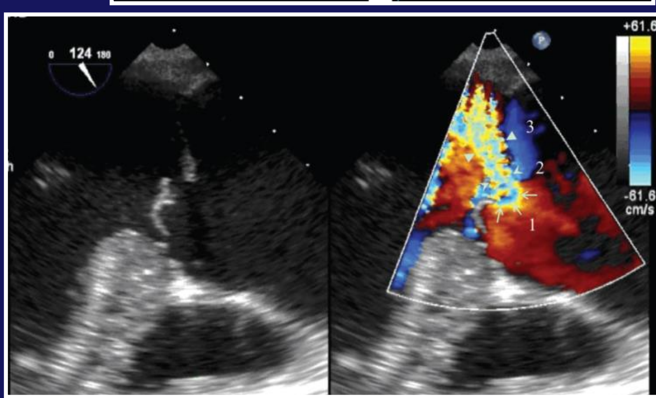


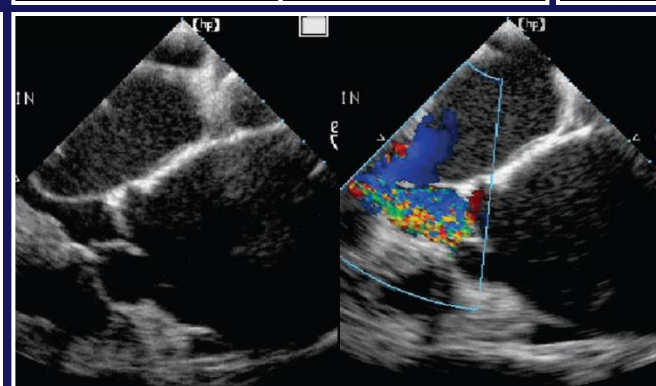
All figures in this paper of 2012 are still only 2D-echo images.

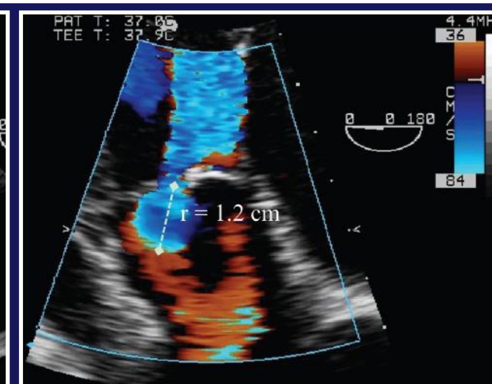




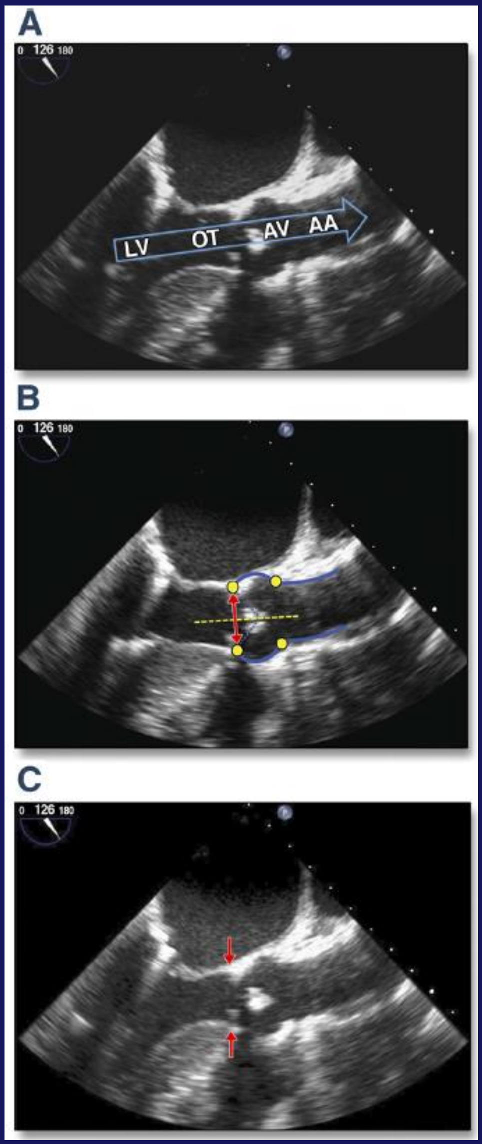








3D- and Multidimensional Echocardiography in Aortic Valve Repair



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

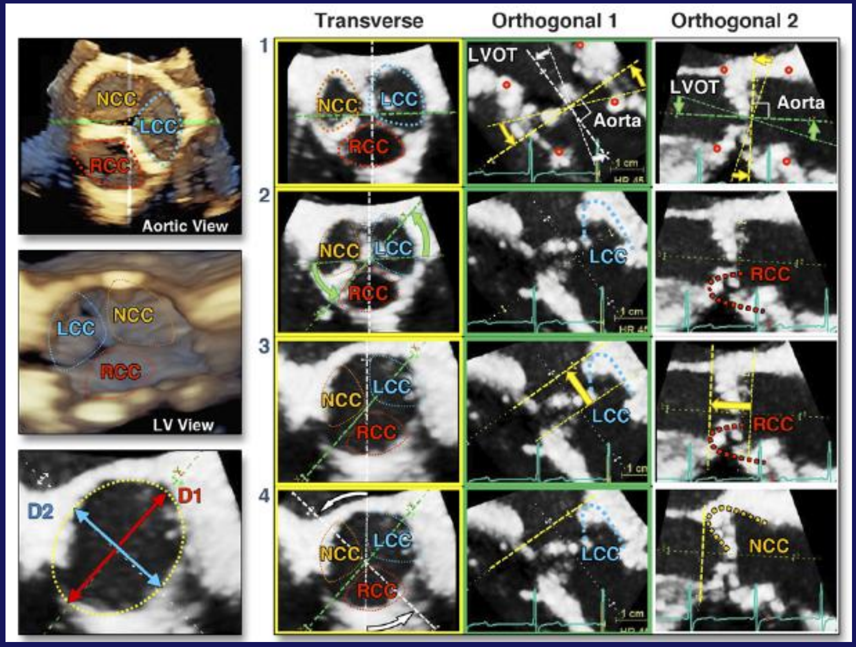
Standardized Imaging for Aortic Annular Sizing

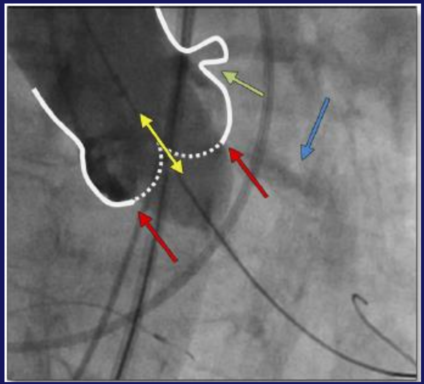
Implications for Transcatheter Valve Selection

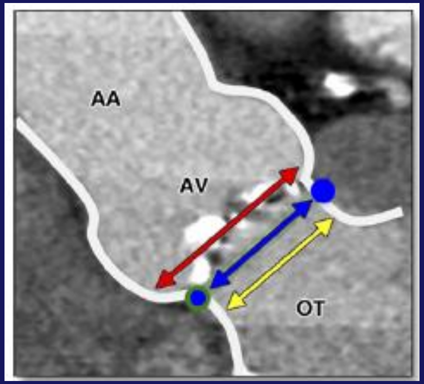
Albert M. Kasel, MD,* Salvatore Cassese, MD,* Sabine Bleiziffer, MD,†
Makoto Amaki, MD, PhD,‡ Rebecca T. Hahn, MD,§ Adnan Kastrati, MD,*
Partho P. Sengupta, MD‡

Multiple other figures are CT and angio images.

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



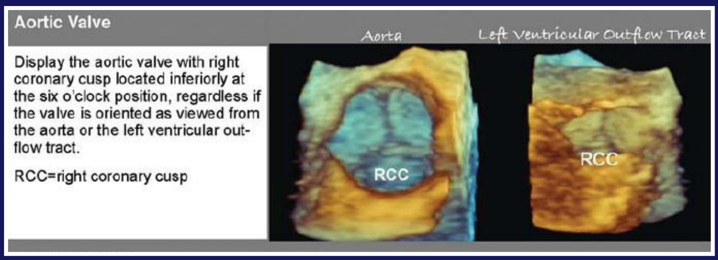


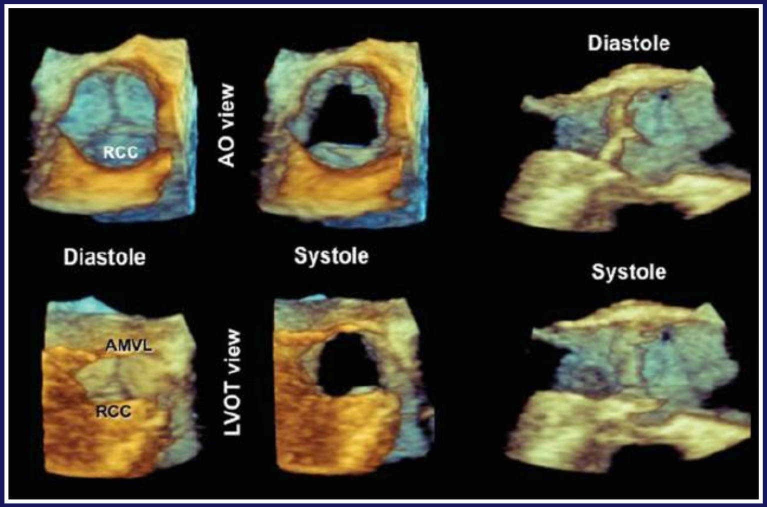


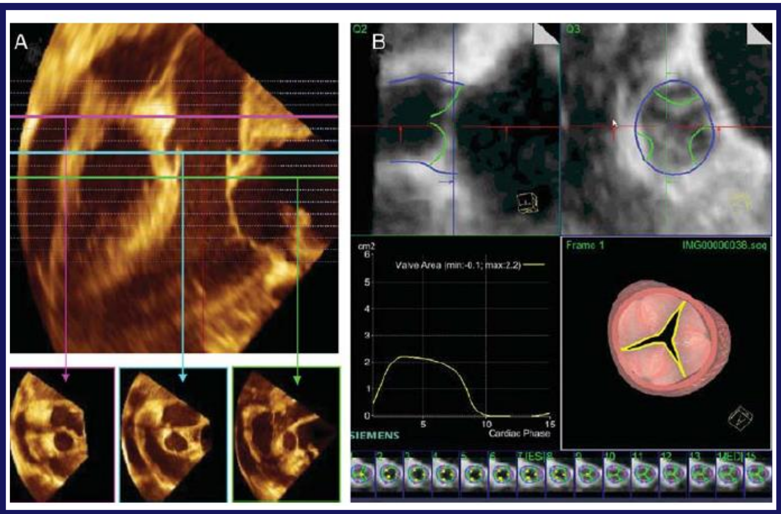
3D- and Multidimensional Echocardiography in Aortic Valve Repair

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 3D- echo technique for the aortic valve is fixed in the echo recommen-dations.

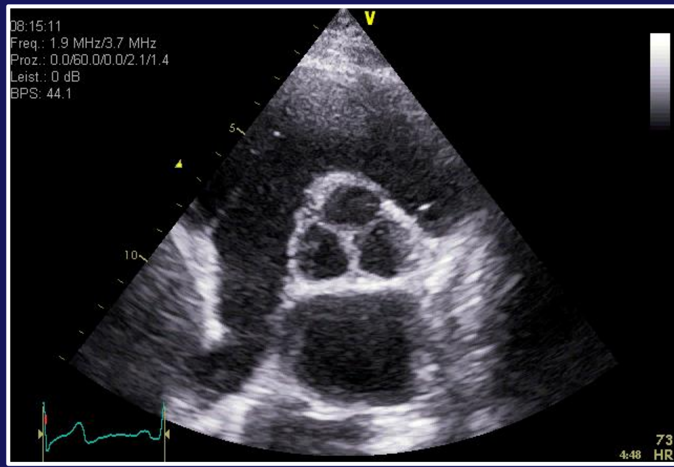
3D/4D-Echocardiography in Aortic Valve Repair

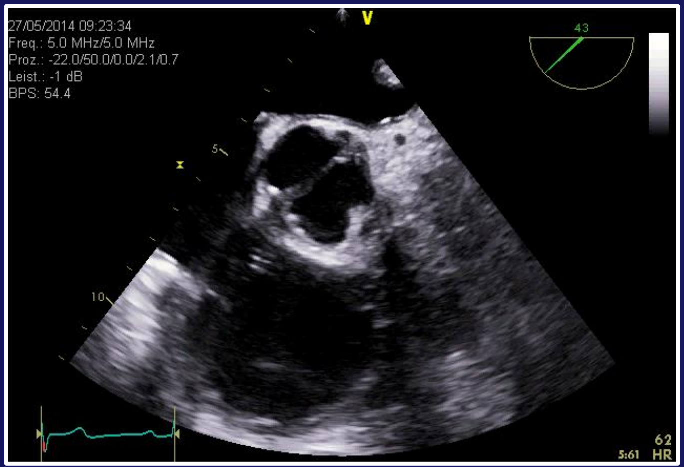
The key questions and challenges of echocardiography in aortic regurgitation – regardless wethter or not only 2D – or 3D echocardiography is used.

1. **The correct diagnosis of aortic regurgitation**
2. The **complete** - convincing and objective (**and at least comprehensable and replicable**) - documentation of the findings
   - 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, E/E`, sPAP,
3. Additional important findings
   - **Number of cusps, calcification of cusps, fusion of cusps, orientation of the commissures**
   - **Calcification of the aortic 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-echocardiography?

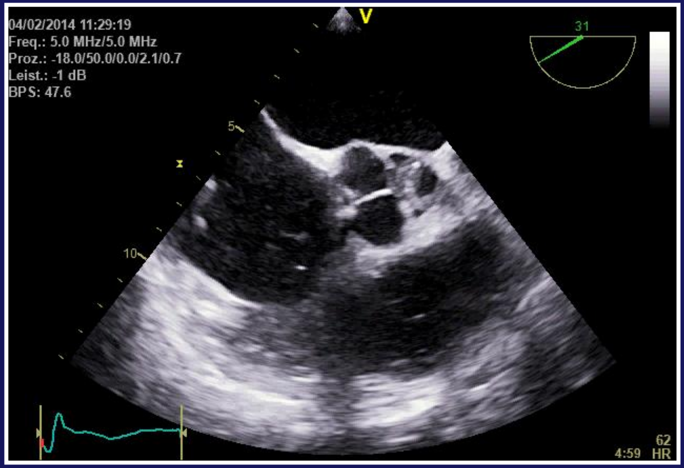
uni-
cuspid

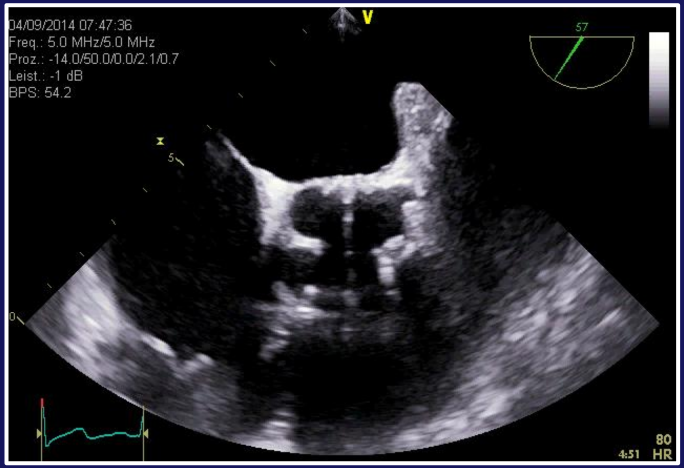




bi-
cuspid

normal
=
tricuspid





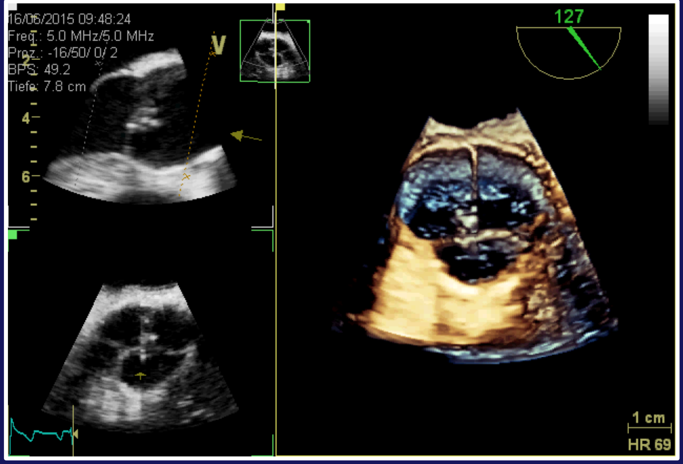
quadri-
cuspid

Transthoracic and transesophageal echocardiography: special practical aspects of 3D-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?
– Of course to get the best image quality - and at least, to get the best rendering in postprocessing.

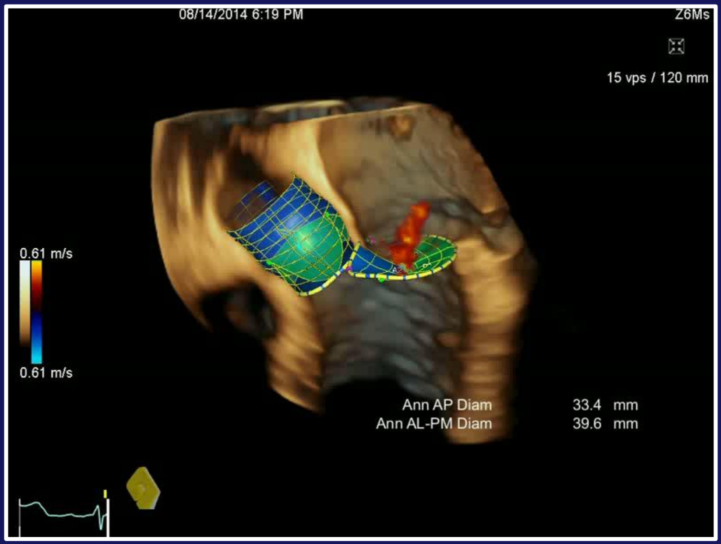
If contours are not excellent, no valid postprocession is possible.

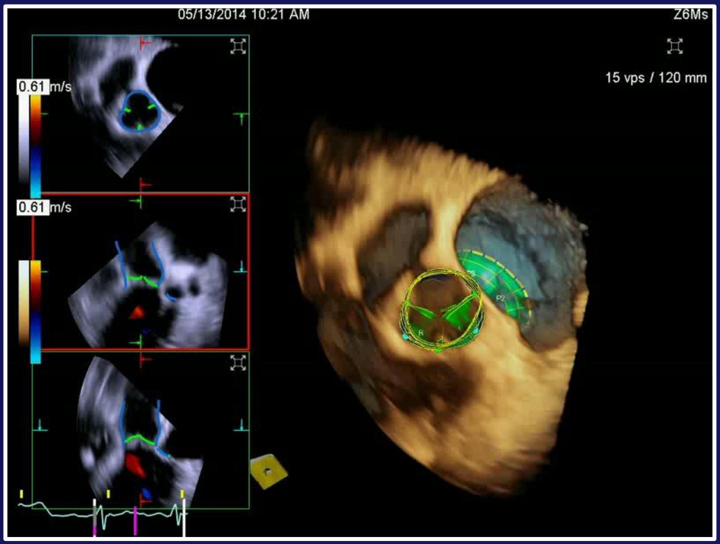


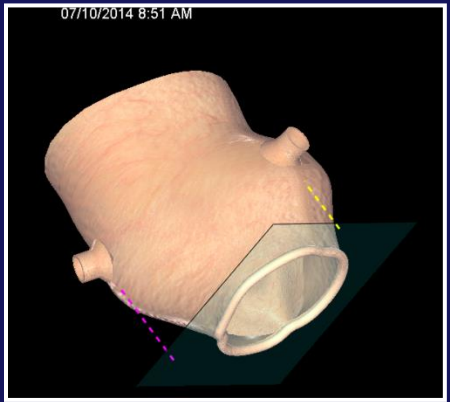
TEE after aortic valve repair: stitched data set

3D- and Multidimensional Echocardiography in Aortic Valve Repair

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







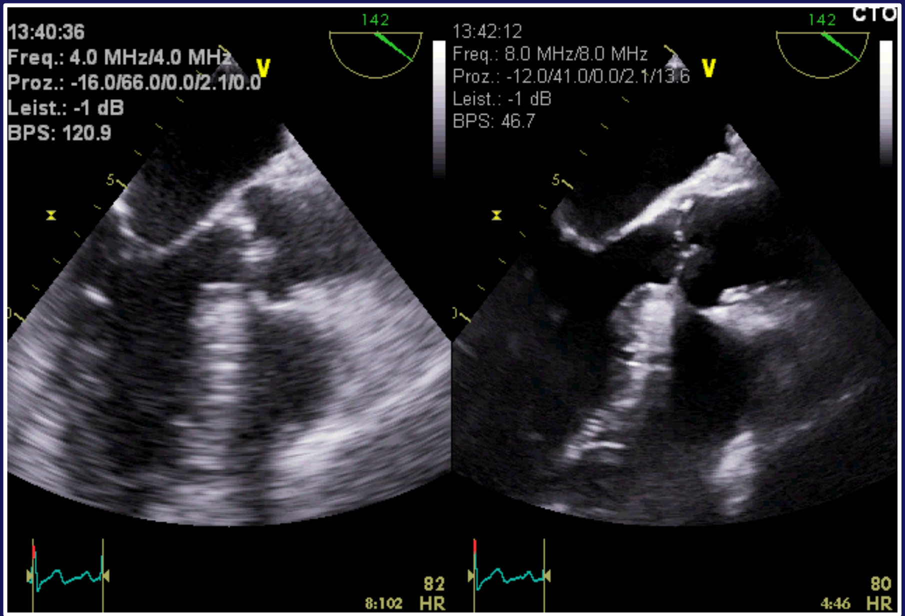
L Ostium Height	17.4	mm
R Ostium Height	22.5	mm

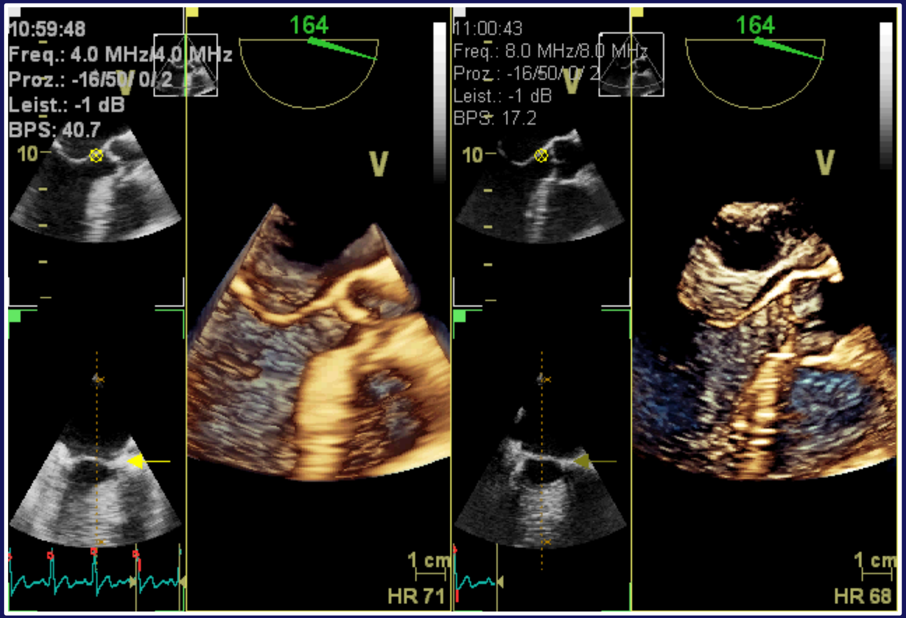
All parameters of aortic valve and aortic root dimensions, especially the distance between the aortic cusps / the aortic annulus and the coronary ostia can be easily measured within a 3D-TEE data set.

Prerquisite for excellent image quality in 2D as well as 3D 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.

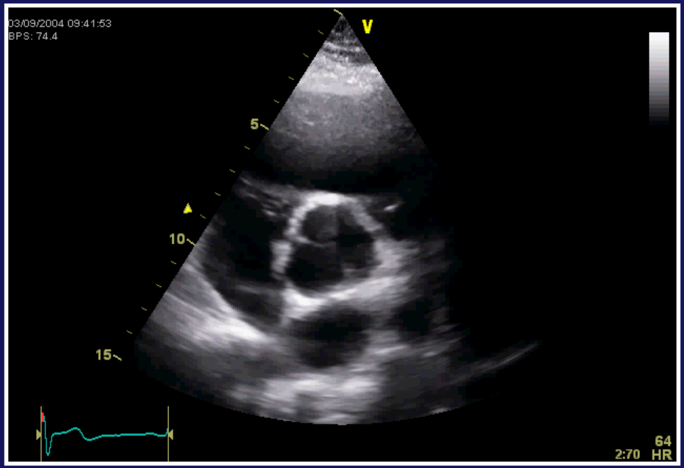
Then, detailed information about aortic valve and aortic root morphology is possible.
The spatial and temporal resolution of 3D TEE is at least comparable to cardiac-CT.

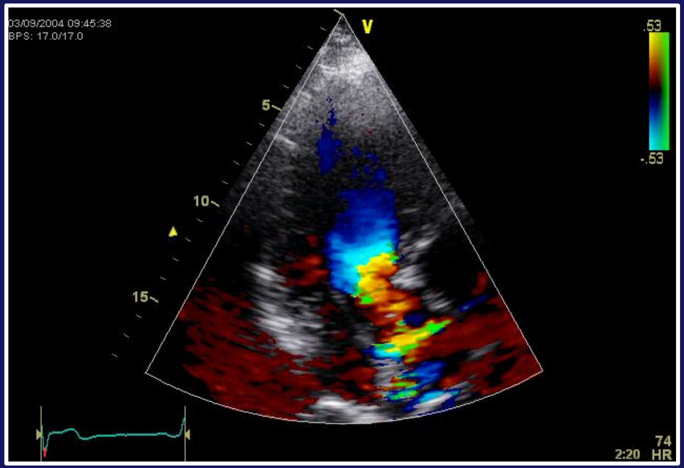


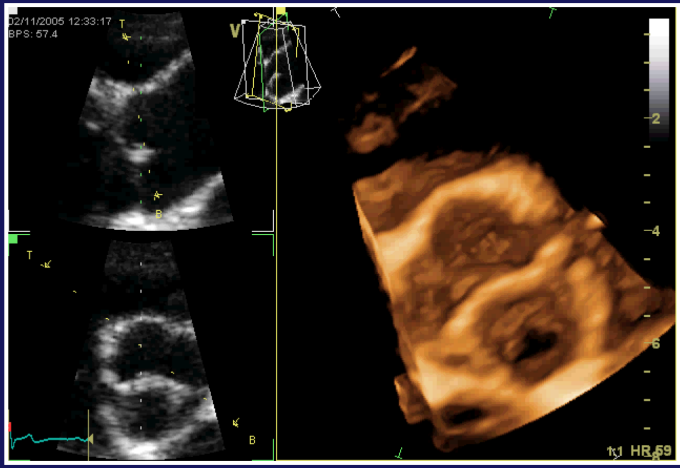


The same patients: „bad“ settings versus optimized settings in 2D and 3D-TEE.

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

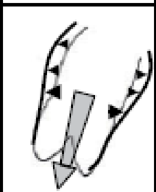
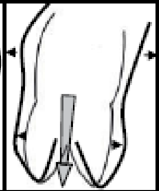
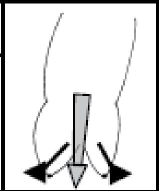
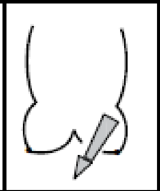
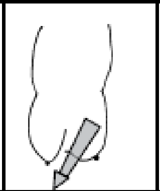
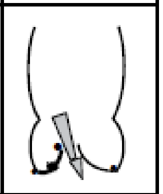


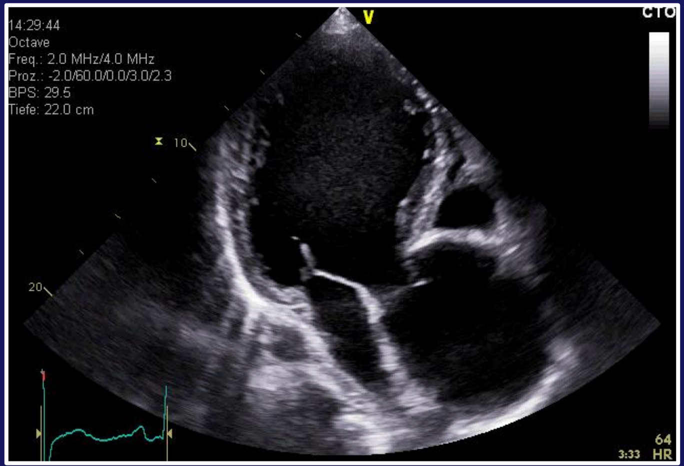




The additional value of information is obvious.
Surface imaging is a complete new modality than sectional scanning.

3D- and Multidimensional Echocardiography in Aortic Valve Repair

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



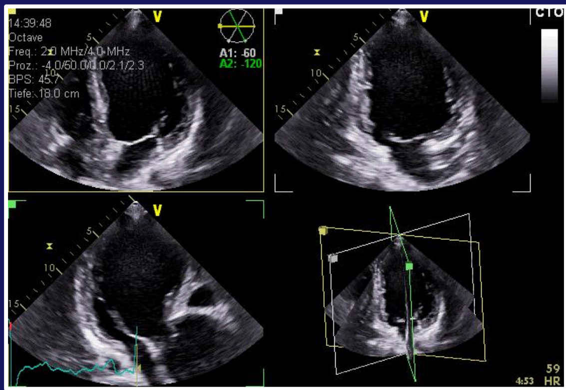
Example of 2D-imaging
Aortic regurgitation type Ia
FAA – functional aortic annulus;
STJ - sinotubular junction;
SCA - subcommissural anuloplasty

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

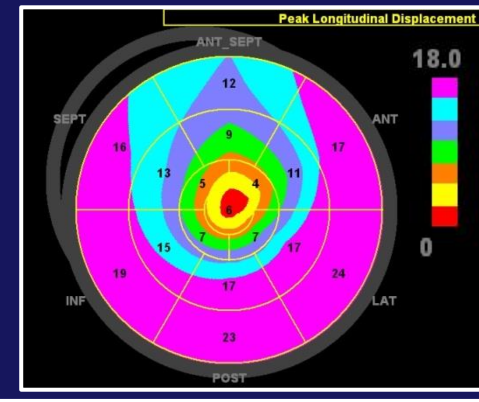
Munir Boodhwani, MD, MMSc, Laurent de Kerchove, MD, David Glineur, MD, Alain Poncelet, MD, Jean Rubay, MD, Parla Astarci, MD, Robert Verhelst, MD, Philippe Noirhomme, MD, and Gébrine El Khoury, MD

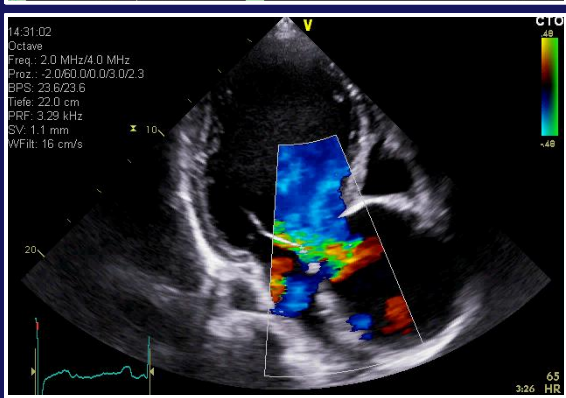
3D- and Multidimensional Echocardiography in Aortic Valve Repair

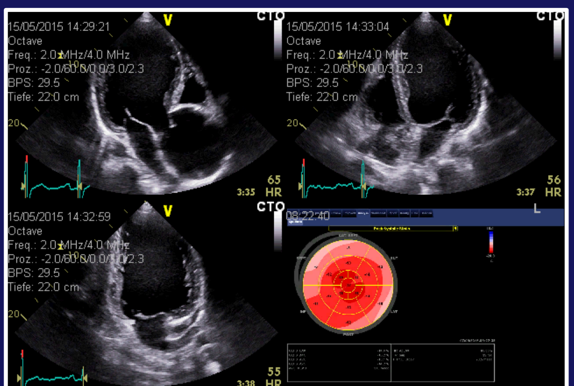


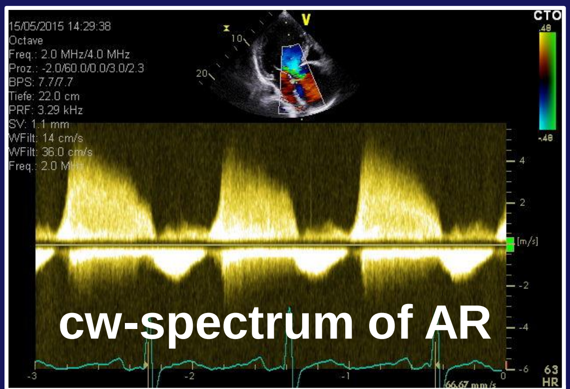
2D-TTE-imaging

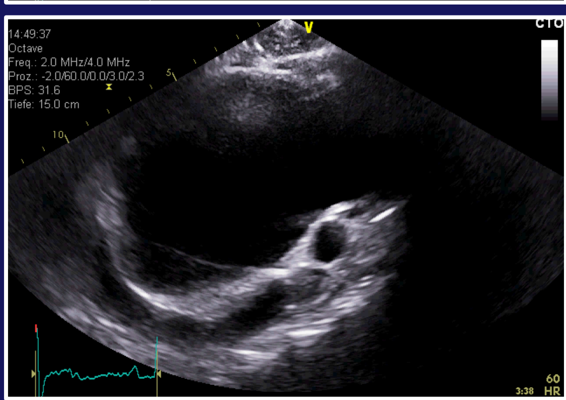
(triplane acquisition a
nd deformation imaging)
Visualisation of the aortic aneurysm
– funcional AR-anaylsis

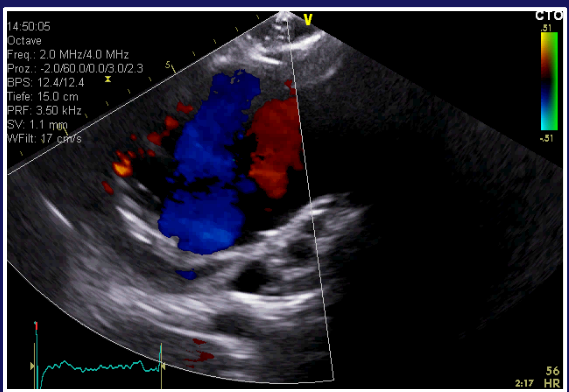


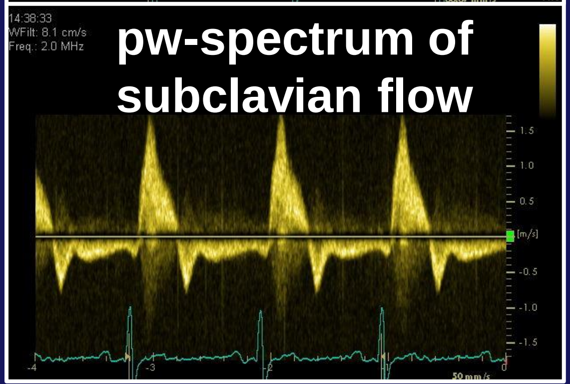






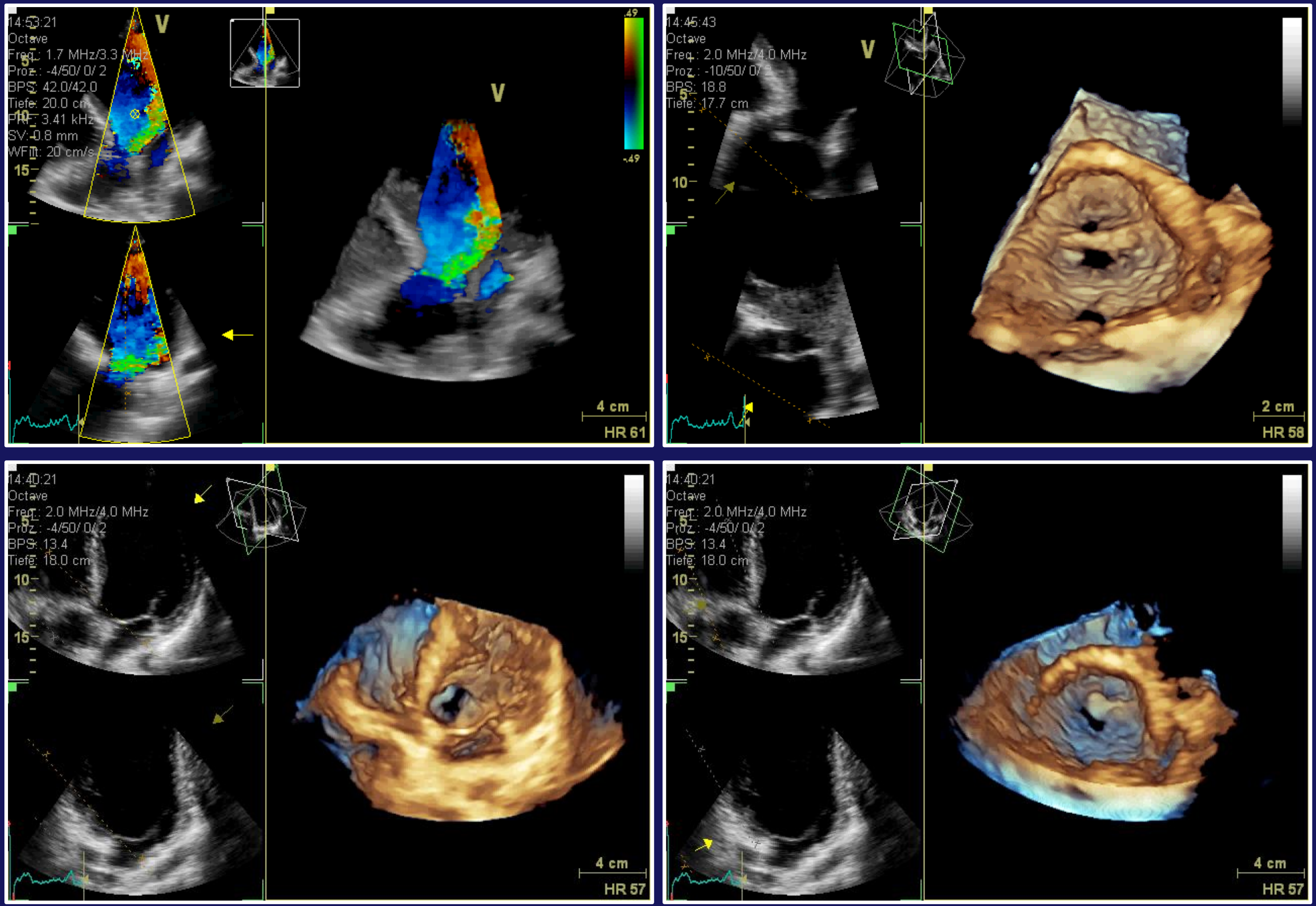






The added value of 3D-TTE-imaging

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

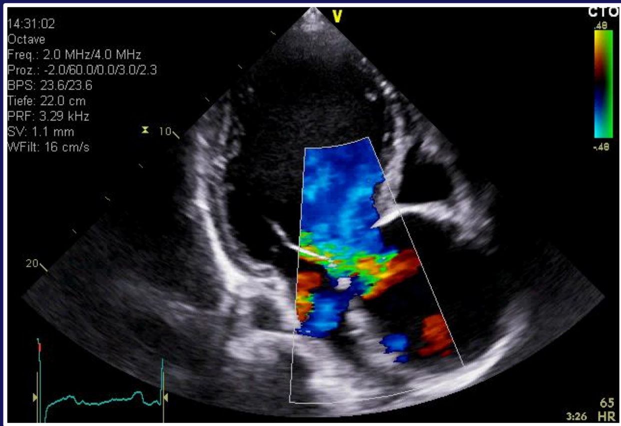


UNIVERSITÄT LEIPZIG
Medizinische Fakultät

3D- and Multidimensional Echocardiography in Aortic Valve Repair

Universitätsklinikum Leipzig
Anstalt öffentlichen Rechts

pre



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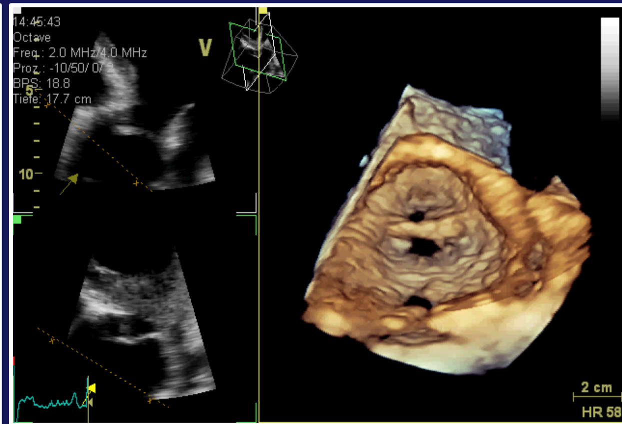

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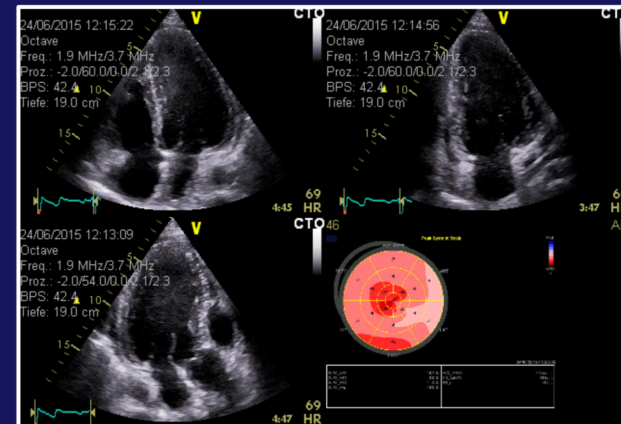
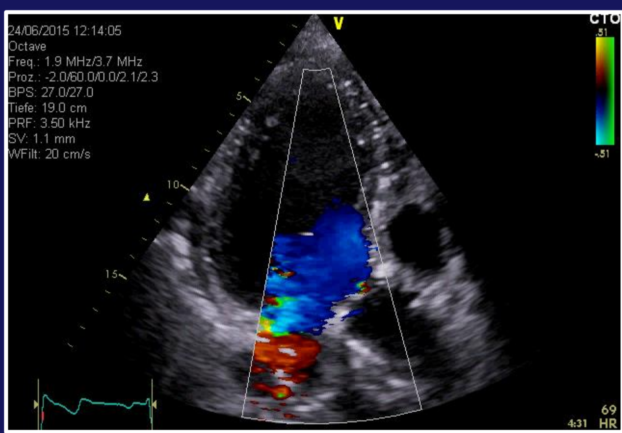


Comparison pre- and post-aortiv valve repair surgery

post



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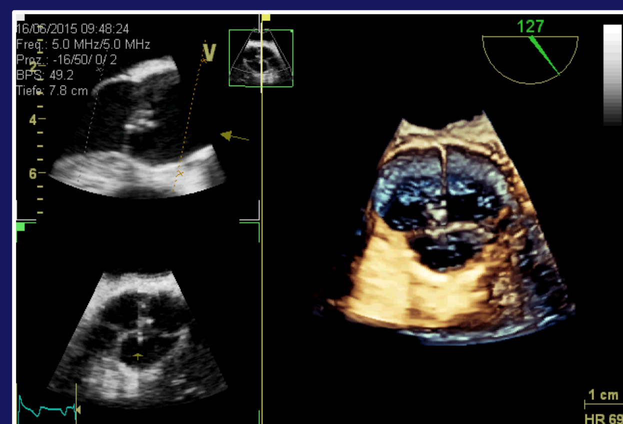

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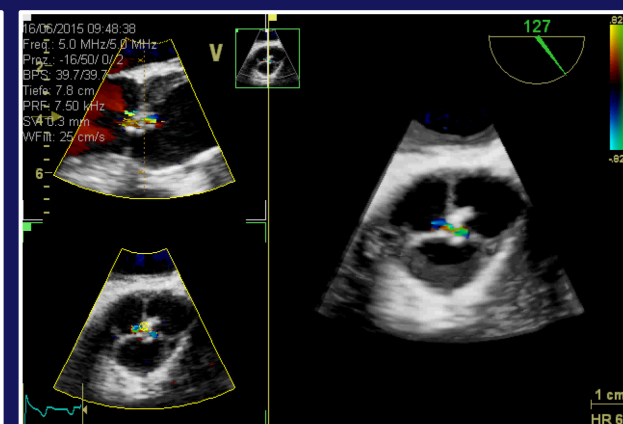


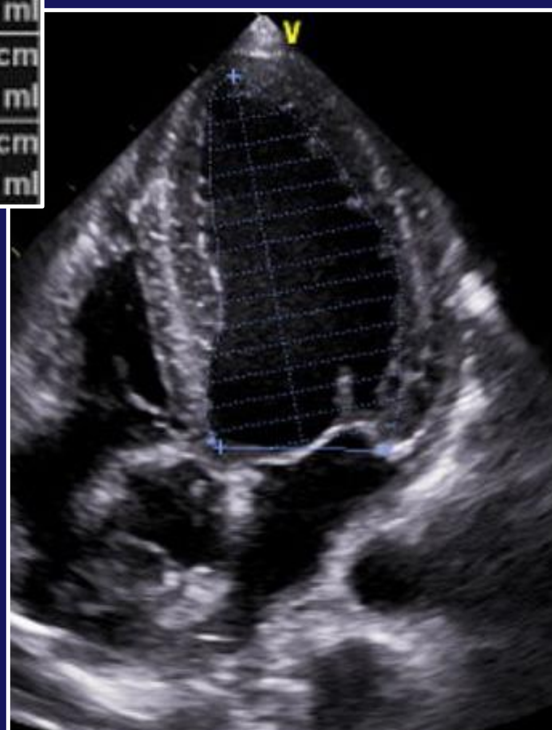
The added value of 3D-TTE-imaging

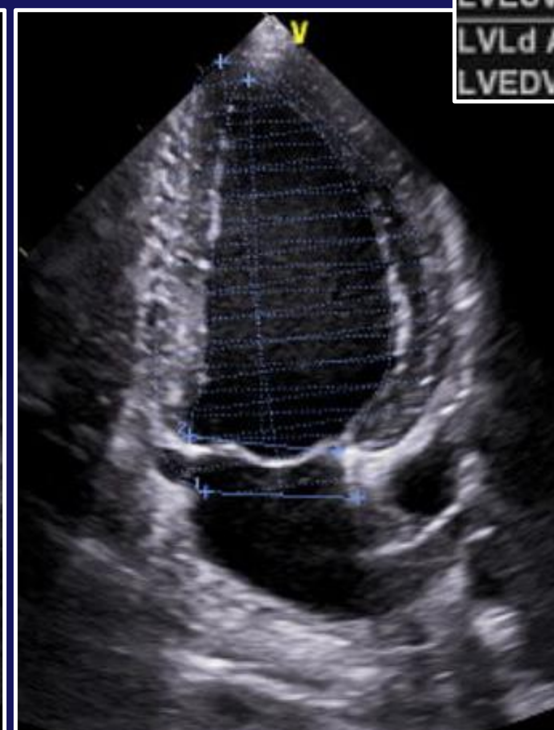
Volume measurement by 3D-imaging
- There are still problems, which are debatable.

EF Biplan	58 %
LVEDV MOD BP	431 ml
LVESV MOD BP	180 ml
LVEF MOD A2C	62 %
SV MOD A2C	279 ml
LVLs A2C	10.7 cm
LVESV MOD A2C	169 ml
LVLd A2C	12.8 cm
LVEDV MOD A2C	448 ml

LVEDV > 400ml
LVESV > 180ml
SV_{total} > 220ml

LVEF MOD A4C	55 %
SV MOD A4C	226 ml
LVLs A4C	11.1 cm
LVESV MOD A4C	186 ml
LVLd A4C	12.6 cm
LVEDV MOD A4C	412 ml



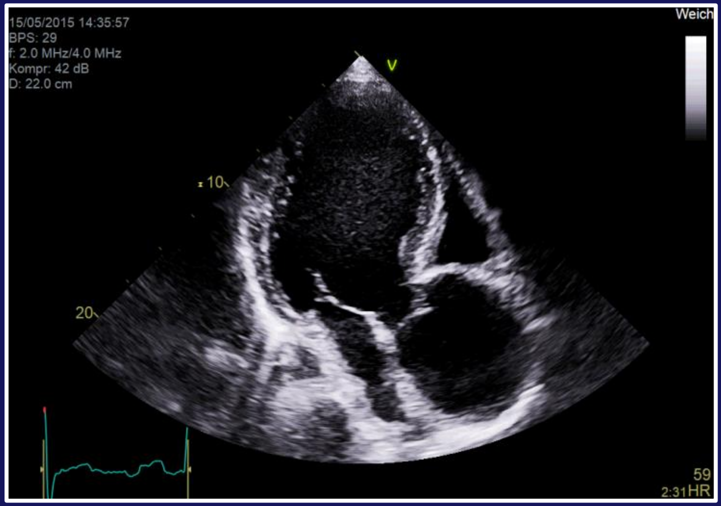


Meaasurements using 2D-techniques in the presence of brilliant image quality.

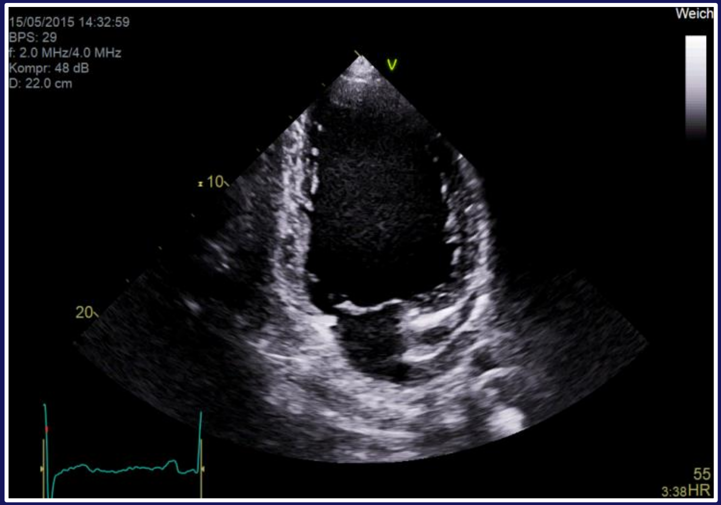
What are the results of the 3D volume measurements?

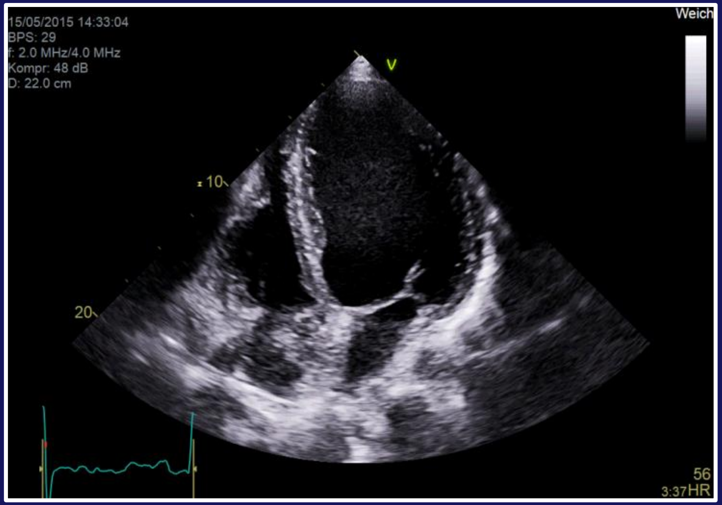
The added value of 3D-TTE-imaging

Volume measurement by 3D-imaging – only in data sets with optimal image quality



Excellent image quality in 2D-images.
Endocardial contour detection is – especially in this example – excellent.



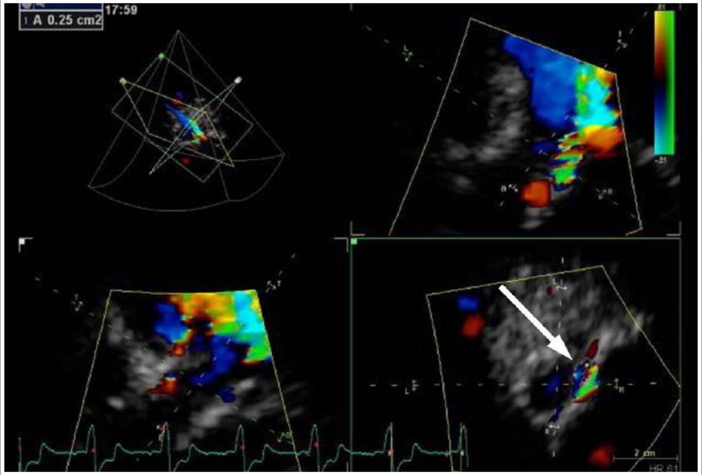


3D- and Multidimensional Echocardiography in Aortic Valve Repair

Comparison of Two- and Three-Dimensional Transthoracic Echocardiography to Cardiac Magnetic Resonance Imaging for Assessment of Paravalvular Regurgitation After Transcatheter Aortic Valve Implantation

Ertunc Altiok, MD[a], Michael Frick, MD[a], Christian G. Meyer, MD[a], Ghazi Al Ateah, MD[a], Andreas Napp, MD[a], Annemarie Kirschfink, MD[a], Mohammad Almalla, MD[a], Shahran Lotfi, MD[b], Michael Becker, MD[a], Lena Herich, PhD[c], Walter Lehmacher, PhD[c], and Rainer Hoffmann, MD[a,*]

In conclusion, 2D TTE considering VARC-2 criteria has limitations in the grading of AR severity after TAVI when CMR imaging is used for comparison. Three-dimensional TTE allows quantification of AR with greater accuracy than 2D TTE. Observer variability on RVol after TAVI is considerable using 2D TTE, significantly less using 3D TTE, and very low using CMR imaging. **(Am J Cardiol 2014;113:1859–1866)**



Echocardiographic studies were performed with a commercially available echocardiographic system (Vivid E9; General Electric Vingmed, Horten, Norway) and 2D transthoracic probe (M5S, General Electric Vingmed, Horten, Norway).

Doppler from the suprasternal window. Paravalvular regurgitant volume (RVol) was calculated as the difference between stroke volume in the left ventricular outflow tract and pulmonary flow in systole assessed by pulse-wave Doppler echocardiography. Regurgitant fraction (RF) was calculated by dividing RVol by stroke volume in the left ventricular outflow tract.

AR after TAVI was graded as none or mild, moderate, or severe according to an integrative approach as recommended by the VARC. This considers a combined analysis of (1) diastolic flow reversal in the descending aorta, (2) circumferential extent of a paravalvular leak determined by color Doppler in the short-axis view, (3) RVol, (4) RF, and (5) effective regurgitant orifice area by 2D TTE.[13]

Important message:

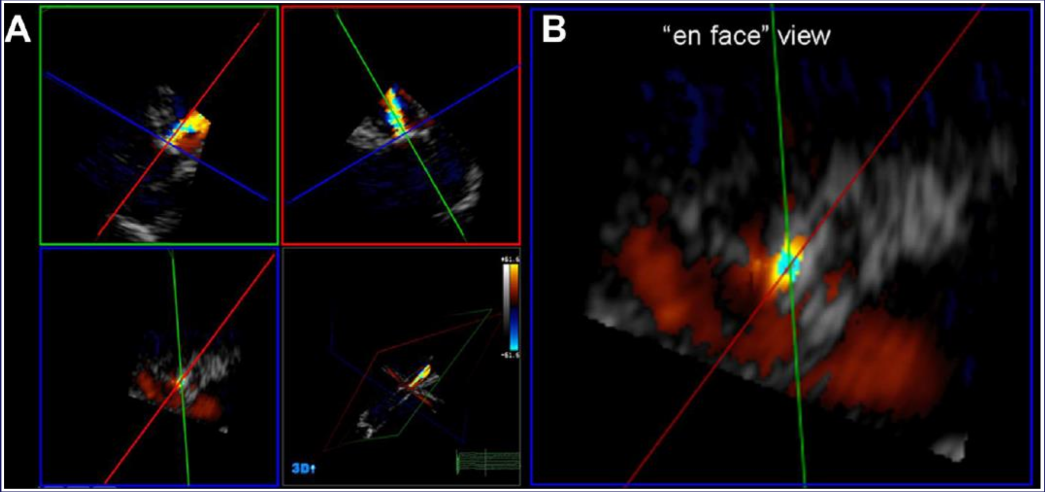
1. No 3D echocardiography was used for LV volume assessment.
2. VARC-criteria for grading of the AR

3D- and Multidimensional Echocardiography in Aortic Valve Repair

Accuracy of Three-Dimensional Versus Two-Dimensional Echocardiography for Quantification of Aortic Regurgitation and Validation by Three-Dimensional Three-Directional Velocity-Encoded Magnetic Resonance Imaging

See Hooi Ewe, MBBS[a,b], Victoria Delgado, MD, PhD[a,*], Rob van der Geest, MSc, PhD[c], Jos J.M. Westenberg, PhD[c], Marlieke L.A. Haeck, MD[a], Tomasz G. Witkowski, MD[a], Dominique Auger, MD[a], Nina Ajmone Marsan, MD[a], Eduard R. Holman, MD, PhD[a], Albert de Roos, MD, PhD[c], Martin J. Schalij, MD, PhD[a], Jeroen J. Bax, MD, PhD[a], Allard Sieders, MD[d], and Hans-Marc J. Siebelink, MD, PhD[a]

In conclusion, AR RVol quantification using 3D TTE is accurate, and its advantage over 2D TTE is particularly evident in patients with eccentric jets. (Am J Cardiol 2013;112:560−566)



Again no 3D echocardiography was used for LV volume assessment.

All patients underwent standard 2D and 3D color Doppler TTE to quantify AR RVol and EROA.

Patients were imaged at rest in the left lateral decubitus position using a commercially available ultrasound system (iE33, Philips Medical Systems, Andover, Massachusetts) equipped with a S5-1 transducer.

For a more quantitative assessment of AR, the PISA method was used.

Aortic regurgitation severity after transcatheter aortic valve implantation is underestimated by echocardiography compared with MRI

Stefan Orwat,[1] Gerhard-Paul Diller,[1] Gerrit Kaleschke,[1] Gregor Kerckhoff,[1] Aleksander Kempny,[1] Robert M Radke,[1] Boris Buerke,[2] Matthias Burg,[2] Christoph Schülke,[2] Helmut Baumgartner[1]

Again no 3D echocardio-graphy was used for LV-volume assessment. Why?

ABSTRACT

Objective Aortic regurgitation (AR) after transcatheter aortic valve implantation (TAVI) is associated with a poor clinical outcome and its assessment therefore crucial. Quantification of AR by transthoracic echocardiography (TTE), however, remains challenging in this setting. The present study used quantitative flow measurement by cardiac MRI (CMR) with calculation of regurgitant fraction (RF) for the assessment of AR and compared the results with TTE.

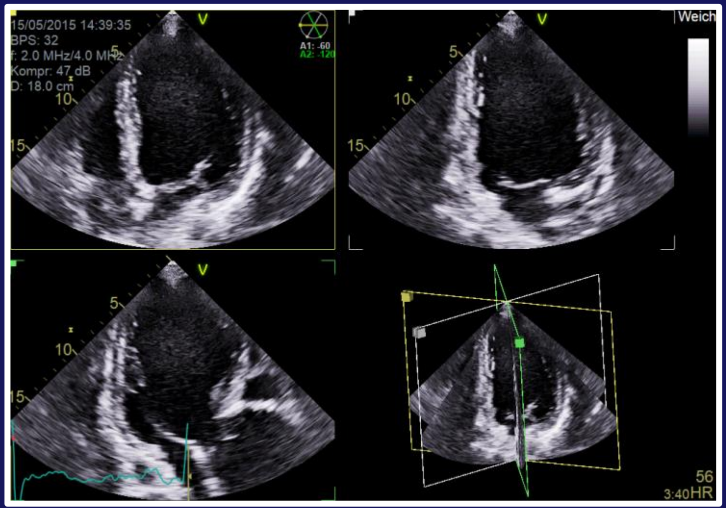
Methods and results We included 65 patients with a mean age of 82.2±8.1 years (38 women) who underwent successful TAVI with Edwards SAPIEN valves (52 transfemoral, 13 transapical). The postinterventional degree of AR was assessed by CMR and by TTE.

All recordings were stored digitally for offline analysis. The AR severity was graded according to the recommendations of the European Association of Echocardiography[18] and the VARC criteria[9 19] with a special focus on semiquantitative parameters like diastolic flow reversal in the descending aorta measured by pulse-wave Doppler and circumferential extent of prosthetic valve paravalvular regurgitation. Unfortunately due to limited acoustic windows, adequate echocardiographic quantification of RF was only possible in a minority of patients and has therefore not been included as part of the analysis.

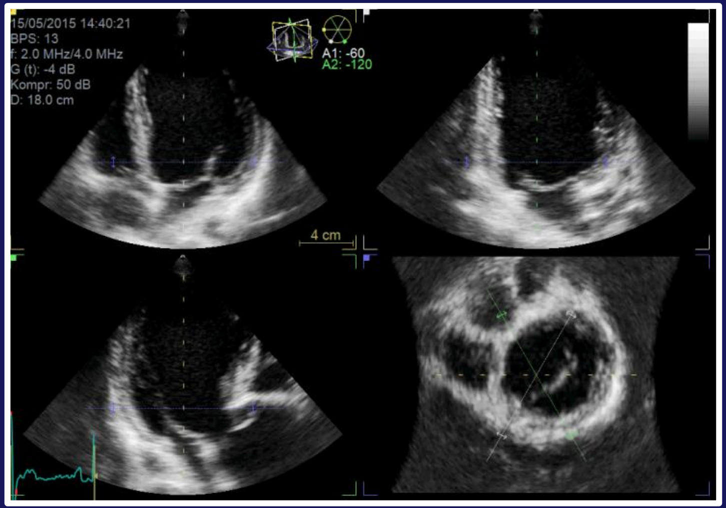
Conclusions Using CMR for the quantification of AR in a sizeable group of TAVI patients, we demonstrate a strong tendency of TTE to underestimate AR compared with CMR. Since higher AR severity on echocardiography has been associated with worse patient outcome, the potential incremental prognostic value of CMR should be studied prospectively in this setting.

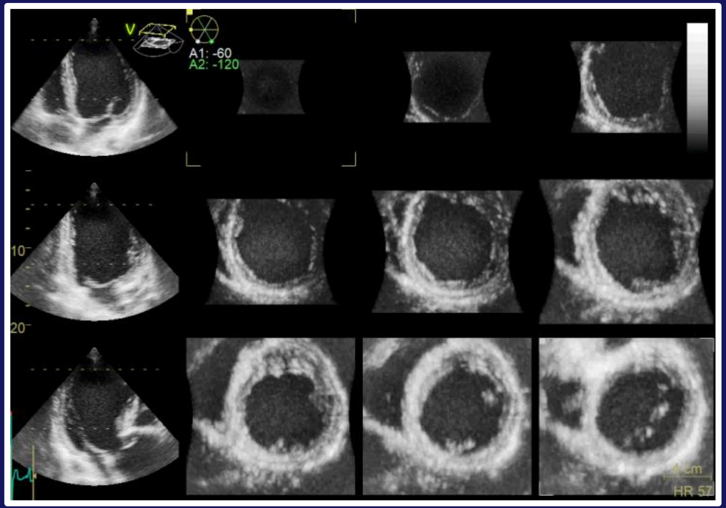
The added value of 3D-TTE-imaging

Volume measurement by 3D-imaging – only in data sets with optimal image quality



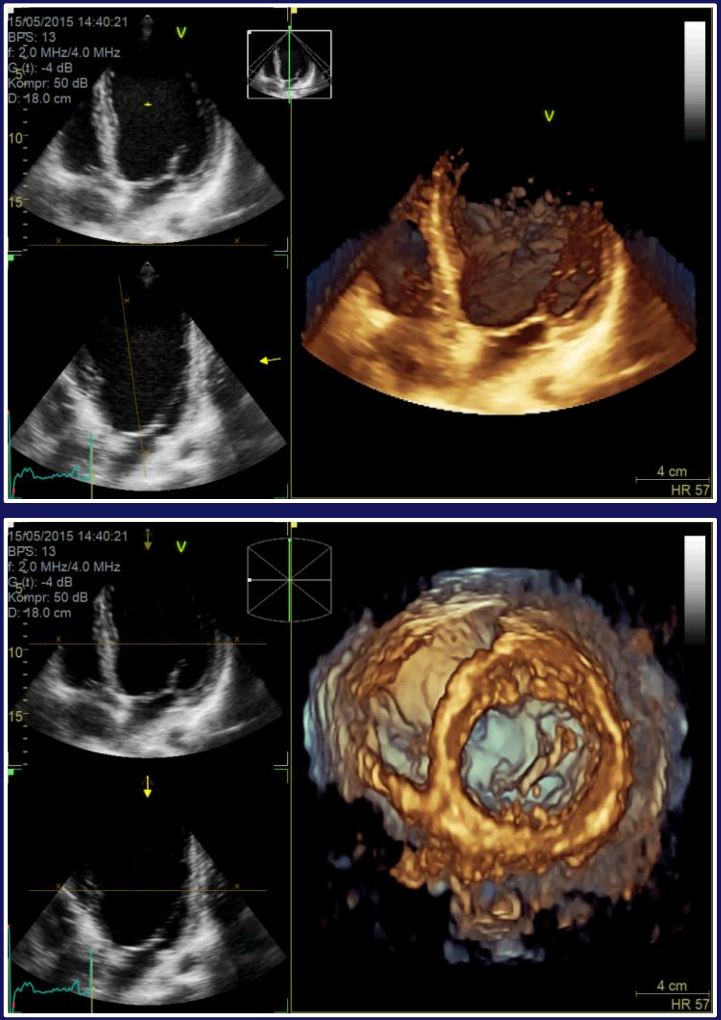
Comparable image quality in comparison to the 2D-images. Endocardial contour detection is also pssible in triplane and multidimensional documentation.
Despite acceptable 3D images the LV volume tools seem to underestimate LV.volume.

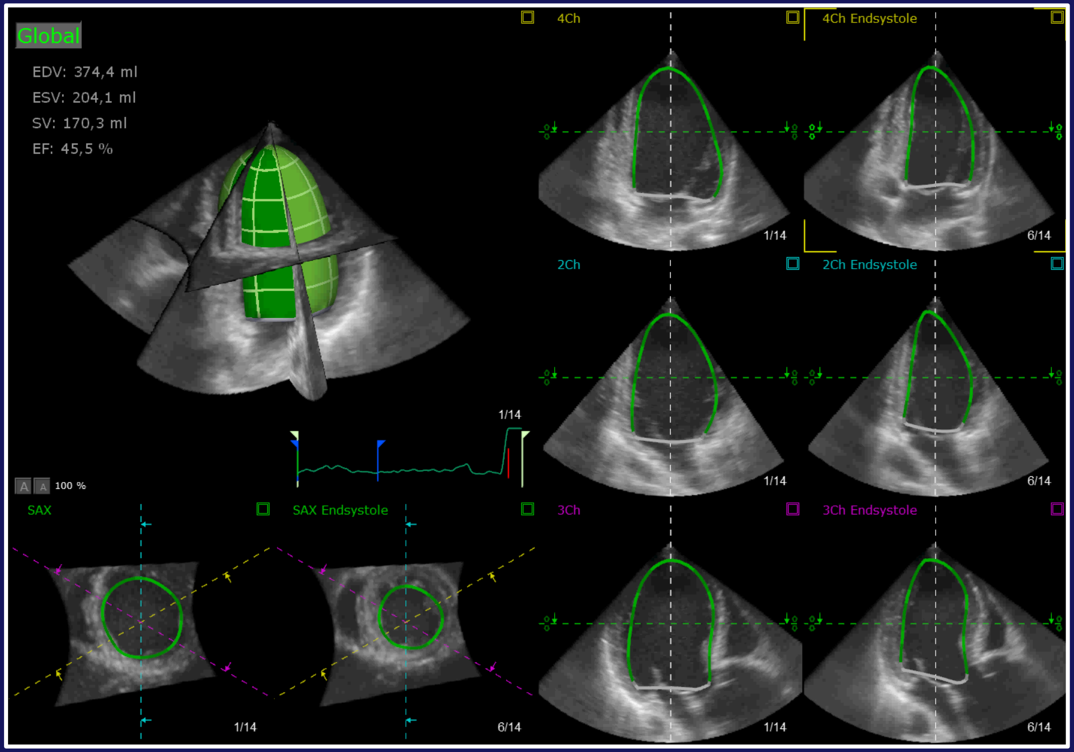




The added value of 3D-TTE-imaging

Volume measurement by 3D-imaging

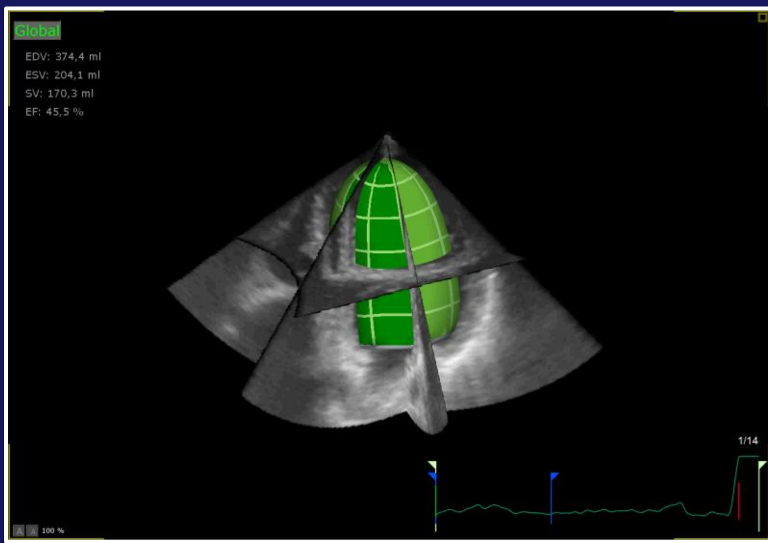


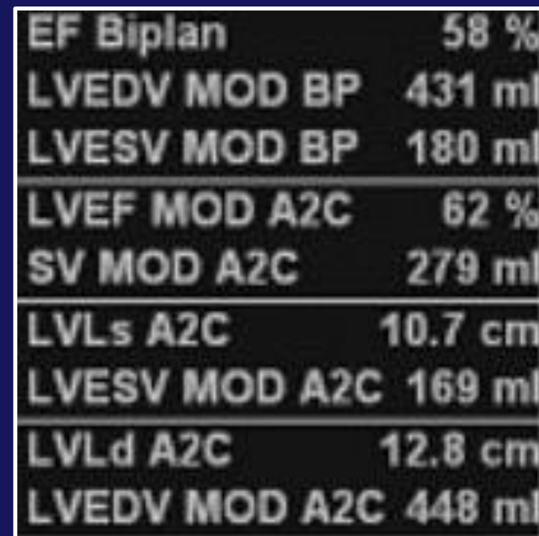


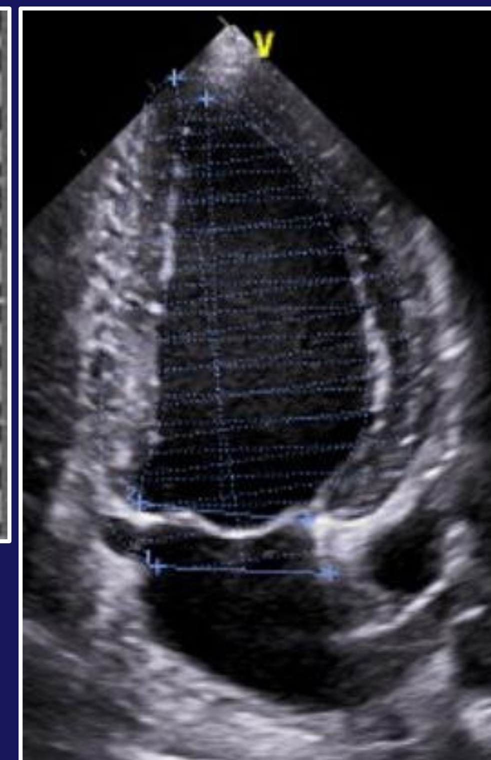
There are some debatable issues in the software of the 3D volume analysis regarding volume detection of the MV tenting area as well as LVOT-volume measurement

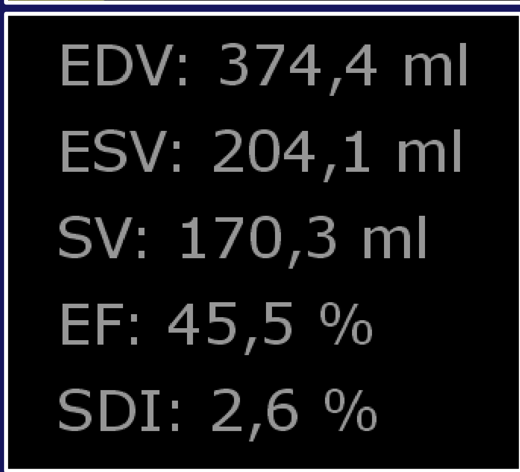
The added value of 3D-TTE-imaging

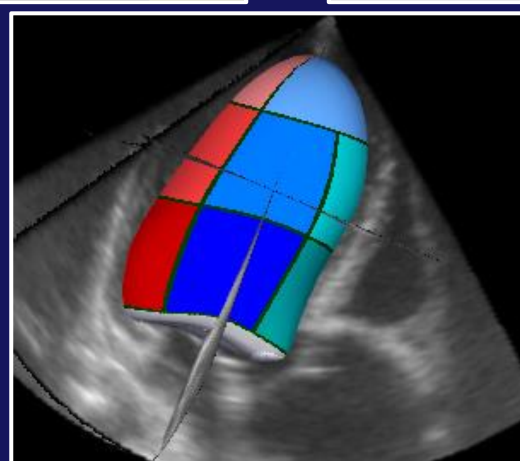
Volume measurement by 3D-imaging





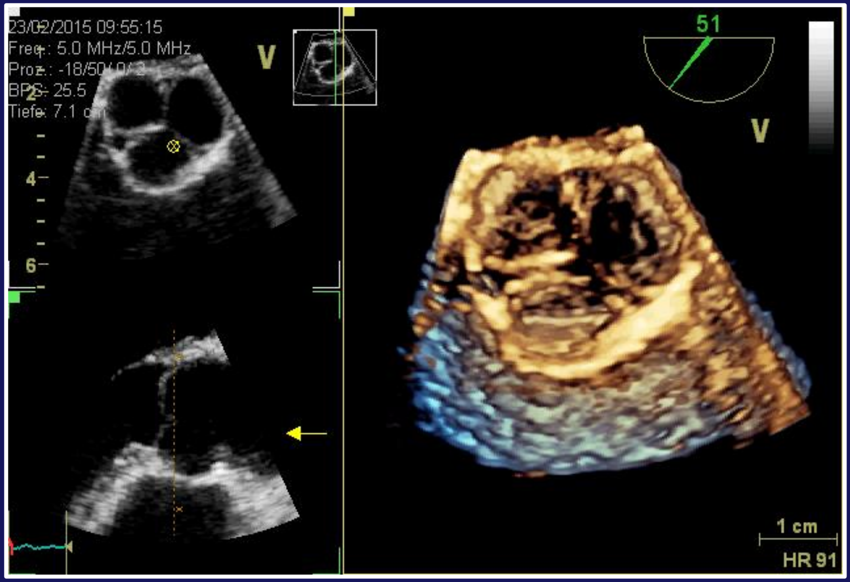




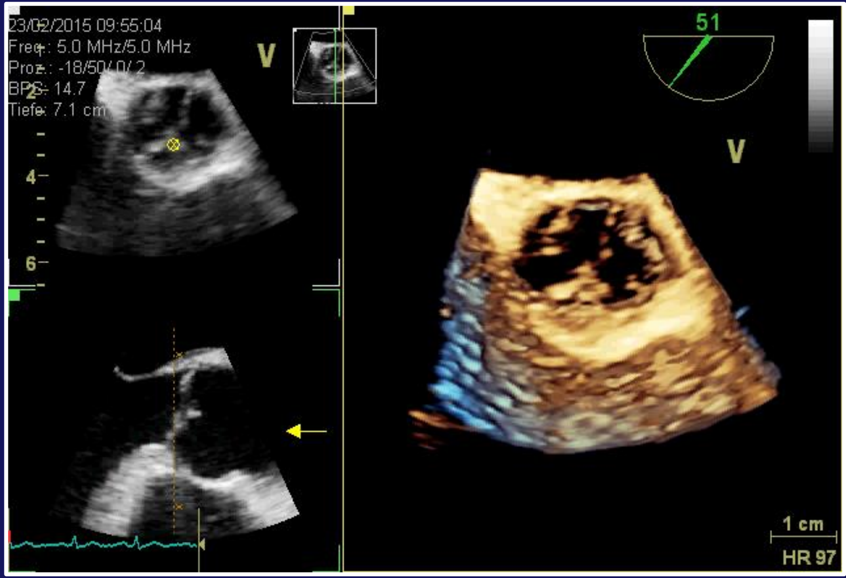


LV-volumes determined in correct standardized views in 2D-echocardiography are still higher than LV volumes determined in 3D data sets.

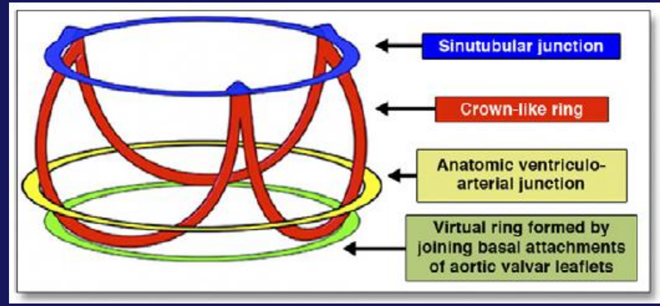
3D- and Multidimensional Echocardiography in Aortic Valve Repair



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.

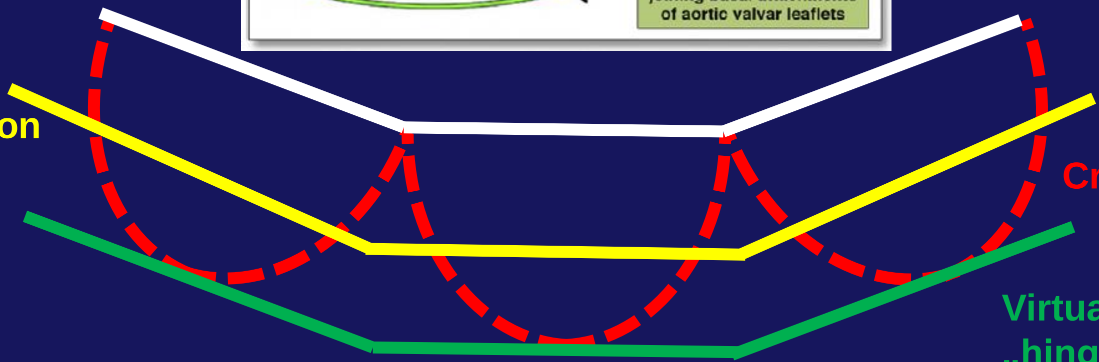


3D- and Multidimensional Echocardiography in Aortic Valve Repair



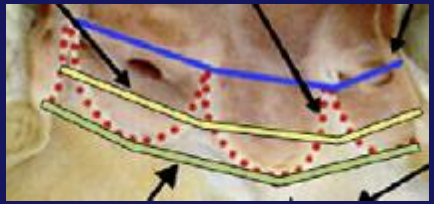
Sinutubular junction

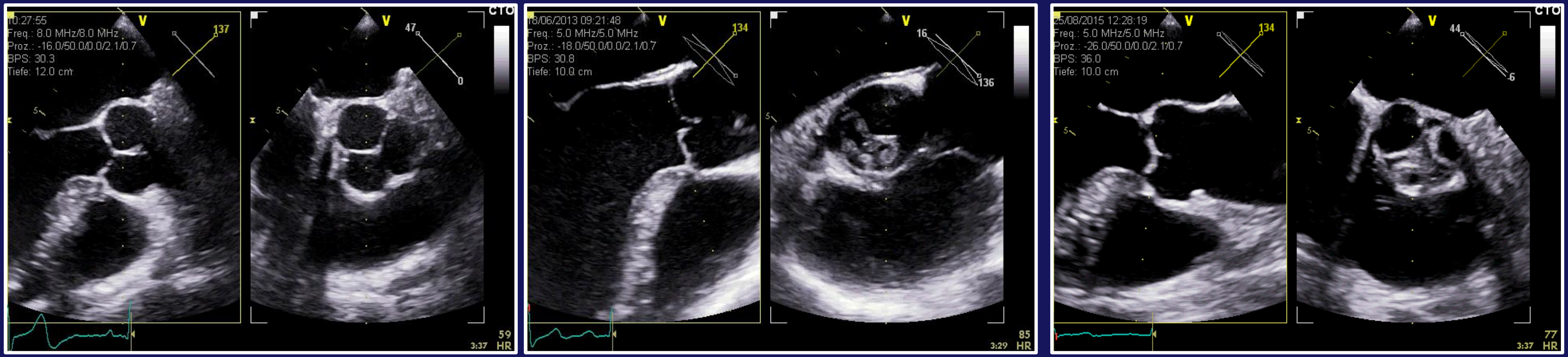
Anatomical ventriculo-arterial junction



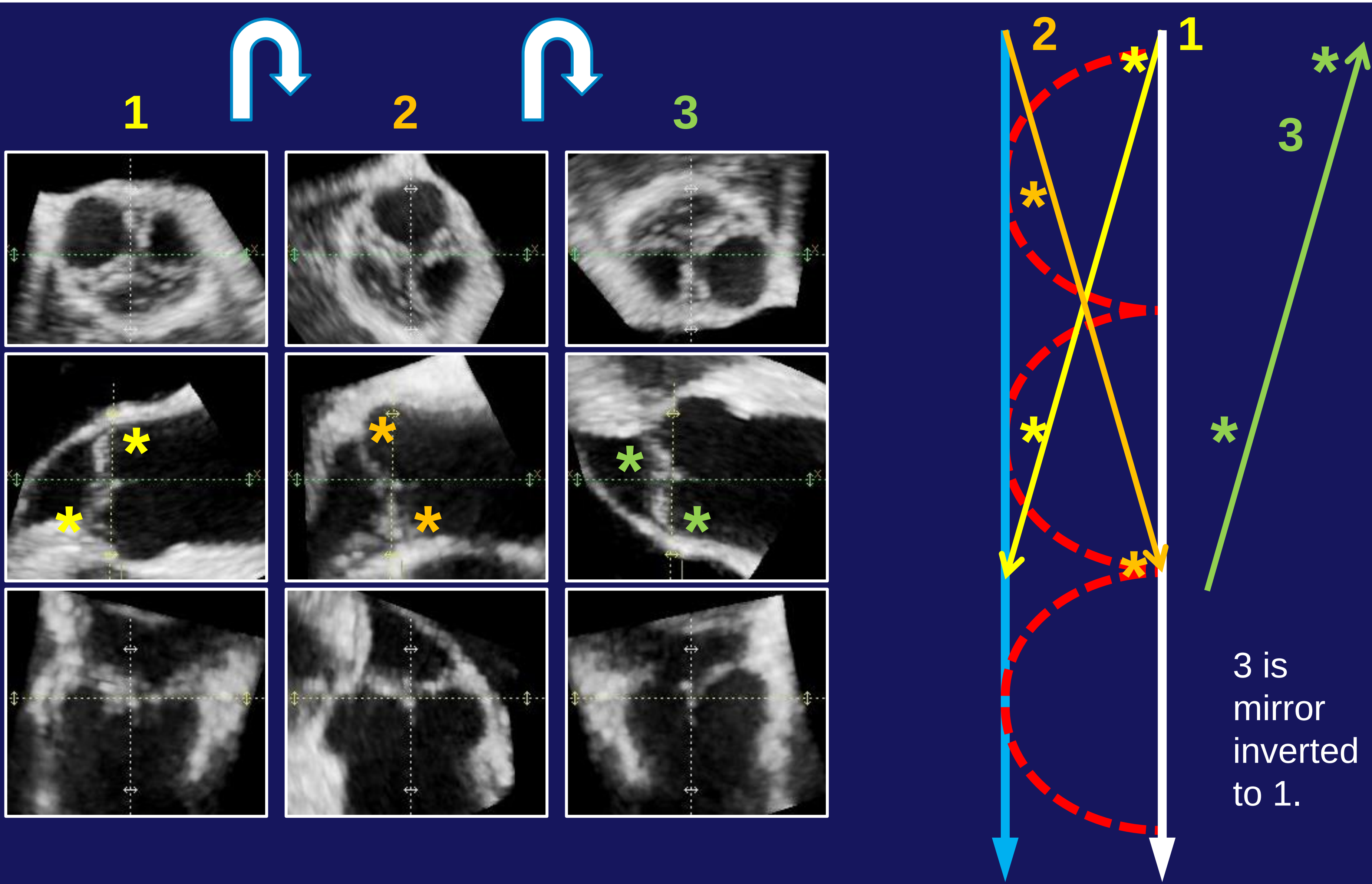
Crown-like ring

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



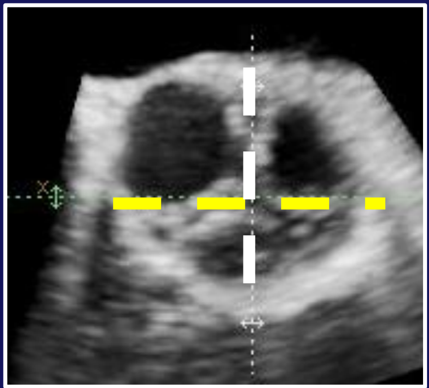


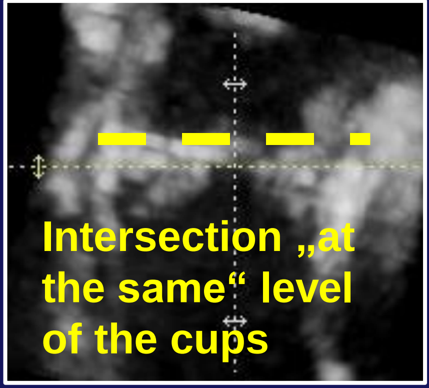
3D- and Multidimensional Echocardiography in Aortic Valve Repair



3 is mirror inverted to 1.

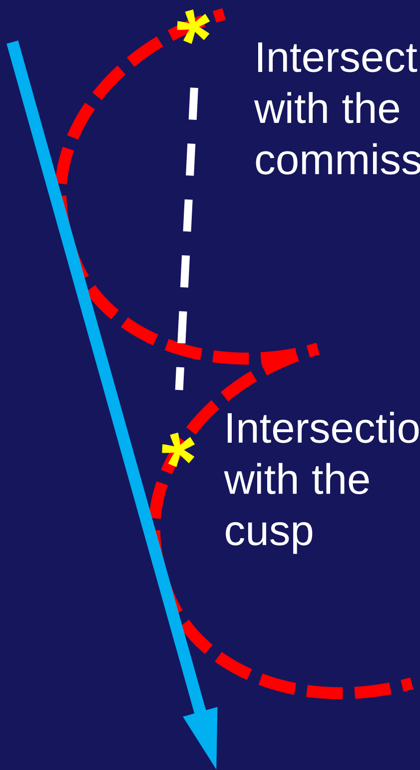
3D- and Multidimensional Echocardiography in Aortic Valve Repair





Diastole

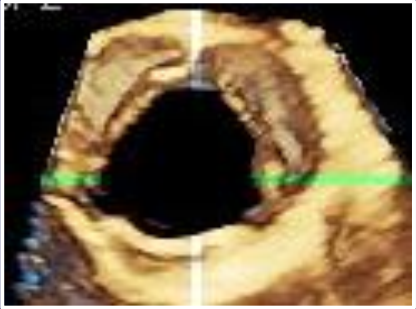
Thus,
how to operate
correctly?

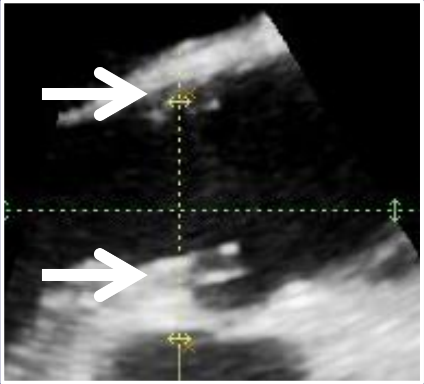


Intersection
with the
commissure

Intersection
with the
cusp

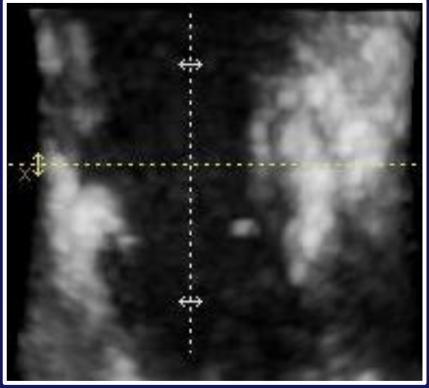
Systole



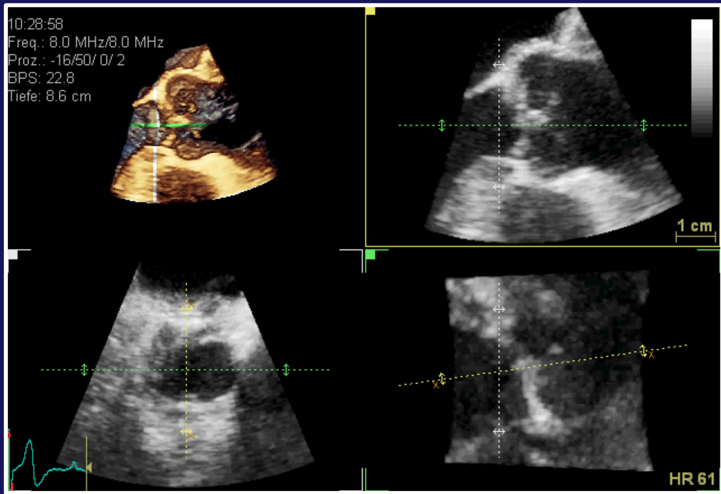


Intersection
with the
commissure

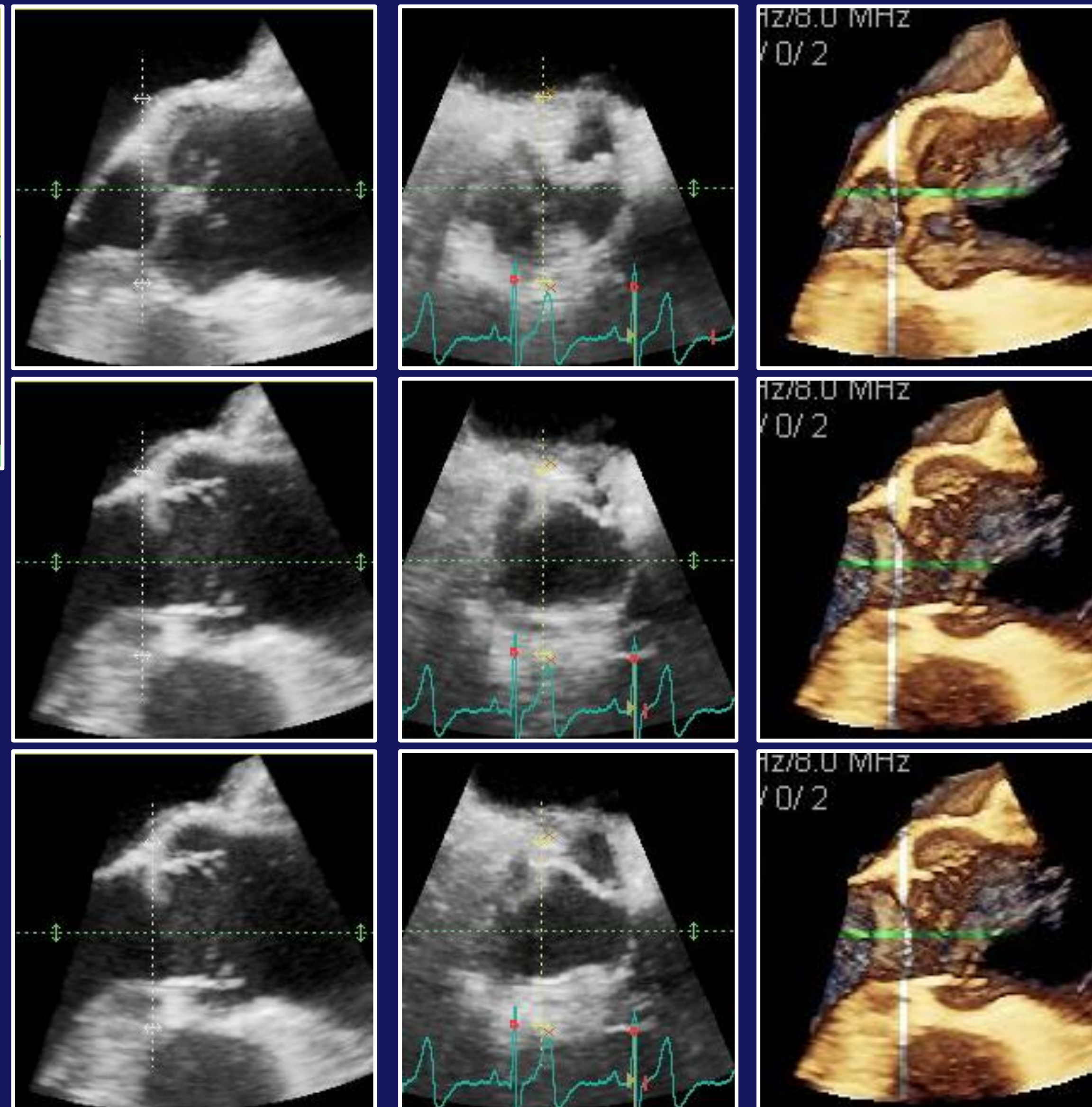
Intersection
with the
cusp



3D- and Multidimensional Echocardiography in Aortic Valve Repair



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



Mechanisms of Recurrent Aortic Regurgitation After Aortic Valve Repair

Predictive Value of Intraoperative Transesophageal Echocardiography

Jean-Benoît le Polain de Waroux, MD,* Anne-Catherine Pouleur, MD,*
Annie Robert, PhD,‡ Agnès Pasquet, MD, PhD,* Bernhard L. Gerber, MD, PhD,*
Philippe Noirhomme, MD,† Gébrine El Khoury, MD,†
Jean-Louis J. Vanoverschelde, MD, PhD*

CONCLUSIONS Our results demonstrate that intraoperative transesophageal echocardiography can be used to identify patients undergoing AR repair who are at increased risk for late repair failure.
(J Am Coll Cardiol Img 2009;2:931–9)

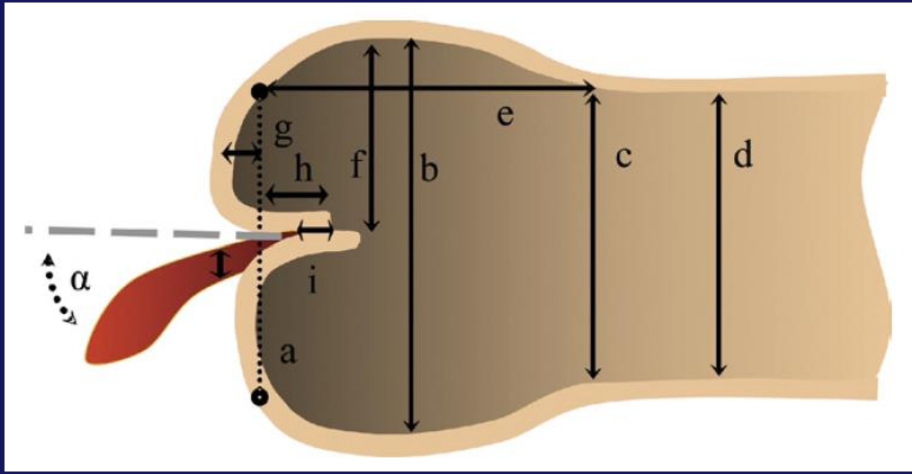
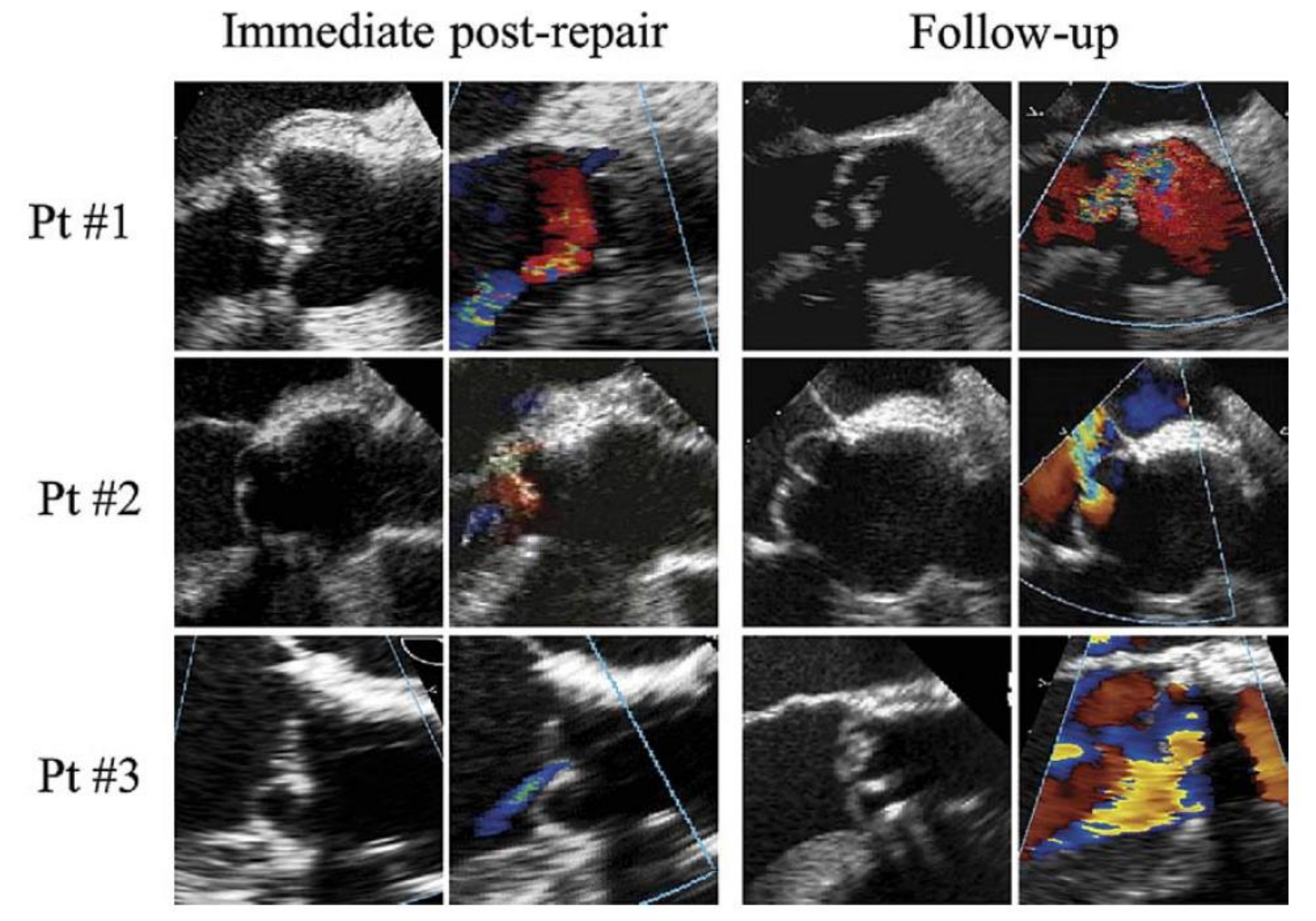


Figure 1. Schematic Representation of the TEE Measurements

Measurements were performed pre-operatively and immediately after bypass. (**a**) Aortic annulus; (**b**) sinuses of Valsalva; (**c**) sino-tubular junction; (**d**) ascending aorta; (**e**) height of the sinus of Valsalva; (**f**) distance from coaptation tips to aortic wall (the symmetry of coaptation within the sinuses of Valsalva was estimated by the absolute difference of the distance separating the tip of the coaptation from the anterior and the posterior border of the sinus of Valsalva); (**g**) distance from the aortic annulus to the belly of the lowest cusp (degree of cusp billowing if present); (**h**) distance from the tip of the cusp coaptation to the aortic annulus (relative level of cusp coaptation); and (**i**) the coaptation length. α = angle between regurgitant AR jet and left ventricular outflow tract. AR = aortic regurgitation; TEE = transesophageal echocardiography.

3D- and Multidimensional Echocardiography in Aortic Valve Repair



according to de Waroux et al., J Am Coll Cardiol Img 2009;2:931-939

Figure 3. Case Failure Examples

Representative examples of immediate post-repair intraoperative and late post-repair TEE in 3 patients with ≥3+ recurrent AR. The post-repair intraoperative TEE illustrates poor, low coaptation level, and eccentric residual AR jets in all 3 patients. In all 3 cases, the follow-up echocardiography as well as the surgical inspection identified cusp prolapse as the cause of AR recurrence. Abbreviations as in Figure 1.

3D- and Multidimensional Echocardiography in Aortic Valve Repair

Steps for measurement of geometric and effective height

1

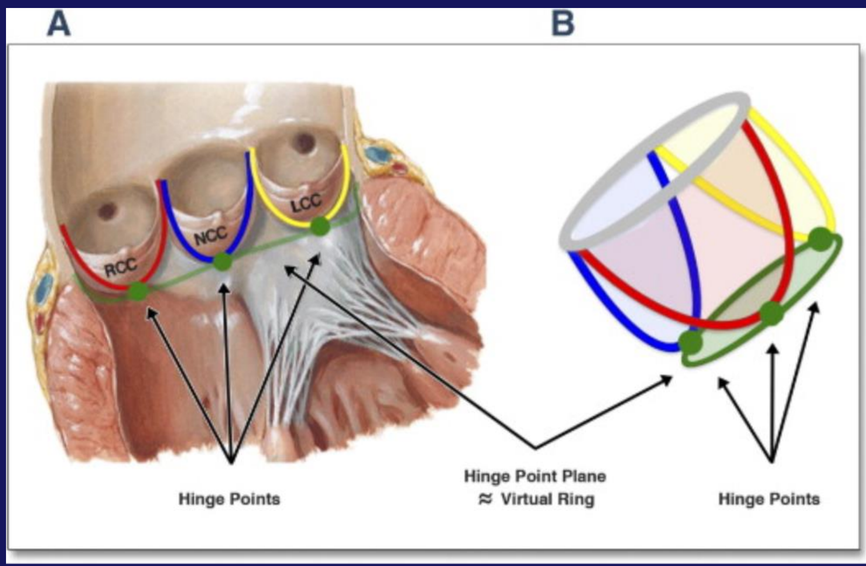
2

3

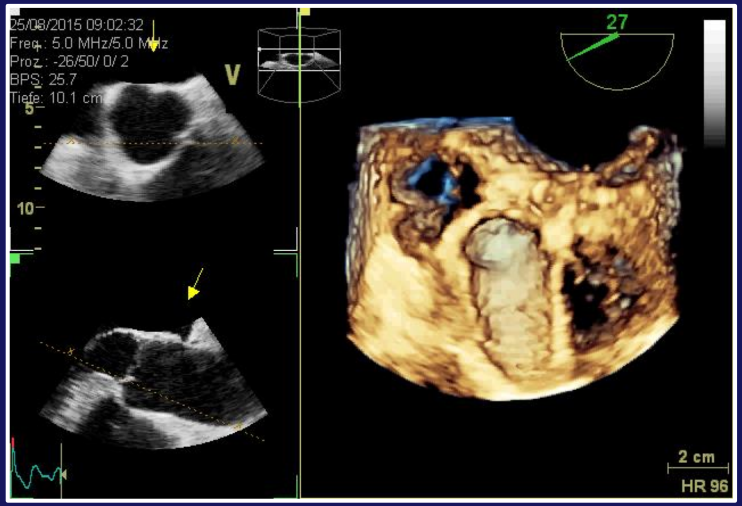
1. Acquire a ZOOM data set of the complete mitral and aortic valve
2. Adjust the central axis of the aortic root in the long axis (systole/diastole)
3. Adjust the central axis of the aortic root in the perpendicular axis
4. Adjust the short axis to the hindge points by translation during diastole
5.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

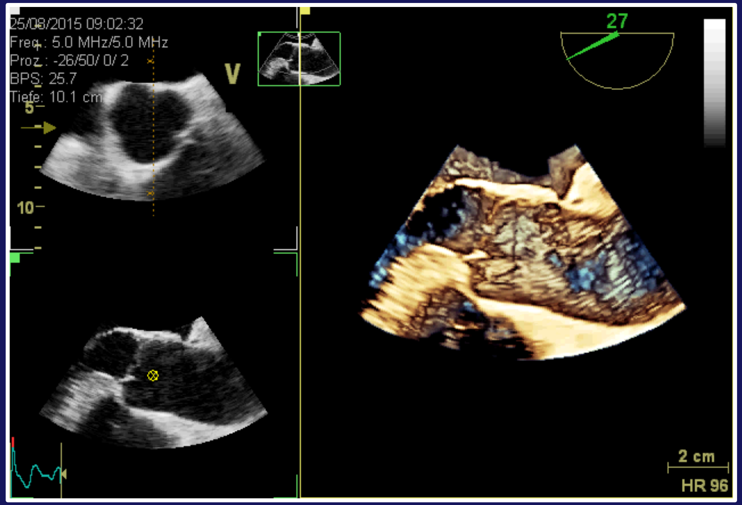
3D- and Multidimensional Echocardiography in Aortic Valve Repair

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





A Study of Functional Anatomy of Aortic-Mitral Valve Coupling Using 3D Matrix Transesophageal Echocardiography

Federico Veronesi, PhD; Cristiana Corsi, PhD; Lissa Sugeng, MD, MPH; Victor Mor-Avi, PhD; Enrico G. Caiani, PhD; Lynn Weinert, BS; Claudio Lamberti, MS; Roberto M. Lang, MD

Conclusions—This is the first study to report quantitative 3D assessment of the mitral and aortic valve dynamics from matrix array transesophageal images and describe the mitral-aortic coupling in a beating human heart. This ability may have impac on patient evaluation for valvular surgical interventions and prosthesis design. (*Circ Cardiovasc Imaging*. 2009;2:24-31.)

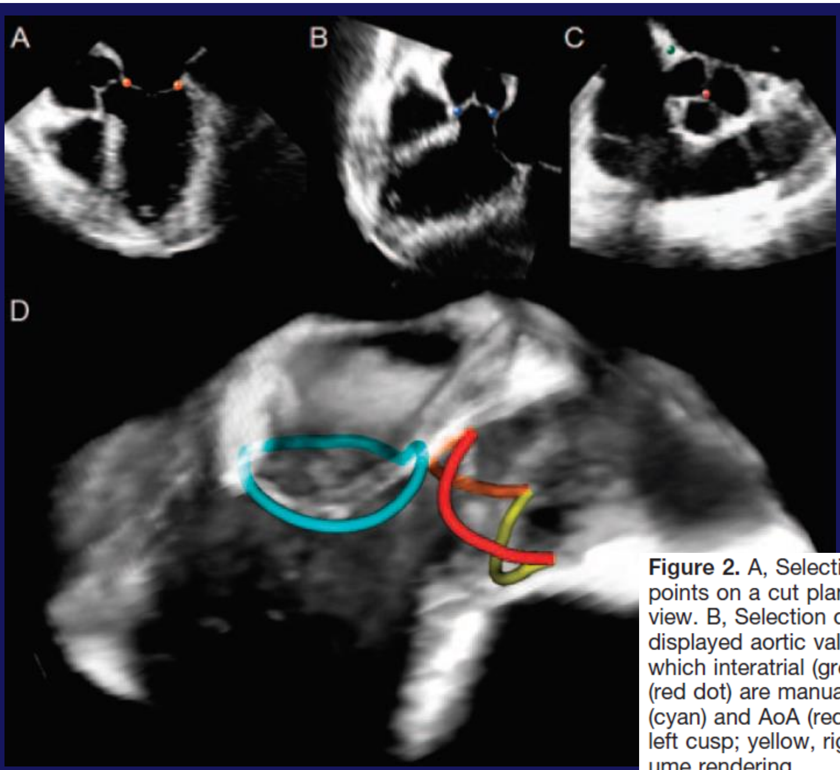


Figure 2. A, Selection of anterior and posterior MA points on a cut plane representing 3-chamber view. B, Selection of AoA points. C, Automatically displayed aortic valve short axis cut plane on which interatrial (green dot) and coaptation point (red dot) are manually identified. D, Computed MA (cyan) and AoA (red, noncoronary cusp; orange, left cusp; yellow, right cusp) splines on RT3DE volume rendering.

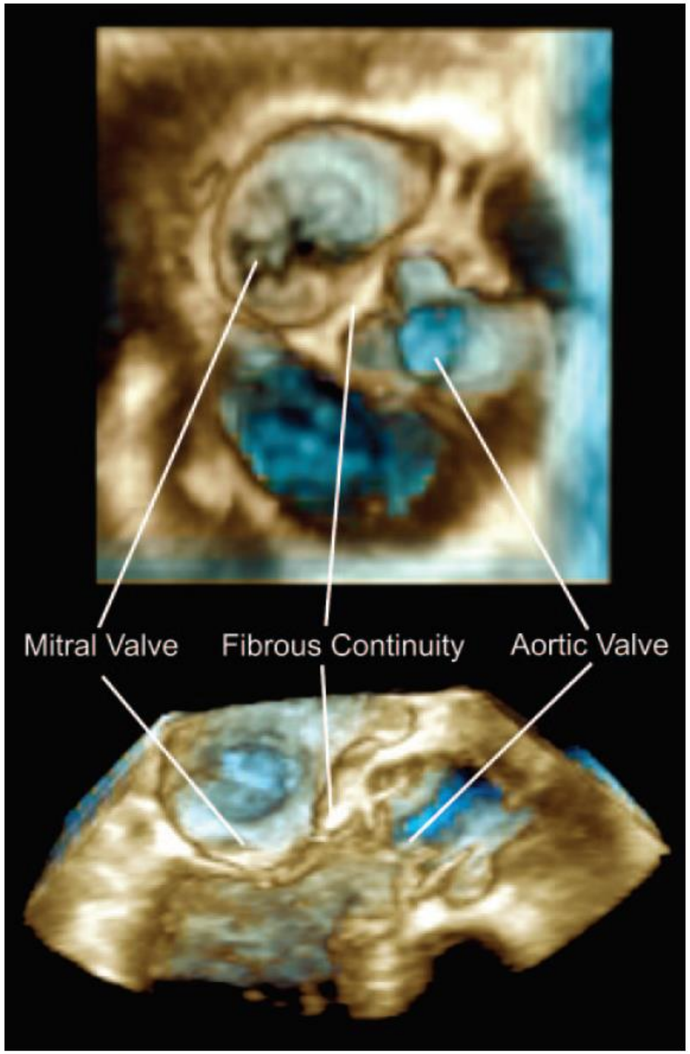


Figure 1. Volume rendering of RT3DE mTEE data visualized from atrium (top) and in a long axis view (bottom).

3D- and Multidimensional Echocardiography in Aortic Valve Repair

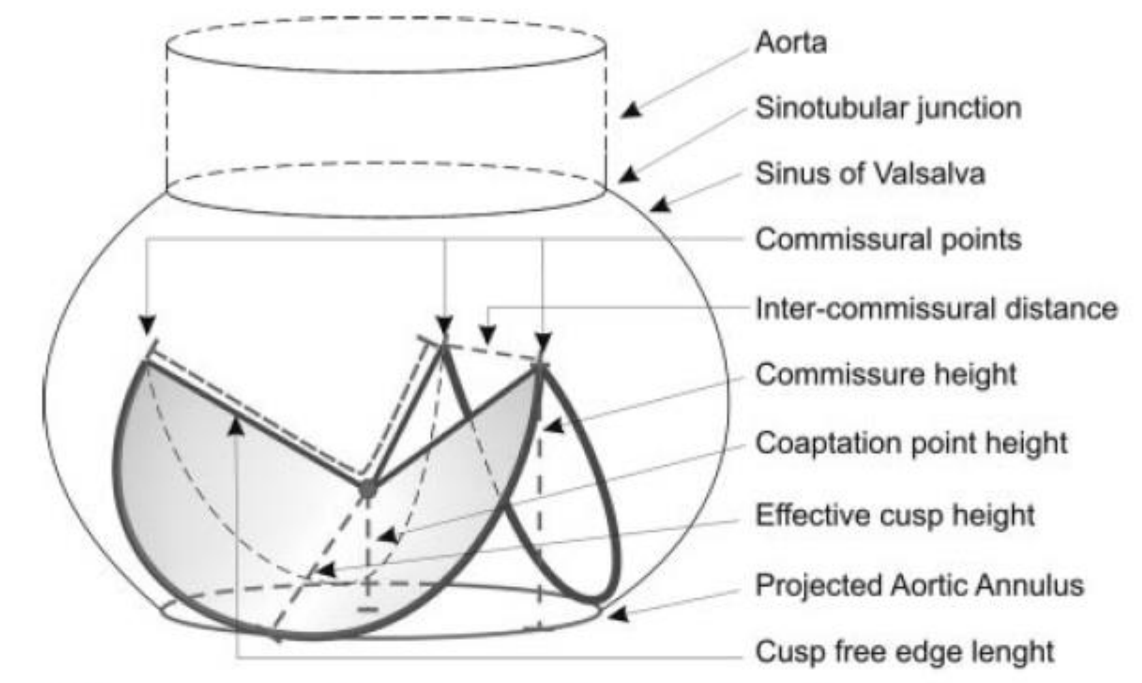


Figure 3. Schematic of automatically extracted AoA measurements.

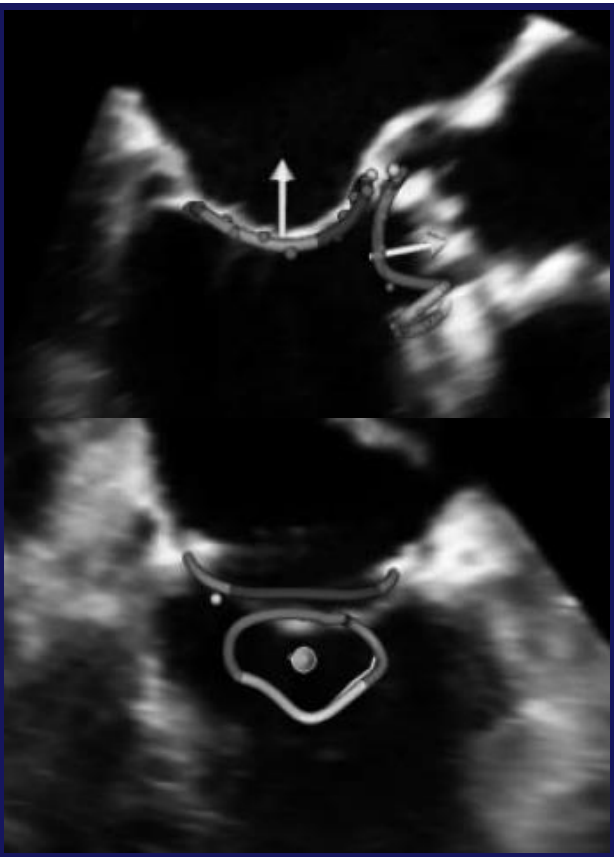


Figure 5. Left, Mitral and aortic annuli computed from a RT3DE data set obtained in a patient with severe sclerocalcific aortic stenosis, shown superimposed on a 3-chamber view. Note that the angle between the 2 valves is severely reduced (93°) compared with normal subjects and also the distance between the 2 valve was just 18 mm and did not changed during cardiac cycle. The aortic stenosis was most likely responsible for the reduced change in projected AoA area during the cardiac cycle, having a negative impact on the aortic-mitral coupling as reflected by a decrease in maximum diastolic area change to only 12%, compared with 25.4% of the ED area in normal subjects (Table 1). Right, Mitral and aortic annuli computed from a RT3DE data set obtained in a patient with implanted mitral ring, shown superimposed on a 2-chamber view. Note the deformation in the shape of the AoA. In this subject, reduced motion of the mitral valve (4.5 mm maximum at ES) and reduced MA height (4.3 mm) at ED was noted. In addition, the intercommissural distances where asymmetrical: the distance between the commissures of the left cusp was smaller (18 mm) compared with the noncoronary and right cusps (28 and 27 mm, respectively). Moreover, the saddle shape of the MA was not preserved because of the rigid ring.

3D- and Multidimensional Echocardiography in Aortic Valve Repair

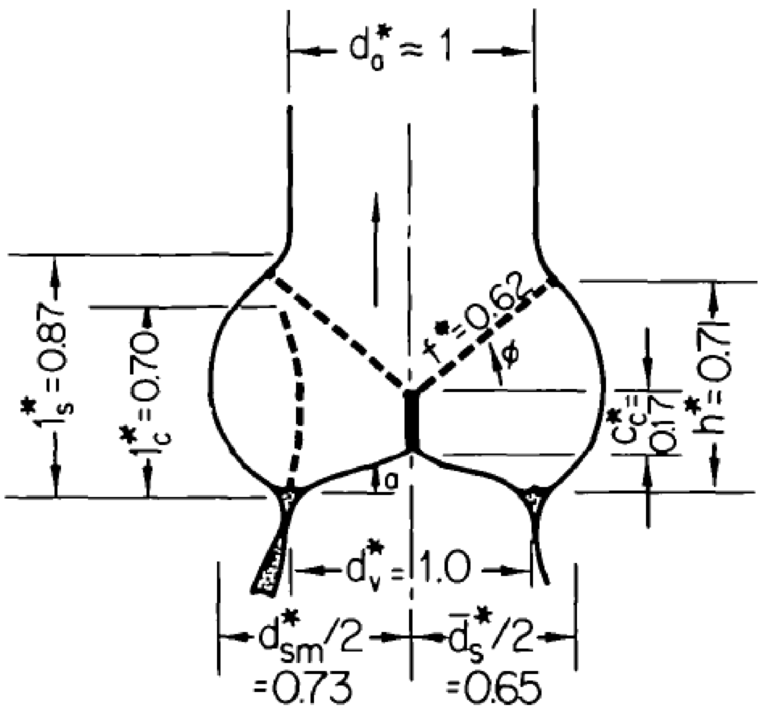
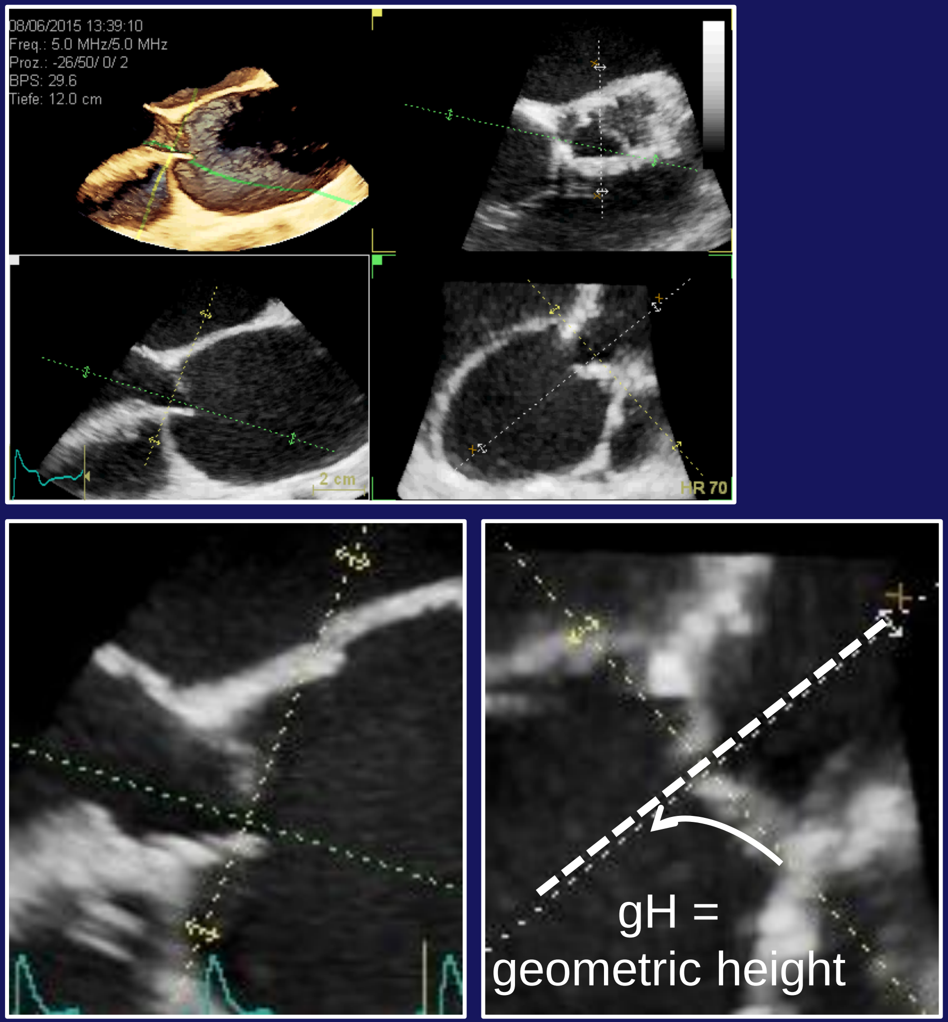


FIGURE 2

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

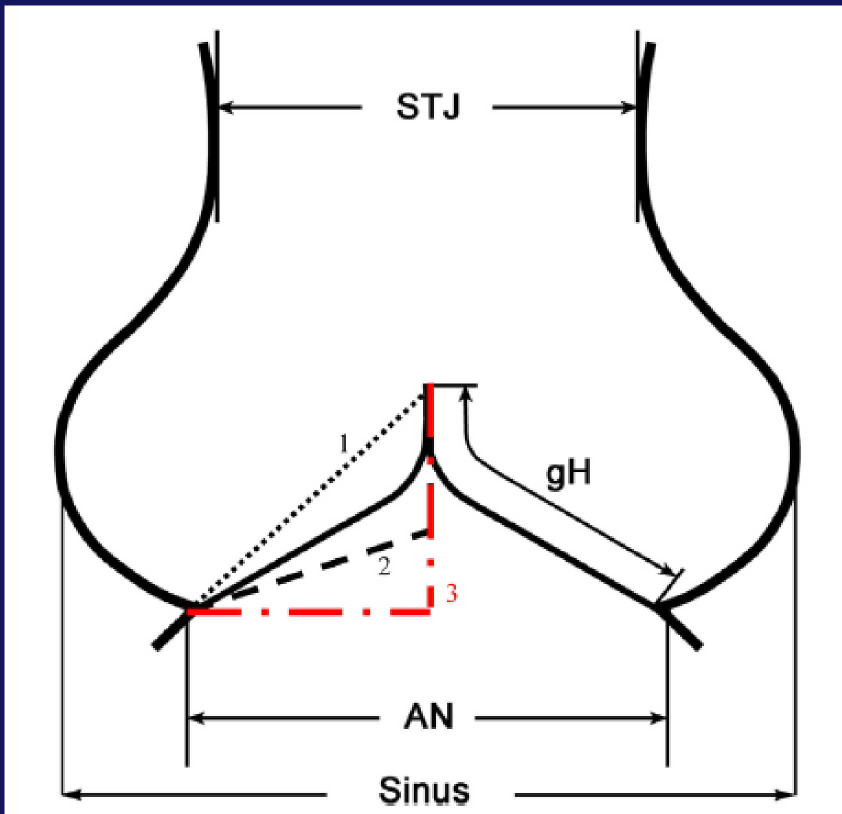
Circulation Research, Vol. 35, December 1974

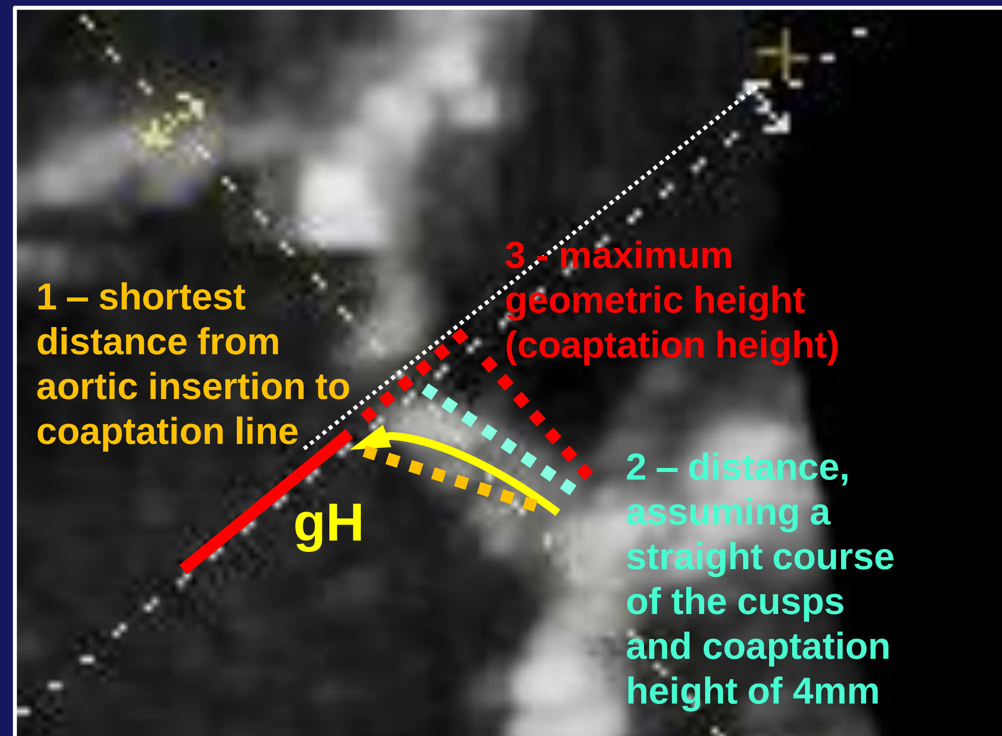


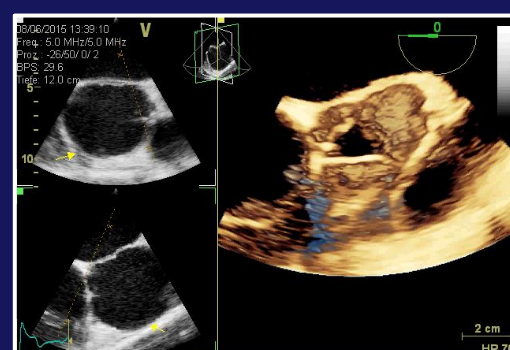
aus Swanson WM and Clark RE. Dimensions and Geometric Relationships of the Human Aortic Valve as a Function of Pressure. Circ Res 1974; 35: 871-882

3D- and Multidimensional Echocardiography in Aortic Valve Repair

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

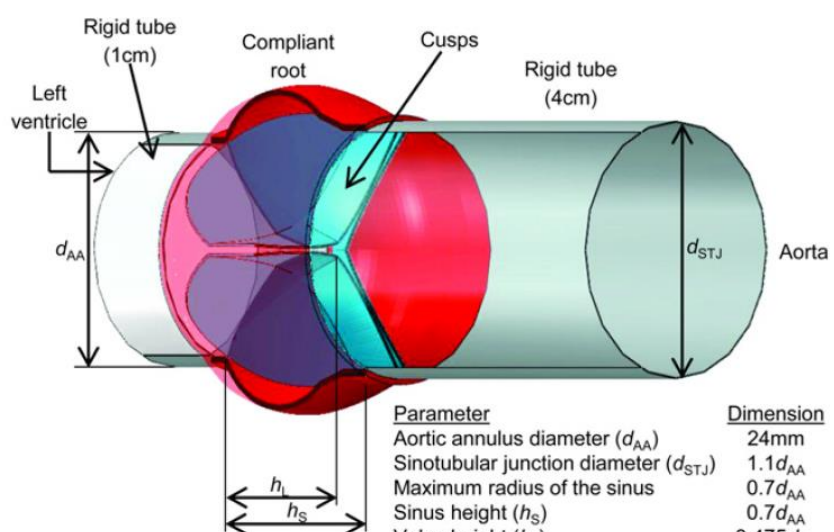
Aortic root numeric model: Annulus diameter prediction of effective height and coaptation in post–aortic valve repair

Gil Marom, MSc,[a] Rami Haj-Ali, PhD,[a] Moshe Rosenfeld, DSc,[a] Hans Joachim Schäfers, MD,[b] and Ehud Raanani, MD[c]

Conclusions: A decreased AA diameter increased the coaptation height and area, thereby improving the effective height during procedures, which could lead to increased coaptation and better valve performance. (J Thorac Cardiovasc Surg 2013;145:406-11)

Abbreviations and Acronyms

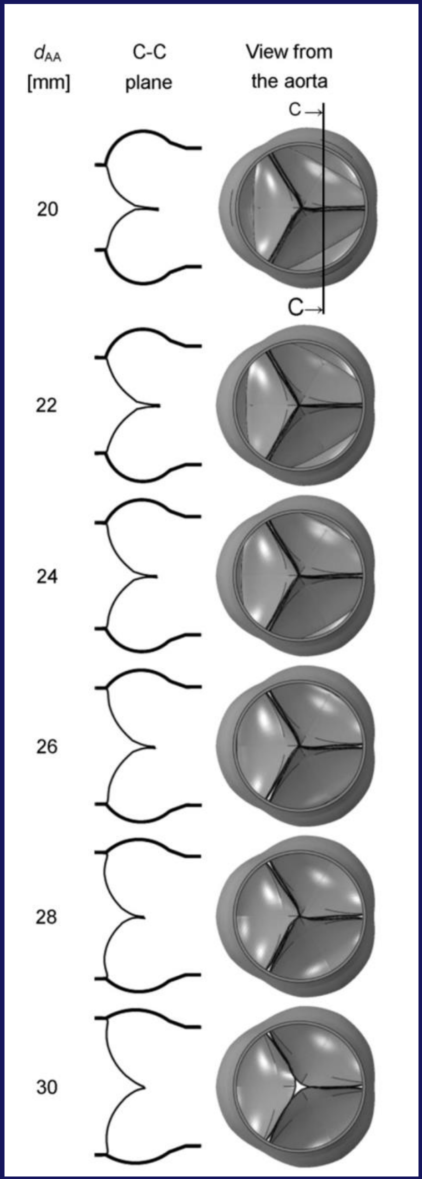
2D	=	2-dimensional
3D	=	3-dimensional
AA	=	aortic annulus
d_{AA}	=	annulus diameter
h_C	=	coaptation height
h_E	=	effective height
FSI	=	fluid structure interaction
NCCA	=	normalized cusp coaptation area



Parameter	Dimension
Aortic annulus diameter (d_{AA})	24mm
Sinotubular junction diameter (d_{STJ})	$1.1d_{AA}$
Maximum radius of the sinus	$0.7d_{AA}$
Sinus height (h_S)	$0.7d_{AA}$
Valve height (h_L)	$0.475d_{AA}$

FIGURE 1. A schematic view of the aortic valve healthy model showing the compliant region and the added rigid tubes.

3D- and Multidimensional Echocardiography in Aortic Valve Repair



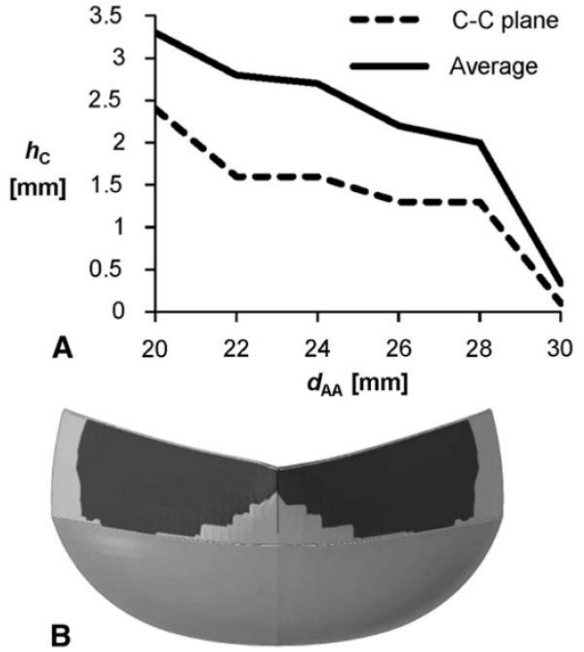


FIGURE 4. A, Coaptation heights (h_C) as a function of annulus diameter (d_{AA}) and (B) coaptation area marked in black for the case of fully closed (1-ms duration) $d_{AA} = 24$ mm valve.

CONCLUSIONS

From our results, it is evident that decreasing the AA diameter increases the coaptation height and area. Furthermore, our results also indicate that measuring the h_E during surgery will closely correlate with postoperative coaptation and improved valve performance.

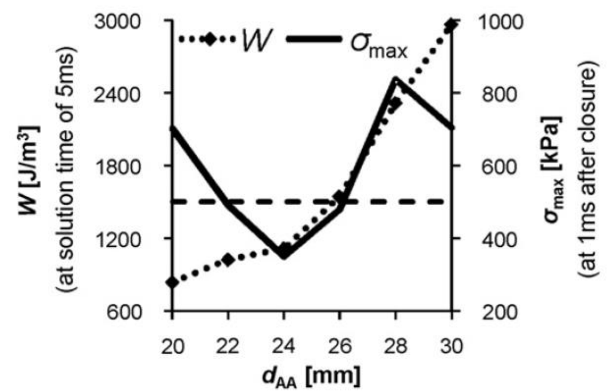


FIGURE 5. Comparison of energy density (W) and the maximum principal stress (σ_{max}) for the various annulus diameters (d_{AA}). The *dashed line* indicates the $\sigma_{max} = 500$ kPa.

FIGURE 3. Projected deformed configurations of the closed valves on the C-C plane with $r = 5$ mm and views from the aorta. The case of $d_{AA} = 28$ mm is open with discontinuous contact, although the aorta view dose not disclose this fact.

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

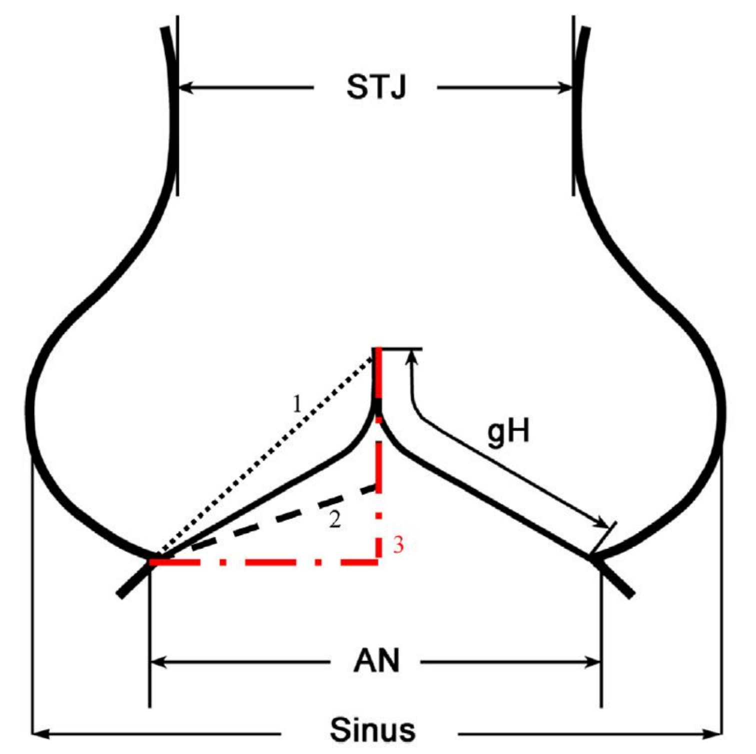
Cusp height in aortic valves

Hans-Joachim Schäfers, MD,[a] Wolfram Schmied, Dipl Psych,[a] Gil Marom, MSc,[b] and Diana Aicher, MD[a]

Conclusions: We found the cusp height was larger than previously published. It shows marked variability and correlates with the clinical variables. These data might serve as the basis for decision making in aortic valve repair. (J Thorac Cardiovasc Surg 2013;146:269-74)

CONCLUSIONS

The cusp geometric height that we found was larger than that previously published. It showed some variability and correlated with the clinical variables. The nonfused cusps of the BAVs were 3 mm larger than those of the TAVs. These data could serve as a basis for decision making in aortic valve repair and serve as a reference for computer simulation studies of the aortic valve.



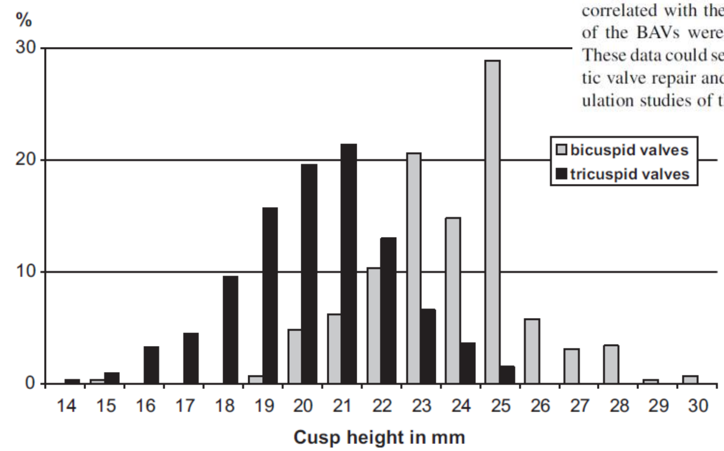
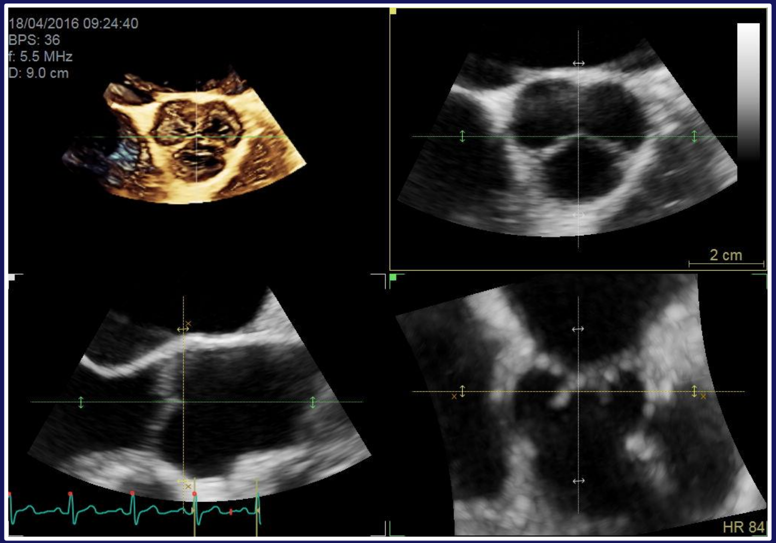
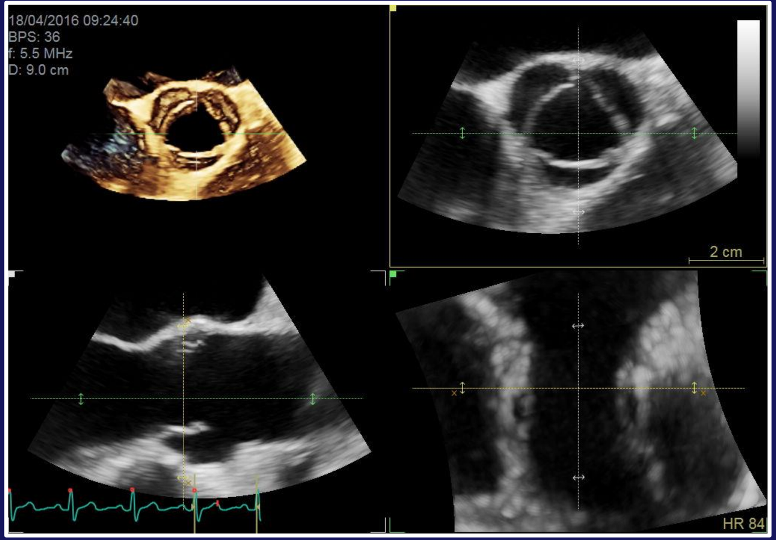


FIGURE 3. Distribution of geometric height in bicuspid (n = 289; nonfused cusps) and tricuspid (n = 332; mean of all 3 cusps) aortic valves.

FIGURE 1. Schematic drawing of the aortic root with graphic description of geometric height. *AN*, Aortoventricular junction; *gH*, geometric height; *STJ*, sinotubular junction; *sinus*, maximal sinus diameter; *1*, shortest distance from aortic insertion to coaptation line; *2*, distance assuming a straight course of the cusp and a coaptation height of 4 mm; *3*, maximum geometric height assuming the effective height is equal to the coaptation height.

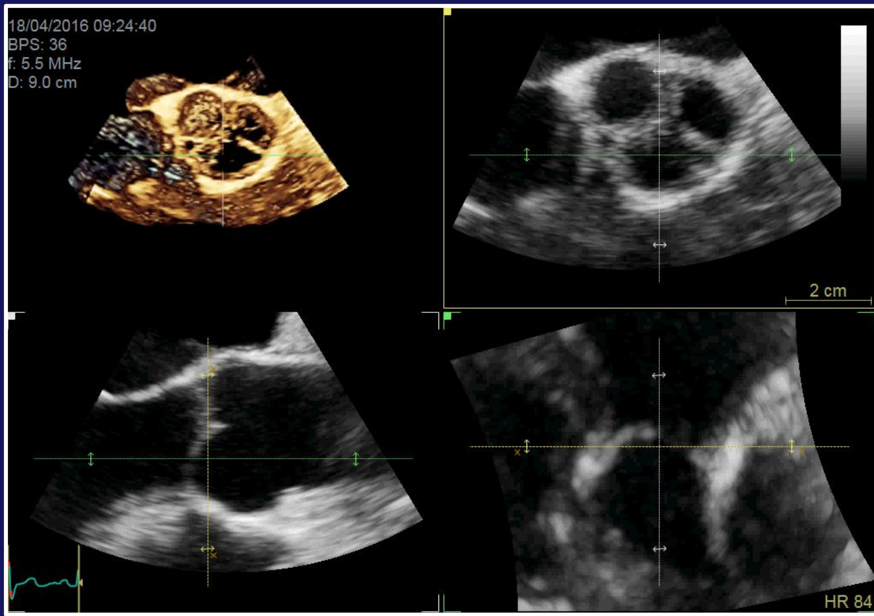
Assessment of Cusp Geometry: Effective and Geometric Height

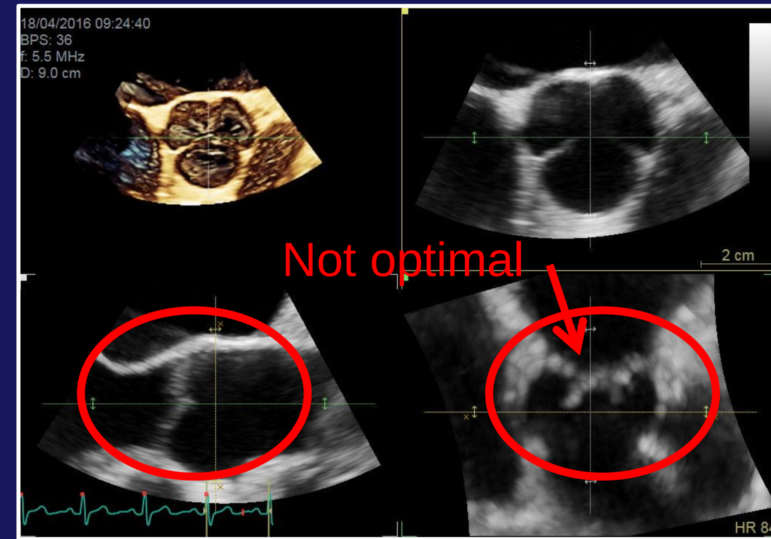




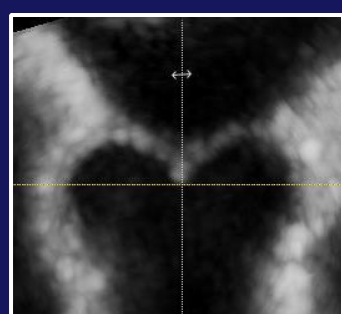
Step 1: Check alignements of the commissure between left and non coronary cusp to be perpendicular to the center of the right coronary cusp
In asymmetric aortic root geometry the corresponding opposite cusp has to be centered.

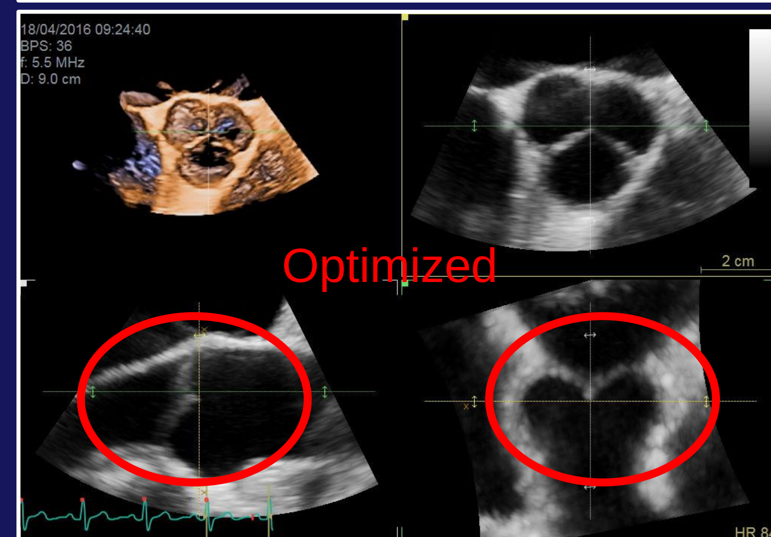
Assessment of Cusp Geometry: Effective and Geometric Height



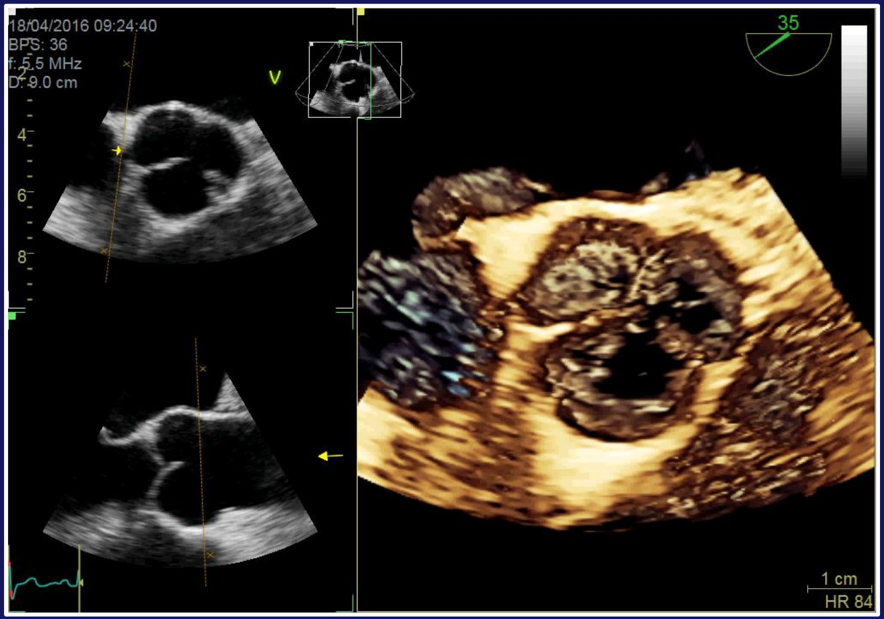


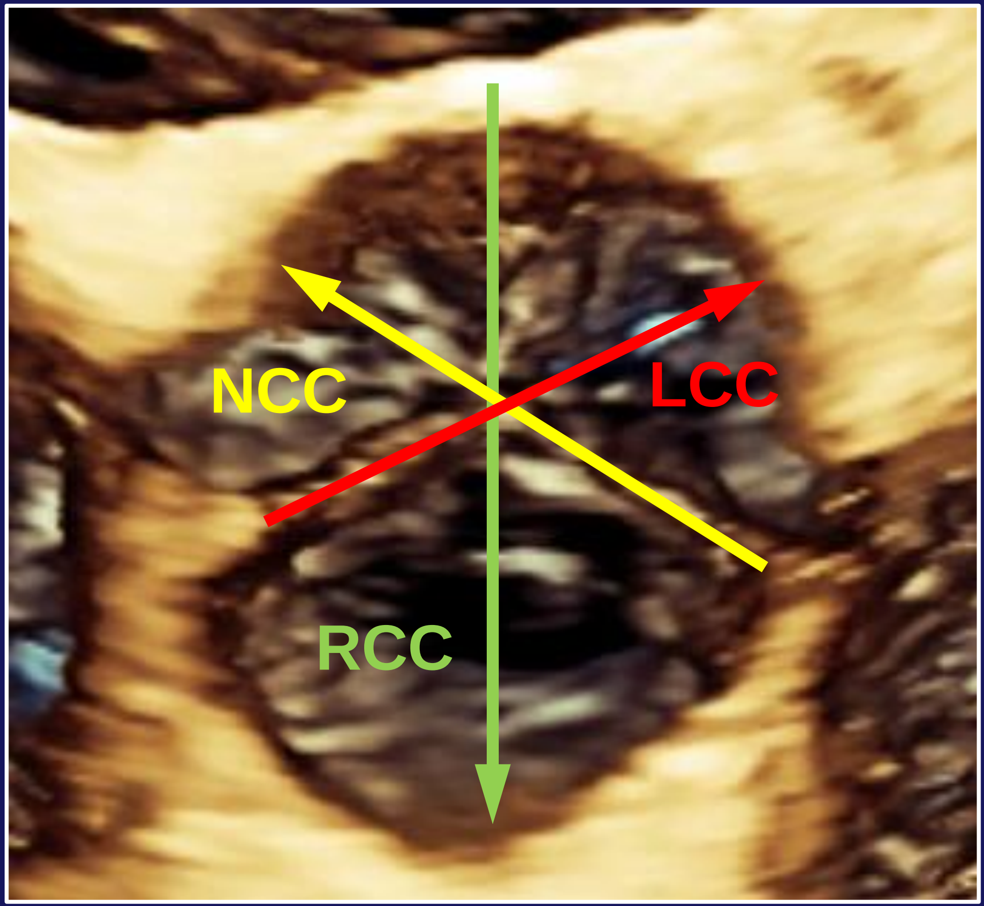
Step 2: Center in tricuspid valves the central point of all commissures





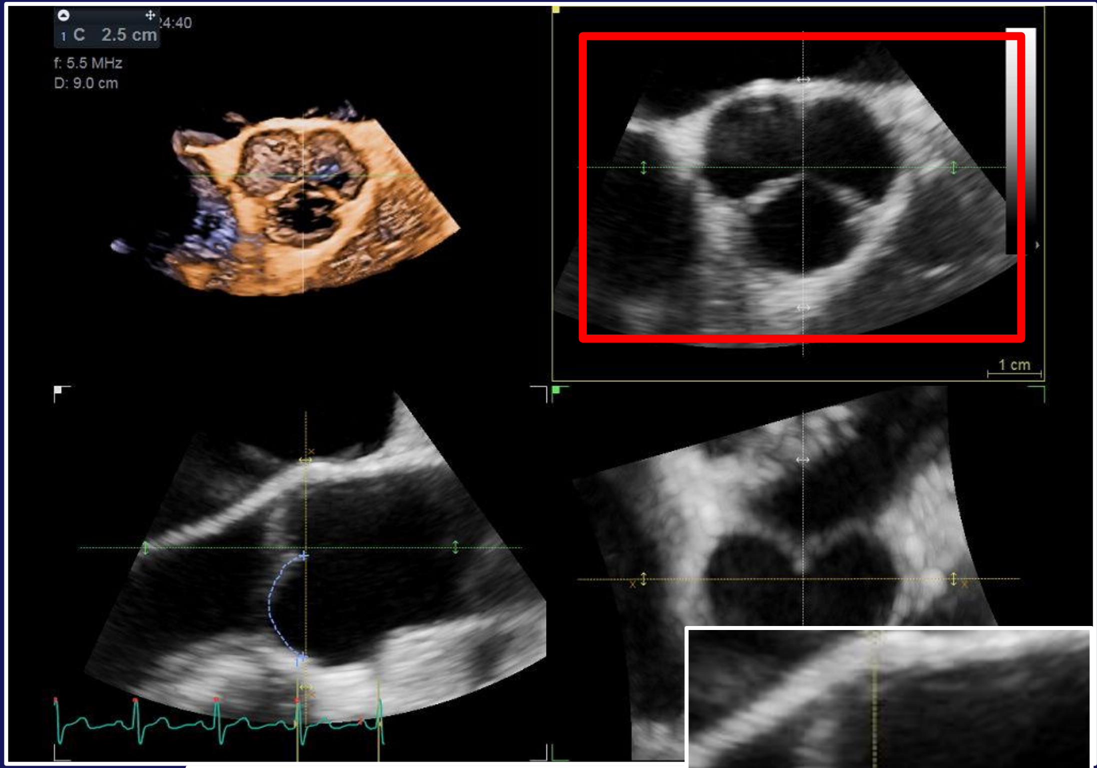
Cusp Geometry: Scheme of the Sectional Planes for Assessment of Geometric Height

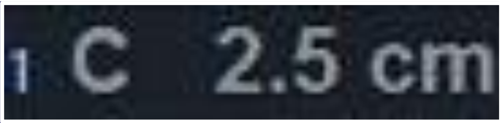




In 2D-TTE and TEE only the exact assessment of the right coronary cusp is possible. The left and non coronary cusp has to be analyzed in 3D data sets.

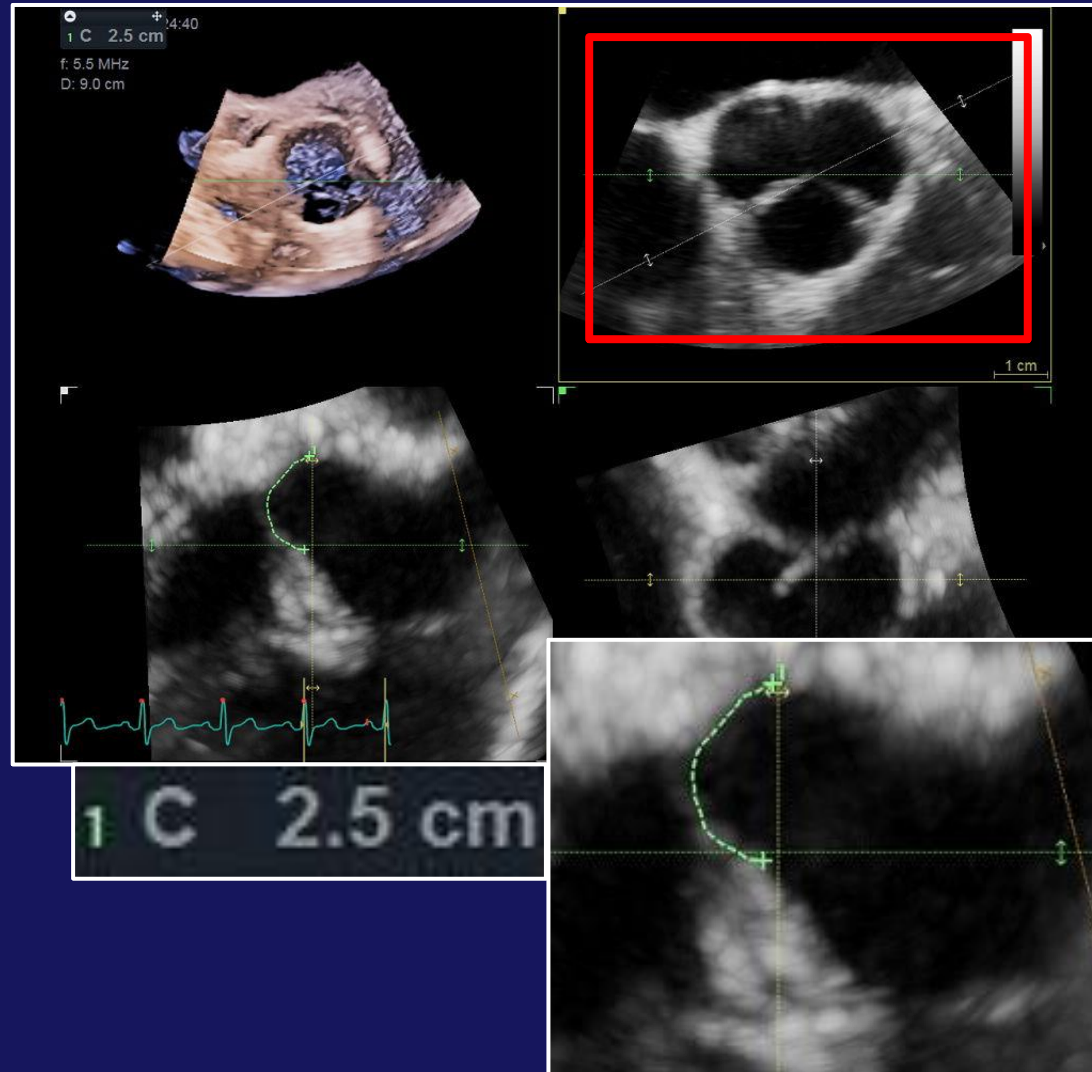
Assessment of Cusp Geometry: Effective and Geometric Height





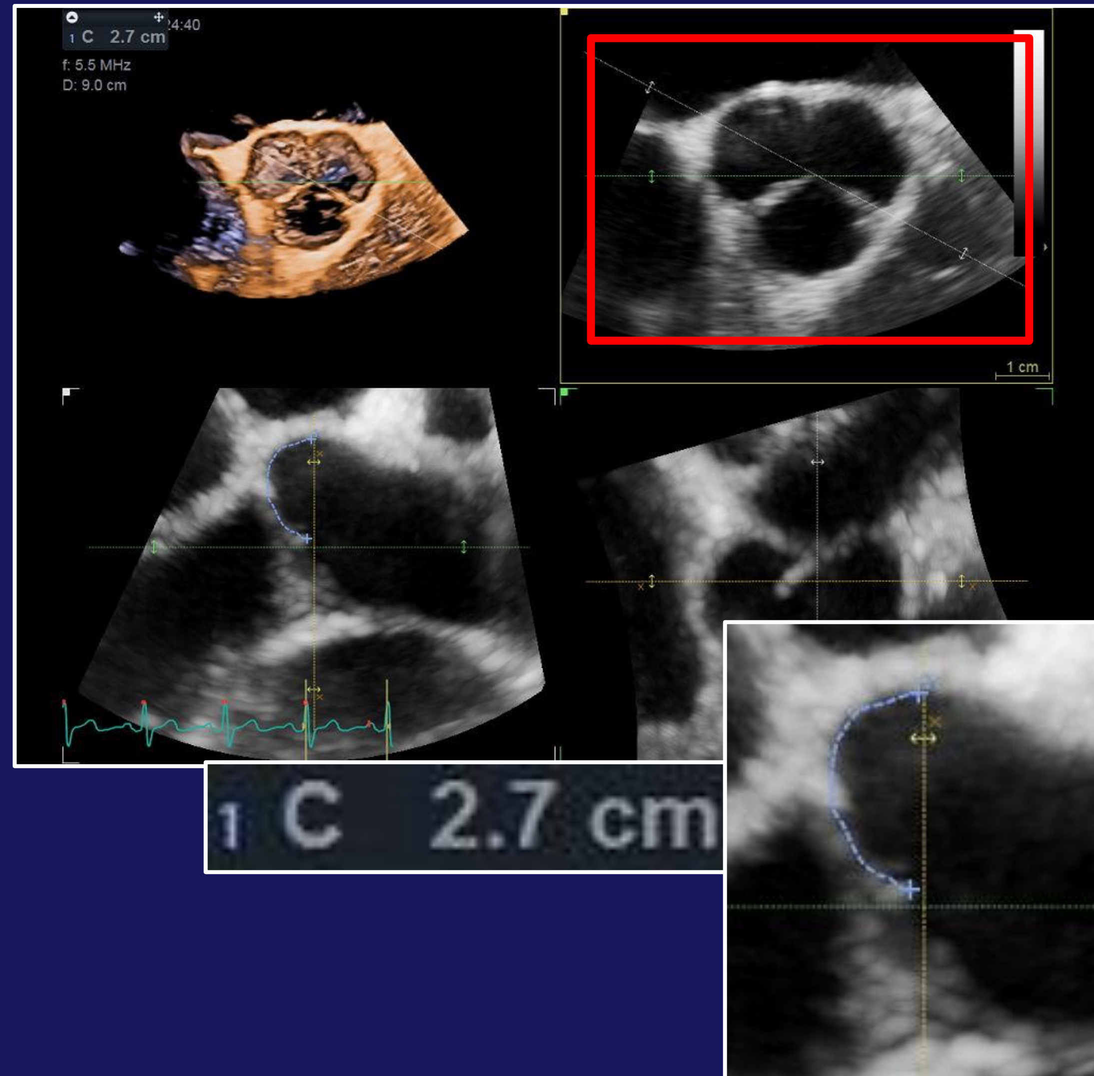
Assessment of the geometic height of the right coronary cusp

Assessment of Cusp Geometry: Effective and Geometric Height



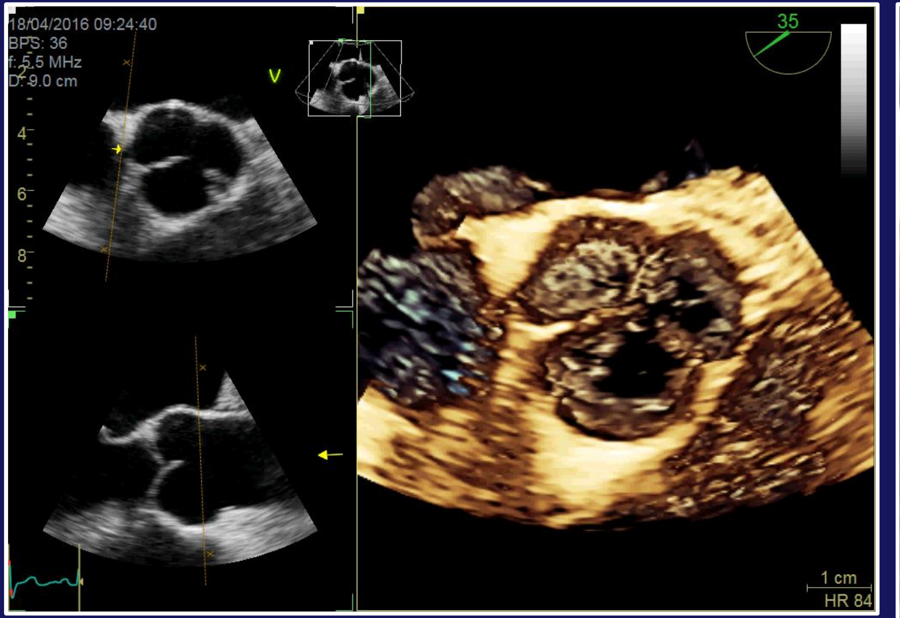
Assessment of the geometic height of the left coronary cusp

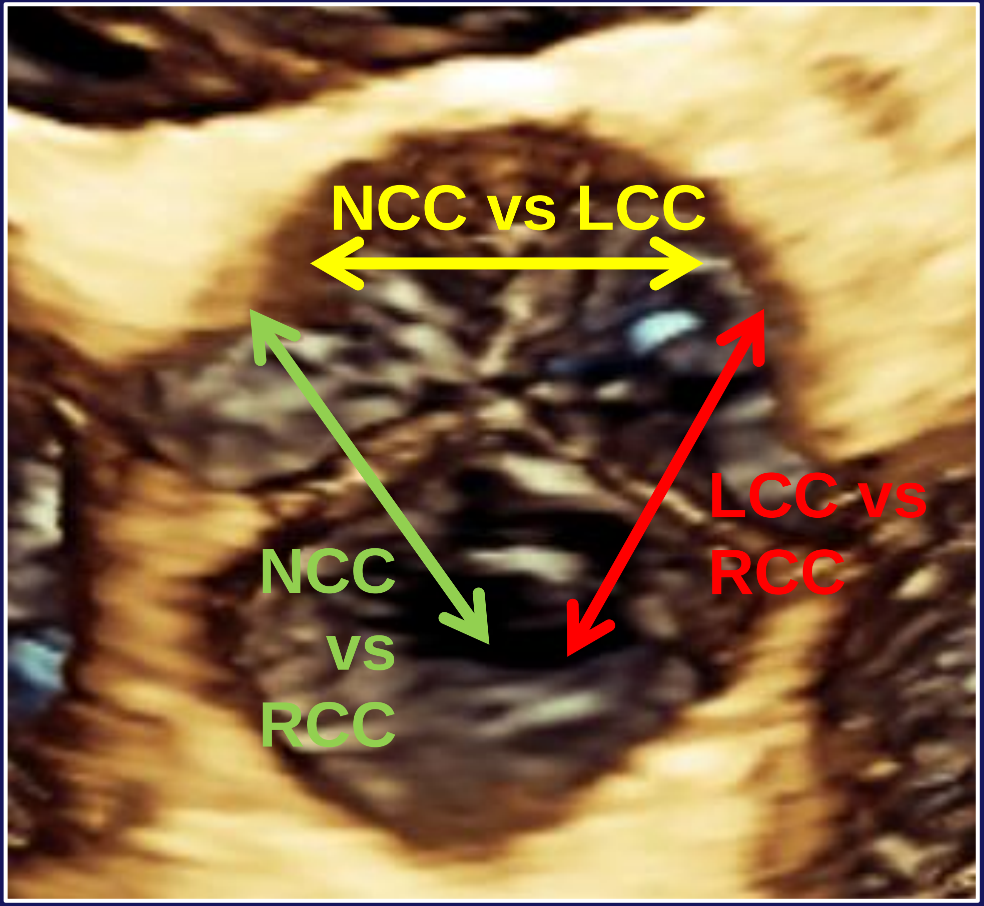
Assessment of Cusp Geometry: Effective and Geometric Height



Assessment of the geometic height of the non coronary cusp

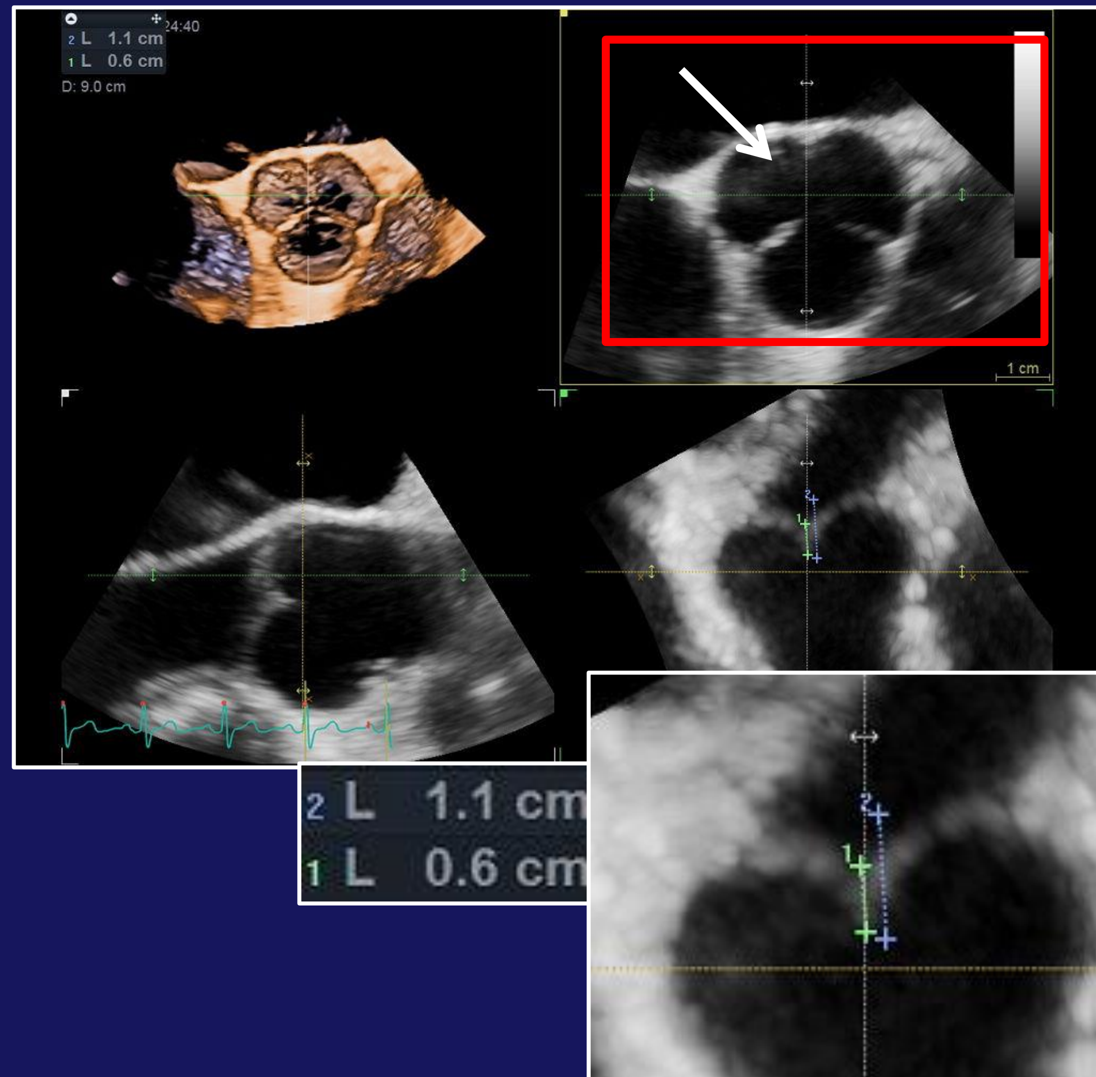
Cusp Geometry: Scheme of the Sectional Planes for Assessment of Effektive Height





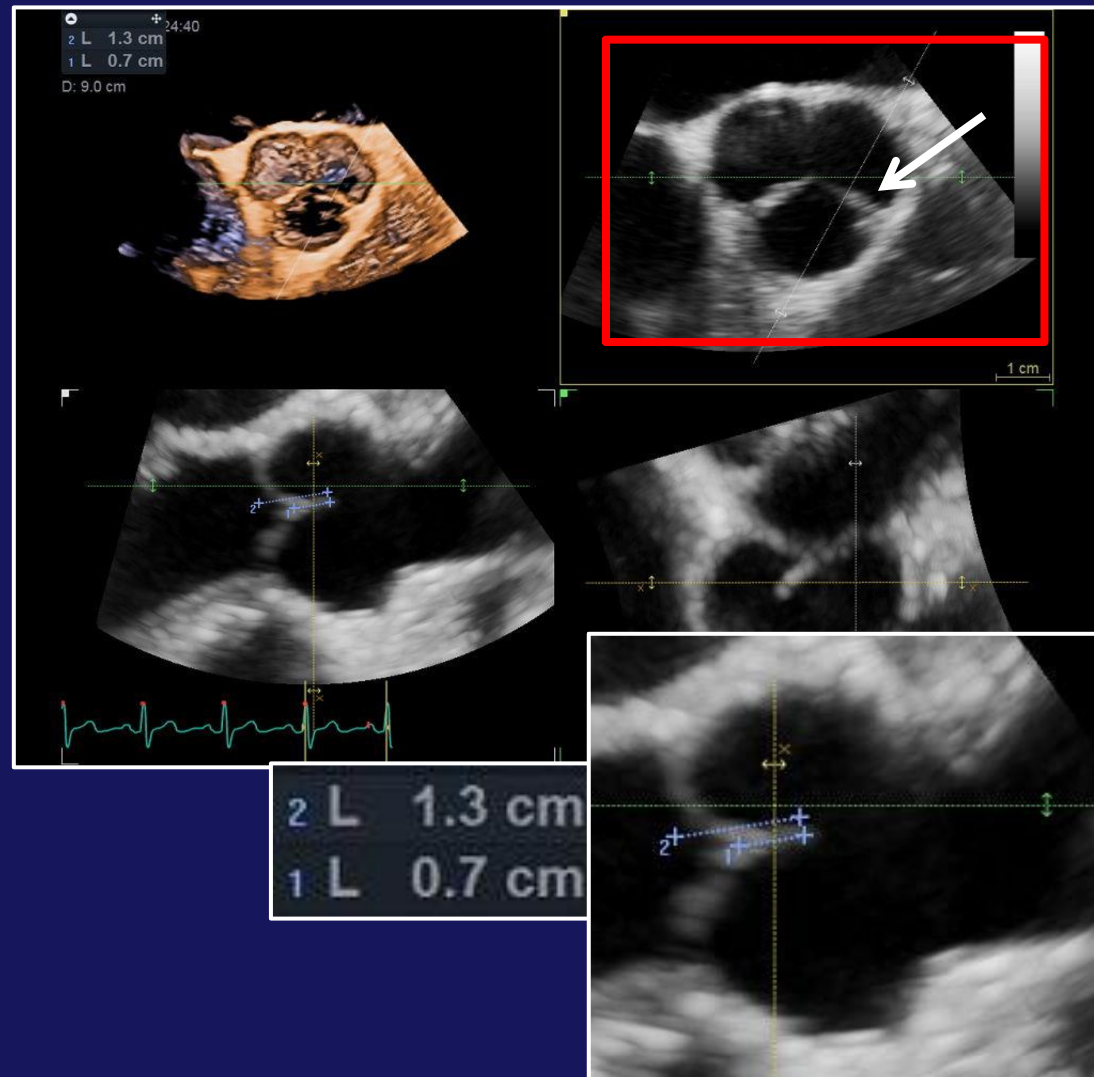
In 2D-TTE and TEE only the exact assessment of the right coronary cusp is possible. The left and non coronary cusp has to be analyzed in 3D data sets.

Assessment of Cusp Geometry: Effective and Geometric Height



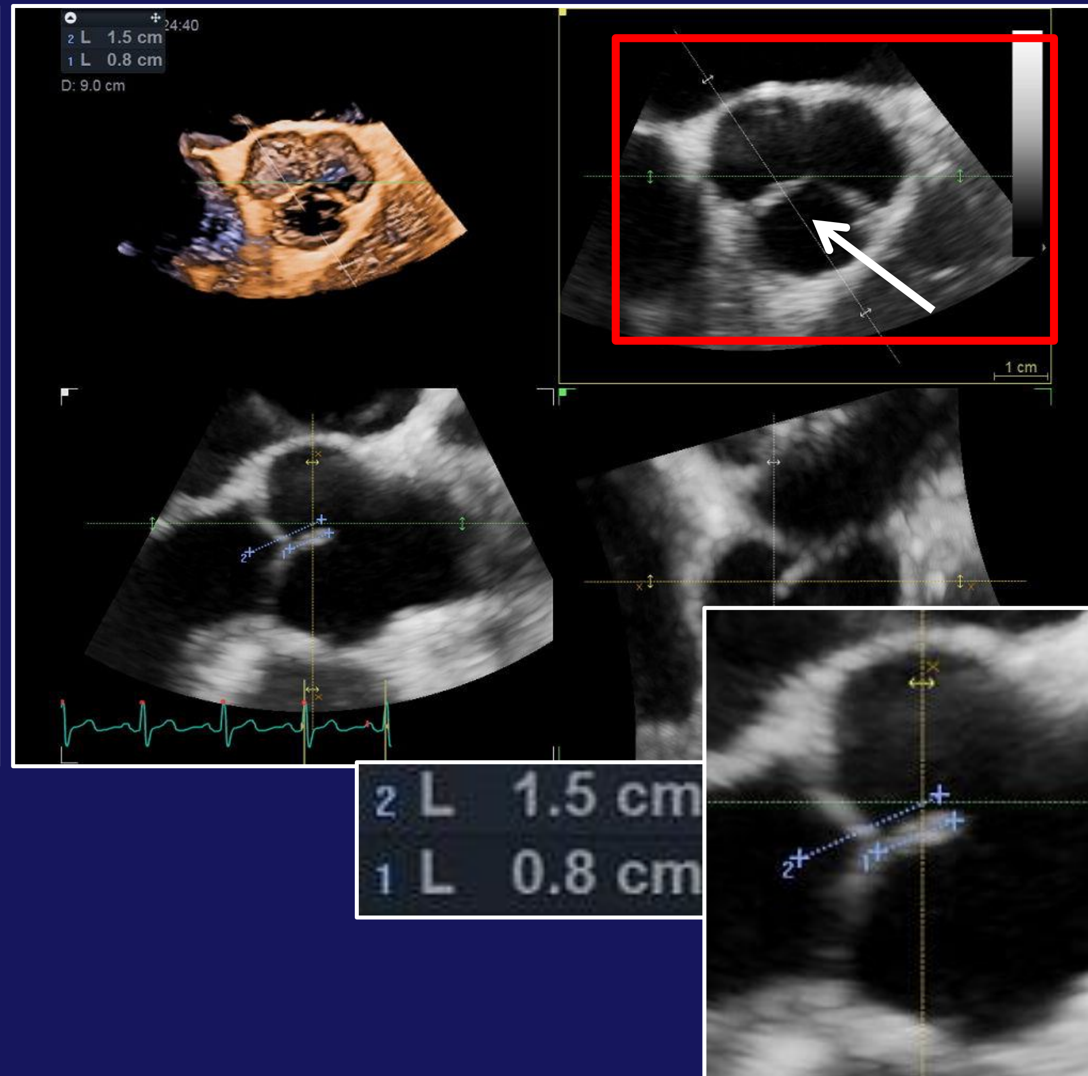
Assessment of the coaptation length and effective height between the left and non coronary cusp

Assessment of Cusp Geometry: Effective and Geometric Height



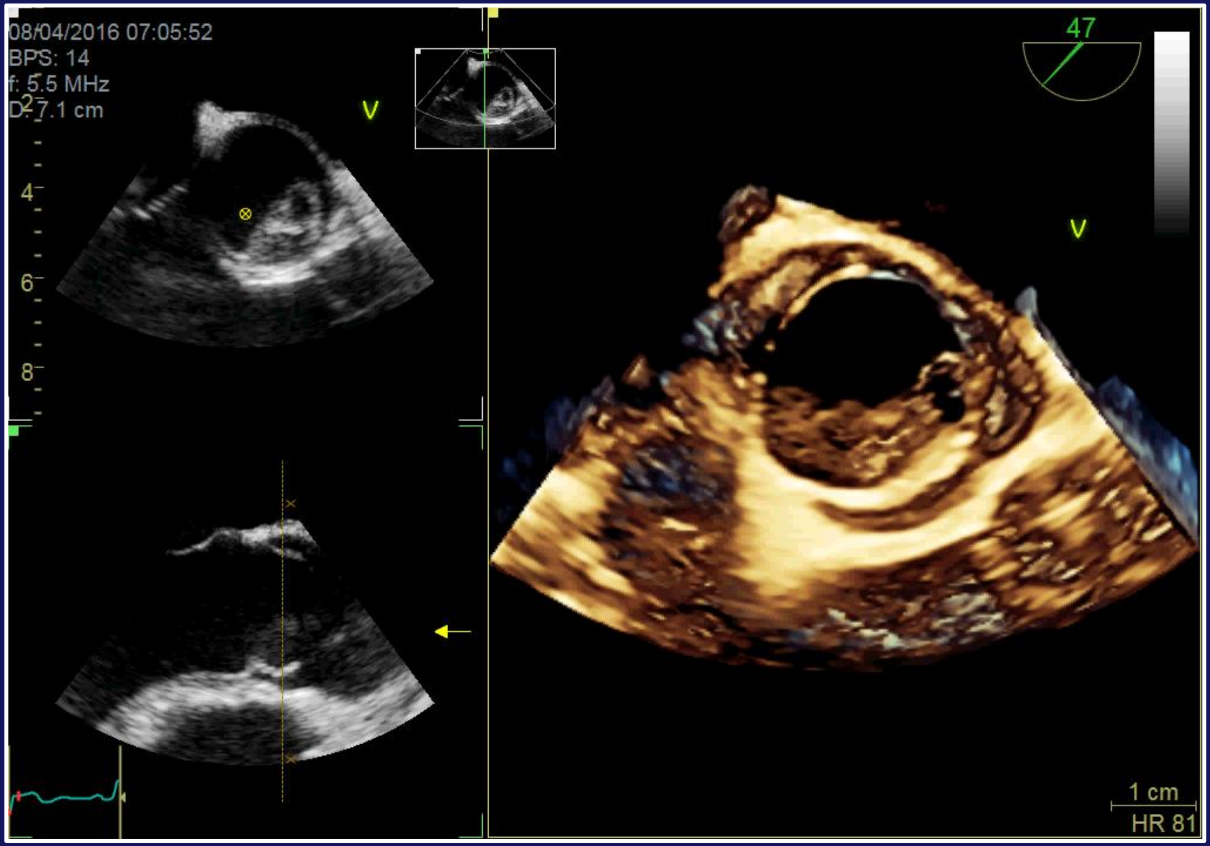
Assessment of the coaptation length and effective height between the left and right coronary cusp

Assessment of Cusp Geometry: Effective and Geometric Height

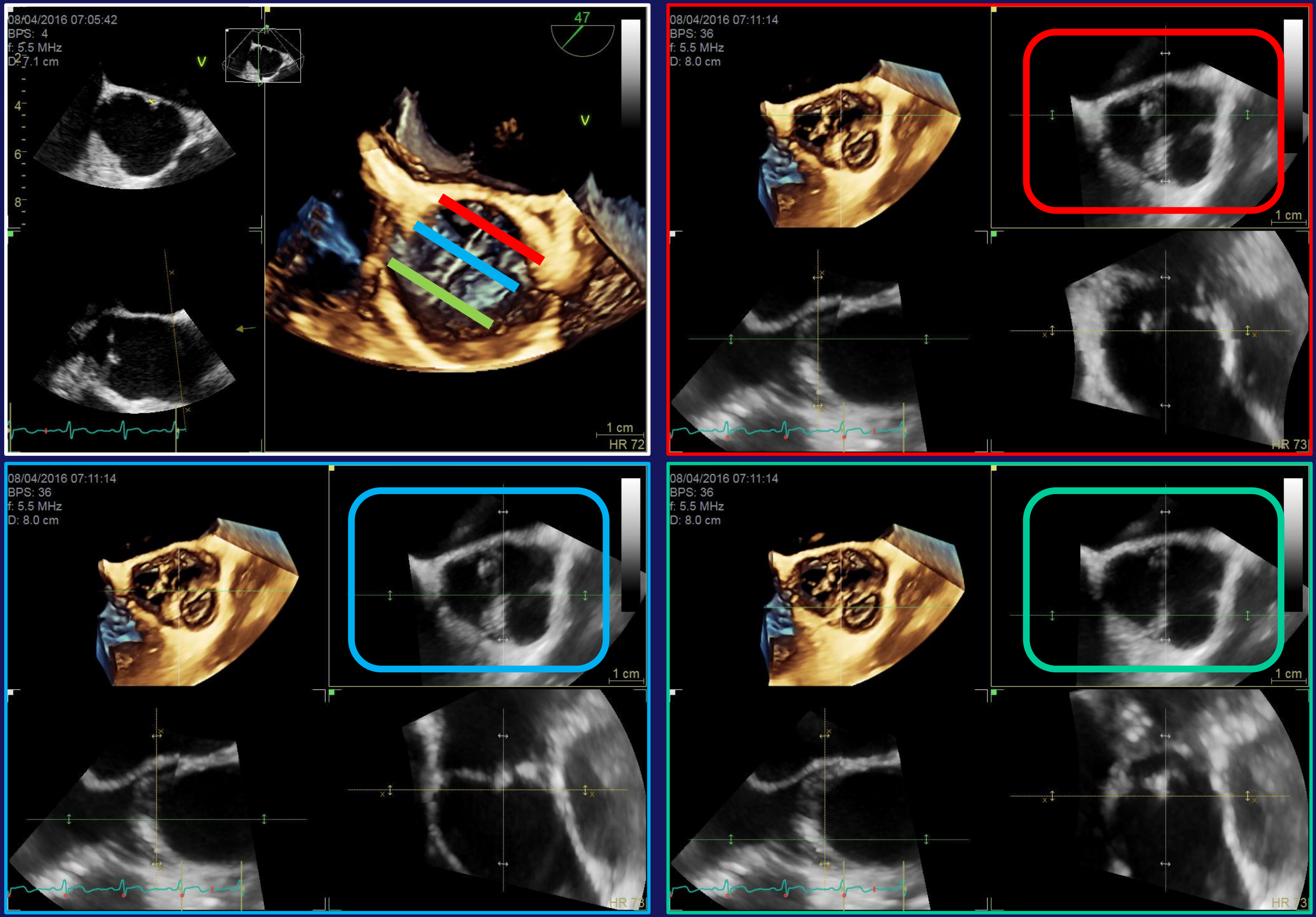


Assessment of the coaptation length and effective height between the right and non coronary cusp

Assessment of Cusp Geometry: Effective and Geometric Height in BAV patients



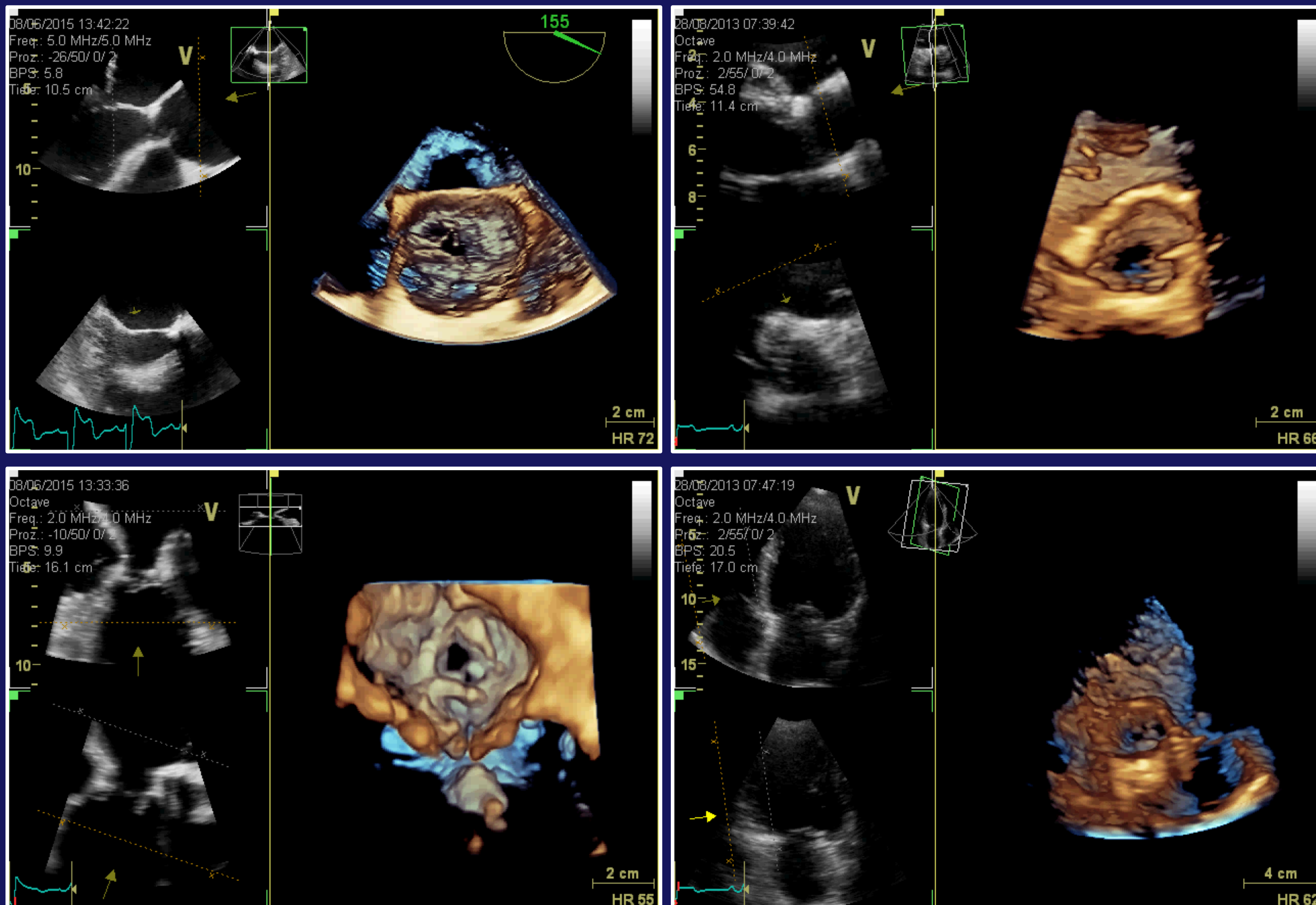
Assessment of Cusp Geometry: Effective and Geometric Height



The 3D4D approach: use the best one.
Parasternal or TEE: The TEE approach is sometimes not the best.

TEE

TTE apical

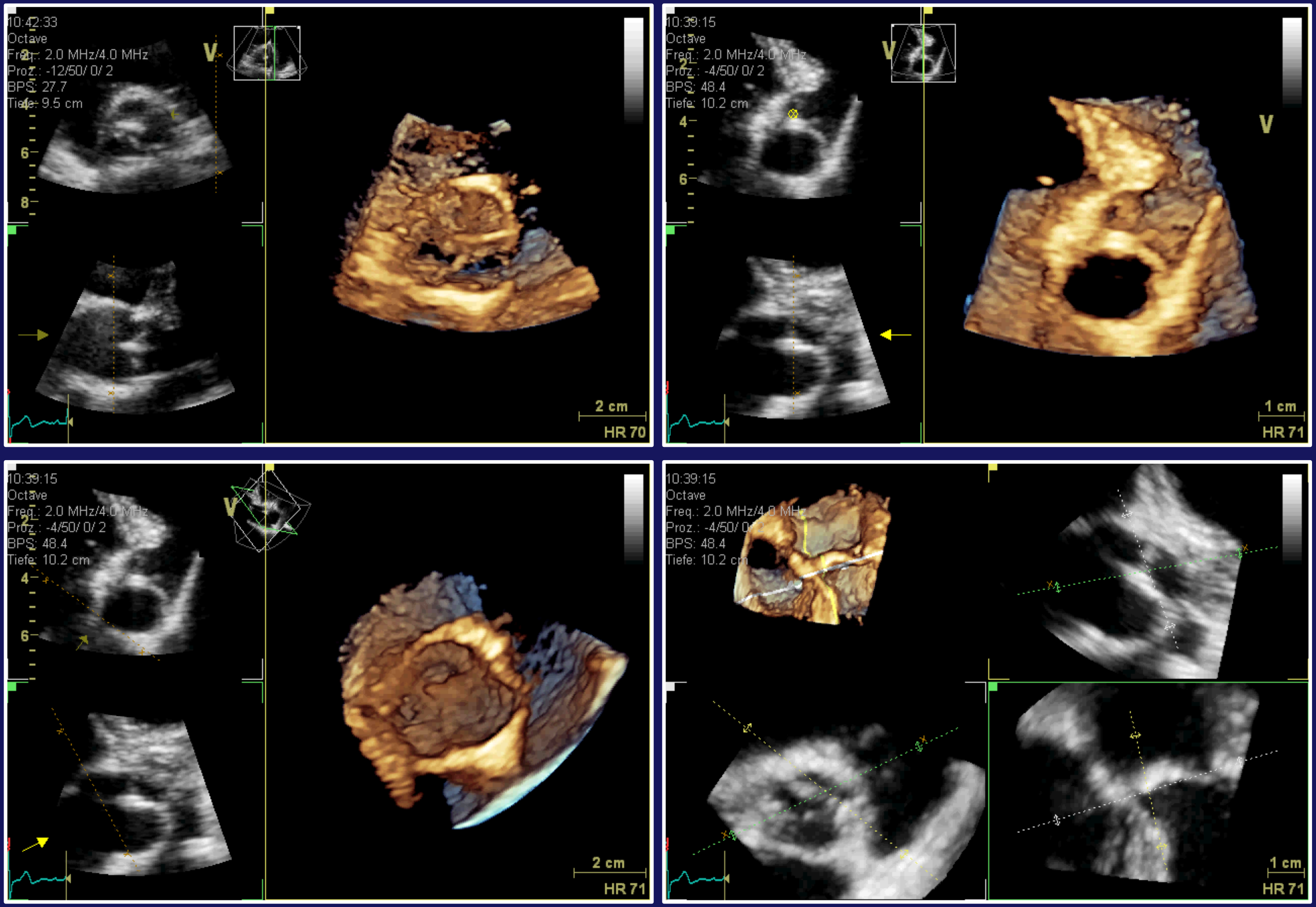


Use the approach with the best reflection speckles of the cusp to get their best visuali-sation.

TTE parasternal aersus apical

3D- and Multidimensional Echocardiography in Aortic Valve Repair

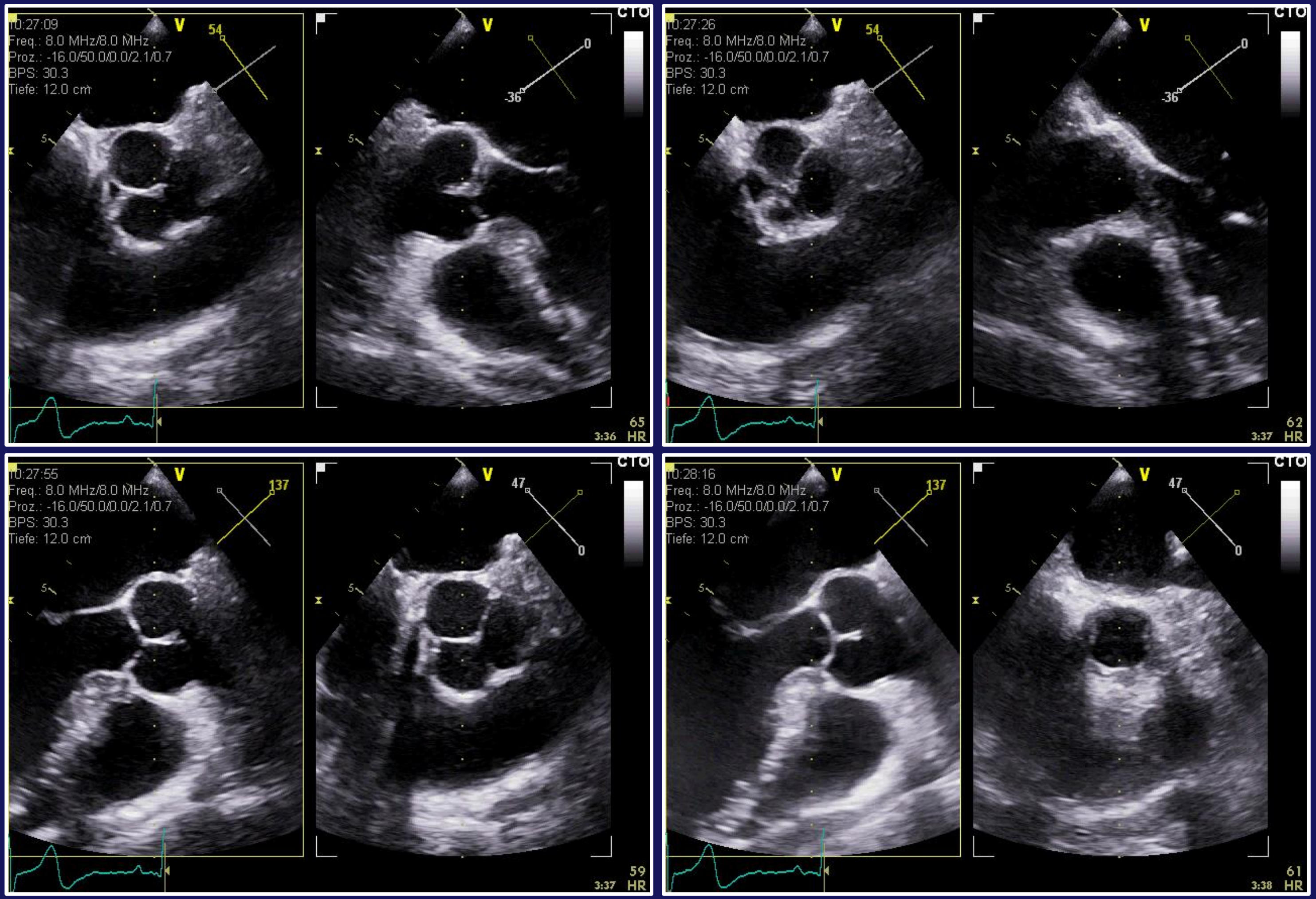
The 3D4D approach: use the best one. Parasternal or TEE: The TEE approach is sometimes not the best.



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

3D- and Multidimensional Echocardiography in Aortic Valve Repair

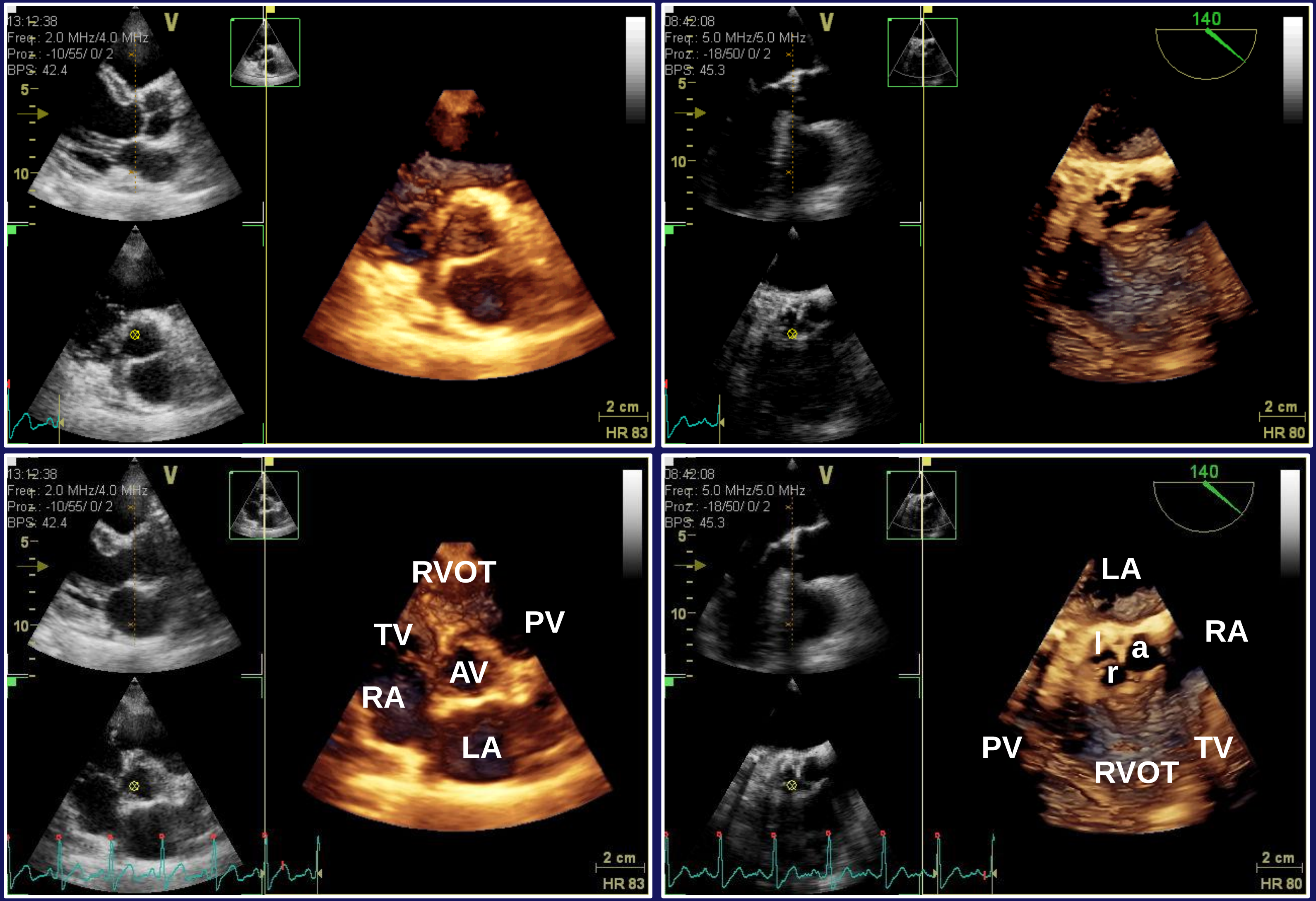
The orientation of imaging in TTE and TEE
It is obvious – but sometimes not present.



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.

Comparisons of views between TTE and TTE

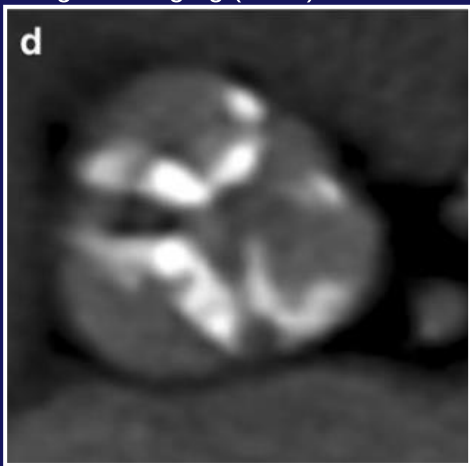
If the primary sectional plane is the long axis view in TTE, the 90° view is again with the blood stream in the LVOT. In TEE - if the primary sectional plane is the long axis view - the short axis view is again with the blood stream in the LVOT, but the view is mirror-inverted.

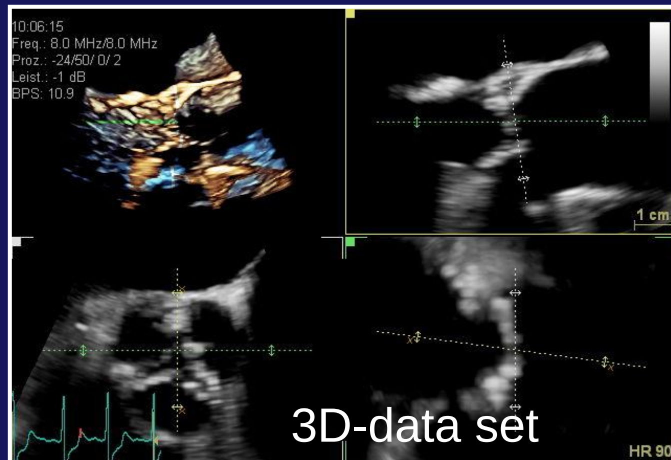


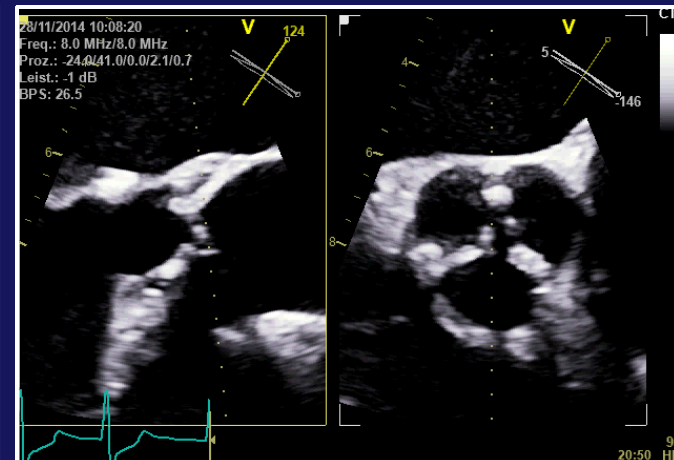
3D- and Multidimensional Echocardiography in Aortic Valve Repair

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.

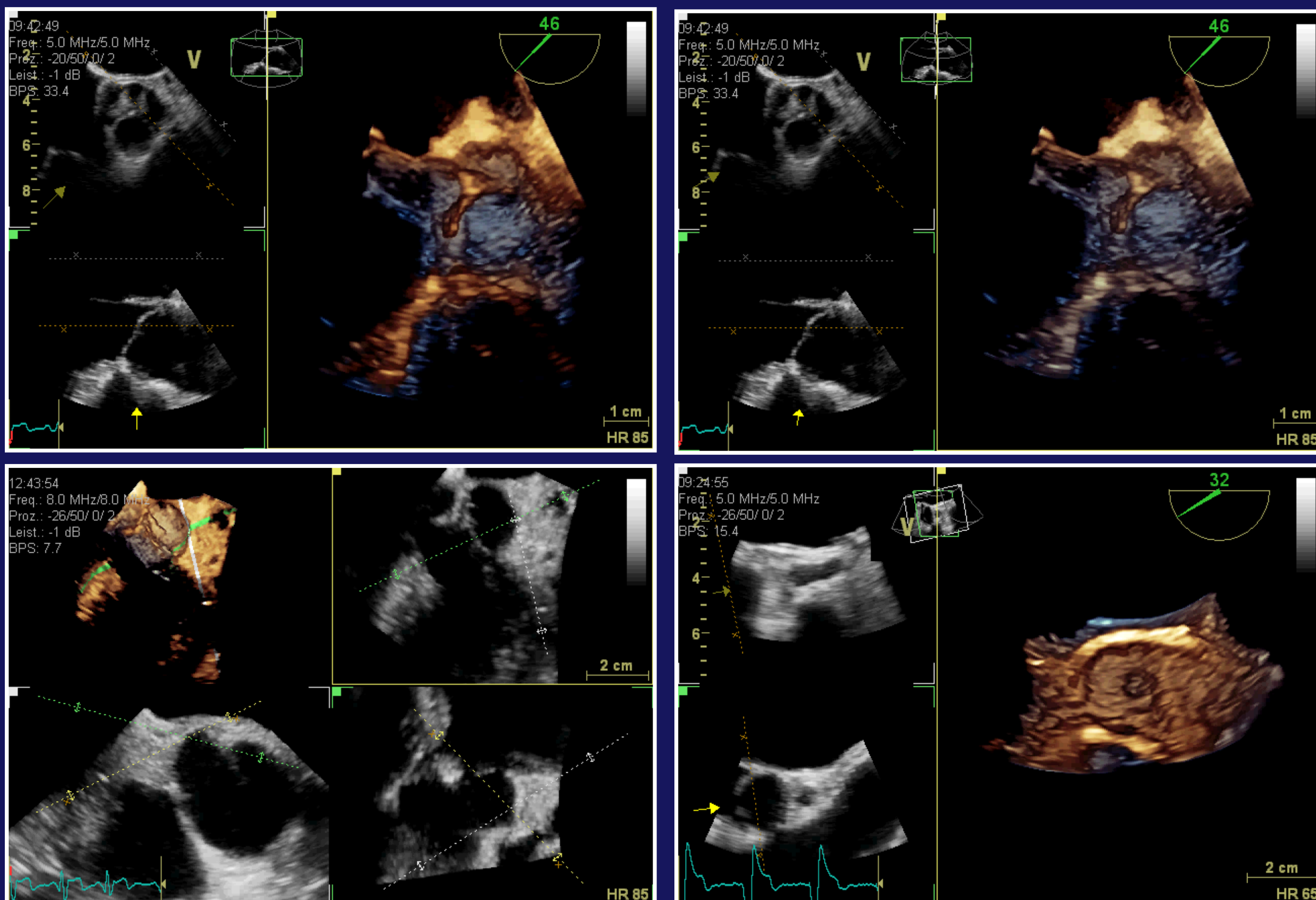






Biplane and 3D spatial resolution is sufficient and at least comparable to CT.

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

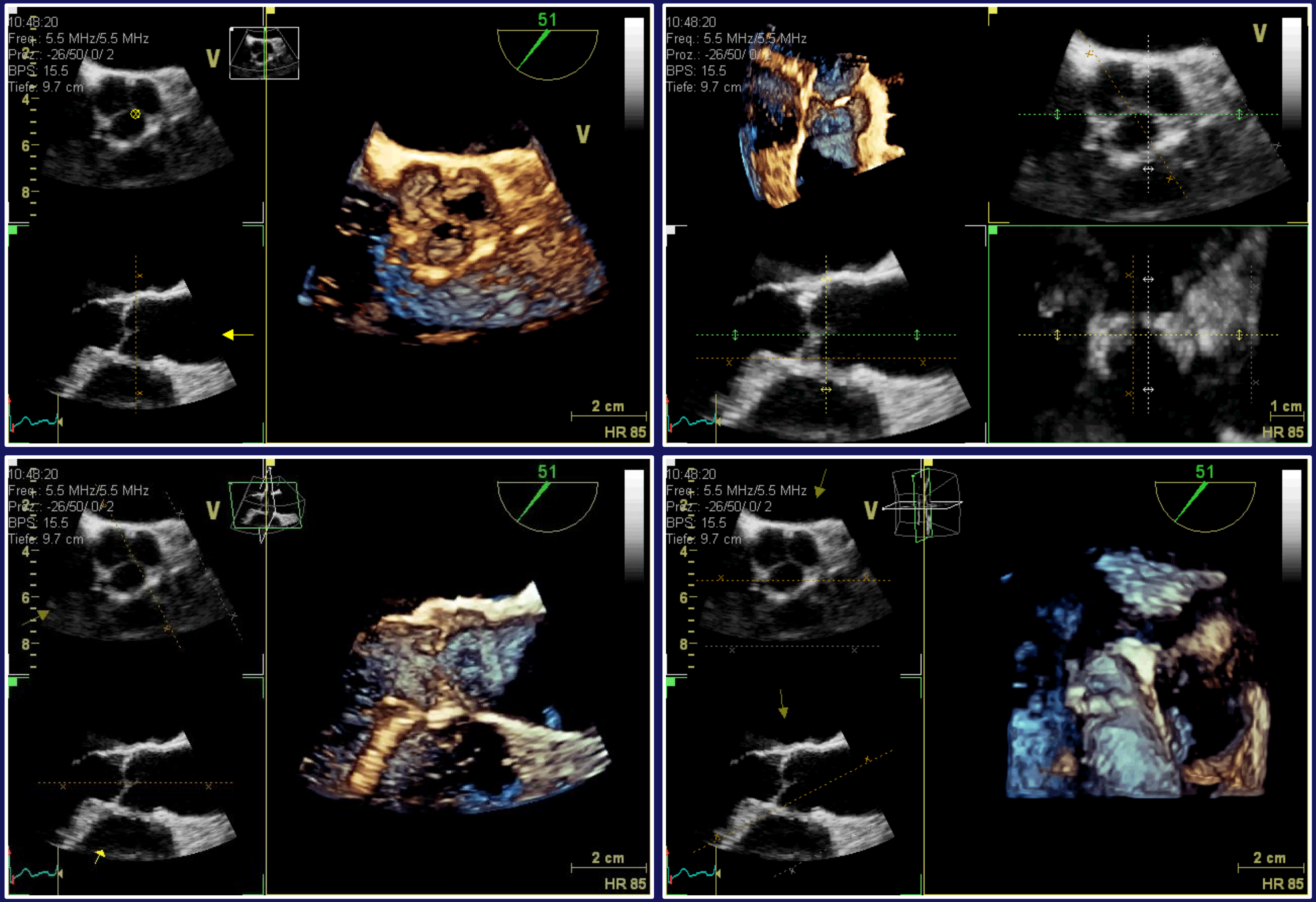


The distances between annulus and the coronary ostia as well as the lenght of the cusps can be easily measured using sectional planes within a 3D4D data set (furthermore the dynamic aspect of the ostial movement can be visualized and analyzed in 3D-TEE data sets.

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

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

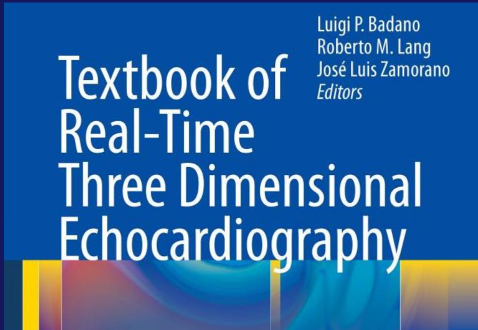
3D4D-data-set: Flexi-slice axis of the aortic valve



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

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

3D- and Multidimensional Echocardiography in Aortic Valve Repair

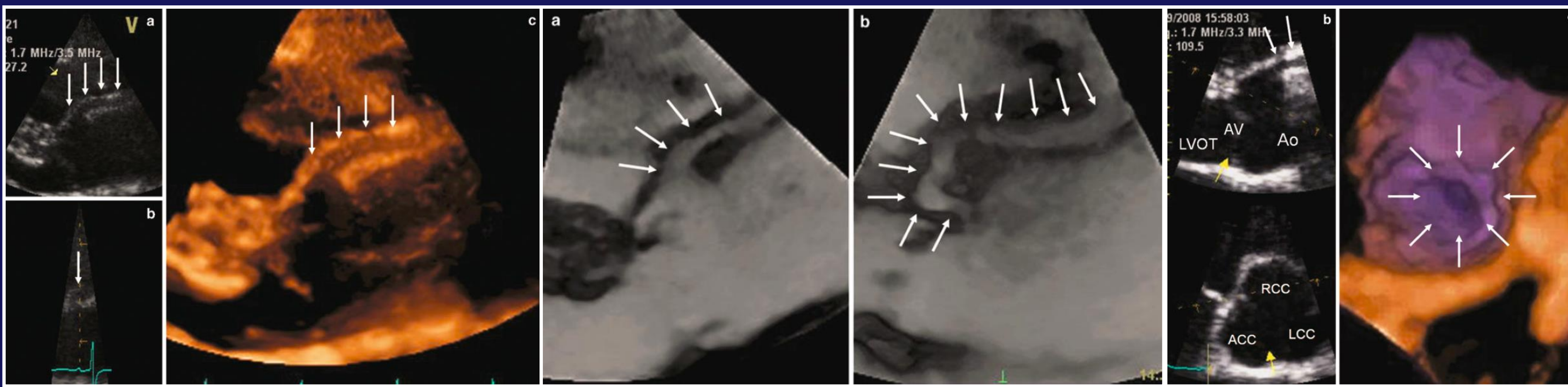


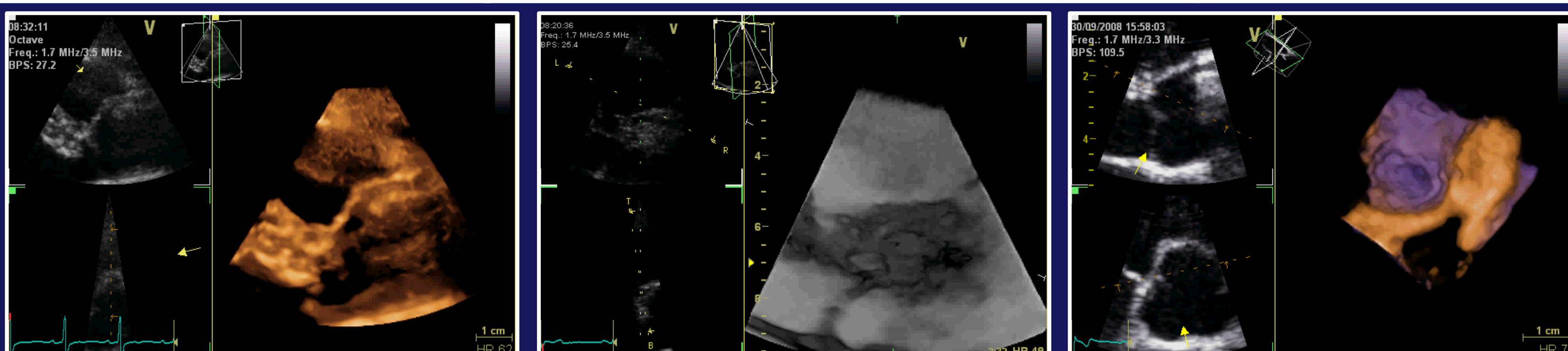
Visualization and Assessment of Coronary Arteries with Three Dimensional Echocardiography

16

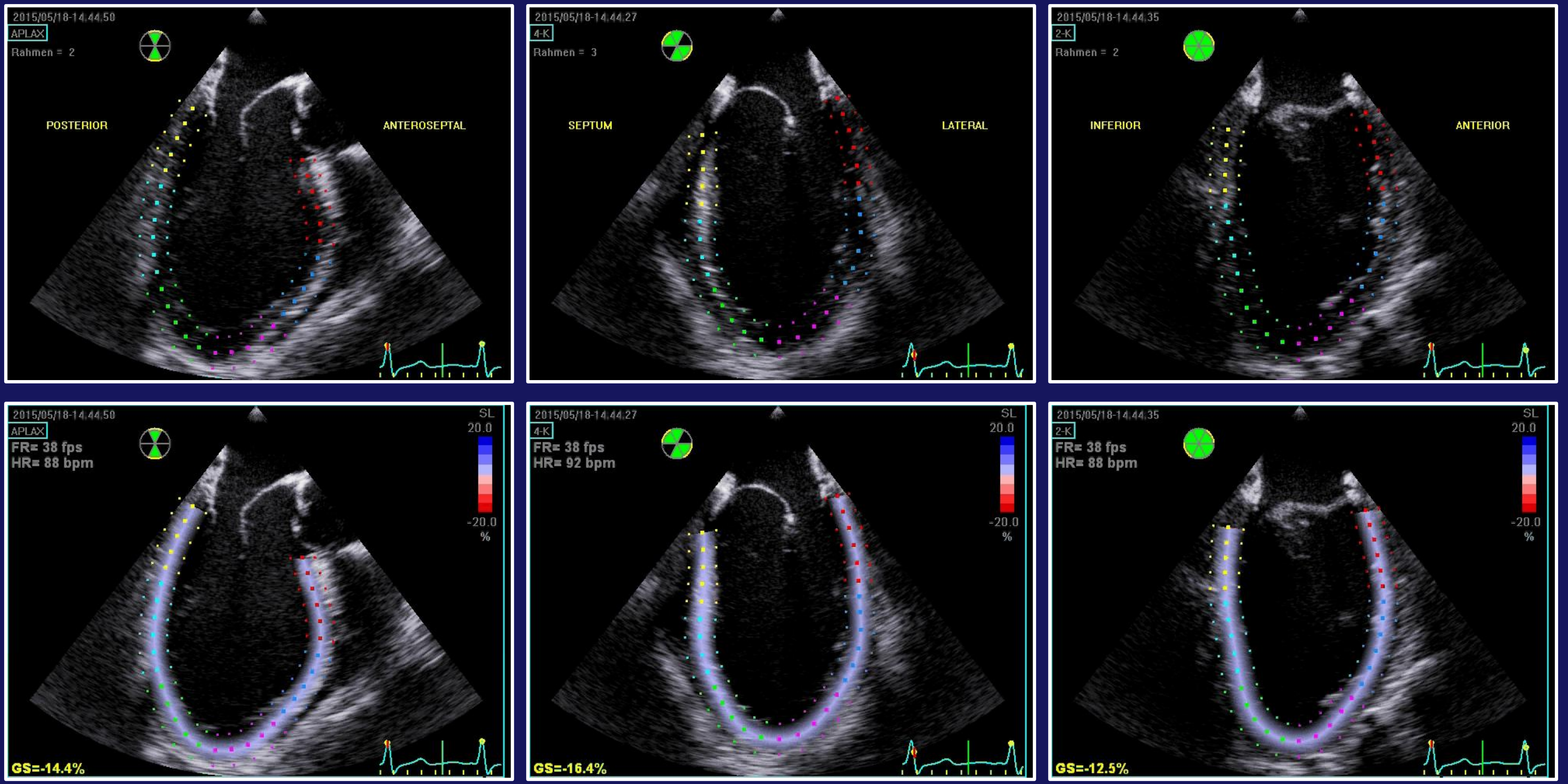
Andreas Hagendorff

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.

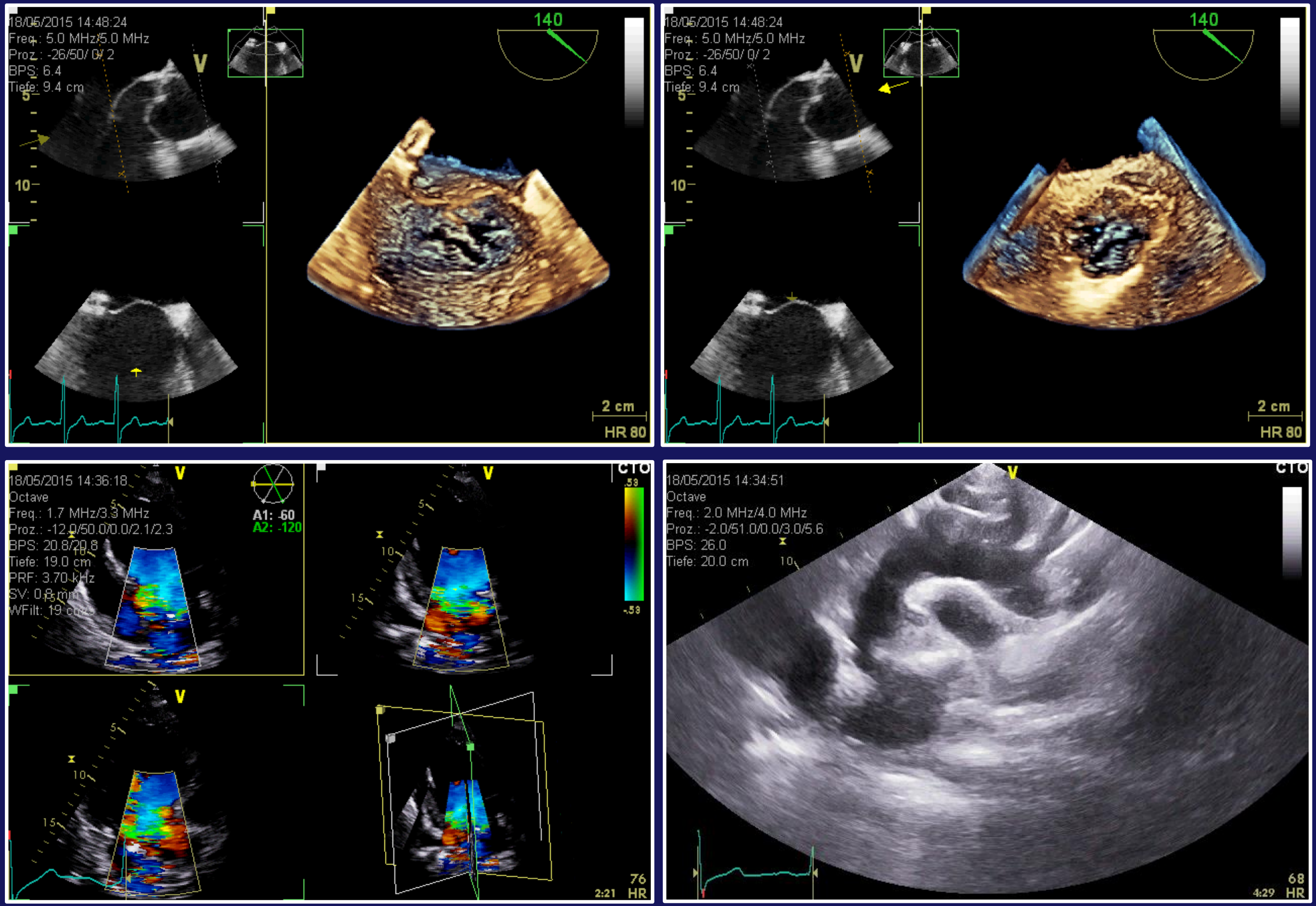




Aortic regurgitation Type Id: The assessment of left ventricular function by TEE „not very new“ – but still unknown: Analysis of deformation imaging in TEE

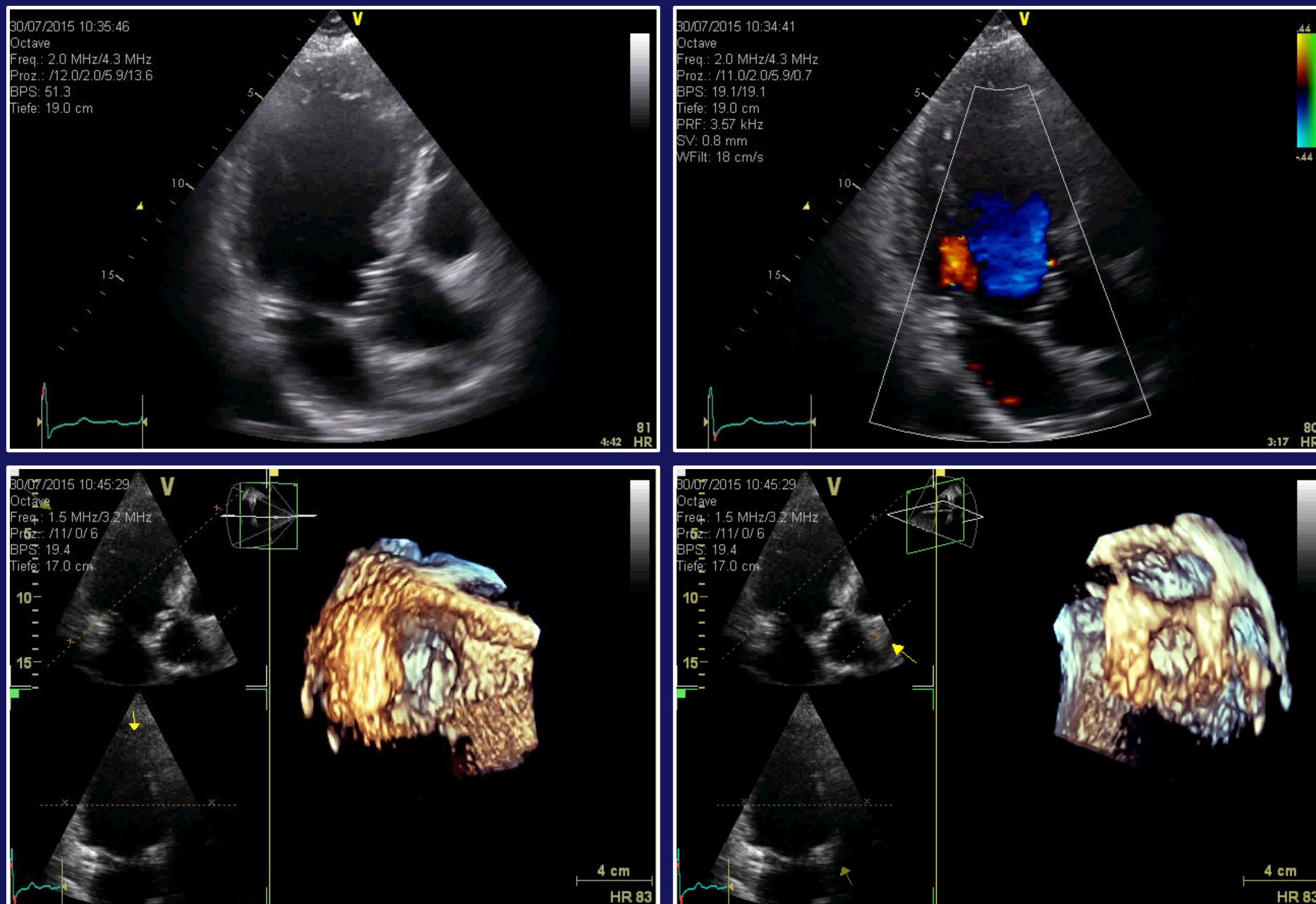


Aortic regurgitation Type Id:
the pre-surgical state prior to aortic valve repaier



3D- and Multidimensional Echocardiography in Aortic Valve Repair

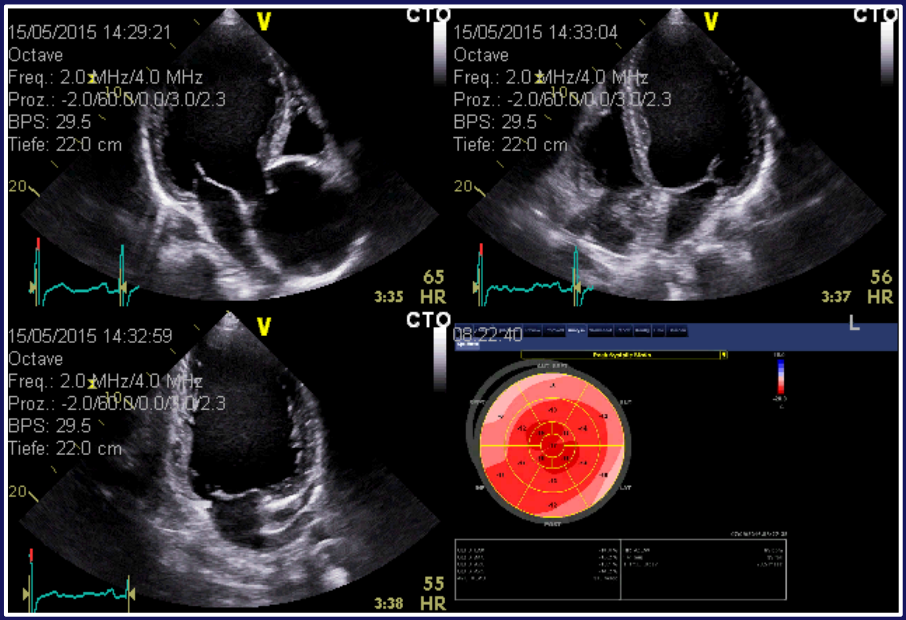
Aortic regurgitation Type Id: the post-surgical state post to aortic valve repaier



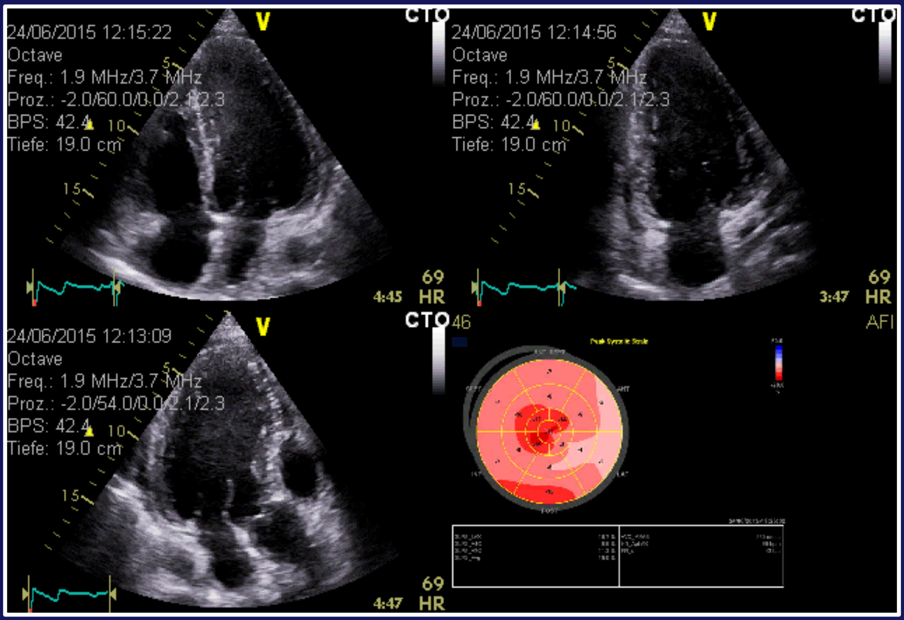
3D- and Multidimensional Echocardiography in Aortic Valve Repair

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?

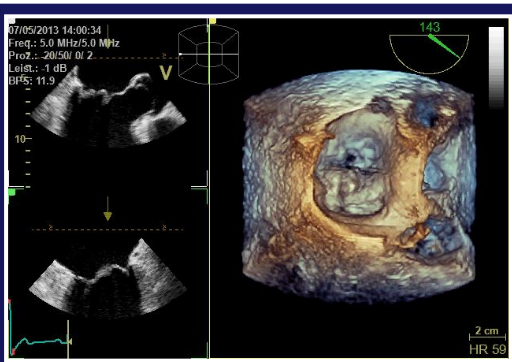
Global strain prior to surgery: -14.2%



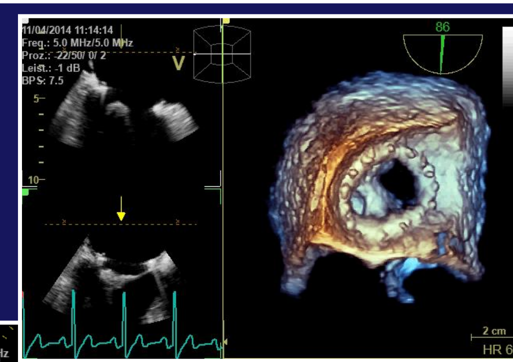
Global strain prior to surgery: -10.8%

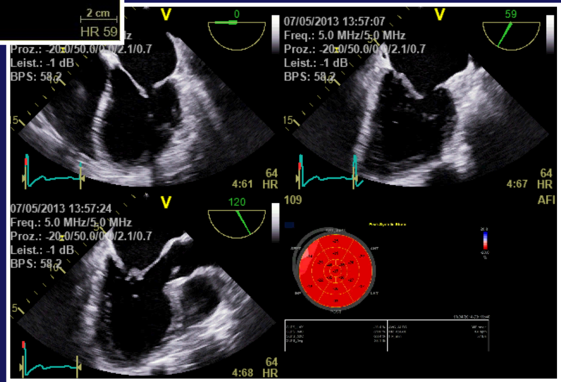


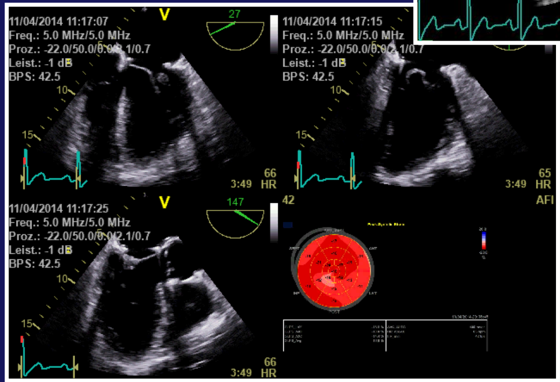
3D- and Multidimensional Echocardiography in Aortic Valve Repair

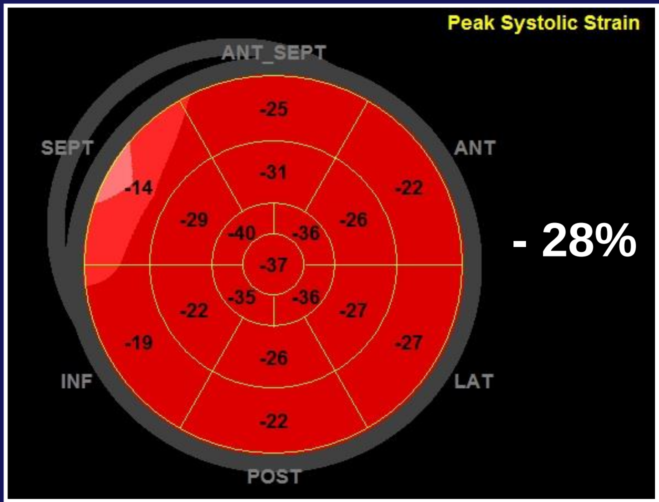


Left ventricular function after mitral valve annuloplasty: What is normal ? A global strain of -16% one year after surgery?



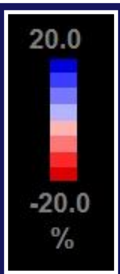






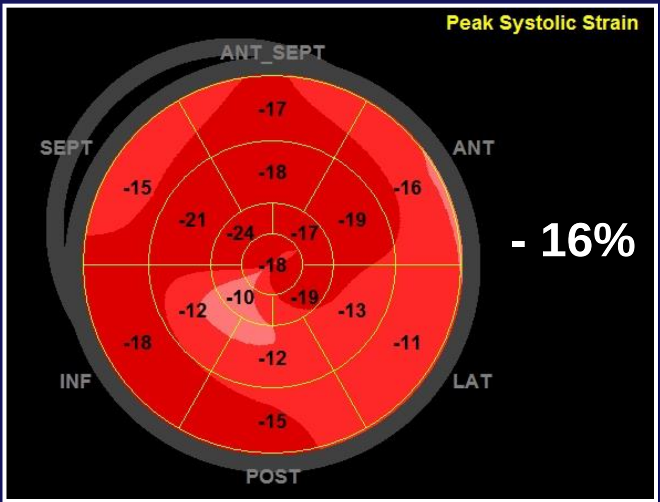
GLPS_LAX	-28.4 %
GLPS_A4C	-29.6 %
GLPS_A2C	-26.4 %
GLPS_Avg	-28.1 %

preoperative



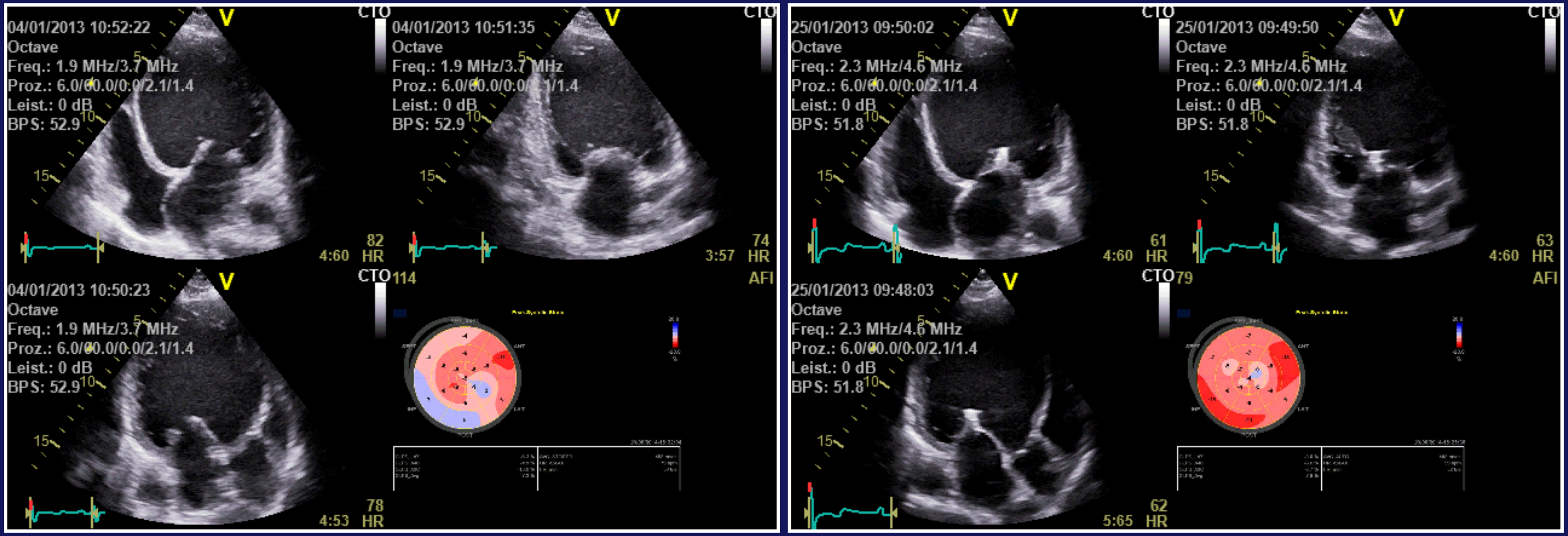
postoperative

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



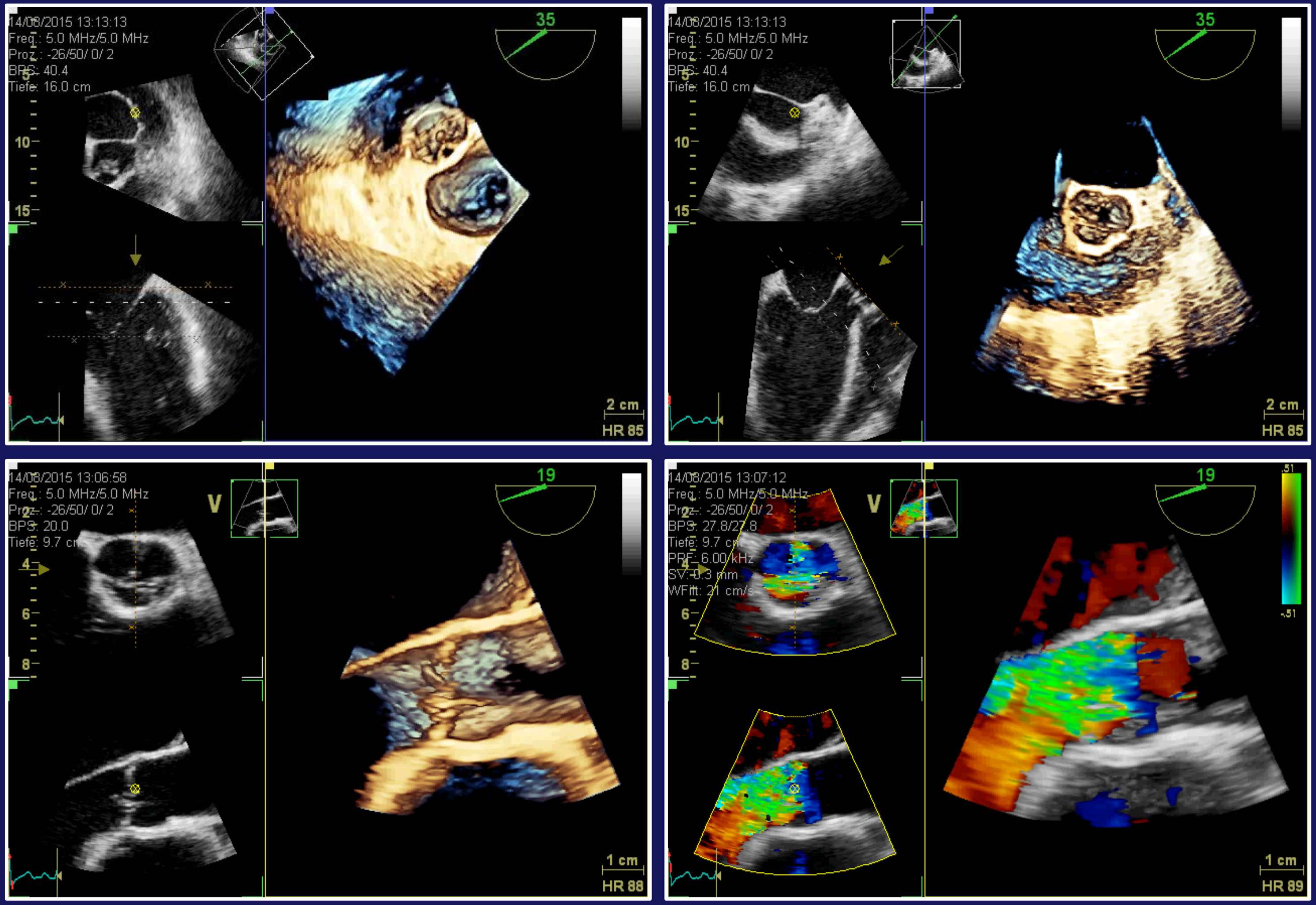
3D- and Multidimensional Echocardiography in Aortic Valve Repair

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.

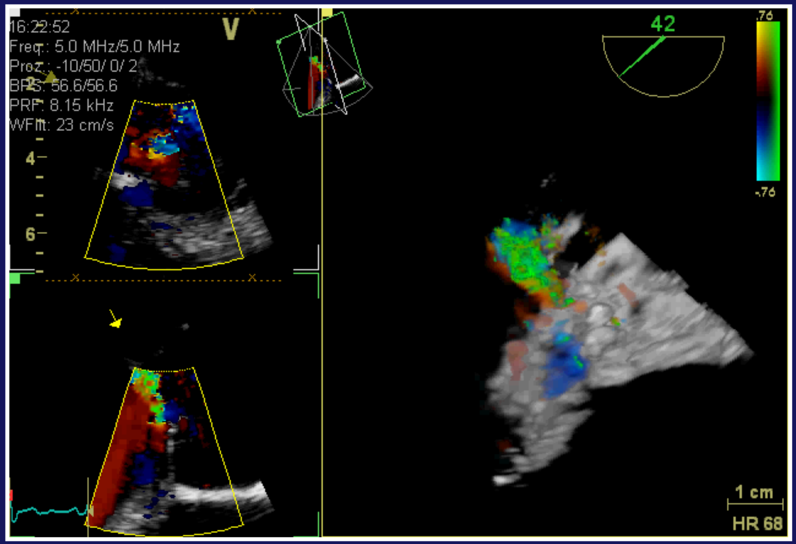


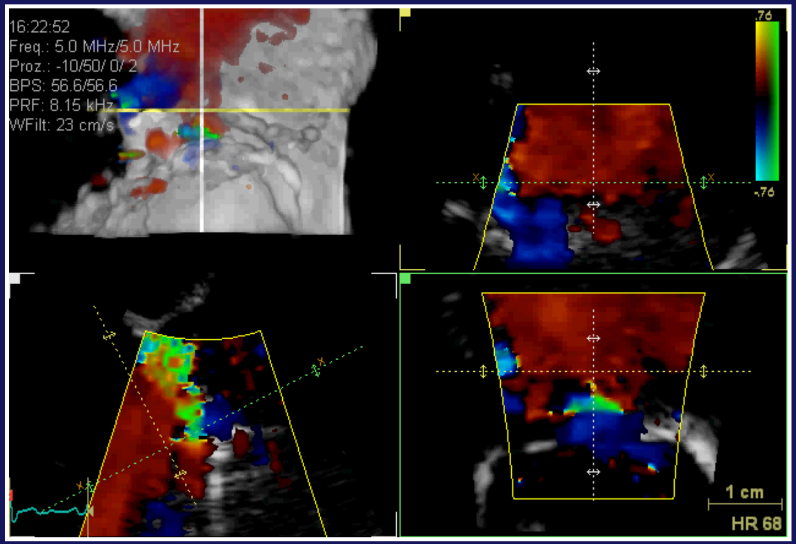
3D- and Multidimensional Echocardiography in Aortic Valve Repair

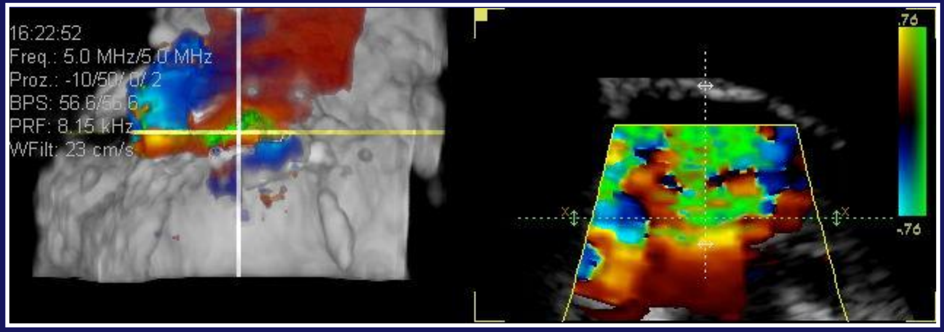
Navigation in the 3D4D-data set enables all views to the aortic valve (auto-alignement, 2-click-cropping and flip crop);
Estimation of effective regurgitant orifice by flexislice in a 3D4D color coded data set

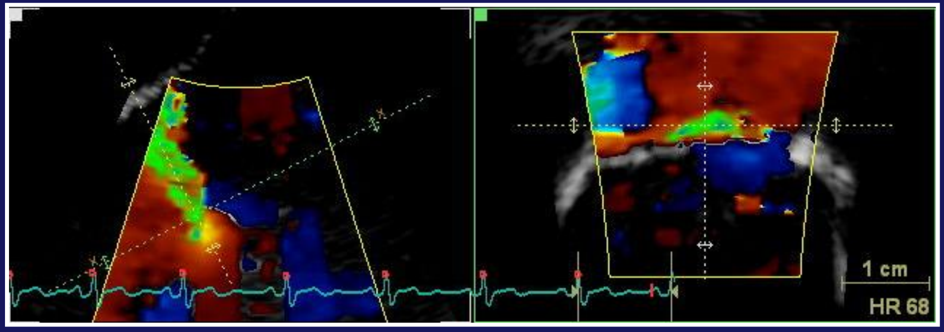


Additional information and better diagnostic impact:
Quantification of an excentric regurgitation in biscuspid aortic valve
Case: ERO - 0.1-0.2 cm^2

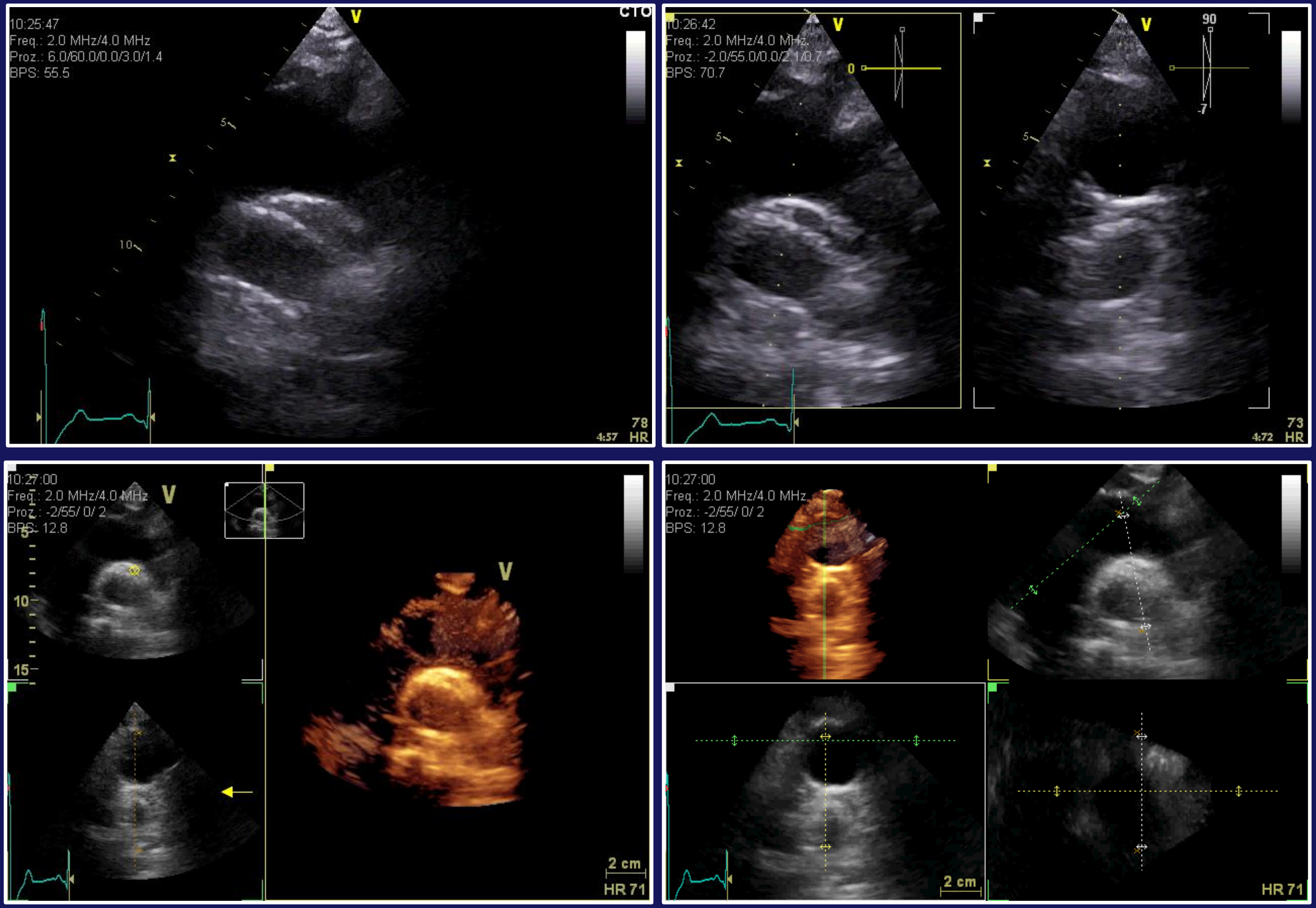






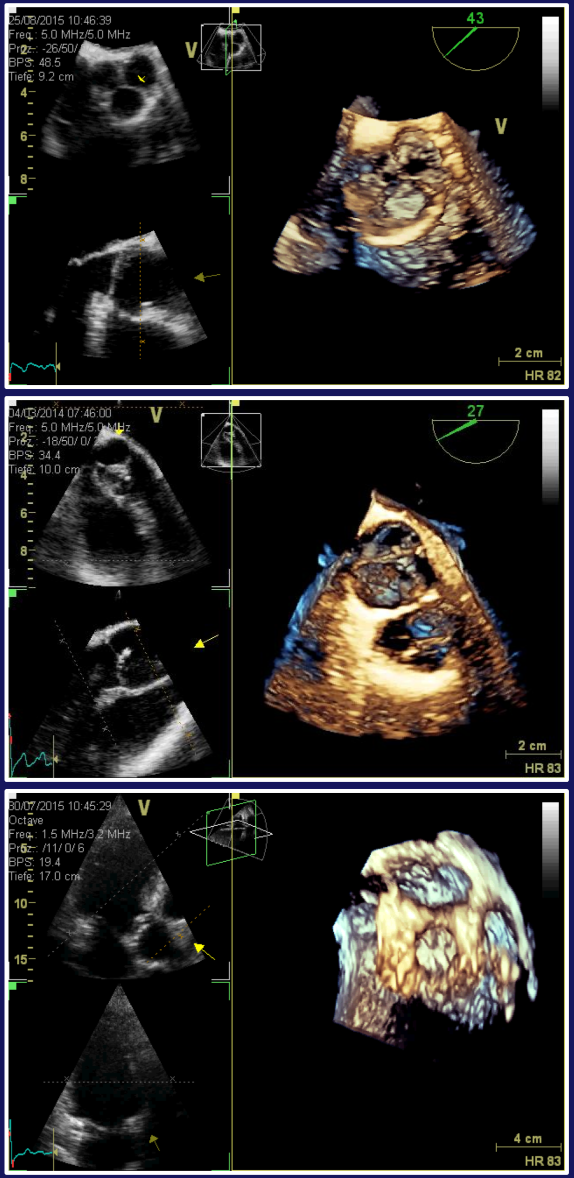


Multidimensional analysis of aortic arch: Objective measurements of aortic dimensions



Summary:

1. 3D 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 3D 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 3D echocardiography can provide important informations.
5. The higher the image quality, the better the information.
6. Thus, training and expertise in 3D echocardiography is a prerequisite for a better diagnosis.



Thank You for Your Attention