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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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.
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


All figures in this paper of 2012 are still only 2D-echo images.
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**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. Scgupta, MD‡

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

Multiple other figures are CT and angio images.
At least, in 2013 the 3D4D-echo technique for the aortic valve is fixed in the echo recommendations.
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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 effective regurgitant orifice 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
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The visualization 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
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
Excellent image quality is the prerequisite for the correct diagnosis and the decision making due to the imaging pre-interventional procedures.

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.
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Prerequisite 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.
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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

<table>
<thead>
<tr>
<th>AI Class</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal cusp motion with FAA dilatation or cusp perforation</td>
<td>Cusp Prolapse</td>
<td>Cusp Restriction</td>
</tr>
<tr>
<td>l_a</td>
<td>l_b</td>
<td>l_c</td>
<td>l_d</td>
</tr>
</tbody>
</table>

**Mechanism**

<table>
<thead>
<tr>
<th>Repair Techniques (Primary)</th>
<th>STJ remodeling</th>
<th>Aortic Valve sparing: Reimplantation or Remodeling with SCA</th>
<th>Patch Repair</th>
<th>Prolapse Repair</th>
<th>Leaflet Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascending aortic graft</td>
<td>STJ Annuloplasty</td>
<td>SCA</td>
<td>SCA</td>
<td>SCA</td>
<td>SCA</td>
</tr>
<tr>
<td>(Secondary)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCA</td>
<td></td>
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</table>

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 and deformation imaging)
Visualisation of the aortic aneurysm – funcional AR-anaylsis

cw-spectrum of AR
pw-spectrum of subclavian flow
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The added value of 3D/4D-TTE-imaging
imaging of regurgitant flow; surface morphology of aortic valve and root
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Comparison pre- and post-aortic valve repair surgery
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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.


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

*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
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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.
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- Sinutubular junction
- Anatomical ventriculo-arterial junction
- Virtual ring formed by joining basal attachments of aortic valvar leaflets
- Crown-like ring

Virtual ring formed by the „hinge points“ of the aortic cusps
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3 is mirror inverted to 1.
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Diastole

Thus, how to operate correctly?

Systole

Intersection with the commissure

Intersection with the cusp

Intersection „at the same“ level of the cups

Intersection with the commissure

Intersection with the cusp
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
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.
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

Standardized Imaging for Aortic Annular Sizing: Implications for Transcatheter Valve Selection
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The following measurements are possible (performed in special centers).

1 – shortest distance from aortic insertion to coaptation line

2 – distance, assuming a straight course of the cusps and coaptation height of 4mm

3 – maximum geometric height (coaptation height)

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

Use the approach with the best reflection speckles of the cusp to get their best visualisation.
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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.
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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.
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.
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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: Anatomoy of coronary ostia and their relation to the aortic cusps

The distances between annulus and the coronary ostia as well as the length 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: long axis view ostium of the LCA

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

2-Click-Crop-view of the ostium of the RCA
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
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Aortic regurgitation Type Id: the pre-surgical state prior to aortic valve repair
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Aortic regurgitation Type Id: the post-surgical state post to aortic valve repaier
There are differences in TTE and TEE speckle tracking – especially, if the sectional planes in TEE are not exactly standardized.
Standardization of sectional planes for conventional LV-function analysis by planimetry can be performed adjusting the planes in a complete 3D4D-TEE data set.
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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%
Left ventricular function after mitral valve annuloplasty: What is normal? A global strain of -16% one year after surgery?

- 28% preoperative

- 16% postoperative
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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.
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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
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Additional information and better diagnostic impact:
Quantification of an excentric regurgitation in bicuspid aortic valve
Case: ERO - 0.1-0.2 cm²
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Multidimensional analysis of aortic arch: Objective measurements of aortic dimensions
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 accurate 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 decision 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.
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Thank You for Your Attention