Σύγχρονες απεικονιστικές προσεγγίσεις

Στην επεμβατική Καρδιολογία

Μαρία Δρακοπούλου
Α’ Καρδιολογική Κλινική
Ιπποκράτειο Νοσοκομείο
Outline

- **Coronary artery Disease**
  - Structural heart disease
  - Congenital heart disease
  - Future perspectives
  - Conclusions
Multimodality imaging in CAD

“The more the better?”

• Combination of at least two out of the four following cardiovascular imaging techniques:

  CT, SPECT, PET, and MRI

Morphological characteristics

Functional characteristics

Diagnostic and prognostic implications
SPECT in patients with stenoses by coronary CTA to increase diagnostic accuracy

J.D. Schuijf et al, JACC, 48 (2006), pp. 2508-2514
Microvascular disease versus 3 VD
CCTA combined with PET-CT

PET adenosine stress can be easily differentiated from severe triple vessel disease by examining the coronary CTA images

S. Kajander et al, Circulation, 122 (2010), pp. 603-613
FDG uptake turned out to be a better predictor for functional recovery

*C. Rischpler et al, EHJ – Cardiovascular Imaging, 16 (2015), pp. 661-669*
Outline

- Coronary artery Disease
- Structural heart disease
  - TAVI
  - PVL
- Congenital heart disease
- Future perspectives
- Conclusions
# Patient Selection for TAVI

## Clinical Suitability

<table>
<thead>
<tr>
<th>Laboratory indices</th>
<th>Full blood count, serum urea, creatinine and electrolytes, C-reactive protein, serum transaminases, serum albumin, coagulation profile, blood culture, sputum culture, mid-stream urine, glycosylated haemoglobin, human immunodeficiency virus, hepatitis serology. Height, weight, body mass index</th>
</tr>
</thead>
</table>

## Anatomical Suitability

<table>
<thead>
<tr>
<th>Physical indices</th>
<th>Detailed clinical history, examination and current medication list. 12 lead electrocardiography, echocardiography (trans-thoracic/transoesophageal), coronary angiography, peripheral vascular screening (contrast angiography/multidetector computed tomography), pulmonary function testing, right heart catheterization.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical data to calculate logistic EuroSCORE or STS score</td>
<td>Pulmonary function tests, carotid, vertebral and abdominal ultrasonography.</td>
</tr>
<tr>
<td>Clinical parameters of comorbid conditions</td>
<td>Grip strength, graded exercise testing, walk test, physical activity level, mini-mental score.</td>
</tr>
<tr>
<td>Fragility and cognitive function*</td>
<td>Echocardiography (trans-thoracic/transoesophageal), exercise stress testing, stress echocardiography.</td>
</tr>
<tr>
<td>Confirmation of aortic stenosis severity and assessment of associated pathology</td>
<td>Multidetector computed tomography/transoesophageal echocardiography.</td>
</tr>
<tr>
<td>Procedural planning</td>
<td>Aortic annulus: Dimensions (minimal, maximal and mean diameter; area; perimeter) and severity/distribution of calcification. Other: Height of coronary arteries, Sinus of Valsalva dimensions ascending aorta dimensions.</td>
</tr>
</tbody>
</table>

TAVI Algorithm

Aortic Stenosis requiring AVR

Surgical Risk?

Logistic EuroSCORE < 10%
Logistic EuroSCORE ≥ 10%
Patient Inoperable

Surgical AVR

Assess Aortic Root Anatomy with TTE

Accepted

Assess Anatomy, Vascular Access and CAD with Angiogram

Accepted

Palliative Balloon Valvuloplasty

Rejected

PCI if required

if further vascular evaluation is required: CT-Angiogram

Femoral
Subclavian
Apical

PAVR
TAVI
2017 ESC/EACTS Guidelines for the management of valvular heart disease
Flow rate και Stress echo
Patients with LFLG AS

Flow rate (Q) = \frac{SV}{Ejection Time (ms)}

In patients with flow rate >200ml/s
AVA at rest is the true AVA

| Change in AVA During Stress, Stratified by Resting LVEF, SVi, and Flow |
|-------------------------|--------|---------------------|---------------------|--------|
|                         | n      | Rest AVA, cm²       | Stress AVA, cm²     | p Value |
| LVEF <50%               | 37     | 0.75 ± 0.14         | 0.87 ± 0.21         | <0.001 |
| LVEF ≥50%               | 30     | 0.79 ± 0.10         | 0.93 ± 0.23         | 0.007  |
| SVi <35 ml/m²           | 47     | 0.74 ± 0.12         | 0.86 ± 0.23         | <0.001 |
| SVi ≥35 ml/m²           | 20     | 0.83 ± 0.10         | 0.98 ± 0.21         | 0.016  |
| Q <200 ml/s             | 48     | 0.74 ± 0.12         | 0.89 ± 0.25         | <0.001 |
| Q ≥200 ml/s             | 19     | 0.85 ± 0.09         | 0.89 ± 0.12         | 0.19   |

Adjusted Logistic Regression Analysis of Rest Function
Covariates Associated With TSAS

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>OR (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resting LVEF, %</td>
<td>0.03</td>
<td>1.03 (0.98-1.10)</td>
<td>0.20</td>
</tr>
<tr>
<td>Resting SVi, ml/m²</td>
<td>0.001</td>
<td>1.00 (0.90-1.10)</td>
<td>0.98</td>
</tr>
<tr>
<td>Resting flow rate, ml/s</td>
<td>-0.05</td>
<td>1.05 (1.00-1.10)</td>
<td>0.002</td>
</tr>
</tbody>
</table>
Criteria that increase the likelihood of severe AS in patients with AVA <1.0cm² and MG <40mmHg in preserved EF

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Details</th>
</tr>
</thead>
</table>
| Clinical criteria                | • Typical symptoms without other explanation  
|                                  | • Elderly patient (>70 years)  |
| Qualitative imaging data         | • LV hypertrophy (additional history of hypertension to be considered)  
|                                  | • Reduced LV longitudinal function without other explanation |
| Quantitative imaging data        | • Mean gradient 30–40 mmHg⁹  |
|                                  | • AVA ≤0.8 cm²  |
|                                  | • Low flow (SVi <35 mL/m²) confirmed by techniques other than standard Doppler technique (LVOT measurement by 3D TOE or MSCT; CMR, invasive data) |
|                                  | • Calcium score by MSCT⁺  
|                                  | Severe aortic stenosis very likely: men ≥3000; women ≥1600  
|                                  | Severe aortic stenosis likely: men ≥2000; women ≥1200  
|                                  | Severe aortic stenosis unlikely: men <1600; women <800 |

2017 ESC/EACTS Guidelines for the management of valvular heart disease
Aortic root
Where does it extend from?

Aortic Root Anatomy

Annulus Measurement
Different Imaging Modalities

Tuzcu et al, JACC 2010;55(3):195-7
Determination of aortic annulus dimensions in CT

\[
\frac{A + B}{2} = \text{Mean Diameter}
\]

\[
\text{Area}
\]

\[
\text{Perimeter}
\]

- Sinus Width
- Diameter of the Sinutubular Junction
- AsAo Width in 4 cm
- Distance from Annulus
- Sinus Height
- Distance to Coronaries
The widths and maximal height of the SOV are important parameters for coronary perfusion after TAVR as they determine whether the valvular prosthesis will be accommodated within the SOV without causing coronary occlusion from displacement of the native valve leaflets.

The ostium of the RCA can be identified using long-axis view of the LVOT permitting measurement of the annular-ostial distance and the length of the RC cusp.

Smith et al, European Heart Journal – Cardiovascular Imaging (2013) 14, 840–850
Case

Distance of coronary ostia from annulus

Left coronary artery

Right coronary artery
Case
Horizontal Aorta

If $>40^\circ$ angulation consider:
- Use of oversized valve
- More proximal access site
- Use of repositionable device
In this X-ray angiogram of the aortic root, the valve plane, and the sinuses of Valsalva are illustrated.

The careful determination of optimal angiographic planes is critical for precise positioning of the stent/value along the centerline of the aortic root.

Ideally this task should be accomplished with limited contrast load.

*Kurra et al, J Am Coll Cardiol Intv 2010;3:105–13*
Vascular Access site

Carotid
Direct Aortic
Subclavian/Axillary
Iliac-Aortic Conduits
Transfemoral
Less than $180^\circ$ of calcification and eccentric calcification are less likely to create procedural difficulty than almost circumferential and luminal calcification. A sheath/femoral artery ratio of 1.05 or higher has also been shown to predict both vascular complications and 30-day mortality.

Femoral arteries assessment

Unsuitable diameter

Suitable diameter
Access vessel diameters

EDWARDS SAPIEN XT TRANSCATHETER HEART VALVE WITH THE NOVAFLEX+ SYSTEM VESSEL ACCESS GUIDE

Edwards Expandable Introducer Sheath Set (eSheath)
- Lower profile than a standard sheath on entry and exit
- Transient sheath expansion reduces radial force on the vessel compared to a compatible standard sheath

<table>
<thead>
<tr>
<th>Edwards SAPIEN XT THV Sizes</th>
<th>23 mm</th>
<th>26 mm</th>
<th>29 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>eSheath ID</td>
<td>16F (5.3 mm)</td>
<td>18F (5.9 mm)</td>
<td>20F (6.6 mm)</td>
</tr>
<tr>
<td>Minimum Access Vessel Diameter*</td>
<td>6.0 mm</td>
<td>6.5 mm</td>
<td>7.0 mm</td>
</tr>
</tbody>
</table>

*Based on non-calcified and non-tortuous access vessels

Lowest Delivery Profile, 14Fr-Equivalent System with InLine Sheath across All Valve Sizes
Improves Access and Reduces Risk of Major Vascular Complications

NOW Indicated for Minimum Transarterial Access Vessel Diameters ≥ 5.0 mm!
Subclavian Access

Left Subclavian Diameter
Min: 0.63 mm
Max: 8.9 mm
Case

Subclavian Access
Case Series

Measurement of minimum mitro-aortic distance

Toutouzas K. Drakopoulou M. et al, JMC in press
Outline

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  - PVL
- Congenital heart disease
- Future perspectives
- Conclusions
Transcatheter PVL Closure

- Patients selection
- Standardized definition of outcomes
- Procedural technique
- Imaging
- Learning curve
- Device improvement
### Imaging of MV interventions

<table>
<thead>
<tr>
<th>Imaging Modality</th>
<th>Main Imaging Tasks</th>
<th>Main Imaging Tasks in Specific Mitral Valve (MV) Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitral stenosis (MS)</td>
<td>Primary mitral regurgitation (MR)</td>
<td>Secondary mitral regurgitation (MR)</td>
</tr>
<tr>
<td><strong>TTE</strong></td>
<td>- Primary imaging modality to define MV abnormality</td>
<td>- Rheumatic/ nonrheumatic MS</td>
</tr>
<tr>
<td></td>
<td>- Grading of MR and MS severity</td>
<td>- Ischemic/non-ischemic MR</td>
</tr>
<tr>
<td></td>
<td>- Associated valve/ heart disease</td>
<td>- Paravalvular vs valvular leak</td>
</tr>
<tr>
<td></td>
<td>- LV/LA function</td>
<td>- Confirm valvular MS or MR</td>
</tr>
<tr>
<td></td>
<td>- Hemodynamic consequences</td>
<td></td>
</tr>
<tr>
<td><strong>2D/3D TEE</strong></td>
<td>- Detailed assessment of MV pathology</td>
<td>- Presence of commissural fusion/ calcification</td>
</tr>
<tr>
<td></td>
<td>- Re-confirmation of NOGMI severity</td>
<td>- Annular dimensions</td>
</tr>
<tr>
<td></td>
<td>- Exclusion of thrombus/ infective endocarditis/ perivalvular effusion</td>
<td>- Exclusion of MR ≥ grade 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Exclusion of specific CI for the planned procedure</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Determination of morphological suitability for a specific transcatheter procedure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- PMVR</td>
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<tr>
<td></td>
<td></td>
<td>- TMVR</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3D TEE Imaging Examples</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CT</strong></td>
<td>- Annular dimensions</td>
<td>- Annular dimensions</td>
</tr>
<tr>
<td></td>
<td>- Localization and extent of calcification of structures of the MV apparatus</td>
<td>- Distribution and extent of calcification</td>
</tr>
<tr>
<td></td>
<td>- Anatomical relationship of target lesions to surrounding cardiac/ extracardiac structures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>When a TMVR procedure is planned:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Annular dimensions</td>
<td>- Annular dimensions</td>
</tr>
<tr>
<td></td>
<td>- Distribution and extent of calcification</td>
<td>- Distribution and extent of calcification</td>
</tr>
<tr>
<td></td>
<td>- Aorto-mitral angle</td>
<td></td>
</tr>
<tr>
<td><strong>MRI</strong></td>
<td>- Evaluation of chamber volumes and ejection fraction</td>
<td>- MR grading when doubtful</td>
</tr>
<tr>
<td></td>
<td>- Regurgitant volumes</td>
<td></td>
</tr>
</tbody>
</table>

- Cardiac CT allows further definition of the size and orientation of PVL in cases in which acoustic shadowing affects interpretation of echocardiographic images but is not needed routinely.
- Cardiac magnetic resonance (CMR) with accurate flow-imaging and volume-based measurements may be useful in certain cases in quantification of multiple paravalvular defects

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**Image Source**: Wunderlich et al, J Am Coll Cardiol Img 2018;11:872–901
<table>
<thead>
<tr>
<th>Procedural Steps</th>
<th>2D TEE</th>
<th>3D TEE</th>
<th>Fluoroscopy</th>
<th>Pre-Procedural CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-procedural evaluation of the defect(s) (number, size, shape, relationship to neighboring structures and the sewing ring/mechanical valve)</td>
<td>++</td>
<td>+++</td>
<td>–</td>
<td>+++</td>
</tr>
<tr>
<td>Pre-procedural evaluation of the severity of peridevice leakage</td>
<td>+++</td>
<td>+++</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Guidance of transseptal puncture</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>–</td>
</tr>
<tr>
<td>Catheter/sheath maneuvering in the left atrium and wiring of the defect (best performed with a steerable sheath; the use of a hydrophilic wire enhances the chance to cross the defect against the direction of the regurgitant jet)</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>–</td>
</tr>
<tr>
<td>Verification of correct canalization of the defect intended for closure</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>–</td>
</tr>
<tr>
<td>Advancement of a catheter through the leak and replacement by a support wire over which the delivery sheath is subsequently advanced</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>–</td>
</tr>
<tr>
<td>Device selection according to the specific anatomy of the defect (crescent shape vs. round)</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Verification of proper mechanical MV function after device placement</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>–</td>
</tr>
<tr>
<td>Device orientation post-deployment (important when an oval-shaped device is used)</td>
<td>+</td>
<td>+++</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>Evaluation of the location, extent and severity of residual leakage after device deployment</td>
<td>++</td>
<td>+++</td>
<td>+</td>
<td>–</td>
</tr>
</tbody>
</table>

Key Points for Successful Paravalvular Mitral Leak Closure
• 68-year-old female patient who presented with progressive dyspnea (NYHA III).

• Previous MVR (twice) for rheumatic valve disease.

• Labs consistent with hemolysis (hemoglobin level, 10.6 g/dL; reticulocyte count, 3.2%; and lactate dehydrogenase level, 1,140 U/L).

• A TEE showed a localized mitral paravalvular leak that caused moderate regurgitation.

• On TEE, the defect was approximately 18x6 mm and in the 2-4 o'clock position.

• Coronary angiography revealed minimal coronary artery disease and a moderate degree of mitral insufficiency.

• After the patient was informed of the treatment options in detail, she agreed to undergo percutaneous closure of the defect.

First Department of Cardiology, Hippokration Hospital
First Department of Cardiology, Hippokration Hospital
First Department of Cardiology, Hippokration Hospital
Outline

- Coronary artery Disease
- Structural heart disease
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- Conclusions
Knowledge of the anatomic features along with common interventions and their sequelae is central to caring for patients with CHD Imaging. The imaging modality is determined by lesion specific patient characteristics, strengths, and weaknesses of imaging modality and institutional resources and expertise.

<table>
<thead>
<tr>
<th></th>
<th>Echo</th>
<th>MRI</th>
<th>CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial resolution (mm)</td>
<td>&gt; 2</td>
<td>1-2</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Temporal resolution</td>
<td>&gt; 30 fps, high resolution, real time</td>
<td>15-30 fps, low resolution, real time</td>
<td></td>
</tr>
<tr>
<td>Physical hazards</td>
<td>None</td>
<td>Magnetic field</td>
<td></td>
</tr>
<tr>
<td>Contrast issues</td>
<td>Perfluorocarbons and unstable patients</td>
<td>Gadolinium allergy, NSF, and renal failure</td>
<td></td>
</tr>
<tr>
<td>Field of view limitations</td>
<td>Ultrasound attenuation by metal, bone, and air</td>
<td>None but metallic susceptibility artifacts</td>
<td></td>
</tr>
<tr>
<td>Patient requirements</td>
<td>Limited acoustic windows in patients with high BMI, COPD, thoracic deformities 30-60</td>
<td>Breath hold, no ferromagnetic implants or pacemakers, regular heart rate preferable 45-90</td>
<td></td>
</tr>
<tr>
<td>Examination duration (min)</td>
<td>Portable, to bedside operating room, and interventional studies</td>
<td>Not portable, hybrid intervention suites requiring special ferromagnetic precautions</td>
<td>Not portable</td>
</tr>
<tr>
<td>System flexibility</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BMI indicates body mass index; COPD, chronic obstructive pulmonary disease; Echo, echocardiography; NSF, nephrogenic systemic fibrosis. Table reprinted from Marcotte et al.6

Gaydos et al, J Thorac Imaging 2017;32:205–216
Choice of imaging in CHD

1. History, Examination, EKG, Chest X-Ray
2. Transthoracic echocardiogram
3. Anatomic and physiological evaluation complete for clinical decision making?
   - No further tests needed
   - Poor acoustic windows?
     - TEE / CMR / CT (see below also)
     - Any of the following needed?
       - Cardiac morphology
       - Coronary artery origin?
       - Quantification of ventricular size or ejection fraction?
       - Evaluation of extracardiac thoracic vessels (size/position)?
     - Contraindications to CMR or artifact limiting CMRs?
       - No
       - Yes
         - CMR
         - Cardiac CT
   - Any of the following needed?
     - Coronary evaluation: interarterial course, coronary artery disease?
     - Evaluation of distal branch pulmonary arteries
     - Filling pressures, transvalvular gradients, pulmonary vascular resistance, transpulmonary gradient
     - Pulmonary pressures & reversibility
     - Transcatheter intervention(s)
   - Cardiac catheterization
4. Evaluation for dynamic gradients / outflow tract obstruction?
   - Stress echocardiography
5. Tissue characterization (scar, myocardial fibrosis)?
   - CMR
6. Evaluation for myocardial ischemia?
   - Stress Echo or Stress SPECT/PET or Stress CMR

Bernoulli equation is validated for valves-not for aorta

**False negative results:**
- Collateral circulation
- Presence of PDA

**False positive results:**
- Arterial compliance- elastic properties of aorta
- Tortuosity of aorta
- Re-CoA
Coarctation of the Aorta Imaging
Coarctation of the Aorta

Coarctation of the aorta
Native Coarctation-Atresia Imaging
Transcatheter pulmonary valve replacement
(Valve-in-Valve)

Peak to peak gradient ~ 110mmHg

Peak to peak gradient ~ 40mmHg
TTE post procedure
Cardiac CT
Balloon dilation of Melody valve
1 month- FU TTE
Outline

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Thirty-six-year-old (86 kg) male patient with d-TGA who underwent Senning operation with an interatrial baffle. A 3D model was printed from cardiac magnetic resonance for education and counseling, showing a hypertrophied systemic RV and thin walled compressed pulmonic LV. The interatrial baffle channels blood flow (catheter course) from the pulmonary veins and LA to the RV and aorta, and directs systemic venous return from the RA to the LV and PA.

Anwar, et al, JACC Cardiovascular imaging 2016
Locations marked with fiducial markers on the 3D images, immediately appear on the fluoroscopic screen.

Faletra et al, European Heart Journal - Cardiovascular Imaging (2018) 19, 715–726
Outline

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Conclusions

• Multimodality’ imaging is the side-by-side interpretation of data obtained from various noninvasive imaging techniques, such as echocardiography, radionuclide techniques, multidetector CT (MDCT), and MRI.

• It allows anatomical, morphological, and functional data to be combined, increases diagnostic accuracy, and improves the efficacy of cardiovascular interventions and clinical outcomes.