Απεικόνιση στην TAVI. Γιατί και Πώς

Μαρία Δρακοπούλου

Α΄ Πανεπιστημιακή Καρδιολογική Κλινική

Ιπποκράτειο Νοσοκομείο
Essential questions in the evaluation for valvular intervention

Guidelines on the management of valvular heart disease

<table>
<thead>
<tr>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>How severe is VHD?</td>
</tr>
<tr>
<td>What is the aetiology of VHD?</td>
</tr>
<tr>
<td>Does the patient have symptoms?</td>
</tr>
<tr>
<td>Are symptoms related to valvular disease?</td>
</tr>
<tr>
<td>Are any signs present in asymptomatic patients that indicate a worse outcome if the intervention is delayed?</td>
</tr>
<tr>
<td>What are the patient’s life expectancy and expected quality of life?</td>
</tr>
<tr>
<td>Do the expected benefits of intervention (versus spontaneous outcome) outweigh its risks?</td>
</tr>
<tr>
<td>What is the optimal treatment modality? Surgical valve replacement (mechanical or biological), surgical valve repair, or catheter intervention?</td>
</tr>
<tr>
<td>Are local resources (local experience and outcome data for a given intervention) optimal for the planned intervention?</td>
</tr>
<tr>
<td>What are the patient’s wishes?</td>
</tr>
</tbody>
</table>

2017 ESC/EACTS Guidelines for the management of valvular heart disease
### 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</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical indices</td>
<td>Height, weight, body mass index</td>
</tr>
<tr>
<td>Clinical data to calculate logistic EuroSCORE or STS score</td>
<td>Detailed clinical history, examination and current medication list, 12 lead electrocardiography, echocardiography (transthoracic/transoesophageal), coronary angiography, peripheral vascular screening (contrast angiography/multidetector computed tomography), pulmonary function testing, right heart catheterization</td>
</tr>
<tr>
<td>Clinical parameters of comorbid conditions</td>
<td>Pulmonary function tests, carotid, vertebral and abdominal ultrasonography</td>
</tr>
<tr>
<td>Fragility and cognitive function*</td>
<td>Grip strength, graded exercise testing, walk test, physical activity level, mini-mental score</td>
</tr>
<tr>
<td>Confirmation of aortic stenosis severity and assessment of associated pathology</td>
<td>Echocardiography (transthoracic/transoesophageal), exercise stress testing, stress echocardiography</td>
</tr>
<tr>
<td>Procedural planning</td>
<td>Multidetector computed tomography/transoesophageal echocardiography, 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, Iliofemoral vessels: Minimal luminal diameter, tortuosity, calcium distribution, Aorta: Aortic plaque distribution, descending aortic tortuosity, proximal ascending aortic diameter</td>
</tr>
</tbody>
</table>

Multidisciplinary approach to TAVR

2017 ESC/EACTS Guidelines for the management of valvular heart disease
Patient Selection

TAVI Algorithm

Aortic Stenosis requiring AVR

Surgical Risk?

EuroSCORE II

<8%

Surgical AVR

EuroSCORE II

>8%

Inoperable patients

Assess Aortic Root Anatomy with TTE

Rejected

Accepted

Assess Anatomy, Vascular Access and CAD with Angiogram

Rejected

Accepted

PCI if required

If further vascular evaluation is required: CT-Angiogram

Femoral

Subclavian

Apical

PAVR

TAVI

Palliative Balloon Valvuloplasty
Anatomical suitability for TAVI

The role of Imaging

<table>
<thead>
<tr>
<th></th>
<th>TTE/TOE</th>
<th>MSCT</th>
<th>CMR</th>
<th>Angiography</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS severity</td>
<td>+++</td>
<td>+</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>LV function</td>
<td>+++</td>
<td>+</td>
<td>+++</td>
<td>-</td>
</tr>
<tr>
<td>LV septal thickness</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
<td>-</td>
</tr>
<tr>
<td>Concomitant valvular disease</td>
<td>+++</td>
<td>+</td>
<td>++++</td>
<td>-</td>
</tr>
<tr>
<td>AV annulus diameter</td>
<td>+++</td>
<td>++++</td>
<td>++++</td>
<td>++</td>
</tr>
<tr>
<td>AV anatomy</td>
<td>++</td>
<td>++++</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>AV calcification</td>
<td>++</td>
<td>++++</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>Aortic root measurements</td>
<td>++</td>
<td>++++</td>
<td>++++</td>
<td>++</td>
</tr>
<tr>
<td>AV annulus—coronary arteries distance</td>
<td>±</td>
<td>++++</td>
<td>++++</td>
<td>±</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Peripheral arteries anatomy</td>
<td>-</td>
<td>++++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Peripheral arteries calcification</td>
<td>-</td>
<td>++++</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

Imaging in TAVI

- Severity of AS
  - Aortic Root and Aorta
  - Vascular Access Site
  - Special Groups
  - New Generation Valves- Future Perspectives
  - Conclusions
Aortic Valve Stenosis Subtypes

Symptoms & AVA <1.0 cm² & ΔPmean <40 mm Hg

- SVi > 35 ml/m²
  - LVEF ≥ 50%
  - Normal-Flow Low-Gradient severity unlikely

- SVi ≤ 35 ml/m²
  - LVEF ≥ 50%
  - Low-Flow Low-Gradient Paradoxical
  - LVEF < 50%
  - Low-Flow Low-Gradient Classical

10-35% of AS patients

Pibarot et al, J Am Coll Cardiol 2012;60:1845–53
Clavel, Magne, Pibarot, Eur Heart J 2016
Discordant Findings in AS

- Measurement error
- Small BMI
- Guideline inconsistencies

2017 ESC/EACTS Guidelines for the management of valvular heart disease
LG AS - Stress Echo

Pibarot et al, J Am Coll Cardiol 2012;60:1845–53
Flow rate και Stress echo
Patients with LFLG AS

Change in AVA During Stress, Stratified by Resting LVEF, SVi, and Flow

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Rest AVA, cm²</th>
<th>Stress AVA, cm²</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVEF &lt;50%</td>
<td>37</td>
<td>0.75 ± 0.14</td>
<td>0.87 ± 0.21</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LVEF ≥50%</td>
<td>30</td>
<td>0.79 ± 0.10</td>
<td>0.93 ± 0.23</td>
<td>0.007</td>
</tr>
<tr>
<td>SVi &lt;35 ml/m²</td>
<td>47</td>
<td>0.74 ± 0.12</td>
<td>0.86 ± 0.23</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SVi ≥35 ml/m²</td>
<td>20</td>
<td>0.83 ± 0.10</td>
<td>0.98 ± 0.21</td>
<td>0.016</td>
</tr>
<tr>
<td>Q &lt;200 ml/s</td>
<td>48</td>
<td>0.74 ± 0.12</td>
<td>0.89 ± 0.25</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Q ≥200 ml/s</td>
<td>19</td>
<td>0.85 ± 0.09</td>
<td>0.89 ± 0.12</td>
<td>0.19</td>
</tr>
</tbody>
</table>

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

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

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>

Chahal N, Drakopoulou M, Gonzalez-Gonzalez AM, Manivarmane R, Khattar R, Senior RJ Am Coll Cardiol Img 2015;8:1133–9
TTE
Calculated AVA by continuity equation = 0.5 cm$^2$

Calculated SV = 33.2 ml

Calculated Flow rate = 135 ml/ms
Low Dose Dobutamine

Calculated AVA by continuity equation = 0.5 cm²
Calculated SV = 38 ml (<25% increase in SV)
Calculated projected AVA = 0.9 cm²
Criteria that increase the likelihood of severe AS in patients with AVA <1.0cm² and MG <40mmHg in preserved EF

### Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th></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 mmHg  
                          | • 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
Imaging in TAVI

- Severity of AS
- Aortic Root, LVOT and Aorta
- Vascular Access Site
- Special Groups
- New Generation Valves- Future Perspectives
- Conclusions
Aortic root
Where does it extend from?

Sinotubular junction

Basal attachment of AV leaflets

Aortic Root Anatomy

Disparity of Aortic Annulus Measurements by 2D TTE

Anatomic short axis of the AV illustrating the disparity between annular diameter as measured by the 2D TTE vs the true anatomic transverse diameter.

Bloomfield et al, J Am Coll Cardiol Img 2012;5: 441–55
Annulus Measurement
Different Imaging Modalities

Tuzcu et al, JACC 2010;55(3):195-7
2D Biplane Echocardiographic Imaging

Identification of the Sagittal Imaging Plane That Bisects the Largest Dimension of the Aortic Annulus

Bloomfield et al, J Am Coll Cardiol Img 2012;5: 441–55
Cardiac CT and 3D TEE

Interchangeable to assess the shape and dimensions of aortic annulus

Determination of aortic annulus dimensions in CT

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

= Area

= Perimeter

= Sinus Width

= Diameter of the Sinutubular Junction

= AsAo Width in 4 cm Distance from Annulus

= Sinus Height

= Distance to Coronaries
Measurements of SOV height, width and perimeter

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.

LVOT Anatomical characteristics

- Right and left fibrous trigone
- Membranous septum
- Central fibrous body
- Membranous septum
- Tricuspid valve
- Mitral valve
- Pulmonary valve
- Infundibulum
- Muscular ventricular septum
Predictors for PPM after TAVI
In Patients Without Baseline Conduction Abnormalities

LVOT/annulus (0.89)

Depth of Implantation (0-8mm)

Study of the LVOT

• When the area of LVOT is much smaller than that of the annulus or/and there is increased calcification of the LVOT this should be taken into account for the selection of a suitable valve device and deployment.

Schymik et al, J Interven Cardiol 2015;28:82–89
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*
Aortic annulus—LCA ostial height

3D TEE zoom mode with multiplanar reconstruction

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
Calcium deposition is a prognostic marker of PVL.

D. John… G. Latsios, U. Gerckens, E. Grube, JACC Cardio Inter, 2010
Aortoventricular angle assessment

- The atroioventricular angle is determined by the angle of the horizontal plane and the angle of the aortic annulus.
- The AV angle can also be established during angiography.
- The angle can also be seen after deployment of the TAVR catheter.

Horizontal Aorta

If >40° angulation consider:
• Use of oversized valve
• More proximal access site
• Use of repositionable device

First Department of Cardiology
• 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/valve along the centerline of the aortic root.
• Ideally this task should be accomplished with limited contrast load.
Imaging in TAVI

- Severity of AS
- Aortic Root, LVOT and Aorta
- Vascular Access Site
- Special Groups
- New Generation Valves- Future Perspectives
- Conclusions
Vascular Access site

- Carotid
- Direct Aortic
- Iliac-Aortic Conduits
- Subclavian/Axillary
- Transfemoral
Less than 180° 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.

Access vessel diameters
Aortic and peripheral vascular access
Iliac Artery Angulation

- Angulations in the iliofemoral system >90° might preclude insertion of large-bore catheters or cause significant vessel trauma.
- In the absence of calcification, iliofemoral arterial tortuosity, even with angles of 90 degrees or slightly more, is not necessarily a contraindication for femoral access. Noncalcified, but tortuous vessel segments can usually be straightened to introduce the sheath.
Contraindications to a femoral/subclavian access include massive elongation with kinking of the aorta, dissection, or large thrombi protruding into the lumen or other obstacles that may prevent advancing the valve through the aortic lumen.
Subclavian Access
Case
Subclavian Access
Aortic and peripheral vascular access
Planning of the direct aortic approach

• If a transaortic approach is considered, the position of the ascending aorta relative to the chest wall is of importance.

• If coronary bypass grafts are present, their position and potential adhesion to the sternum may be of relevance if emergency conversion to open heart surgery is required.

Trans-Aortic TAVI

Left Iliac Artery Diameter: 3.8 mm
Right Iliac Artery Diameter: 4.2 mm

Left Subclavian Artery Diameter: 3.3 mm
Right Subclavian Artery Diameter: 5.1 mm
Trans-Aortic TAVI

TAo-TAVI
Transapical Approach

55 yo F, Sev AS, COPD, CRF-hemodialysis
no TF/SC access, declined by surgeons
Implantation of TA-TAVI with Sapien XT
Imaging in TAVI

- Severity of AS
- Aortic Root, LVOT and Aorta
- Vascular Access Site
- Special Groups
- New Generation Valves- Future Perspectives
- Conclusions
Case – Bicuspid Valve
Implantation of Evolut Pro
Female patients 70y with AV bioprosthesis
Implantation of Evolut Pro
Female patients 70y with AV bioprosthesis
Case

TAVI in the presence of Mitral Valve prosthesis

Case

Measurement of minimum mitro-aortic distance

Toutouzas et al, submitted
Imaging in TAVI

- Severity of AS
- Aortic Root, LVOT and Aorta
- Vascular Access Site
- Special Groups

New Generation Valves- Future Perspectives

Conclusions
Level of the working portion of bioprosthesis

Sapien™ 3 valve

Evolut™ R valve
Evolut Pro
‘skirt’ to decrease PVL

6.4 mm Hg
single digit
gradients

2.0 cm²
Large EOA

Wrap covers first 1 1/2 inflow cells and extended skirt.

Supra-annular Valve | Optimizes coaptation in non-circular anatomy with supra-annular valve position

Annulus | Conforms to the native annulus
TAVR in Pure Native AR

Outcomes According to Devices

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Incidence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early-Generation Devices</td>
<td></td>
</tr>
<tr>
<td>Second Valve Implantation</td>
<td>24.4</td>
</tr>
<tr>
<td>Aortic Regurgitation</td>
<td>18.8</td>
</tr>
<tr>
<td>Absence of Device Success</td>
<td>18.9</td>
</tr>
<tr>
<td>Pacemaker</td>
<td>17.5</td>
</tr>
<tr>
<td>30-Day Mortality</td>
<td>13.4</td>
</tr>
<tr>
<td>New-Generation Devices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12.7</td>
</tr>
<tr>
<td></td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>18.6</td>
</tr>
<tr>
<td></td>
<td>9.4</td>
</tr>
</tbody>
</table>

Mortality and Post-Procedural Aortic Regurgitation

Log-rank $p = 0.001$

Imaging in TAVI

- Severity of AS
- Aortic Root, LVOT and Aorta
- Vascular Access Site
- Special Groups
- New Generation Valves- Future Perspectives
- Conclusions
Conclusions

• Understanding how a particular aortic valve prosthesis may interact with the aortic root anatomy and the left ventricular outflow tract determines proper placement, residual aortic regurgitation, as well as impact on the conduction system, mitral valve, and coronary ostia.

• Multimodality imaging allows detailed insights into the complex anatomy of the aortic root in vivo for better understanding of device–anatomy interactions.