Pre-procedural CT angiography for Transcatheter Aortic Valve Implantation: What a Radiologist Needs to Know?

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Learning Objectives:

- To describe the role of CT angiography in pre-procedural work up for Transcatheter aortic Valve Implantation (TAVI).

- To describe the importance of a standardized CT protocol.

- To describe pearls and pitfalls when reporting CT angiography in pre-operative TAVI patients.
  - Offer template of standardized report
Aortic Stenosis

- Most prevalent cardiac valvular disease in Western World
- Valve replacement indicated once patient symptomatic with severe AS to increase
  - Quality of Life
  - Life Expectancy
- However approximately 30% patients unfit for surgery due to high operative risk.
  ➔ Non surgical option: Transcatheter Aortic Valve Implantation (TAVI)
In 2016, we retrospectively reviewed 10 pre-procedural CT angiograms performed in our institution over the last year in patients being considered for TAVI

- Compared our current CT protocol to current gold standard recommendation
- Discussed with interventionists what were key findings which they wished to know from our CT reports
Transcatheter Aortic Valve Implantation (TAVI)

Two systems

**Balloon-expandable Edwards Sapien valve** (Edwards Lifesciences, Irvine, California)

**Self-expandable CoreValve ReValving system** (Medtronic, Minneapolis, Minnesota)
TAVI

Procedure
1. Access
   • Retrograde via femoral or subclavian arteries
   • Antegrade transapical approach

2. Balloon valvuloplasty allows passage of stent in stenotic native valve

2. Expansion of stent
   • Balloon expandable system deployed during short period of ventricular pacing
   • Self expandable system does NOT require pacing
Pre-procedural Imaging

- Transthoracic echocardiogram (TTE)
- Transesophageal echocardiogram (TEE)
- Multidetector CT angiography

Benefit of CT angiography over echocardiogram
- 3D assessment of aortic annulus
- Allows assessment of access sites
  - Large delivery catheter require minimum lumen diameter >8-9mm
Contraindications to TAVI

Imaging Contraindications

**Absolute**
- Inadequate annulus size (<18 mm, >29 mm)
- Short distance between the annulus and the coronary ostium
- Ascending aorta plaques with mobile thrombi

**Relative**
- Inadequate vascular access for transfemoral or subclavian approach (however transapical approach may be used as alternative)
- Severe LV dysfunction

Bicuspid valve no longer contraindication to TAVI

Also clinical contraindications e.g. estimated life expectancy <1 year or associated or comorbidities which would limit improvement of quality of life regardless of TAVI

⇒Accurate pre-procedural imaging is essential to identify suitable candidates
Optimal Positioning is Key for Procedural Success

Why? Deployment displaces native valve leaflets so stent lies within aortic annulus

Too High
- Aortic injury
- Paravalvular regurgitation
- Embolization to aorta

Too Low
- Mitral valve dysfunction
- Paravalvular regurgitation
- Embolization to Left Ventricle
- Heart Block

CT angiography also allows pre-procedural assessment of angle of deployment.
Pre TAVI CT Protocol

- MDCT with 64 detector minimum
- No additional beta blockers even if high HR
  - Relative contraindication in severe AS
- Scan range: Acquire from proximal supraaortic vessels to below femoral heads
- ECG gated thoracic component
  - Allows motion free images of aortic root
- Retrograde acquisition
  - Allows to compensate for arrhythmias such as Atrial fibrillation
  - HOWEVER
    - Higher radiation dose
    - Longer scan time
    - Increases volume of contrast media required
- Systolic phase images
  - Largest dimensions of the aortic annulus are ordinarily found during systole
  - Allows valves area and aortic annular measurements to be similar to echo
- To minimize contrast media volumes
  - Many patients have impaired renal function so require reduced dose: literature as low as 40mls
- Data sent to post procedural software with cardiac reformatting package for analysis
Aortic Annulus Analysis

- Complex 3D structure
- 3-pronged coronet rather than a circular structure
  - 3D assessment required
- Semilunar attachments extending from the basal attachment of the aortic valve cusps within the left ventricle to peripheral attachment at the level of the sinotubular junction.
  - Widest at the midpoints of the sinus
  - Narrowest at the basal attachment of the leaflets and the sinotubular junction
- Often oval shaped
  - Approximately 50% of patients evaluated for TAVI

![Schematic of aortic root](image)

- Aortic cusps
- Virtual ‘Annular ring’
- Schematic of aortic root
- Hinge point
Aortic Annulus Analysis

Accurate measurement is critical to ensure proper implantation, as existing valves are designed for specific annular sizes

- Unlike surgery when valve can be sized intraoperatively
- If not sized appropriately then risk of paravalvar regurgitation

Although CT is emerging as a comprehensive modality in the work-up for TAVR, current recommendations, clinical practice and randomized trial data are based on echocardiographic measurements of the annulus.

- But 3D imaging techniques, such as TEE and CTA offers more comprehensive assessment of the aortic root and annular geometry
Planes for Analysis

Reconstructed in the coronal, sagittal and axial orientation, and then analyzed using a multiplanar oblique tool.

- Coronal and sagittal planes
  - However if oval configuration of valve mean difference between coronal and sagittal measurements of 3.0 ± 1.9 mm
- Double Oblique Transverse
  - Basal ring diameter below the hinge point of the aortic valve cusps
- 3-chamber view
  - Replicates the parasternal long axis acquired in TTE and TEE

We use Double Oblique Transverse view preferentially but regardless of the plane used
Absolute difference of CTA and TTE/TEE >>> TEE and TTE
78 year old male with Severe Aortic Stenosis

Image a: Coronal oblique: Aortic diameter 26mm
Image b: Sagittal oblique: Aortic diameter 23mm

Due to non-circular structure of valve mean difference between coronal and sagittal measurements of $3.0 \pm 1.9$ mm can occur with evaluation in these planes.
Double Oblique Transverse View

Double Oblique Transverse image of basal annular ring in 78 year old male with critical stenosis.

Note: Non circular valve
How to Create Double Oblique Transverse Image

A. On a coronal projection of aortic root, vertical oblique plane is placed to create a sagittal oblique of ascending aorta
b. On sagittal reconstruction a transverse plane is placed at aortic valve hinge point.
c. Creating transverse oblique image of aortic root.
3D chamber image (a) analogous to parasternal long axis echocardiograph image (b) in 83 year old man with critical stenosis, measuring 19mm and 20mm respectively.
Additional aortic root measurements

Vary depending on *stent specifications*

- Distance to left coronary artery ostium and left cusp
- Distance to right coronary artery ostium to cusp
- Height and diameter of aortic sinus
Aortic Root Measurements

The distance between the insertion of the left coronary cusp and the left coronary artery ostium must be measured as risk of CAD occlusion with stent deployment.

- A distance $>14\text{mm}$ is adequate in most centers.
- Some centers $>11\text{mm}$

Patient A: Coronal Oblique: Not suitable as distance $<14\text{mm}$

Patient B: Coronal Oblique, suitable due to risk of LCA occlusion
CT angiography also allows assessment of coronary vessels. Axial and coronal oblique images of left coronary artery in 79 year old man with critical stenosis. The LCA is located 14mm from left coronary cusp however there is a high burden of calcified atheromatous disease, a potential relative contraindication for TAVI due to increase risk of occlusion.
Aortic Sinus Diameter

With Medtronic CoreValve must measure
- Aortic sinus diameter and height
- Diameter of the ascending aorta

Trans-sinus dimension of > 27 mm
Ascending aorta diameter of <43 mm
Iliofemoral Access

Vascular complications noted in early TAVI procedures
- 33% patients with critical AS have unfavorable iliofemoral arteries
- 77% lumen size <8mm

Therefore 3D assessment of arteries, including MIPs, should be performed to allow analyze of
- Tortuosity
- **Minimal lumen diameter >8-9mm**
- Degree and burden of atherosclerosis
- Complex atheroma
  - *Circumferential/horseshoe configuration of atheroma* is relative contraindication in transfemoral approach due to risk of
    - Dissection
    - Inability of large profile delivery catheter to pass
- Vascular complications
  - Aneurysm
  - Dissection
3D reconstructions (image a) of distal abdominal aorta and iliac vessel in 74-year-old man with corresponding axial images (image b) demonstrating narrow calibre of Right Common Iliac Artery (lumen diameter 9mm) with circumferential ‘horseshoe’ configuration calcification, a potential limitation to transfemoral approach TAVI.
Additional information:

Prediction of Appropriate Angle of Deployment

- Valve stent needs to be deployed in a projection that is perpendicular to the native valve annulus
  - Misplacement increases risk of stent embolization

- Traditionally done at periprocedural angiogram
  - Increased time, contrast media used and radiation dose

- With pre-procedural MDCT, the dataset can be used to provide orientation of the aortic root, which may predict the appropriate angle of implantation
  - Currently not available with software in our institution
Prediction of Appropriate Angle of Deployment

Procedure:

• Double oblique transverse multiplanar reconstructions are performed
• Points are deposited on the most inferior aspect of the aortic sinuses, and the points are then linked to form a triangle
• A 3D volume rendered reconstruction of the aorta is then created with the triangle superimposed upon it
• The reconstruction can then be rotated through a series of any angles
  – Aim to find angiographic projections representing perpendicularly to the native valve plane in 3 axes
    1. cranial-caudal with no RAO or LAO angulation
    2. straight RAO to LAO as needed with no cranial or caudal angulation
    3. LAO 30° with cranial or caudal angulation as needed
Conclusion

Pre procedural CT angiography is routinely being integrated into TAVI assessment.

Requirements for concise and accurate reporting:
- Standardized CT protocol
- Comfort with post processing tools
- Understanding of key principles such an aortic root geometry and essential measurements

Thus we created a standardized report template to facilitate reporting.
# Standardized Report

<table>
<thead>
<tr>
<th>Aortic Valve</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Valve Anatomy</td>
<td>Tricuspid/Bicuspid</td>
</tr>
<tr>
<td>Degree of calcification</td>
<td>Mild/Moderate/Severe</td>
</tr>
<tr>
<td>Distribution of calcification</td>
<td>Symmetrical/Asymmetrical/Extend to LVOT</td>
</tr>
<tr>
<td>Root dimension</td>
<td>Area, short and long axis dimensions</td>
</tr>
</tbody>
</table>
| Additional information    | -Distance of right and left coronary ostia to annulus  
                            | -Leaflet length                       
                            | -Diameter of aortic sinus and sinotubular junction |
| Aortic Root orientation *** | If available                        |

| Coronary arteries         | Calcification
                            | Anomalies                      |

| Ascending Aorta and arch  | -Maximal dimensions    
                            | -Degree and burden of ATH     |

| Descending and abdominal Aorta | -Maximal dimensions 
                              | -Tortuosity                   |

| Iliofemoral Access Route   | Tortuosity

| Calcifications             | Location
                            | None/Mild/Moderate/Severe  
                            | - horseshoe/circumferential calcifications |

| Diameter                  | Common iliac artery
                            | External iliac artery      
                            | Common femoral artery      |
## Important Numbers

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annulus diameter</td>
<td>&gt;18 mm but &lt;29 mm</td>
</tr>
<tr>
<td>Trans-sinus dimension</td>
<td>&gt;27 mm</td>
</tr>
<tr>
<td>Ascending aorta diameter</td>
<td>&lt;43 mm</td>
</tr>
<tr>
<td>LCA ostium distance to valve</td>
<td>&gt;14 mm</td>
</tr>
<tr>
<td>Diameter of iliofemoral lumen</td>
<td>&gt;8-9 mm</td>
</tr>
</tbody>
</table>
Recommended Reading

Multidetector Computed Tomography in Transcatheter Aortic Valve Implantation
J Leipsic et al. JACC: Cardiovascular Imaging Apr 2011, 4 (4) 416-429

CT in Transcatheter Aortic Valve Replacement
P Blanke et al. Radiology 2013 269:3, 650-669

Transcatheter aortic valve implantation: Indications
Further Questions?

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