The Aortic Annulus: The Role of CT Angiography In Transcatheter Aortic Valve Implantation (TAVI)

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Goals:

- Review aortic annulus anatomy.
- CT protocols to optimize assessment of aortic annulus.
- Describe necessary measurements at the aortic root/annulus and femoral/iliac vessels.
**Introduction:**

Aortic stenosis is the most prevalent cardiac valvular disease in the western world. Surgical valve replacement is indicated in symptomatic patients and has been the mainstay of therapy for aortic stenosis; however, 30% of patients are not surgical candidates. Trans catheter Aortic Valve Implantation (TAVI) can performed in these selected high risk patients. Accurate imaging assessment of aortic annulus dimensions is very important to decide the size of correct transcatheter valve size; thereby reducing post procedural complications, such as paravalvular regurgitation, annular rupture or valve embolization.
Facts in our institution:

- In our community hospital, there is a large population of high risk or inoperable patients with symptomatic aortic stenosis.

- Our cardiologists started TAVI in October 2014 and successfully completed 104th TAVI recently.

- TAVI is a multidisciplinary venture with active participation of Cardiothoracic surgery, Interventional cardiology, Radiology, Anesthesiology.
Aortic Root Anatomy

The aortic root is the direct continuation of the left ventricular outflow tract and extends from the basal attachment of the aortic valve cusps within the left ventricle to their peripheral attachment at the level of the sinotubular junction.

The root is widest at the midpoints of the sinus and narrowest at the basal attachment of the leaflets and sinotubular junction.

The aortic root consists of several distinct components, including the aortic annulus, the sinuses of Valsalva (or aortic sinuses), and the sinotubular junction.
Aortic Annulus

- Aortic annulus (in Latin, *anulus*, meaning a small ring) is a virtual ring formed by the nadir of the attachment sites of the aortic valve leaflets at the ventriculoaortic junction.

- **Anatomic versus hemodynamic annulus:**
  - Anatomic or surgical annulus is a thick fibrous coronet, or crown-shaped structure, that follows the valve insertions, and provides support to the aortic valve complex.
  - Hemodynamic annulus ➔ see next slide
Hemodynamic annulus

- So-called aortic annulus by echocardiography, angiography, or computed tomography corresponds to the narrowest area in the blood path between the left ventricle and the aorta.

- The size of the hemodynamic aortic annulus determines the appropriate choice of the prosthetic valve to be implanted.

- For the purpose of this presentation, annulus refers to the hemodynamic ventriculoarterial junction defined by imaging.
Aortic root

- Sinotubular junction
- Sinuses of Valsalva
- Aortic Annulus

- Sinuses of Valsalva
- Aortic annulus
- Left coronary cusp
- Right coronary cusp
- Non coronary cusp
Congenital and acquired abnormalities of aortic valve:

- Unicuspid aortic valve
- Bicuspid aortic valve
- Quadricuspid aortic valve
- Lanbl’s excrescences → fine filaments lesions of valvular leaflets, considered degenerative change due to mechanical wear and tear.
- Papillary fibroelastoma → benign avascular tumor
- Aneurysmal dilatation of sinuses of valsalva in patients with connective tissue disorders like Marfan and Loeys-Dietz.
Aortic stenosis:

- In developed countries, aortic stenosis is generally a degenerative process, however, worldwide rheumatic heart disease accounts for most of aortic stenosis.

- **Severe** aortic valve stenosis:
  - valve area < 1.0 cm² (in small patients < 0.6 cm²)
  - Aortic jet velocity of > 4 m/sec
  - Mean Pressure gradient > 40 mm Hg.

- Overall prevalence is estimated to be 5%, mostly affecting the elderly population 2%-3% of >75 years of age have severe aortic valve valve stenosis.
Accepted Indications for Aortic Valve Replacement in Aortic Stenosis

• Severe aortic stenosis defined by either:
  • Aortic valve area <1.0 cm²
  OR
  • Maximum aortic velocity >4 m/sec
• AND either
  • Symptoms referable to aortic stenosis
  OR
  • Evidence of left ventricular dysfunction (ejection fraction < 50%).

• TAVI has currently gained acceptance as a minimally invasive therapeutic option for patients with high risk for conventional surgery.

• August 2016: The U.S. Food and Drug Administration approved an expanded indication for patients at intermediate risk for death or complications associated with open-heart surgery.
Contraindications for aortic valve replacement:

**Absolute:**
- Estimated life expectancy < 1 year
- Comorbidities suggesting lack of improvement in quality of life
- Active endocarditis
- Symmetric valve calcification
- Short distance between annulus and coronary ostium
- Plaques and mobile thrombi in ascending aorta

**Relative:**
- Inadequate vascular access for approach
- Hemodynamic instability
- Severe Left ventricular dysfunction
- Bicuspid valve (No longer applicable)
Role of Computed Tomography (CT) Angiogram

- Evaluate the aortic annulus in order to choose the appropriate size of replacement valve.
- Assess the arterial pathway from chosen entry point to the aortic annulus.
- Assess potential complicating factors, for example, large protruding aortic atheromas which could cause stroke, or variant arterial anatomy.
CT angiogram protocols for TAVI at our institution:

- 64-slice multidetector scanner.

- Study obtained in 2 phases:
  - chest
  - abdomen/pelvis

- Data is acquired in craniocaudal direction during inspiratory breath hold.
Phase 1: CT angiogram of Chest:

- Retrospective ECG gated acquisition
- Coverage: lung apices to dome of liver
- Scan timing: Bolus triggering. Region of interest placed within ascending aorta at 2 cm above carina. Scan triggered at 80HU.
- 100 cc of intravenous contrast material with high concentration (370 mg/dl) at a rapid rate of 5 cc/sec
Phase 2: CT angiogram of Abdomen/Pelvis:

- Non ECG gated acquisition
- Coverage: from top of diaphragm to below femoral lesser trochanters
- 80cc of intravenous contrast with rapid rate of 4-5 cc/sec.
Post processing

- Coronal and sagittal multiplanar reconstructions
- ECG gated acquired chest data is reconstructed at 75% and in every 10% of RR interval of the cardiac cycle.
- Data set with least motion at aortic root/annulus is chosen and sent to dedicated 3D workstation software.
- Dedicated 3D imaging software is used for the specific measurements of the aortic root.
Special CT angiogram protocols for patients with renal insufficiency

- Split studies: chest and abdomen/pelvis studies are performed few days or one week apart.
- Alternative (scanner dependent): administer a single dose of 120 cc of contrast to obtain focused imaging of the aortic root with ECG-gating, and then immediately scan the chest, abdomen and pelvis in the arterial phase.
- Low kV techniques (80-100 kV) can potentially optimize intravenous contrast density while decreasing radiation dose without compromising imaging quality.
Special CT angiogram protocols for patients with renal insufficiency

- Severe renal dysfunction: very low intravenous contrast volume of 60cc (or as low as 20 cc) diluted with saline. Restrict coverage from above aortic arch to heart base.

- Described low dose intravenous techniques must be used with caution in overweight patients, and in patients with severe cusp or annular calcification, as artifact and decreased image quality may limit the accuracy of measurements.
TAVI

- Approach
  - Trans femoral, Trans subclavian and Transapical

- Pre and intraoperative imaging workup:
  - Pre procedural CT angiogram
  - Trans esophageal Echocardiogram (pre and intra-procedure)
  - Fluoroscopy (intra-procedure)
Types of Valve:
- Edwards SAPIEN (approved in USA and Europe)
- Medtronic CoreValve (approved in Europe only)
Evaluation of Aortic root:

Aortic root is composed of:

✓ Aortic valve leaflets
✓ Leaflet attachments
✓ Sinuses of Valsalva:
✓ interleaved trigones
✓ Sinotubular junction
✓ annulus
Measurements

- Circumference, area and diameters (measured and derived) of annulus.
- Distance from aortic annulus to ostia of left main and right coronary arteries.
- Heights of coronary sinuses.
- Ascending aorta and sinotubular junction diameters.
- Distance from commissure to right, left and non coronary sinuses.

Aortic annulus

Classification of extent of calcifications of valve and cusps.
The aortic annulus plane is obtained by double oblique technique, followed by free hand rotation of the axial plane.
Diameters, circumference and cross sectional area of the aortic annulus is subsequently obtained via direct measurement and hand drawing. Arithmetically derived diameters are also separately calculated from the area and circumference.
Crosshairs perpendicular to the plane of the aortic annulus are traced to obtain the distance to the coronary arterial ostium.

The minimum distance from the annulus to the coronary ostia should be 10 mm to avoid the complication of ostial occlusion during deployment.
Right coronary artery

Right coronary Cusp

Left Coronary Artery

Left Coronary Cusp
FINDINGS - VASCULAR CHEST:
Left ventricle:
Aortic annulus calcification description:
Aortic cusp calcification description:
Aortic valve cuspidity:

Annular cross-sectional long axis x annular cross-sectional short axis:
Cross-sectional derived mean diameter (long axis + short axis)/2:
Aortic annulus circumference/perimeter:
Circumference-derived diameter:
Aortic annulus area:
Area-derived diameter:
Distance from aortic annulus to right coronary artery:
Distance from aortic annulus to left coronary artery:
Commissure to right coronary sinus apex, width:
Right coronary sinus height:
Commissure to left coronary sinus apex, width:
Left coronary sinus height:
Commissure to non-coronary sinus apex, width
Non-coronary sinus height:
Sinotubular junction diameter:

Ascending aorta diameter 40 mm distal to aortic annulus:
Maximal ascending aorta diameter:
Ascending aorta description:
Mid-aortic arch diameter:
Descending thoracic aorta diameter:
Descending thoracic aorta description:

FINDINGS - VASCULAR ABDOMEN AND PELVIS:
Abdominal aorta description:
Infrarenal abdominal aorta maximal diameter:

Right iliofemoral vessels description:
Narrowest right common iliac artery diameter:
Narrowest right external iliac artery diameter:
Narrowest right common femoral artery diameter:

Left iliofemoral vessels description:
Narrowest left common iliac artery diameter:
Narrowest left external iliac artery diameter:
Narrowest left common femoral artery diameter:
Conclusion

TAVI is a complex procedure requiring the special skills of a multidisciplinary team including interventional cardiologists, cardiac surgeons and radiologists.

As this procedure is made increasingly available, the radiologist must master implementation and interpretation of pre-procedural CT angiogram scans, for which a sound understanding of the aortic root anatomy and pertinent reconstruction techniques is fundamental.


6. Christopher J. Bennett, MD, Joseph J. Maleszewski, MD and Phillip A. Araoz, MD ; CT and MR Imaging of the Aortic valve: Radiologic- Pathologic correlation.


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