Aortic Root Dynamics: Beyond Leaflet Mobility
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Lecture Objectives:
1. Review the anatomy of the aortic root and adjacent cardiac structures in order to be able to
describe the inter-leaflet triangles, as well as the relationship between the aortic root and the
left ventricular outflow tract, membranous septum, right ventricular outflow tract (RVOT),
right atrium, and left atrium.
2. Describe dynamic aortic root opening, timing, and dimensional changes throughout the
cardiac cycle
3. Understand the aortic-mitral separation anatomy
4. Recognize that the sinotubular junction can become blunted (frequently in the setting of
hypertension).
5. Determine the ways in which the sinuses of valsalva can dilate
6. Understand the incidence and classification of bicuspid aortic valves
7. List the information that can be obtained using TEE that can be used to guide aortic valve
and aortic root surgery
8. Understand the aortic root measurements and assessments that can be useful for
transcutaneous aortic valve implantation (TAVI)

Lecture Notes:
1. The dynamics of the aortic root are influenced by the anatomy, pathology and function of
its components: the cusps, the sinuses of valsalva, the sinotubular junction, and the
inter-leaflet triangles (fibrous areas on the left ventricular outflow tract side of the aortic
valve that are situated between where the aortic cusps attach to the periphery of the aortic
root).1
   i. The tricuspid aortic valve is crown shaped with the bases of the cusps at
the aortic annulus and the peripheral attachments of the aortic cusps at the
sinotubular junction
ii. Aortic root dynamics can also be influenced by cardiac structures adjacent
to the aortic root.

Table 1. Relationship of Components of the Aortic Root to Surrounding Cardiac
Structures (assuming a tricuspid aortic valve)2

<table>
<thead>
<tr>
<th>Component of the Aortic Root</th>
<th>Adjacent Cardiac Structure</th>
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<tbody>
<tr>
<td>non-coronary sinus of valsalva</td>
<td>right and left atria and the transverse sinus</td>
</tr>
<tr>
<td>right coronary sinus of valsalva</td>
<td>right atrium, right ventricular outflow tract, and free pericardium</td>
</tr>
<tr>
<td>left coronary sinus of valsalva</td>
<td>left atrium and free pericardium</td>
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<tr>
<td>interleaflet triangle between non &amp; right coronary cusps (part of the membranous interventricular septum)</td>
<td>right atrium, interventricular conduction system, septal leaflet of tricuspid valve, and right ventricle</td>
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<tr>
<td>interleaflet triangle between the right &amp; left coronary</td>
<td>the potential space between the aorta</td>
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cusps and the trunk of the pulmonary artery
interleaflet triangle between the left and non coronary cusps (part of the subaortic curtain) left atrium and constitutes a portion of the anterior leaflet of the mitral valve

The ascending aorta is the segment of the aorta extending from the sinotubular junction to the innominate artery

2. Whether aortic root dimensions change throughout the cardiac cycle is somewhat controversial.
   i. A study using multi-detector CT suggests that the aortic annulus remains fairly constant during systole and diastole but that the sinotubular junction may dilate slightly during systole. This suggests that the commissures of the aortic valve absorb relatively more force of blood ejected through the aortic valve during systole.³
   ii. Other studies suggest a systolic increase in the sinotubular junction diameter along with a corresponding decrease in the diameter of the basal annulus of the aortic valve.⁴ Effective aortic valve area has been shown to be larger in patients with a compliant aortic root versus a stiff aortic root.⁵

3. Because the interleaflet triangle between the left and non-coronary cusps is actually part of the anterior leaflet of the mitral valve, it is not uncommon for aorto-annular abscess to develop a fistula into the left atrium over the anterior leaflet of the mitral valve.
   i. One third of the aortic valve circumference consists of fibrous continuity of the anterior leaflet of the mitral valve

4. Over time (with or without connective tissue disease of the aorta) in the setting of persistent hypertension, the sinotubular junction can become “blunted” or dilated, leading to compromised support of the aortic cusps by the aortic root. The sinotubular junction is thicker than the tissue of the sinuses of valsalva and has a role in supporting the cusps of the aortic valve. Dilation or blunting of the sinotubular junction can result in aortic insufficiency as the aortic cusps get pulled apart.

5. When blood is ejected through the aortic valve, animal studies suggest that systolic expansion of the sinuses of valsalva is greatest for the right coronary sinus of valsalva.⁶ Dilation of the sinuses of valsalva can occur in several different ways and can influence aortic valve cusp mobility resulting in aortic valve dysfunction. Sinus of valsalva aneurysms are best visualized in the mid-esophageal short axis view of the aortic valve. It is important to characterize both symmetric and asymmetric sinus of valsalva dilation for the surgeon so that decisions can be made about full replacement of the aortic root versus partial replacement/repair.

6. Bicuspid aortic valves affect 1-2% of the US population, with a 2:1 male preponderance.⁷ Bicuspid aortic valve patients present for cardiac surgery secondary to aortic stenosis, aortic insufficiency, endocarditis or ascending aortic aneurysm. If a bicuspid aortic valve patient presents with isolated aortic insufficiency, aortic valve repair can be considered.⁸
i. Bicuspid aortic valves can be considered according the orientation of the aortic valve coaptation line.  
   1. Fusion of left and right coronary cusp - most frequent  
   2. Fusion of the right and non coronary cusp - increased risk for aortic stenosis or aortic insufficiency  
   3. Fusion of non coronary cusp and left coronary cusp – least frequent  
ii. There is usually a raphe where the cusps are fused.  
   1. Calcification tends to focus here.  
   2. Sometimes the presence of a raphe can give the appearance of a tricuspid aortic valve, but if the systolic orifice is football shaped rather than circular, this suggests that the valve is functioning as a bicuspid valve  
iii. Bicuspid valves have also been grouped by types according to presence and completeness of a raphe in the aortic valve cusp  
   1. Type 1: a bicuspid valve with two complete cusps that are approximately the same size, only two sinuses of valsalva, and no raphe in either cusp  
   2. Type 2: bicuspid vale where one cusp has a fibrotic raphe; 2 or 3 sinuses of valsalva  
   3. Type 3: one big leaflet and two smaller cusps separate by a commissure  
iv. While bicuspid aortic valve is usually an isolated defect, at least 20% of patients with a bicuspid aortic valve have other congenital cardiovascular lesions.  
   1. Bicuspid aortic valves occur more frequently than the general population for patient’s with coarctation of the aorta or Turner’s syndrome.  
   2. Up to 30% of adult patients with congenital VSDs also have a bicuspid aortic valve  
v. Significantly higher incidence of dilated aortic root/ascending aorta in patients with bicuspid aortic valve. The threshold for replacing the ascending aorta is lower than for the general population because it is know that these patients are likely to have continued aneurismal progression.  
vi. Presence of bicuspid aortic valve is presently considered a contraindication to transcatheter aortic valve implantation

7. In order to guide **repair versus replacement** of the aortic valve, it is important to define for the surgeon the type of aortic valve pathology observed including the mobility, height and coaptation lengths of the aortic cusps, the dimensions of the aortic annulus and the sinotubular junction. There are at least two very complete 2010 review articles in the anesthesia literature regarding the role of TEE in aortic repair surgery.  
9,10
8. TEE assessment of the aortic root is useful for transcatheter aortic valve implantation (TAVI)\textsuperscript{4}

i. Bicuspid aortic valve presently considered contraindication for TAVI

ii. At present the two most common TAVI bioprosthesis are the Edwards SAPIEN and the CoreValve Revalving System

iii. Need to assess height of take-off of coronary arteries.\textsuperscript{4}

1. Usually the coronary ostia are just proximal to the sinotubular junction in the left and right sinuses of valsalva. Location of the coronary ostia even more proximal within the sinuses of valsalva can result in coronary occlusion with TAVI if:

2. the skirt on the prosthesis that is designed to prevent paravalvular leak actually occludes the coronary ostia

3. when the transcatheter aortic valve is deployed it crushes the native aortic cusps against the wall of the aortic root. This is a particular risk if the coronary ostia are low-lying, the native aortic valve is heavily calcified, the native aortic valve cusps are long, or if the sinuses of valsalva are narrow (leaving little room to accommodate the displaced native aortic valve)\textsuperscript{4}

iv. Presence of septal hypertrophy within the LVOT may make placing the transcatheter aortic valve prosthesis challenging. This may be particularly true for the CoreValve since it extends further into the LVOT than the SAPIEN valve\textsuperscript{4}

v. Inadvertent placement of the aortic valve prosthesis too low in the LVOT can compress the anterior mitral valve annulus and impair mitral valve function.\textsuperscript{4}

vi. If aortic valve prosthesis is deployed only a few mms too low in the LVOT, cardiac conduction tissue including the AV node can be damaged. This can be a problem with any of the TAVI devices. In one series, 40% of patients receiving the CoreValve developed new onset LBBB.\textsuperscript{11}

\textbf{Table 2: Aortic valve and root measurements required for TAVI}\textsuperscript{12}

Note that the sinus of valsalva and sinotubular junction diameter measurements are not as important for the SAPIEN valve because that valve does not extend as far into the aortic root and ascending aorta as the CoreValve.

<table>
<thead>
<tr>
<th>Aortic valve/Aortic root measure</th>
<th>CoreValve 26mm</th>
<th>CoreValve 29mm</th>
<th>SAPIEN 23mm</th>
<th>SAPIEN 26mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective orifice area of aortic valve (cm\textsuperscript{2})</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;0.8</td>
<td>&lt;0.8</td>
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<tr>
<td>Aortic valve annulus (mm)</td>
<td>20-23</td>
<td>24-27</td>
<td>18-21</td>
<td>22-24.5</td>
</tr>
<tr>
<td>Sinus of valsalva diameter (mm)</td>
<td>≥27</td>
<td>≥28</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Sinotubular junction (mm)</td>
<td>≤40</td>
<td>≤43</td>
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<td>--</td>
</tr>
<tr>
<td>Aortic valve to coronary ostial height</td>
<td>≥14</td>
<td>≥14</td>
<td>&gt;10</td>
<td>&gt;11</td>
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References: