How do I valve size for a TAVI procedure?

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Disclosure: Proctor for Medtronic
Industry sizing recommendation by vendor

- **Edwards Sapien**:  
  - 23 mm: Annulus > 18 and ≤ 21 mm  
  - 26 mm: > 21 and ≤ 25 mm

- **Medtronic CoreValve**:  
  - 26 inflow: Annulus of 20-23 mm  
  - 29 inflow: Annulus of 24-27 mm
3 unanswered Questions

- What is the “annulus” needed to measure?
- How to measure (which dimension)?
- What modality to use?
The aortic annulus is the virtual circumferential connection of the aortic leaflets' basal attachments (virtual basal ring)
Annulus by 2D echo (TTE, TEE)

Diameter perpendicular to the long axis of the root, measured between the endothelial point (white-black interface) that trisects the posterior aortic wall, the non-coronary hinge and the anterior mitral lealfet and the point that bisects the septal endocardium and the right coronary hinge at early to mid systole. Diameter measurements are most accurate using the zoom mode with careful angulation of the transducer and with gain and processing adjusted to optimize the images.

*Modified after Derek Chin Eur J Echo 2009*
Standard 2D echo underestimates the effective annulus diameter not just because of ellipticity.

In an elliptic anatomy the 2D echo diameter (red) is typically close to the minor diameter of the ellipse (blue). The major diameter (white) is not taken into account, this underestimates the effective annulus diameter.

Even in a round anatomy, the diameter (blue) is underestimated by 2D echo (red) as the measurement does not pass through the center.
Assessment of the aortic annulus

Hamdan, Schwammenthal J Am Coll Cardiol 2012
Assessment of the aortic annulus
The aortic annulus is generally elliptical. The degree of annular ellipticity varies substantially among patients.

- Patients can have widely differing annulus sizes despite identical anteroposterior diameters.
- One-dimensional measurement (standard 2D Echo) cannot accurately assess the aortic annulus.
Assessment of the aortic annulus

Ellipticity index = max/min diameter

Hamdan, Schwammenthal J Am Coll Cardiol 2012
3D CT images were reconstructed in 10% increments of the RR-interval.
Variation of annular dimensions throughout the cardiac cycle:

Perimeter shows least variation

Hamdan, Schwammenthal
J Am Coll Cardiol 2012
Relative percent change of aortic annular dimensions

In Normal subjects strain averages 2.2 %, in Aortic Stenosis 0.6 %

Hamdan, Schwammenthal J Am Coll Cardiol 2012
“Valvular interdependence” of the aorto-mitral orifice: Aorto-Mitral Coupling

Aortic and mitral annulus are embedded within one common aorto-mitral orifice, so that reciprocal changes of size and shape of each element result from the pressure-sensitive motion of its common aorto-mitral septum.

Hamdan, Schwammenthal J Am Coll Cardiol 2012
A larger area can be inscribed by the same perimeter (finger length) by assuming a rounder (less elliptic) shape.

The circle is the shape with the largest area for a given length of perimeter.
What can we learn from that for sizing in TAVI?
Requirements for an ideal annular parameter for sizing

- Integrates dimensions across the whole 2-dimensional annular plane
- Is most stable during the cardiac cycle
- Independent of annular shape
Only annular Perimeter fulfills these requirements

- Circumferentially integrates annular dimension (effective, or mean circumferential diameter can be easily obtained by dividing perimeter into $\pi$)
- Shows minimal variation during the cardiac cycle
- Is not affected by shape (in contrast to area) and stretches only minimally at physiologic pressures
Annulus pre post TAVI with CoreValve

Self-expanding valves: systolic annular shape and perimeter remain constant

Schultz et al., JACC 2009
Annulus pre post TAVI with Edwards Sapien

Reshaping of annulus:
Increase in minor D, decrease in major D, some increase in area, BUT NO INCREASE IN PERIMETER!

Blanke et al., Eur J Cardiothorac Surg 2010
Annulus pre post TAVI with Edwards Sapien

Pre

Post

aortomitrail continuity

membranous septum

2.57 cm X 1.98 cm

2.48 cm X 2.50 cm
Mean: 22.8 mm
(regular long axis was 21-21.5 mm)
It’s the parameter, not the modality: TEE short-axis assessment of virtual basal plane

Clinically, does it really make such a difference?
Gross undersizing based on echocardiographic measurements (which were very variable)
Oversizing in a calcified, not very reshapable annulus based on echocardiographic measurements

Jilaihawi et al. 2012
Cross-Sectional Computed Tomographic Assessment Improves Accuracy of Aortic Annular Sizing for Transcatheter Aortic Valve Replacement and Reduces the Incidence of Paravalvular Aortic Regurgitation

Circumferential Diameter (perimeter-derived) had a considerably greater discriminatory value for predicting significant PVL.

### Table 2
Receiver-Operating Characteristic Curve Analysis for Multiple Baseline Measures of the Aortic Annulus With Post-TAVR Paravalvular Regurgitation > Mild as the Outcome Measure

<table>
<thead>
<tr>
<th>Variable</th>
<th>Area Under the Curve</th>
<th>SE</th>
<th>p Value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CT parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta D_{\text{circ}}$ = ($D_{\text{circ}}$ - TAVR size)</td>
<td>0.81</td>
<td>0.063</td>
<td>&lt;0.001</td>
<td>0.69–0.94</td>
</tr>
<tr>
<td>$\Delta D_{\text{area}}$ = ($D_{\text{area}}$ - TAVR size)</td>
<td>0.78</td>
<td>0.072</td>
<td>&lt;0.001</td>
<td>0.64–0.92</td>
</tr>
<tr>
<td>$\Delta D_{\text{max}}$ = ($D_{\text{max}}$ - TAVR size)</td>
<td>0.82</td>
<td>0.062</td>
<td>&lt;0.001</td>
<td>0.70–0.94</td>
</tr>
<tr>
<td>$\Delta D_{\text{min}}$ = ($D_{\text{min}}$ - TAVR size)</td>
<td>0.67</td>
<td>0.079</td>
<td>0.029</td>
<td>0.52–0.83</td>
</tr>
<tr>
<td>$\Delta D_{\text{mean}}$ = ($D_{\text{mean}}$ - TAVR size)</td>
<td>0.78</td>
<td>0.066</td>
<td>&lt;0.001</td>
<td>0.65–0.91</td>
</tr>
<tr>
<td>$\Delta D_{\text{coronal}}$ = ($D_{\text{coronal}}$ - TAVR size)</td>
<td>0.65</td>
<td>0.083</td>
<td>0.061</td>
<td>0.49–0.81</td>
</tr>
<tr>
<td>$\Delta D_{\text{OS}}$ = ($D_{\text{OS}}$ - TAVR size)</td>
<td>0.64</td>
<td>0.083</td>
<td>0.088</td>
<td>0.47–0.80</td>
</tr>
<tr>
<td><strong>Echocardiographic parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta D_{\text{TEE}}$ = ($D_{\text{TEE}}$ - TAVR size)</td>
<td>0.49</td>
<td>0.086</td>
<td>0.94</td>
<td>0.33–0.66</td>
</tr>
<tr>
<td>$\Delta D_{\text{TTE}}$ = ($D_{\text{TTE}}$ - TAVR size)</td>
<td>0.53</td>
<td>0.08</td>
<td>0.67</td>
<td>0.37–0.70</td>
</tr>
<tr>
<td>$\Delta D_{\text{TEE}(\text{MAX})}$ = ($D_{\text{TEE}(\text{MAX})}$ - TAVR size)</td>
<td>0.64</td>
<td>0.09</td>
<td>0.087</td>
<td>0.46–0.81</td>
</tr>
</tbody>
</table>
3-Dimensional Aortic Annular Assessment by Multidetector Computed Tomography Predicts Moderate or Severe Paravalvular Regurgitation After Transcatheter Aortic Valve Replacement

A Multicenter Retrospective Analysis

Wilson et al. JACC 2012
Sizing in TAVI

- Sizing by standard echo means using a 2D-imaging technique to derive a 1-D parameter (diameter) to assess a 3-D anatomy
- The best parameter for sizing is perimeter (when divided by $\pi$ gives mean circumferential, i.e. effective diameter)
- Currently, the best method is CT
- Rather than enter into denial mode echocardiographers should enter the field of cardiac CT (they are best suited; radiologists alone won’t provide the relevant info)
- Echocardiographers should also try to replicate the CT approach (3D data set to derive a 2D parameter)
- A good echo measurement is still better than a bad CT
The best advice to TAVI patients comes from Plato, who inscribed it above the entrance to his Academy 2400 years ago:

ἀγεωμέτρητος μηδεὶς εἰσίτω

"Let no one untrained in geometry enter!"

Thank you!