Anatomical Considerations and Imaging of the Aortic Root in Candidates for Transcatheter Aortic Valve Implantation

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Conflict of Interest:
Consultant for Medtronic

The surgical anatomy of the aortic root☆

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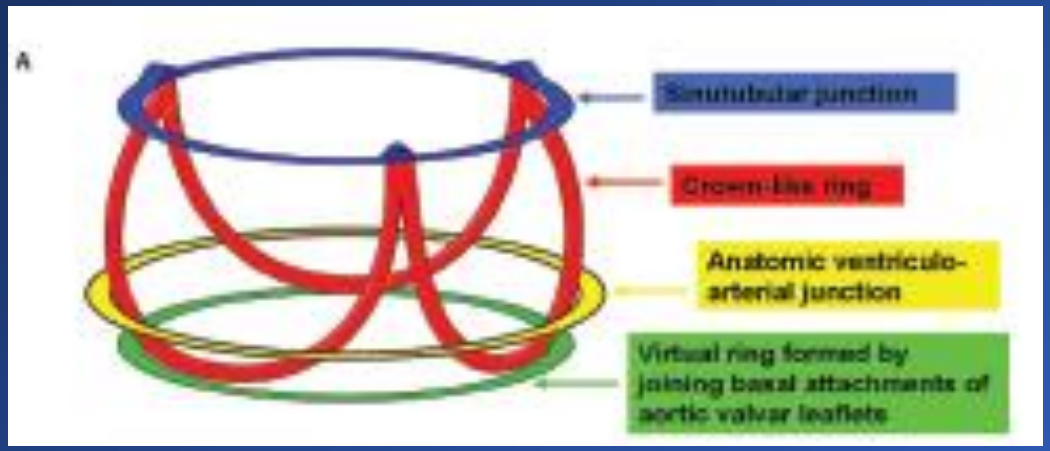
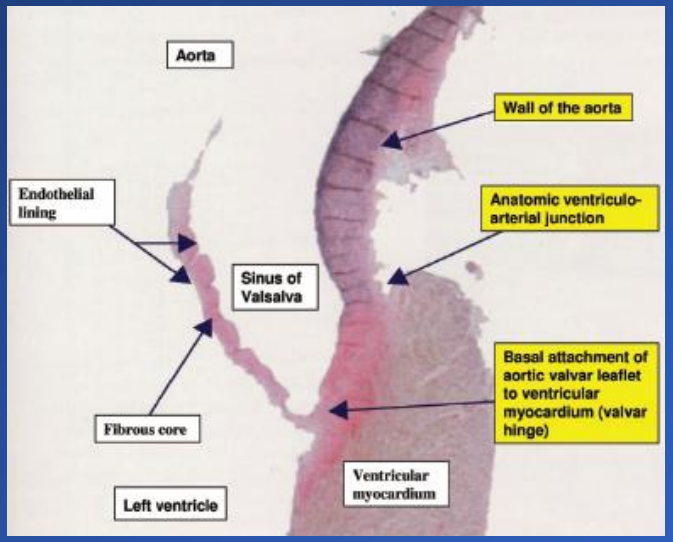
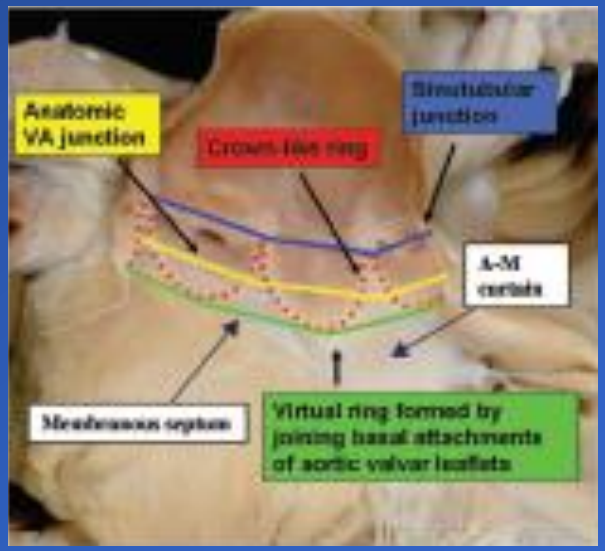
"There is still no consensus on the best way to describe the anatomy of the aortic root. Different surgeons use the term 'annulus' to describe different parts of the components of the aortic valve. There is also lack of agreement within the surgical literature with regard to the nature of the ventriculo-aortic junction…The semilunar lines of attachment of the leaflets cross the anatomic ventriculoartic junction…The overall three-dimensional arrangement of the leaflets takes the form of a crown. It is questionable whether this crown is best described as an 'annulus'…"

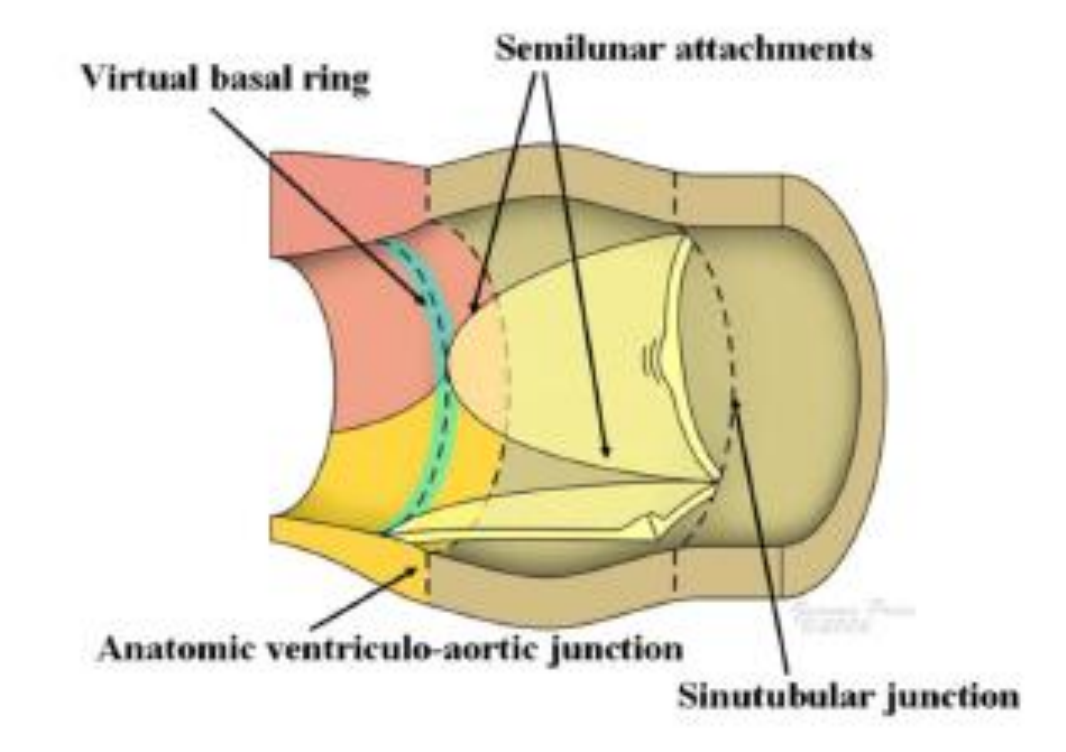
3D arrangement of the aortic root







Piazza, Anderson et al. Circulation 2008



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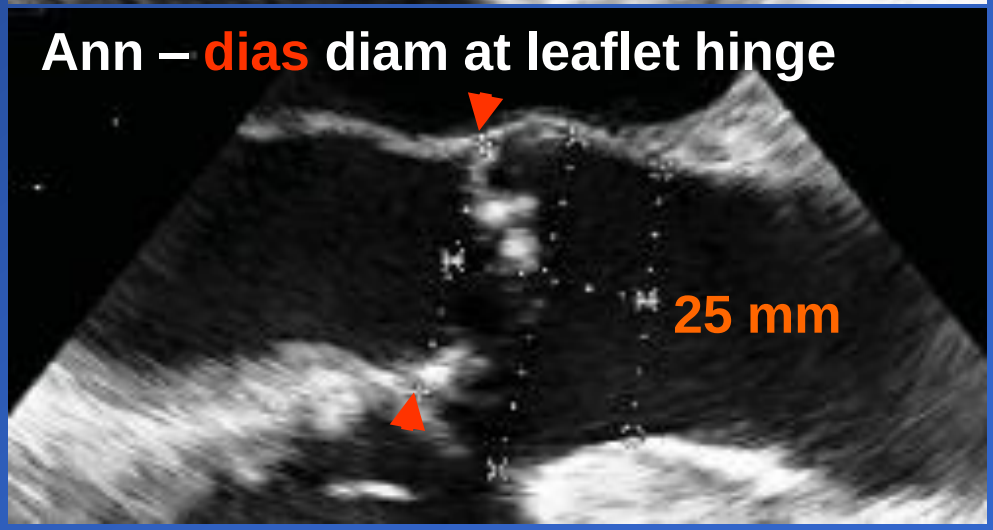
- The aortic annulus is not a distinct anatomical structure
- What is called “diameter of the aortic annulus” is typically an arbitrary, approximately antero-posteriorly oriented 2D-echo measurement, either of the virtual basal ring (nadir of the leaflet attachments), or the anatomical ventriculo-aortic junction (extending beyond leaflets)
- In practice, there is substantial variation of how this is measured and when (midsystole/enddiastole)

Two different definitions of LVOT and Annulus which are in use

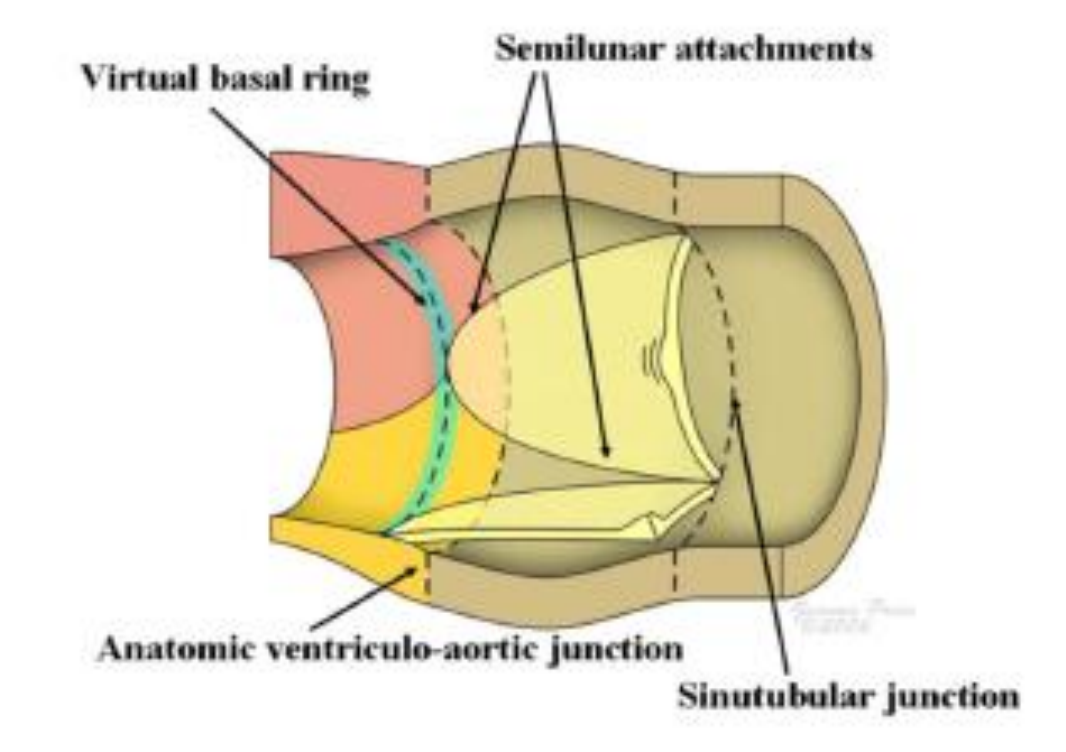
Annulus – sys inner edge-to-edge diameter at leaflet insertion

LVOT diameter – 5 mm below

Arnold Ng, et al.



Derek Chin

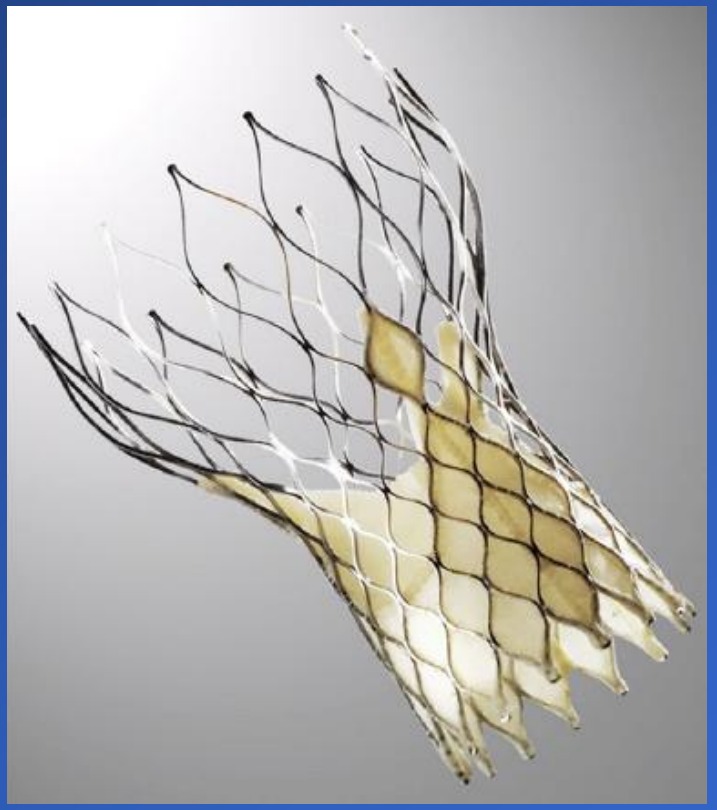


RH Anderson

- The aortic annulus should be identified with the virtual basal ring, not the anatomic ventriculo-aortic junction
- The LVOT should be identified as the 5 mm segment proximal to the LV

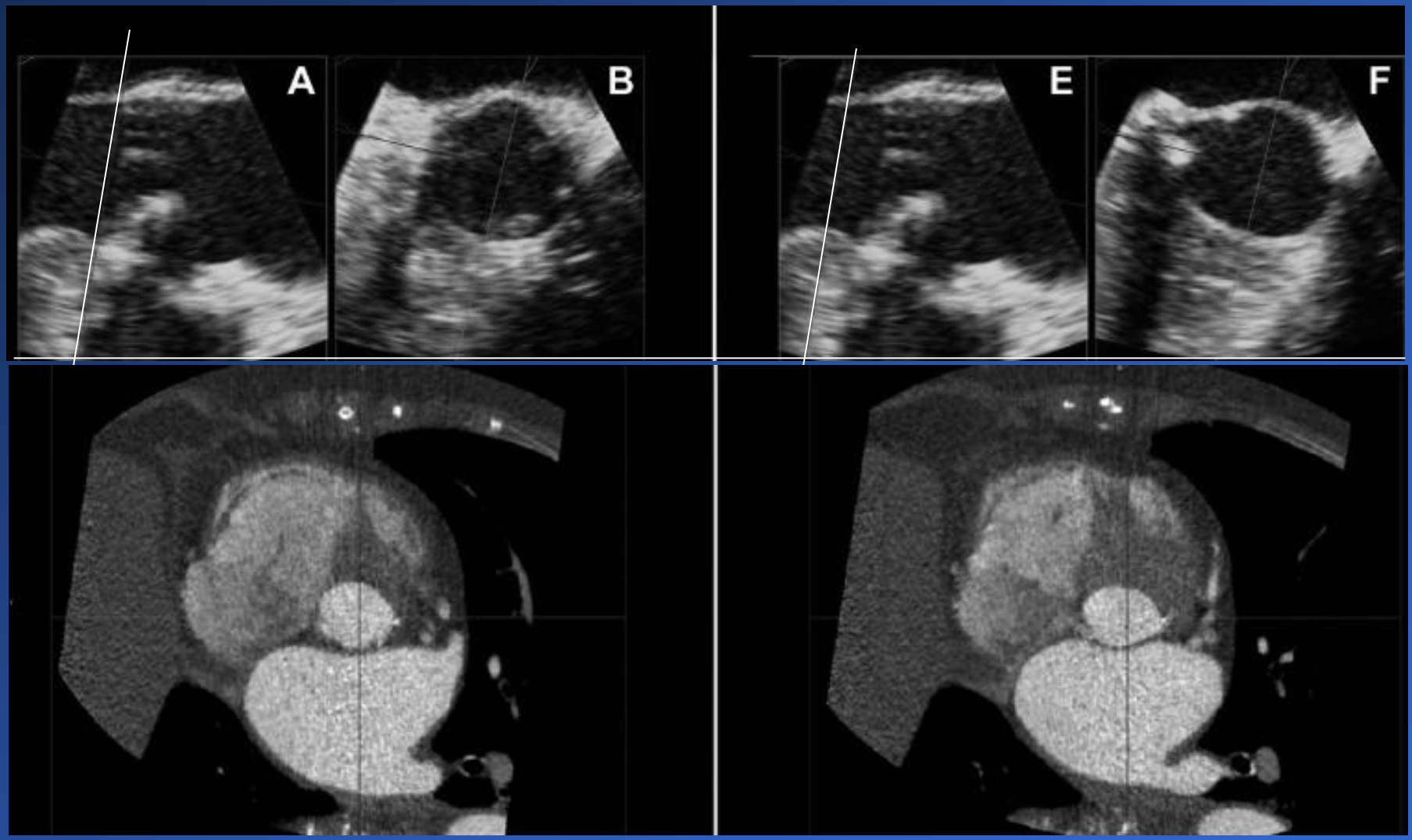
(How) does TAVI affect the outflow tract geometry and (how) does the anatomy affect the frame shape?

Edwards Sapien



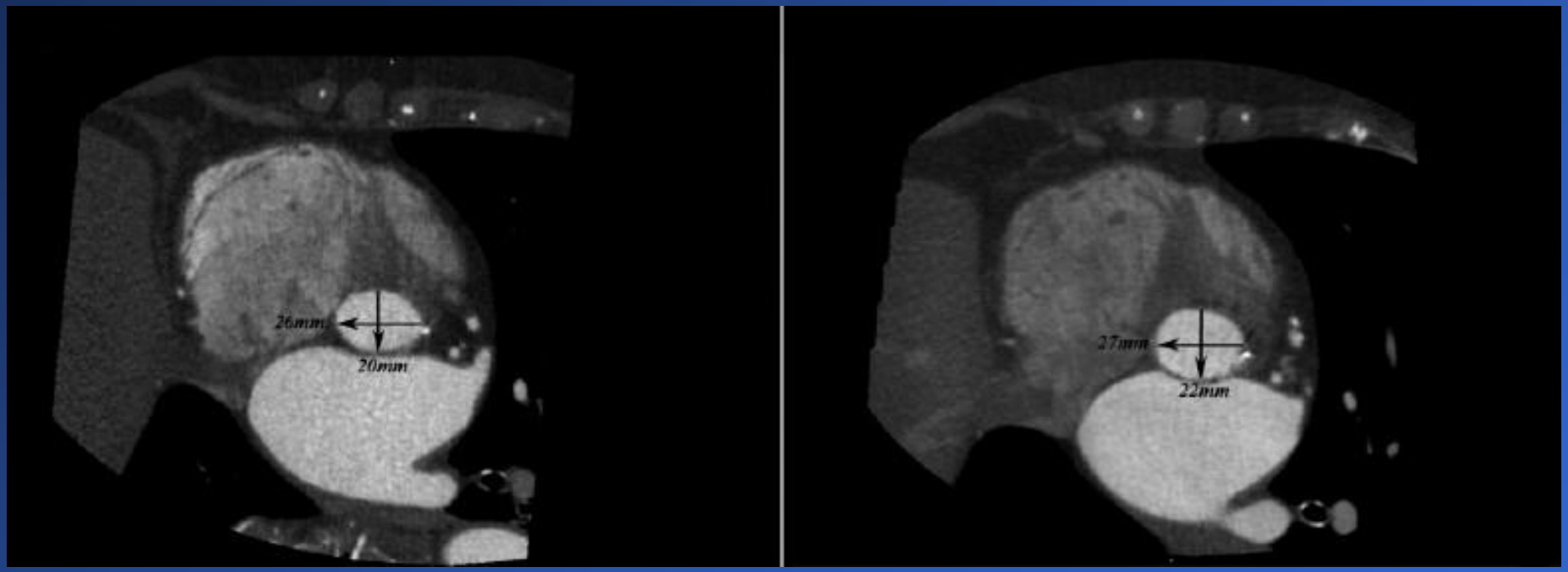
Medtronic CoreValve

Annulus/LVOT is not circular and becomes progressively more elliptical when moving into the LV (3D TEE and MSCT)



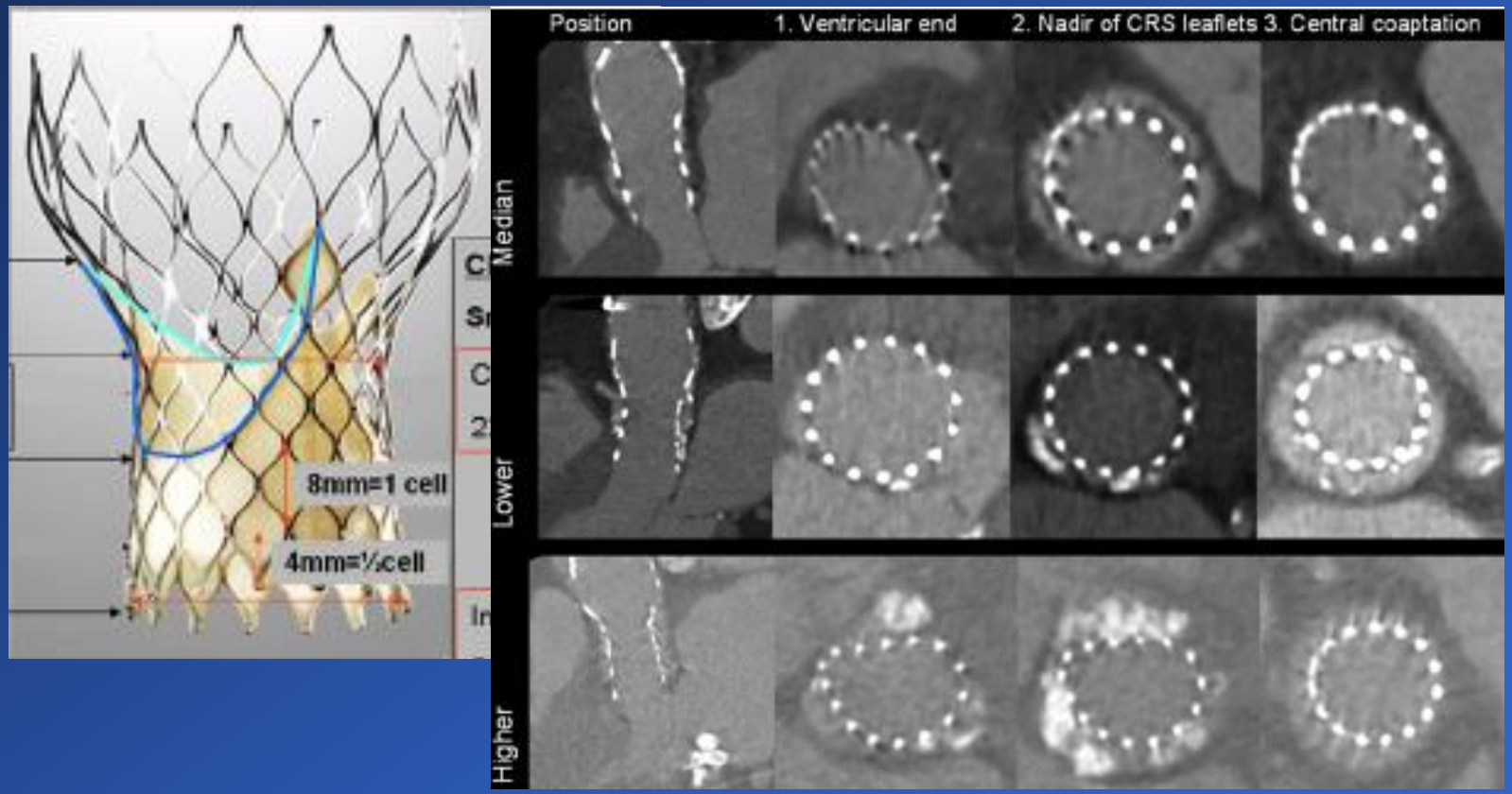
Ng, Bax, et al Circ Cardiovasc Imaging 2010

Outflow tract ellipticity will decrease to some extent after TAVI if a more circular geometry is forced upon LVOT by a stainless steel prosthesis (Edwards Sapien)



Ng, Bax, et al Circ Cardiovasc Imaging 2010

Outflow tract ellipticity may be more preserved after TAVI with the use of a Nitinol frame prosthesis (Medtronic CoreValve)



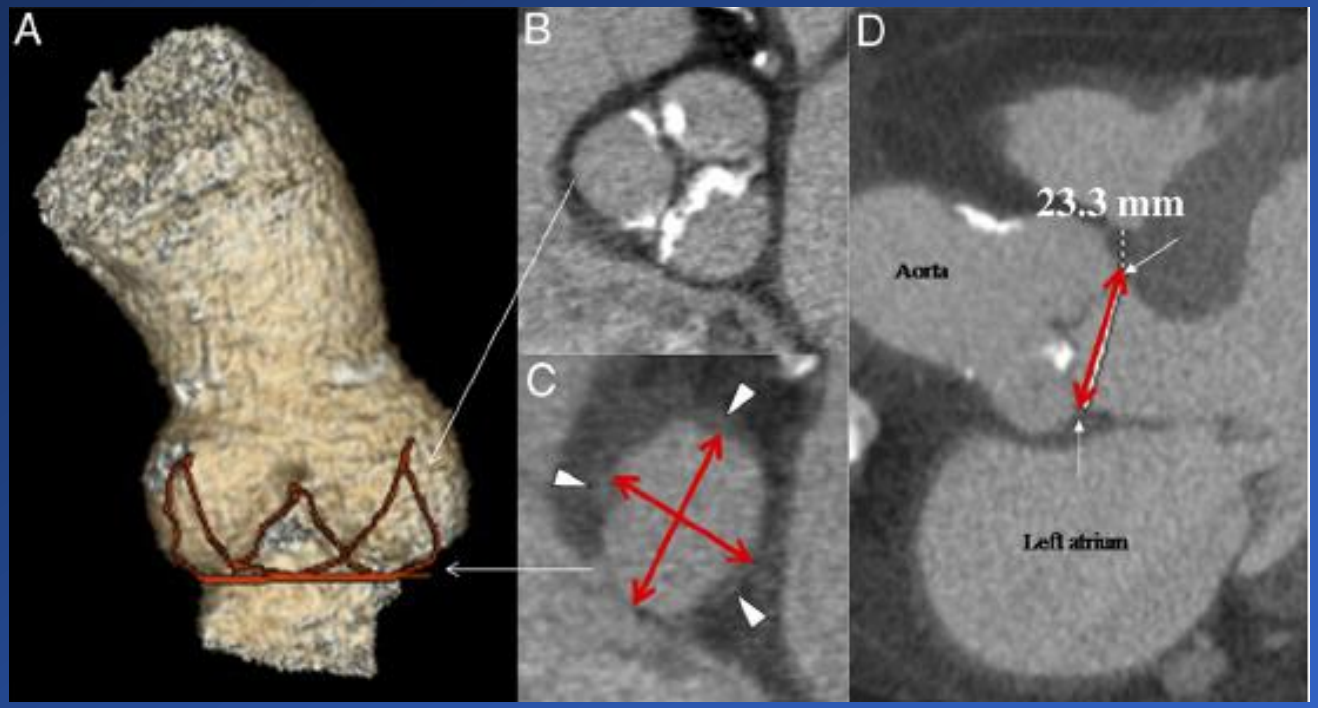
Schultz CJ et al. JACC 2009

Outflow tract/annulus geometry before and after TAVI

- Ellipticity of ouflow tract results in underestimation of its area when using assumption of circularity by an average of 0.2 cm^2 already shown by Baumgartner et. al. 20 years ago
- The degree of underestimation will decrease after TAVI if the (stainless steel) prosthesis results in reshaping of the outflow tract. Now that the smaller circular internal dimension of the deployed prosthesis forming the annulus/LVOT as shown by Ng et al.
- Nitinol frames may conform themselves more to the noncircular anatomy of the LVOT rather than reshaping it as shown by Schultz et al. (however, no preop measurements)

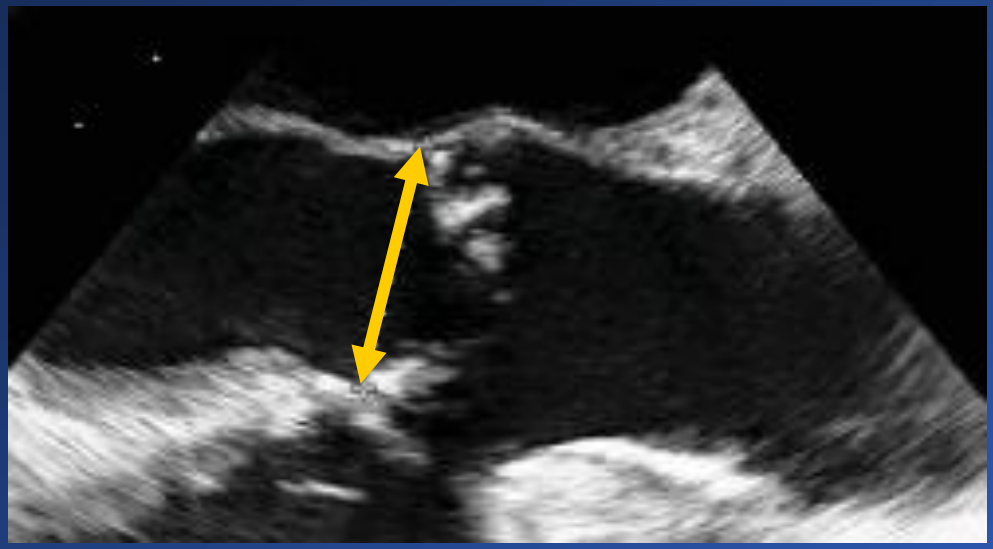
Baumgartner H et al . Cardiology 1990
Ng ACT et al. Circ. Cardiovasc Imaging 2010
Schultz CJ et al. JACC 2009

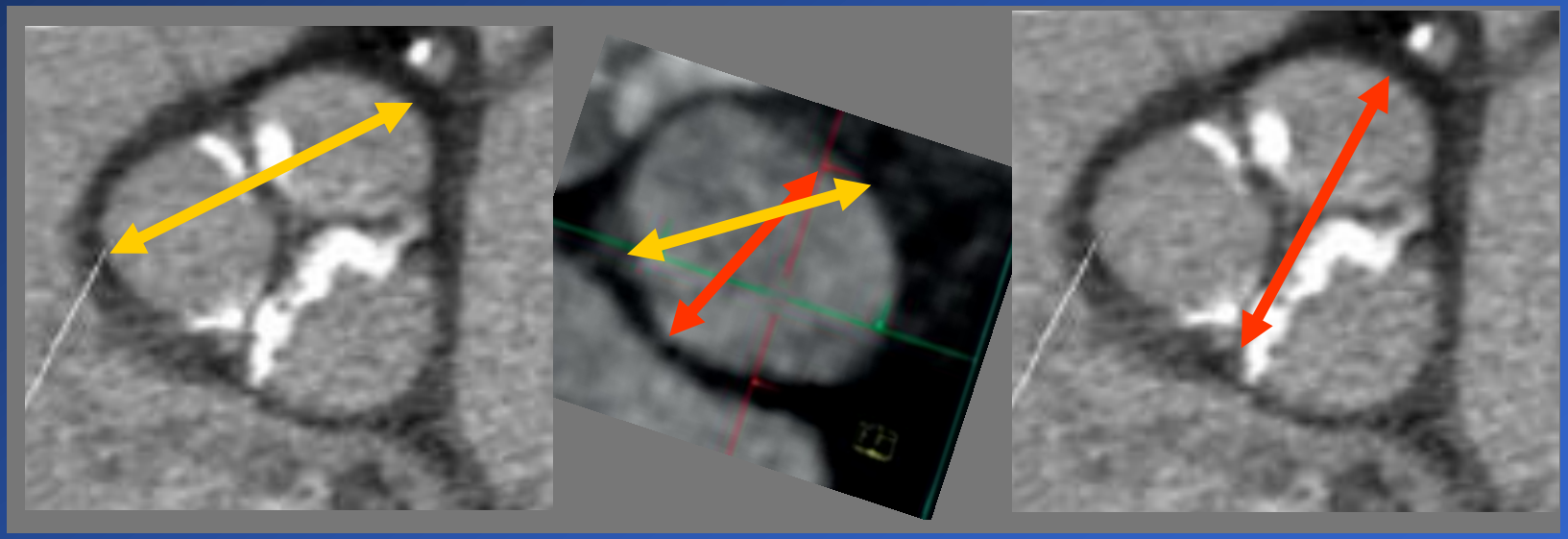
Multimodality measurements of the aortic annulus (virtual basal plane)



Messica-Zeitoun et al found only modest agreement between MSCT diameters (major, minor, mean) and TTE or TEE, but good agreement (r = 0.7) between MSCT-3 chamber measurements (23.8 ± 2.6) and those by TTE (23.9±2.1 mm) and TEE (24.1±2.1 mm)

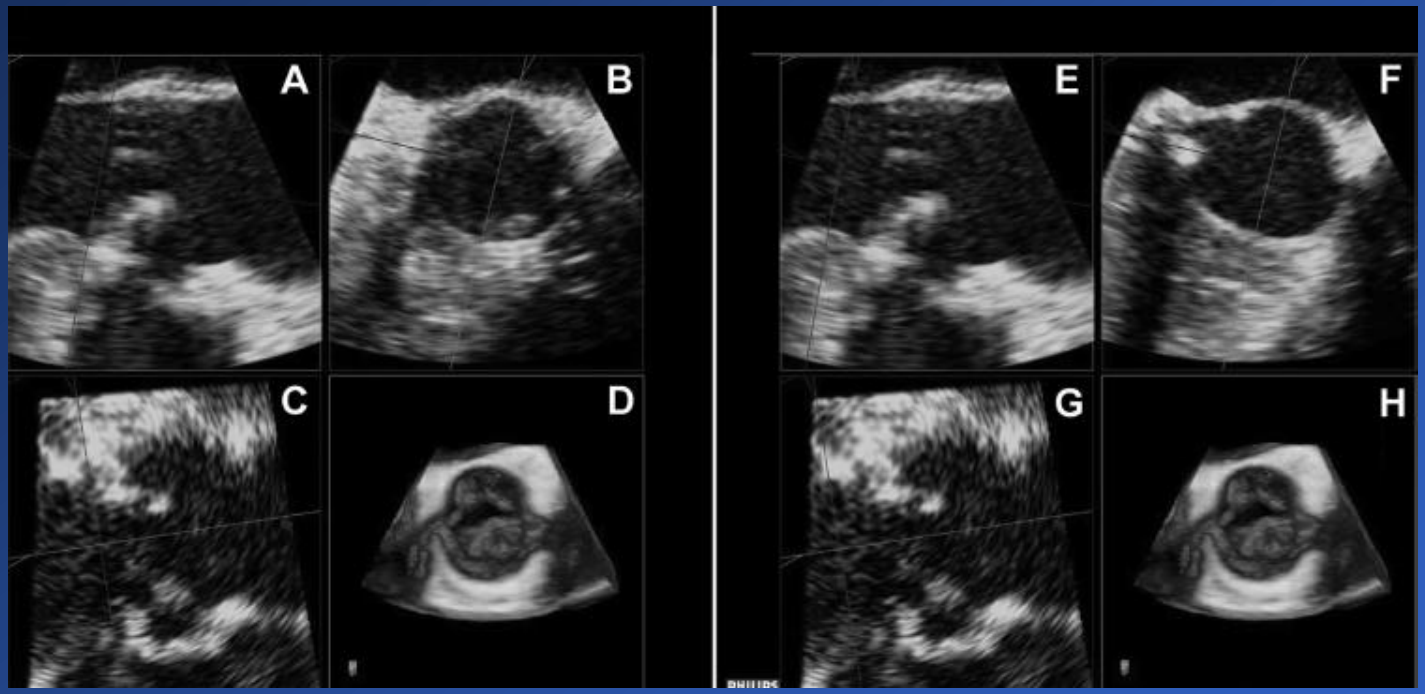
David Messica-Zeitoun et al, JACC 2010





The TEE long-axis plane cuts obliquely through the elliptic aortic annulus. The echo diameter is therefore normally greater then the minimum diameter of this ellipse; it underestimates the mean diameter as assessed in an axial MSCT plane typically by 1 mm (0.5 – 1.5 mm)

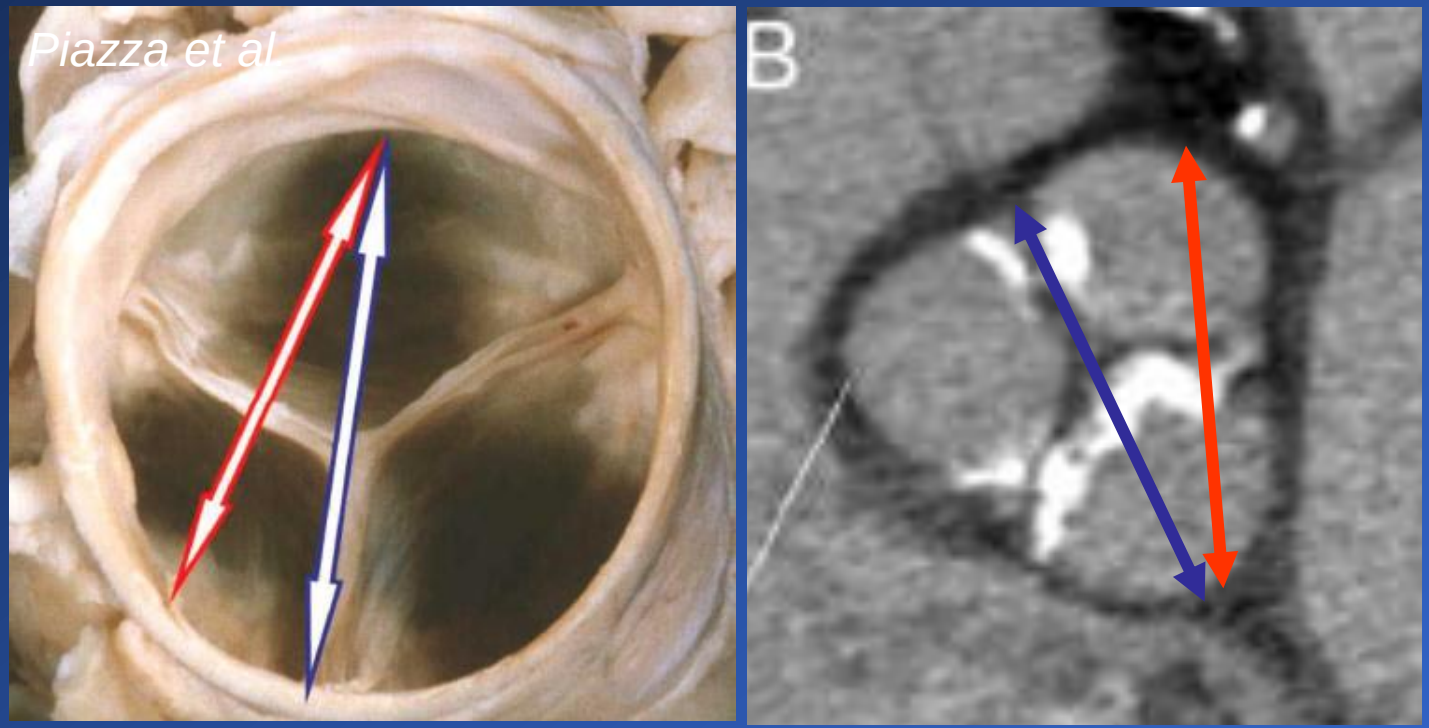
Multimodality measurements



Arnold Ng et al. showed that MSCT planimetered annulus/LVOT area (4.65±0.82 cm2) was underestimated by 2D TEE (3.89±0.74 cm2) and 3D TEE (4.06±0.79 cm2) when using circularity assumption, but much less by 3D TEE planimetry (4.22±0.77cm2). 3D TEE planimetry decreased the degree of underestimation roughly from 25 to 10%

David Messica-Zeitoun et al, JACC 2010

Problem of 2D techniques for measuring "Annulus" and "Sinus of Valsalva diameter"



Measurements made using the basal attachments of the leaflets do not transsect the full diameter of the outflow tract (in the center)

A "sinus of Valsalva diameter (from sinus to sinus)" must always be a tangent, since opposite to a sinus (through a line which passes through the center of the valve) is a commissure, not a sinus

MSCT: Outflow tract and Root Assessment

Sigmoid Septum

Distance to LM

Tops et al. JACC Img 2008

Conclusion

- The complex geometry of the aortic root , the native valve, and the outflow tract need to be recognized when performing “sizing” for TAVI
- Unfortunately, “annulus” and “LVOT” are used differently by different groups. It is important make sure you know what the other person is talking about
- Echocardiography is an appropriate screening tool for TAVI
- MSCT may improve accuracy of sizing, reduce inter-observer variability, and add further information
- The goal should be to use 2D TEE and 3D TEE in a way to capture aortic root anatomy similar to MSCT (including axial/horizontal planes)
- Since the outflow tract/annulus are elliptical perimeter-based sizing may be more useful than simple diameter measurements and could improve fit