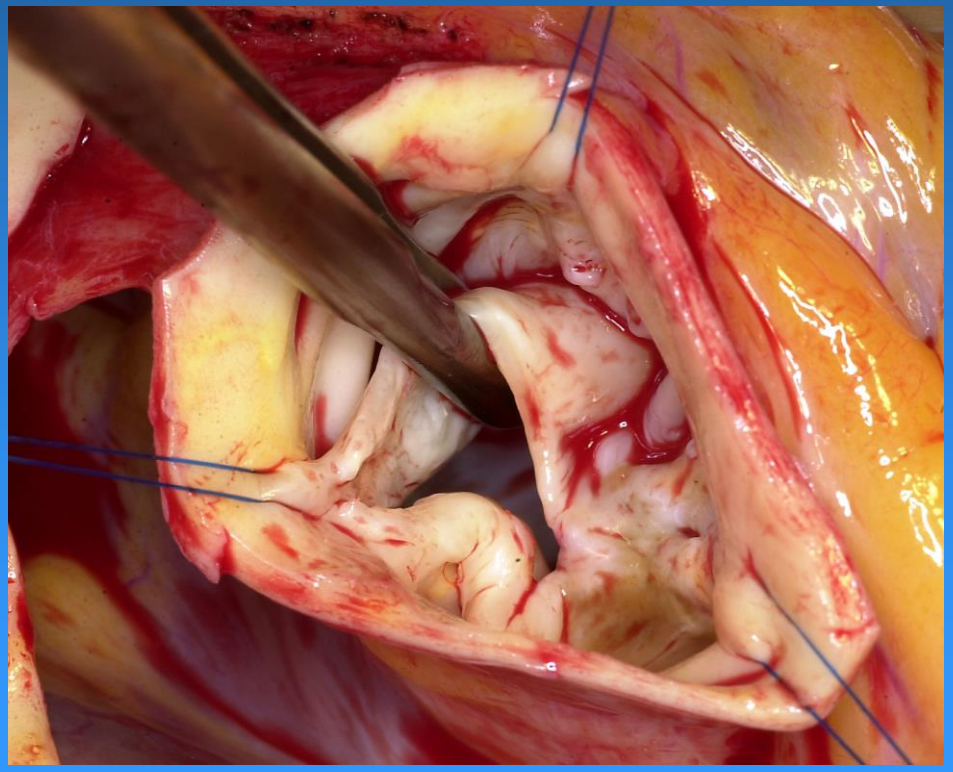
# Anatomy of the Aortic Valve & Root

Frank Langer

Reconstruction of the Aortic Valve and Root



Sept 12-14, 2018

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|---|---|---|---|
| I have received (a) research grant(s) / in kind support | I have been a speaker or participant in accredited CME/CPD ... | I have been a consultant / strategic advisor etc. ... | I am a holder of (a) patent / shares / stocks or ownership... |
| **A** | **A** | **A** | **A** |
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| YES: X / NO: X | YES: X / NO: X | YES: X / NO: X | YES: X / NO: X |
| **B** | **B** | **B** | **B** |
| ... from any institution | ... from any institution | ... for any institution | ... not related to presentation |
| YES: X / NO: X | YES: X / NO: X | YES: X / NO: X | YES: X / NO: X |

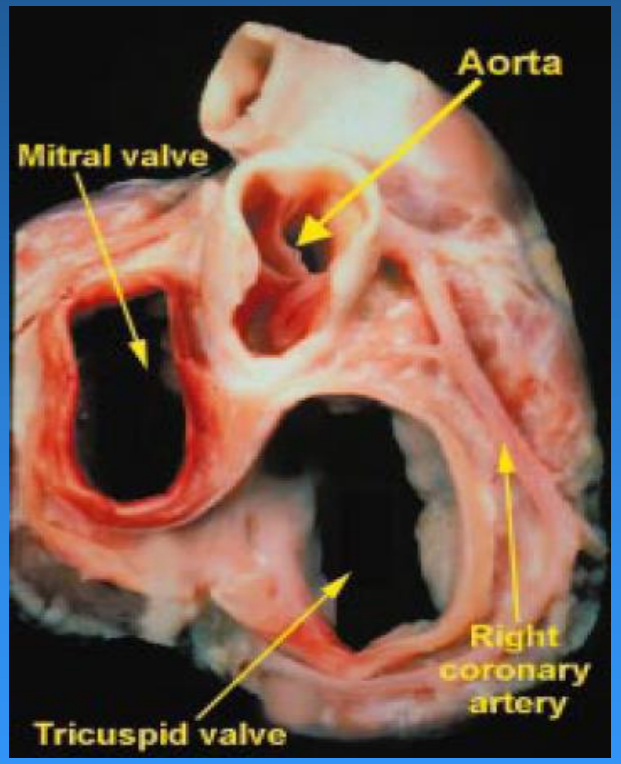
# SCORE: 1234

# Aortic Valve/Root Anatomy

- Location / Co-Location
- Anatomic Components
- Dimensions
- Congenital Variations
- Failure Modes

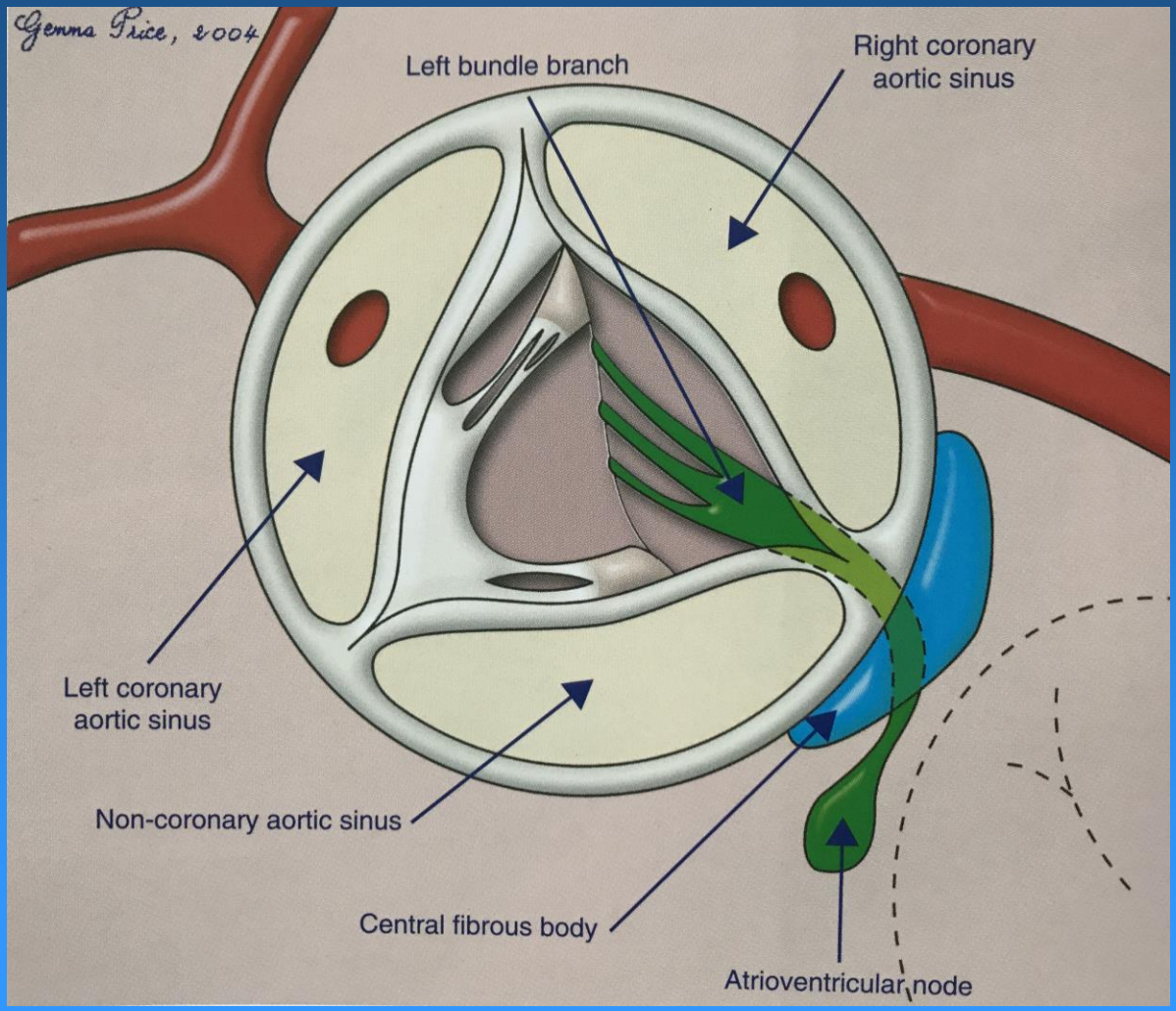
# Aortic Root: Location

- Posterior / right relative to the subpulmonary infundibulum
- Wedged between the orifices of the two AV-valves




Anderson Heart 2000

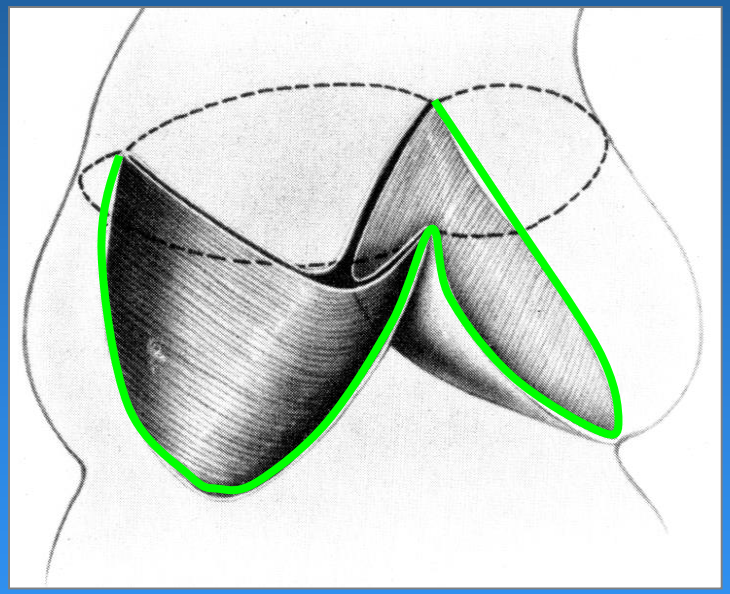
# Co-Location




Wilcox Cook Anderson Cambridge 3rd ed

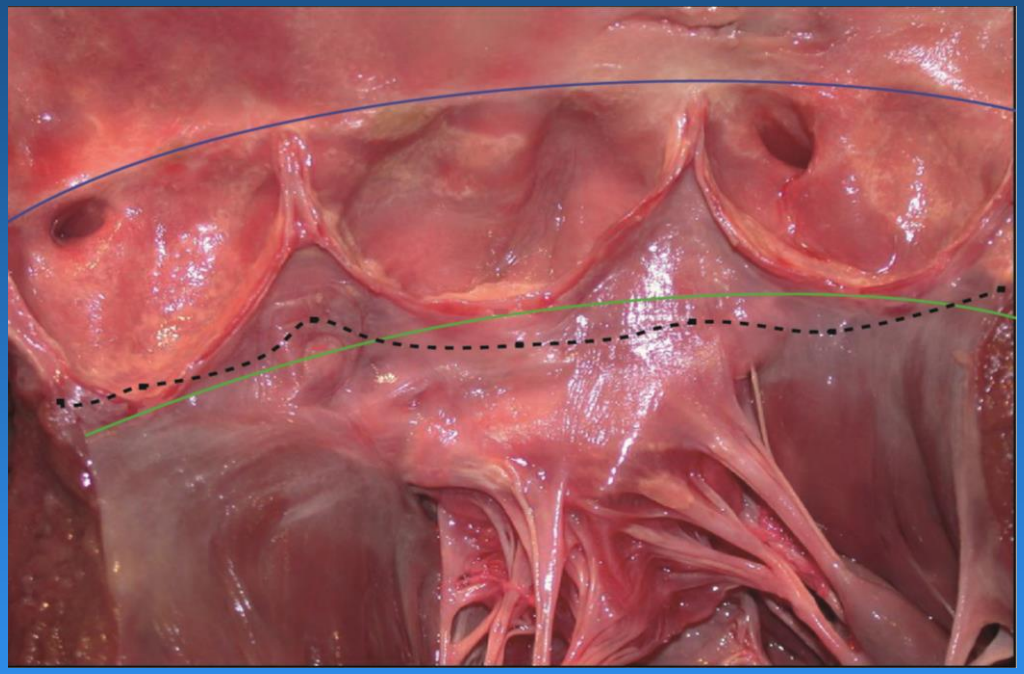
# Anatomical Aortic Annulus

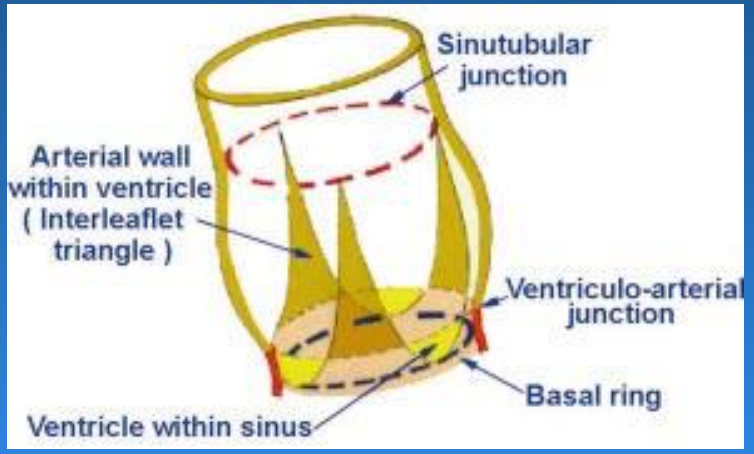
- Unites aortic cusps and sinuses
- Scalloped shape
- Fibrous throughout its course
- Strands extend into myocardium and the fibrous continuity with AML



Crown-shaped hemodynamic junction marked by semilunar attachments of the aortic cusps

# Functional Aortic Annulus

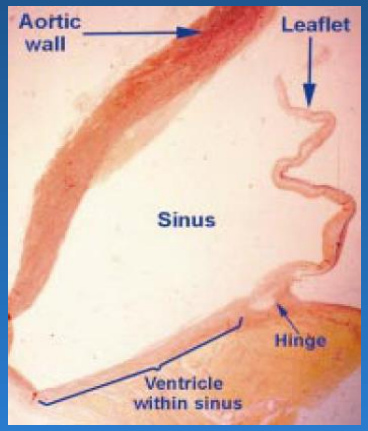





Anderson Heart 2000

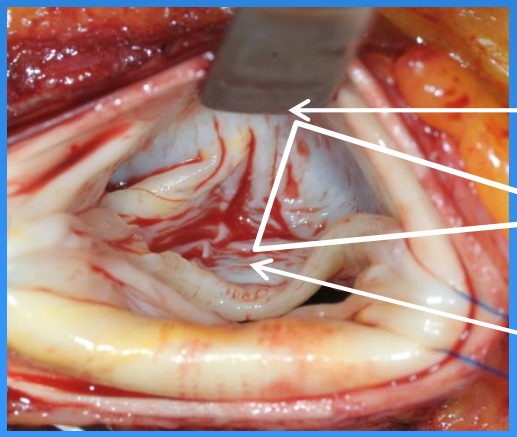
- **Ring**-like anatomical ventriculo-arterial junction
- **Ring**-like joining base line of semilunar attachments
  (virtual) basal ring

# Basal Ring ≠ AV-junction

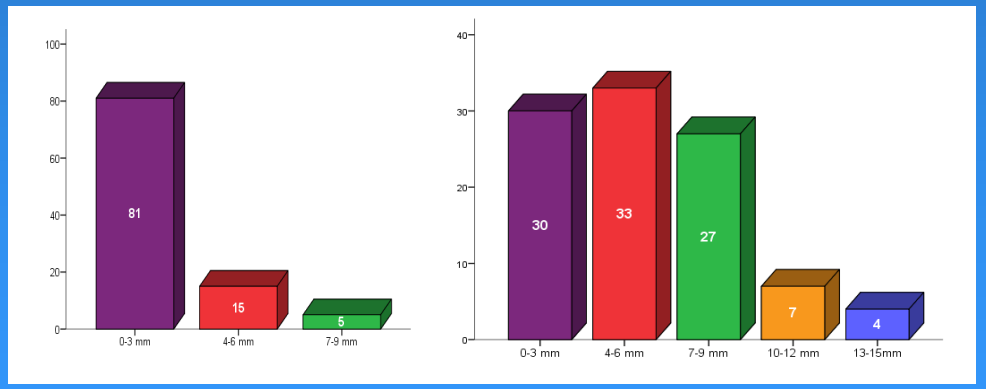



Crescents of LV musculature at base of left and right sinus (variable)

Anderson Heart 2000




Morphometric study (BAV)

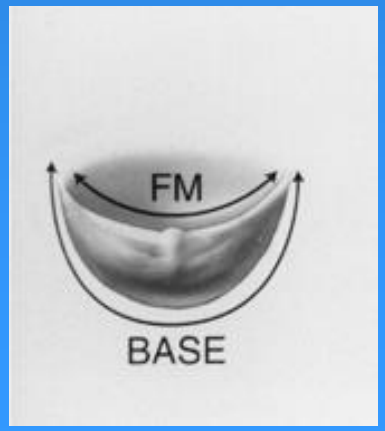


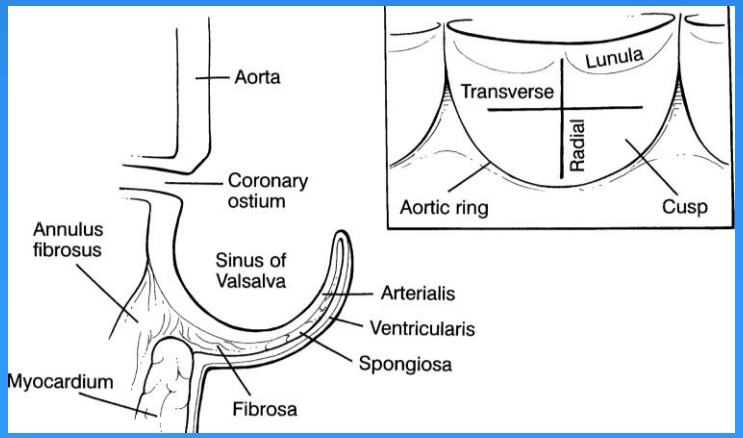

left sinus

right sinus

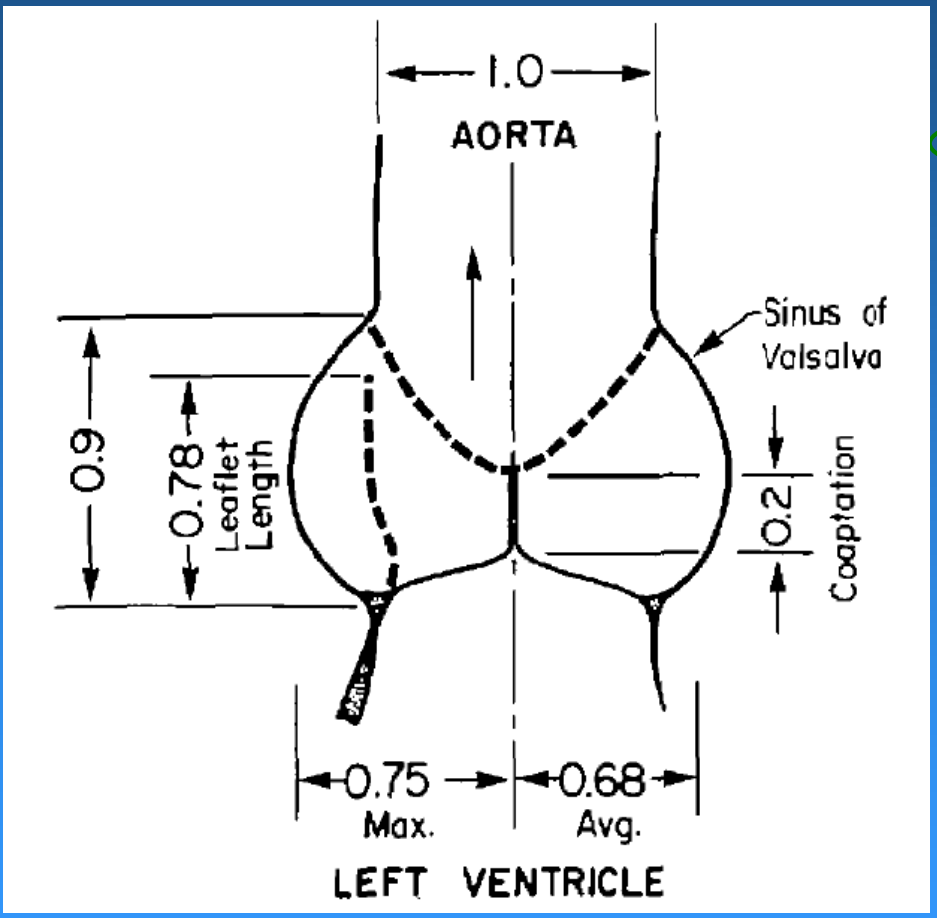
# Aortic Cusps

- Consist of collagen, elastin, glycosaminoglycans
- Attached to (anatomical) aortic annulus
- Cusps meet at commissures below sinotubular junction
- Semilunar shape - base 1.5 x free margin



# Dimensions: Valve / Root



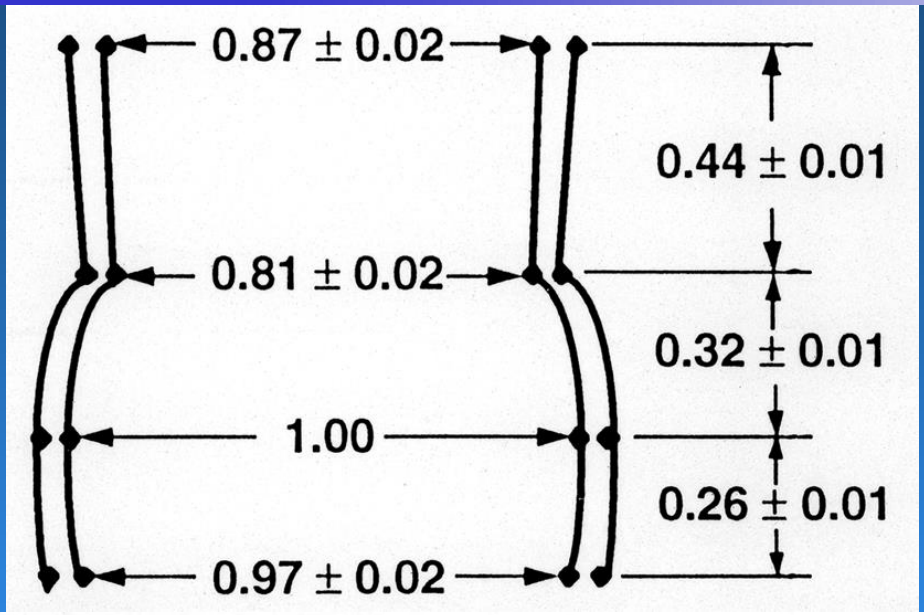

**AORTIC GEOMETRY**

A cross section of the geometry in the region of the aortic valve is sketched in Figure 2. Dimensions are shown as fractions of base aortic diameter (approximately the annulus diameter at the base of the aortic valve). The coaptation ratio of 0.2 at the apex of the leaflets is of interest. The maximum coaptation ratio of 0.4 is about midway along the contact or the free edge of the leaflets. The leaflet length ratio is 0.75–0.8. The maximum diameter ratio of the sinus cavities is about 1.5. The area-averaged diameter ratio of the sinus region calculated from the measured maximum cross-sectional area through the sinuses is 1.36. These measurements are the averages of measurements on silicone rubber casts of nine human valves (made by the authors) at pressures from 0 to 100 mm Hg corresponding to those during the pulse cycle.

No change in leaflet dimensions occurs following the time when left ventricular pressure reaches aortic pressure, since there is no longer any pressure gradient across the valve.

Swanson Clark CIRC Res 1973

# Dimensions: Root




10 normal cryopreserved tricuspid homografts

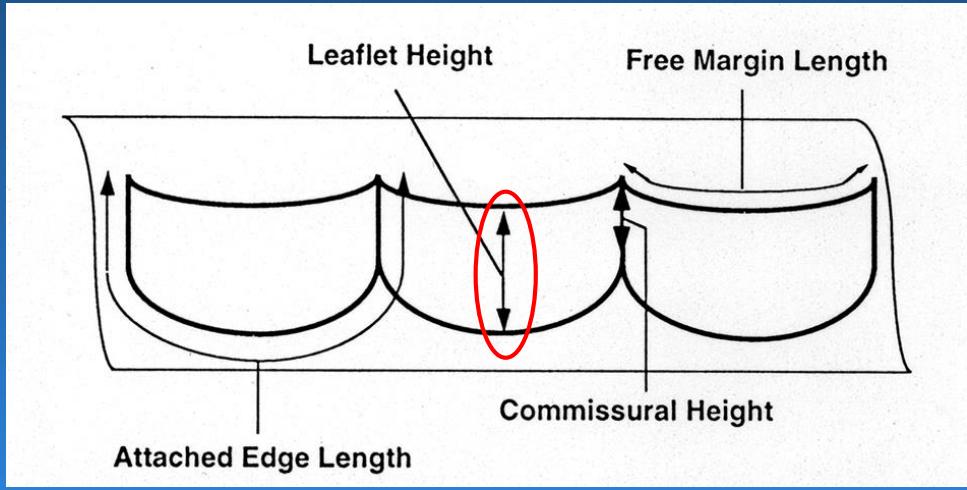
*Human aortic root measurements*

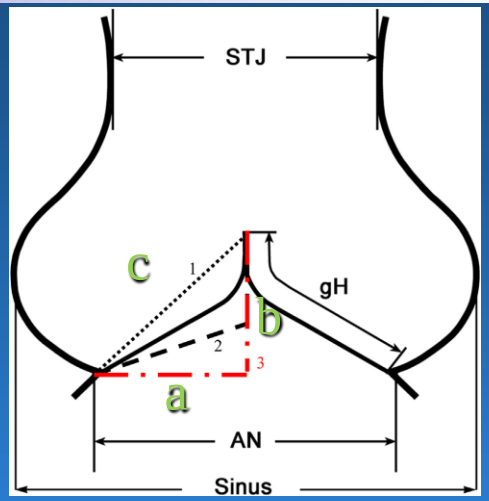
| Level | Orifice area ($cm^2$) | Diameter (mm)* | Diameter (mm)† | Thickness (mm) | Interlevel distance (mm) |
|---|---|---|---|---|---|
| $STJ_1$ | 3.40 ± 0.38 | 21.1 ± 1.0 | 20.6 ± 1.0 | 1.9 ± 0.2 | 10.0 ± 0.0 |
| $STJ_0$ | 2.98 ± 0.32‡ | 18.9 ± 0.9‡ | 19.3 ± 0.9‡ | 1.8 ± 0.2 | 7.3 ± 0.4 |
| SINUS | 4.49 ± 0.40§ | 22.4 ± 1.7§ | 23.7 ± 1.0§ | 1.3 ± 0.1 | 62.4 ± 0.4 |
| BASE | 4.24 ± 0.44 | 23.4 ± 1.2 | 23.0 ± 1.1 | 0.8 ± 0.1 | |

Valves given as mean plus or minus standard error of the mean.

Kunzelman, Grande, David et. al JTCVS 1994

# Dimensions: Cusps




$a^2 + b^2 = c^2$ ➔ $c = \sqrt{(a^2 + b^2)}$

e.g. $12^2 + 10^2 = c^2$ ➔ $c = \sqrt{(244)} = 15.62$

*Human aortic leaflet dimensions*

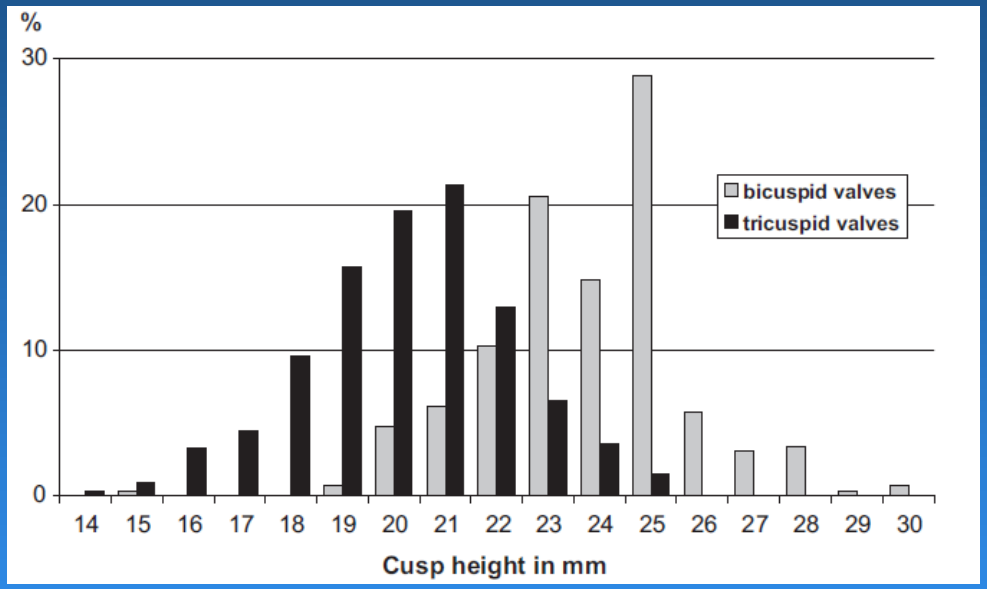
| | *Right* | *Left* | *Noncoronary* | *Average* |
|---|---|---|---|---|
| Height (cm) | 1.33 ± 0.06 | 1.39 ± 0.08 | 1.37 ± 0.04 | 1.36 ± 0.06 |
| Free margin length (cm) | 3.30 ± 0.14 | 3.15 ± 0.14* | 3.27 ± 0.13 | 3.24 ± 0.13 |
| Attached edge length (cm) | 4.64 ± 0.20 | 4.76 ± 0.22 | 4.81 ± 0.16 | 4.74 ± 0.19 |
| Perimeter (cm) | 7.94 ± 0.33 | 7.91 ± 0.35 | 8.08 ± 0.28 | 7.98 ± 0.31 |
| Area ($cm^2$) | 2.97 ± 0.17 | 3.09 ± 0.27 | 3.17 ± 0.18 | 3.07 ± 0.21 |

Values given as mean plus or minus standard error of the mean.

*$p < 0.05$, left < right, left < noncoronary, one-way ANOVA.

Kunzelman, Grande, David et. al JTCVS 1994

# Dimensions: Cusps



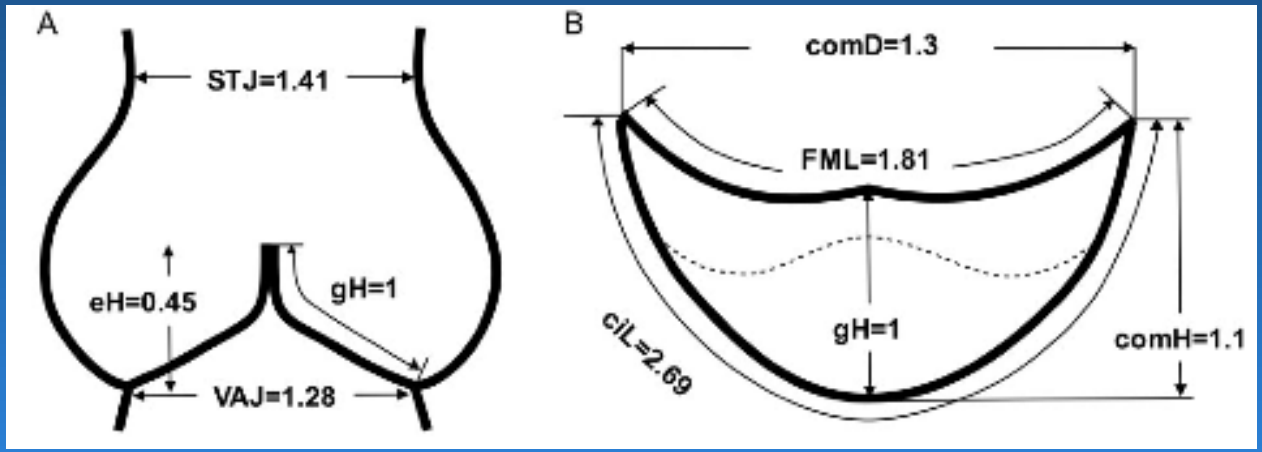

Geometric height measured intraoperatively in 621 patients:

BAV non-fused cusp 23.8 ± 2.0 mm

TAV NCC 20.7 ± 2.2 mm, LCC & RCC 20.0 ± 2.1 mm

Schäfers JTCVS 2013

# Dimensions: Cusps

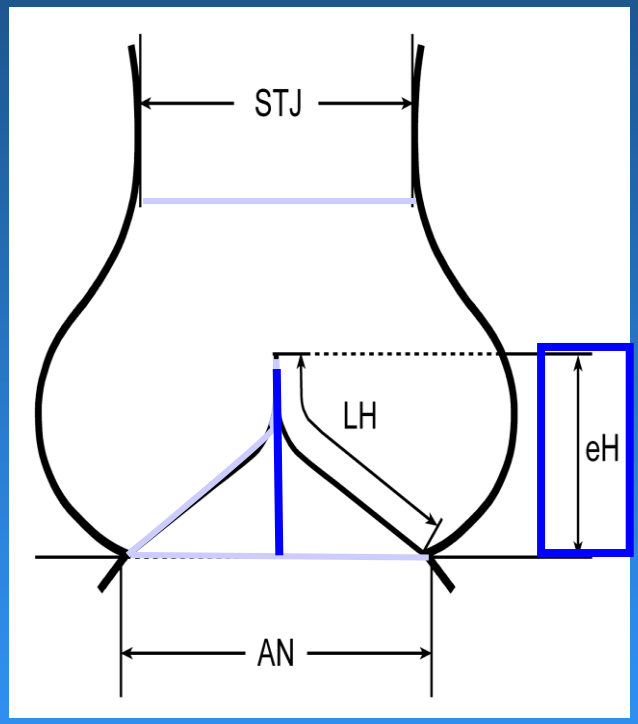


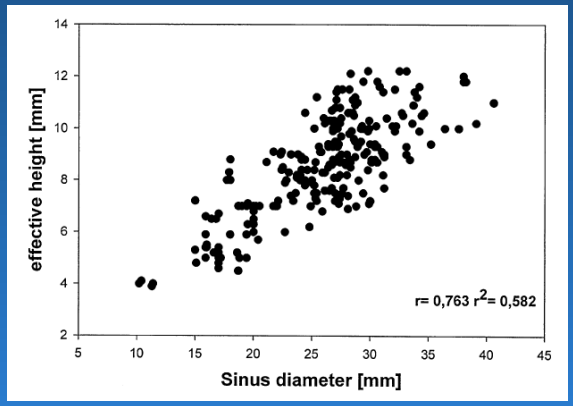

| | |
|---|---|
| Geometric height (mm), mean ± SD | 18.9 ± 1.5 |
| NC | 19.0 ± 1.7 |
| LC | 19.0 ± 1.7 |
| RC | 18.7 ± 1.9 |

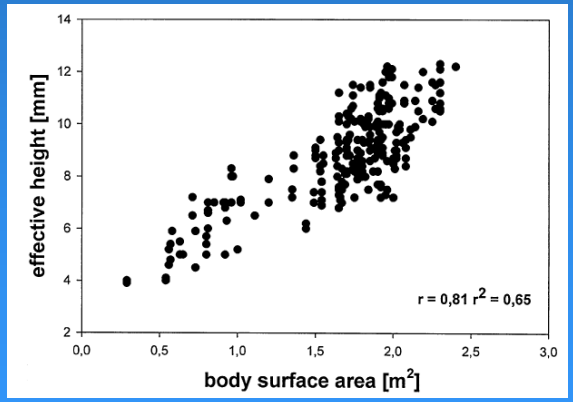
Geometric height measured in 25 fresh tricuspid aortic root homografts

De Kerchove Eur JCTS 2017

# Cusp Configuration



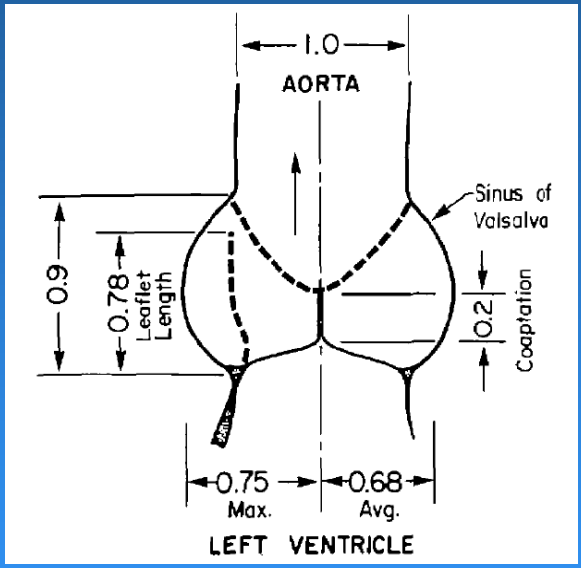



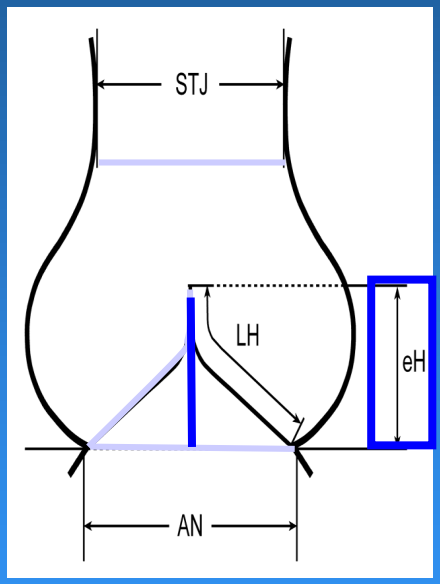



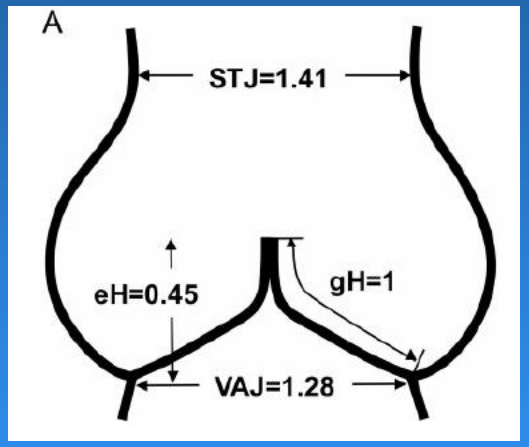

Effective height measured in TTE:
130 healthy volunteers
(100 adults, 30 children)

Bierbach Eur JCTS 2010

# Cusp Configuration



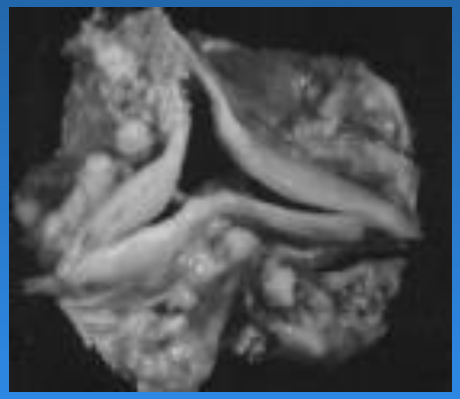




eH = 0.45-0.5 x gH

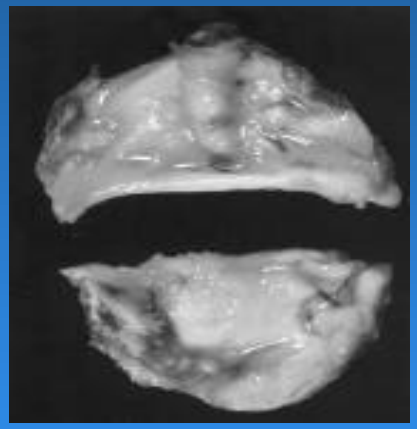
Swanson Clark CIRC Res 1973  Bierbach Eur JCTS 2010  De Kerchove Eur JCTS 2017

# Congenital Variations

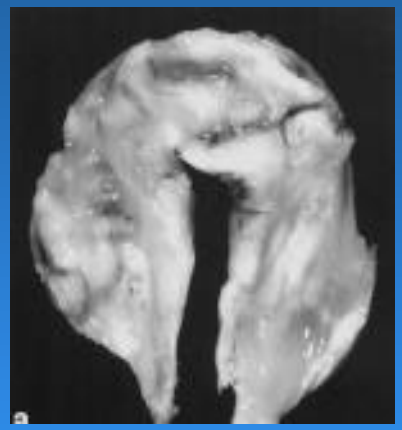
## Valve specimens after AVR



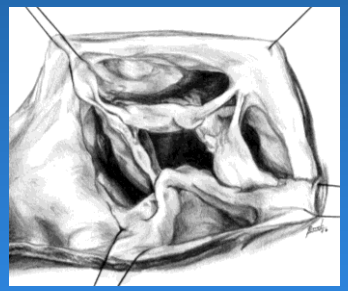
TAV
45 %



BAV
49 %



UAV
5 %



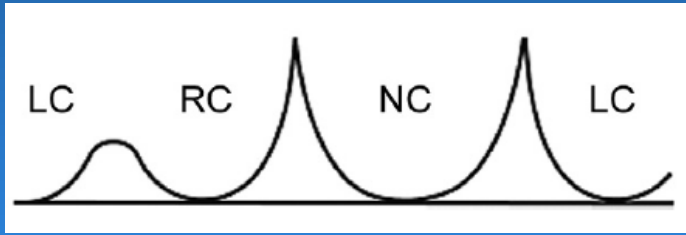
QAV ?

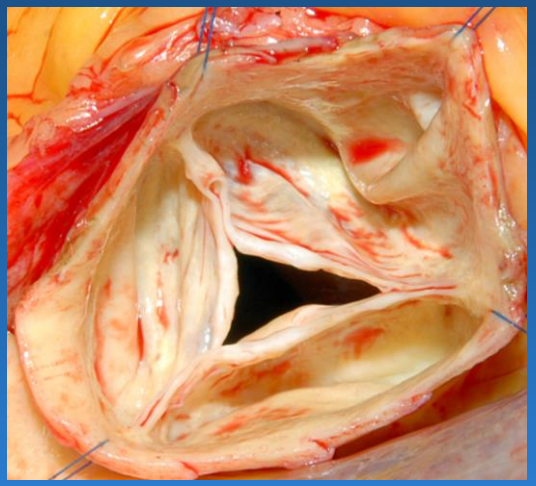
Roberts CIRC 2005

# Congenital Variations: BAV

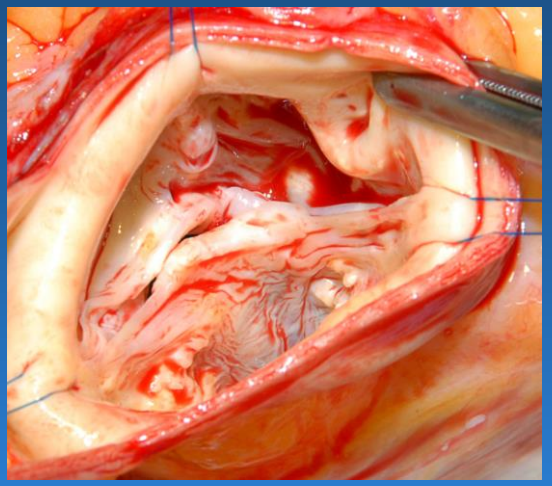
- Prevalence 1 – 2 %
- Aortopathy in (40 –) 60 %

Nistri Heart 1999
Masri Heart 2017

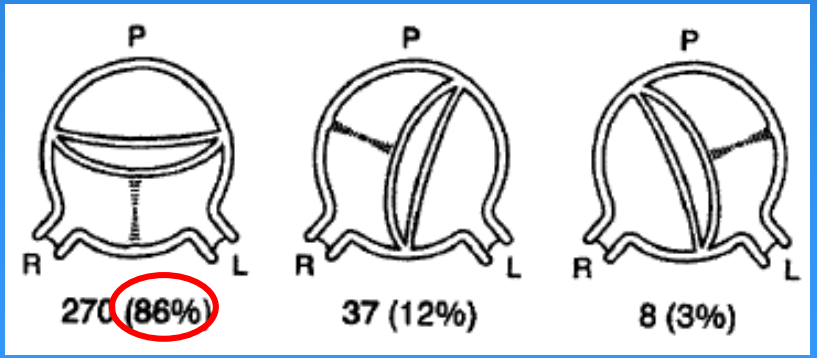


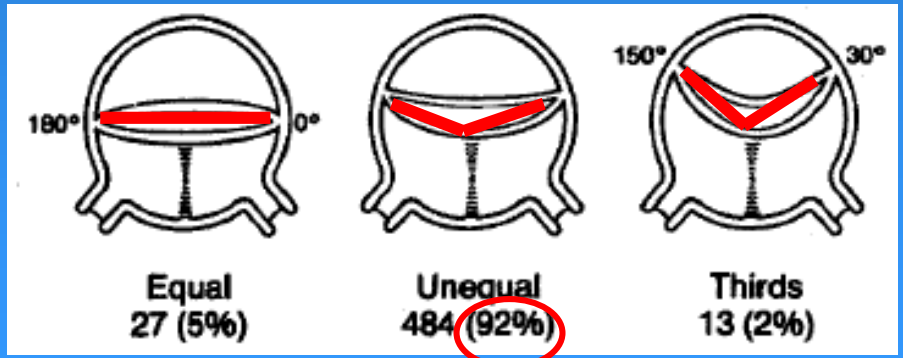
Partial Fusion



Complete Fusion

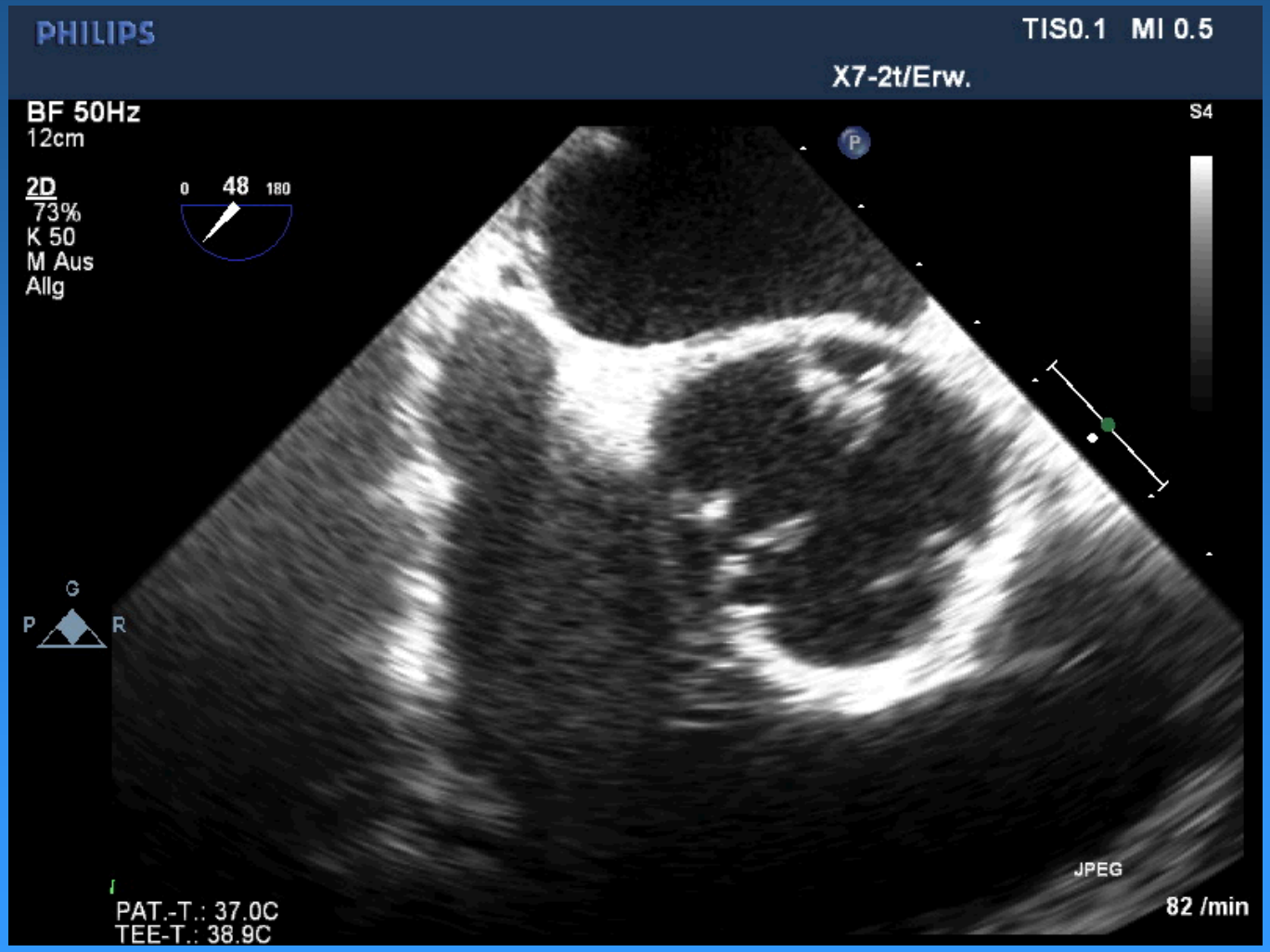



Cusp fusion

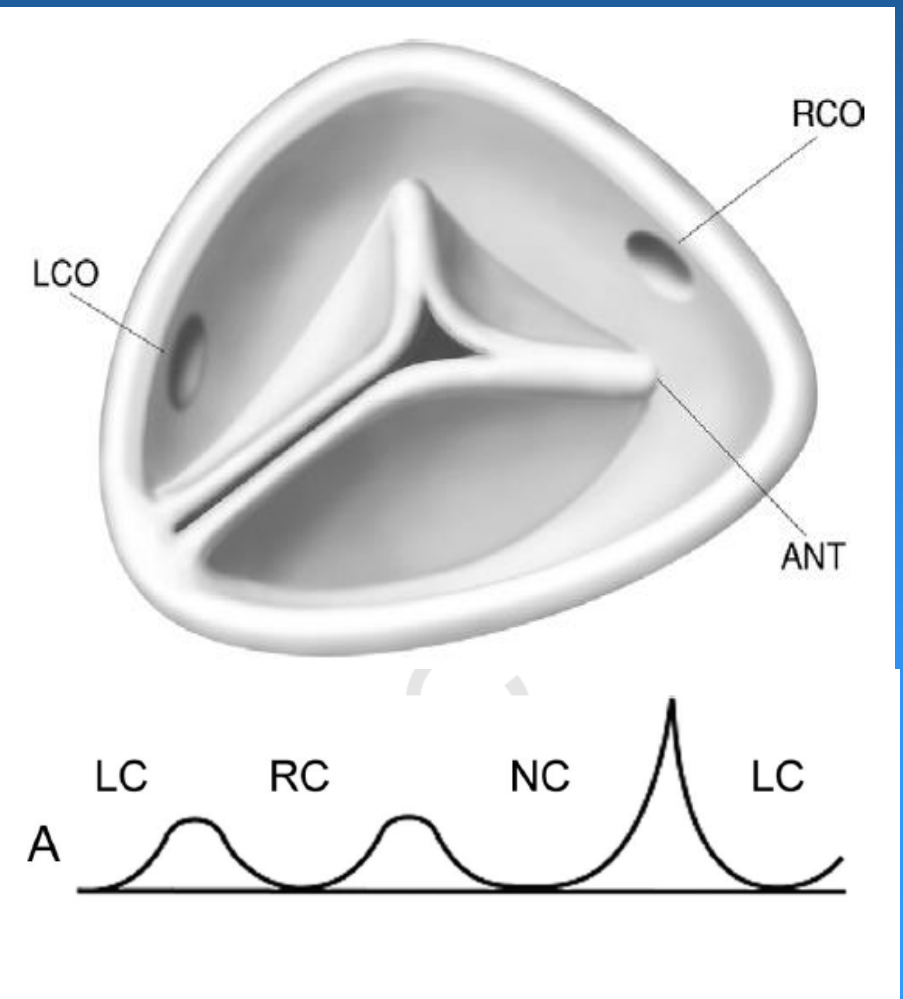



Commissural orientation

# Congenital Variations: BAV



# Congenital Variations: UAV

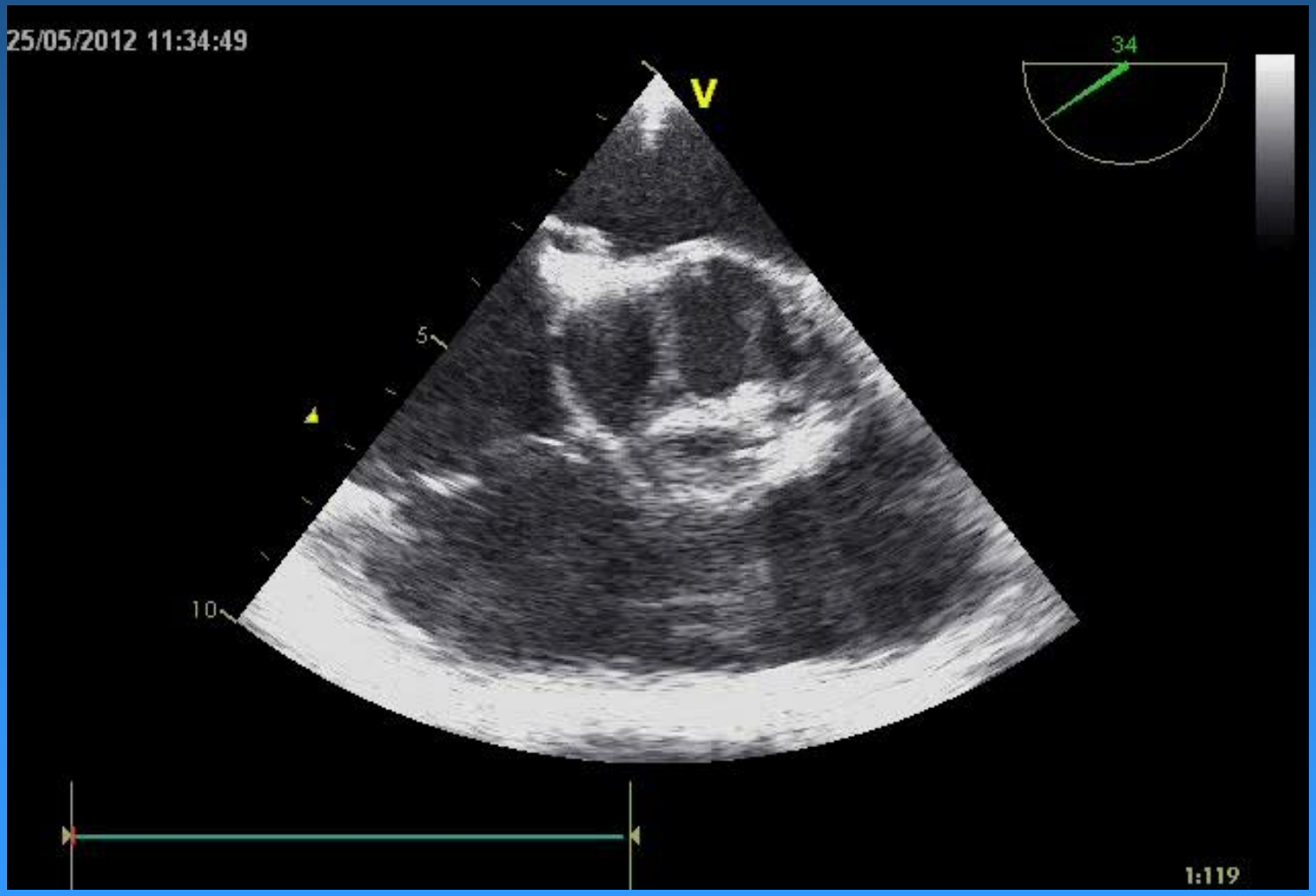



- Prevalence 0,02 %

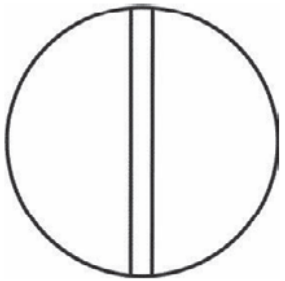
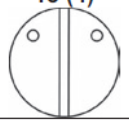
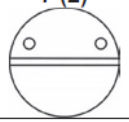
- Unicommissural variant:
  - 1 fully developed commissure
  - commonly in posterior location
  - rudimentary commissures lower

  congenital fusion:
  - RCC-LCC
  - RCC-NCC
- Acommissural variant (rare)
- Critical AS in infancy or childhood
- AS or AR in 3rd or 4th decade of life
- Prevalence of aortopathy ?

# Congenital Variations: UAV



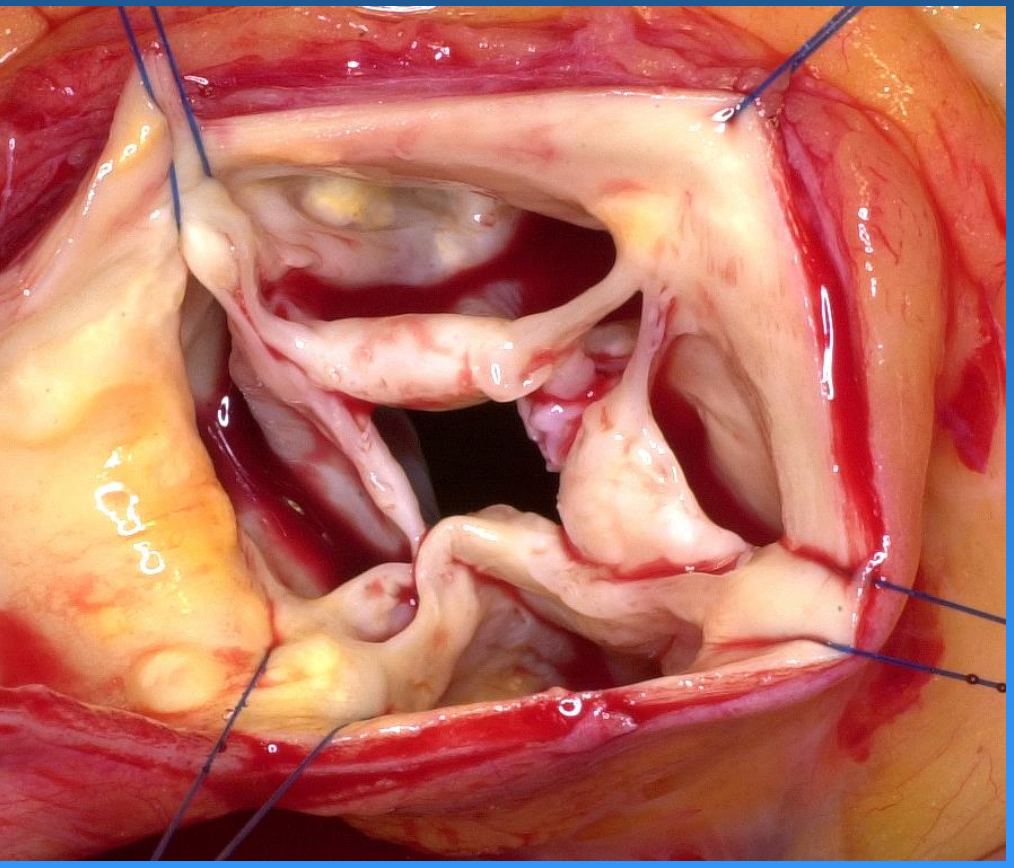
# Congenital Variations

| main category: number of raphes | 0 raphe - Type 0 | | 1 raphe - Type 1 | | | 2 raphes - Type 2 |
|---|---|---|---|---|---|---|
| |  | |  | | |  |
| | 21 (7) | | 269 (88) | | | 14 (5) |
| 1. subcategory: spatial position of cusps in Type 0 and raphes in Types 1 and 2 | lat 13 (4)  | ap 7 (2)  | L – R 216 (71)  | R – N 45 (15)  | N – L 8 (3)  | L – R / R – N 14 (5)  |
| 2. subcategory: | | | | | | |
| VALVULAR FUNCTION I | 6 (2) | 1 (0.3) | 79 (26) | 22 (7) | 3 (1) | 6 (2) |
| VALVULAR FUNCTION S | 7 (2) | 5 (2) | 119 (39) | 15 (5) | 3 (1) | 6 (2) |
| VALVULAR FUNCTION B (I + S) | | 1 (0.3) | 15 (5) | 7 (2) | 2 (1) | 2 (1) |
| VALVULAR FUNCTION No | | | 3 (1) | 1 (0.3) | | |

- Type 0 and 1 = bicuspid
- Type 1: commissural orientation ?  fusion complete / partial ?
- Type 2 = unicuspid

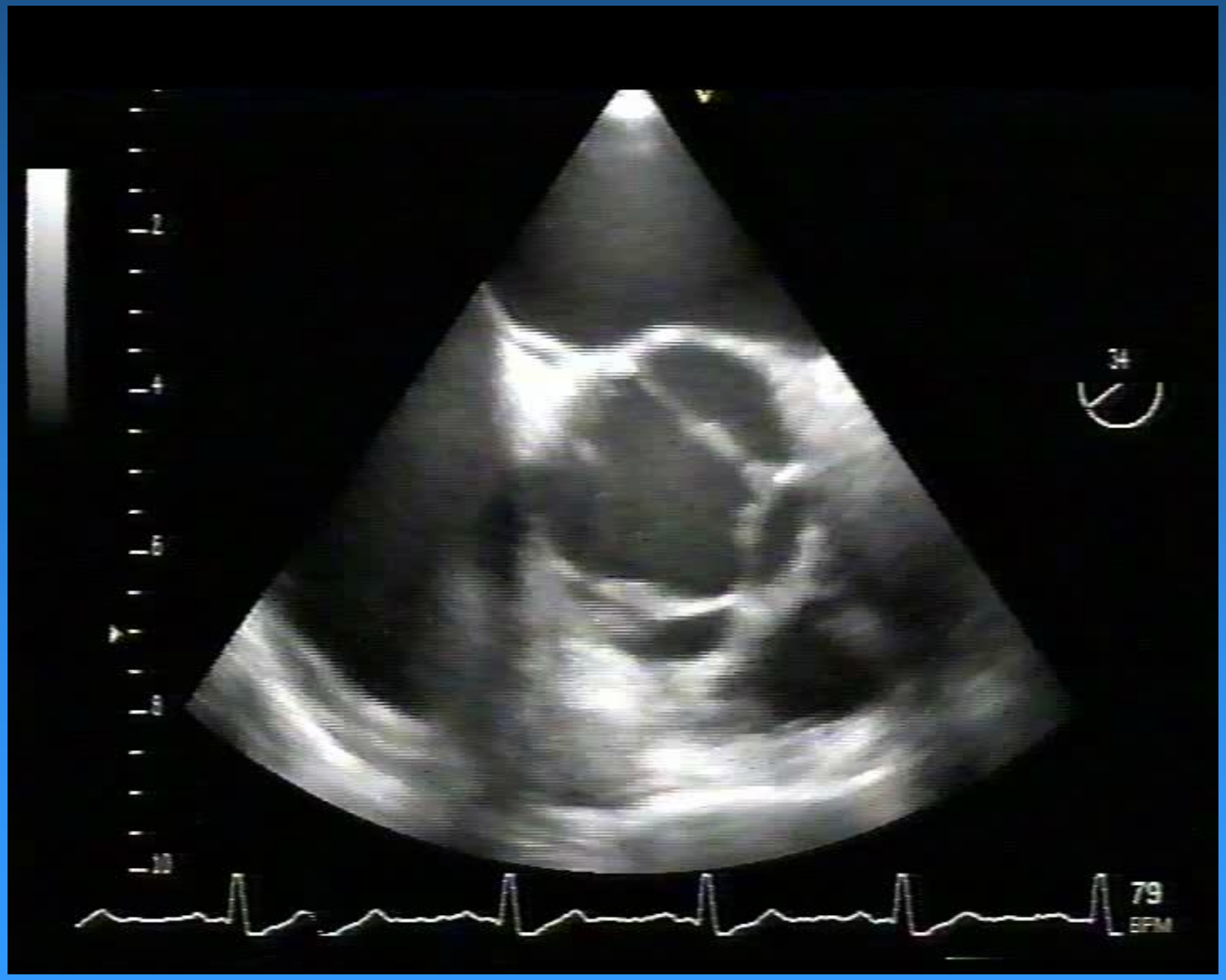
Sievers JTCVS 2007

# Congenital Variations: QAV



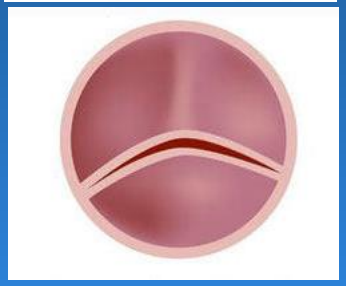
- Prevalence 0,01 - 0,04 %
- Seven different types (A-G)
- LCA displaced leftward/upward
- AR in 5th or 6th decade of life
- AS rare

# Congenital Variations: QAV

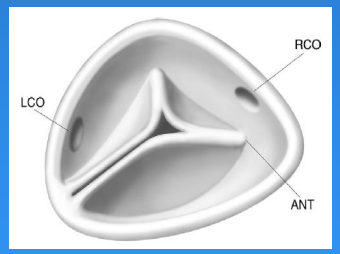


# Failure Modes in AR

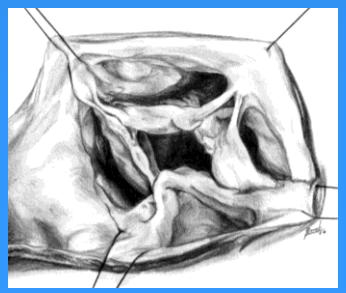
- prolapse
- retraction
- aortic dilatation



- prolapse of fused cusp
- annular dilatation




- commissural height
- annular dilatation



- restriction

# Conclusions

- The normal aortic valve function depends on correct interactions between root and cusp configuration.
- Different morphological cusp variants exist and may lead to aortic valve dysfunction.
- In reconstruction of the aortic valve the different cusp configurations and failure modes have to be considered as part of the repair strategy.