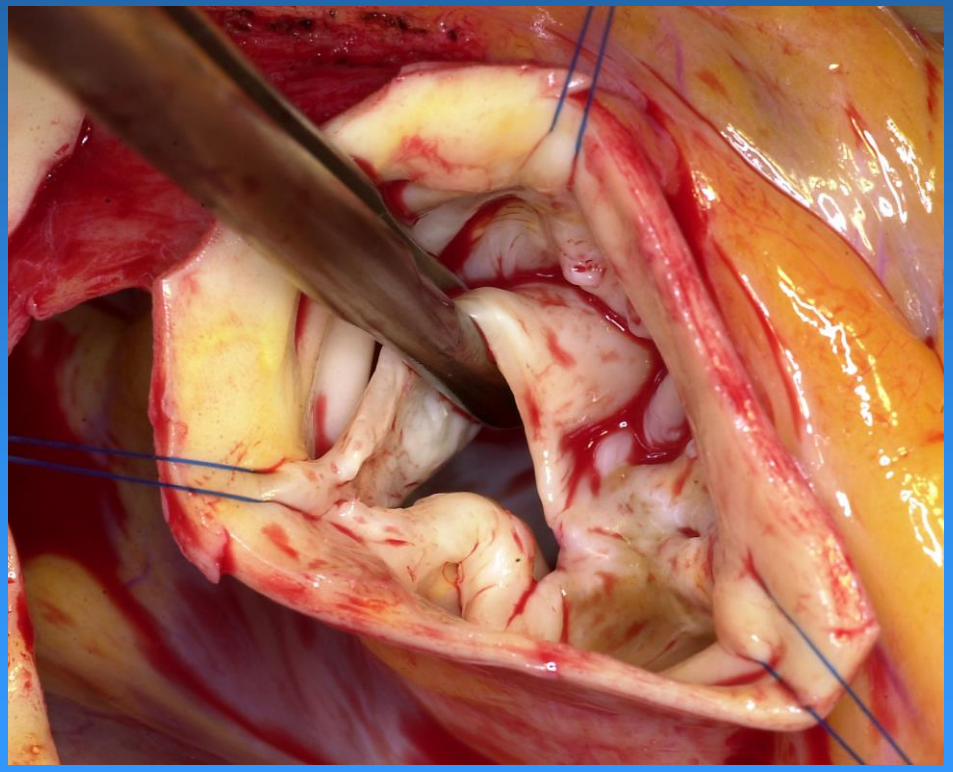
Anatomy of the Aortic Valve & Root

Frank Langer

Reconstruction of the Aortic Valve and Root



Sept 13-15, 2017

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YES: X / NO: X	YES: X / NO: X	YES: X / NO: X	YES: X / NO: X

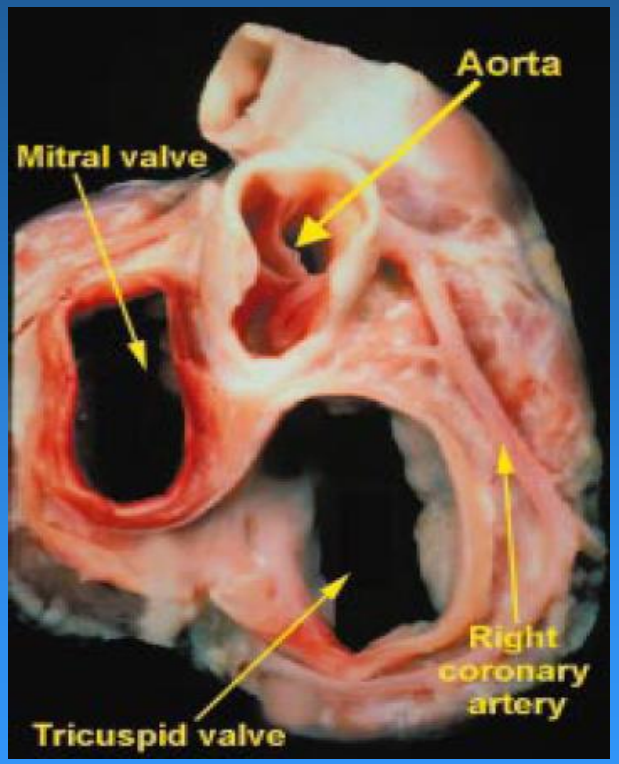
SCORE: 1234

Aortic Valve/Root Anatomy

- Location / Co-Location
- Anatomic Components
- Dimensions
- Dysfunction
- Congenital Variations

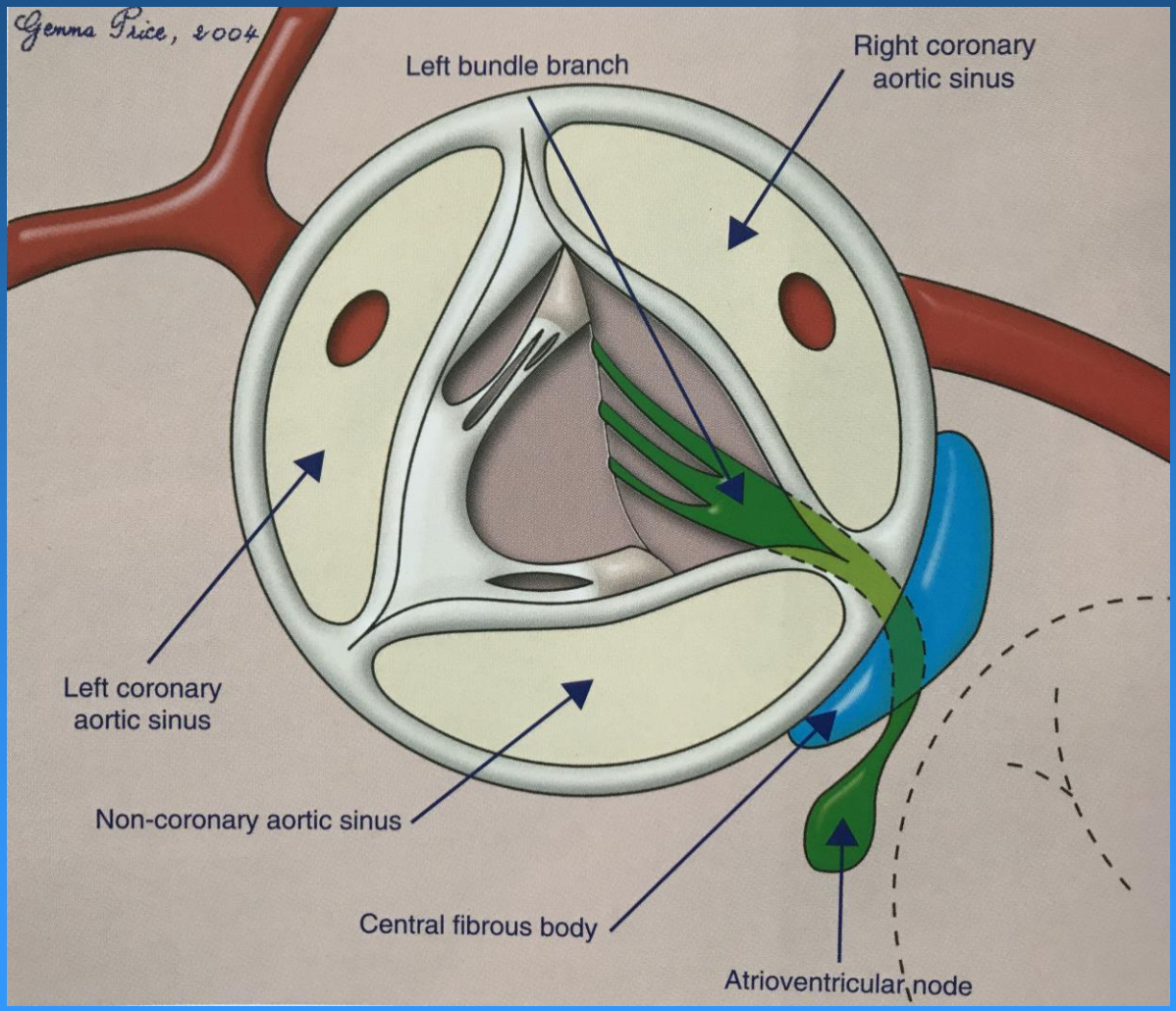
Aortic Root: Location

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



Anderson Heart 2000

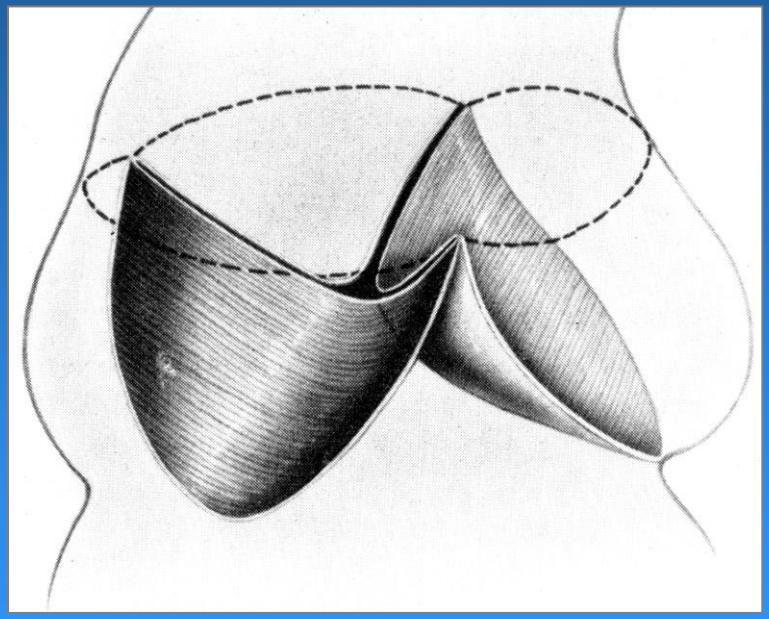
Co-Location



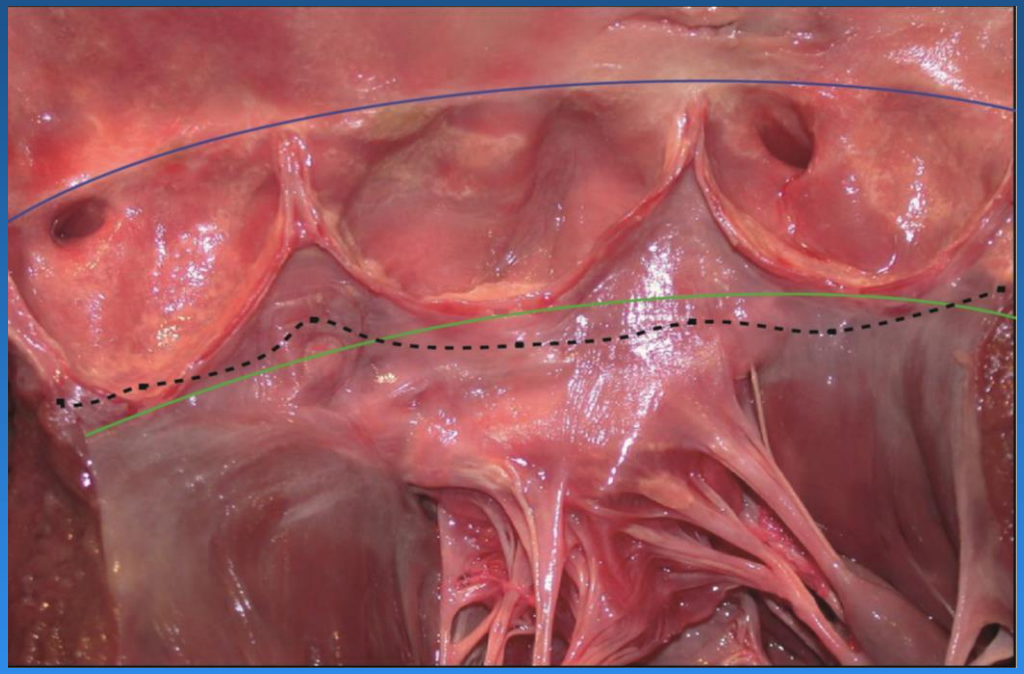
Wilcox Cook Anderson Cambridge 3rd ed

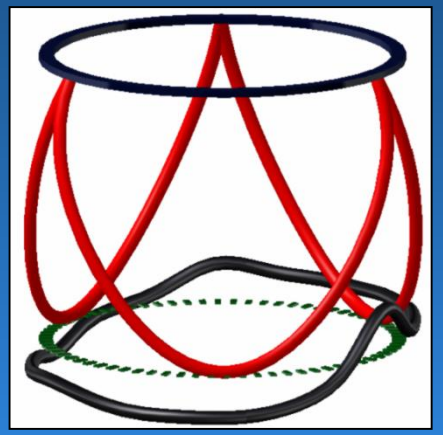
Aortic Annulus

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



Aortic Annulus = Ring ???

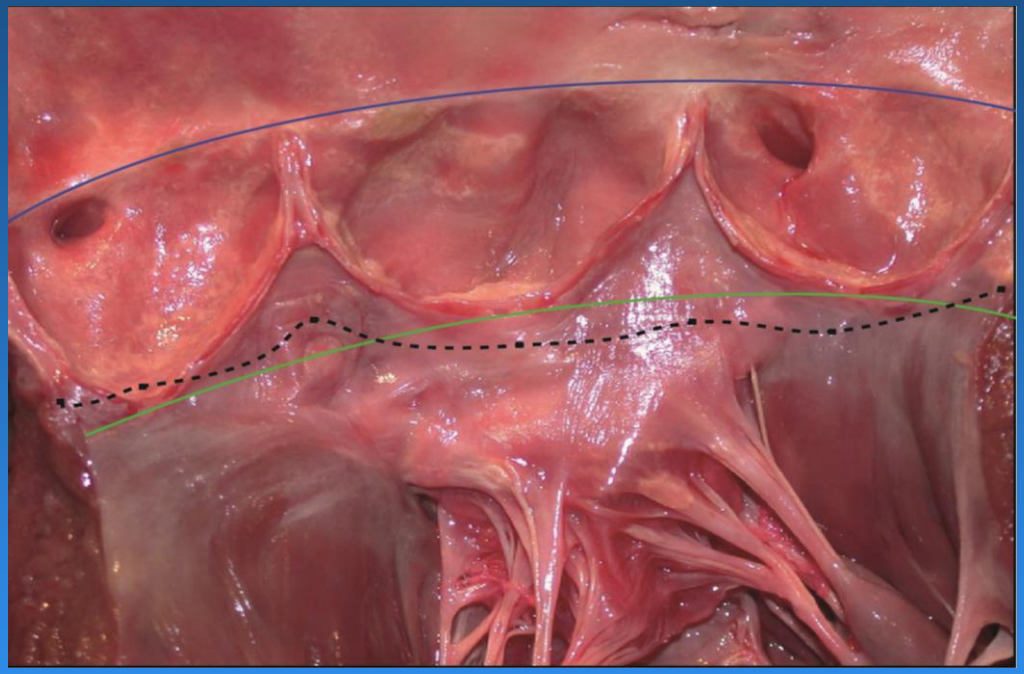


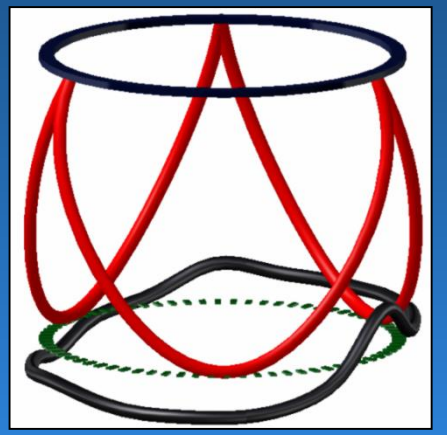


- Crown-shaped hemodynamic junction marked by semilunar attachments of the aortic cusps ?
- **Ring**-like ventriculo-arterial junction
- Ring-like joining base line of semilunar attachments (virtual) basal ring

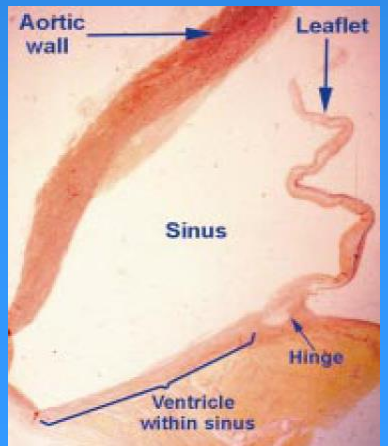
Courtesy of E. Lansac

Sinus Valsalvae





Non-coronary sinus fibrous (aorto-mitral continuity)

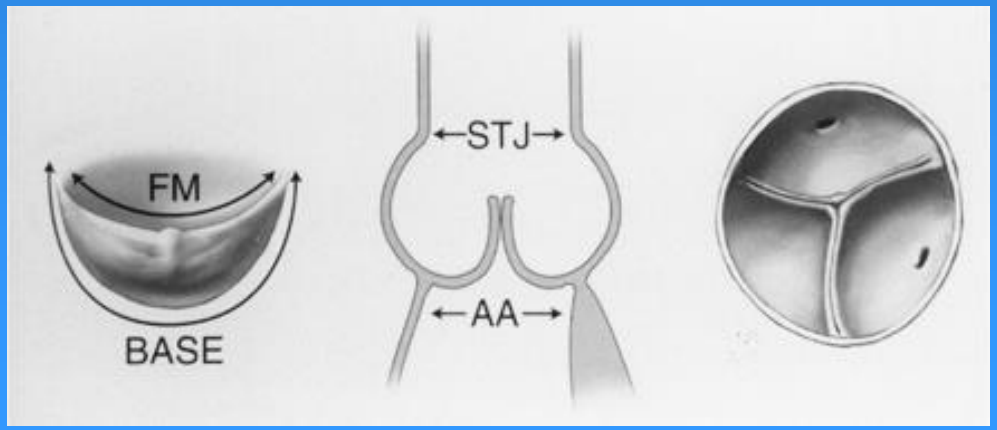


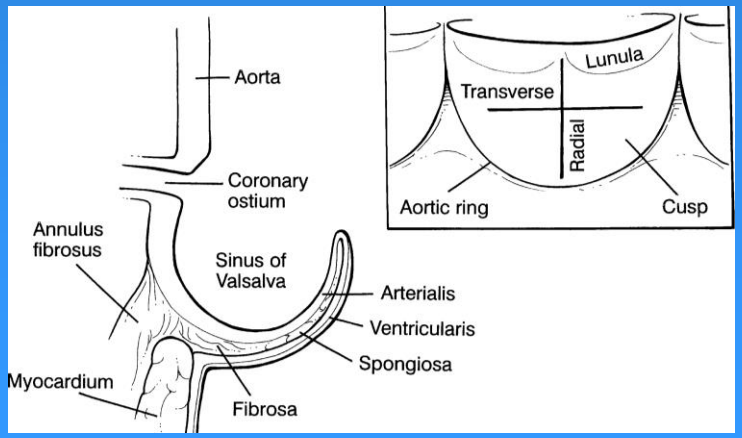
Crescents of LV musculature at base of left and right sinus (variably)

Anderson Heart 2000

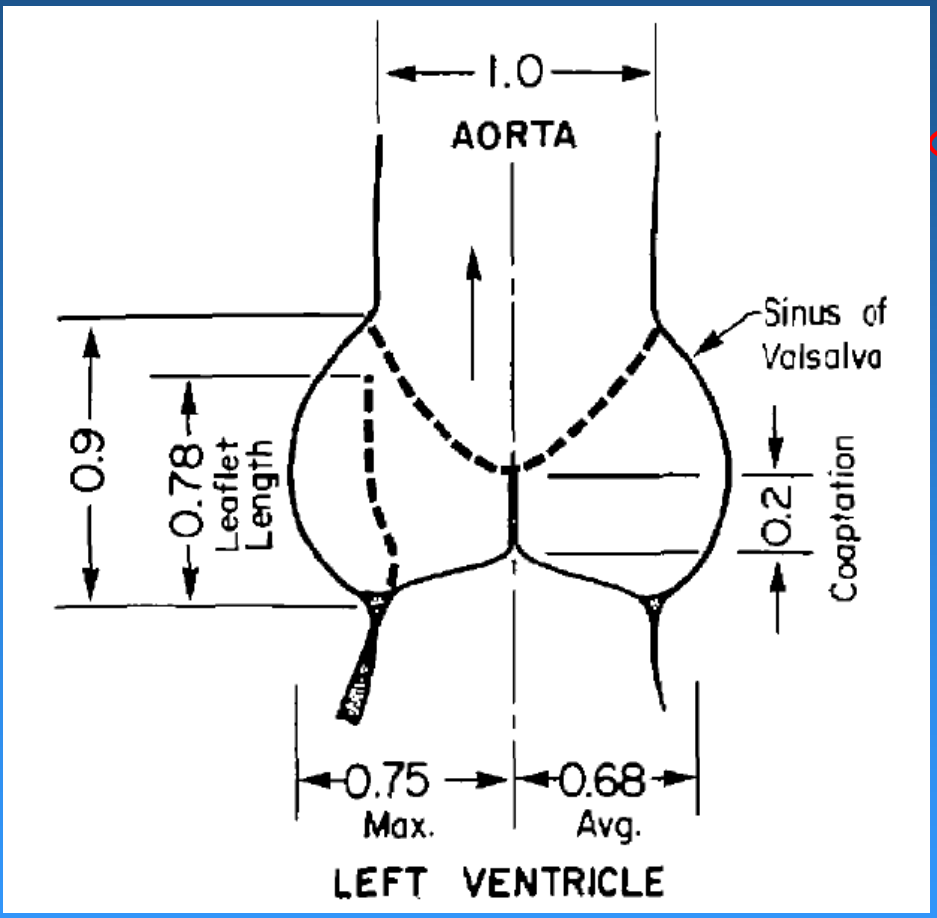
Aortic Cusps

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





Dimensions



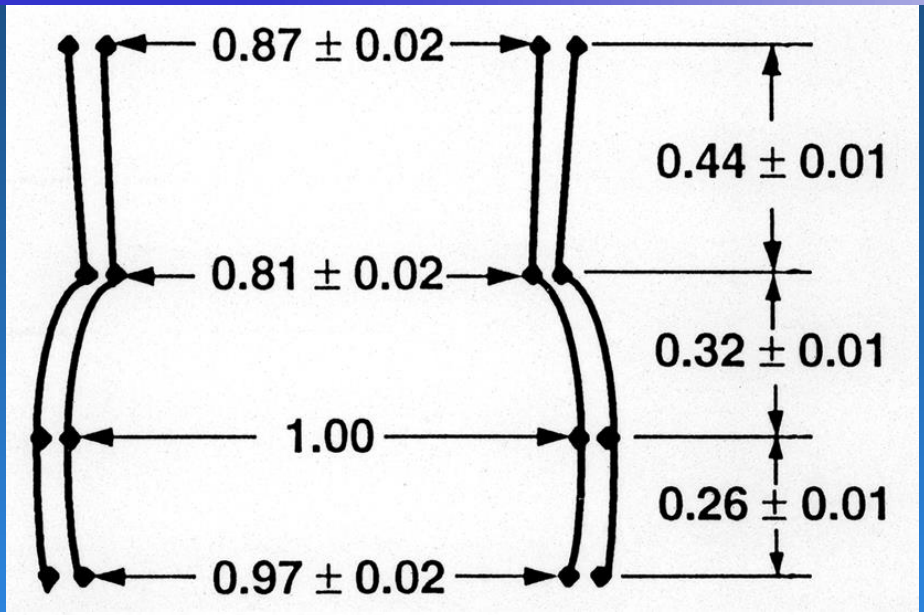
AORTIC GEOMETRY

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



10 normal cryopreserved tricuspid homografts

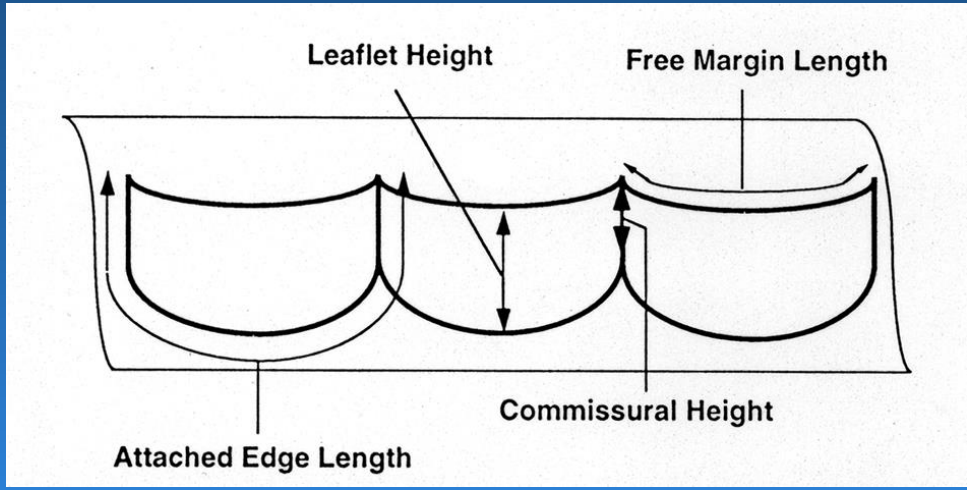
Human aortic root measurements

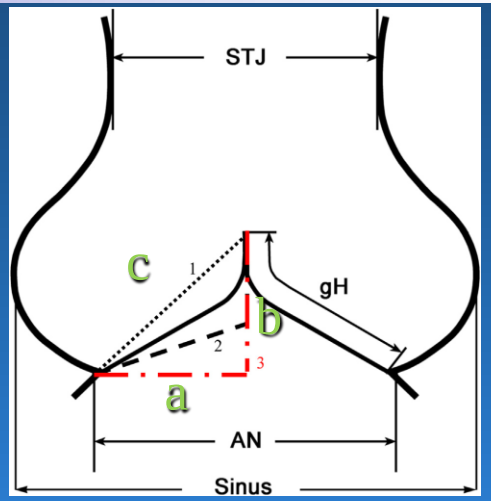
Level	Orifice area (cm^2)	Diameter (mm)*	Diameter (mm)†	Thickness (mm)	Interlevel distance (mm)
STJ_I	3.40 ± 0.38	21.1 ± 1.0	20.6 ± 1.0	1.9 ± 0.2	10.0 ± 0.0
STJ_0	2.98 ± 0.32‡	18.9 ± 0.9‡	19.3 ± 0.9‡	1.8 ± 0.2	7.3 ± 0.4
SINUS	4.49 ± 0.40§	22.4 ± 1.7§	23.7 ± 1.0§	1.3 ± 0.1	62.4 ± 0.4
BASE	4.24 ± 0.44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





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

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

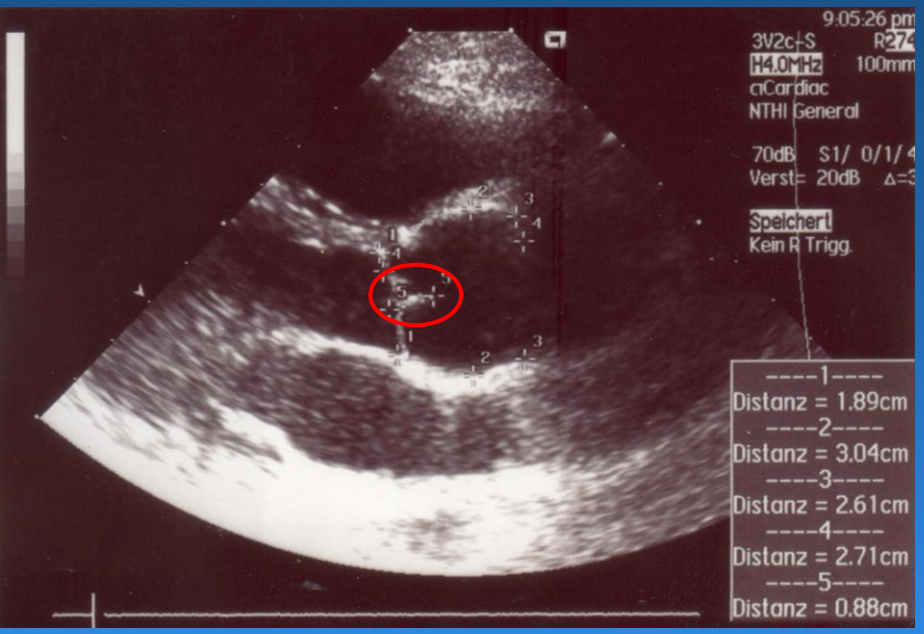
Human aortic leaflet dimensions

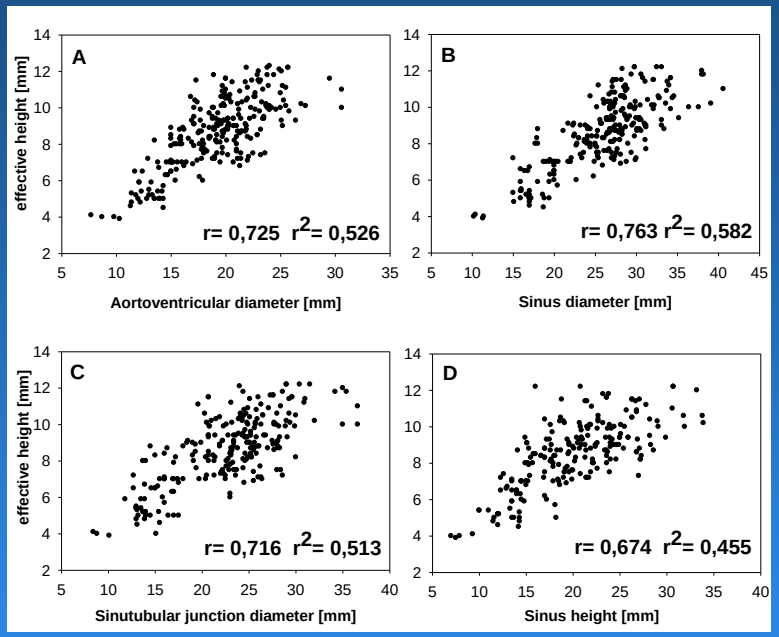
	Right	*Left*	*Noncoronary*	*Average*
Height (cm)	1.33 ± 0.06	1.39 ± 0.08	1.37 ± 0.04	1.36 ± 0.06
Free margin length (cm)	3.30 ± 0.14	3.15 ± 0.14*	3.27 ± 0.13	3.24 ± 0.13
Attached edge length (cm)	4.64 ± 0.20	4.76 ± 0.22	4.81 ± 0.16	4.74 ± 0.19
Perimeter (cm)	7.94 ± 0.33	7.91 ± 0.35	8.08 ± 0.28	7.98 ± 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





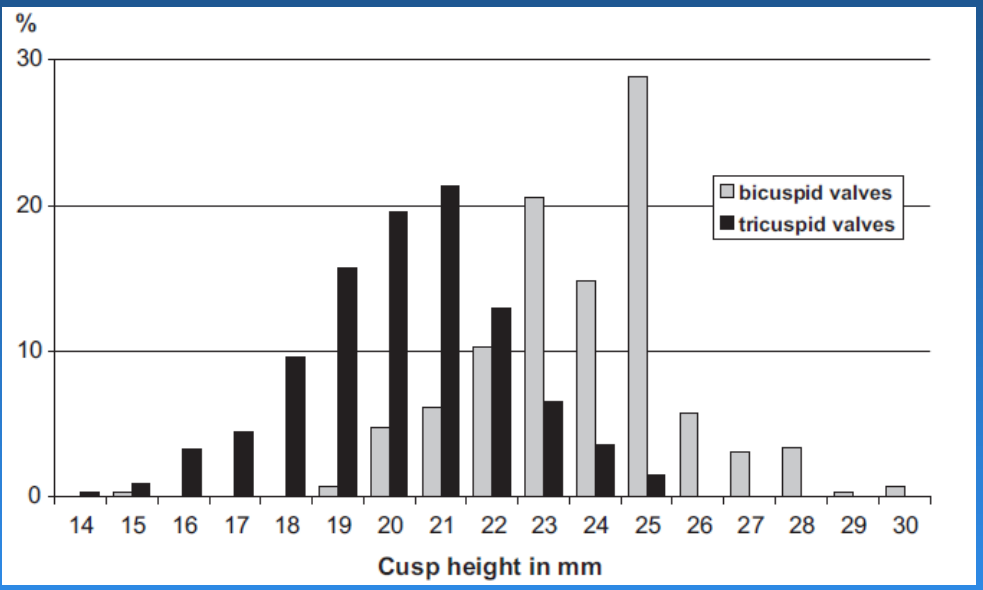
	Adults, $n = 100$
Age (years)	33.8 ± 14 (19–76)
Body height (m)	1.75 ± 0.09 (1.5–2)
Body weight (kg)	71.9 ± 12.6 (42–105)
Body surface area (m^2)	1.87 ± 0.2 (1.35–2.4)
Effective height (mm)	9.5 ± 1.4 (7–12)
Aortoventricular diameter (mm)	21 ± 2.8 (13.5–30.6)
Sinus Valsalva diameter (mm)	28.5 ± 3.5 (21.1–40)
Sinutubular junction (mm)	25 ± 3.7 (16–36.6)
Sinus height (mm)	22.4 ± 4.2 (33.9)

Effective height measured in

130 healthy volunteers (TTE: 100 adults, 30 children)

Bierbach Eur JCTS 2010

Dimensions



Variable	BAVs		TAVs	
	r	*P* Value	*r*	*P* value
Age	–0.263	.000	–0.155	.005
Female gender	–0.290	.000	–0.520	.000
Body height	0.305	.000	0.472	.000
Body weight	0.150	.012	0.391	.000
BSA	0.202	.001	0.444	.000
BMI	–0.023	.703	0.151	.007
Preoperative AR	0.248	.000	–0.075	.172
AV junction (TEE)	0.363	.000	0.584	.000
AV junction (intubation)	0.360	.000	0.530	.000
Sinus diameter	0.201	.002	0.492	.000
STJ diameter	0.196	.002	0.343	.000

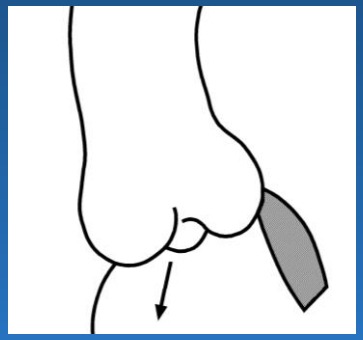
Geometric height measured intraoperatively in 621 patients:

BAV non-fused cusp 23.8 ± 2.0 mm

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

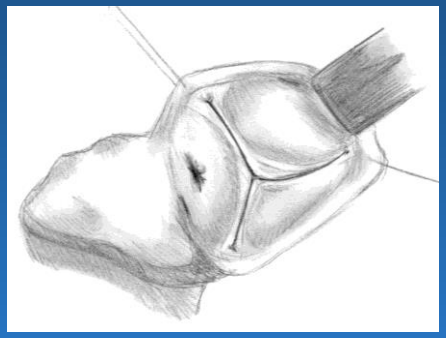
Schäfers JTCVS 2013

Dysfunction of Aortic Cusps



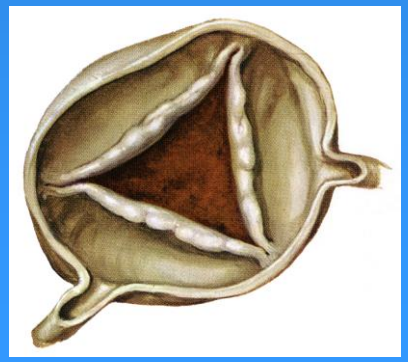
Prolapse

Perforation

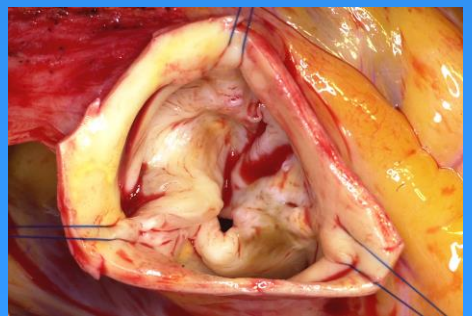


Cusps

Retraction



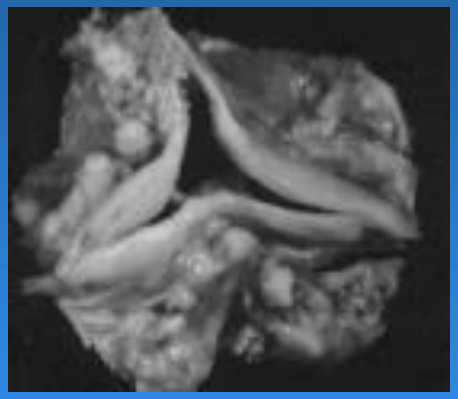
Congenital Malformation



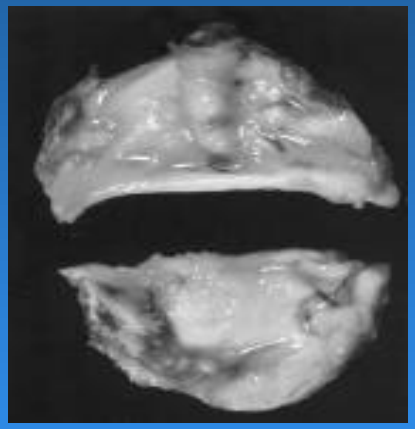
Fenestration

Congenital Variations

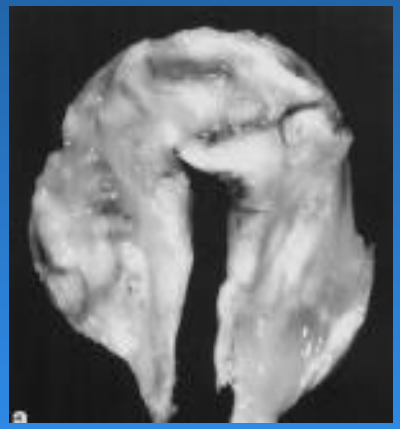
Valve specimens after AVR



TAV
45 %



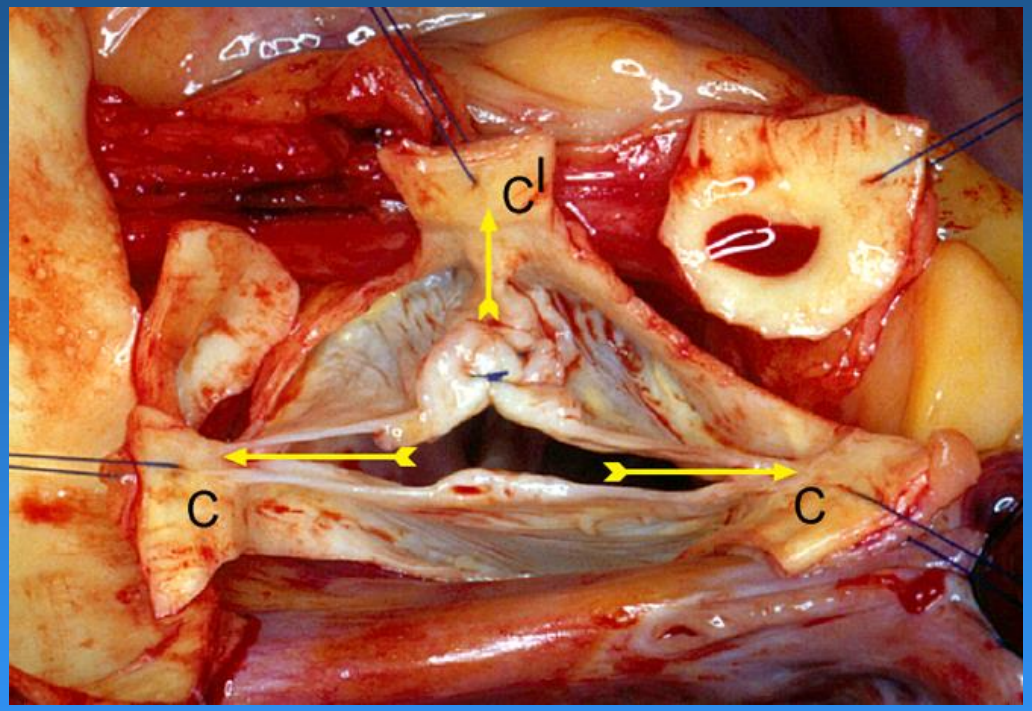
BAV
49 %

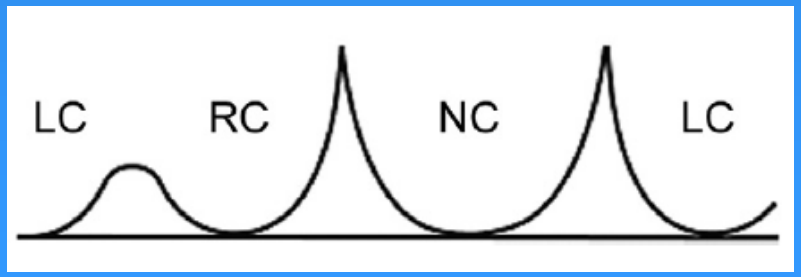


UAV
5 %

Roberts CIRC 2005

Congenital Variations: BAV

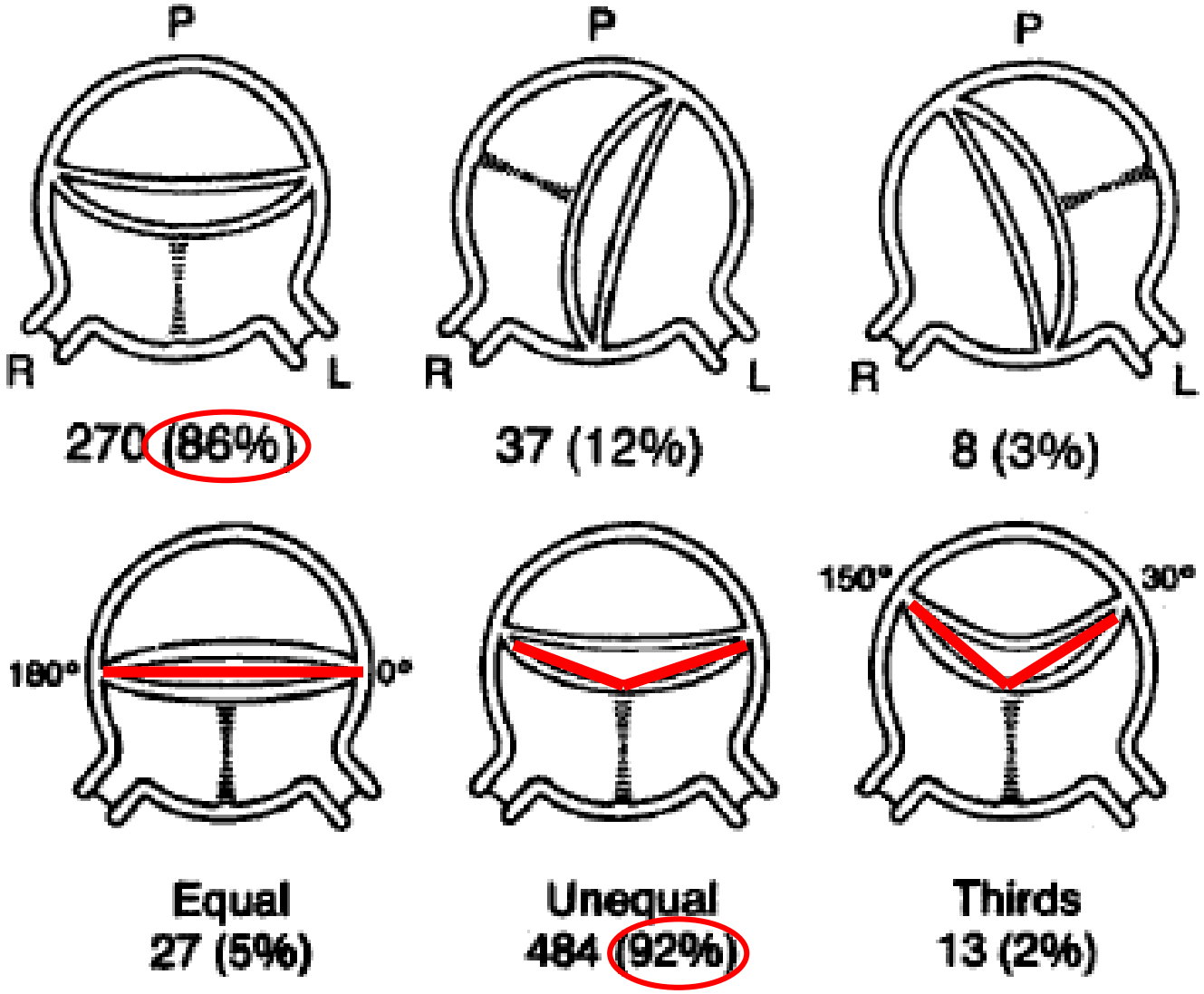




- Prevalence 1 – 2 %
- Aortopathy in 40 – 60 %

Nistri Heart 1999
Masri Heart 2017

Congenital Variations: BAV



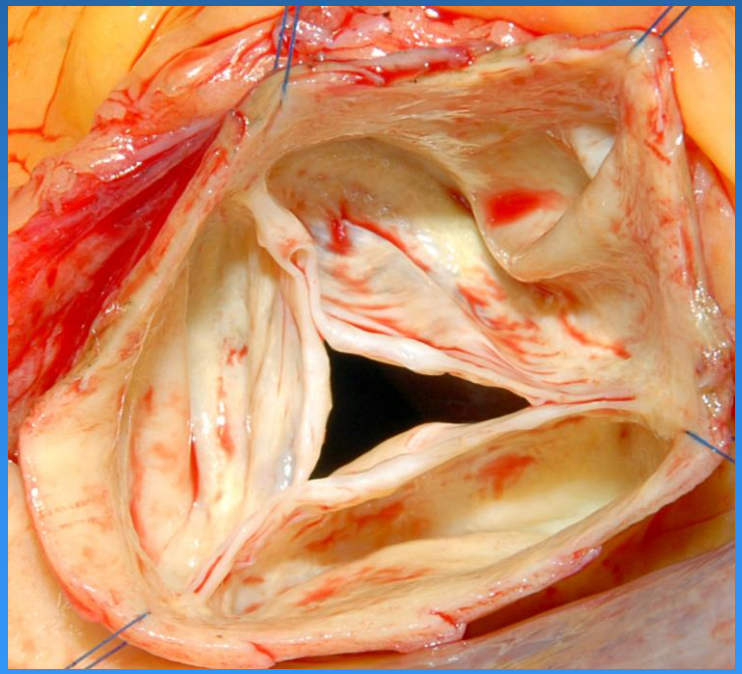
Cusp fusion

Commissural orientation

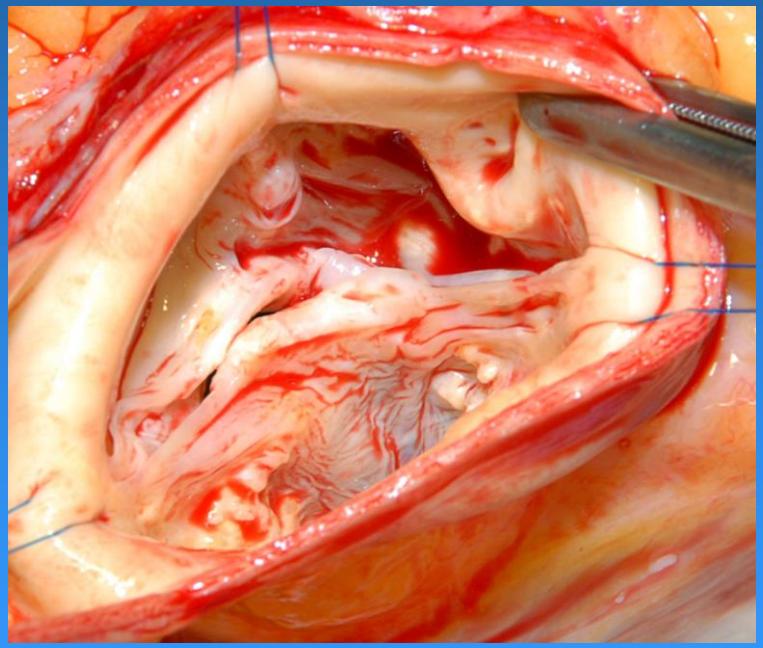
Sabet Mayo Clin Proc 1994

Congenital Variations: BAV

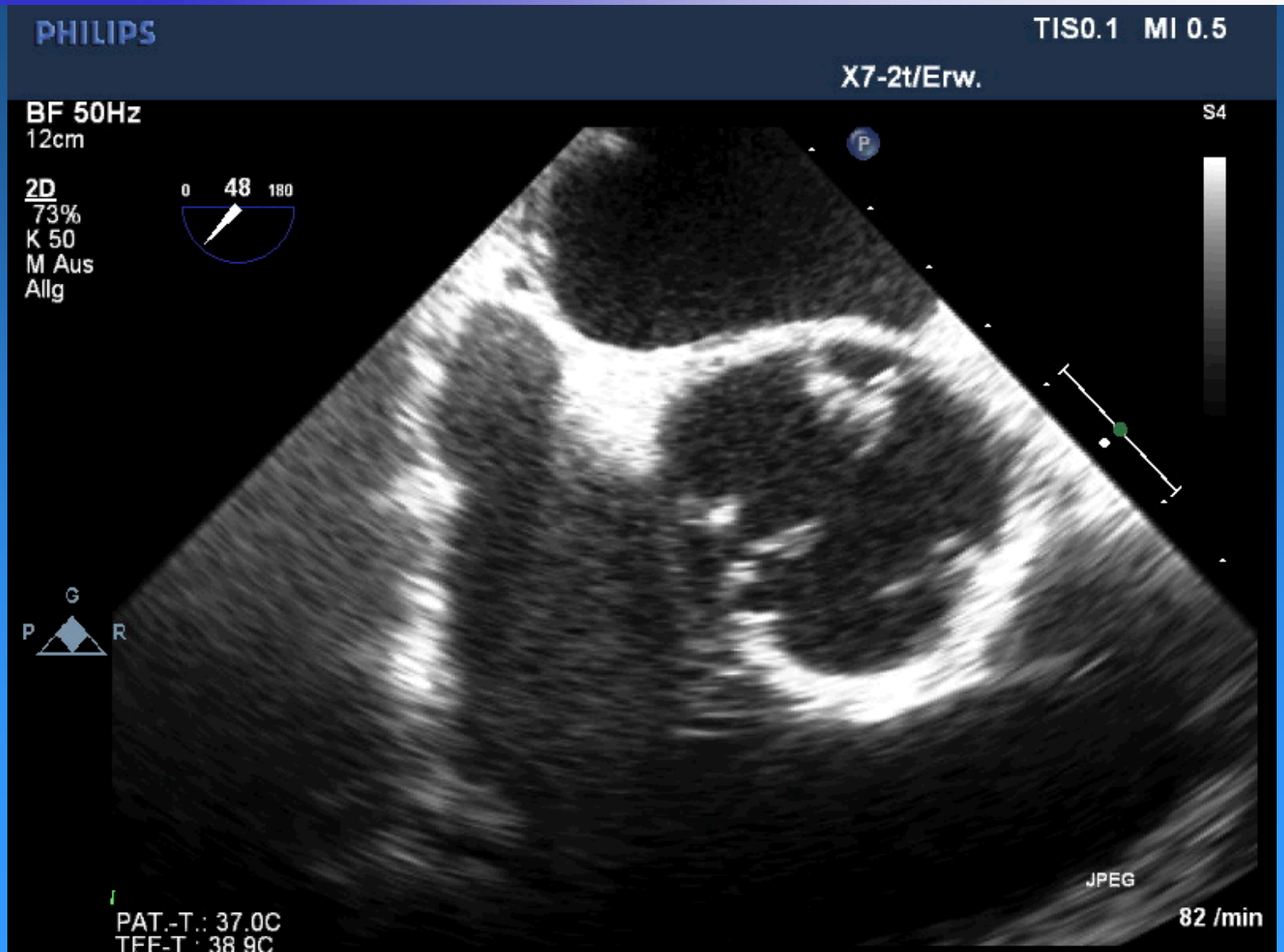
Partial Fusion (?)



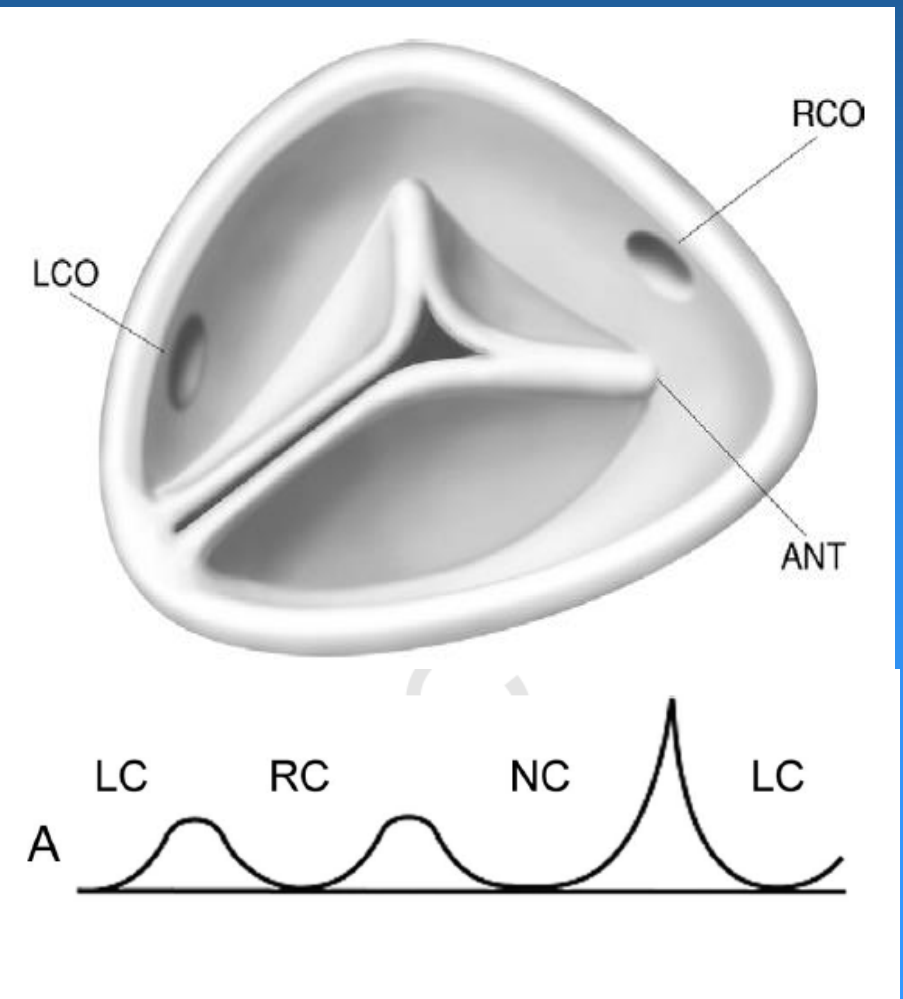
Complete Fusion



Congenital Variations: BAV



Congenital Variations: UAV



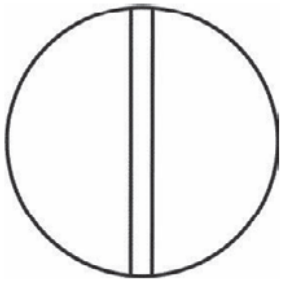
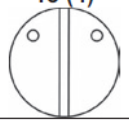
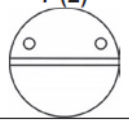
- Prevalence 0,02 %

- 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

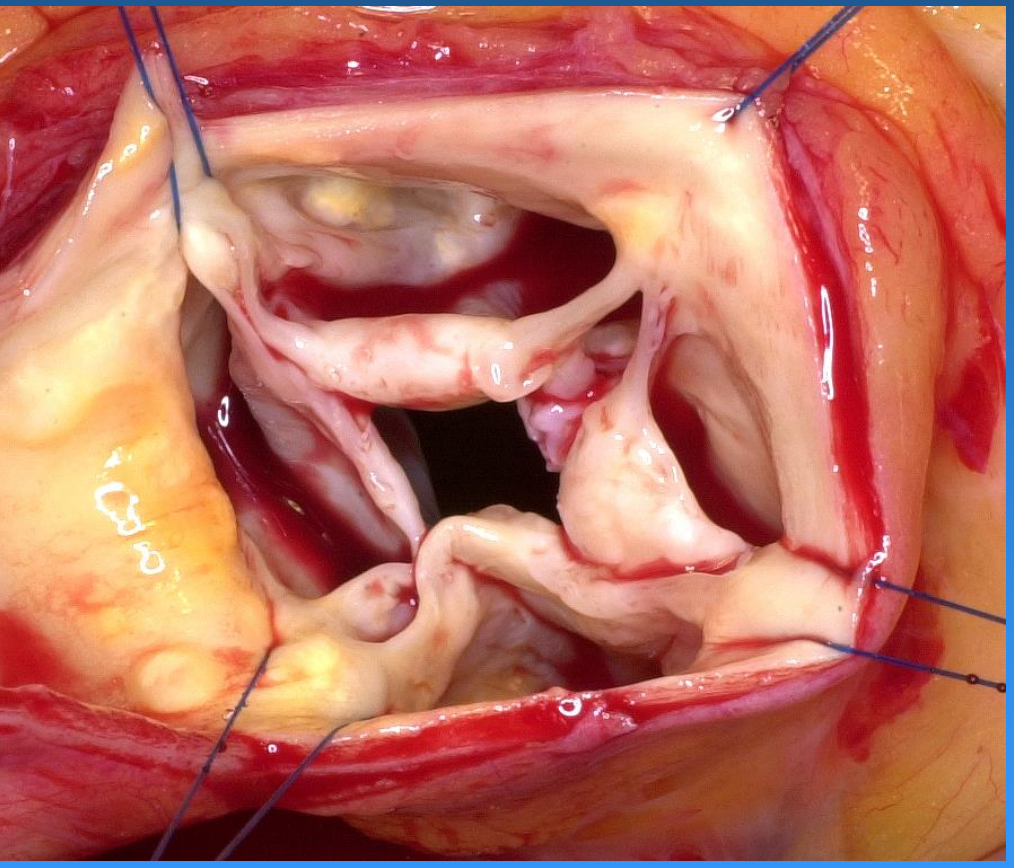
Congenital Variations

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

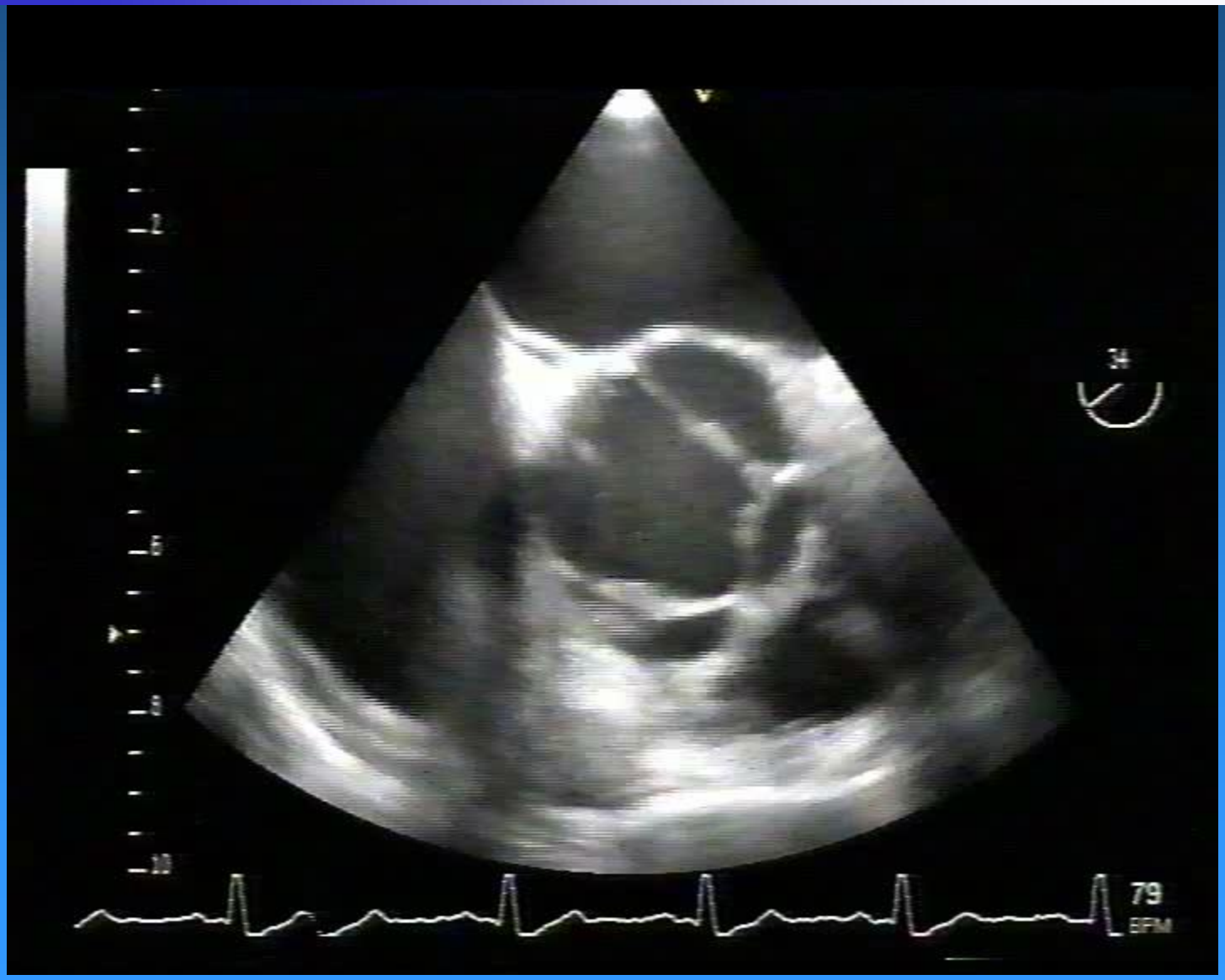
Sievers JTCVS 2007

Congenital Variations: QAV



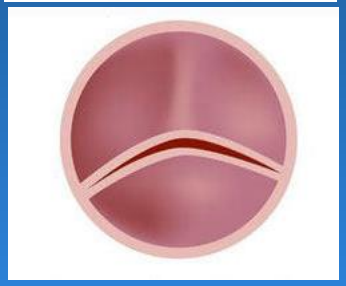
- Prevalence 0,01 - 0,04 %
- Seven different types (A-G)
- LCA displaced leftward/upward
- AR in 5th or 6th decade of life
- AS rare

Congenital Variations: QAV

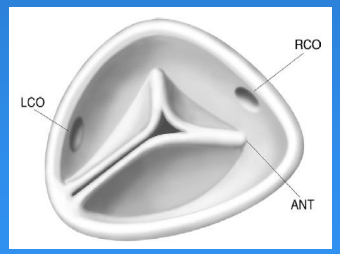


Failure Modes

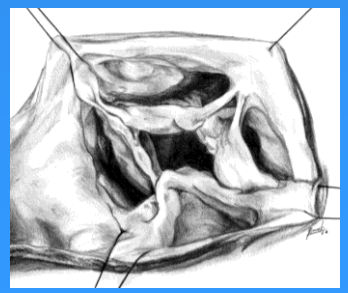
- prolapse
- retraction
- annular dilatation



- prolapse of fused cusp
- annular dilatation



- calcification
- commissural height
- annular dilatation



- restriction

Conclusions

- The normal aortic valve function depends on correct interactions between root and cusp configuration.
- The natural aortic valve is ideally designed for unobstructed LV ejection and valve closure.
- Different cusp pathologies and morphological 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.