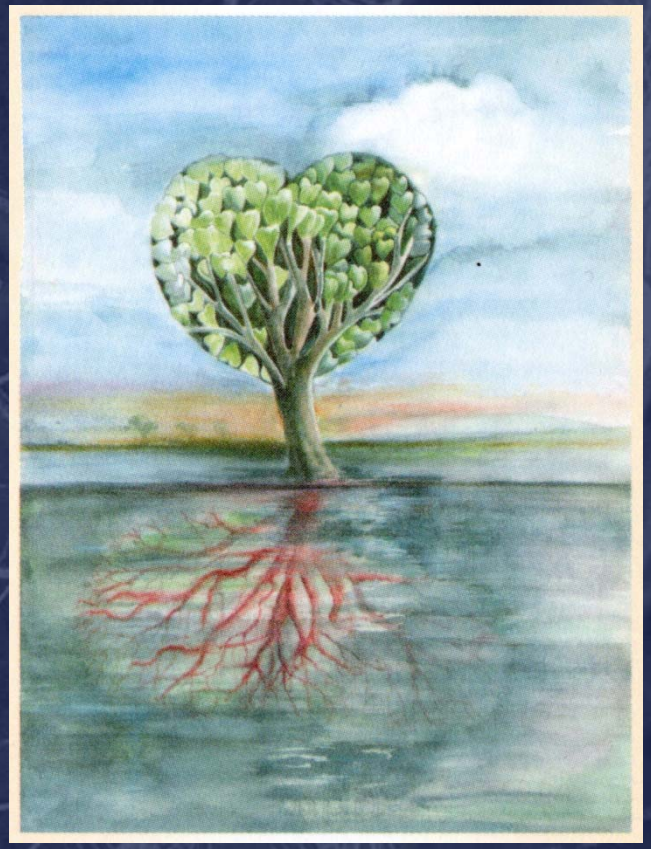

Functional anatomy of aortic regurgiation

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Brussels, Belgium

Functional Anatomy of Aortic Regurgitation

What are the prerequisites to successful aortic valve repair ?

Functional Anatomy of Aortic Regurgitation

1- To have a clear understanding of the mechanisms of aortic valve dysfunction

Functional Anatomy of Aortic Regurgitation

Lessons from mitral valve repair

« Surgeons are not basically concerned with lesions. We care more about function. Therefore one may define the aim of a valve reconstruction as restoring normal valve fonction rather than normal valve anatomy »

A. Carpentier. The « French Correction » 1983

Functional Anatomy of Aortic Regurgitation

Lesson n°1 : Perform a thorough valve analysis

- Identification of the mechanism / dysfunction causing mitral valve dysfunction is key to a successful repair.
- This requires a systematic and thorough valve analysis, which will help in choosing the appropriate repair techniques.

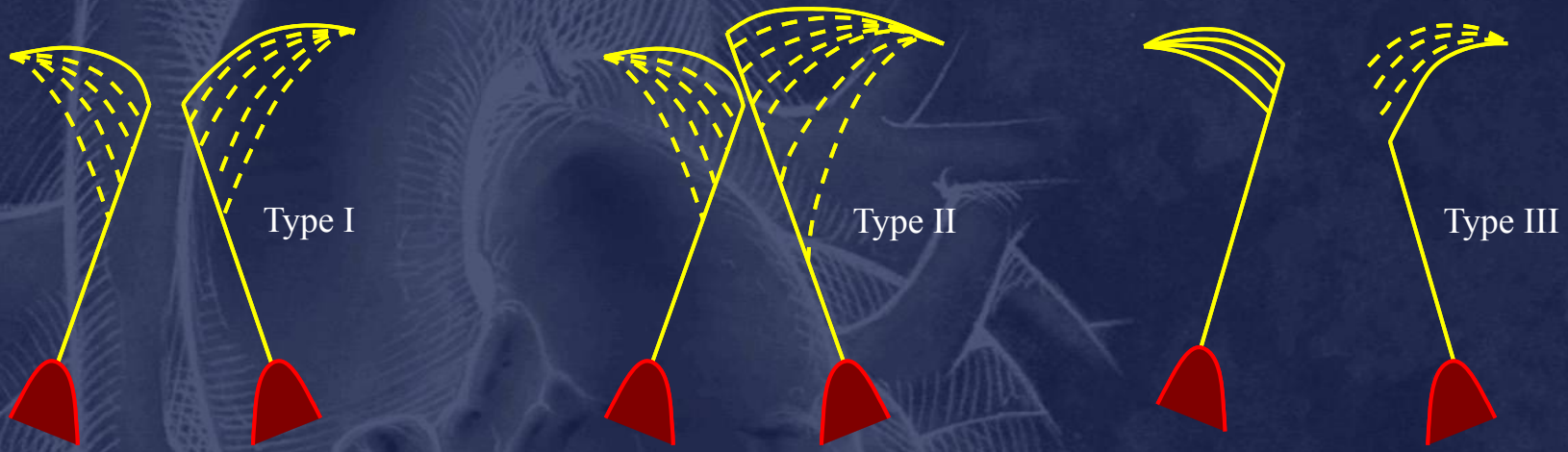
Functional Anatomy of Aortic Regurgitation

Lesson n°2 : Look for multiple dysfunctions

- Mitral regurgitation can have several concomitant causes / dysfunctions.
- Failure to identify each and every dysfunction will lead to incomplete surgical correction and is a frequent cause of immediate and late repair failure.

Functional Anatomy of Aortic Regurgitation

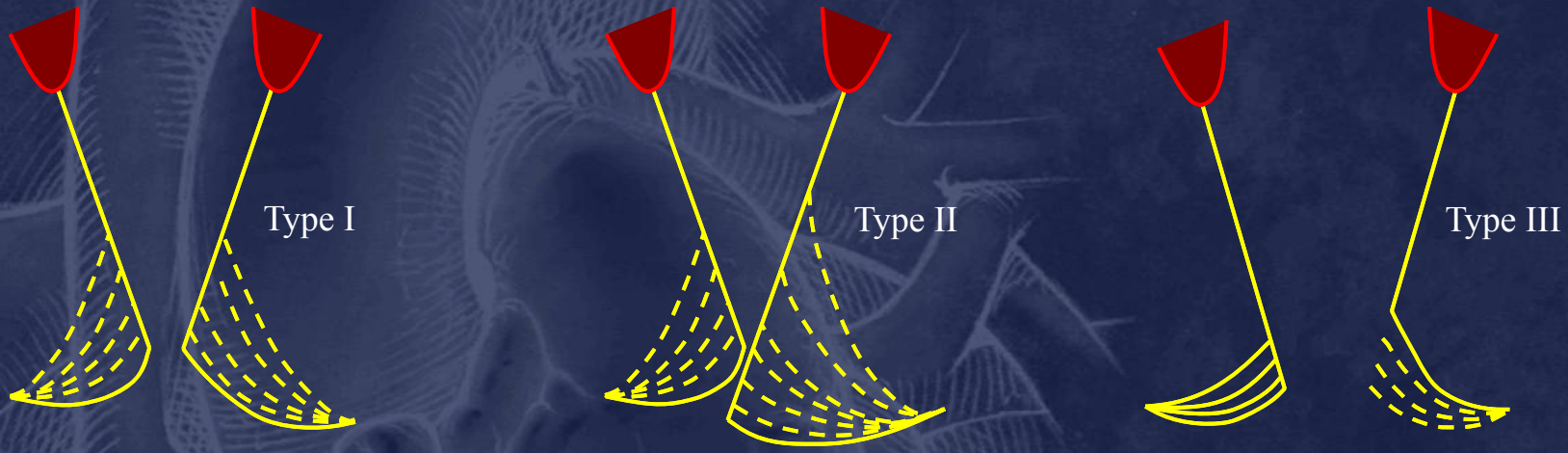
Carpentier's classification of mitral valve dysfunction



Dysfunction	Lesions
Type I : normal motion	• Annular dilatation • Leaflet perforation
Type II : excess leaflet motion	• Chordal rupture or elongation • Papillary muscle rupture or elongation
Type III : restricted leaflet motion	• Commisural ± chordal fusion • Valve thickening and/or calcification

Functional Anatomy of Aortic Regurgitation

El Khoury's classification of aortic valve dysfunction



Dysfunction	Lesions
Type I : normal motion	• Annular (FAA) dilatation • Cusp perforation
Type II : excess leaflet motion	• Cuspal prolapse (spontaneous or surgical) • Commisural disruption
Type III : restricted leaflet motion	• Commisural • Valve thickening and/or calcification

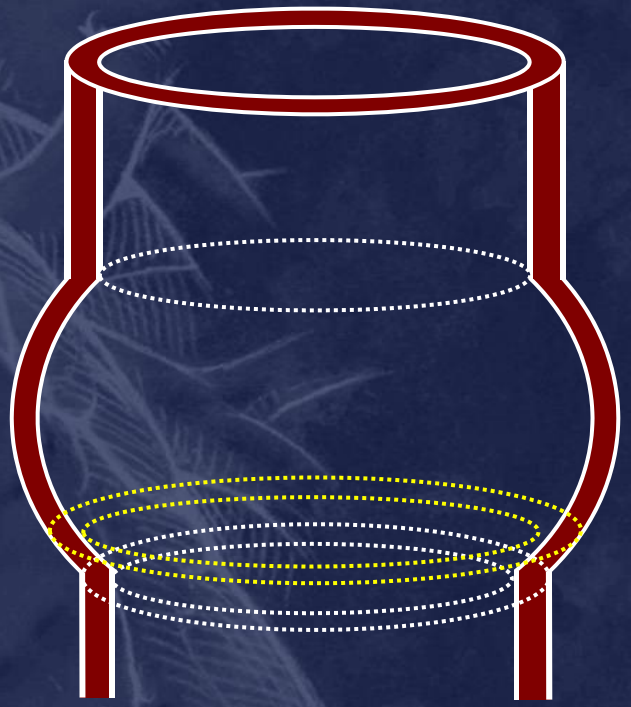
Functional Anatomy of Aortic Regurgitation

~~Lesson n°3 : Stabilize the repair by a ring annuloplasty~~

- Mitral regurgitation leads to mitral annulus dilatation which in turn aggravates the severity of regurgitation.
- Leaflet repair should always be accompanied by a ring annuloplasty, to restore the matching between leaflet and annulus area.

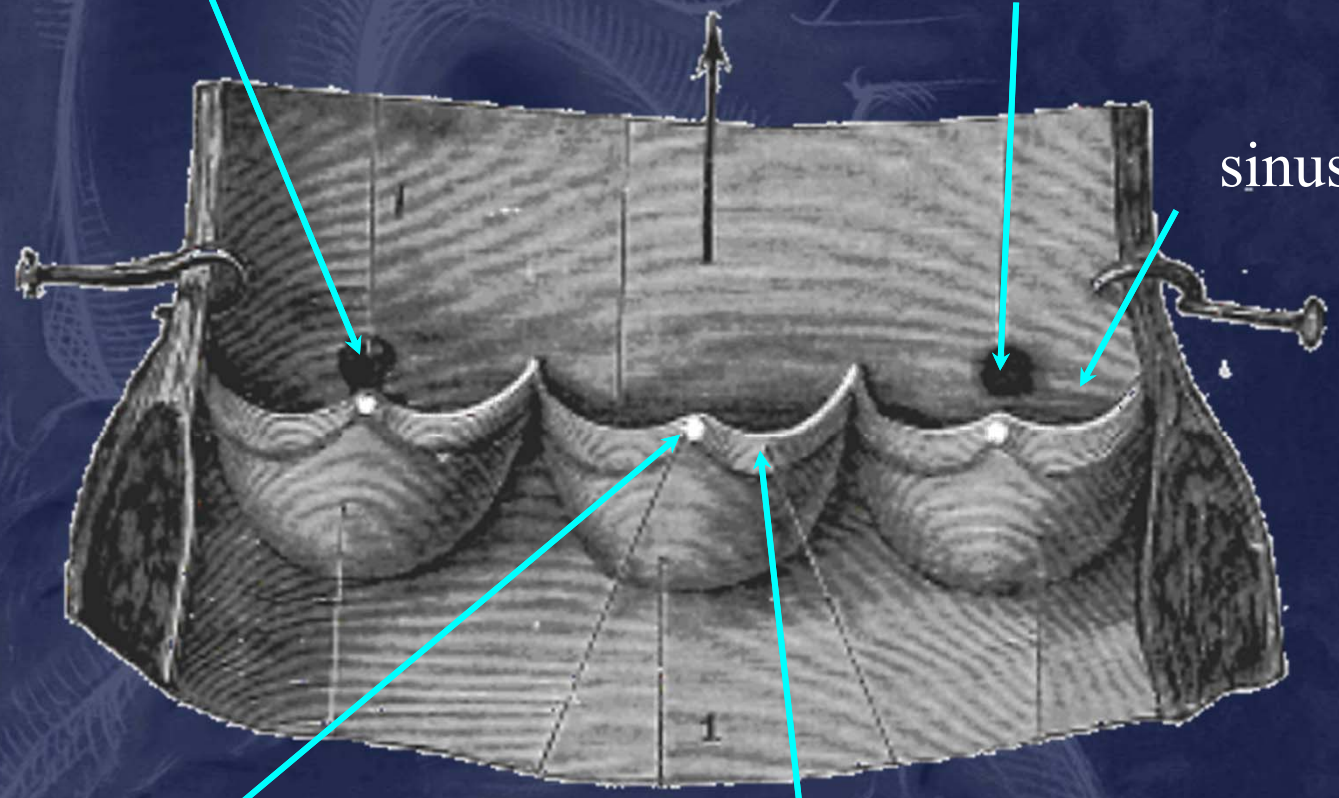
Functional Anatomy of Aortic Regurgitation

- Sinotubular junction
- Commissures
- Aortic cusps
- Valsalva sinuses
- Aorto-ventricular junction
- Aortic annulus



Functional Anatomy of Aortic Regurgitation

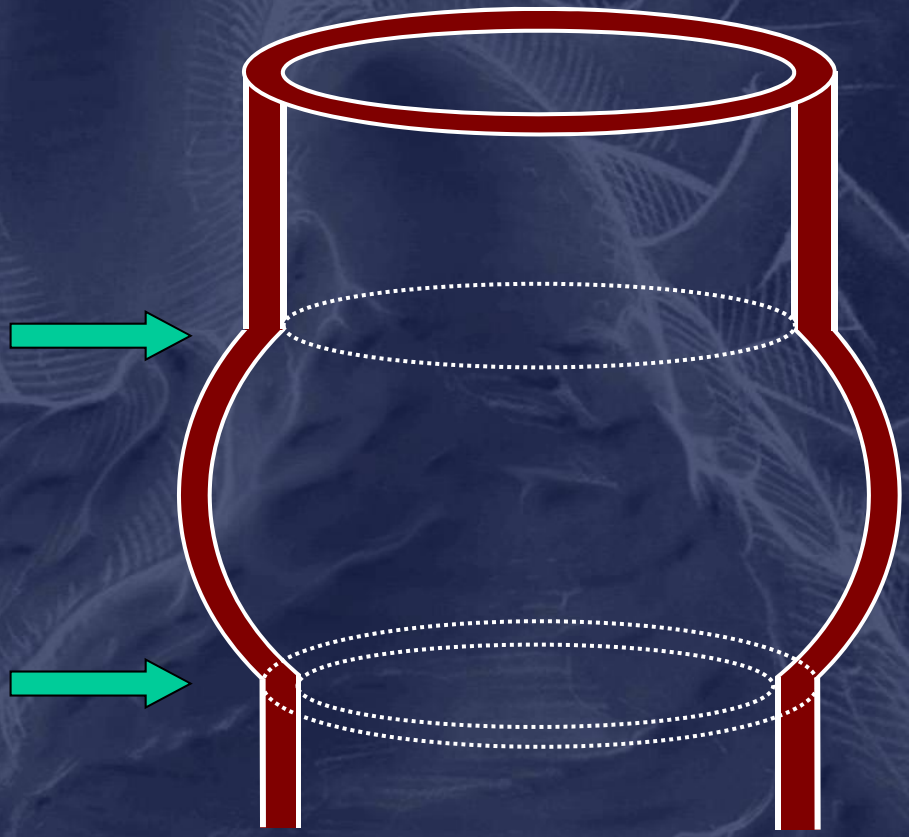
The normal aortic root and valve



Functional Anatomy of Aortic Regurgitation

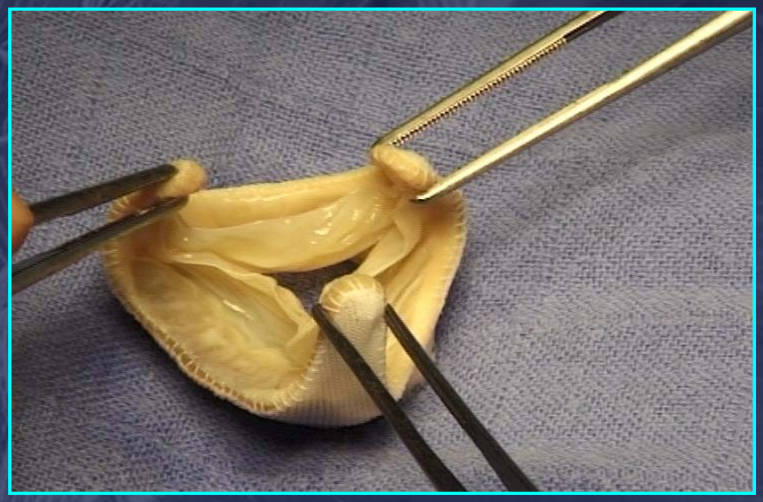
Functional Anatomy of Aortic Regurgitation

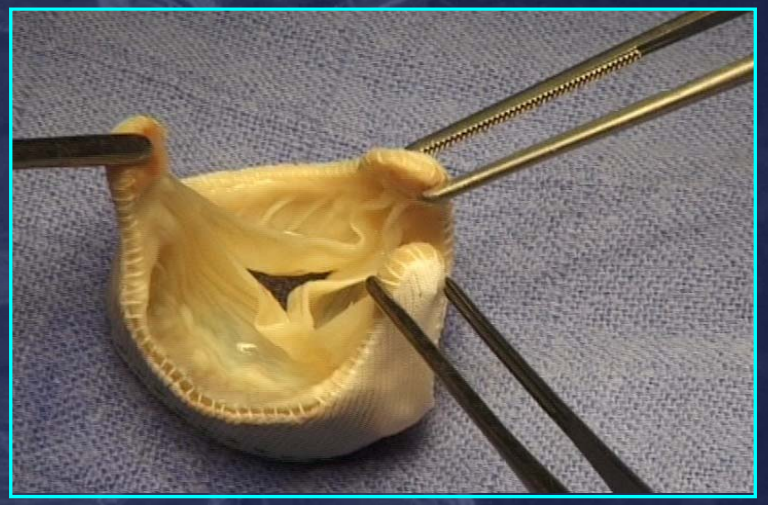
The functional aortic annulus



Functional Anatomy of Aortic Regurgitation

The functional aortic annulus



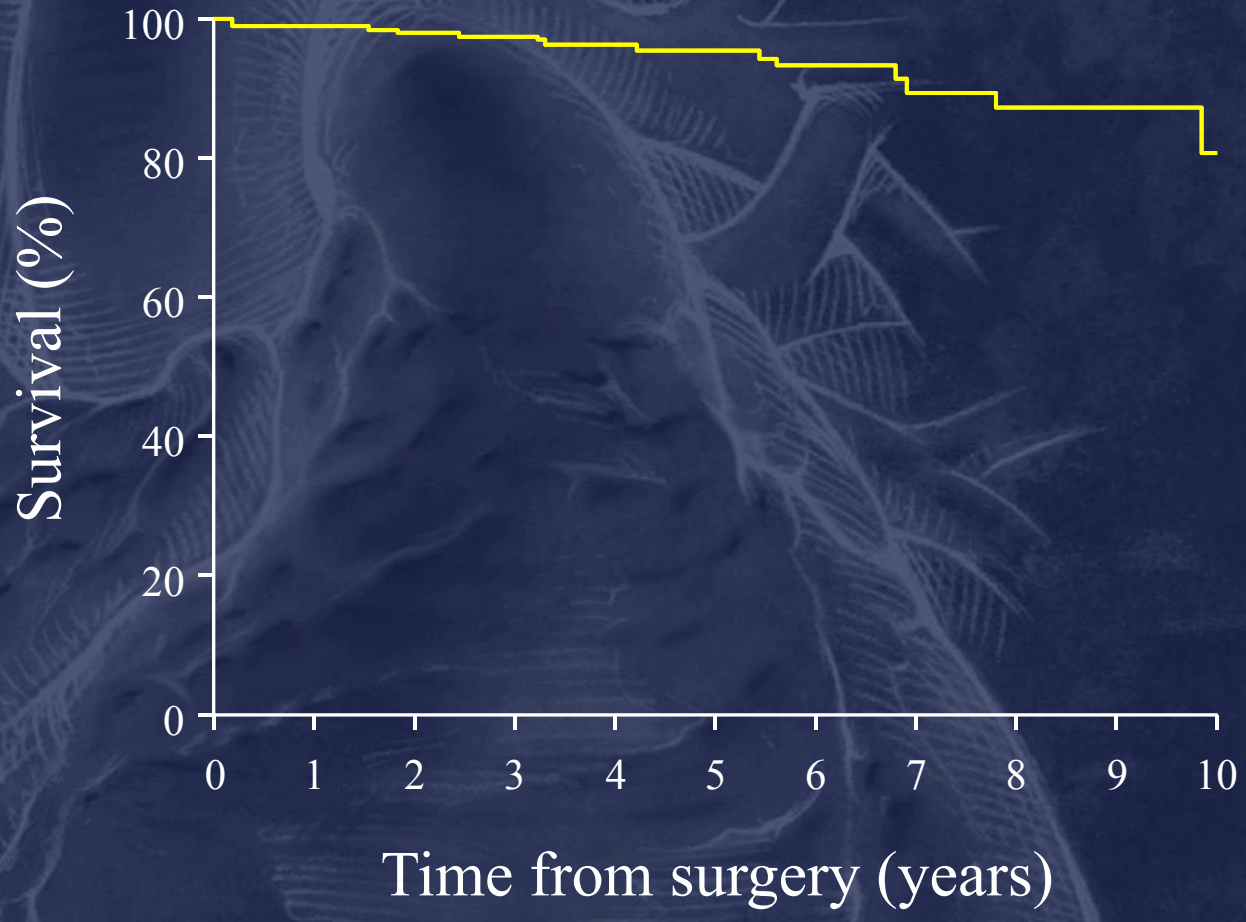


Functional Anatomy of Aortic Regurgitation

2- To understand the anatomical features associated with post post-operative results

Functional Anatomy of Aortic Regurgitation

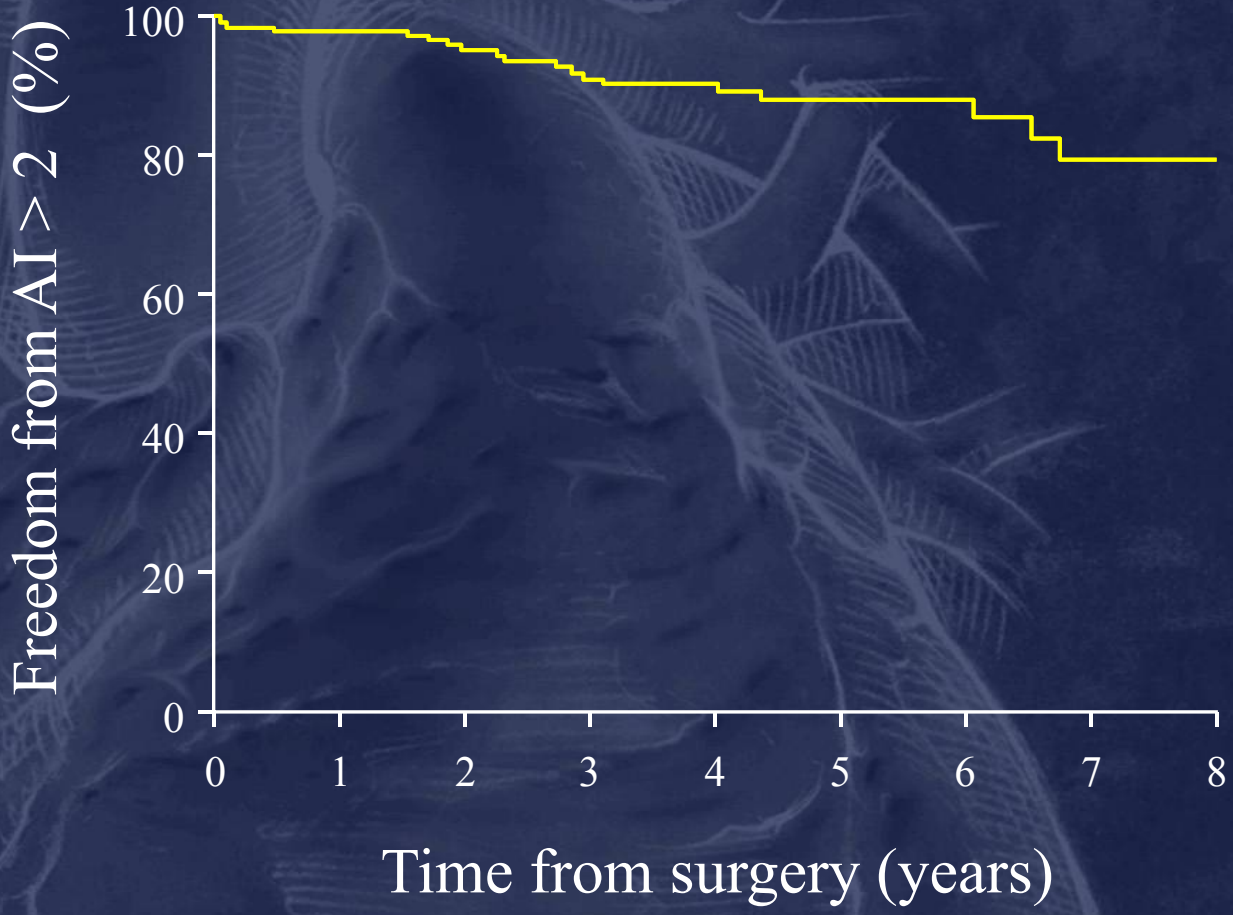
Outcome after aortic valve repair : long-term survival



Boodhwani et al., *J Thorac Cardiovasc Surg* 2009;137:286-294

Functional Anatomy of Aortic Regurgitation

~~Outcome after aortic valve repair : freedom from recurrent regurgitation~~



Boodhwani et al., *J Thorac Cardiovasc Surg* 2009;137:286-294

Functional Anatomy of Aortic Regurgitation

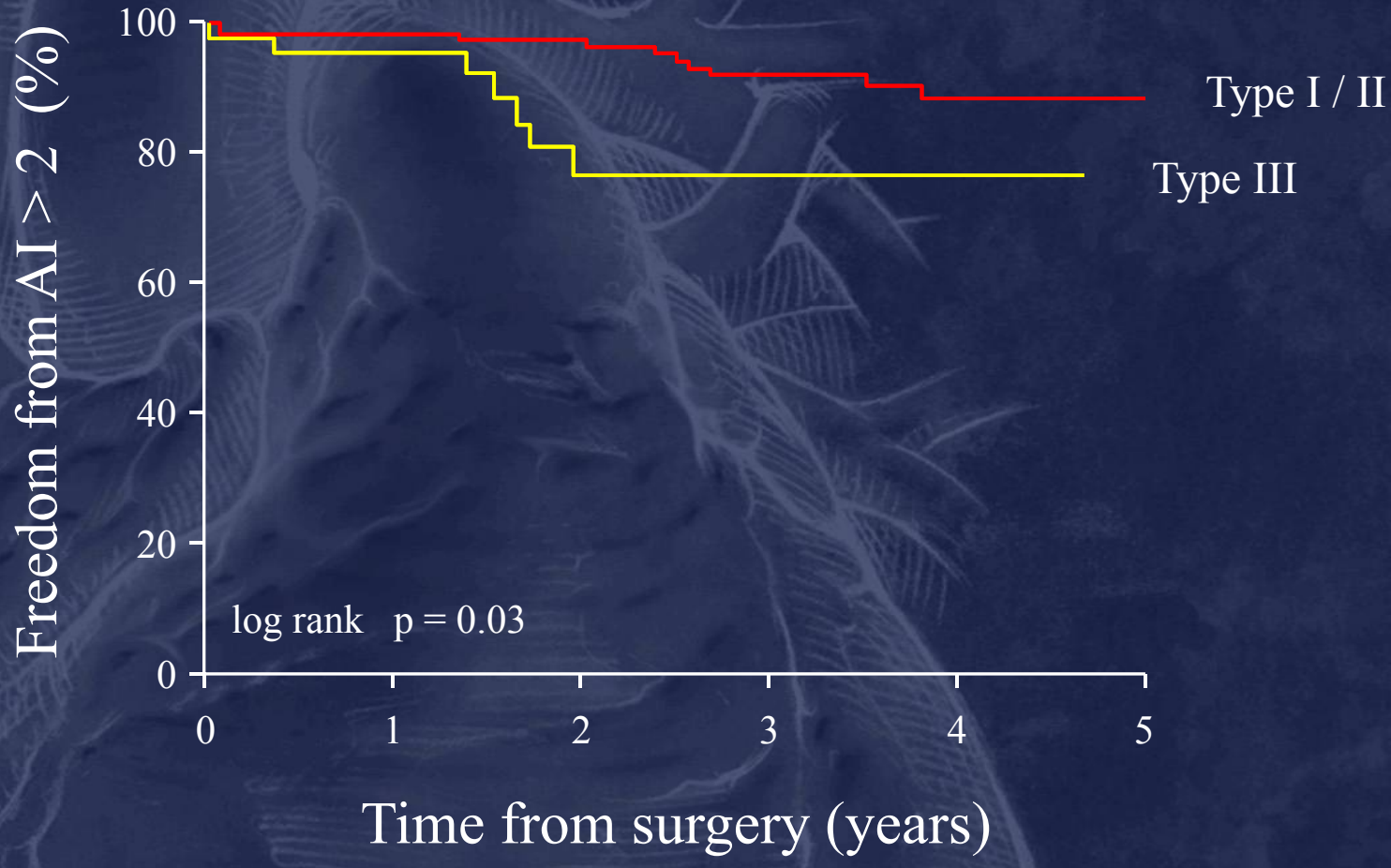
Pre-operative characteristics of patients with recurrent regurgitation

	No AR (n=112)	1+ - 2+ AR (n=23)	3+ AR (n=41)	*P value or* χ^2
Marfan (%)	2 (2%)	2 (9%)	6 (15%)	0.005
Type 3 AR (%)	15 (14%)	10 (43%)	19 (46%)	< 0.001
Annulus (mm)	25 ± 4	24 ± 4	26 ± 6	0.27
Sinus (mm)	39 ± 8	35 ± 9	41 ± 13	0.61
ST junction (mm)	35 ± 9	35 ± 9	34 ± 9	0.93
Tubular Aorta (mm)	42 ± 11	40 ± 8	37 ± 13	0.14

Le Polain de Waroux et al., *J Am Coll Cardiol Imag* 2009;2:931-939

Functional Anatomy of Aortic Regurgitation

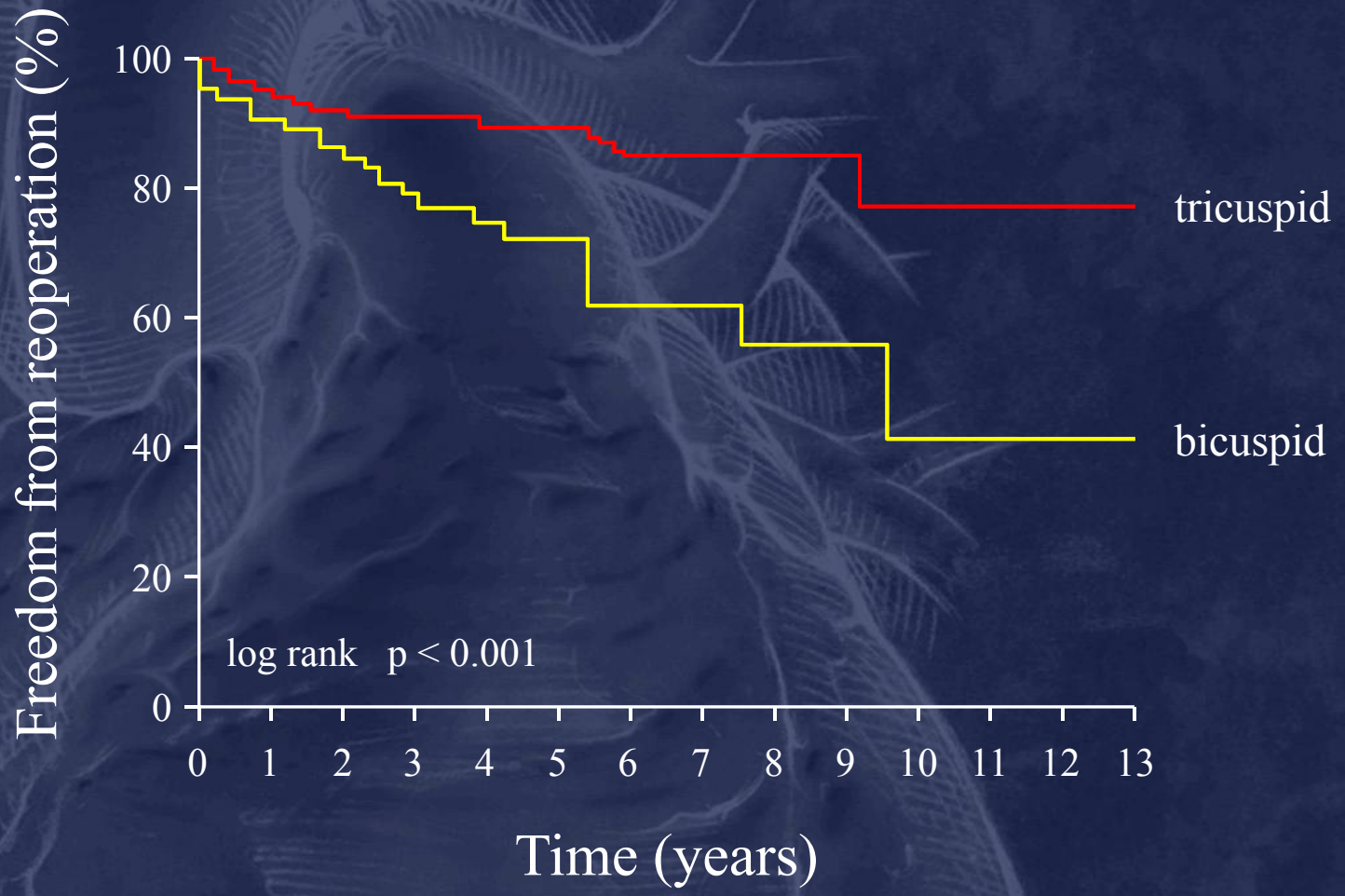
Outcome after aortic valve repair : freedom from recurrent regurgitation



Boodhwani et al., *J Thorac Cardiovasc Surg* 2009;137:286-294

Functional Anatomy of Aortic Regurgitation

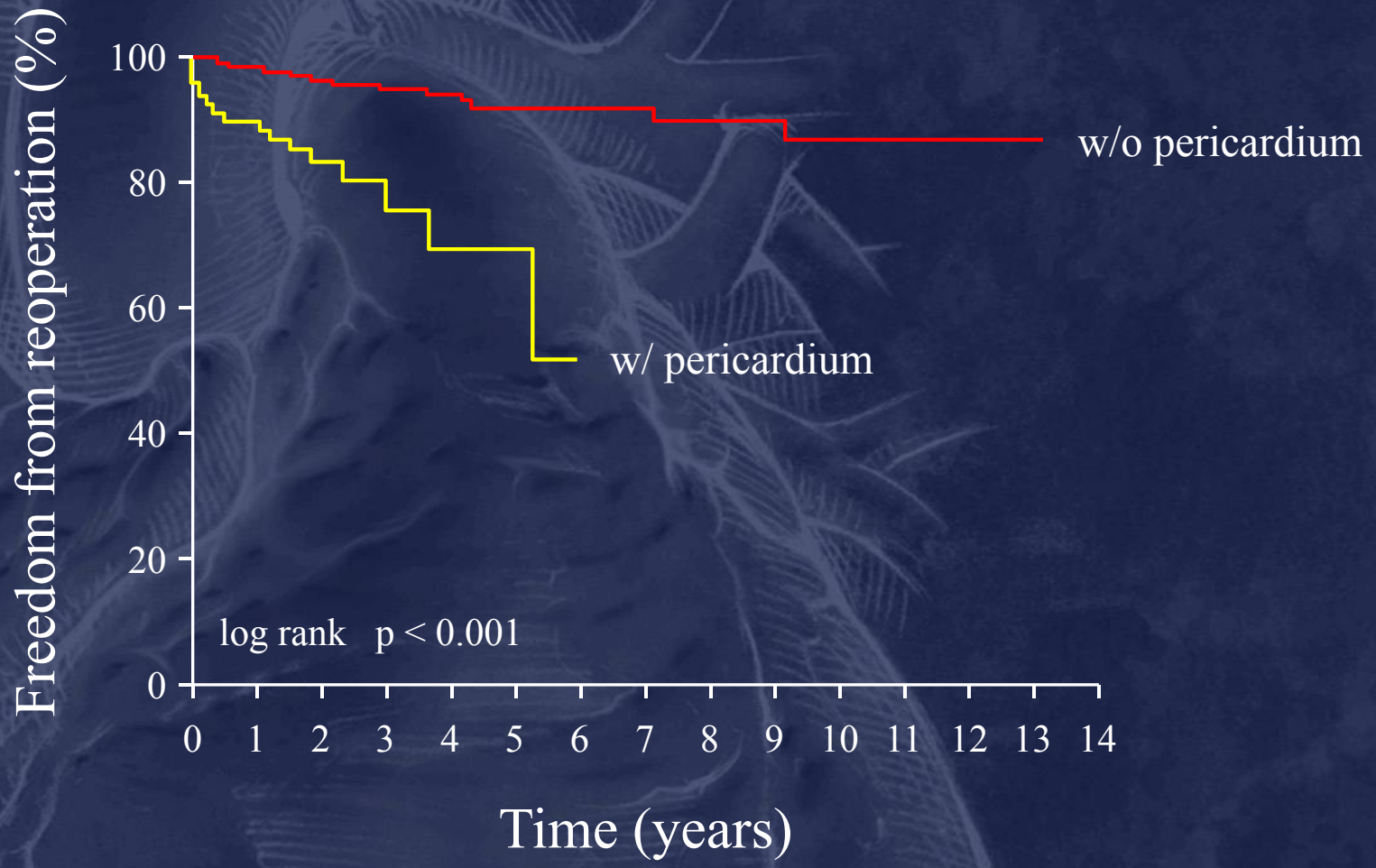
Outcome after aortic valve repair : impact of cuspal configuration



Aicher D. et al., *Eur J Cardiothorac Surg* 2010;37:127-132

Functional Anatomy of Aortic Regurgitation

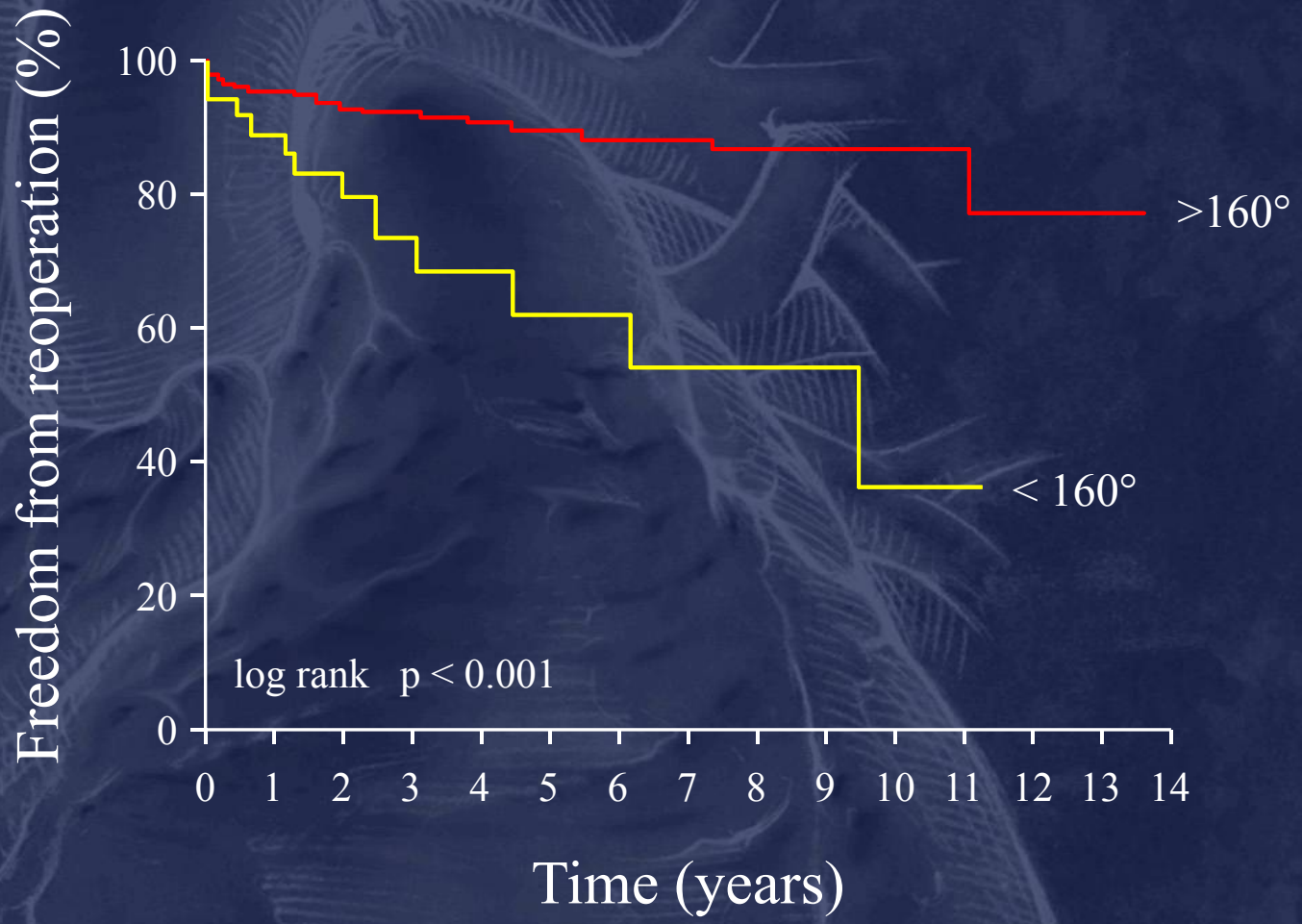
Outcome after bicuspid valve repair : impact of pericardial patching



Aicher D. et al., *Eur J Cardiothorac Surg* 2010;37:127-132

Functional Anatomy of Aortic Regurgitation

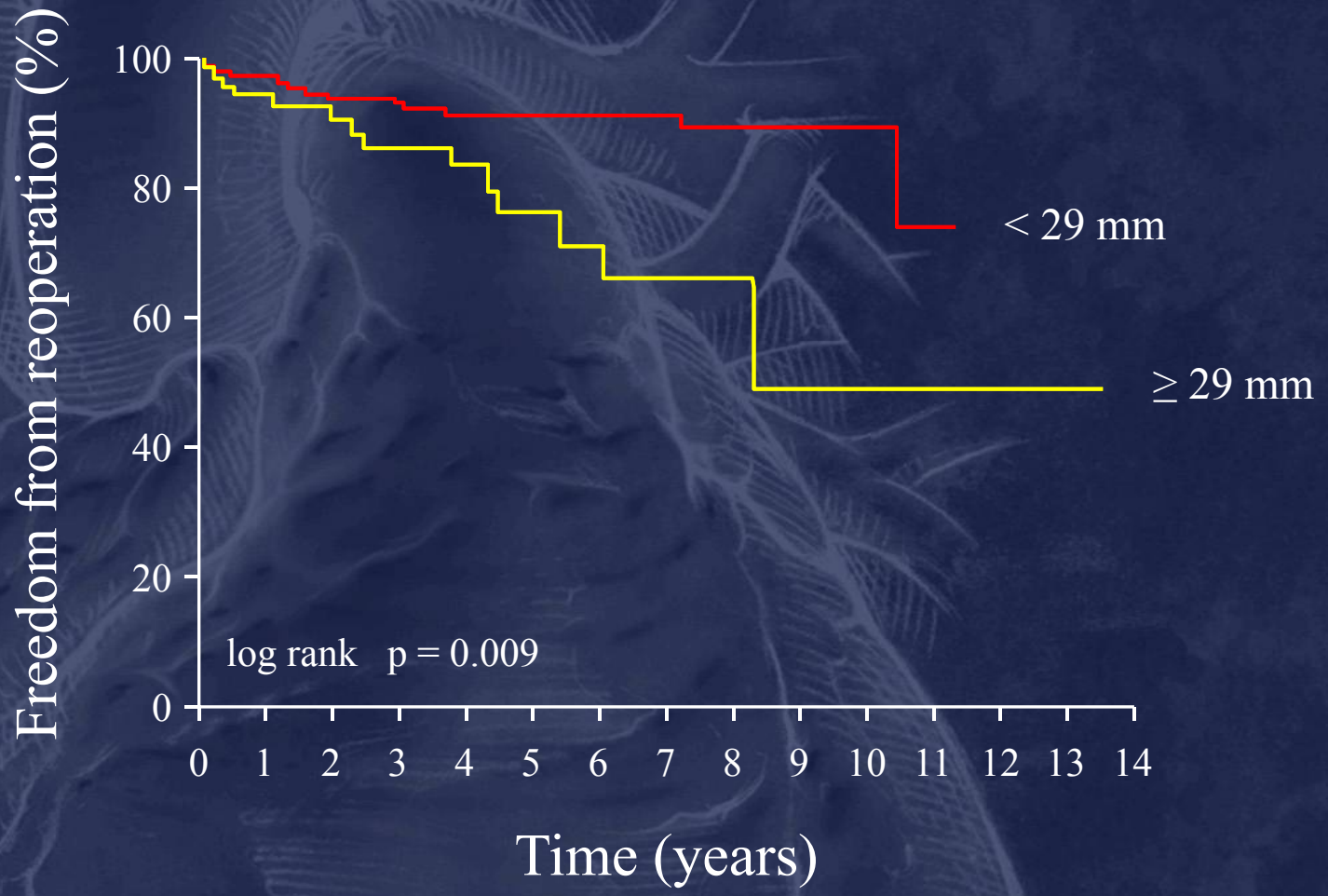
Outcome after bicuspid valve repair : impact of commissural orientation



Aicher D. et al., *Eur J Cardiothorac Surg* 2010;37:127-132

Functional Anatomy of Aortic Regurgitation

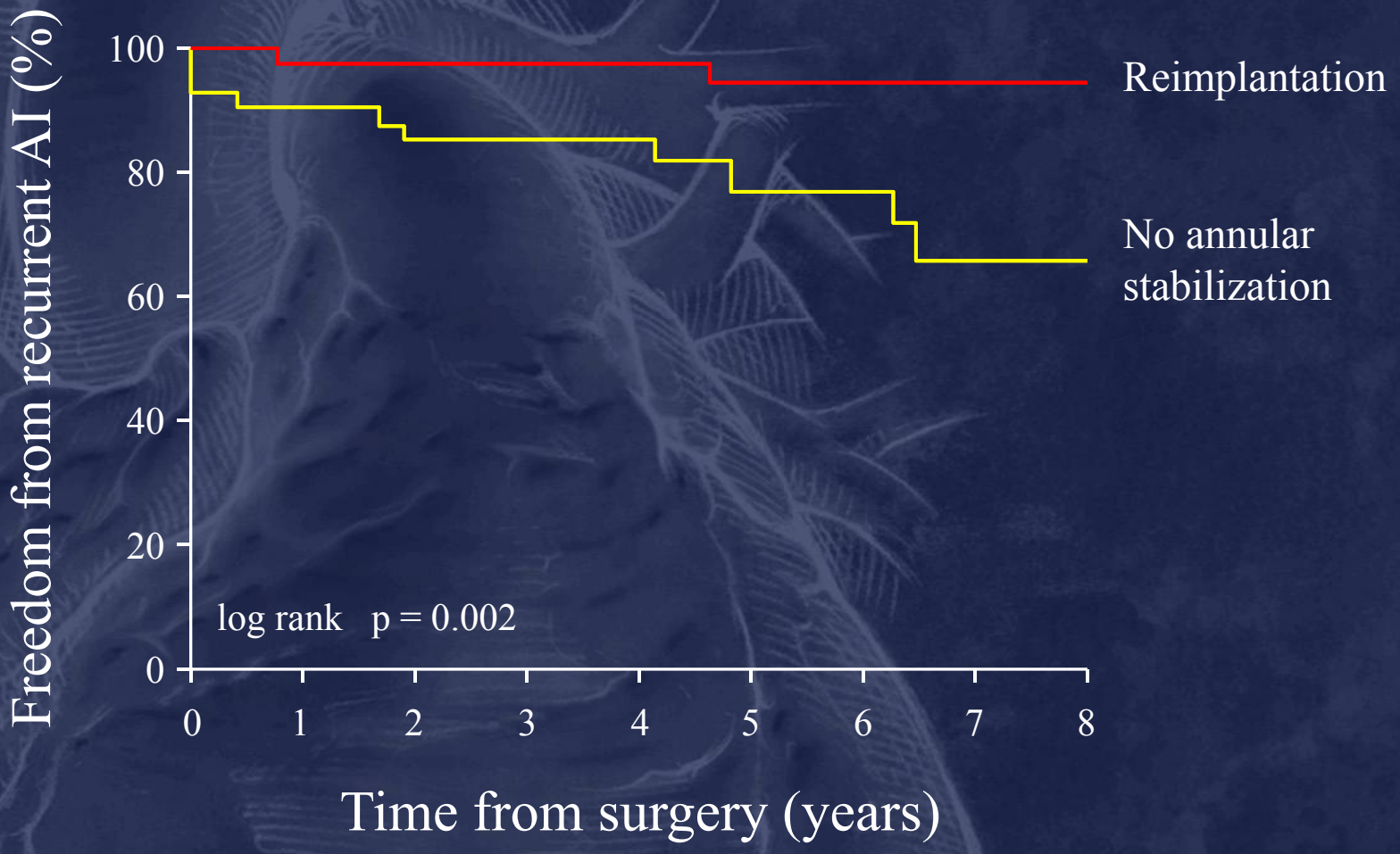
Outcome after bicuspid valve repair : impact of annular size



Aicher D. et al., *Eur J Cardiothorac Surg* 2010;37:127-132

Functional Anatomy of Aortic Regurgitation

Outcome after aortic valve repair : impact of annular stabilization



de Kerkhove et al., *J Thorac Cardiovasc Surg* 2011;142:1430-1438

Functional Anatomy of Aortic Regurgitation

Echo prediction of valve pathology and repairability

Repairability was determined based on tissue quality and leaflet calcifications.

- Smooth, thin and large leaflets with redundant tissue were considered as repairable.
- Small, restrictive, fibrous or thickened leaflets were thought to preclude surgical repair.
- Heavily calcified valves (≥ grade 3) were usually considered as non repairable (except if localized at the level of the free margins)

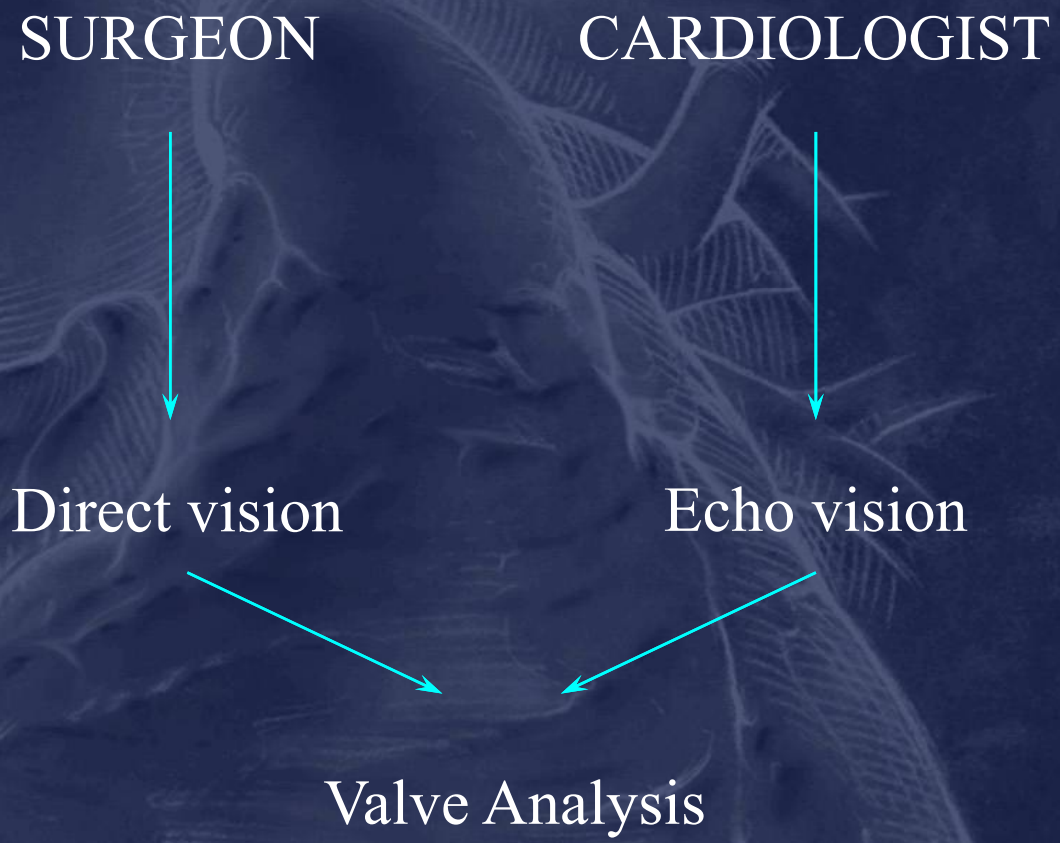
Le Polain de Waroux et al., *Circulation* 2007;116:I-264

Functional Anatomy of Aortic Regurgitation

Pre-operative echocardiographic evaluation
Identification of AR dysfunction

Functional Anatomy of Aortic Regurgitation

Feasibility of aortic repair: a team approach



Functional Anatomy of Aortic Regurgitation

Surgical classification of aortic dysfunction

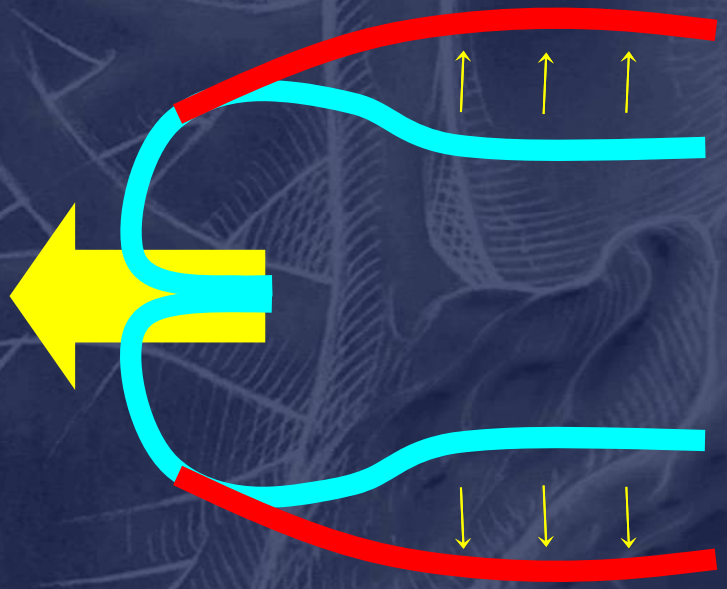
I Normal cusp motion

II Increased cusp motion

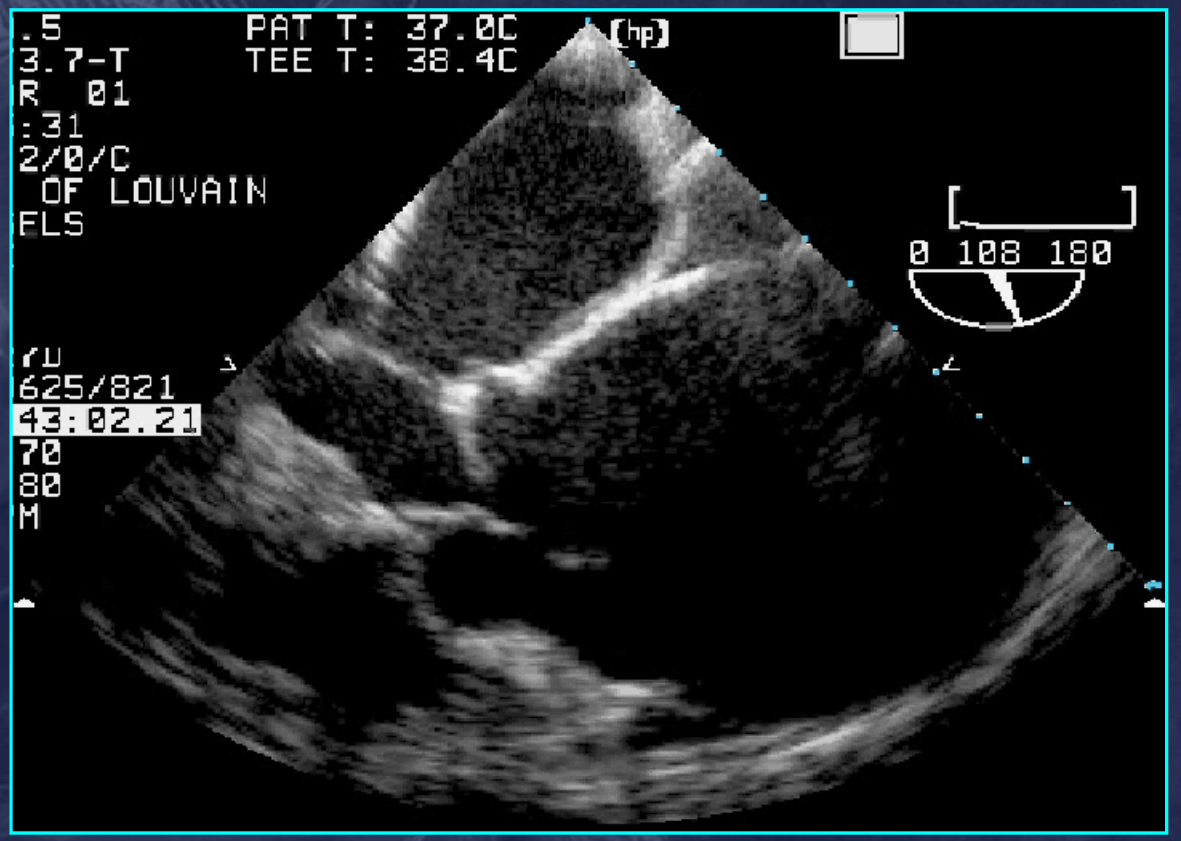
III Poor cusp quality or quantity

Functional Anatomy of Aortic Regurgitation

Type Ib: Aortic root and Valsalva sinus aneurysm

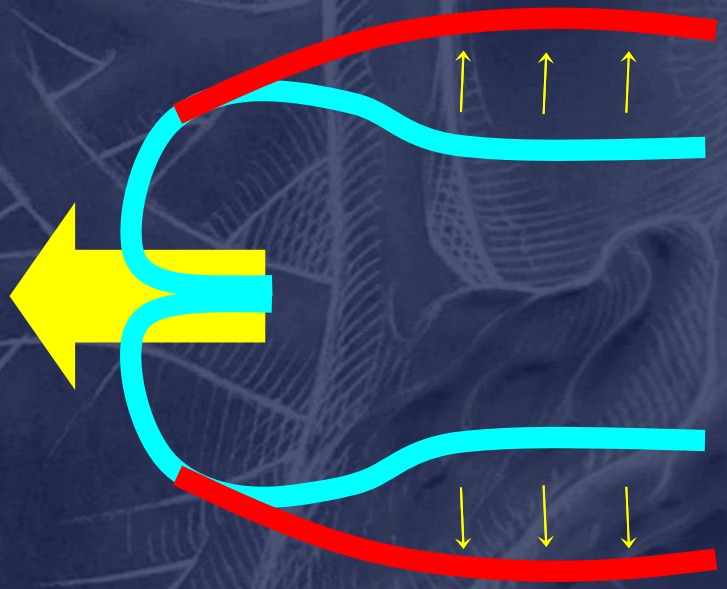


Aortic root aneurysm

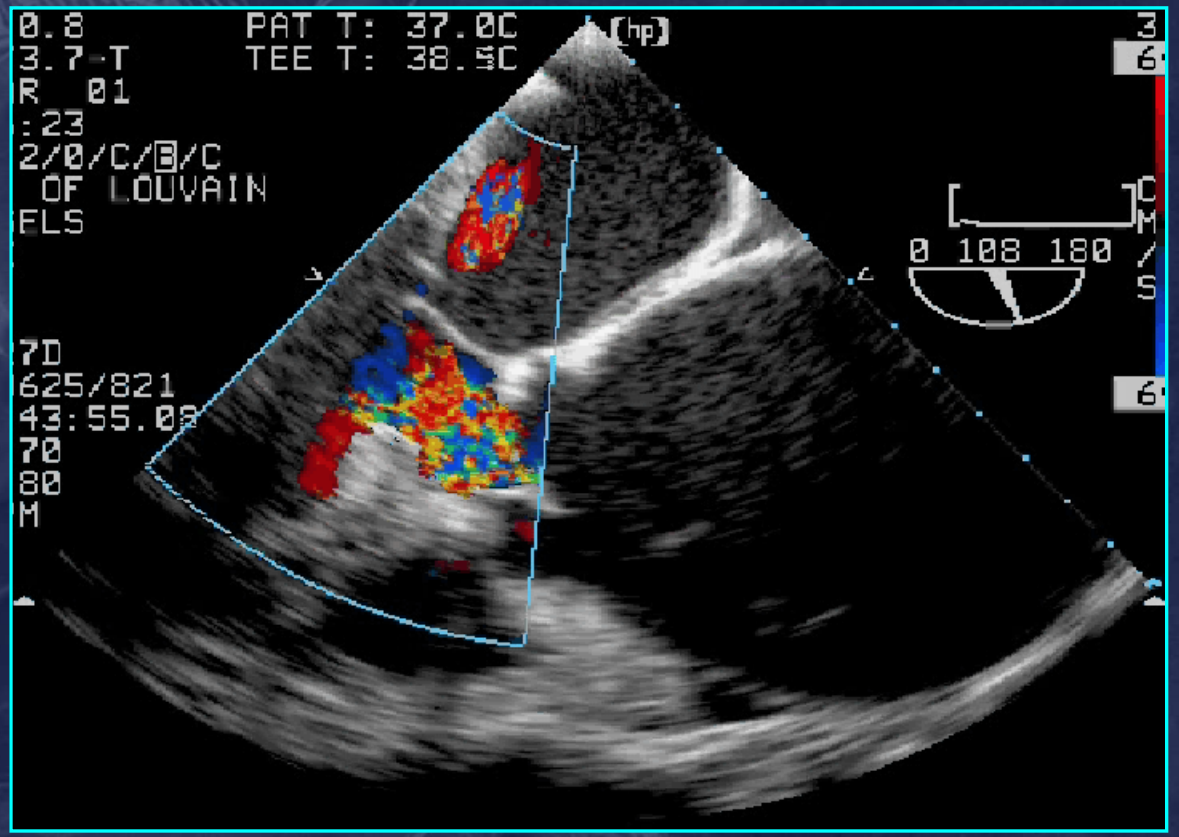


Functional Anatomy of Aortic Regurgitation

Type Ib: Aortic root and Valsalva sinus aneurysm

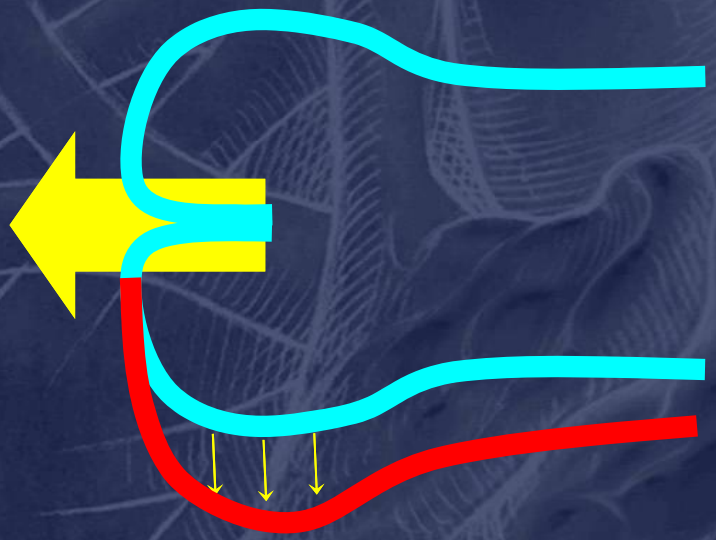


Aortic root aneurysm

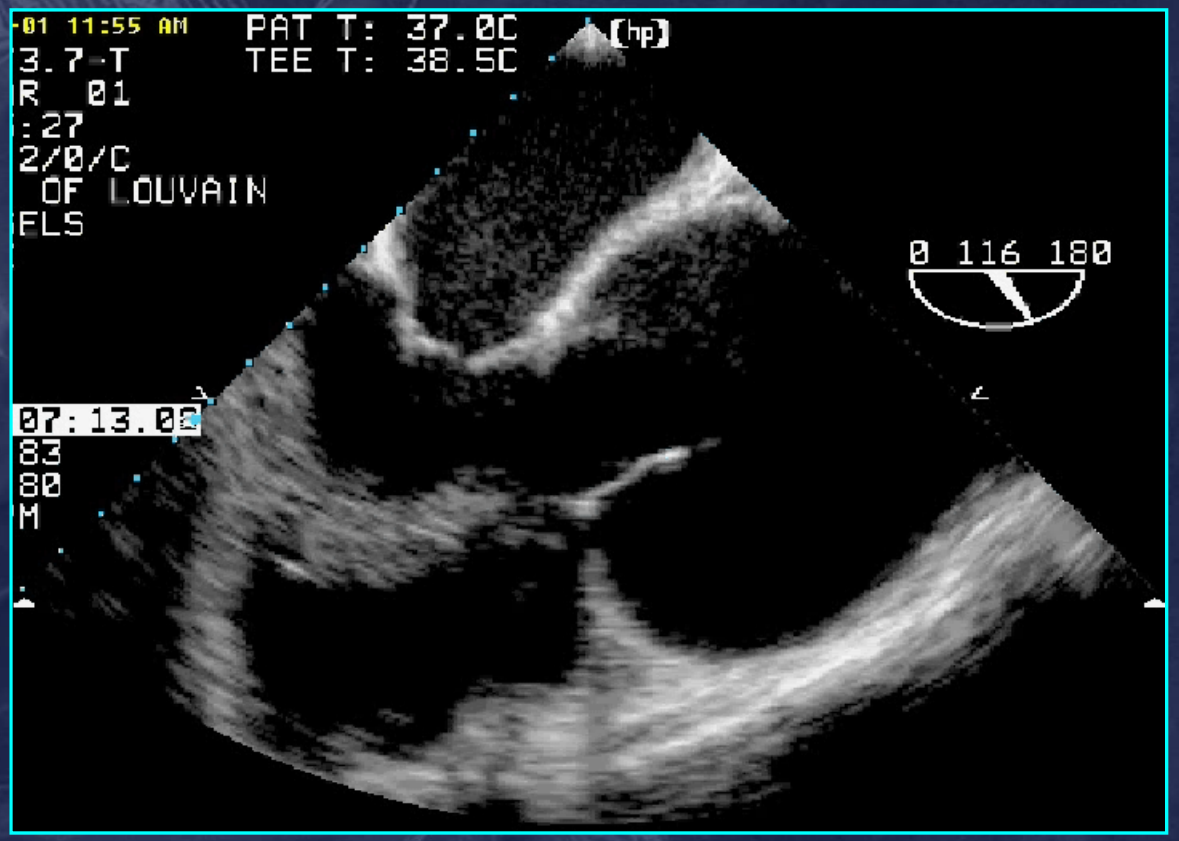


Functional Anatomy of Aortic Regurgitation

Type Ib: Aortic root and Valsalva sinus aneurysm

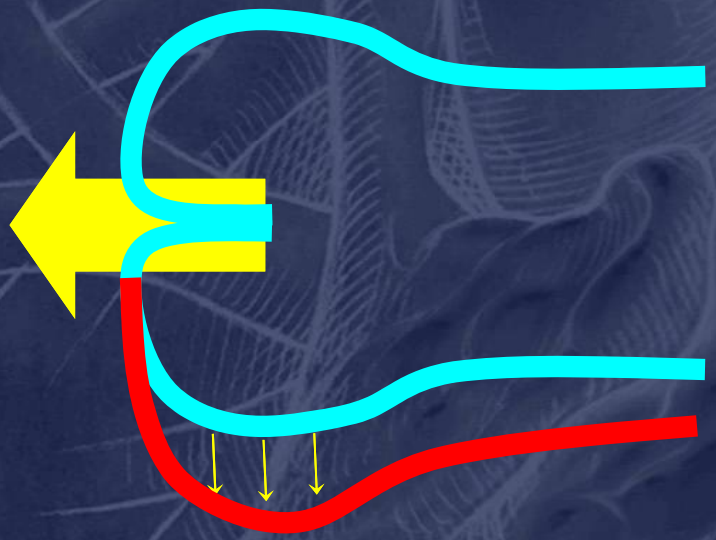


Sinus of Valsalva aneurysm

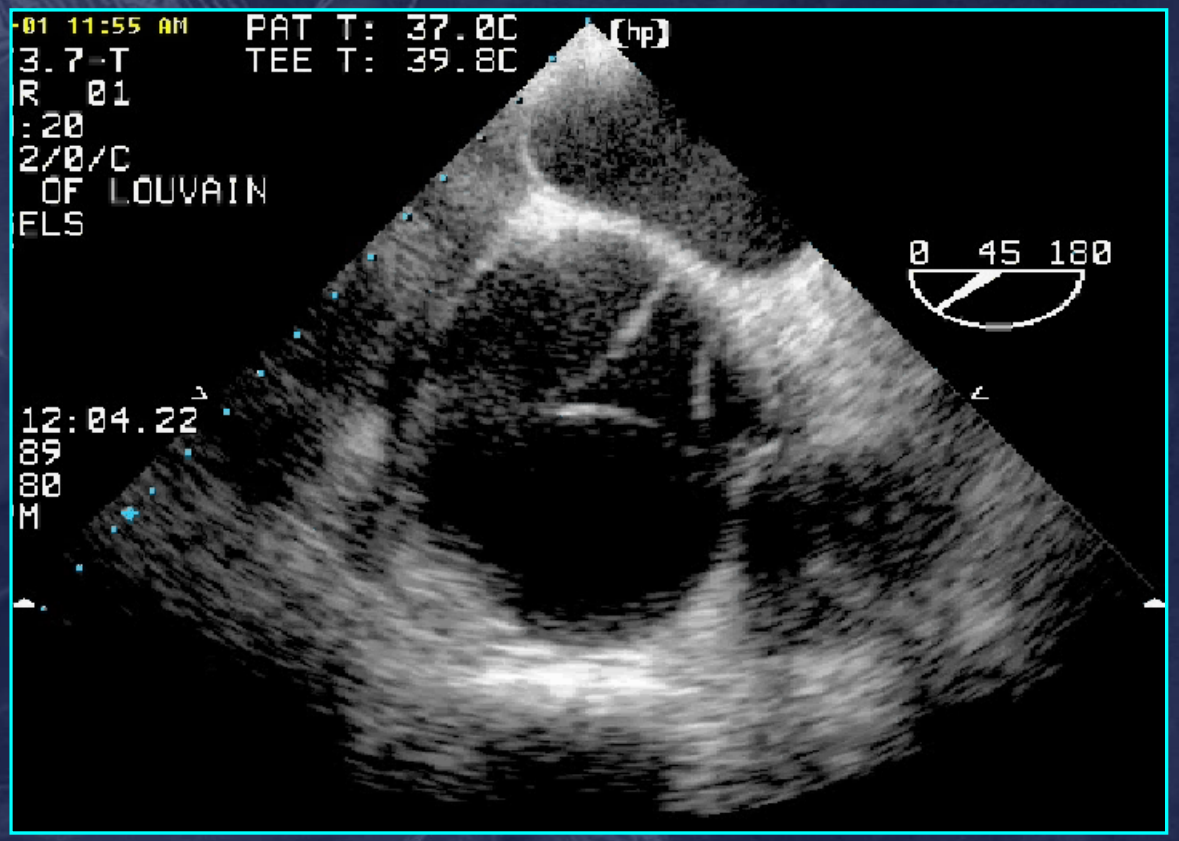


Functional Anatomy of Aortic Regurgitation

Type Ib: Aortic root and Valsalva sinus aneurysm

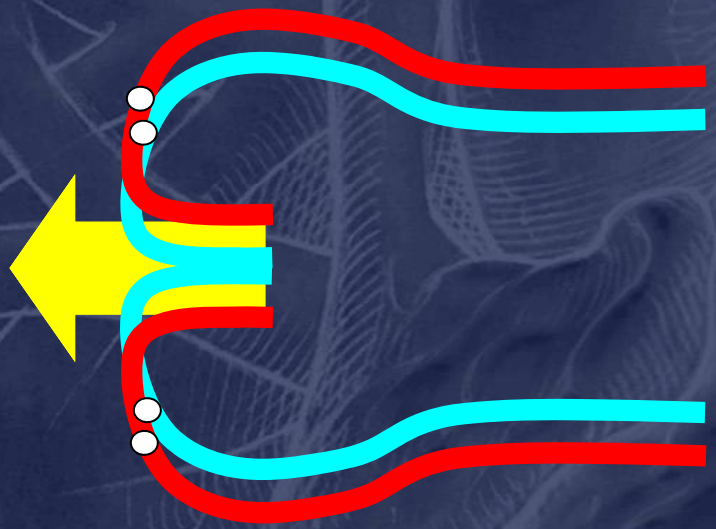


Sinus of Valsalva aneurysm

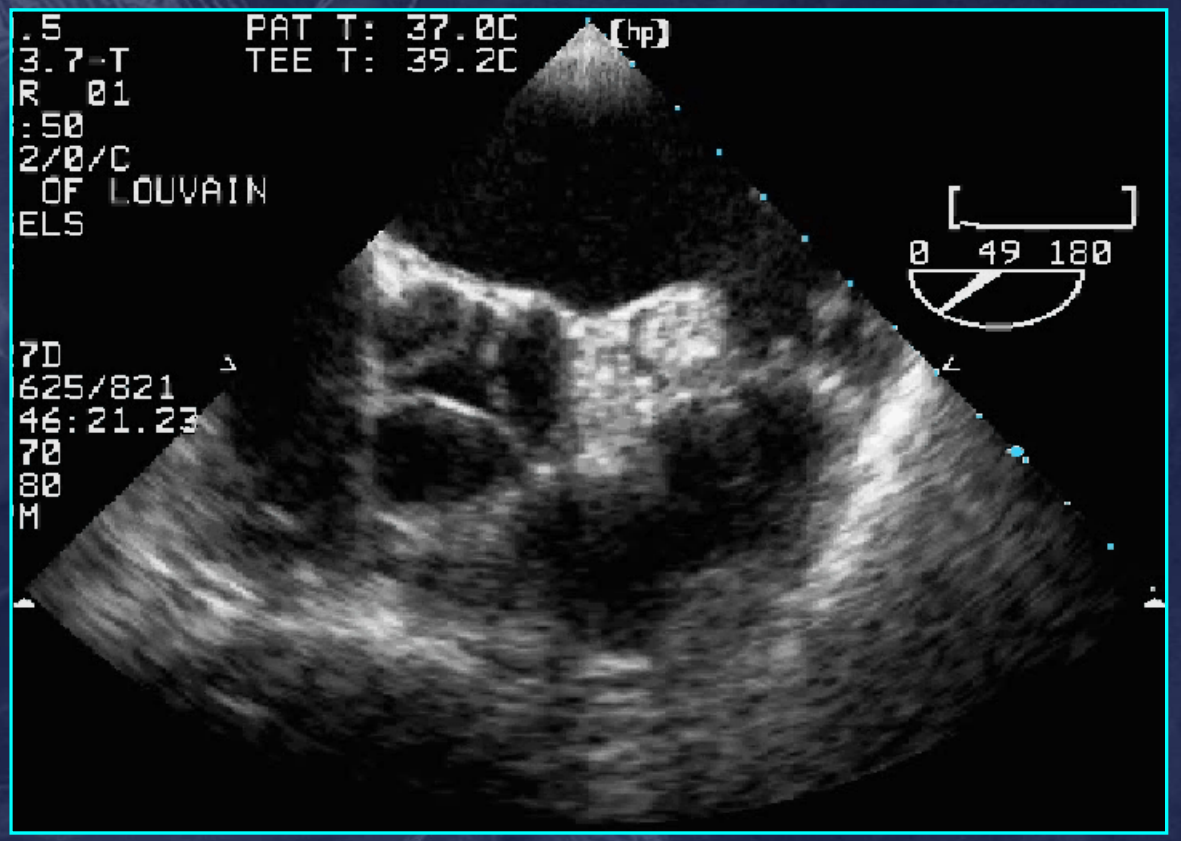


Functional Anatomy of Aortic Regurgitation

Type Ic: "Annular dilatation"

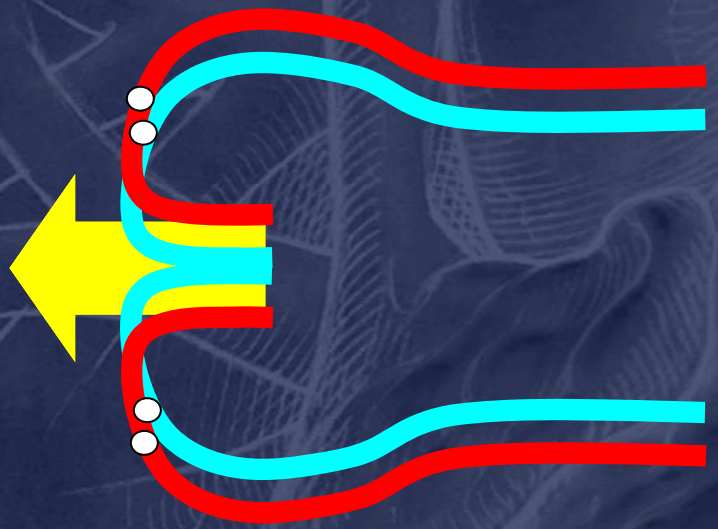


Annular dilation

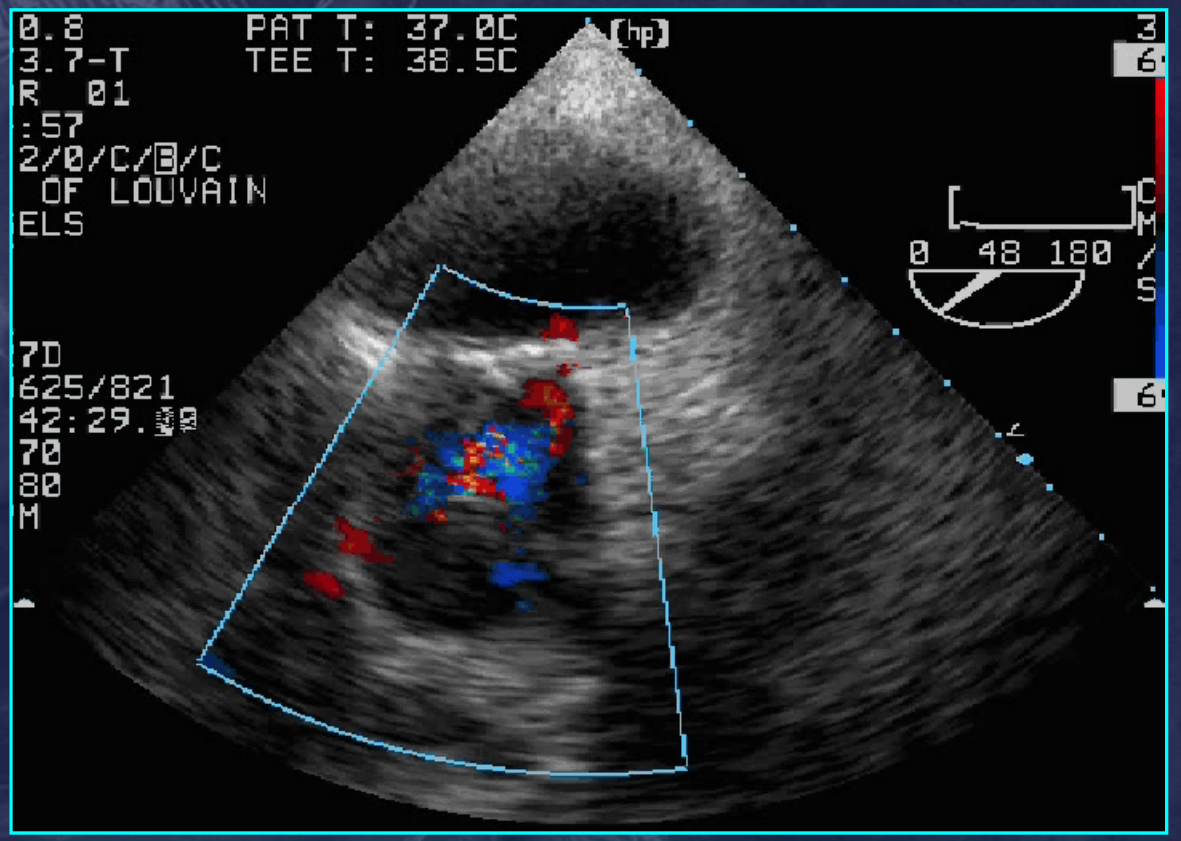


Functional Anatomy of Aortic Regurgitation

Type Ic: Annular dilatation

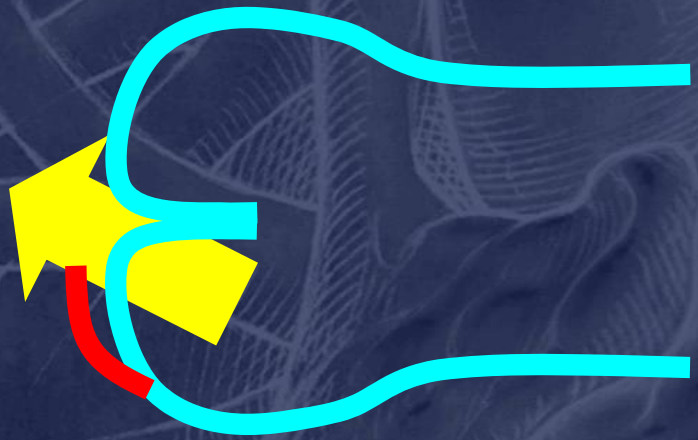


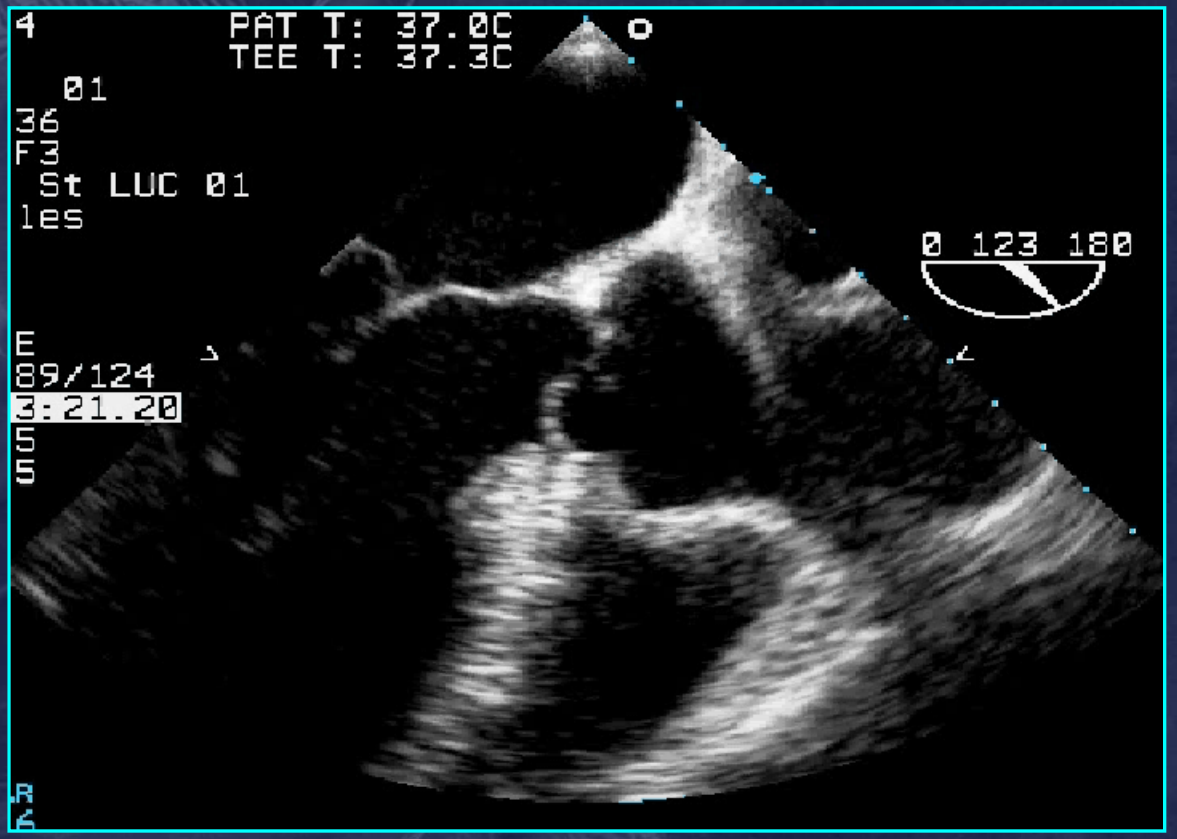
Annular dilation



Functional Anatomy of Aortic Regurgitation

Type II: flail aortic cusp

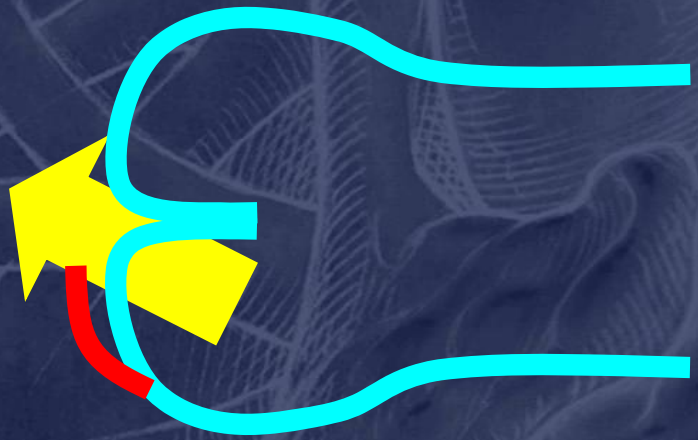


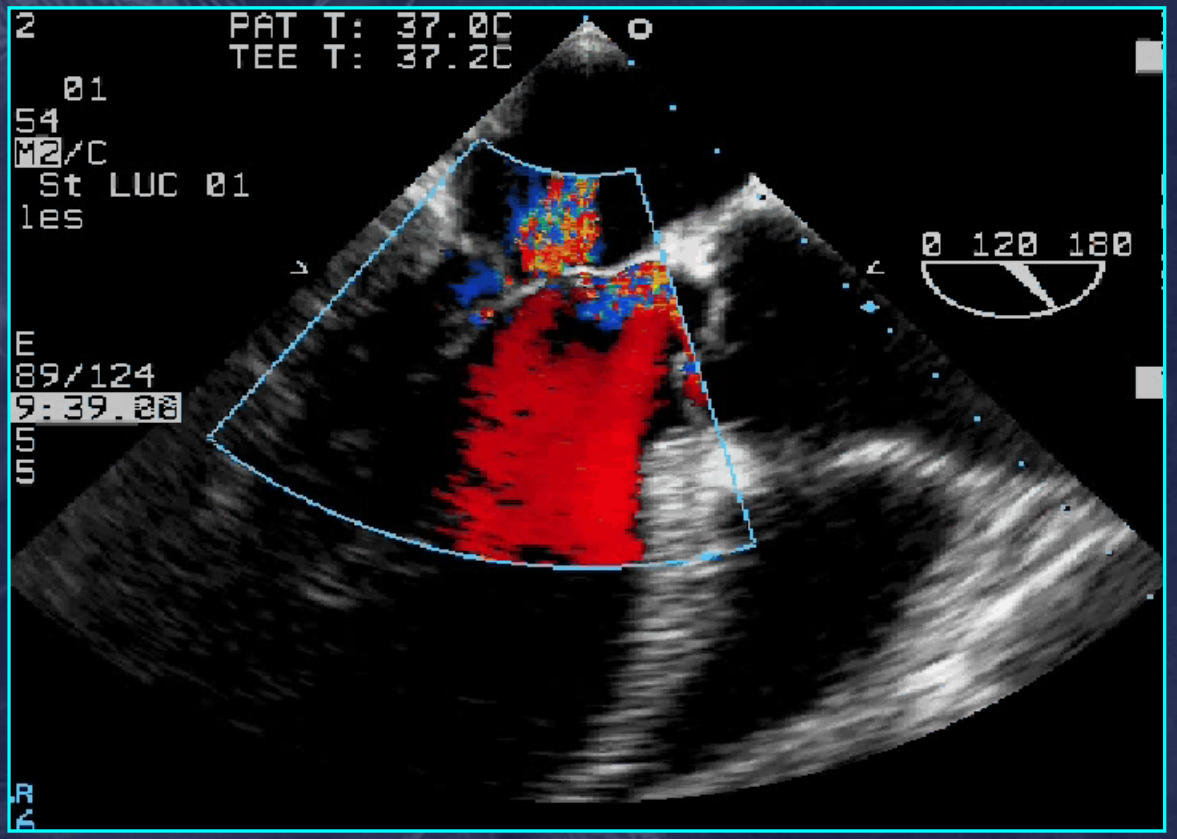


Cusp prolapse

Functional Anatomy of Aortic Regurgitation

Type II: flail aortic cusp

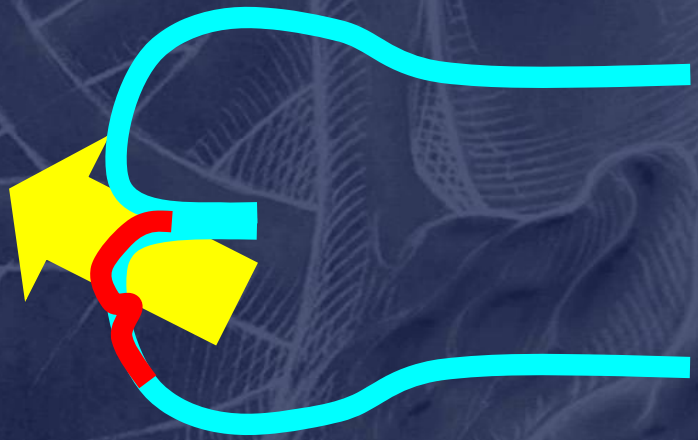




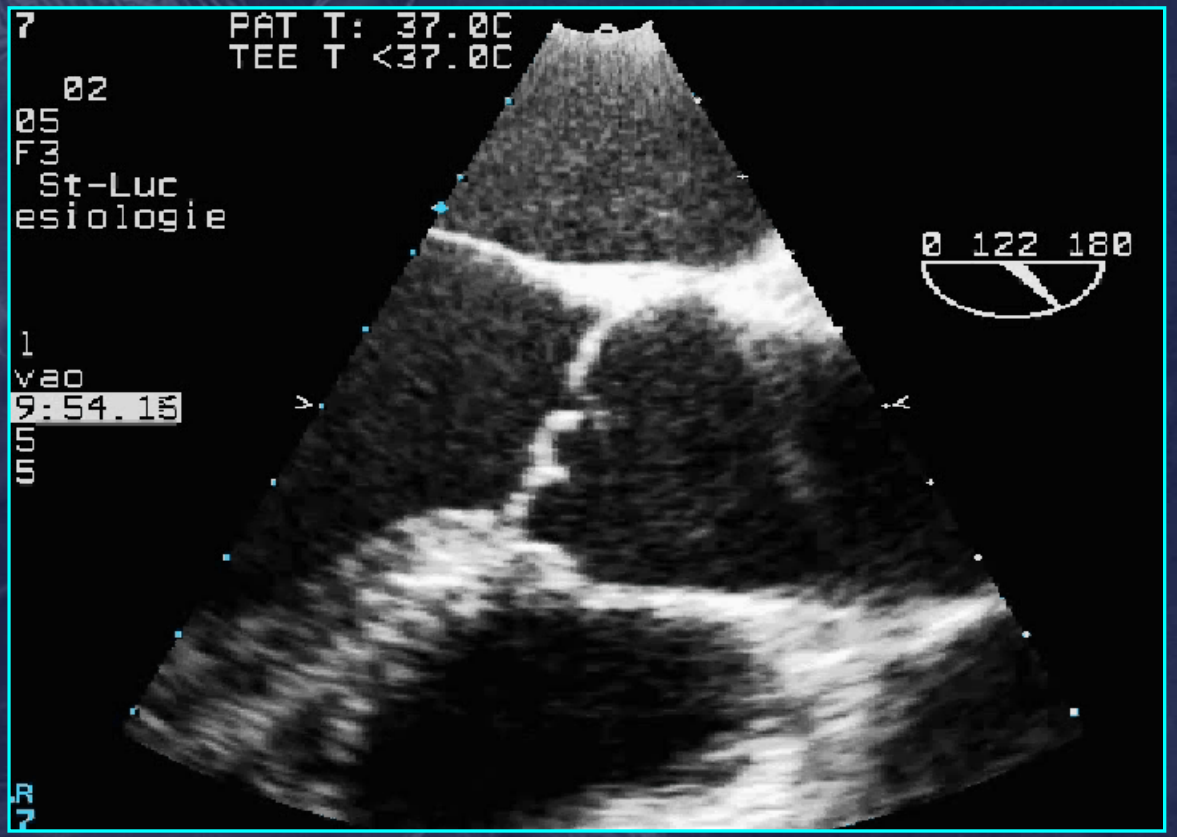
Cusp prolapse

Functional Anatomy of Aortic Regurgitation

Type II: partial cusp prolapse

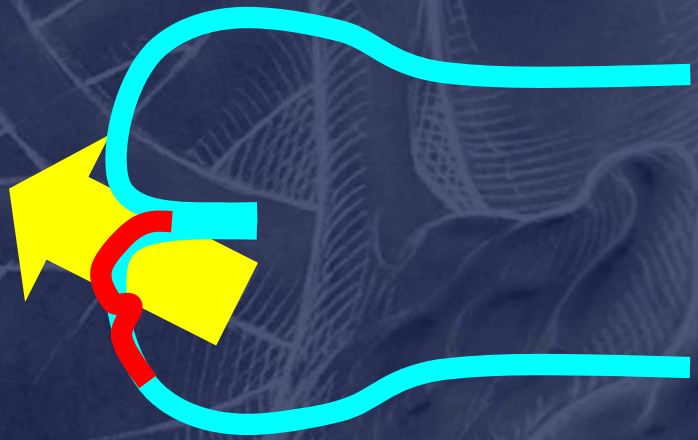


Cusp prolapse

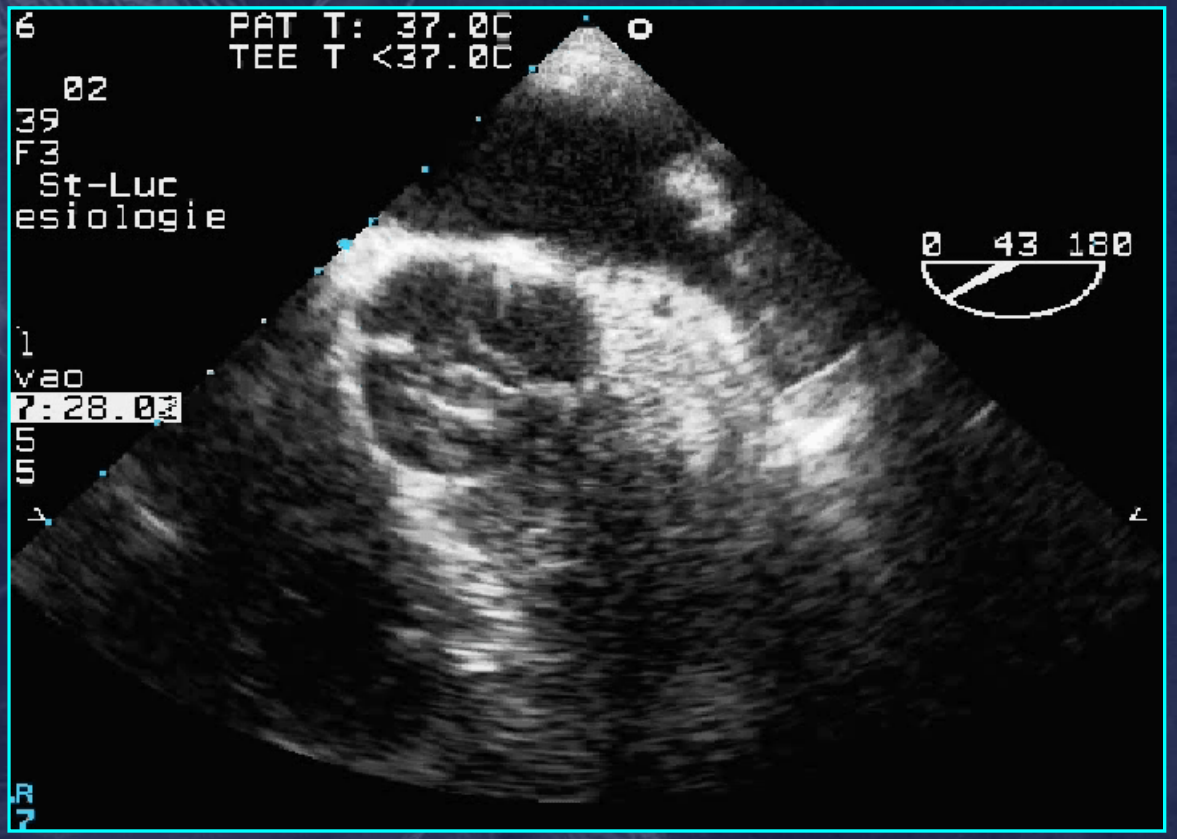


Functional Anatomy of Aortic Regurgitation

Type II: partial cusp prolapse

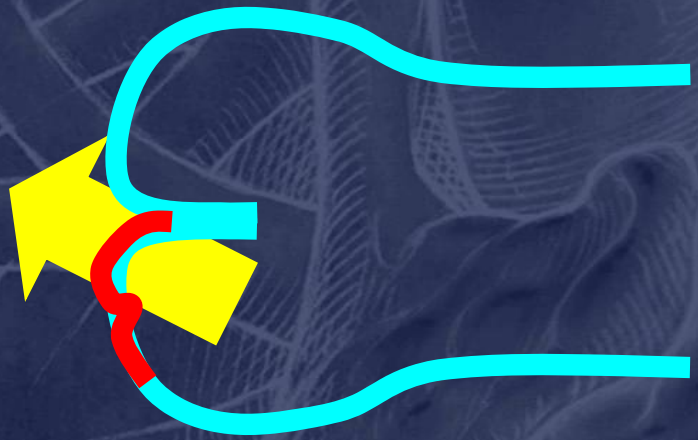


Cusp prolapse

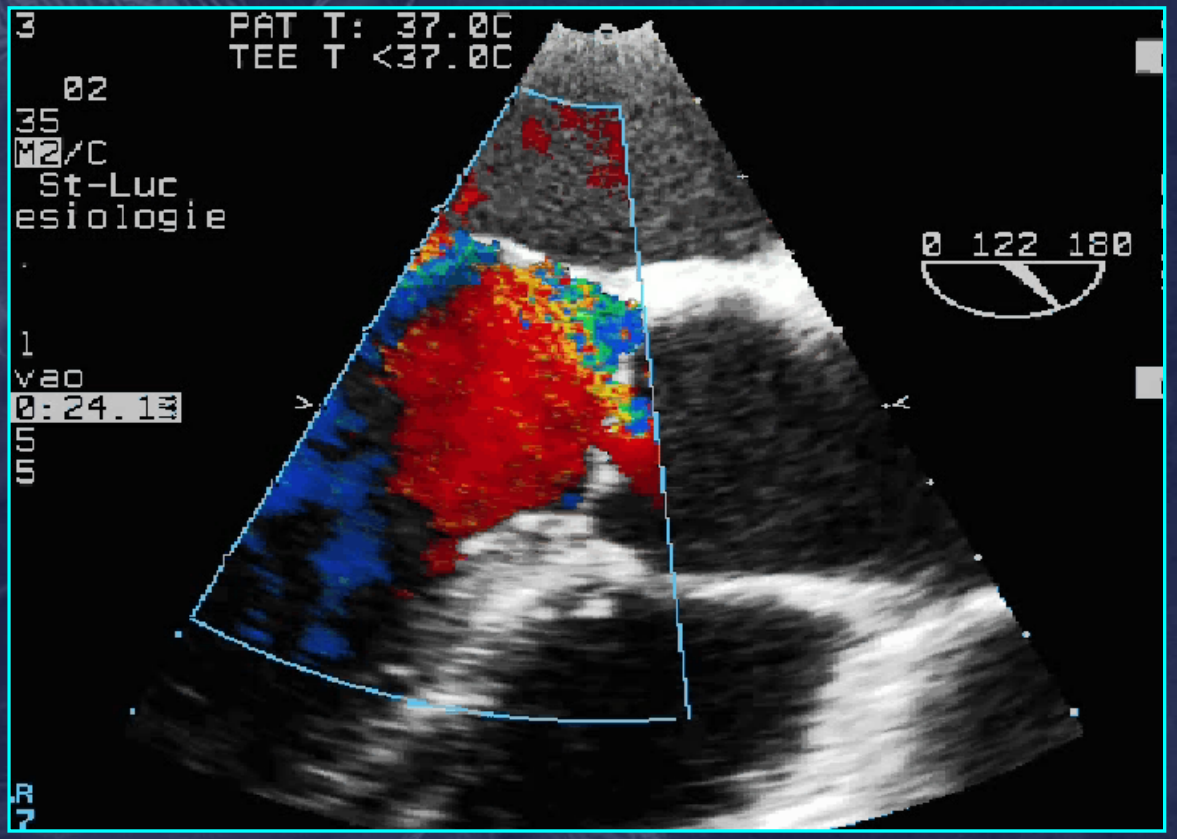


Functional Anatomy of Aortic Regurgitation

Type II: partial cusp prolapse

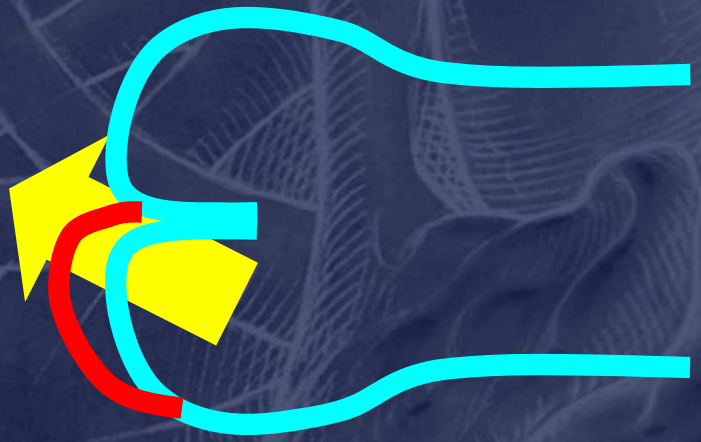


Cusp prolapse

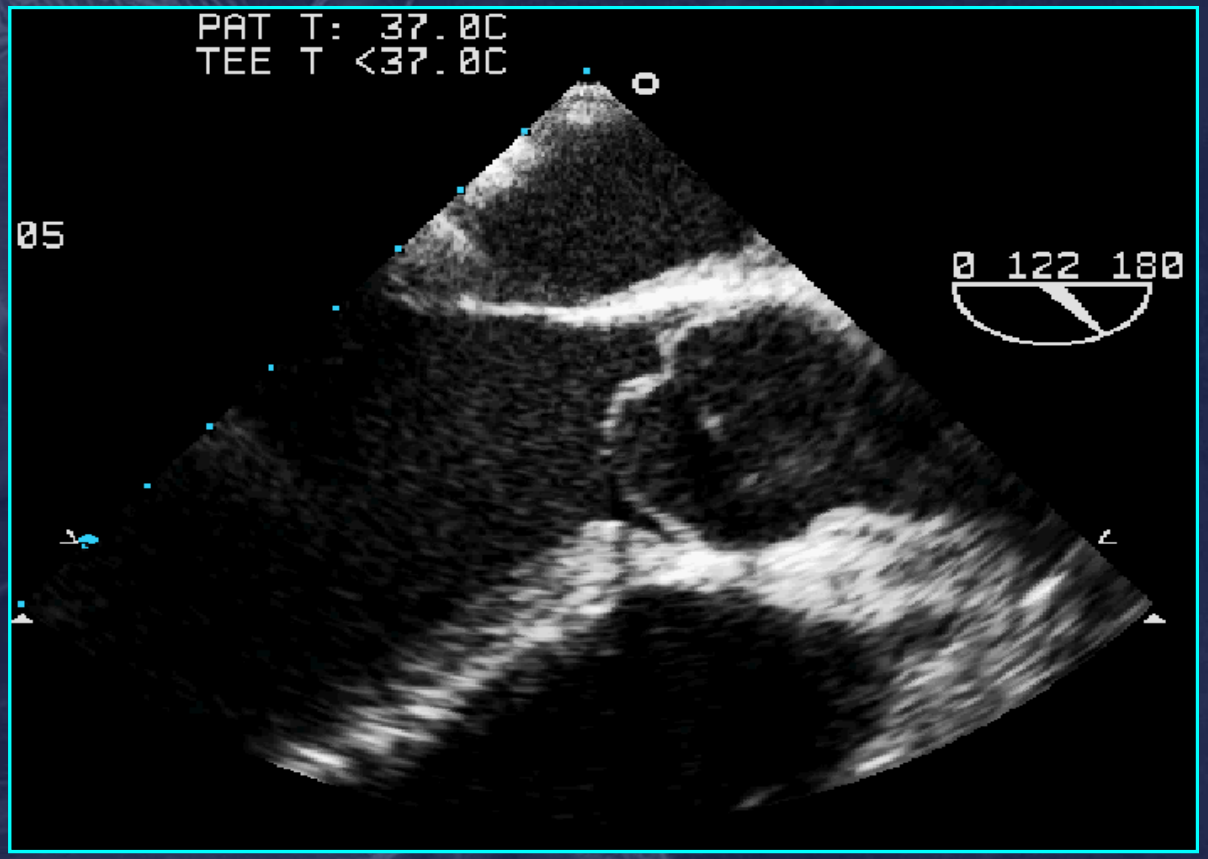


Functional Anatomy of Aortic Regurgitation

Type II: whole cusp prolapse

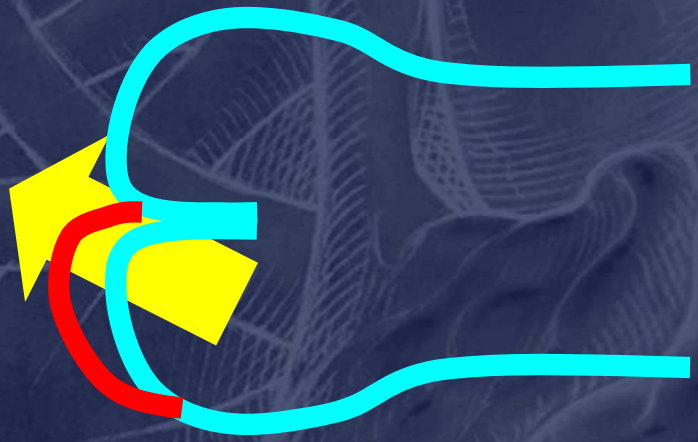


Cusp prolapse

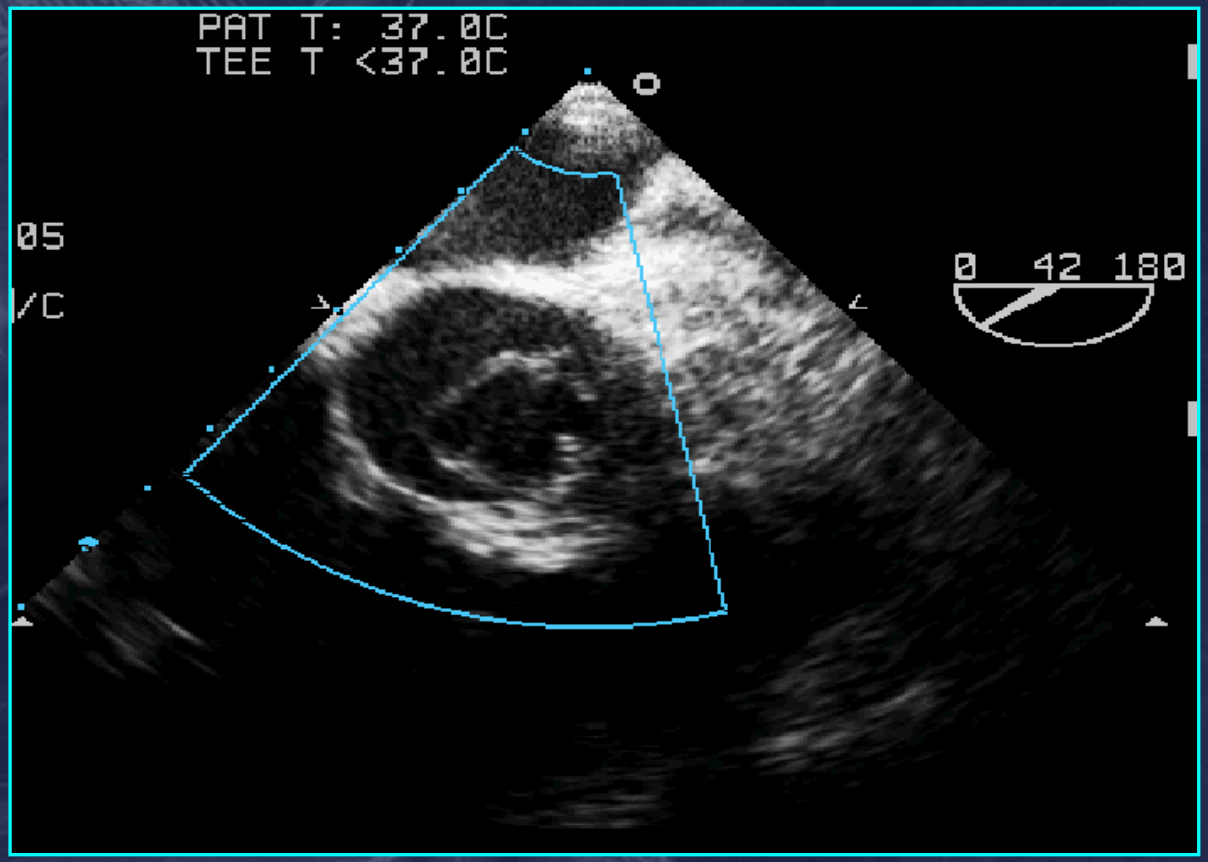


Functional Anatomy of Aortic Regurgitation

Type II: whole cusp prolapse

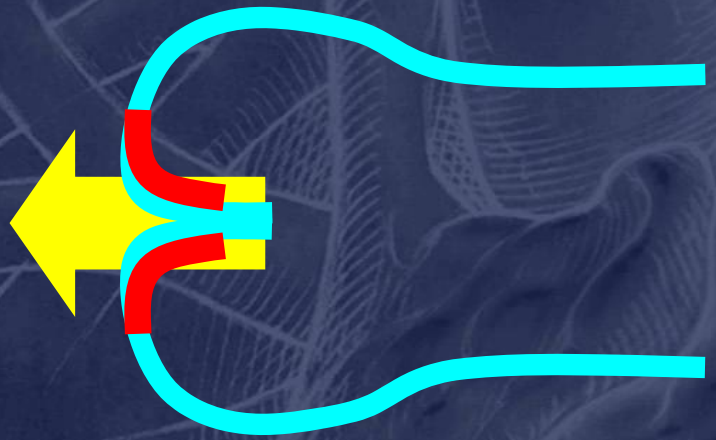


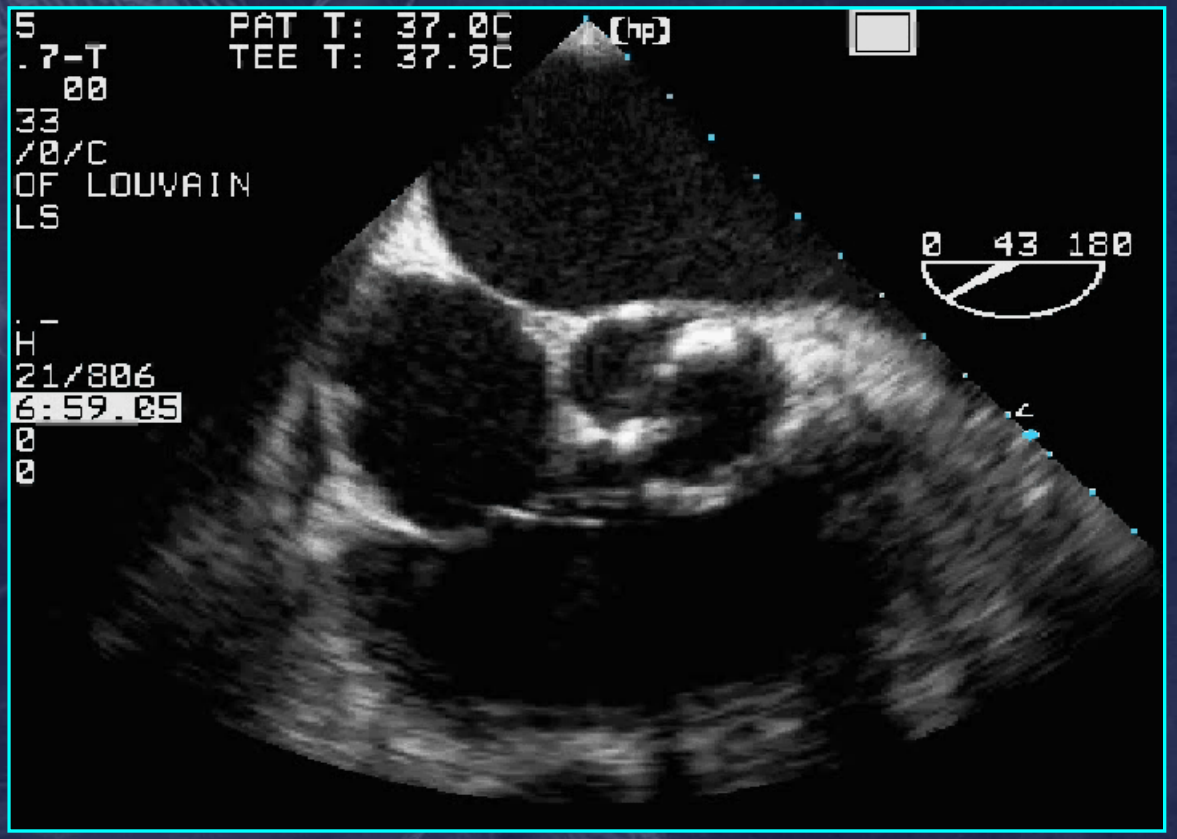
Cusp prolapse



Functional Anatomy of Aortic Regurgitation

Type III: Heaviliy calcified valve

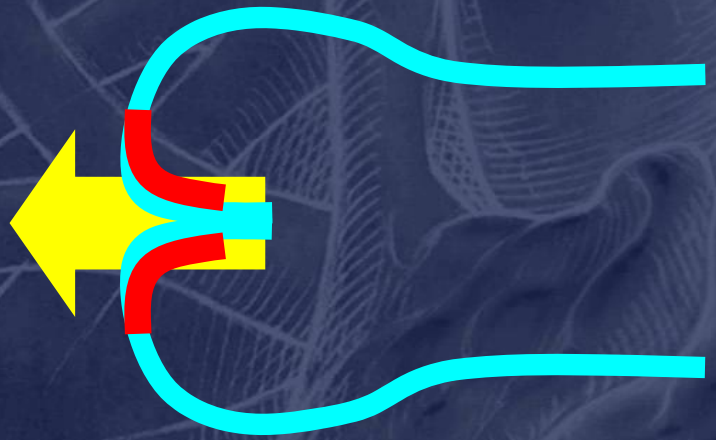


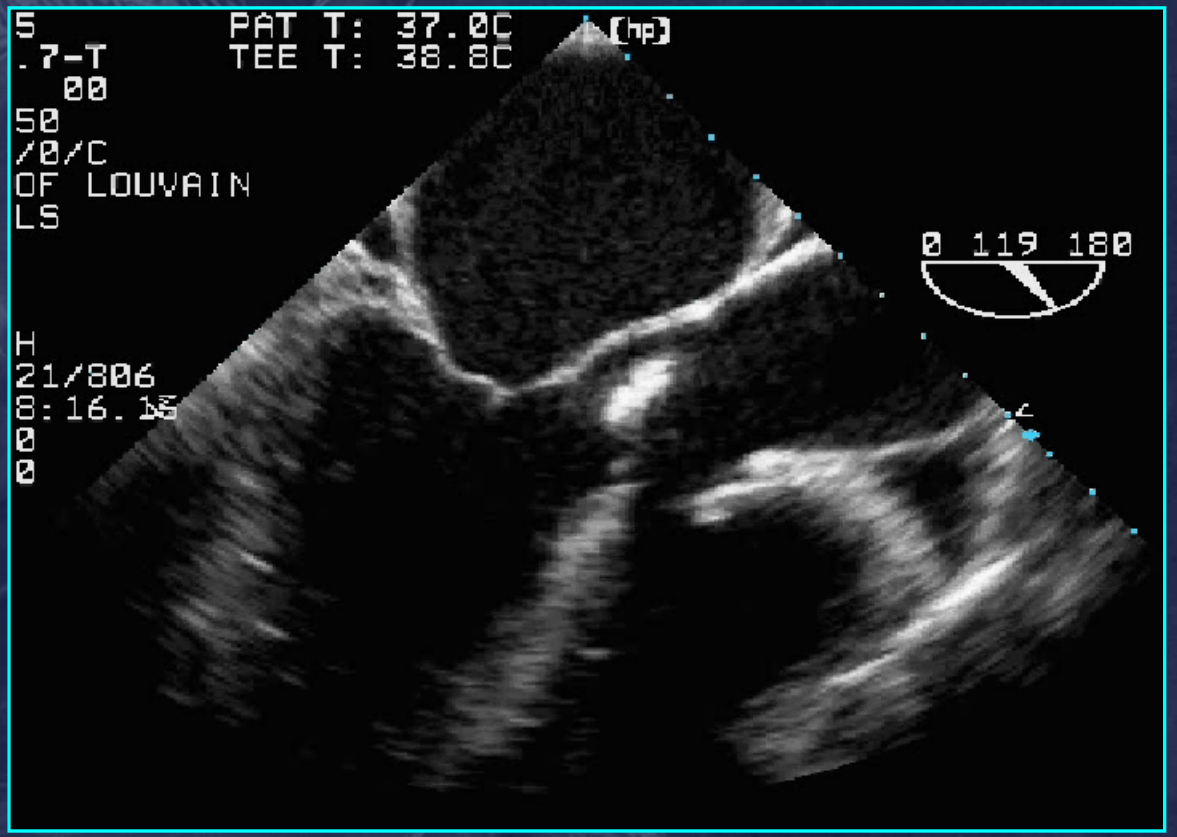


Cusp restriction

Functional Anatomy of Aortic Regurgitation

Type III: Heaviliy calcified valve

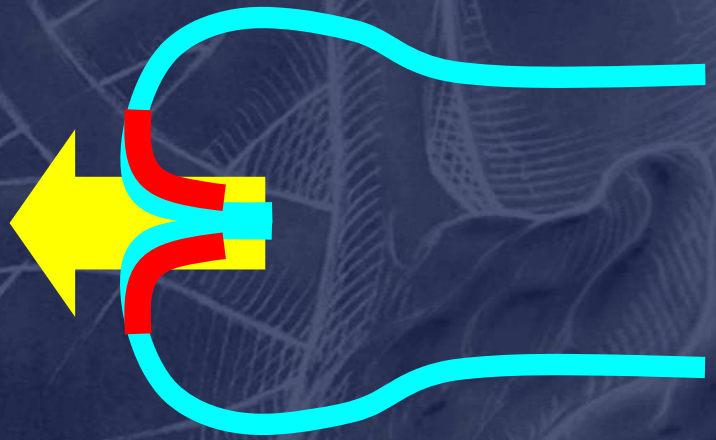


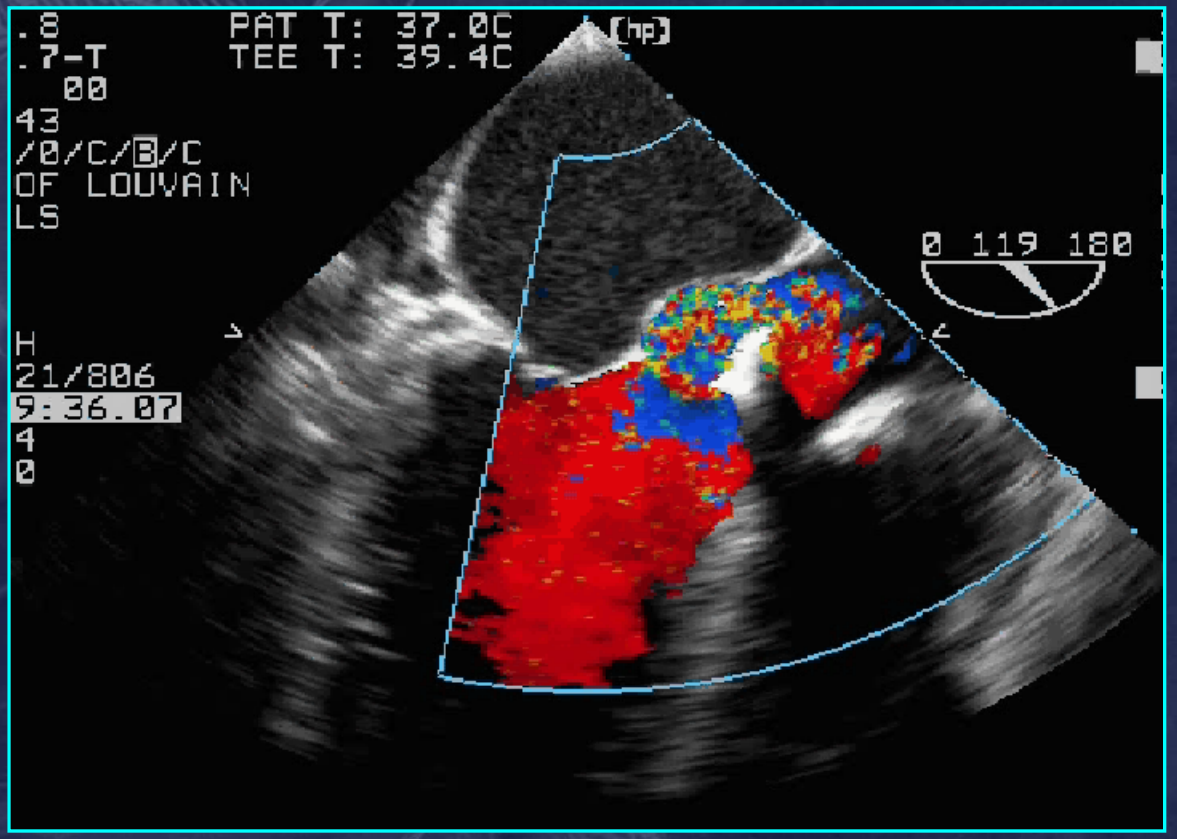


Cusp restriction

Functional Anatomy of Aortic Regurgitation

Type III: Heaviliy calcified valve

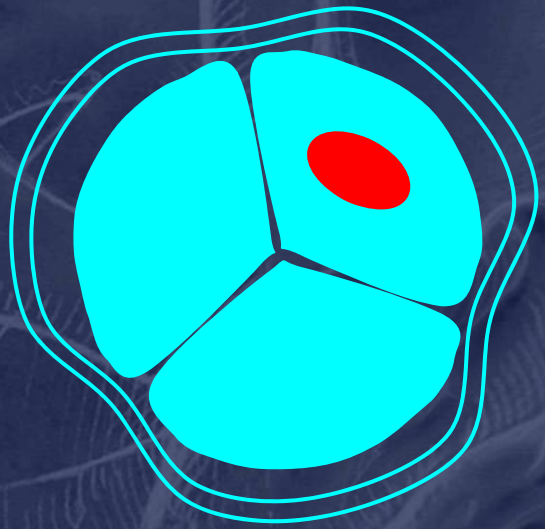




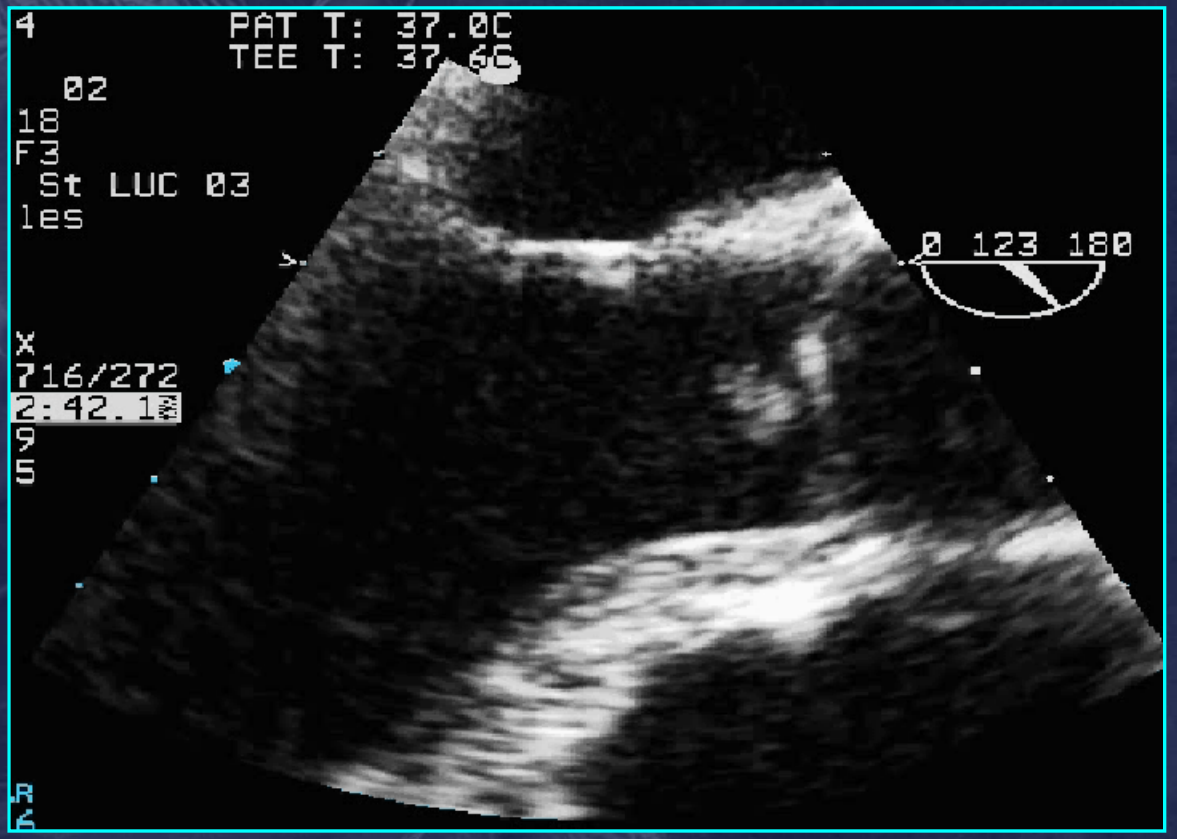
Cusp restriction

Functional Anatomy of Aortic Regurgitation

Type Id: Endocarditis and cusp perforation

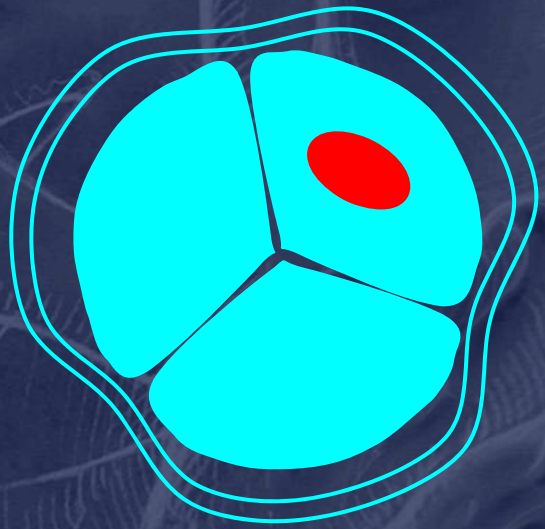


Cusp perforation

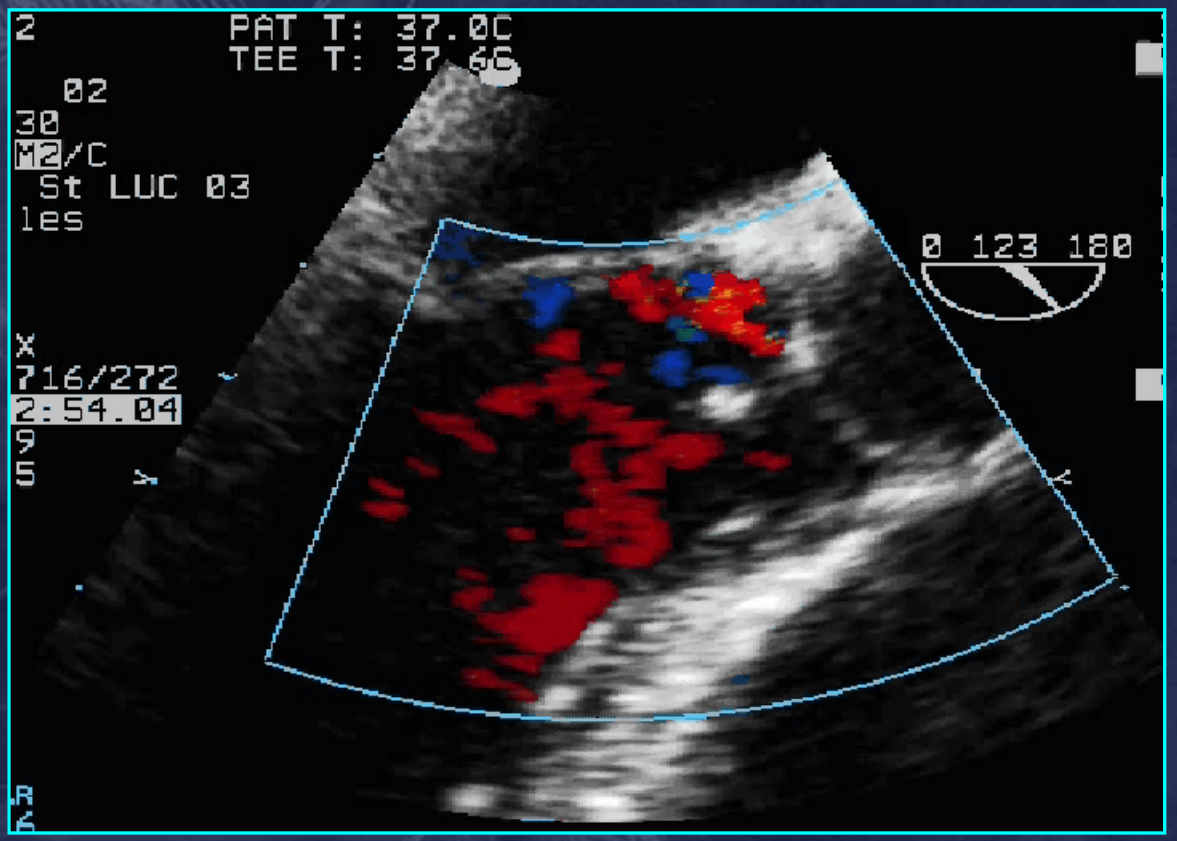


Functional Anatomy of Aortic Regurgitation

Type Id: Endocarditis and cusp perforation



Leaflet perforation



Functional Anatomy of Aortic Regurgitation

Echocardiographic prediction
of aortic valve repairability

Functional Anatomy of Aortic Regurgitation

Echo prediction of valve pathology and repairability

		Surgery			Total
		Type 1	Type 2	Type 3	
TEE	Type 1	36	3	0	39
	Type 2	3	58	2	63
	Type 3	2	1	58	61
Total		41	62	60	163

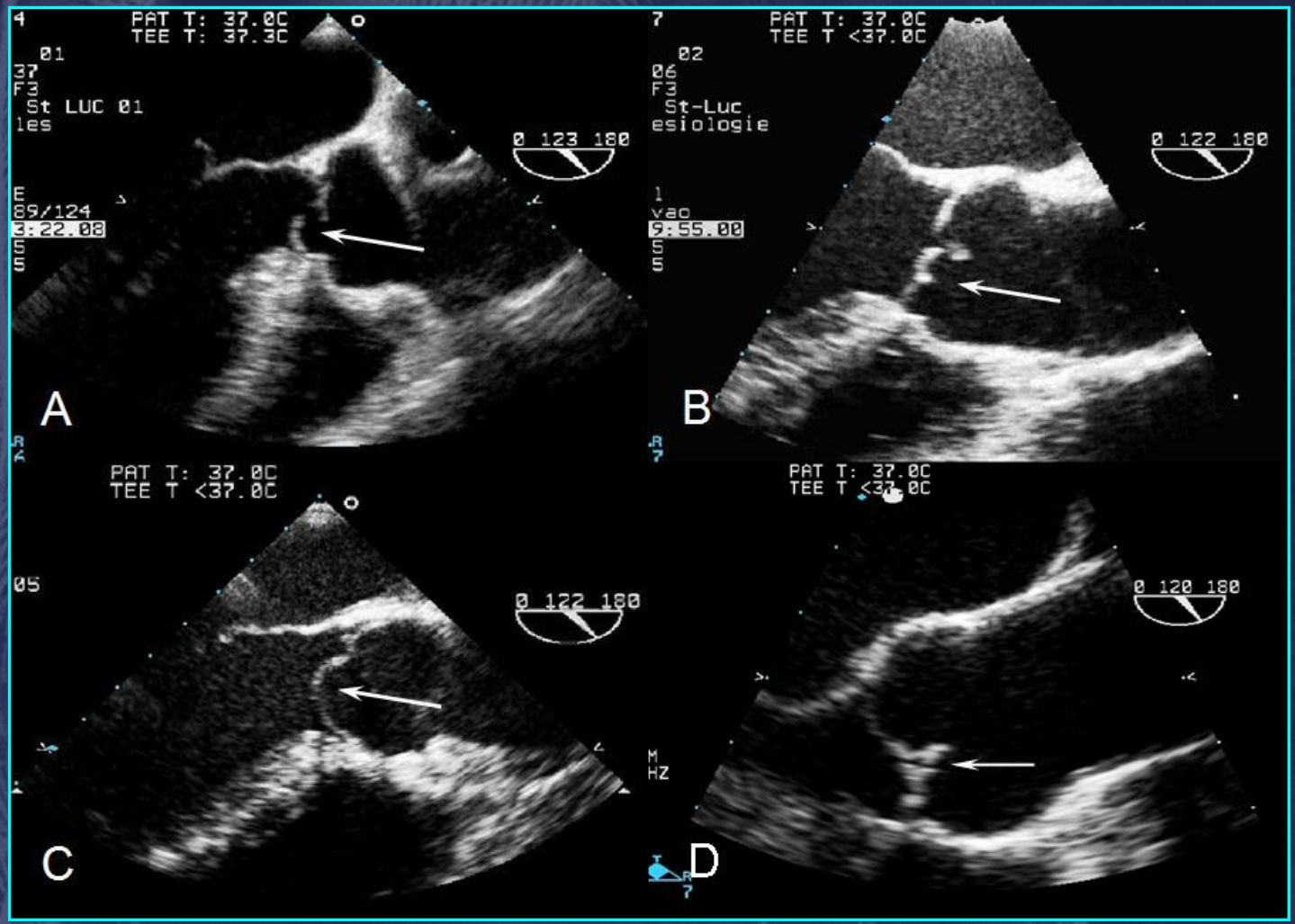
Le Polain de Waroux et al., *Circulation* 2007;116:I-264

Functional Anatomy of Aortic Regurgitation

Echo prediction of valve pathology and repairability

Flail

Partial



Whole

Fenestration

Le Polain de Waroux et al., *Circulation* 2007;116:I-264

Functional Anatomy of Aortic Regurgitation

Echo prediction of valve pathology and repairability

		Surgery				
		Cusp flail	Whole cusp prolapse	Distal cusp prolapse	Free edge fenetrations	Total
TEE	Cusp flail	3	1	0	0	4
	Whole cusp prolapse	0	25	0	1	26
	Partial cusp prolapse	0	2	11	1	14
	Fenestrations	0	2	1	11	14
	Type 1	0	0	0	3	3
	Type 3	0	0	0	1	1
	Total	3	30	12	17	62

Le Polain de Waroux et al., *Circulation* 2007;116:I-264

Functional Anatomy of Aortic Regurgitation

Echo prediction of valve pathology and repairability

Repairability was determined based on tissue quality and leaflet calcifications.

- Smooth, thin and large leaflets with redundant tissue were considered as repairable.
- Small, restrictive, fibrous or thickened leaflets were thought to preclude surgical repair.
- Heavily calcified valves (≥ grade 3) were usually considered as non repairable (except if localized at the level of the free margins)

Le Polain de Waroux et al., *Circulation* 2007;116:I-264

Functional Anatomy of Aortic Regurgitation

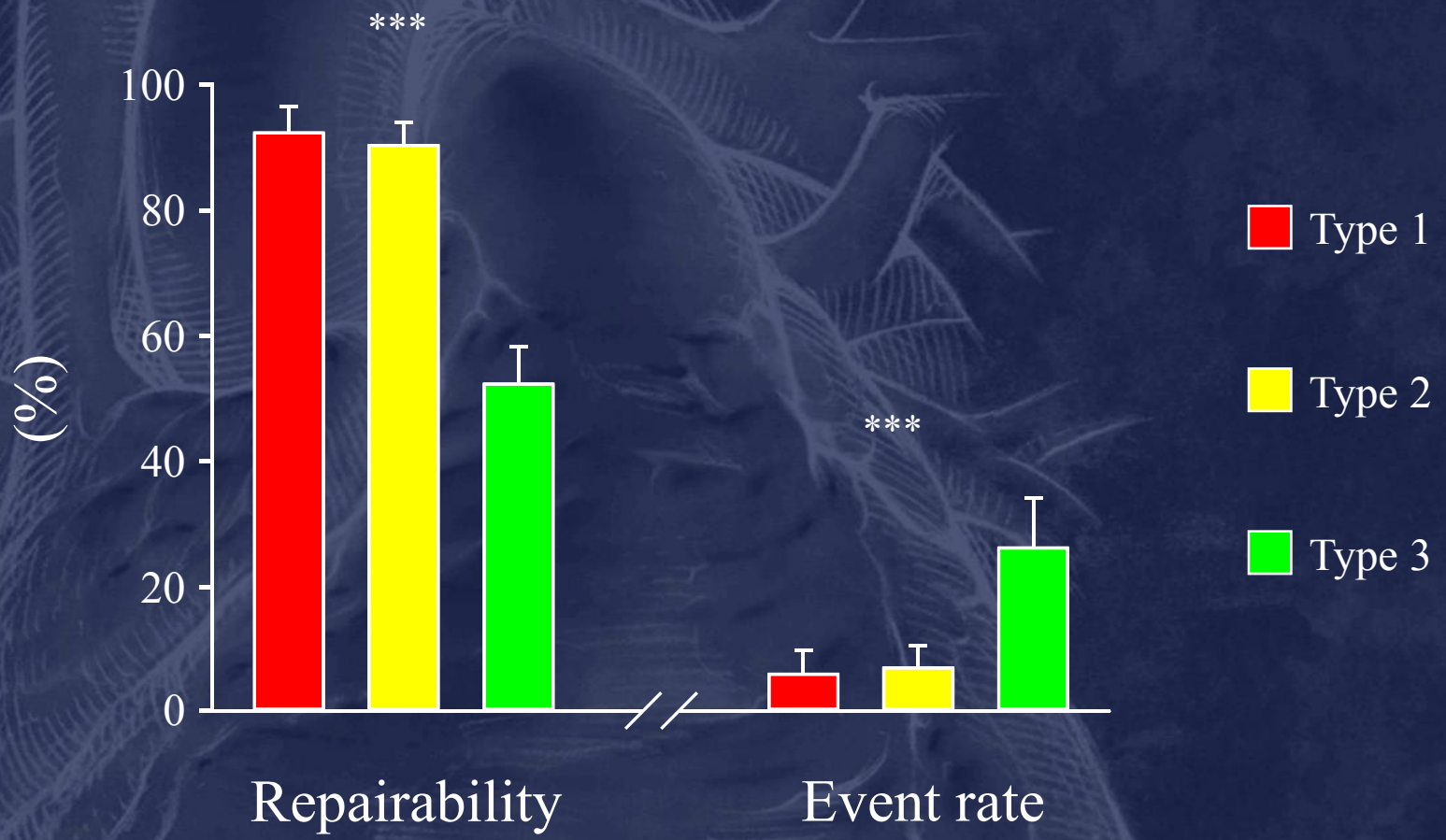
Echo prediction of valve pathology and repairability

		Final surgical procedure		Total
		replacement	repair	
TEE-predicted procedure	replacement	35	17	52
	repair	3	108	111
Total		38	125	163

Le Polain de Waroux et al., *Circulation* 2007;116:I-264

Functional Anatomy of Aortic Regurgitation

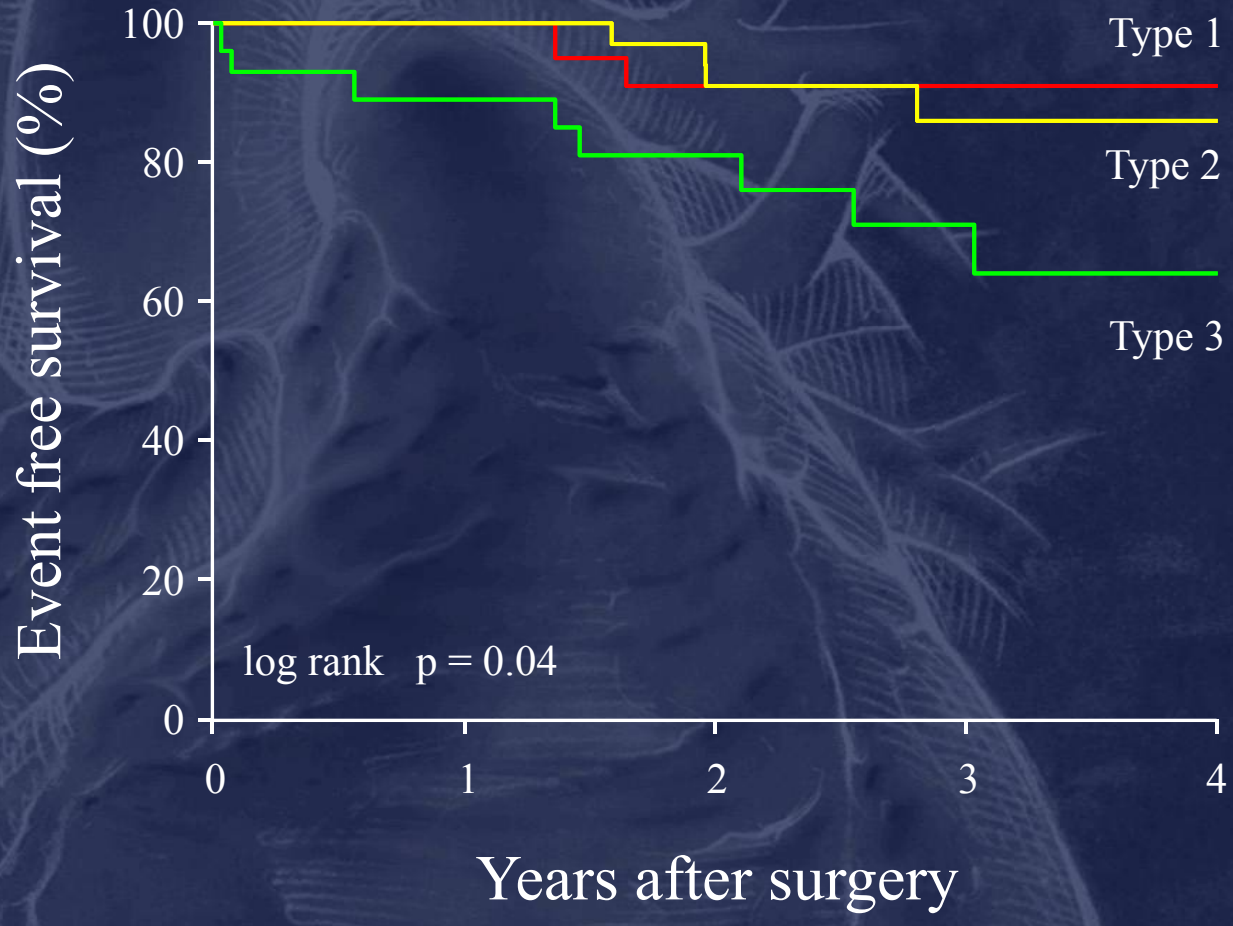
AR repair: prediction of valve repairability



Le Polain de Waroux et al., *Circulation* 2007;116:I-264

Functional Anatomy of Aortic Regurgitation

Echo prediction of valve pathology and repairability



Le Polain de Waroux et al., *Circulation* 2007;116:I-264

Functional Anatomy of Aortic Regurgitation

Intra-operative echocardiographic evaluation:
Risk of recurrent AR

Functional Anatomy of Aortic Regurgitation

Echo prediction of long term repair failure

- 186 consecutive AR repair patients with available pre-operative, intraoperative and follow-up echo data.

  - 122 pts (group A, 53 ± 13 yrs) with no AR recurrence
  - 23 pts (group B, 50 ± 16 yrs) with 1+ to 2+ recurrent AR
  - 41 pts (group B, 63 ± 12 yrs) with 3+ recurrent AR

Le Polain de Waroux et al., *J Am Coll Cardiol Imag* 2009;2:931-939

Functional Anatomy of Aortic Regurgitation

Follow-up results

Over a mean follow-up of 24 months, 41 pts had recurrent 3+ AR, 23 of whom needed a redo operation.

F-up Echocardiography identified the cause of repair failure as

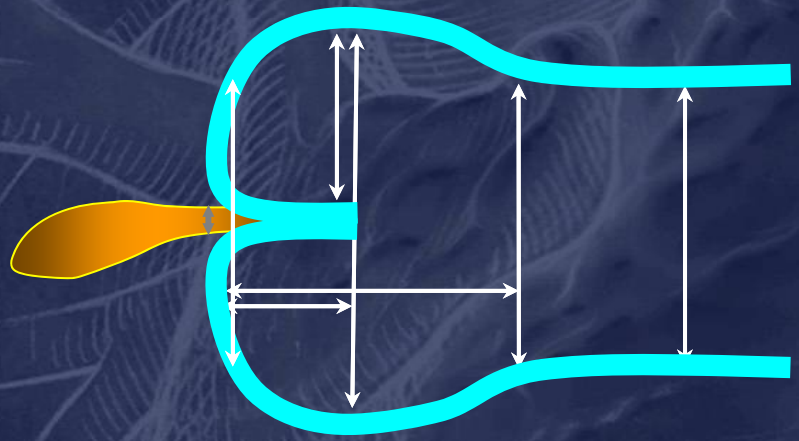
- Presence cusp prolapse (type 2 AR) : 26 pts
- Restrictive cusp motion (type 3 AR) : 9 pts
- Dehiscence of valvar sutures : 3 pts
- Aortic dissection : 2 pts
- Endocarditis : 1 pt

Le Polain de Waroux et al., *J Am Coll Cardiol Imag* 2009;2:931-939

Functional Anatomy of Aortic Regurgitation

Immediate post-operative measurements

120 degree - LAX



- ✓ Annulus
- ✓ Sinuses
- ✓ ST junction
- ✓ Tubular aorta
- ✓ Height of the sinuses
- ✓ Coaptation length
- ✓ Symmetry of the coaptation
- ✓ Tips to annulus
- ✓ Cusp's belly to annulus
- ✓ Eccentric Jet
- ✓ Vena contracta width

Le Polain de Waroux et al., *J Am Coll Cardiol Imag* 2009;2:931-939

Functional Anatomy of Aortic Regurgitation

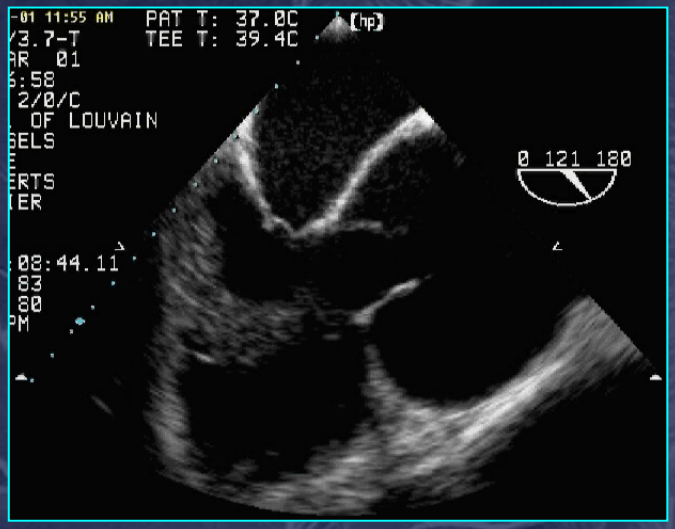
Multivariate analysis

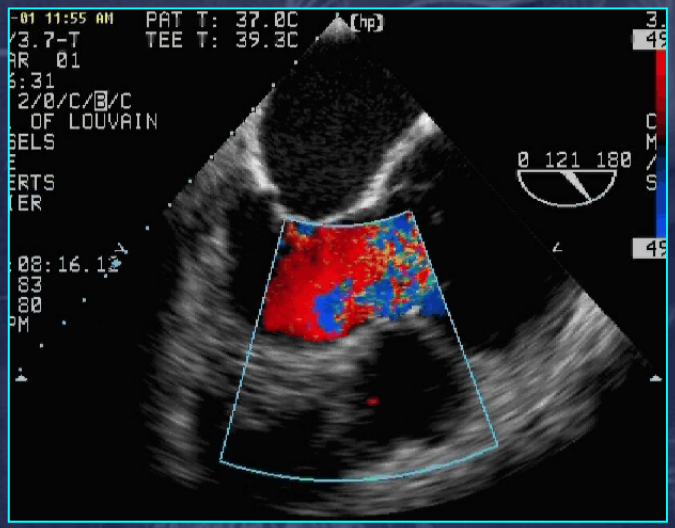
	HR	Cox P value
Coaptation length	0.82	0.54
Tips - annulus	4.72	0.08
Tips below the annulus	7.9	0.003
Annulus size	1.18	0.012
Residual AR	5.3	0.01

Le Polain de Waroux et al., *J Am Coll Cardiol Imag* 2009;2:931-939

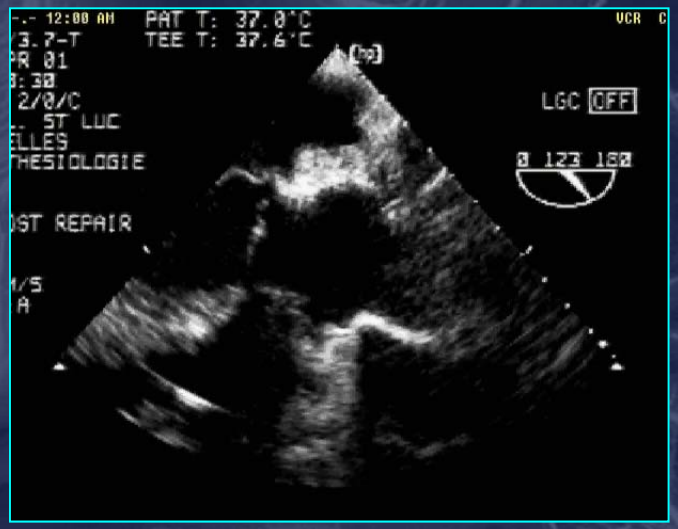
Functional Anatomy of Aortic Regurgitation

Representative exemple

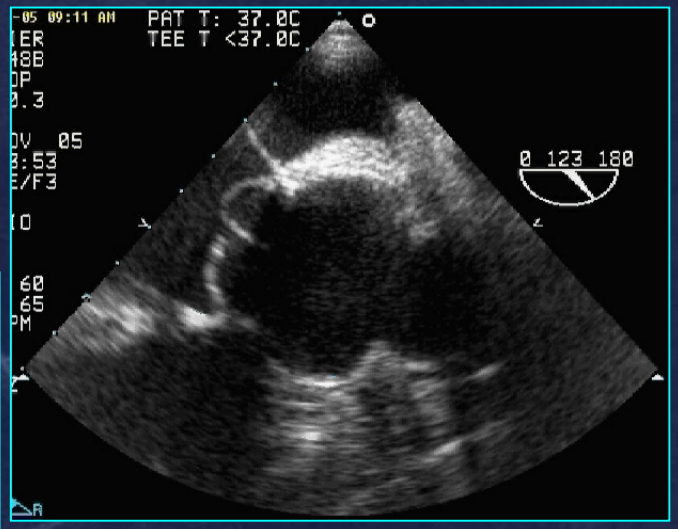


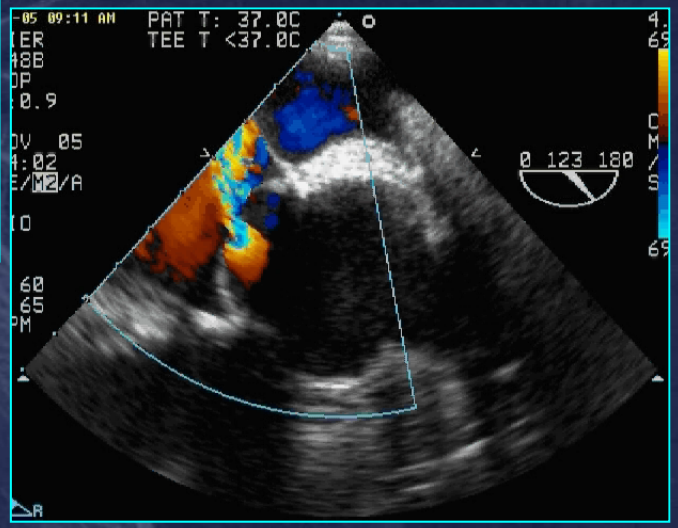


Pre-op



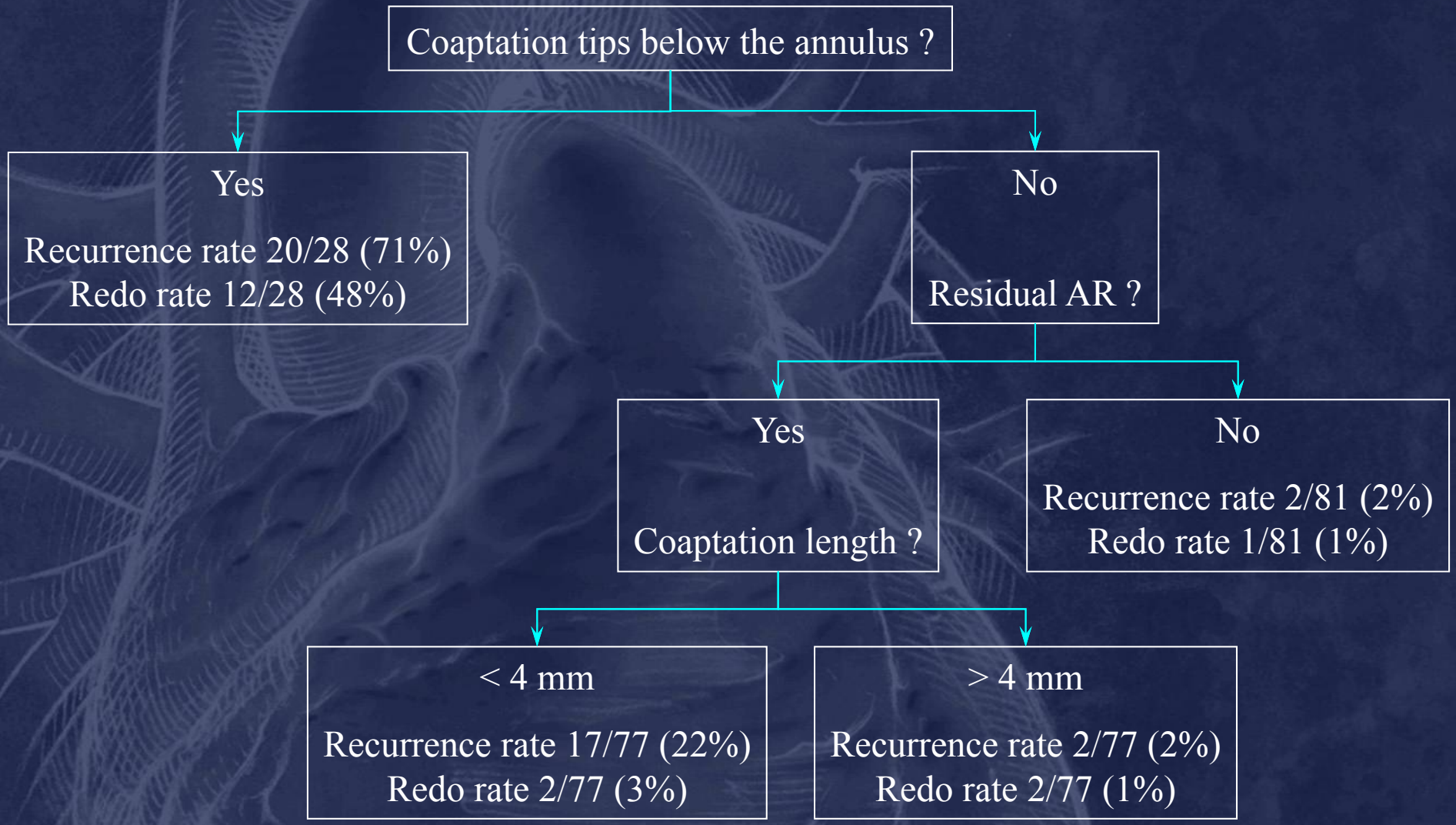
Intra-op





F-Up

Functional Anatomy of Aortic Regurgitation



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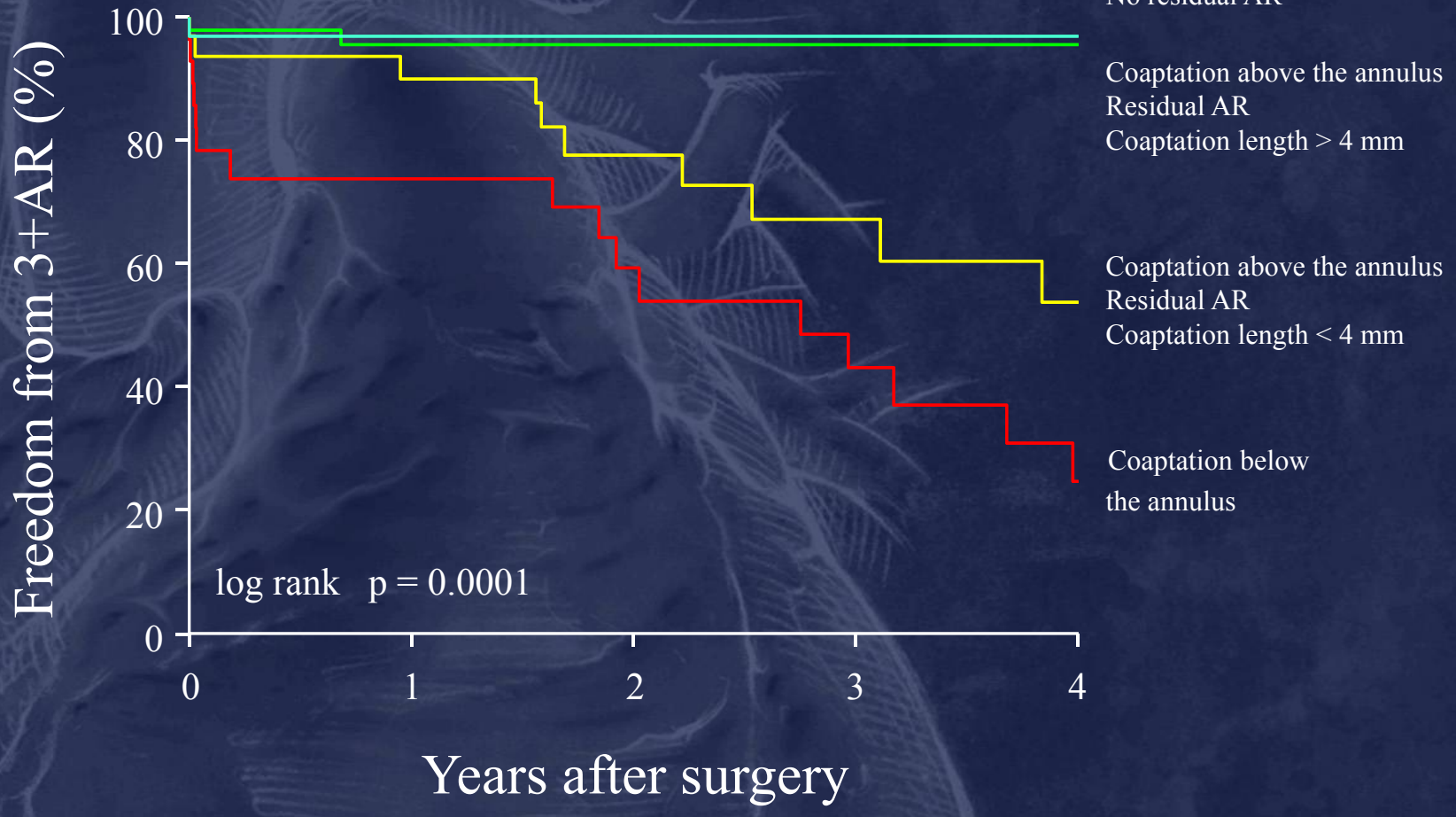
Functional Anatomy of Aortic Regurgitation

AR repair: freedom 3+ AR recurrence



Le Polain de Waroux et al., *J Am Coll Cardiol Imag* 2009;2:931-939

Functional Anatomy of Aortic Regurgitation

Conclusions

- Transesophageal echocardiography allows for accurate delineation of the mechnisms of aortic regurgitation when compared to surgery.
- In both Type 1 and Type 2 dysfunction by TEE, the likelihood of successful and durable repair is > 90%.
- In Type 3 dysfunction by TEE, the likelihood of repair does not exceed 50%. More than 40% of attempted repairs in Type 3 dysfunction fail over the next 4 years.
- Transesophageal echocardiography also allows for the intra-operative evaluation of repair results and can be used to decide whether further surgery is needed.