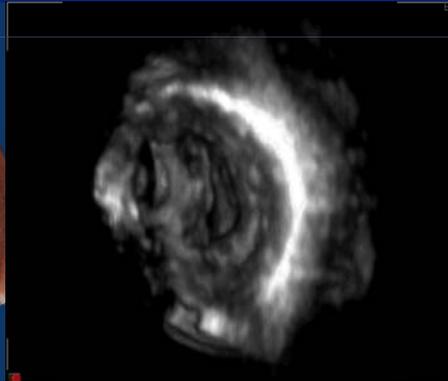
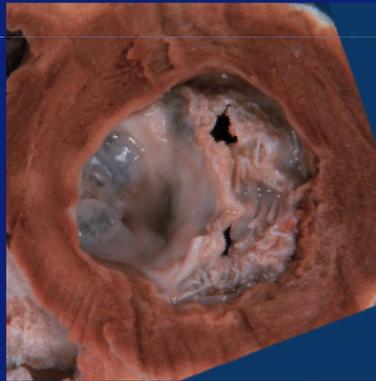


# Mechanisms of mitral regurgitation - role of 3D echo illustrated by cases -



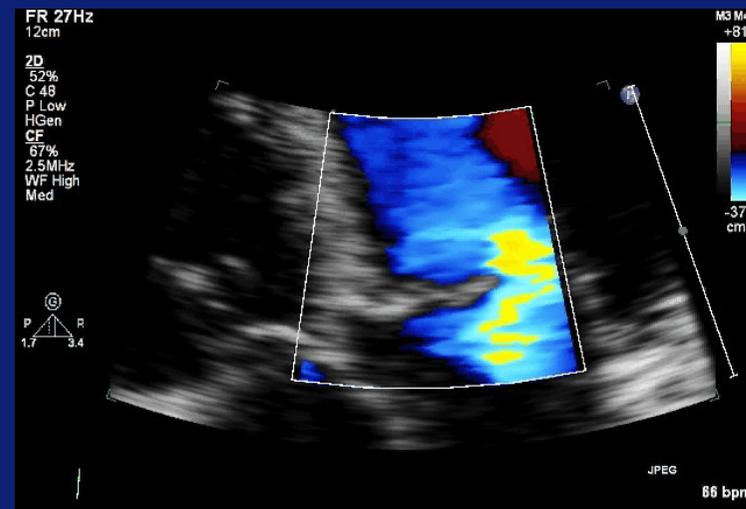
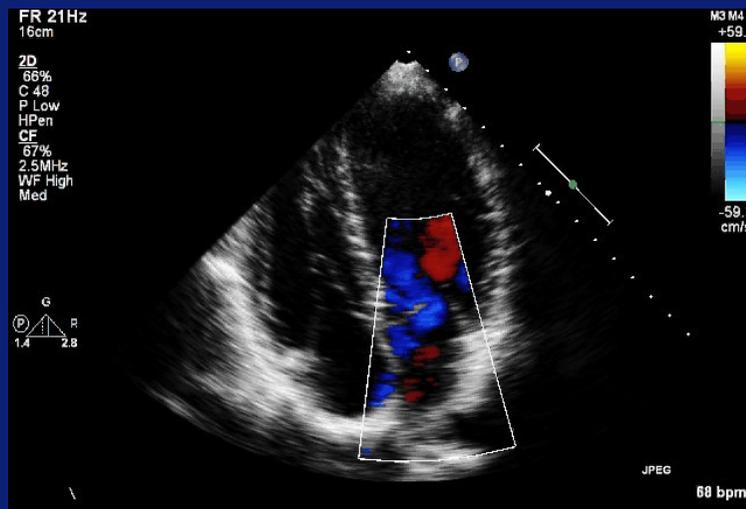
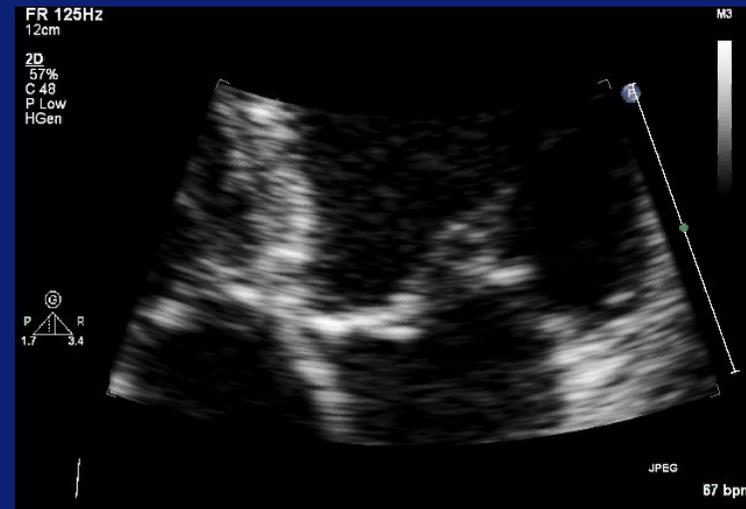
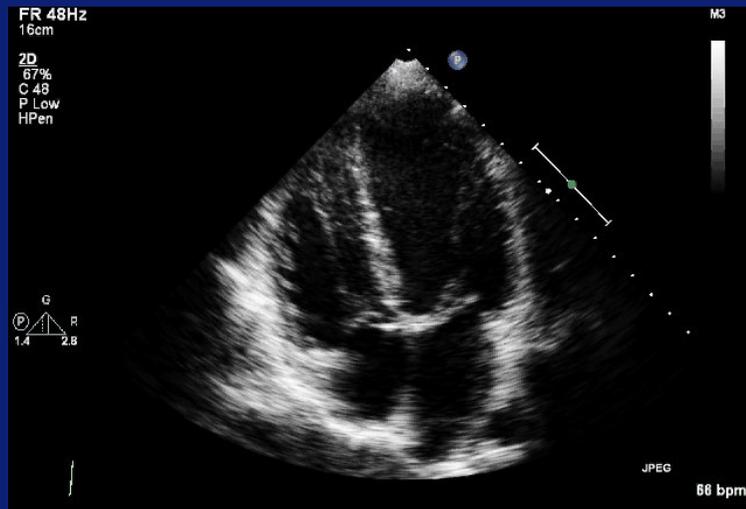
M.L. Geleijnse

Department of Cardiology, Thoraxcenter  
Erasmus MC, Rotterdam, The Netherlands

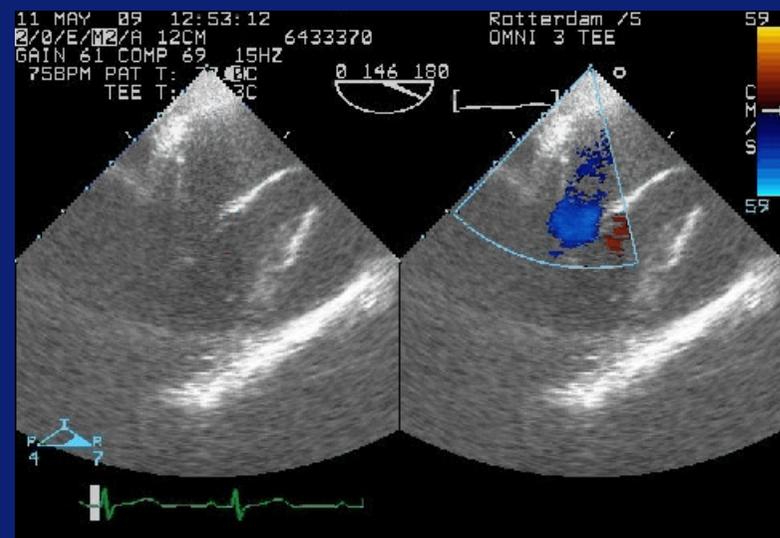
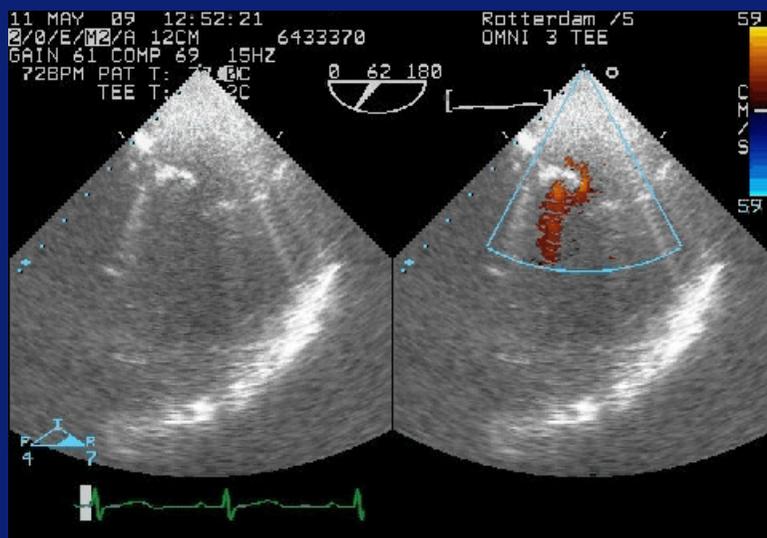
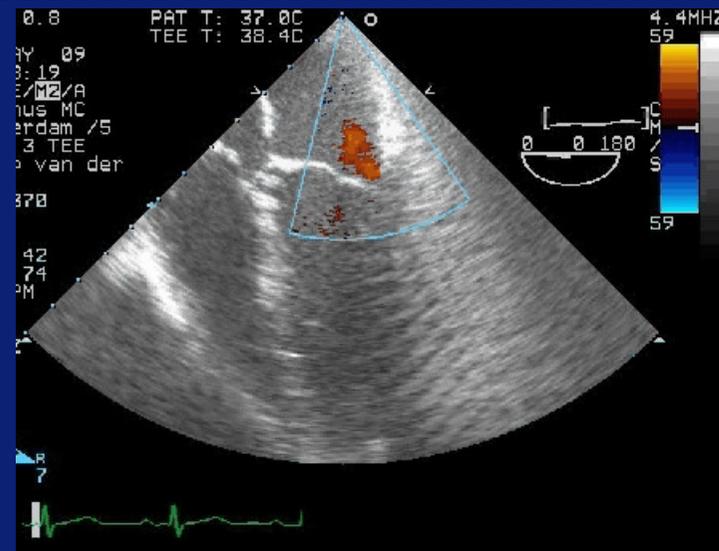
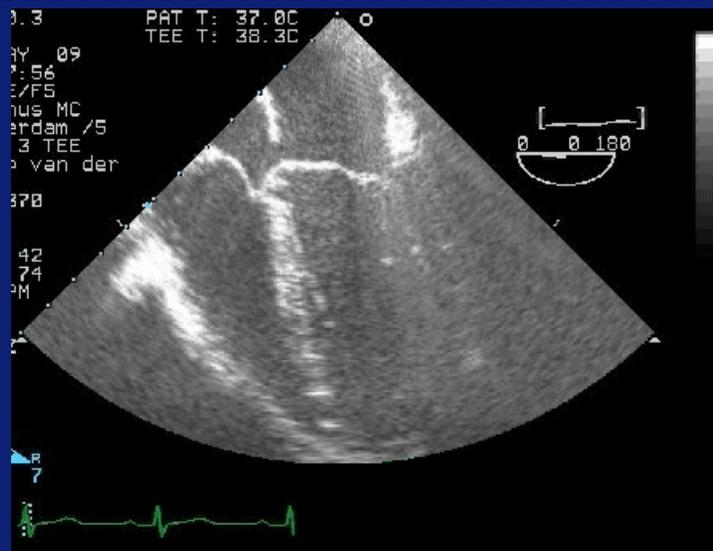
# Patient case 1

- 28 year-old-female
- Correction of a partial atrio-ventricular septal defect at the age of 4 year
- Progressive shortness of breath, no other complaints
- ECG: sinus rhythm
- Echo: no residual shunt at atrio-ventricular level

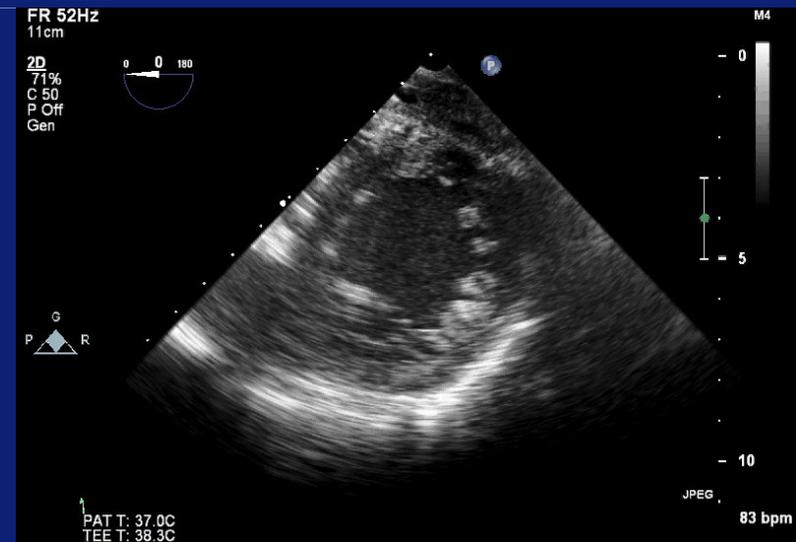
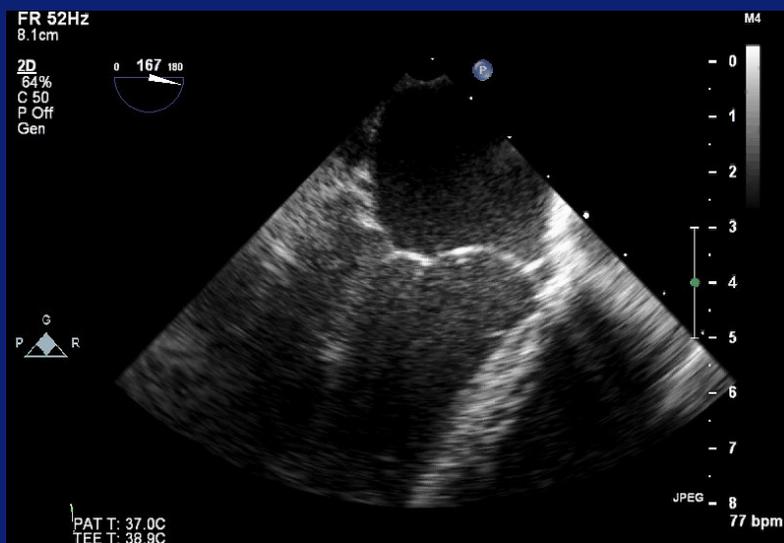
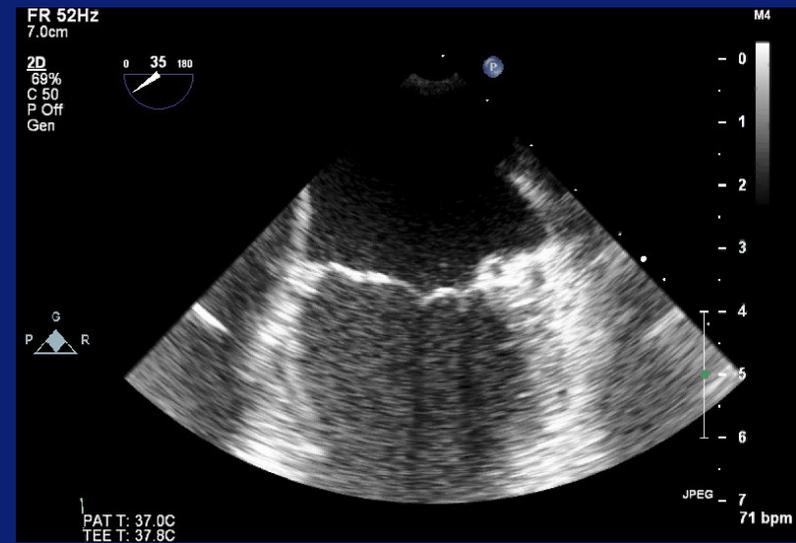
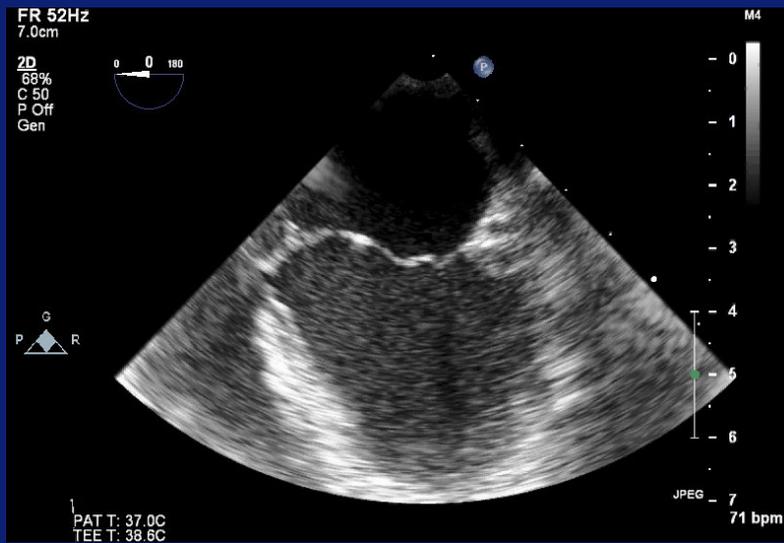
# Mitral regurgitation



# Mitral regurgitation



# Mitral regurgitation



## Question 1

Do you routinely assess LV dyssynchrony in patients in sinus rhythm with LBBB, heart failure NYHA class 3, and LV-EF <35%?

1. Yes, in all patients
2. Yes, in selected patients
3. No

## Question 3-D

**What technique do you use for assessment of intra-LV-dyssynchrony?**

Color-coded TDI Yu-index

1. Yes

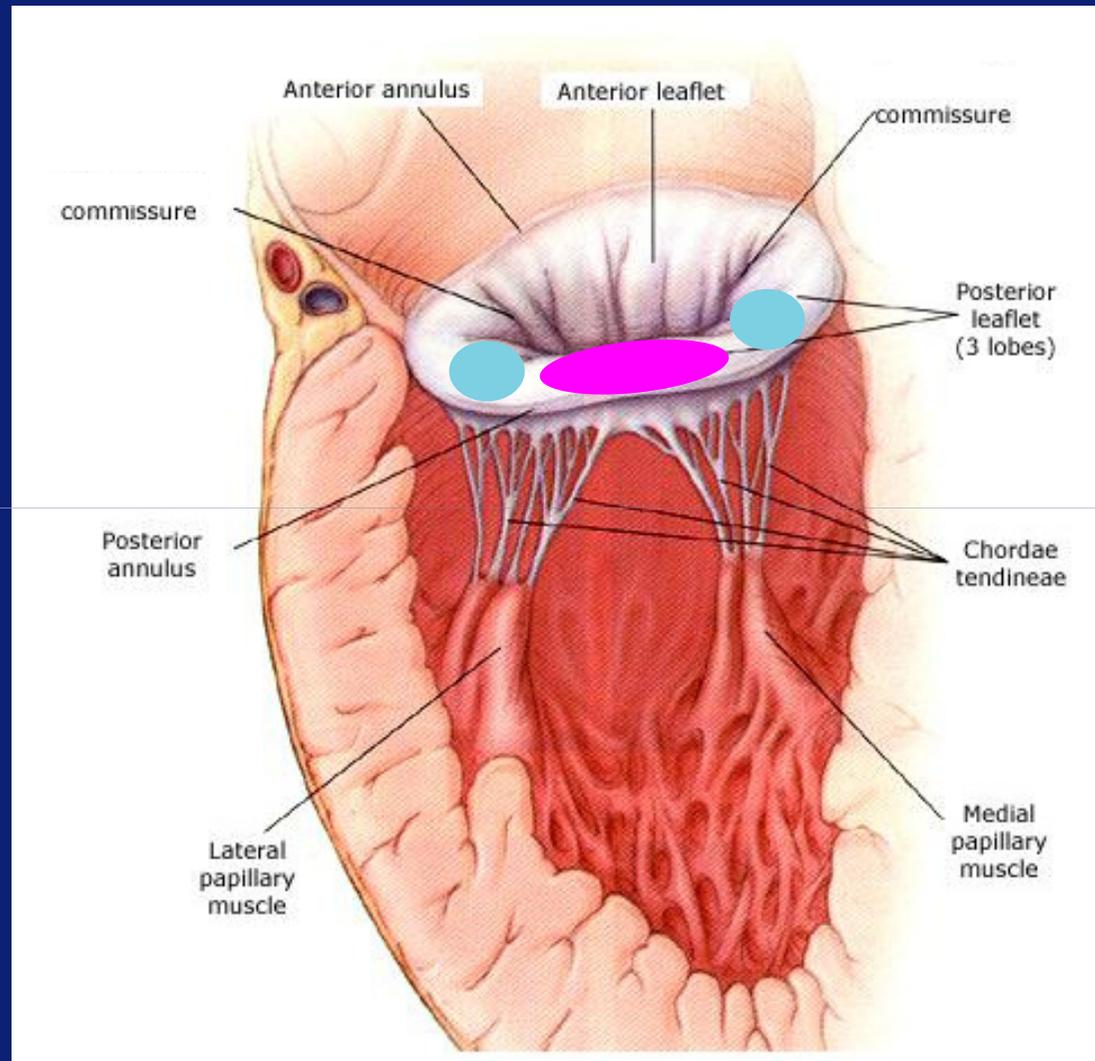
2. No

# Question 1

What is the main mechanism of mitral regurgitation in this patient?

1. Prolaps
2. Restriction
3. Cleft
4. I do not know

# Mitral valve apparatus



# Importance of recognizing MR mechanism

Condition	Example	Pathology
Primary valve	Asks for valve repair or replacement	
Functional mitral	May improve with <ul style="list-style-type: none"><li>• medical therapy (ACE-inhibitors, beta-blockers, diuretics)</li><li>• resynchronization therapy</li><li>• coronary revascularisation</li></ul>	

# Importance of recognizing MR mechanism

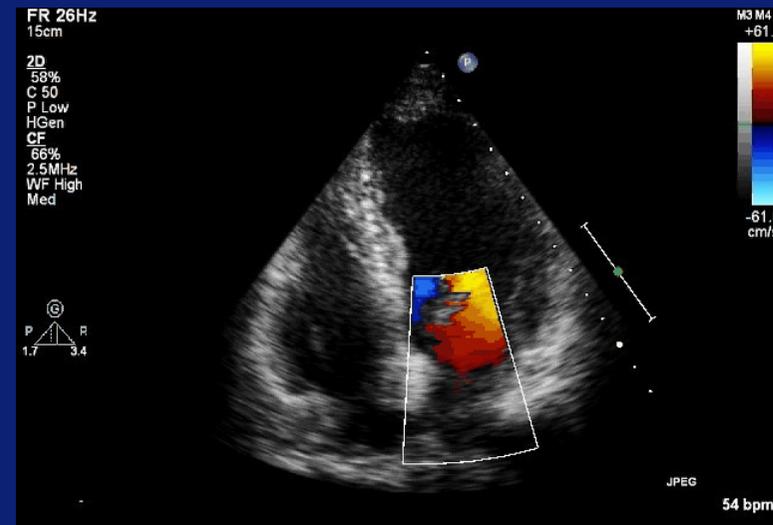
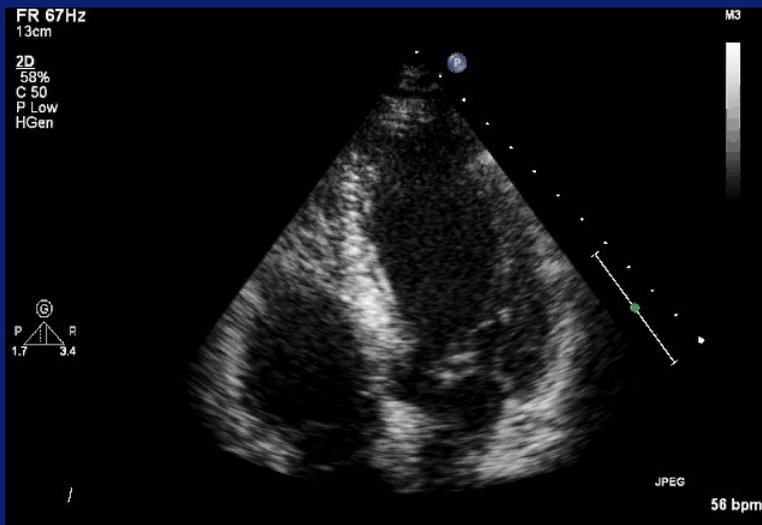
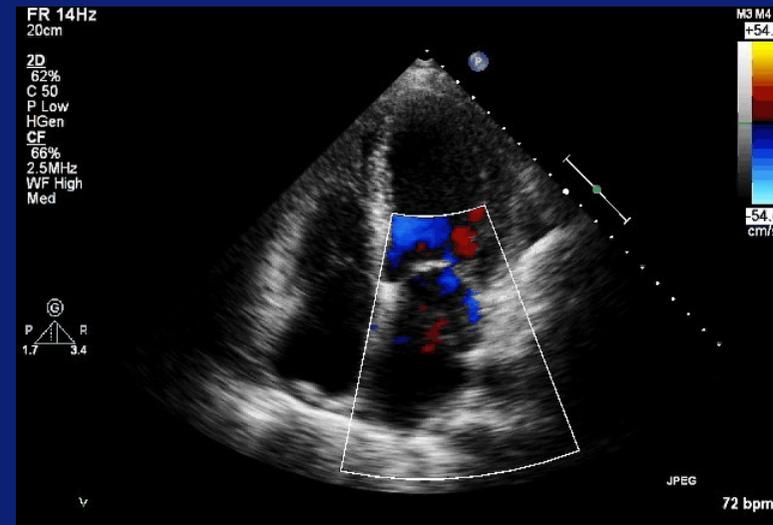
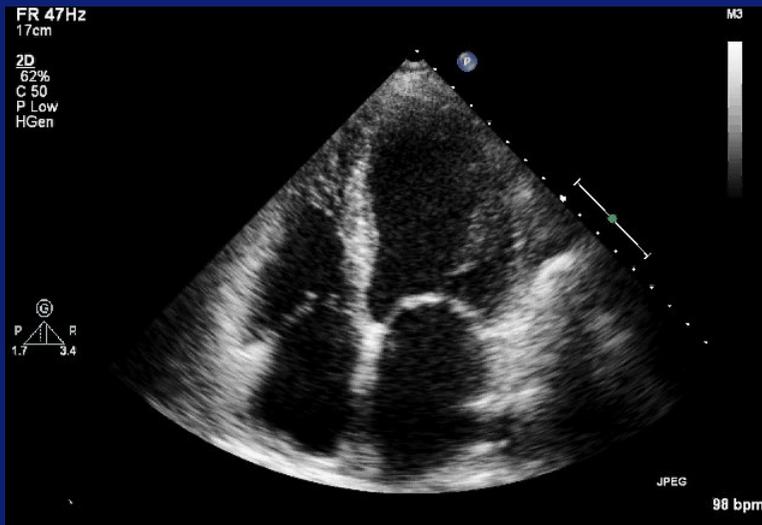
## Primary MR: due to a valvular problem

- valve repair or replacement

## Secondary or functional MR: due to a LV problem

- heart failure therapy (ACE-inhibitors, beta-blockers, diuretics)
- cardiac resynchronization therapy (CRT)
- coronary revascularisation (PCI or CABG)

# Importance of recognizing MR mechanism



# Importance of MR mechanism: axioma 1

Successful valve repair is preferable to valve replacement for most patients with mitral valve disease

# Importance of MR mechanism: axiomas

- 1) successful mitral valve repair is preferable to mitral valve replacement for most patients
- 2) accurate assessment of the functional anatomy is a prerequisite for successful and long-lasting mitral valve repair
- 3) surgical inspection of the mitral valve in a flaccid arrested heart at the time of surgery does not reflect true functional pathology of the diseased mitral valve

## Importance of MR mechanism: axioma 2

Accurate assessment of functional anatomy is a prerequisite for successful and long-lasting repair

## Importance of MR mechanism: axioma 3

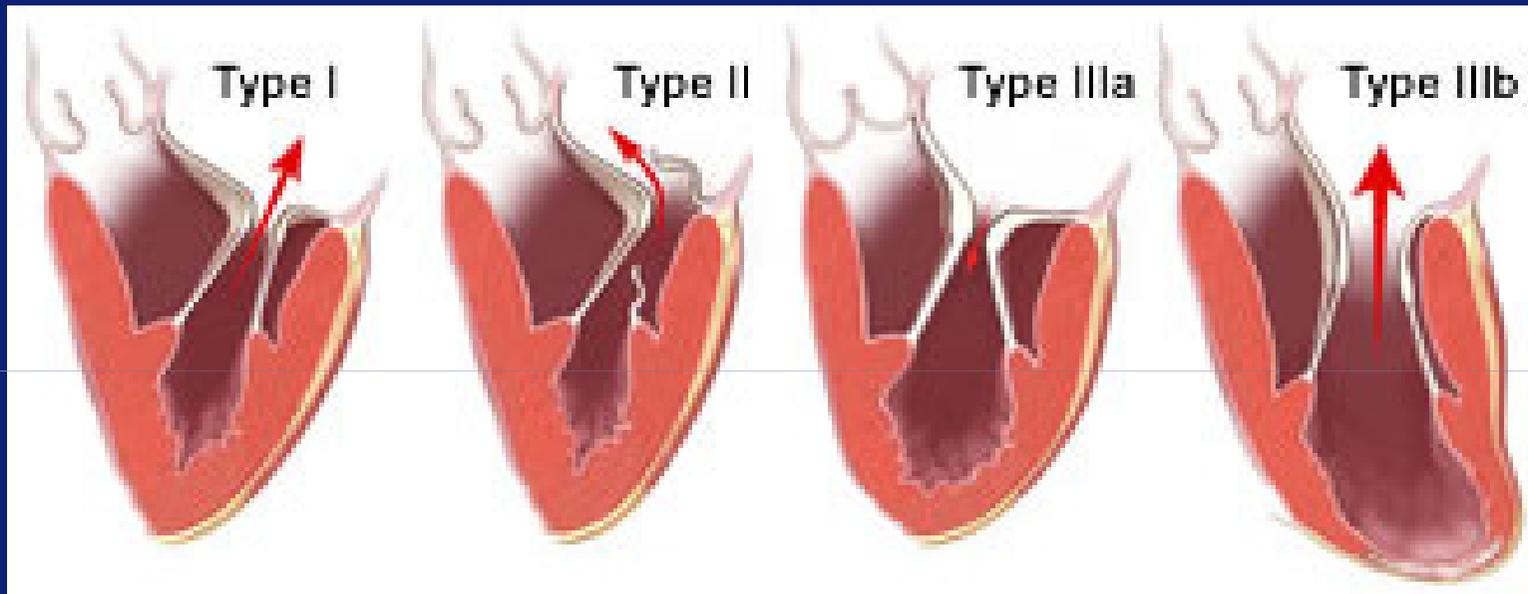
Surgical inspection of the mitral valve in a flaccid arrested heart at the time of surgery does not reflect true functional pathology of the diseased mitral valve

## Importance of MR mechanism: axioma 4

The preoperative assessment of the functional pathology of the mitral valve is as relevant to a surgeon as a well-charted route to Curacao is to a pilot before take-off

# Carpentier functional classification

based on the opening and closing motion of the mitral valve leaflets in relation to the mitral annulus



**Type I** normal motion with annular dilatation

**Type II** increased motion (prolapse)

**Type IIIa** decreased motion (restriction) in diastole and systole

**Type IIIb** decreased motion particular in systole

Erasmus MC

# Shaw's functionele classificatie

- Type I Normale beweging klepbladen
- Type II Toegenomen beweging (prolaps)
- Type III Afgenomen beweging

# Pathologie van de mitralisklep

## Type III Afgenomen beweging van klepbladen

A Systolische en diastolische restrictie  
(reumatisch vitium)

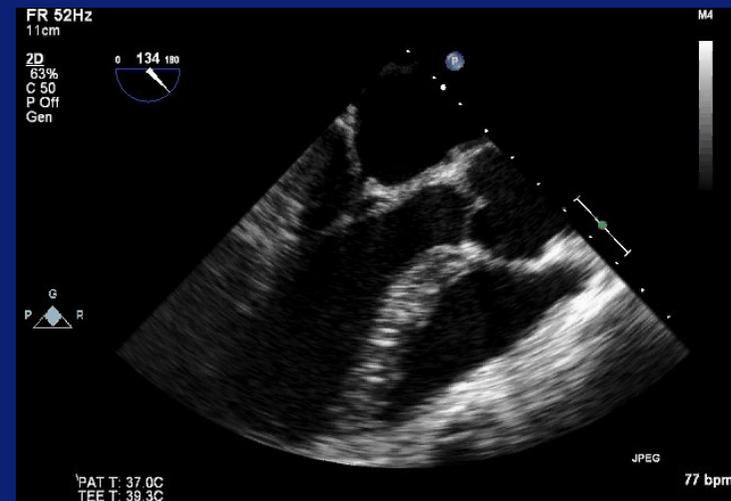
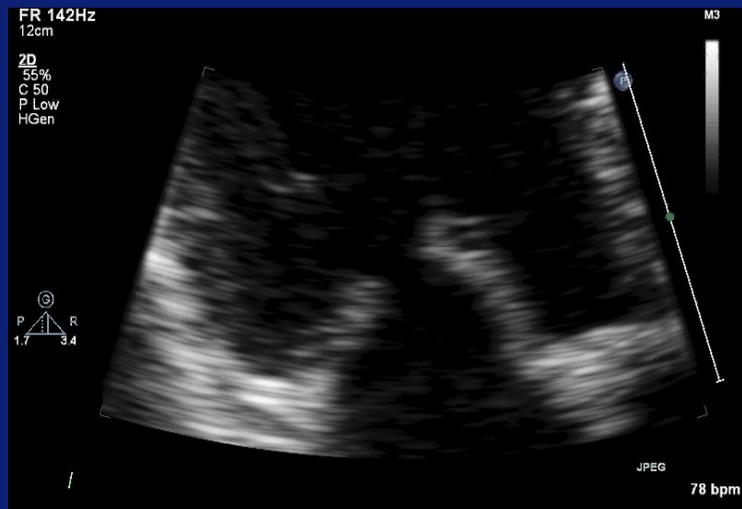
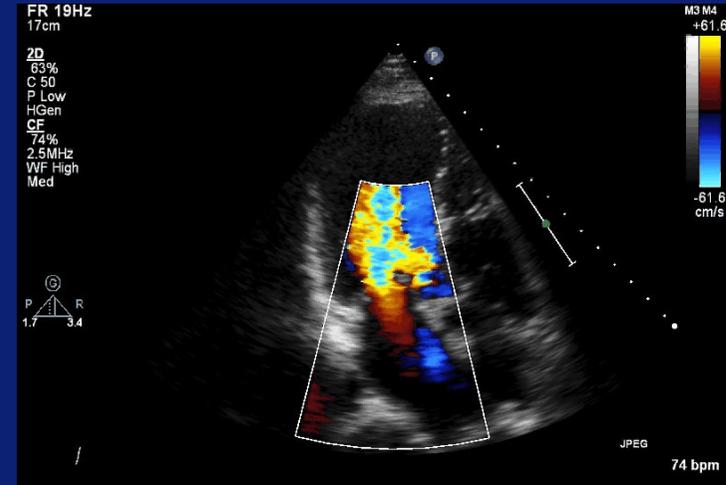
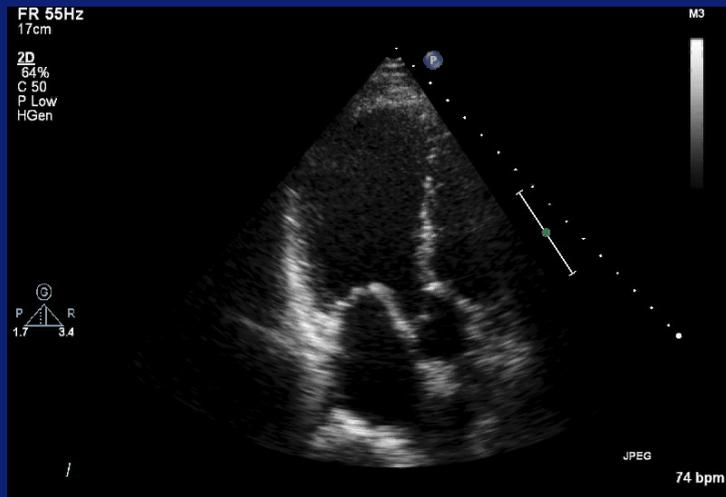
B Symmetrische systolische restrictie (twee  
tethered klepbladen, centrale jet)

C Asymmetrische systolische restrictie met één  
tethered klepblad en één overrijdend non-  
tethered klepblad (excentrische jet)

# Pathology of the mitral valve

- Type III Decreased motion of the valve leaflets
  - A Systolic en diastolic restriction (rheumatic disease)

# Type IIIA Restriction

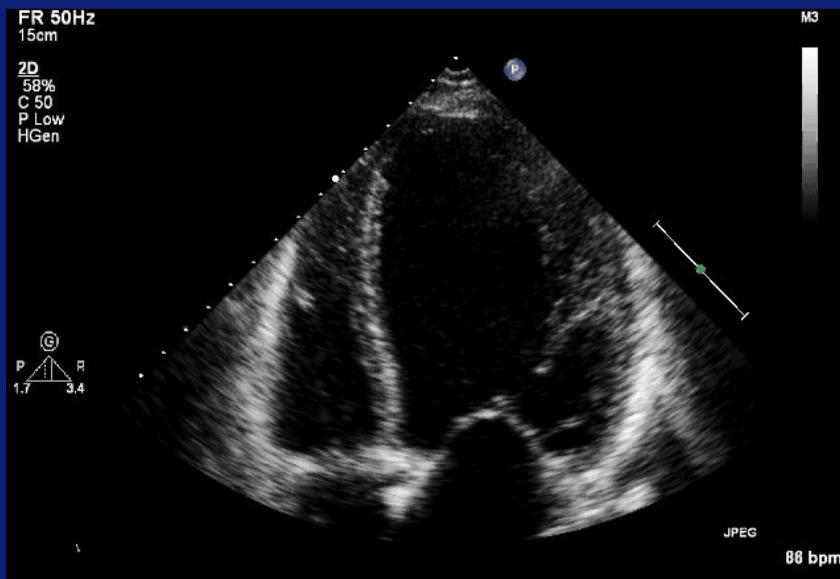
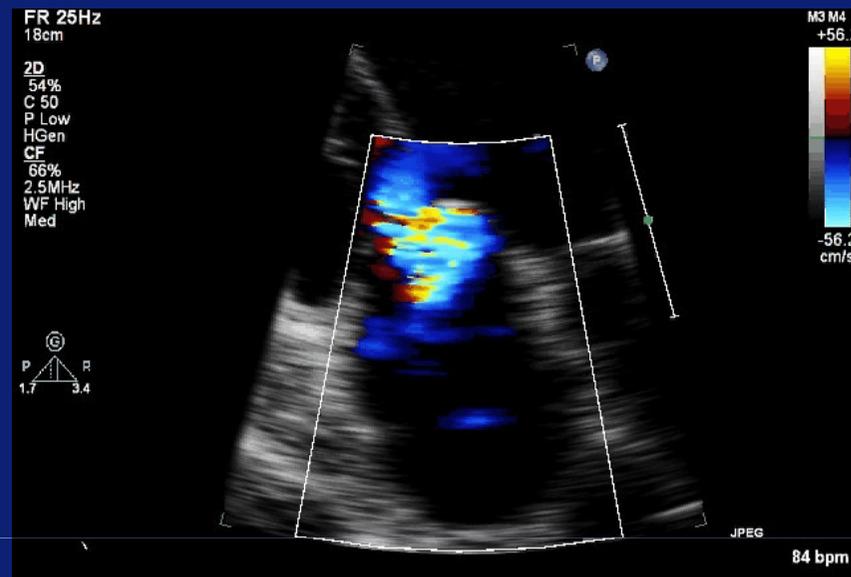


# Pathology of the mitral valve

Type III Decreased motion of the valve leaflets

B Symmetric systolic restriction (two tethered leaflets, central jet)

# Type IIIB Restriction

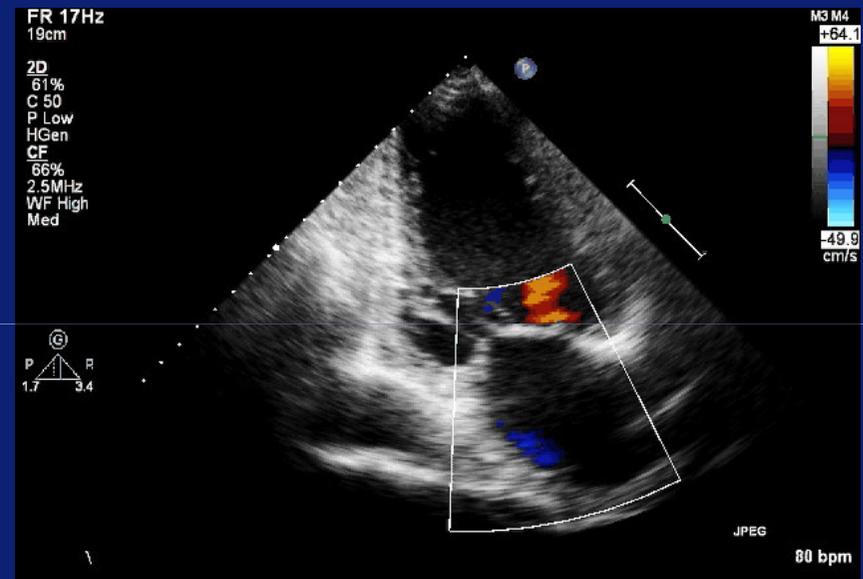
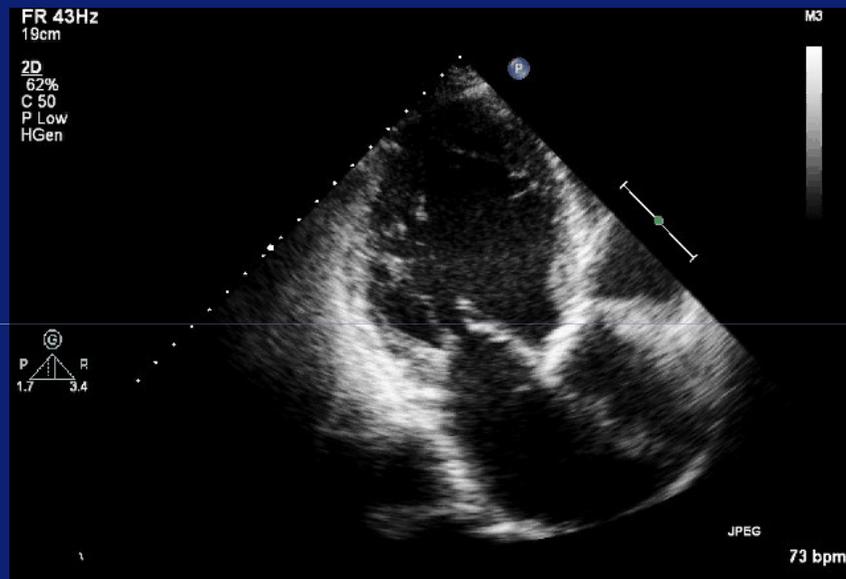


# Pathology of the mitral valve

Type III Decreased motion of the valve leaflets

C Asymmetric systolic restriction with one tethered leaflet and one overriding non-tethered leaflet (eccentric jet)

# Type IIIC Restriction



# Pathology of the mitral valve

## Type II Increased motion of the valve leaflets

- A Flail leaflet (eccentric jet)
- B Billowing both leaflets (central jet)
- C Billowing both leaflets with a flail leaflet (central and eccentric jet)

# Type II - Increased motion of the valve leaflets

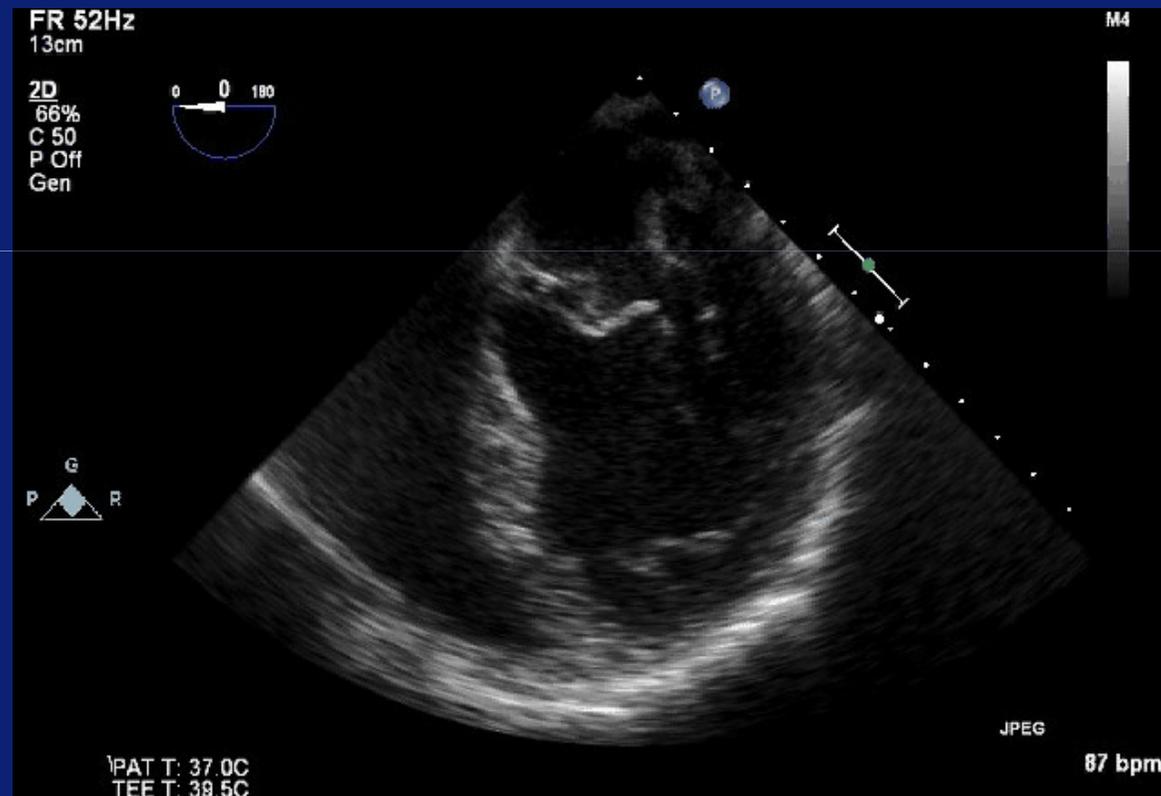
- Normal = closure below the annular plane with a coaptation zone of at least 5-8mm
- Billowing = superior displacement past the annular plane of the **body** of the leaflet
  - PMVL
  - AMVL >2mm in LAX or >5mm in 4CH
- Prolapse = superior displacement past the annular plane of the **free margin** of the leaflet
- Flail = severe prolapse due to chordal or papillary muscle rupture or extreme chordal elongation



# Pathology of the mitral valve

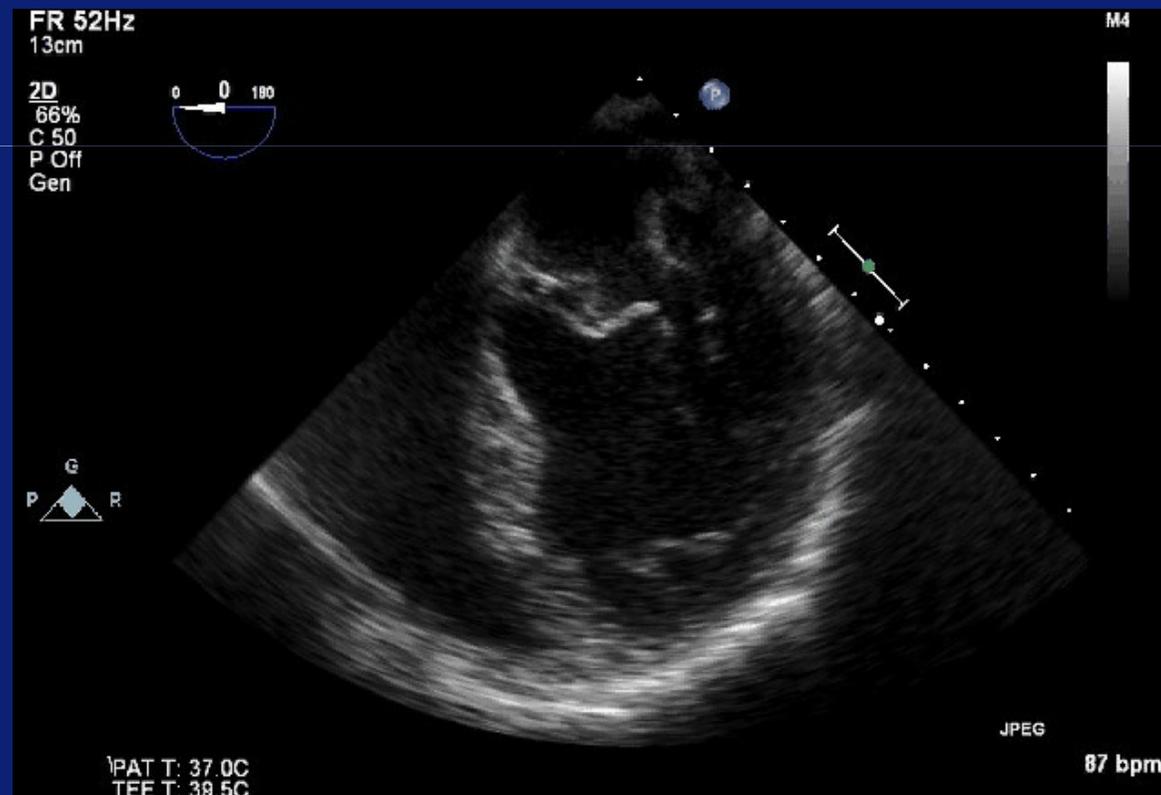
## Type II Increased motion of the valve leaflets

### A Flail leaflet (eccentric jet)



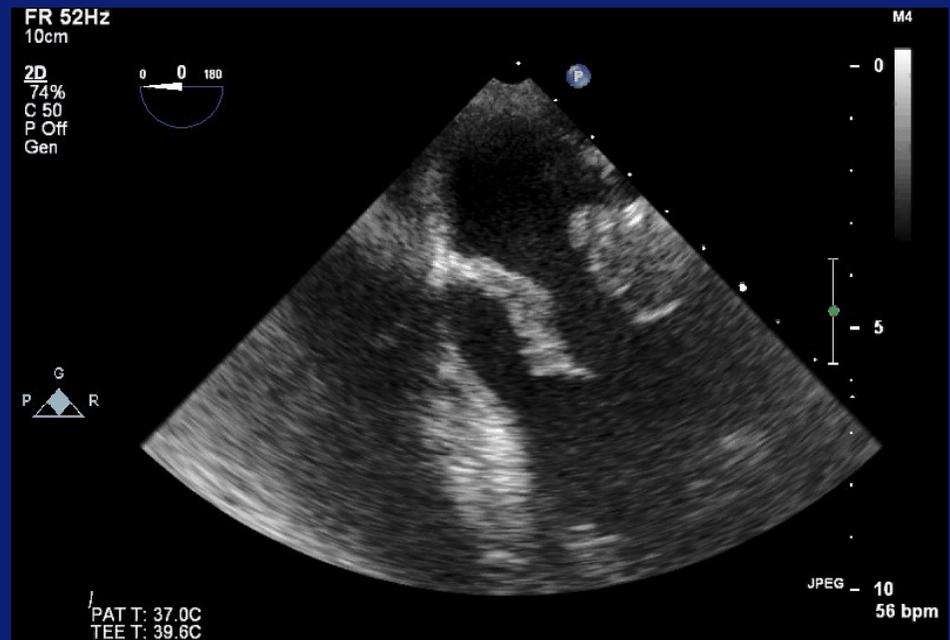
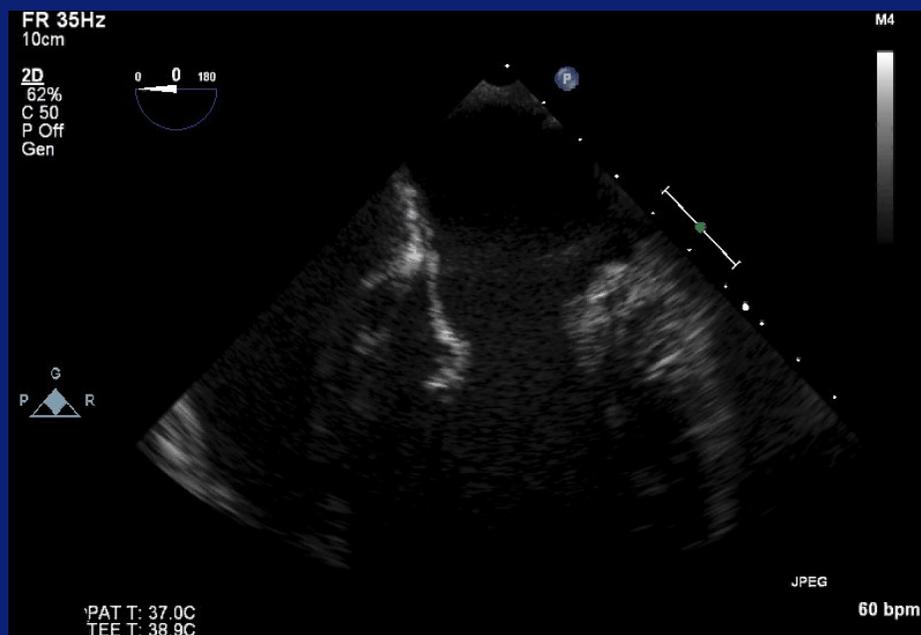
# Type II - Increased motion of the valve leaflets

Fibro-elastic deficiency with thin leaflets and thin and friable chordae (usually P2 prolapse)



# Type II - Increased motion of the valve leaflets

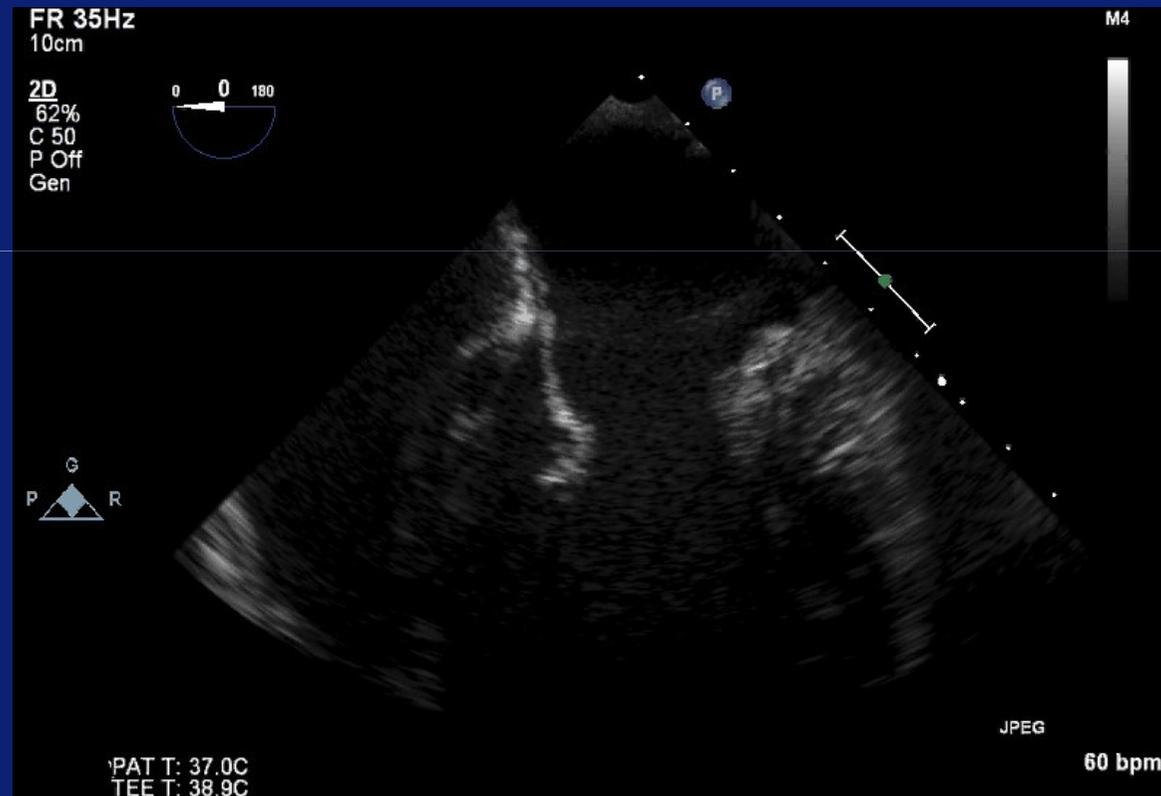
Degenerative or myxomatous disease with excessive leaflet tissue and elongated chordae (classic form Barlows disease)



# Pathology of the mitral valve

## Type II Increased motion of the valve leaflets

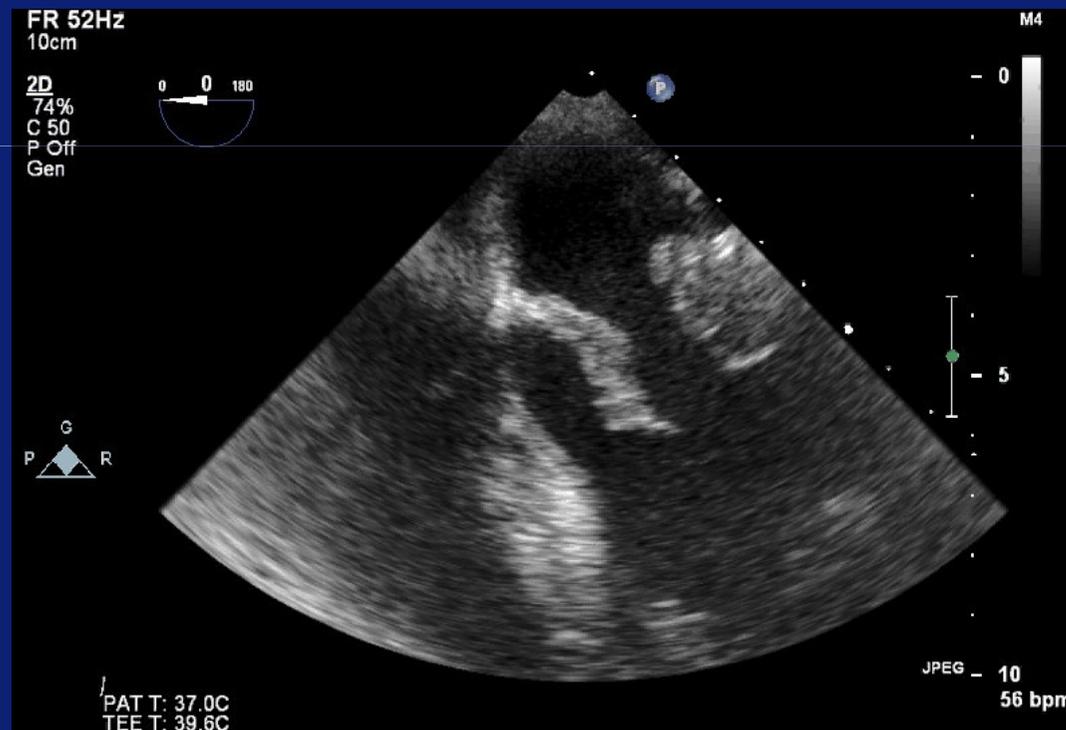
### B Billowing both leaflets (central jet)



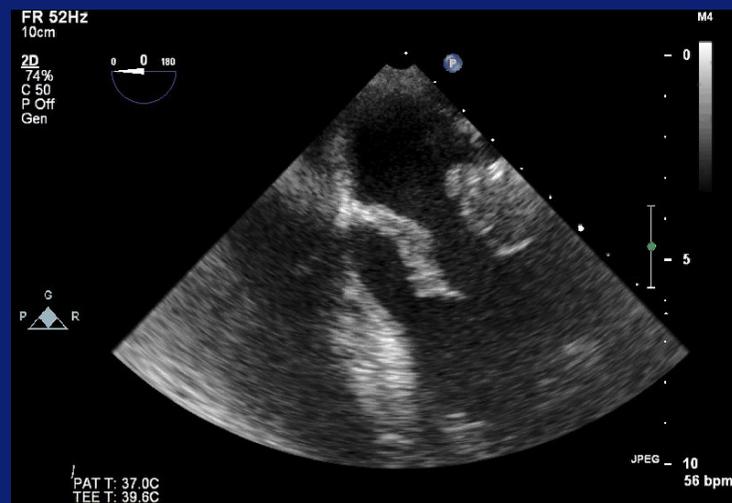
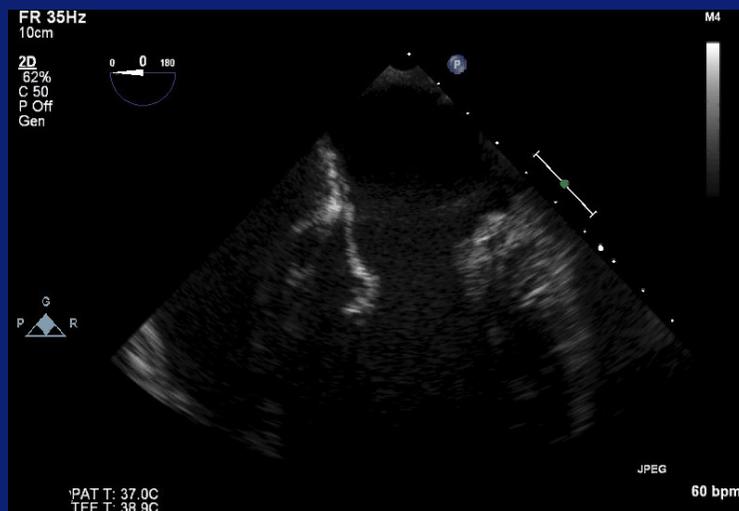
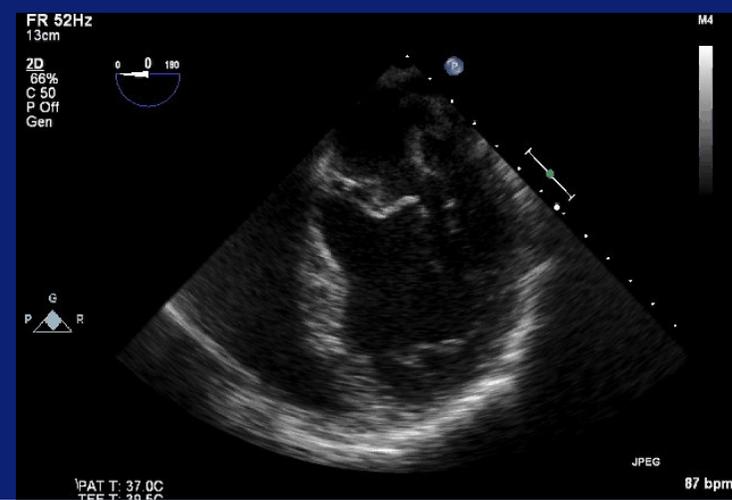
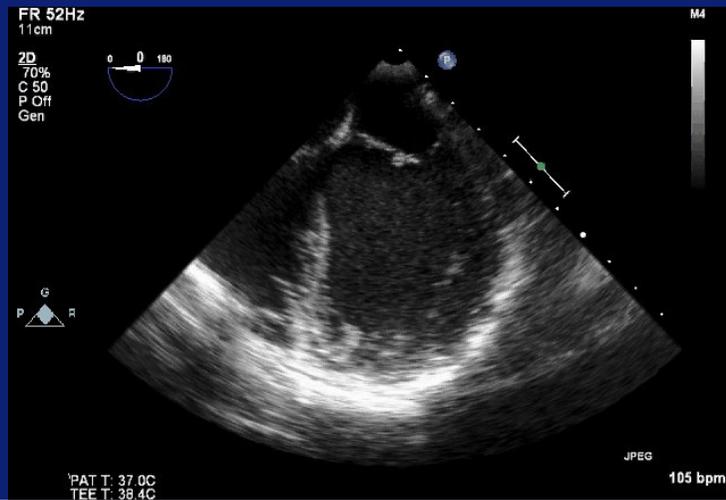
# Pathology of the mitral valve

## Type II Increased motion of the valve leaflets

- C Billowing both leaflets with a flail leaflet (central and eccentric jet)



# Degenerative mitral valve disease spectrum



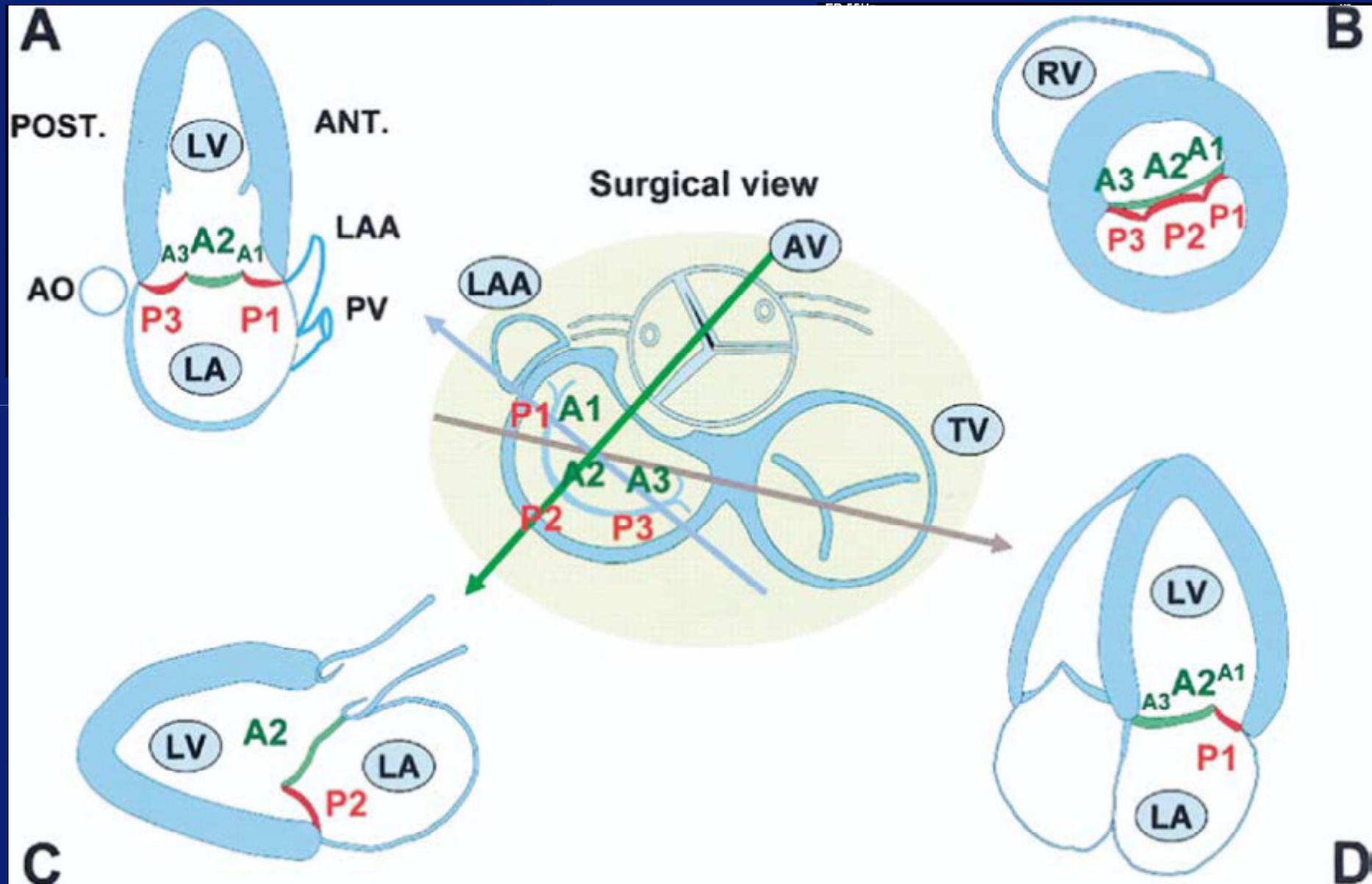
Recognizing site and extent of prolaps

defines the difficulty of surgery

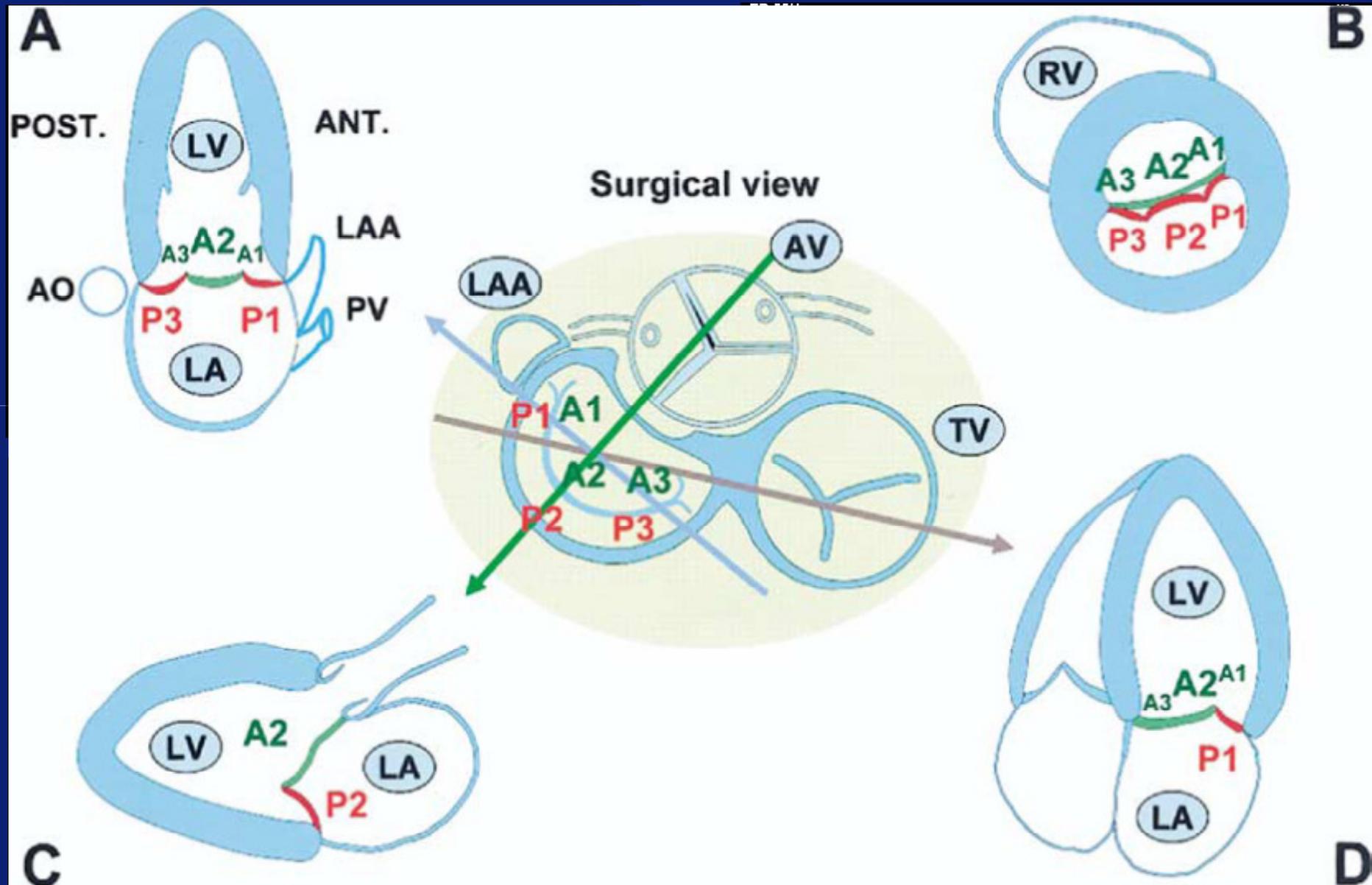
and (hopefully) thereby

defines the selection of the surgeon

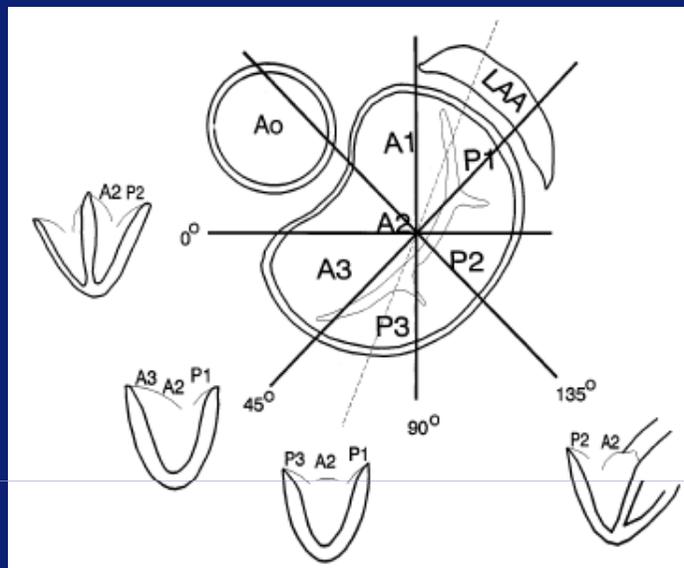
# Scallops visualisatie met 2D TTE



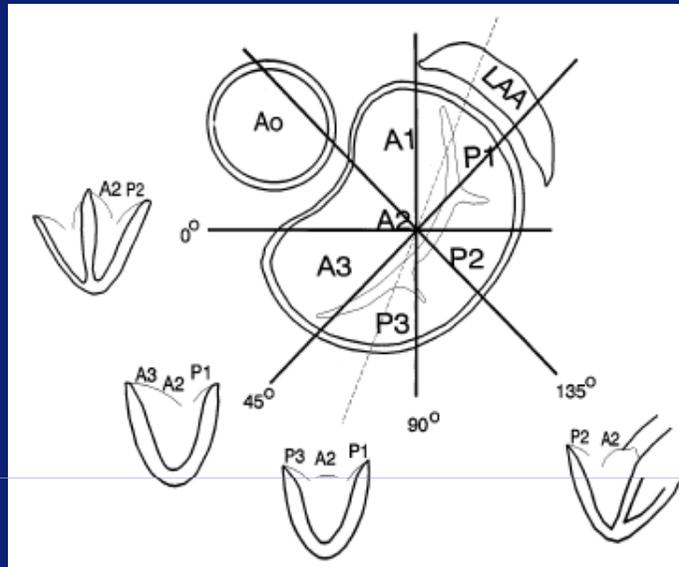
# Scallops visualisation with 2D TTE



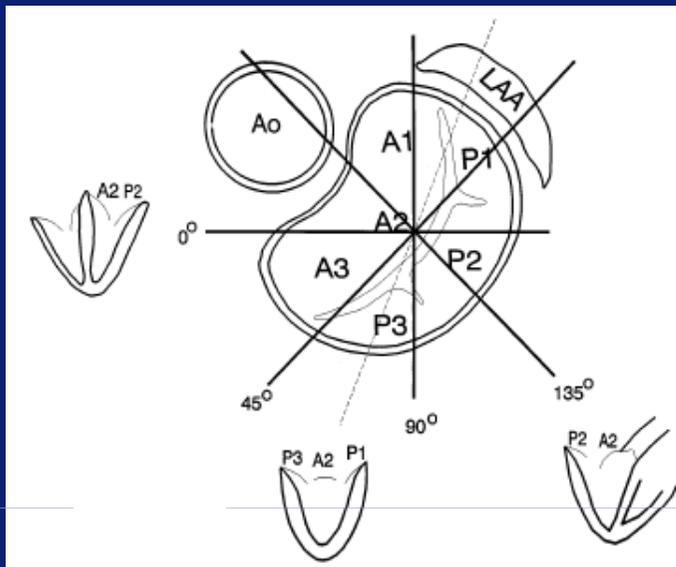
# Scallops visualisation with 2D TEE



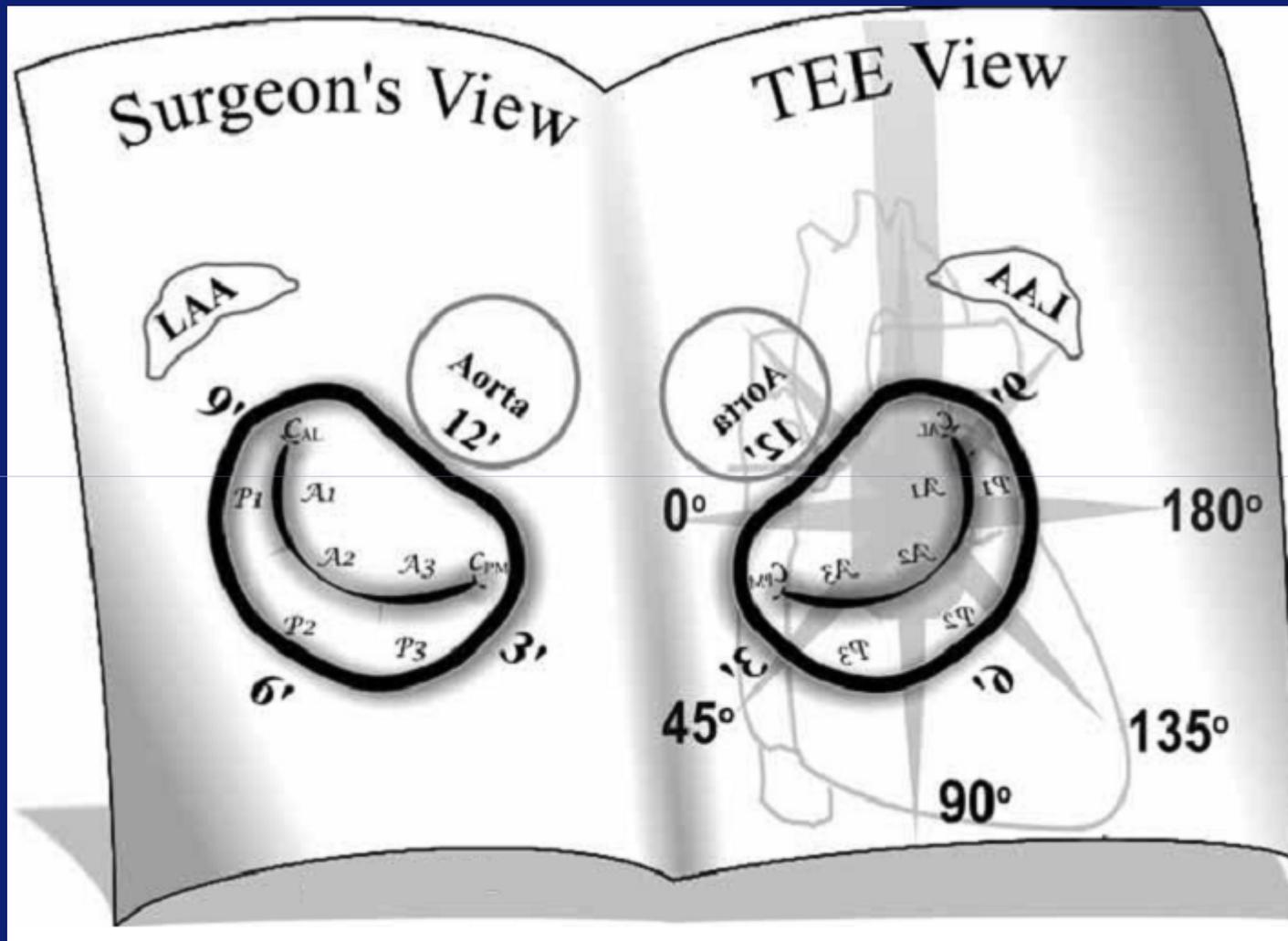
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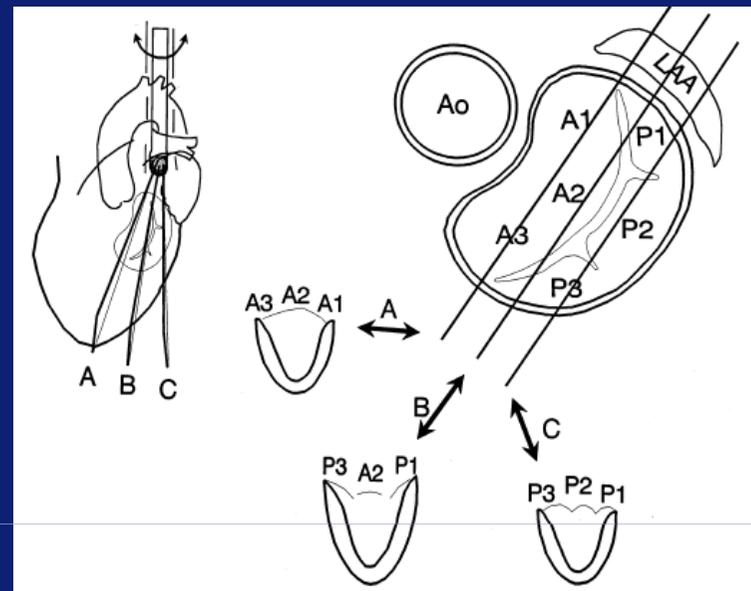
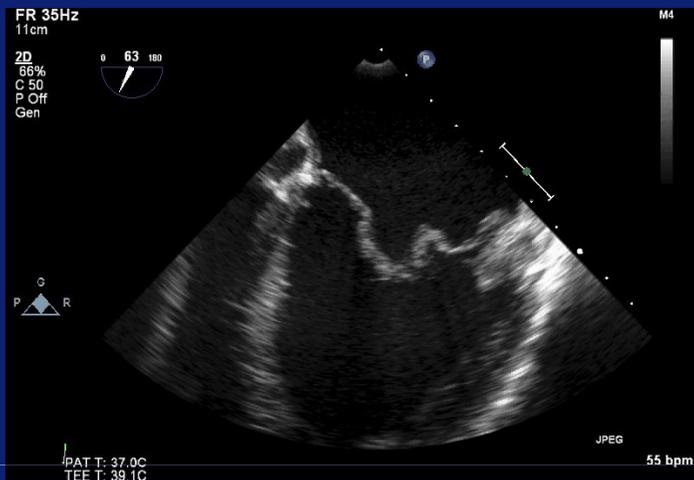
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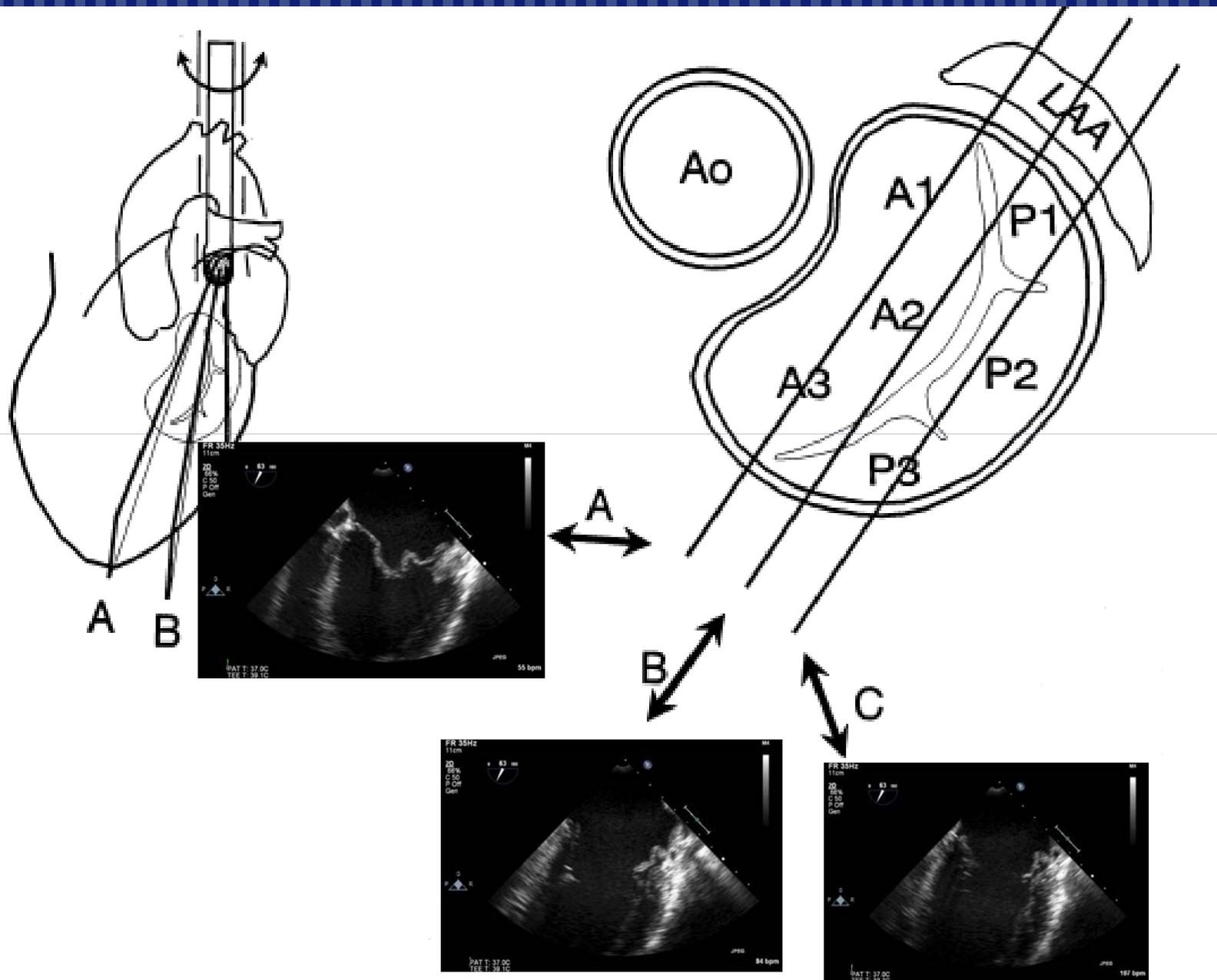
# Scallops visualisation with 2D TEE



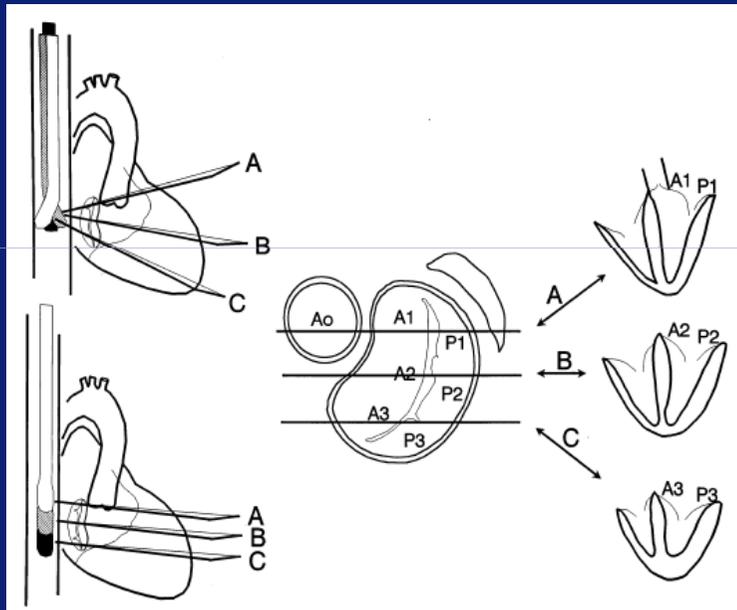
# Scallops visualisatie met 2D TEE



# Scallops visualisatie met 2D TEE



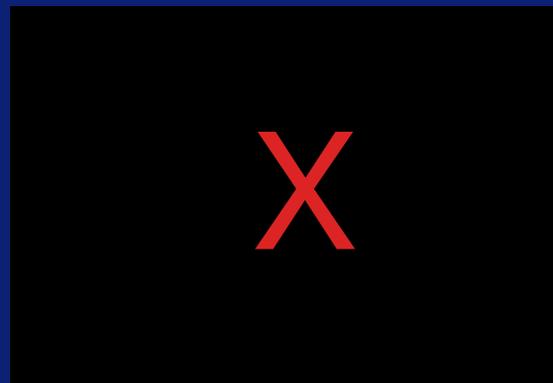
# Scallops visualisation with 2D TEE



A1 - P1

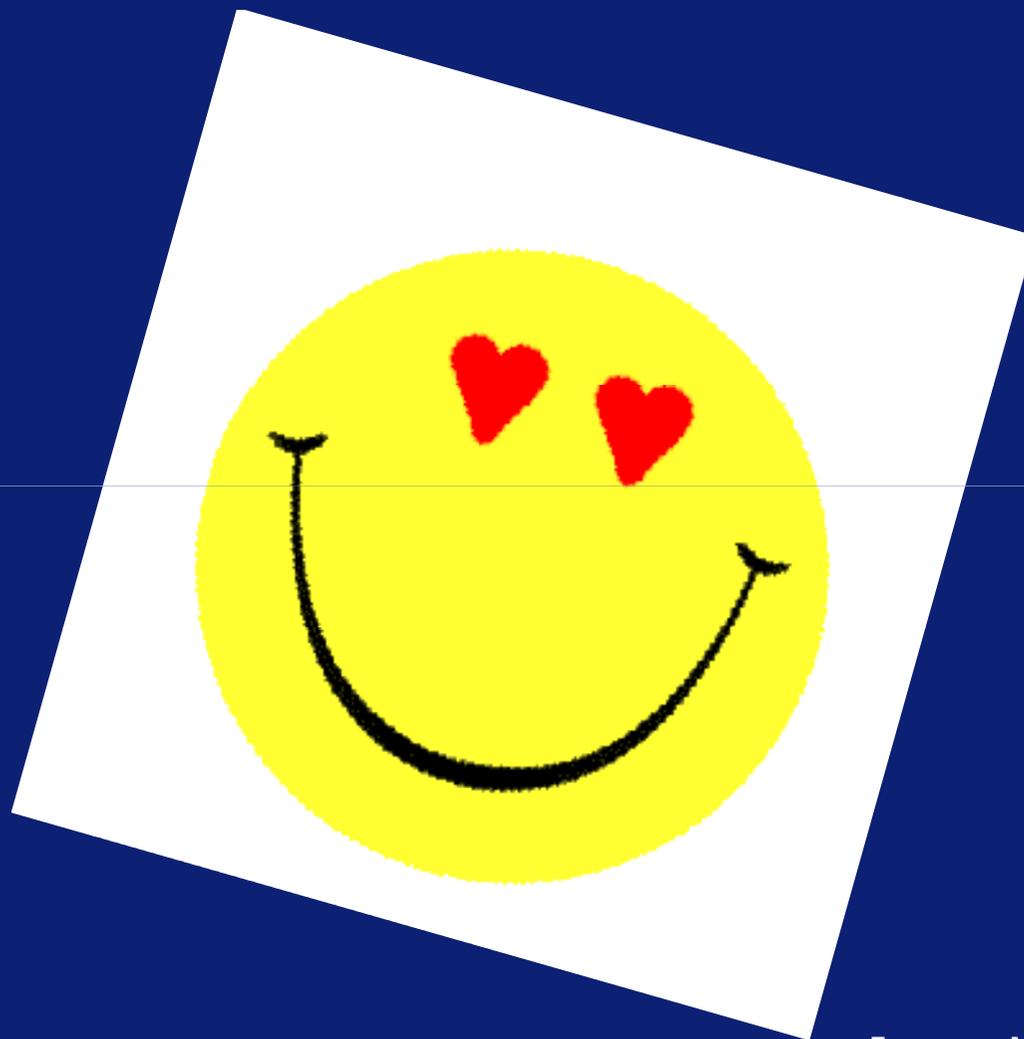
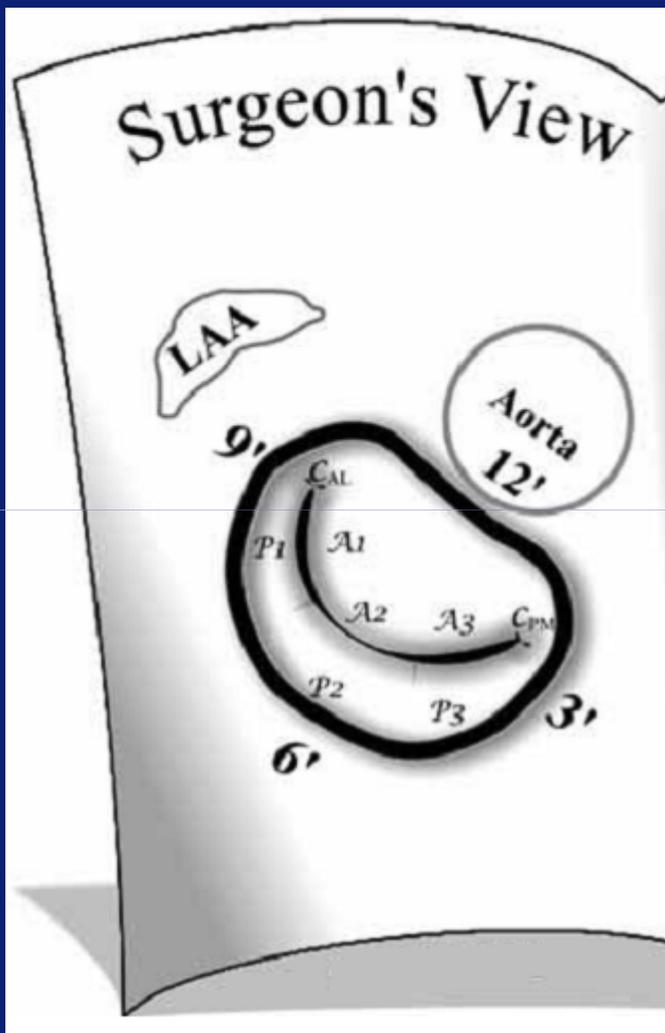


A2 - P2

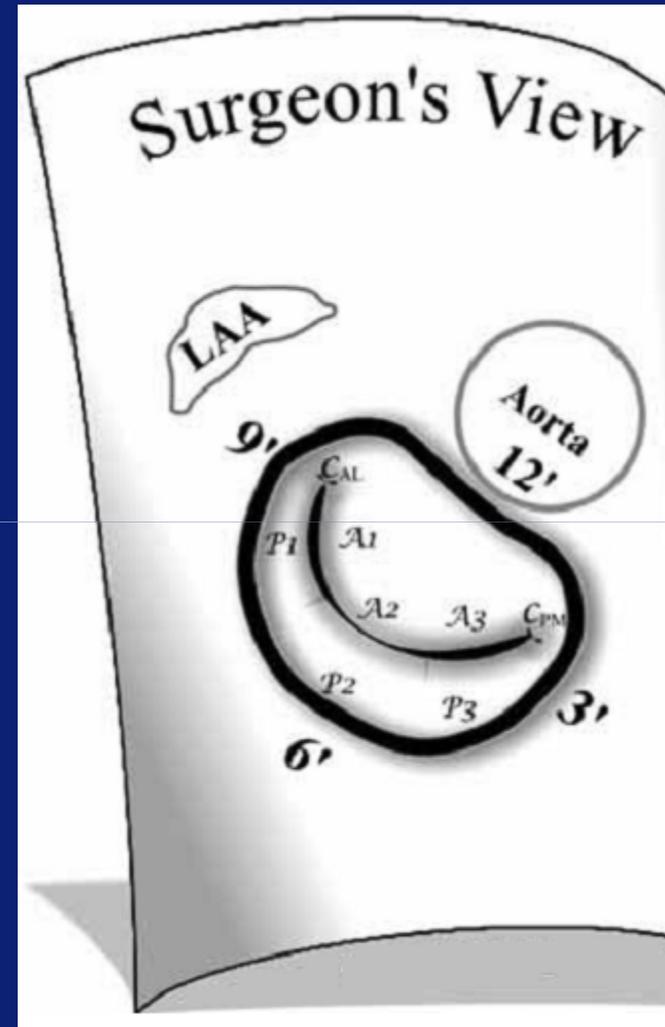
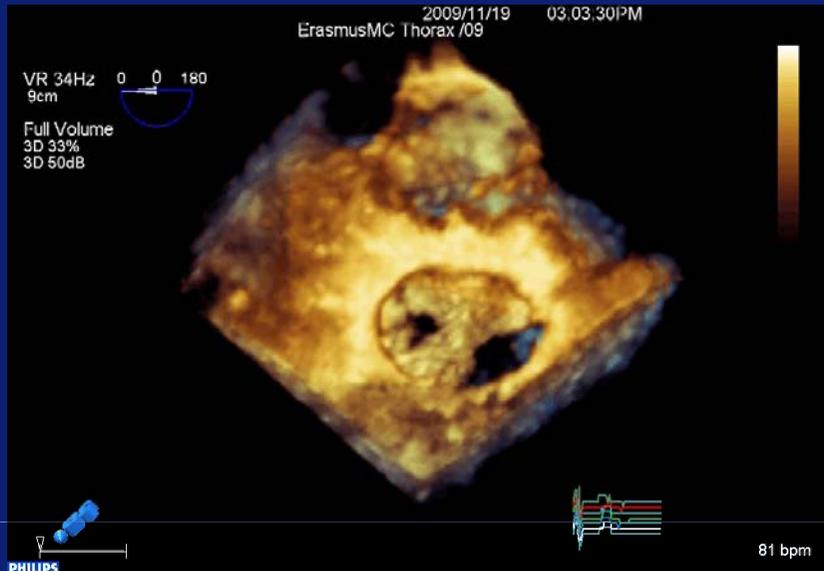


A3 - P3

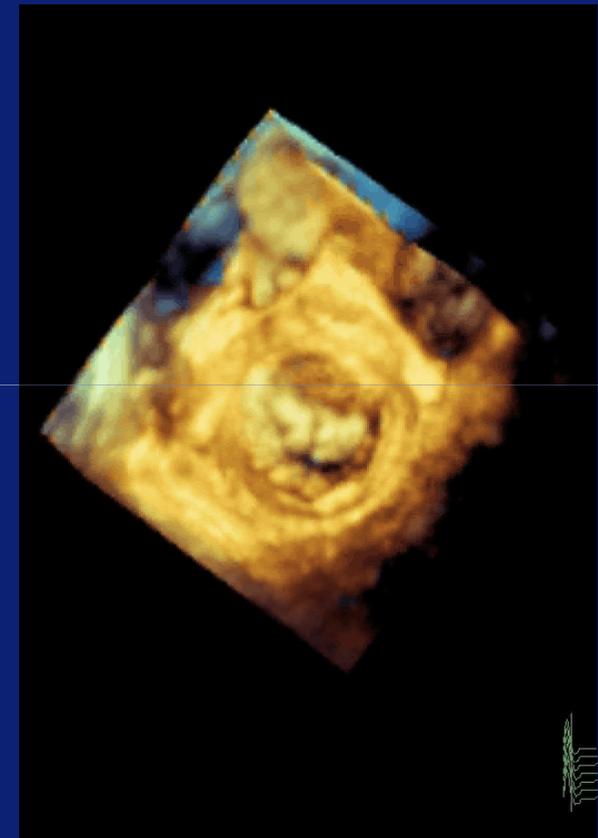
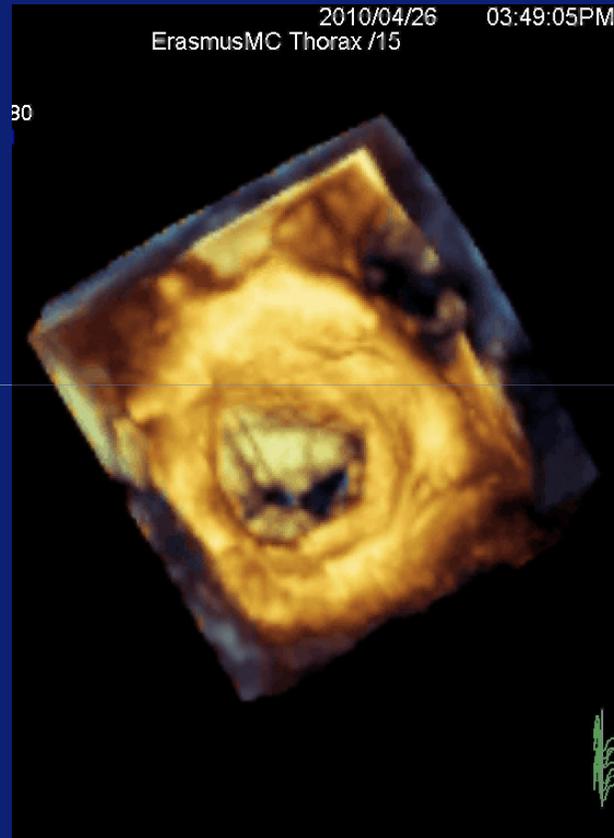
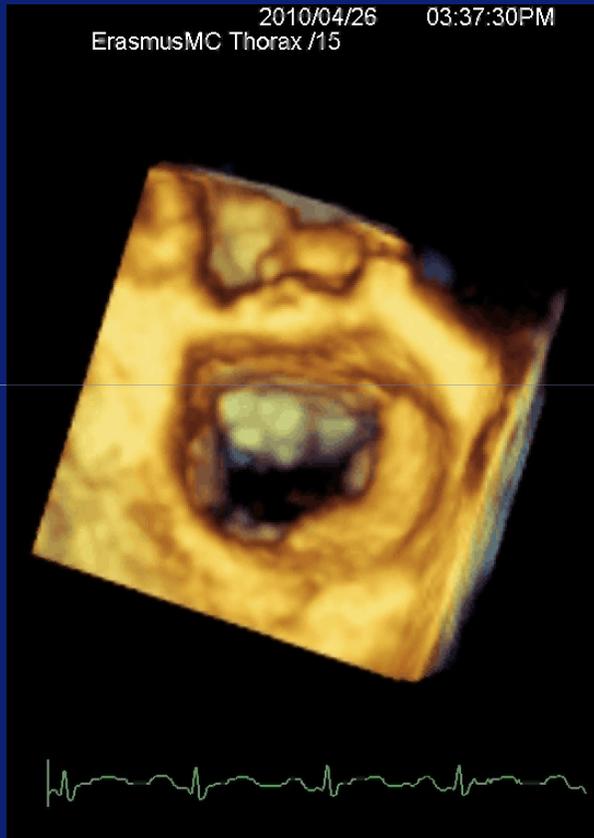
# Surgical view



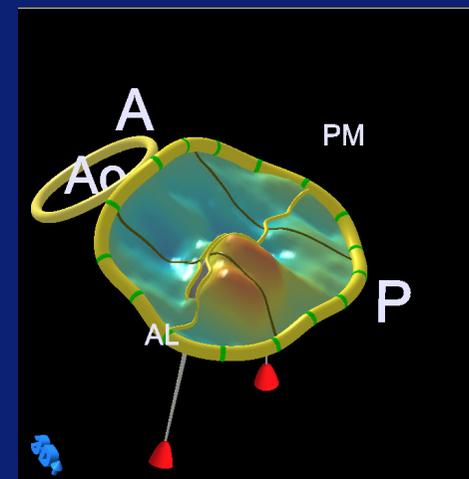
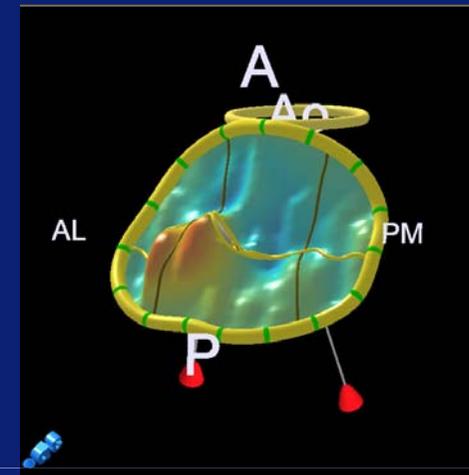
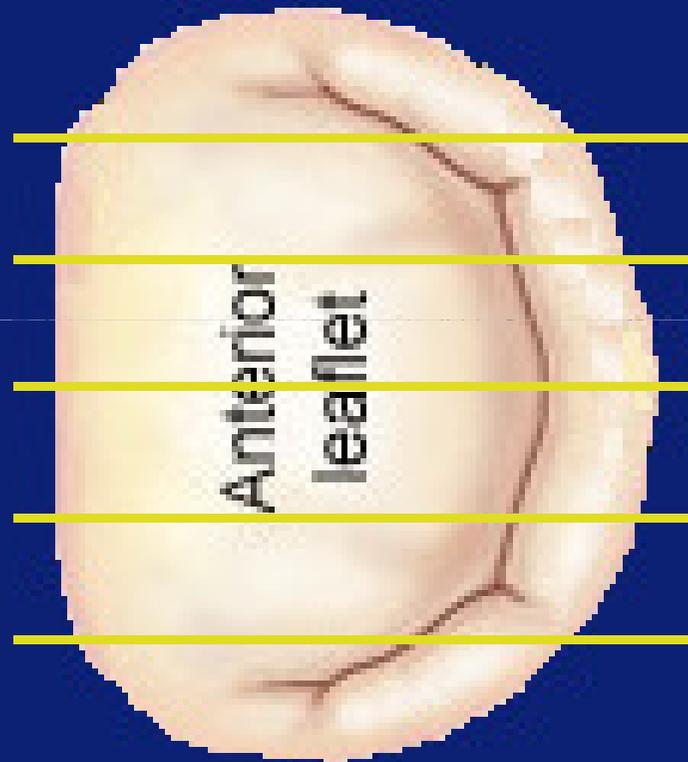
# Surgical view



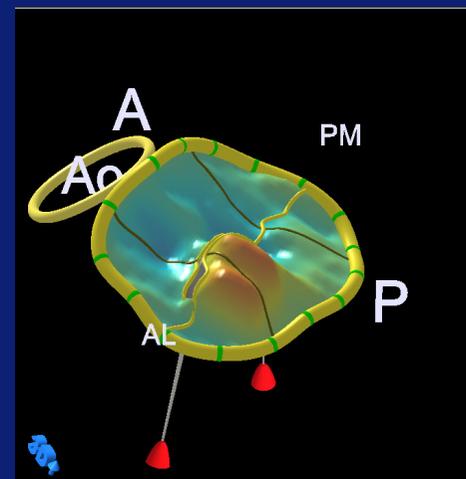
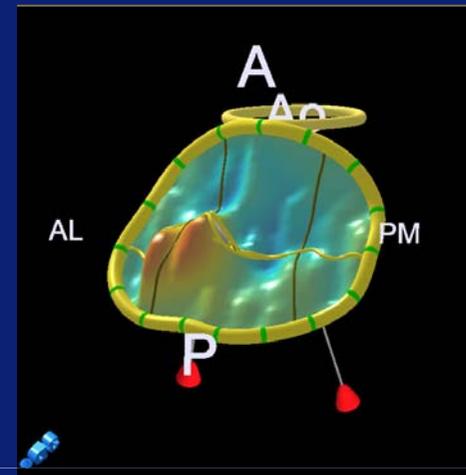
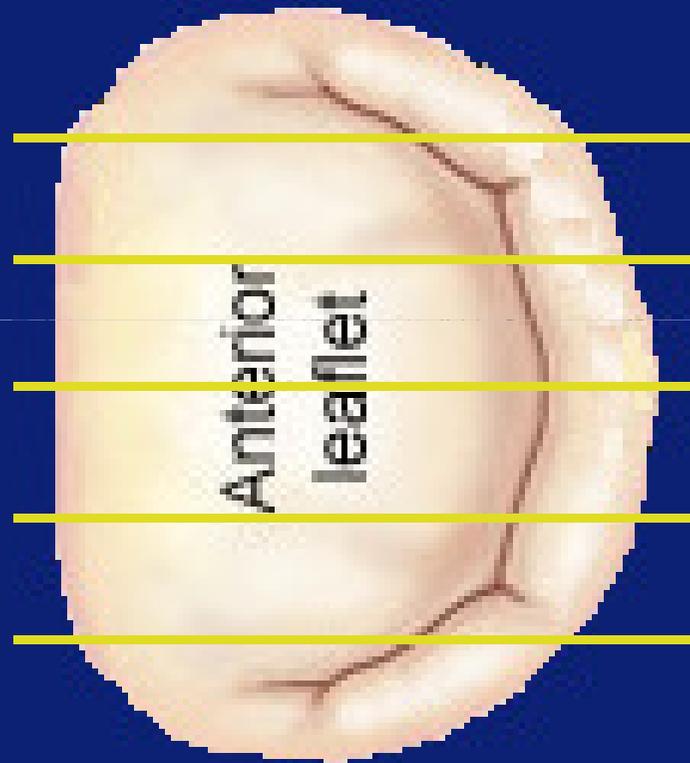
# 3D TEE: real-time 3D zoom or full-volume



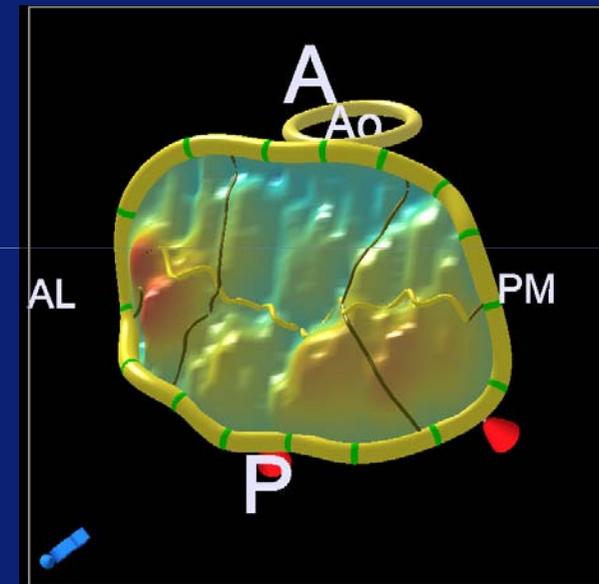
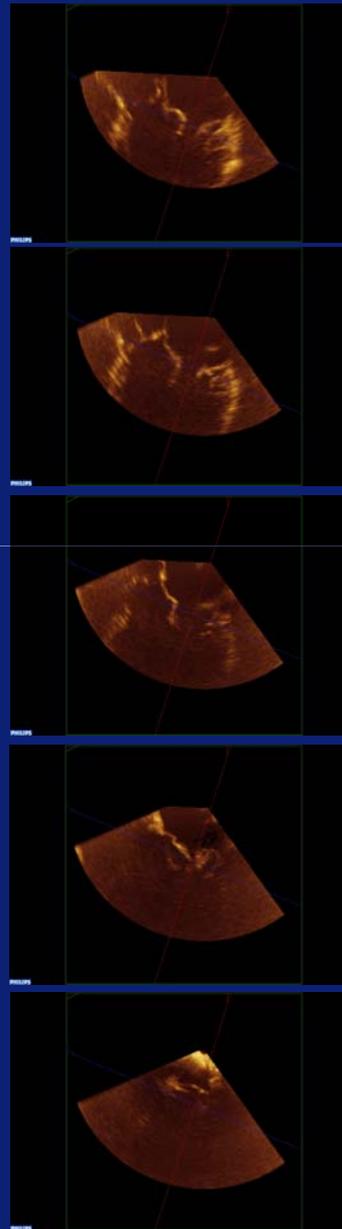
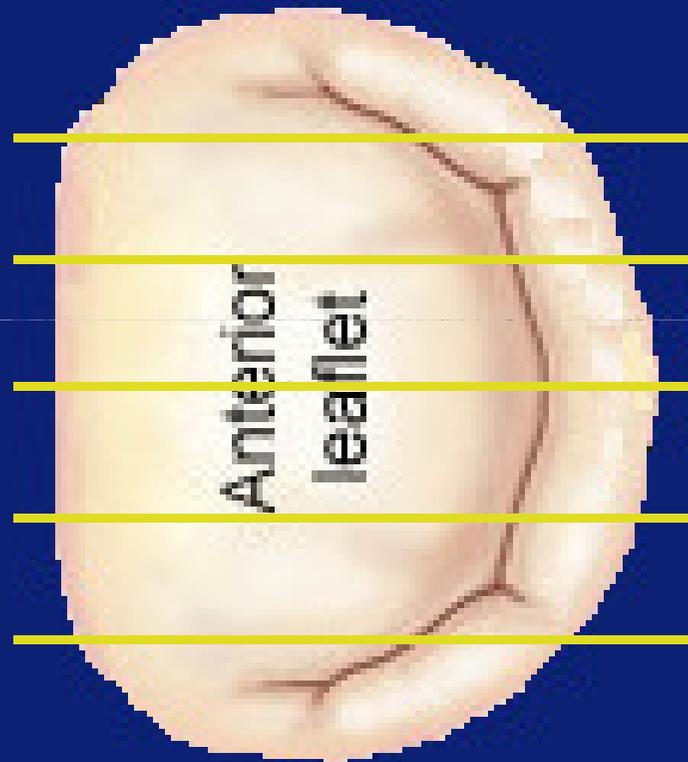
# Scallops visualisation with 3D TEE



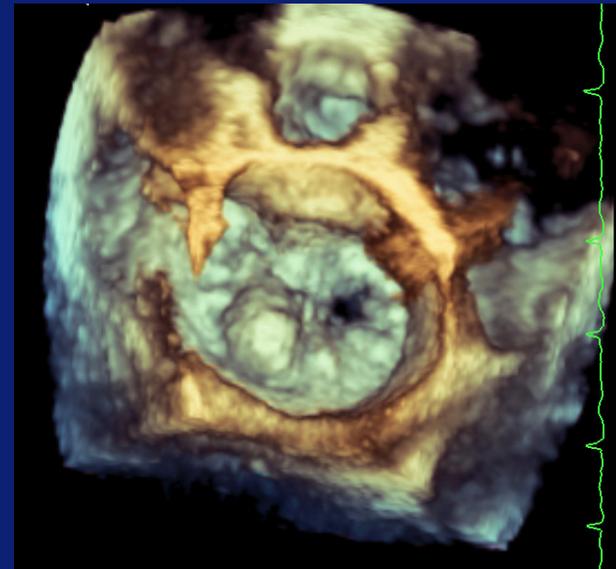
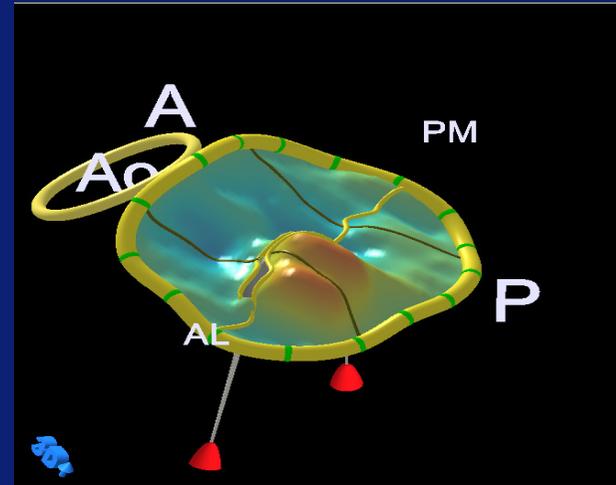
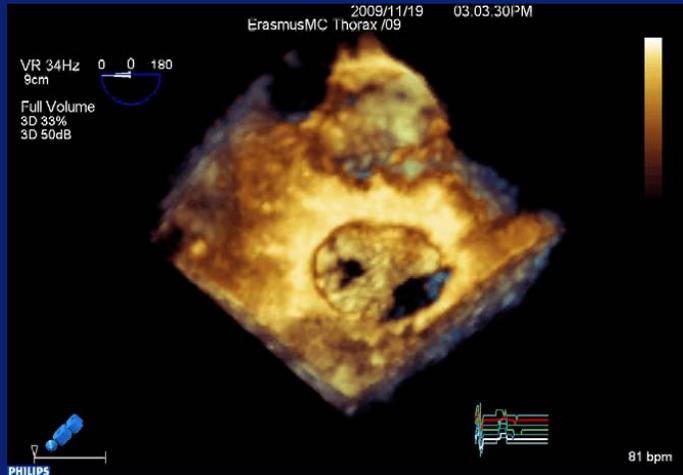
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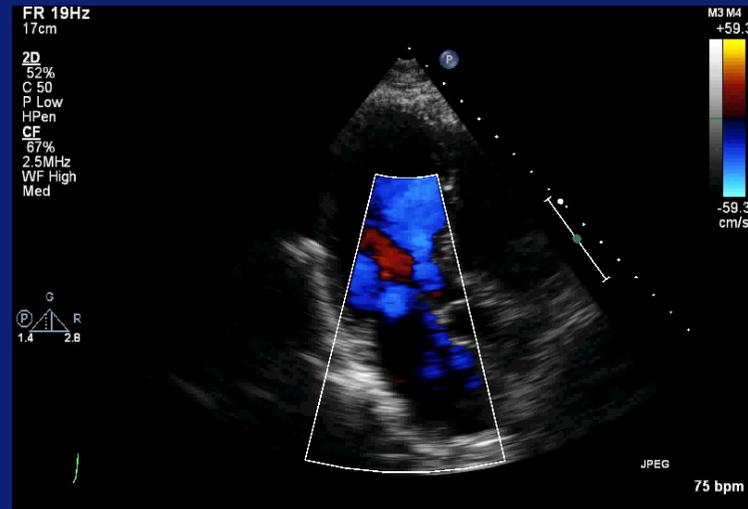
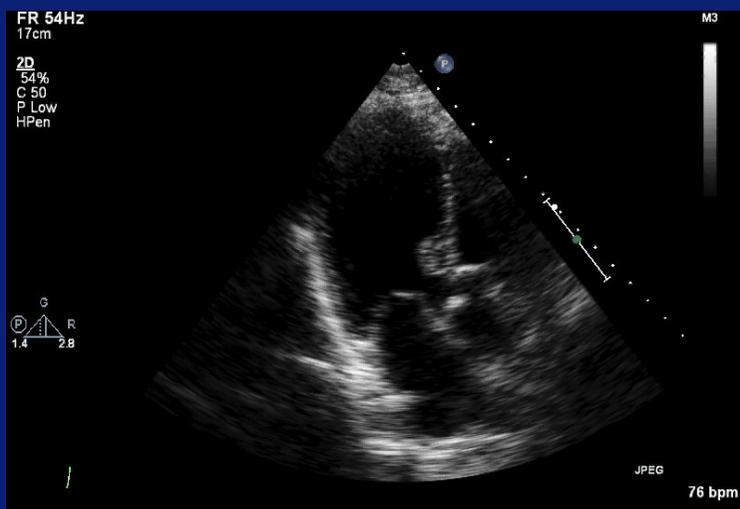
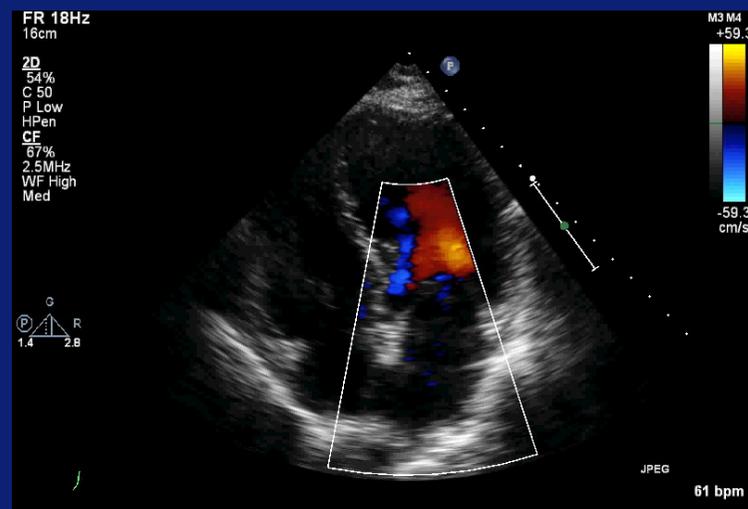
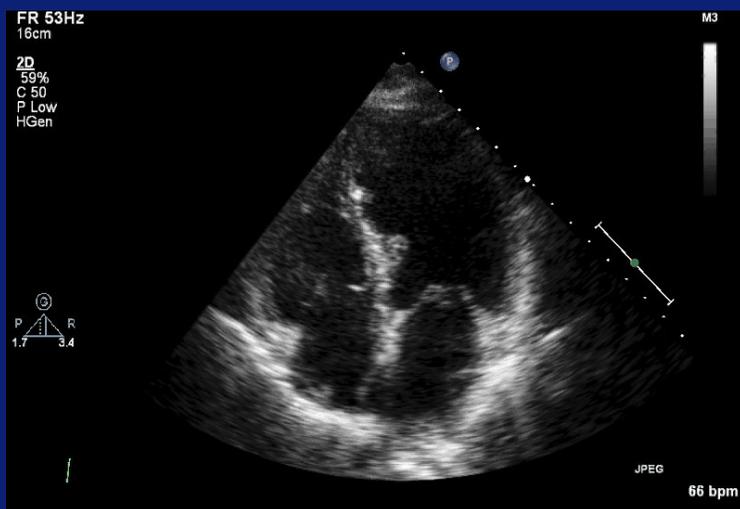
# Scallops visualisatie vanuit 3D TEE



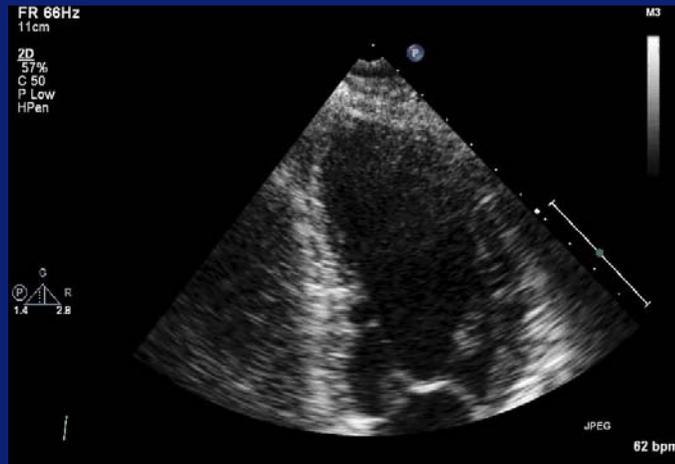
# Patient example 1



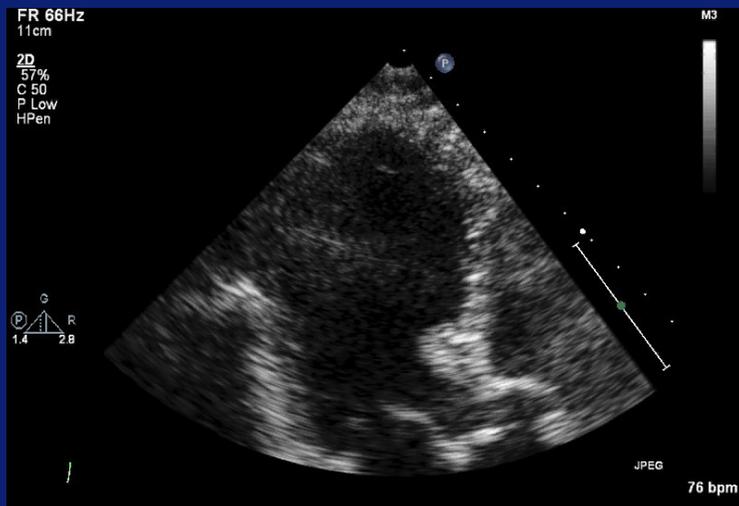
# Patient case 2: which scallop?



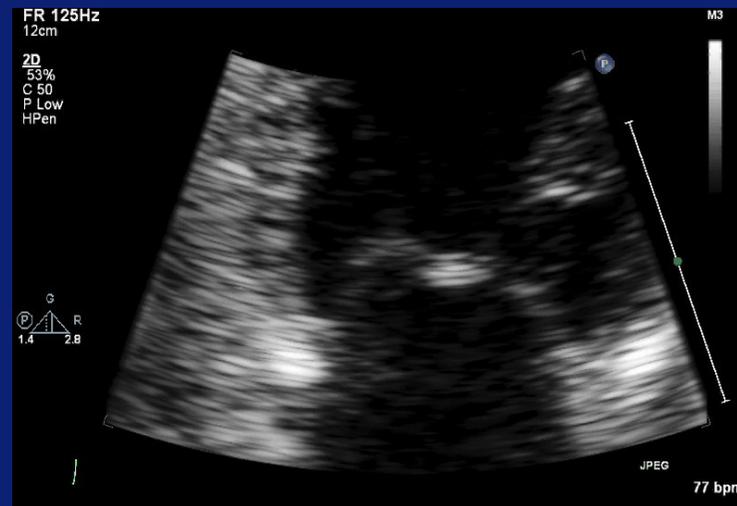
# Patient case 2: which scallop?



4CH view



3CH view



2CH view

## Question 2

What is the site of prolaps in this patient?

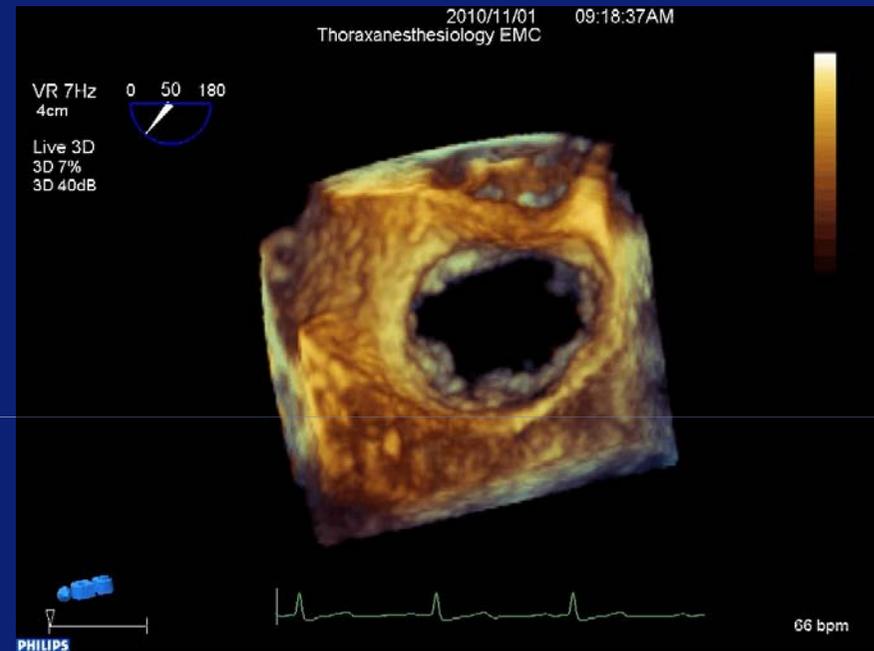
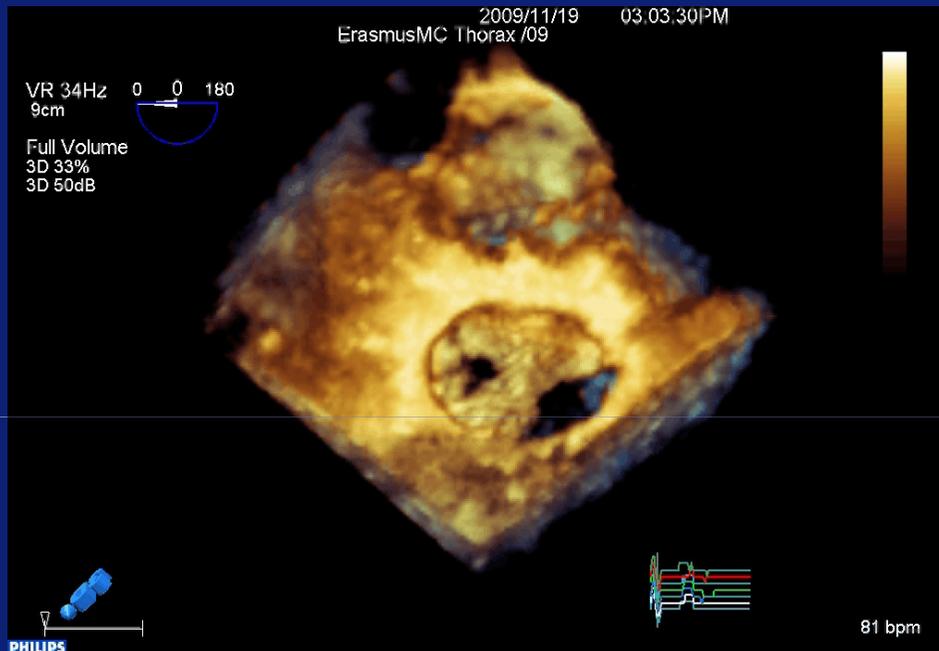
1. P2

2. P3

3. P2 and P3

4. I do not know

# Patient case 2: which scallop?



## Question 3

What is the site of prolaps in this patient?

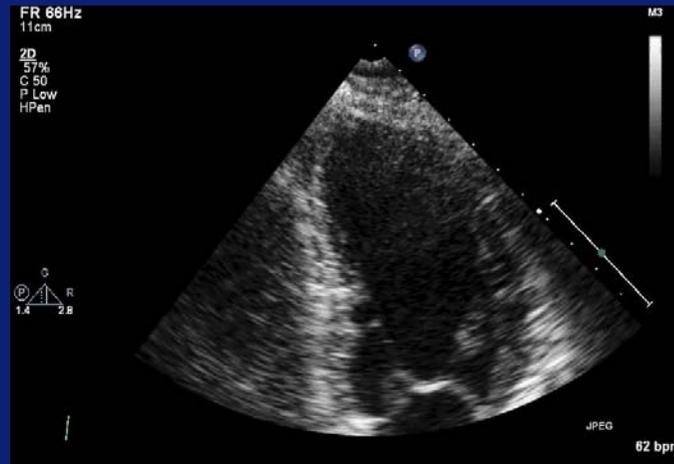
1. P2

2. P3

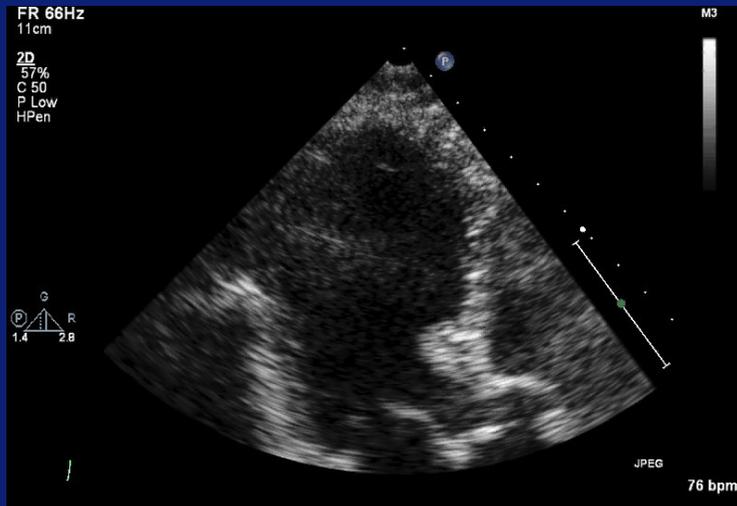
3. P2 and P3

4. I do not know

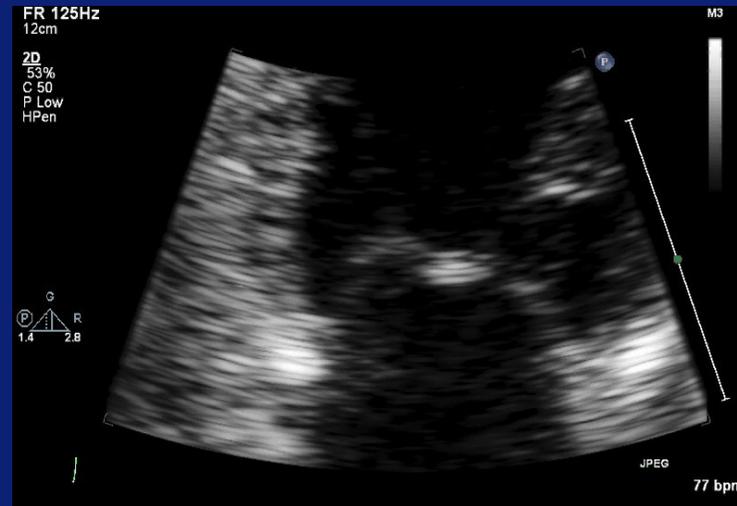
# Patient case 2: which scallop?



A3 - A2 - P1

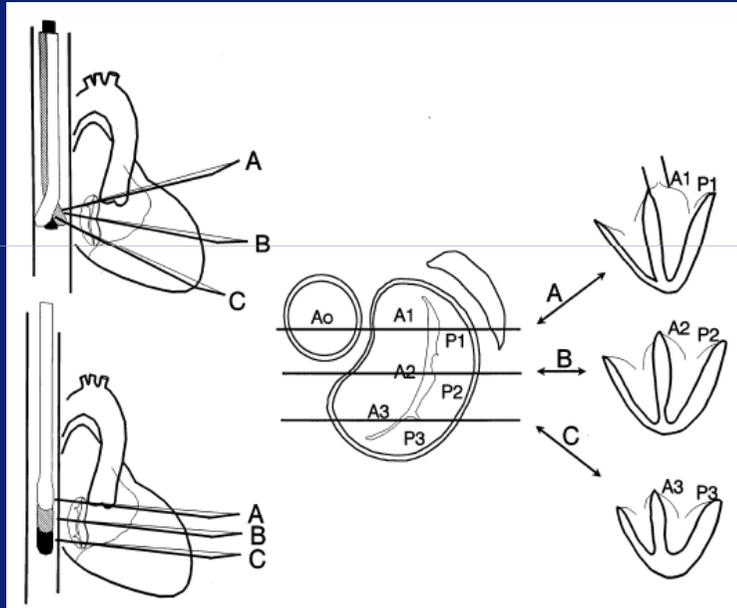


P2 - A2



P3 - A2 - P1

# Patient case 2: which scallop?



A1 - P1



A2 - P2

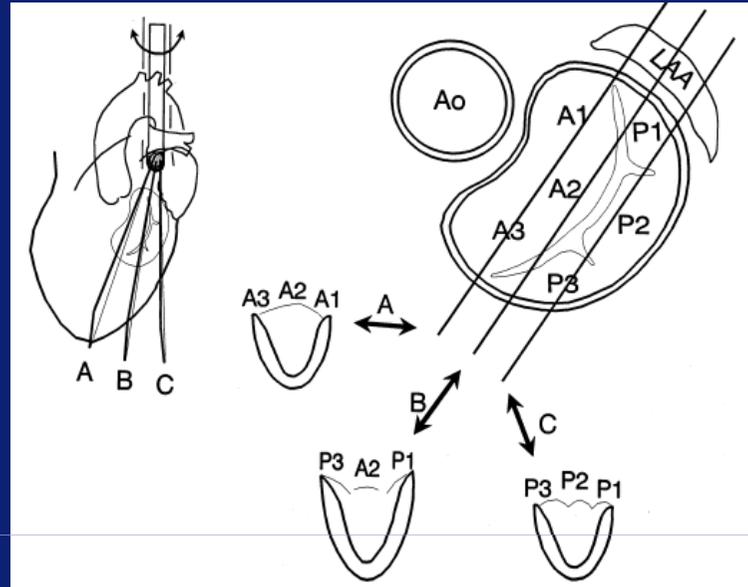
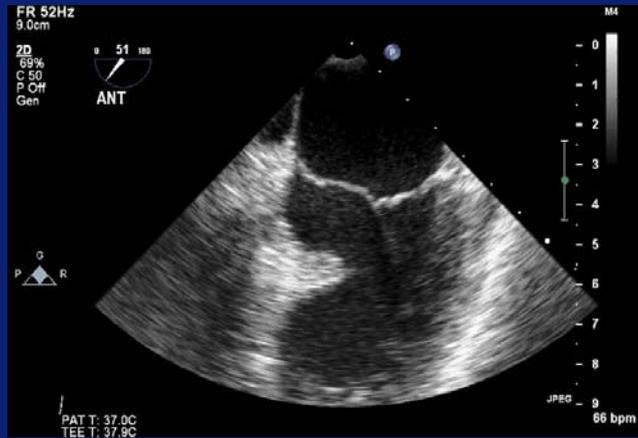


A3 - P3

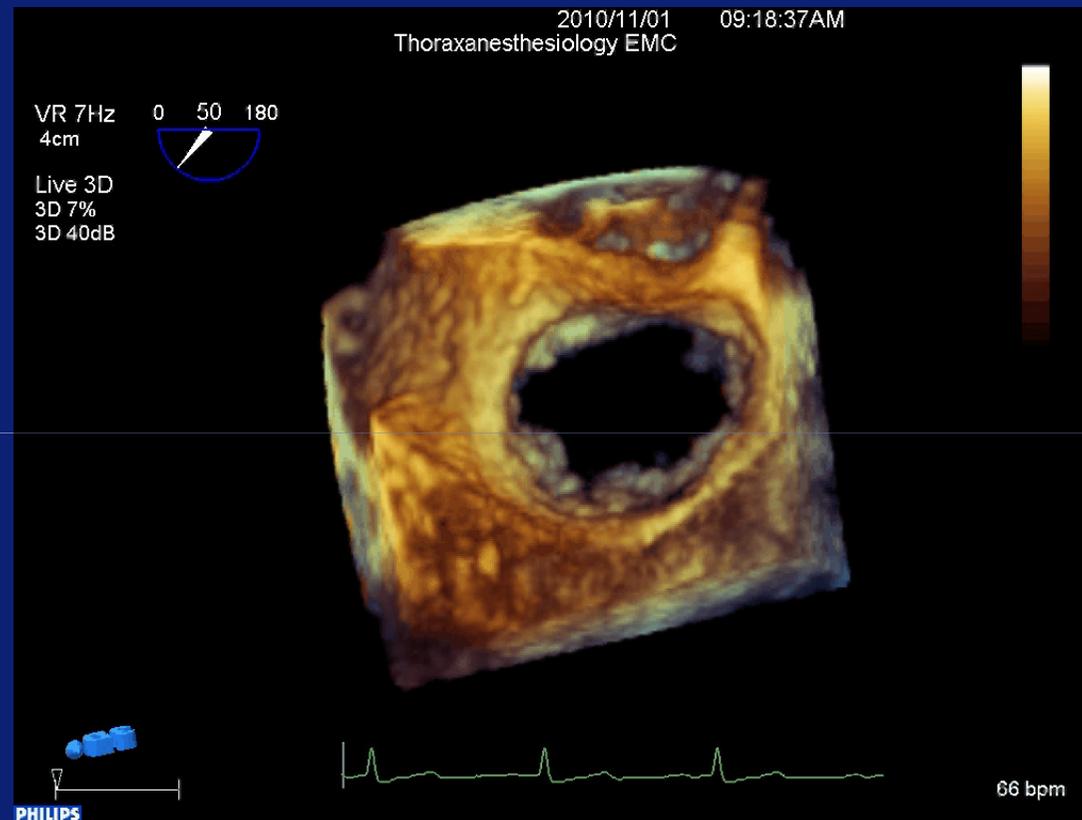
Erasmus MC



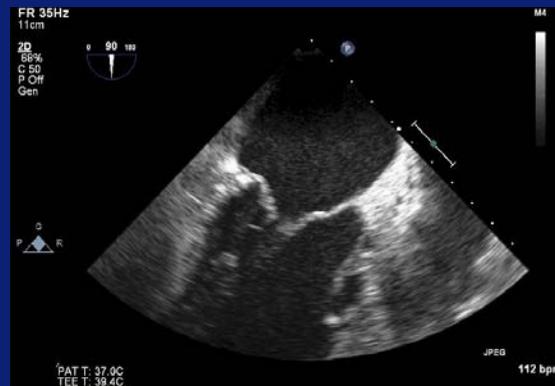
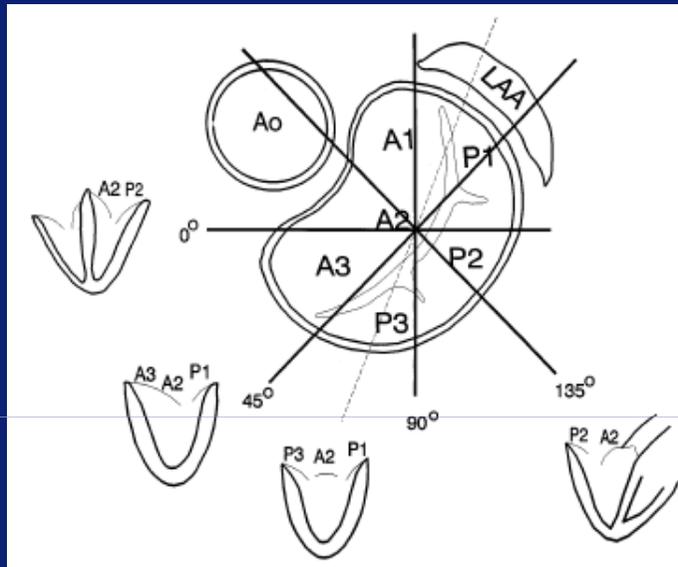
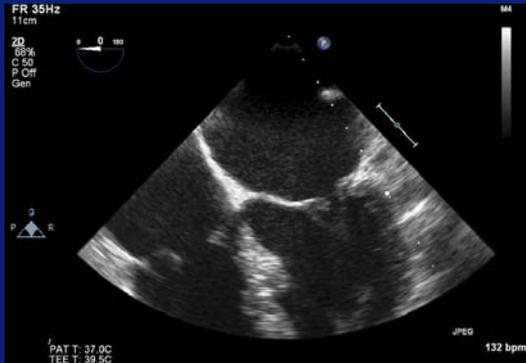
# Patient case 2: which scallop?



# Patient case 2: which scallop?



# Patient case 3: which scallop



## Question 4

What is the site of prolaps in this patient?

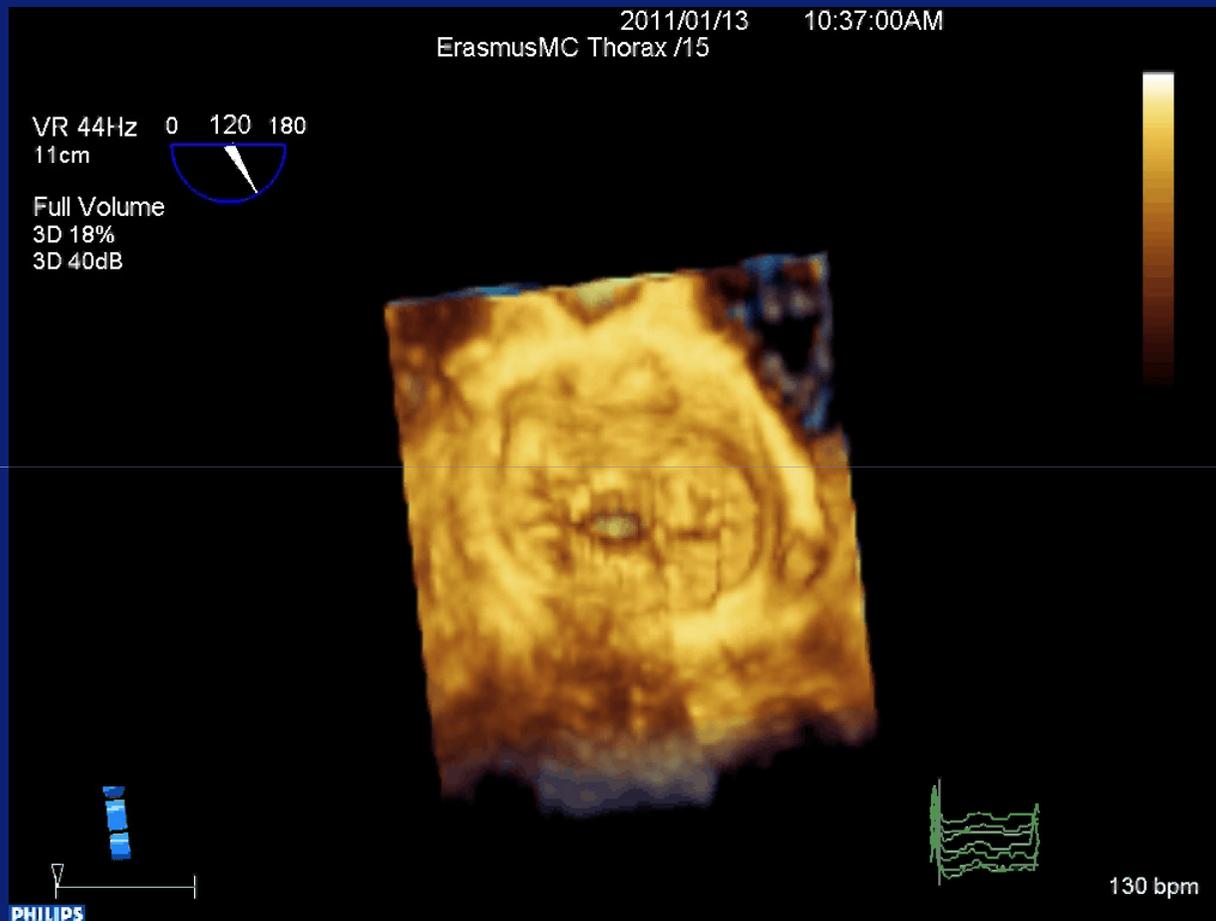
1. P2

2. P2 + P3

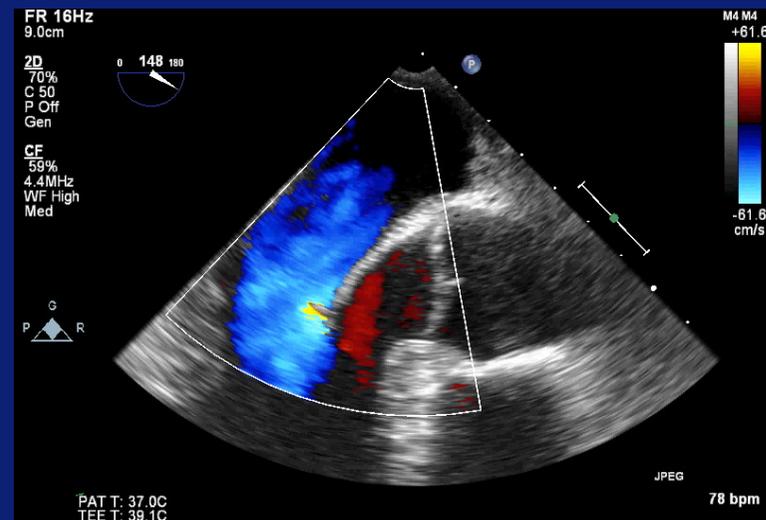
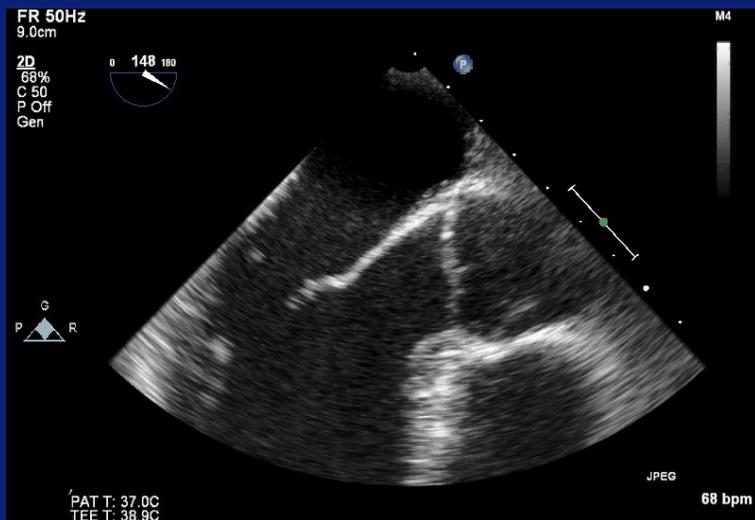
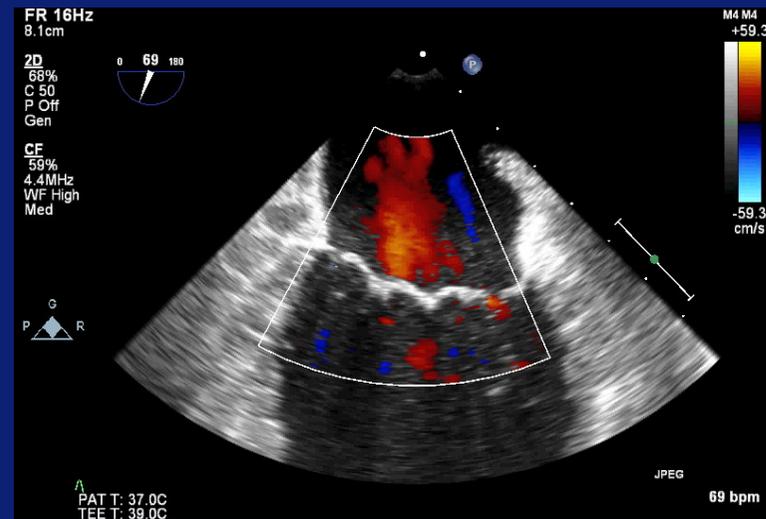
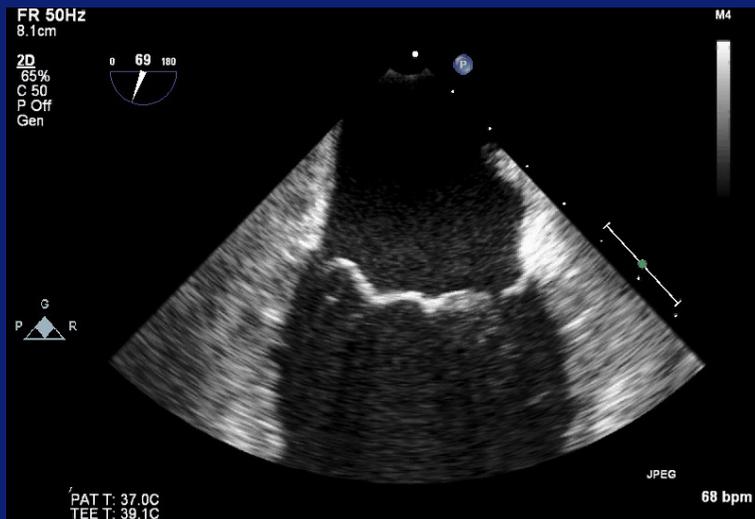
3. P1 + P2 + P3

4. I do not know

# Patient case 3: which scallop



# Patient case 4: which scallop



## Question 5

What is the site of prolaps in this patient?

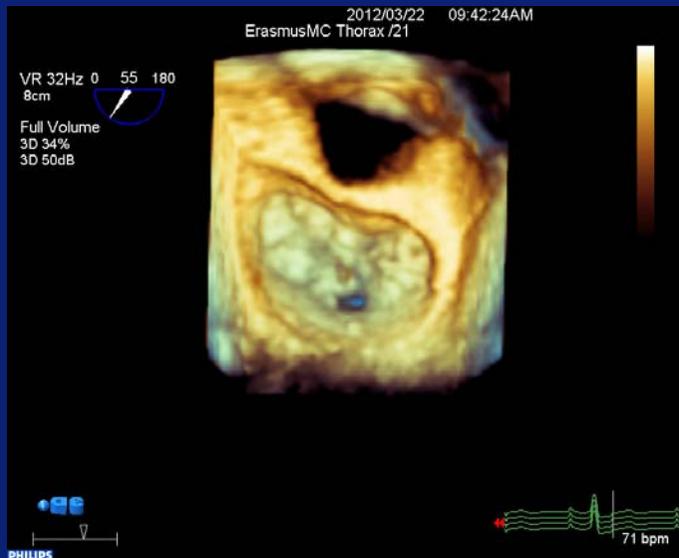
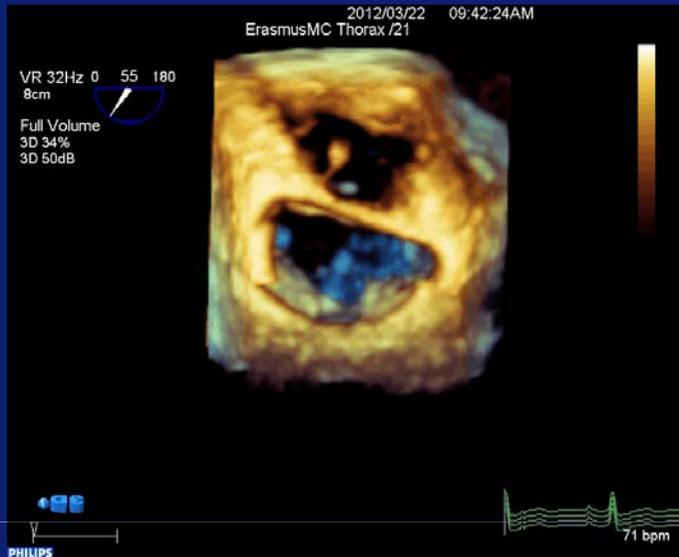
1. P2

2. P3

3. There is no prolaps, may be perforation

4. I do not know

# Patient case 4: which scallop



## Question 6

What is the site of prolaps in this patient?

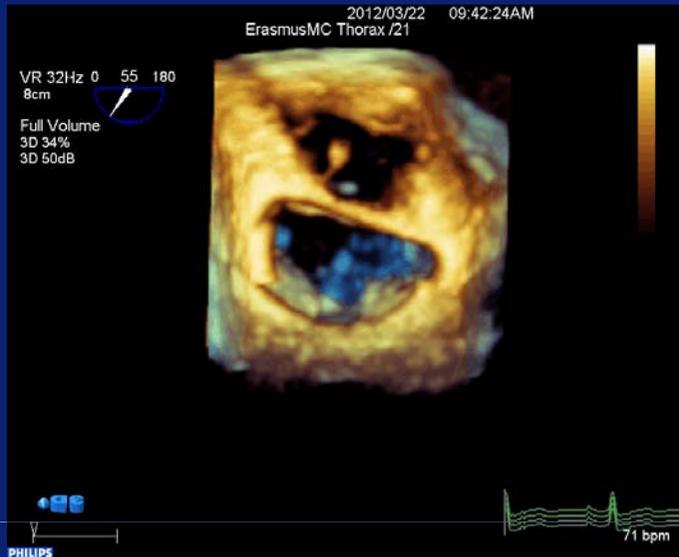
1. P2

2. P3

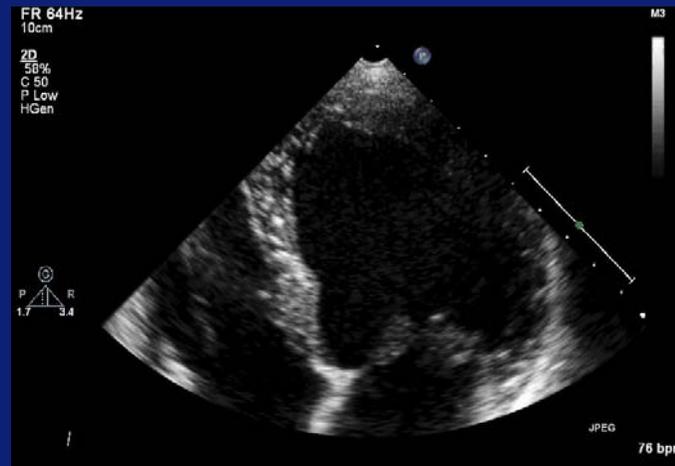
3. There is no prolaps, only perforation

4. I do not know

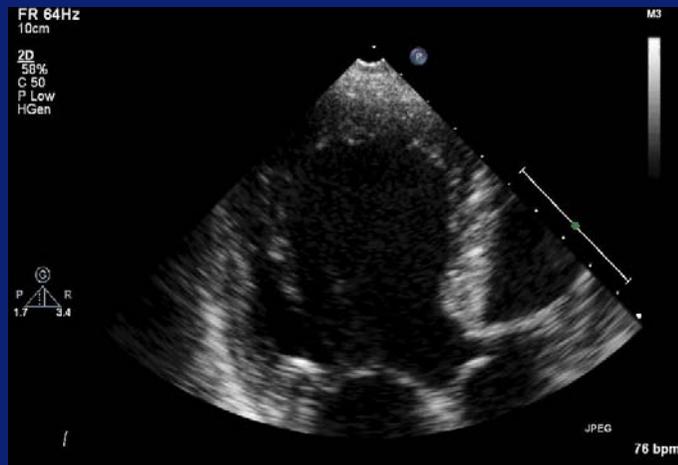
# Patient case 4: which scallop



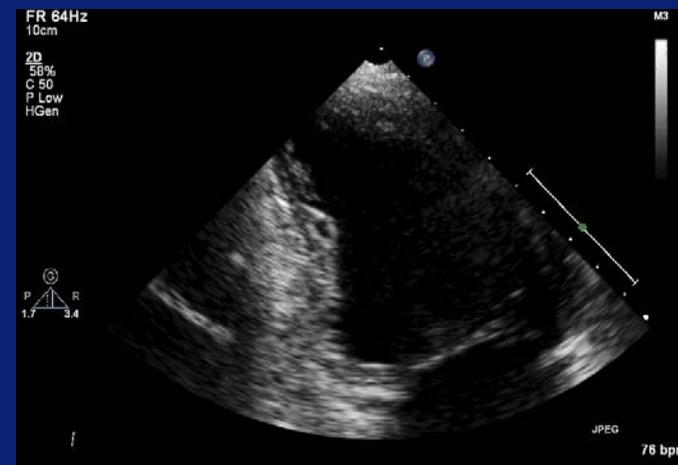
# Patient case 5: which scallop



A3 - A2 - P1



P2 - A2



P3 - A2 - P1

Erasmus MC

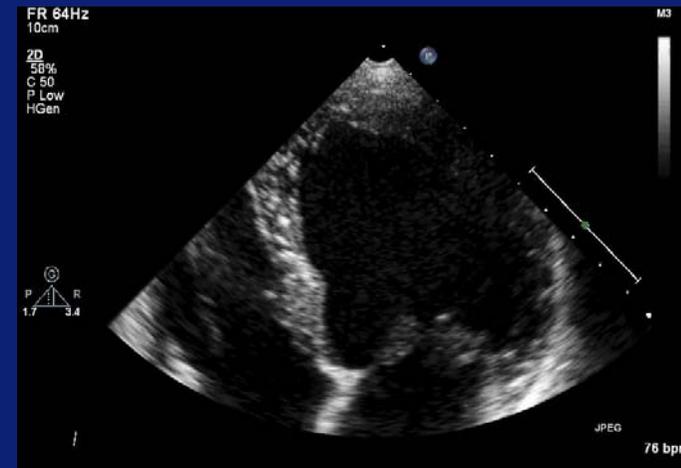
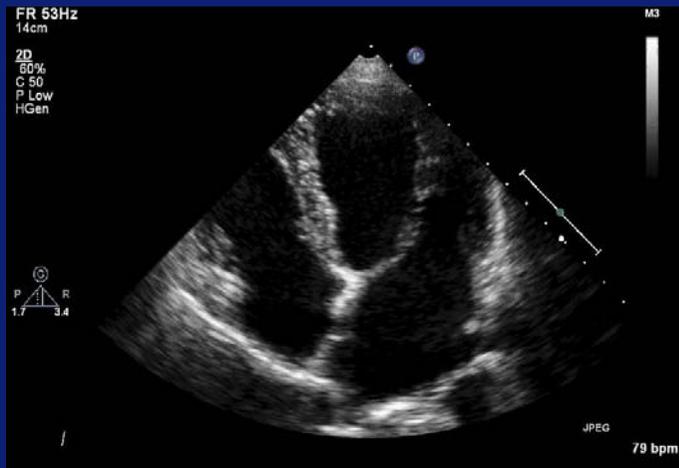


## Question 7

What is the site of prolaps in this patient?

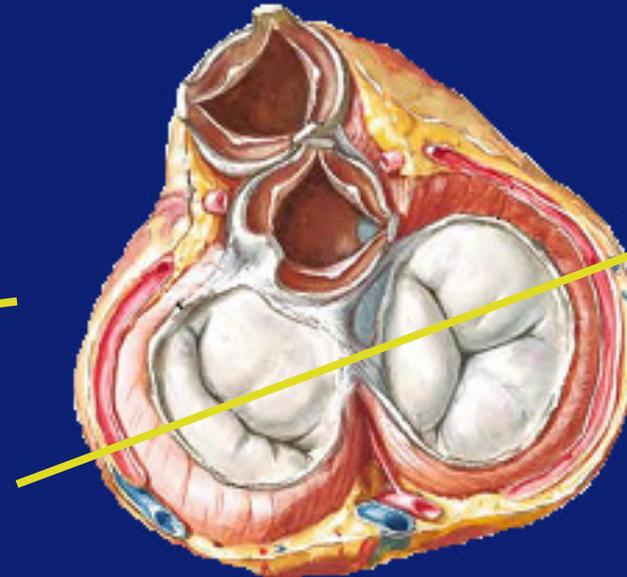
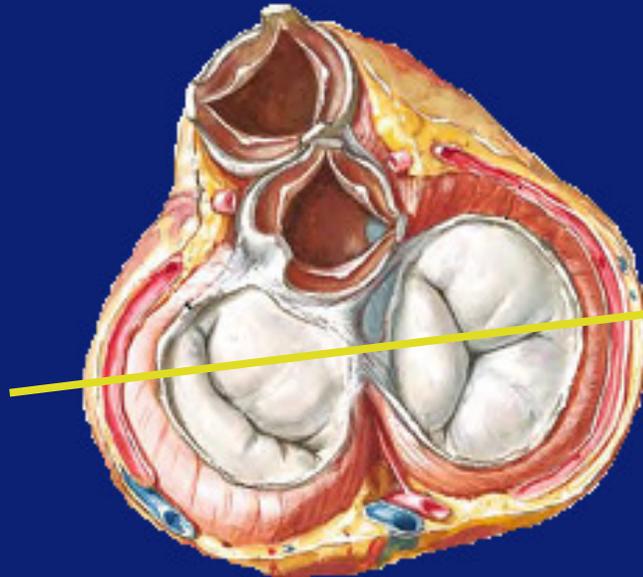
1. Classic P3-P2-P1
2. May be P3-P2-P1 but may also be P3-P2
3. May all be true but may also be P3 only
4. I do not know

# Patient case 5: which scallop

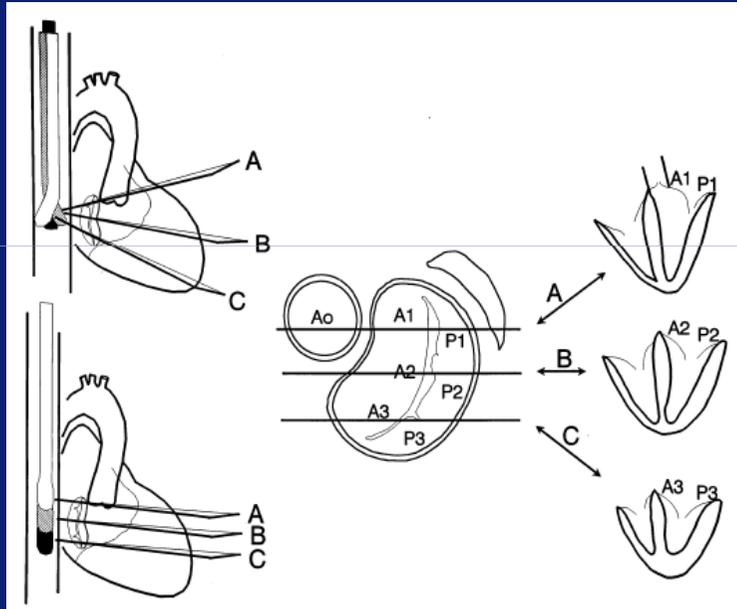


A3 - A2 - P1

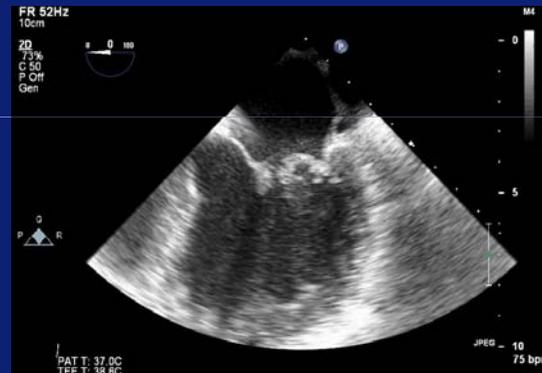
A3 - A2 - P2



# Patient case 5: which scallop



A1 - P1

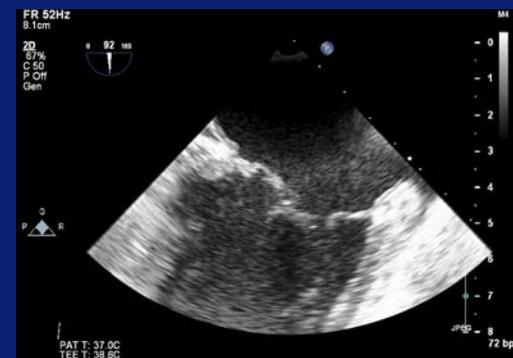
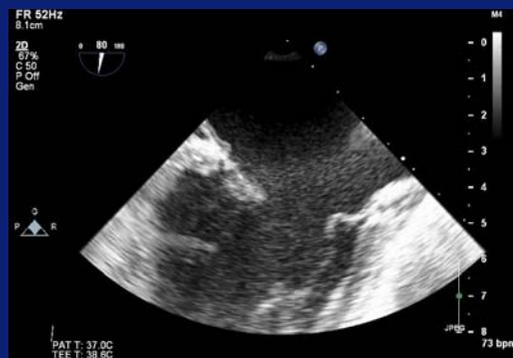
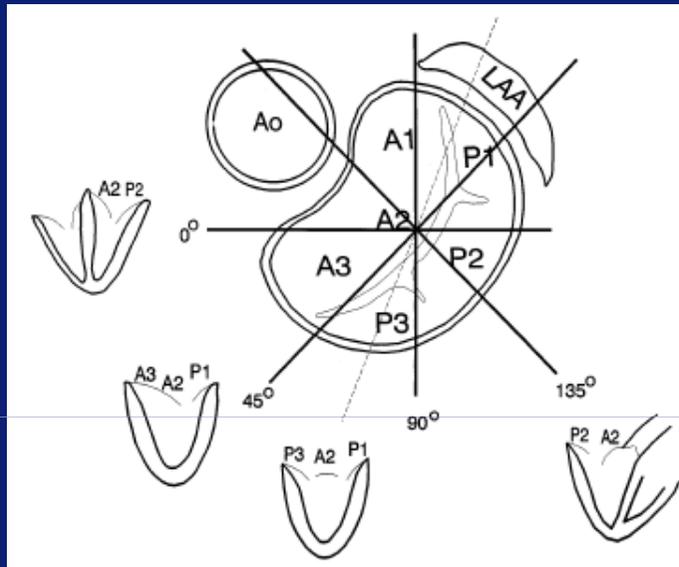


A2 - P2

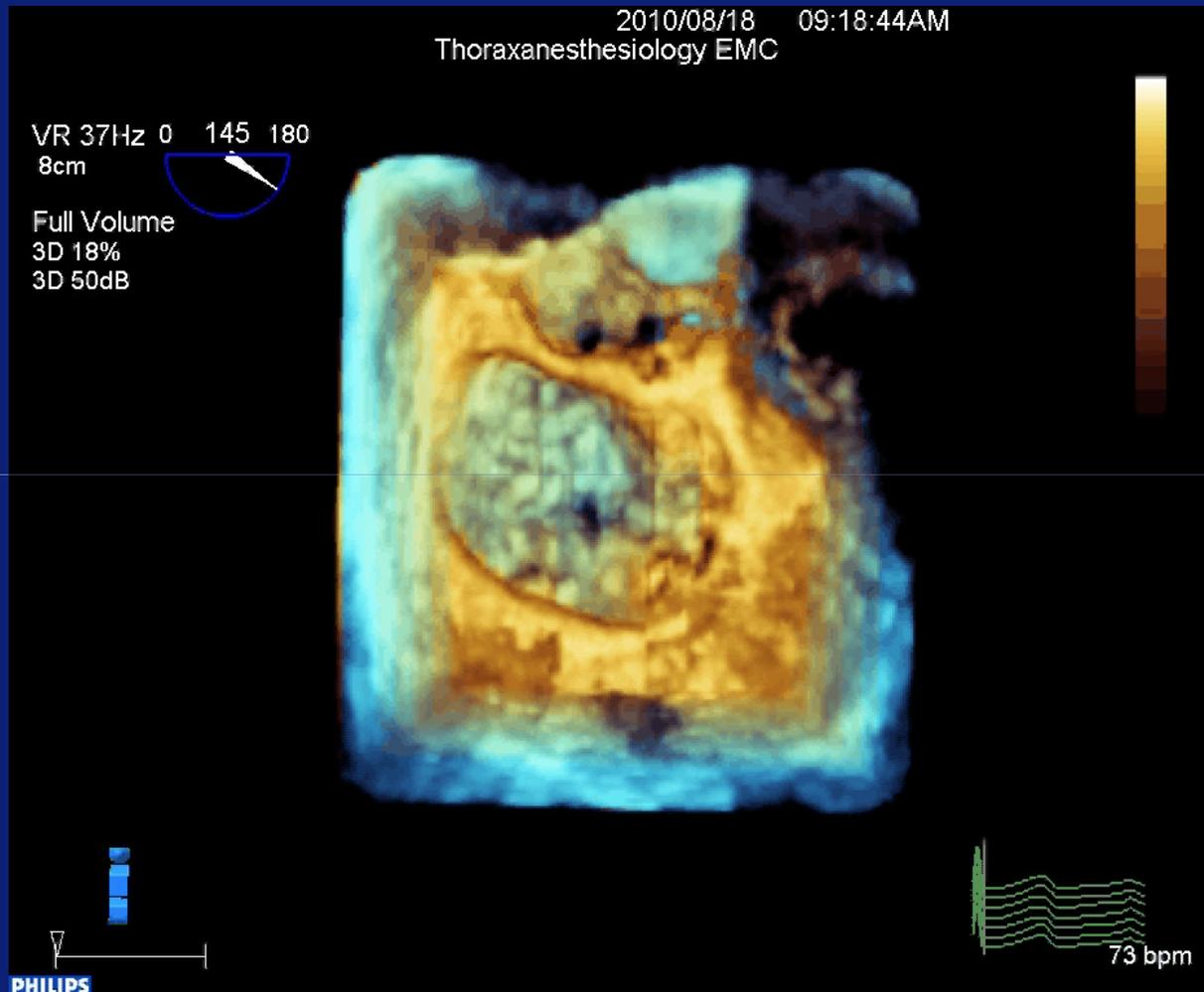


A3 - P3

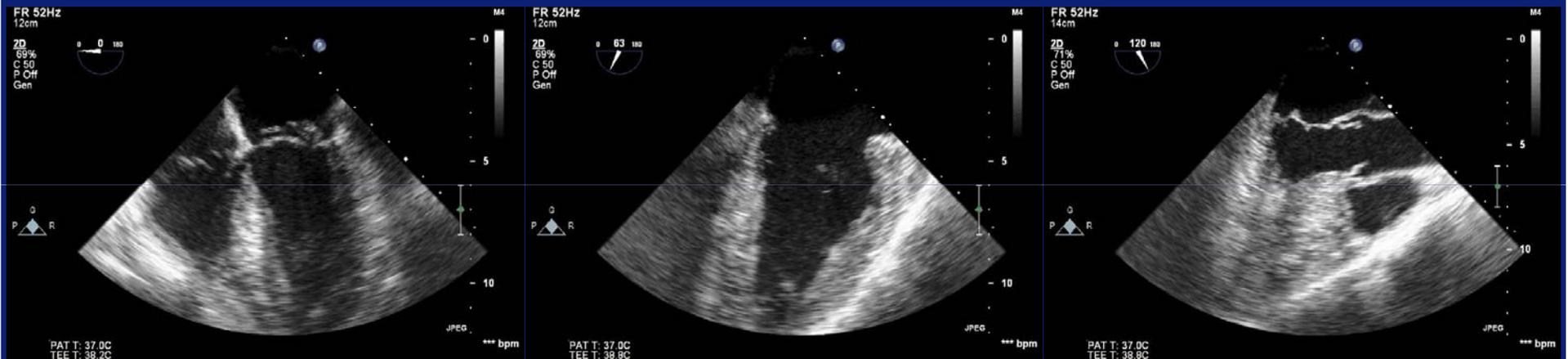
# Patient case 5: which scallop



# Patient case 5: which scallop



# Type IC Annulus dilatation



4CH-view

2CH-view

3CH-view

Erasmus MC

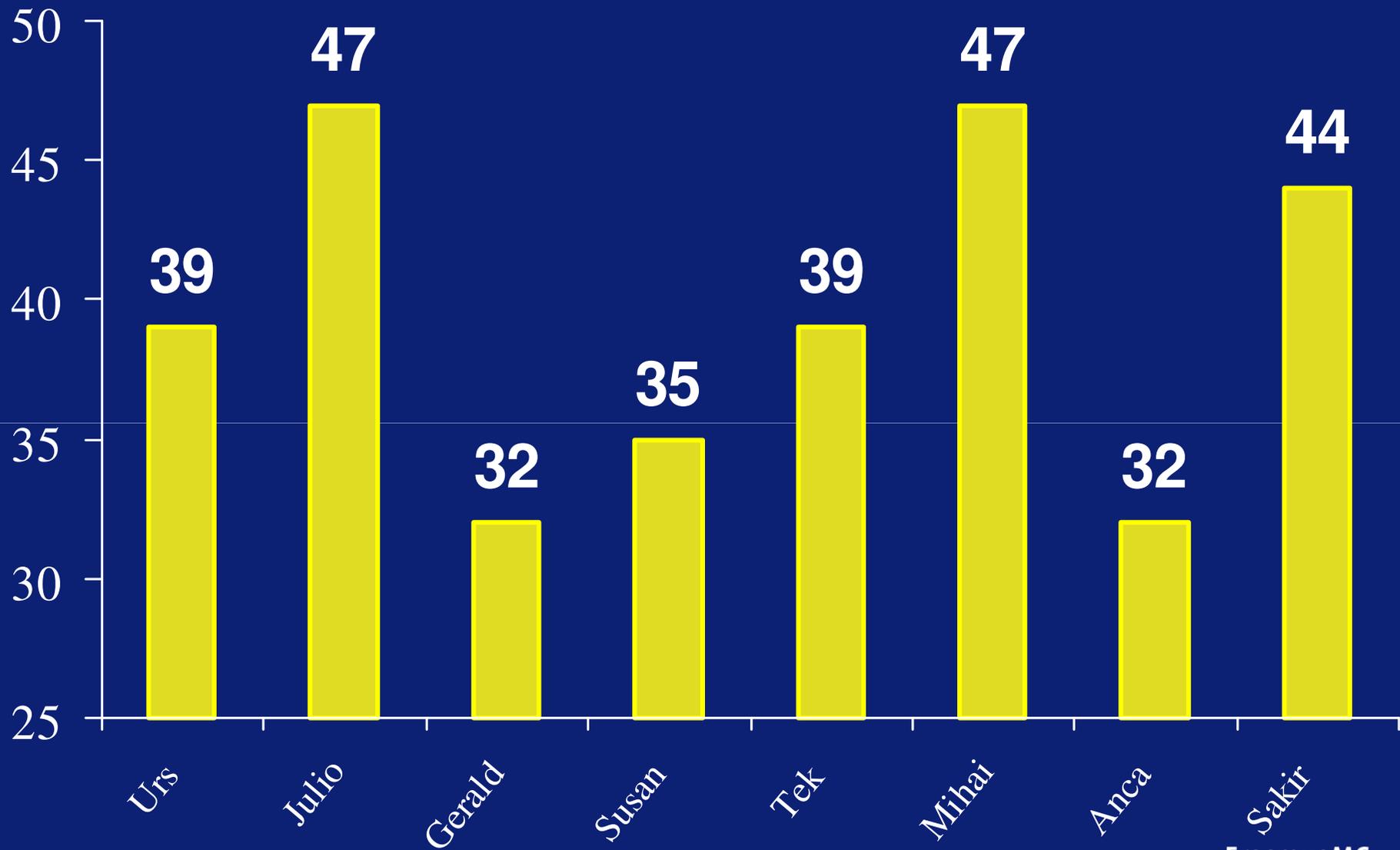


## Question 8

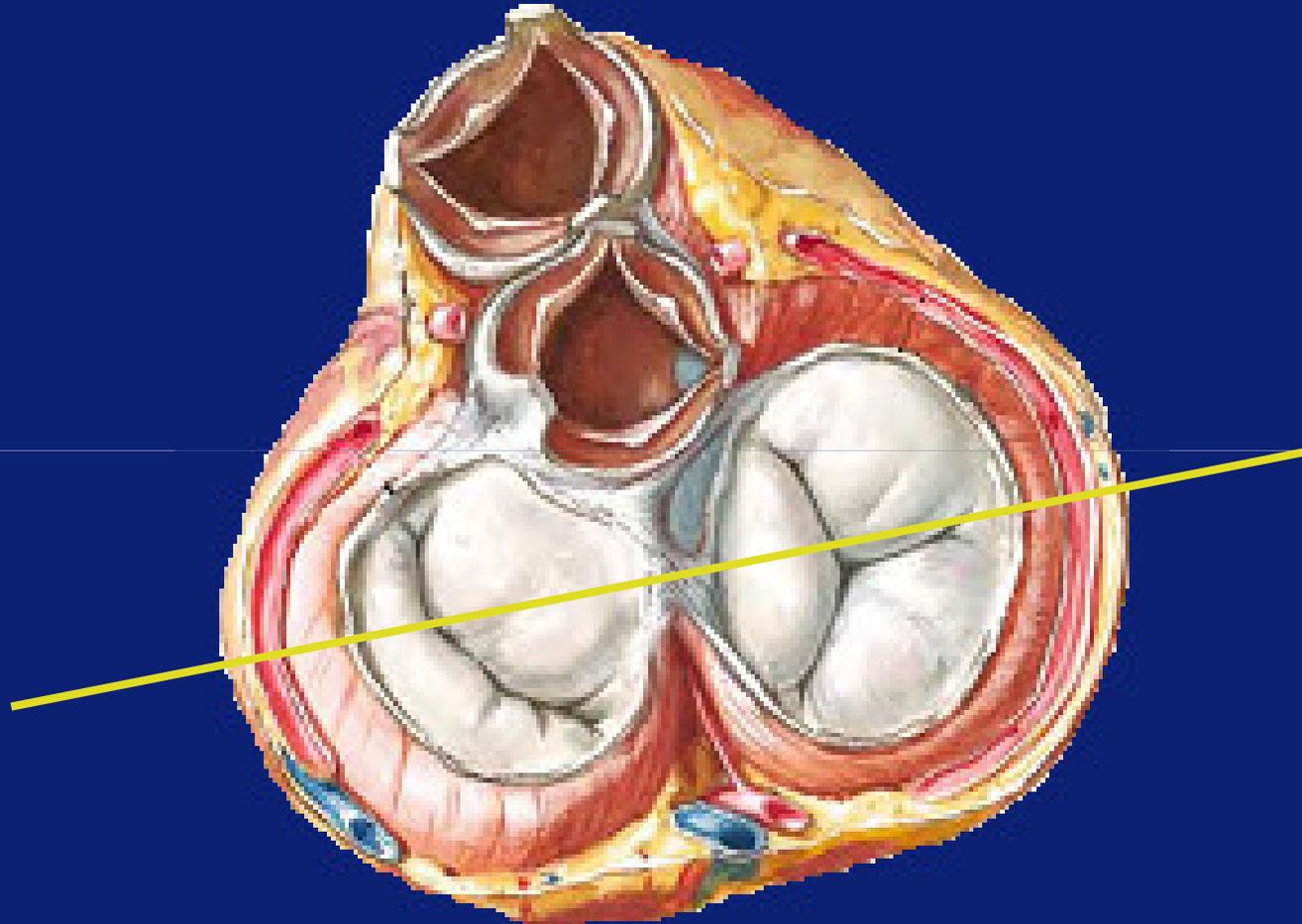
Where do you measure the annulus?

1. 4-Chamber view
2. 2-Chamber view
3. 3-Chamber view
4. Any of the views above-mentioned

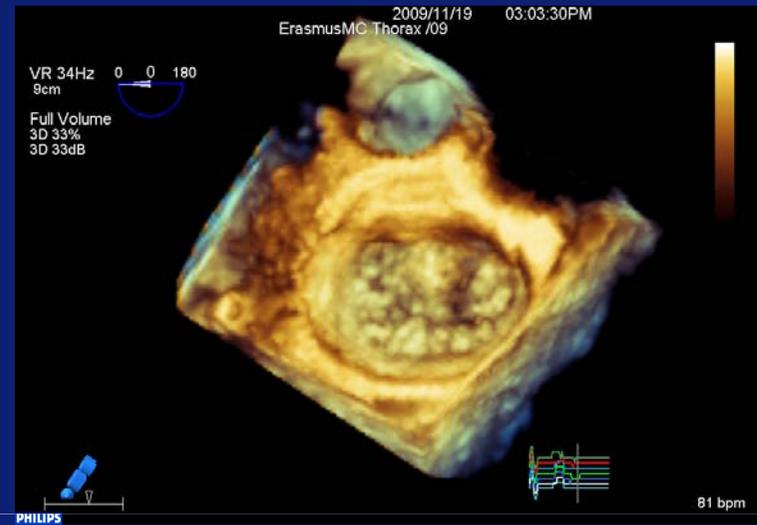
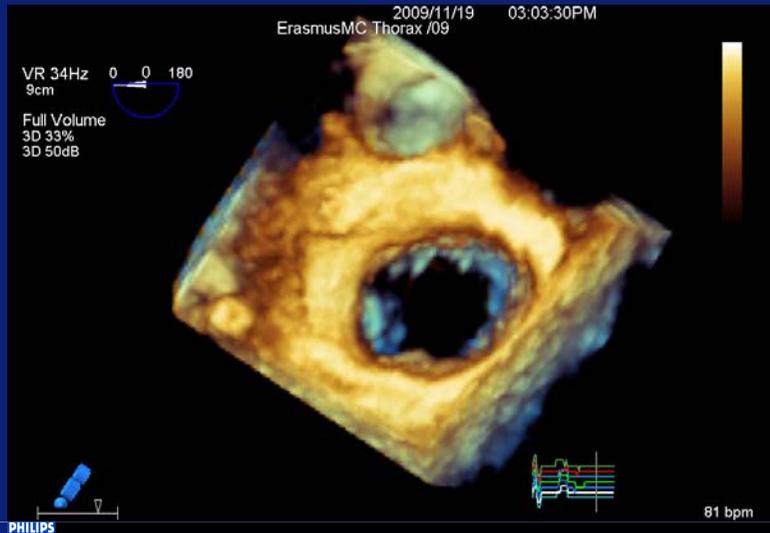
# Type IC Annulus dilatation



# Type IC Annulus dilatation



# Type IC Annulus dilatation

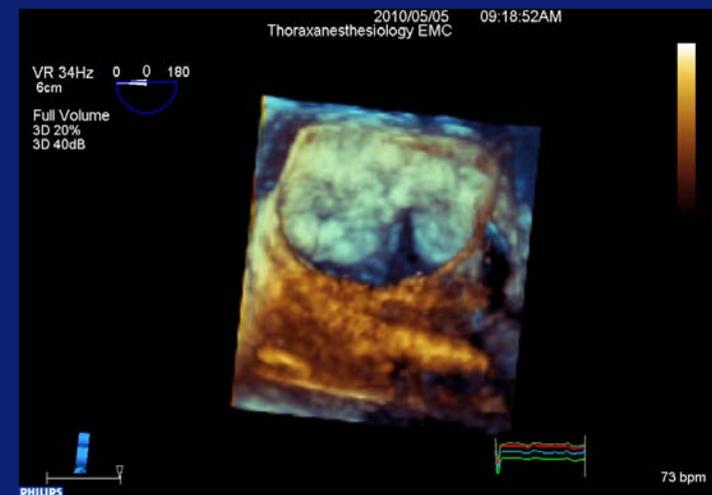
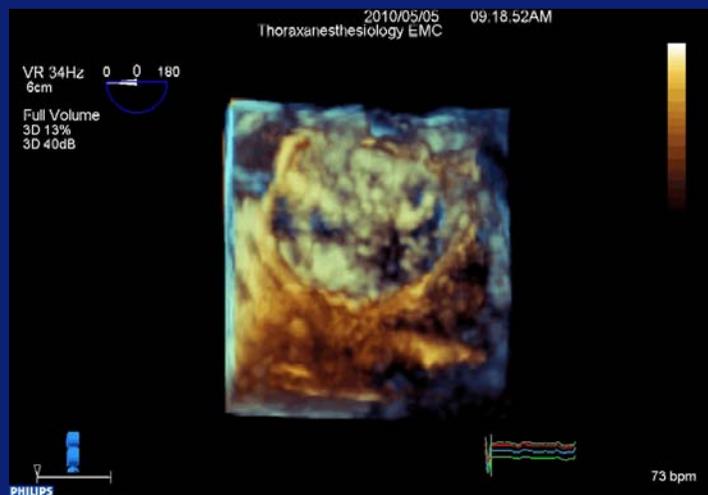
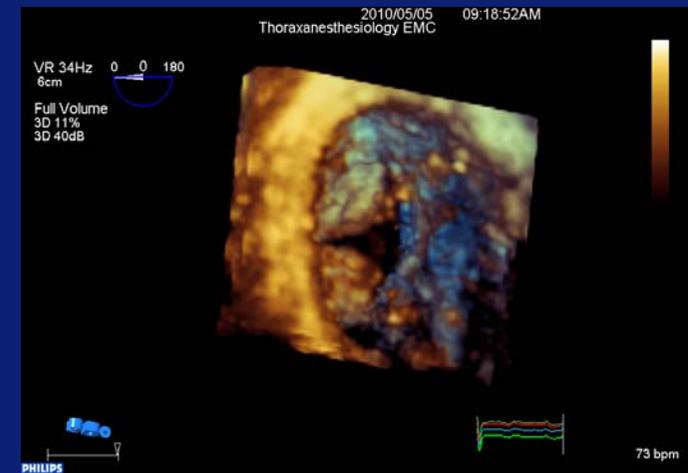
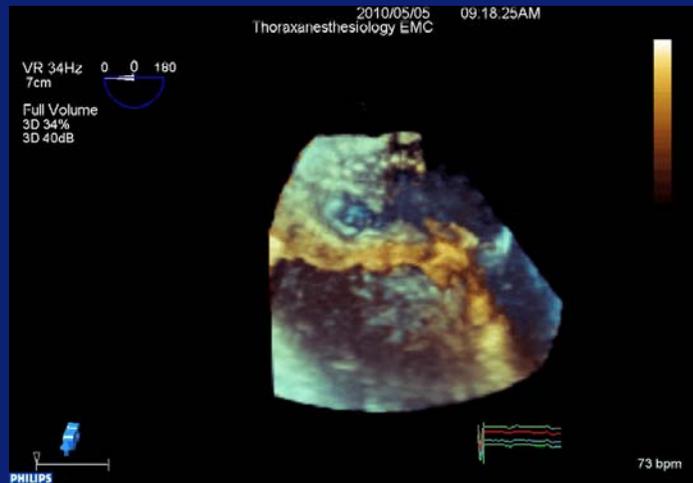


# Question 1

What is the main mechanism of mitral regurgitation in this patient?

1. Prolaps
2. Restriction
3. Cleft
4. I do not know

# The 3D image



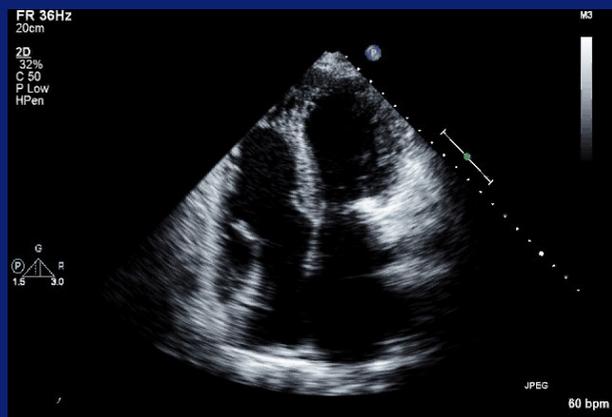
## Question 9

What is the main mechanism of mitral regurgitation in this patient?

1. Prolaps
2. Restriction
3. Cleft
4. I do not know

# Patient Case = Mitral valve cleft

- Unusual congenital lesion most often encountered in association with other congenital heart defects (atrio-ventricular endocardial cushion defects)
- Responsible for 1/3 of congenital mitral regurgitation
- Cleft diagnosis is difficult because of the position, dimensions and shape of the lesion



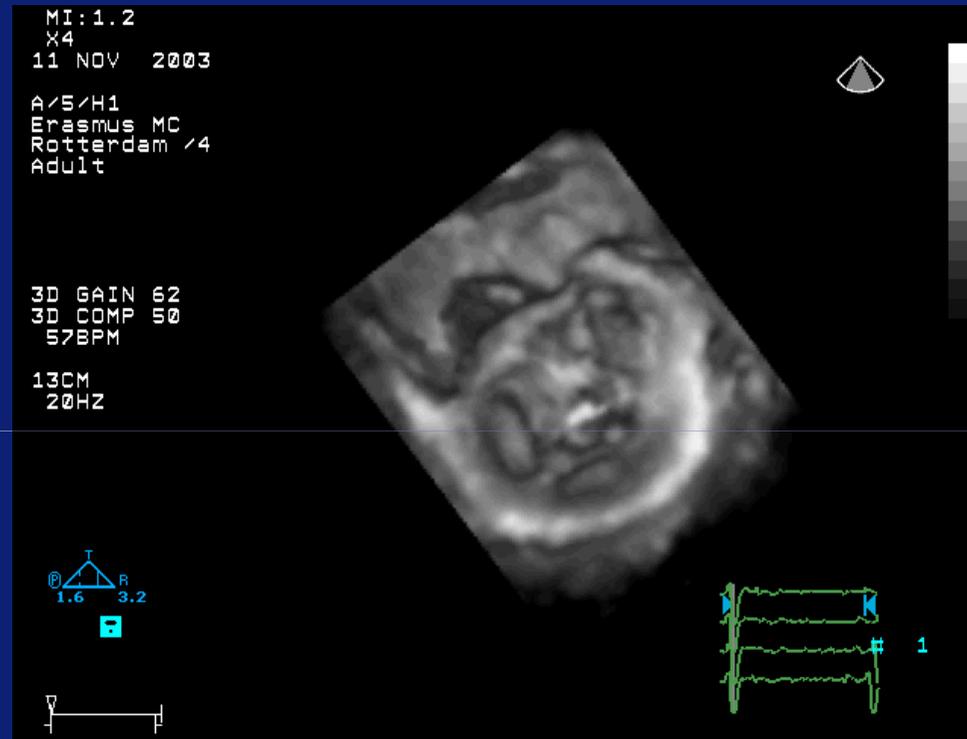
# Conclusions 3D

- easier to understand (surgeon)
  - faster (only one recording)
  - more accurate (extent)

**change or be changed**

(Jack Welch, former CEO of General Electric)

# What can 3D do better?



# Scallops visualisatie vanuit 3D TEE

## Mitral Valve Anatomy Report

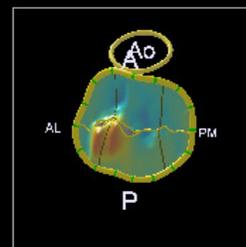
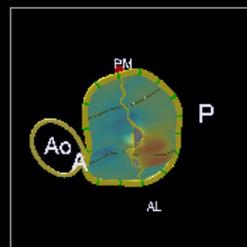
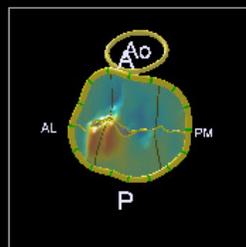
Annulus			Leaflet Volume		
DAIPm	42.8	mm	VTent	1.6	ml
DAP	36.6	mm	VProI	0.9	ml
H	8.2	mm	<b>Leaflet Len./Ang.</b>		
C3D	134.3	mm	θ Ant	17.3	°
A2D	1294.7	mm <sup>2</sup>	θ Post	28.2	°
			θ NPA	134.5	°
			HTent	4.8	mm
			HProI	7.2	mm

### Aortic-Mitral

θ 123.1 °

### Papillary

LChordAI 31.8 mm  
LChordPm 27.4 mm



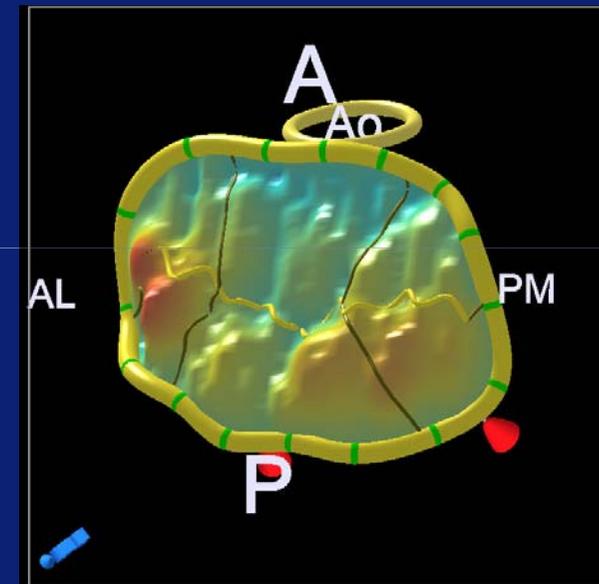
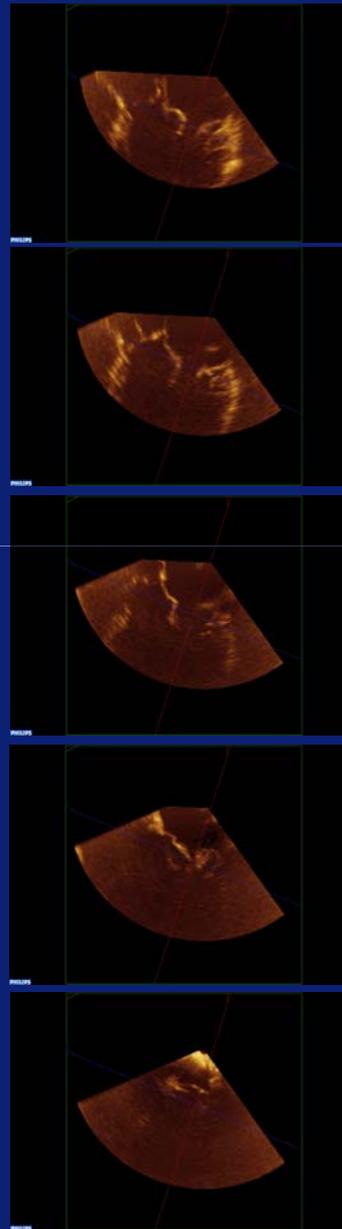
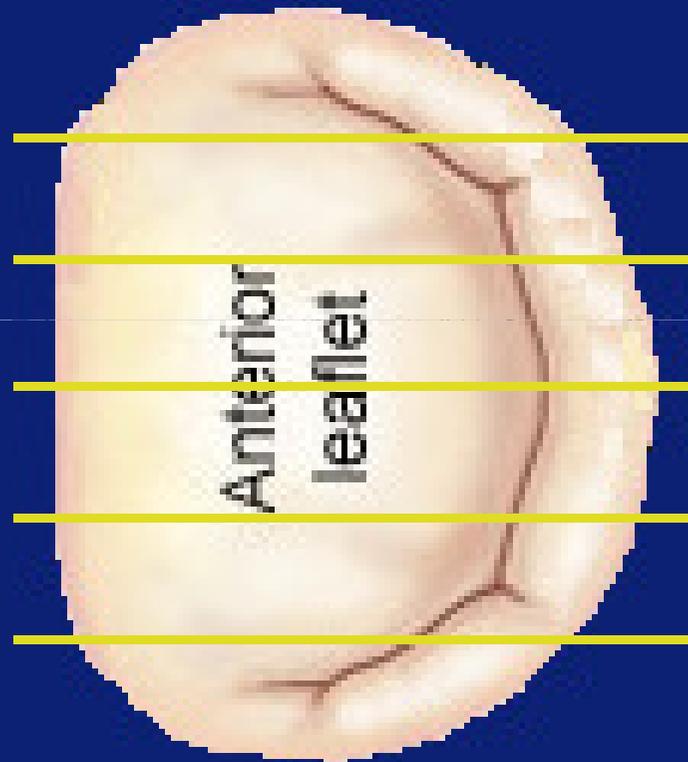
Annulus	
DAIPm	= 42.8 mm
DAP	= 36.6 mm
H	= 8.2 mm
C3D	= 134.3 mm
A2D	= 1294.7 mm <sup>2</sup>
Leaflet Area	
A3DE Ant	= <del>mm<sup>2</sup></del>
A3DE Post	= <del>mm<sup>2</sup></del>
Leaflet Volume	
VTent	= 1.6 ml
VProI	= 0.9 ml
Leaflet Len./Ang.	
L3DE A2	= <del>mm</del>
L3DE P2	= <del>mm</del>
θ Ant	= 17.3 °
θ Post	= 28.2 °
θ NPA	= 134.5 °
HTent	= 4.8 mm
HProI	= 7.2 mm
Coaptation	
L2DAIPm	= <del>mm</del>
Aortic-Mitral	
θ	= 123.1 °
Papillary	
LChordAI	= 31.8 mm
LChordPm	= 27.4 mm

PHILIPS

Erasmus MC



# Scallops visualisatie vanuit 3D TEE



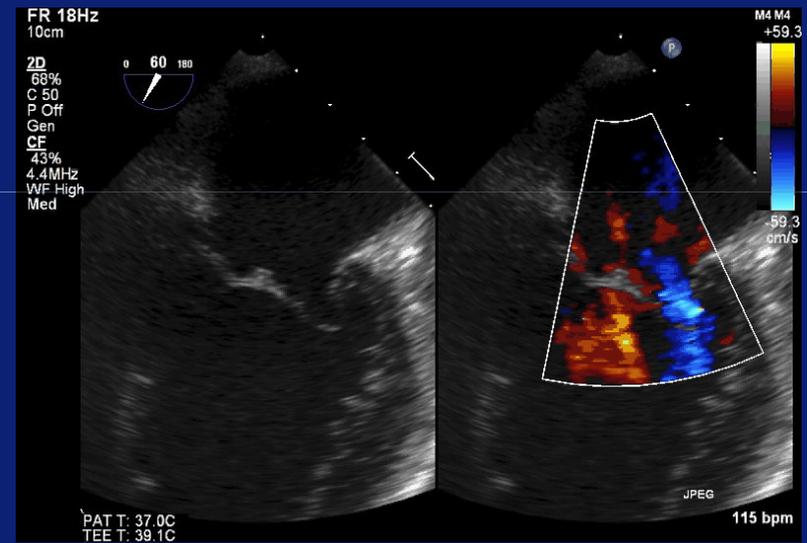
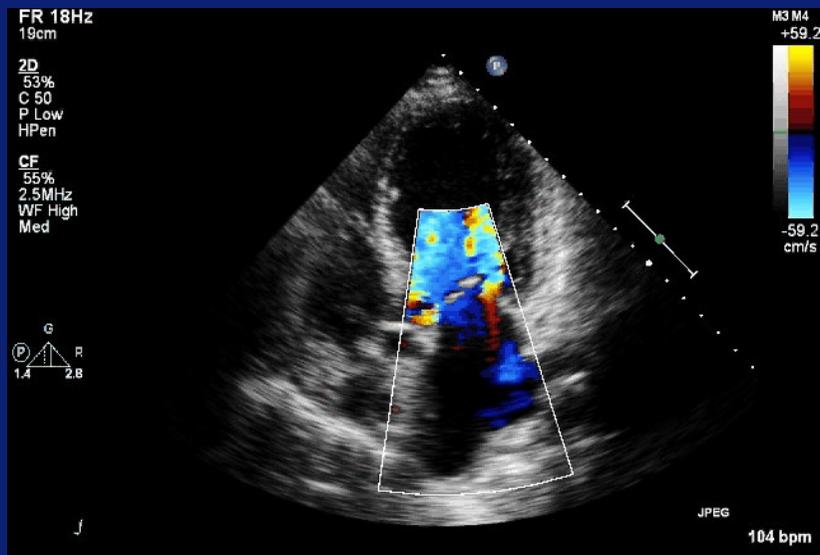
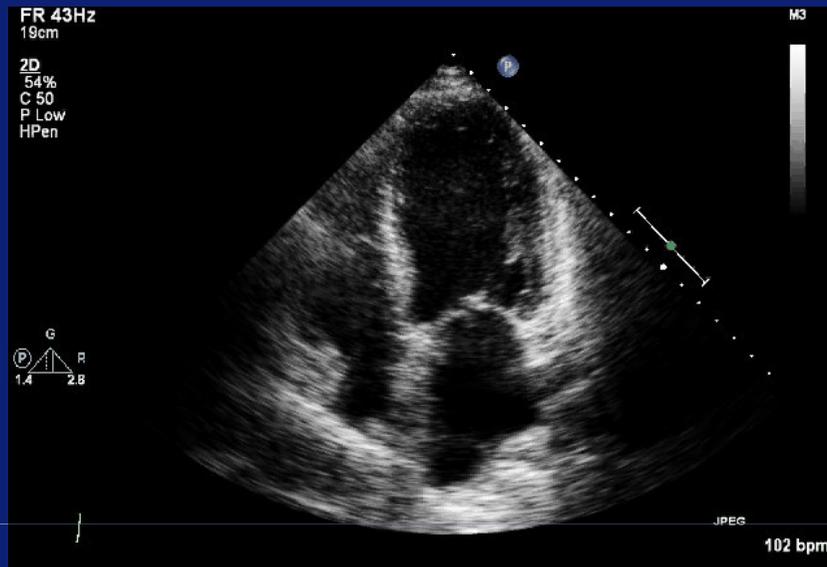
# Pathologie van de mitralisklep

- Type I Normale beweging van klepbladen**
- A Perforatie (endocarditis)
  - B Aangeboren cleft
  - C Gedilateerde annulus zonder restrictie (tethering) van de klepbladen

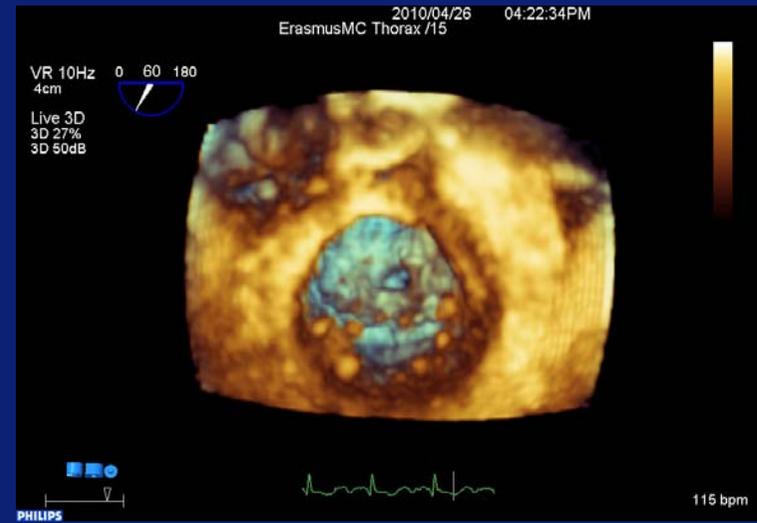
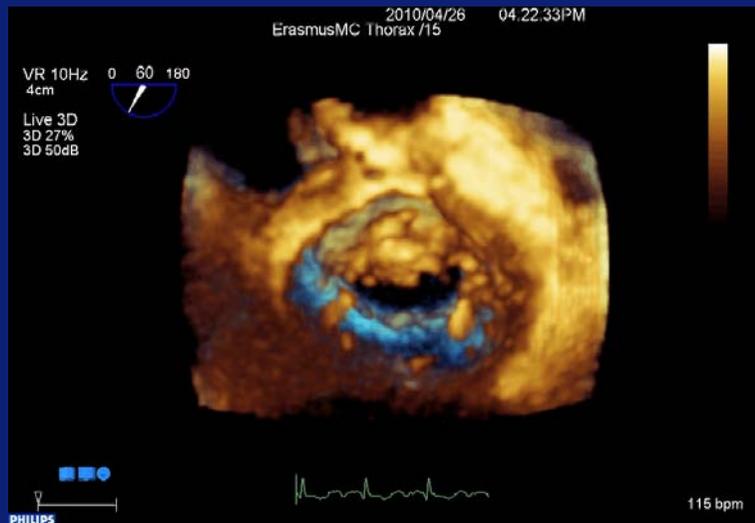
# Pathologie van de mitralisklep

- Type I Normale beweging van klepbladen
  - A Perforatie (endocarditis)

# Type IA Perforation



# Type IA Perforation

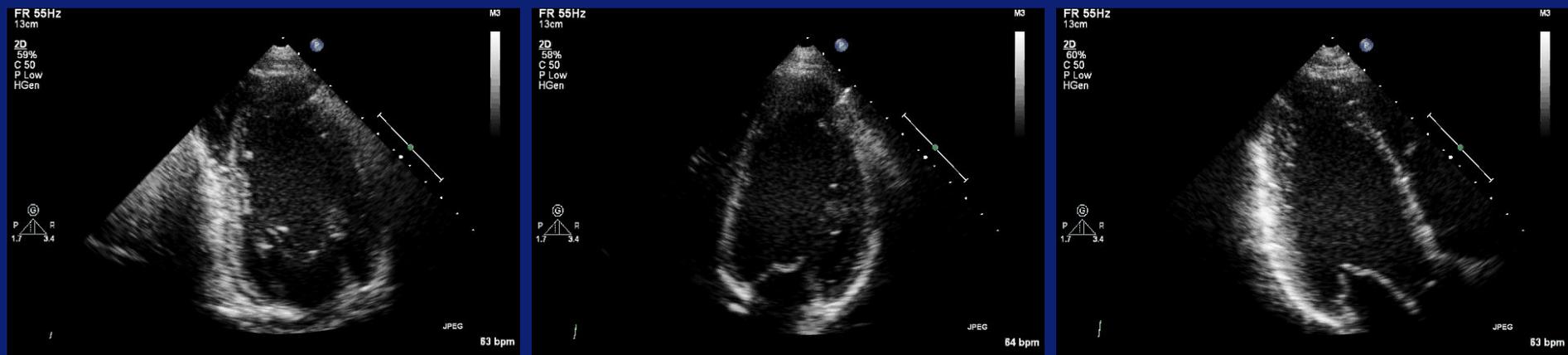
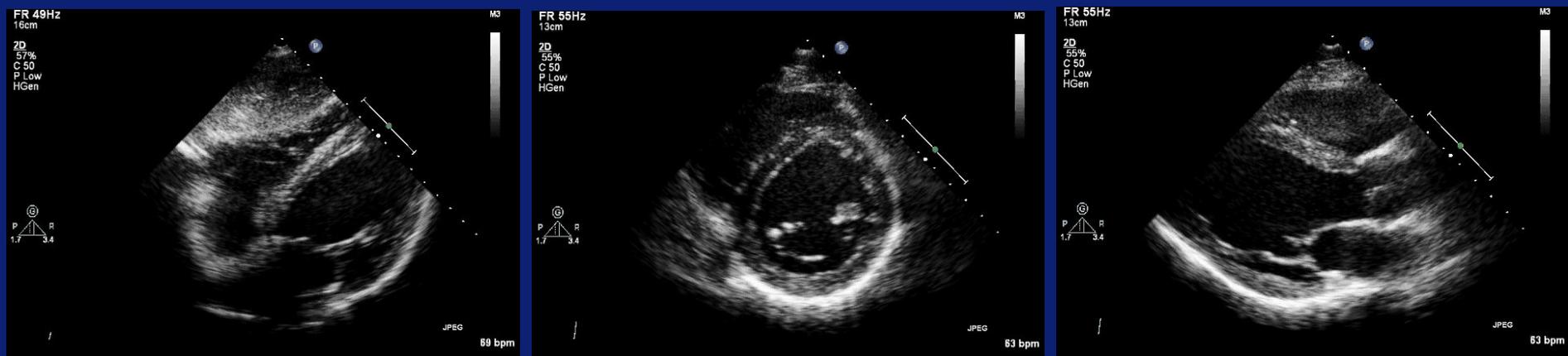


# Pathologie van de mitralisklep

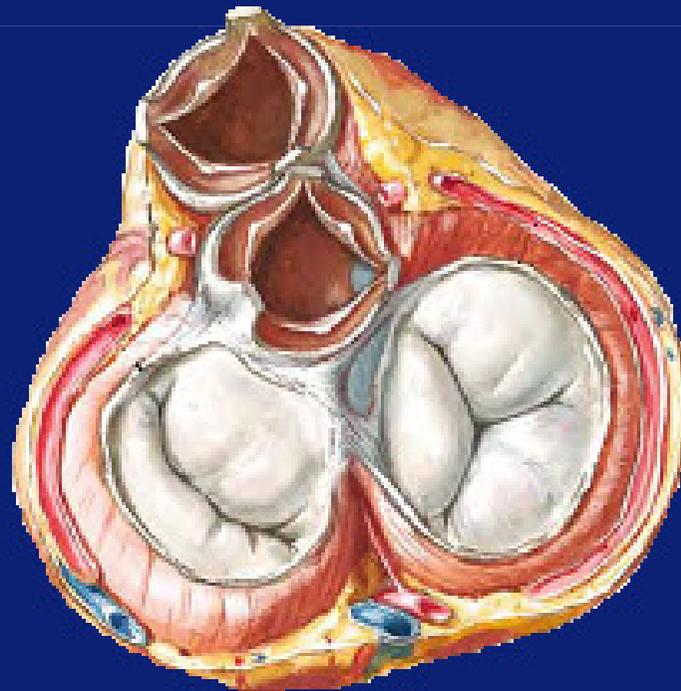
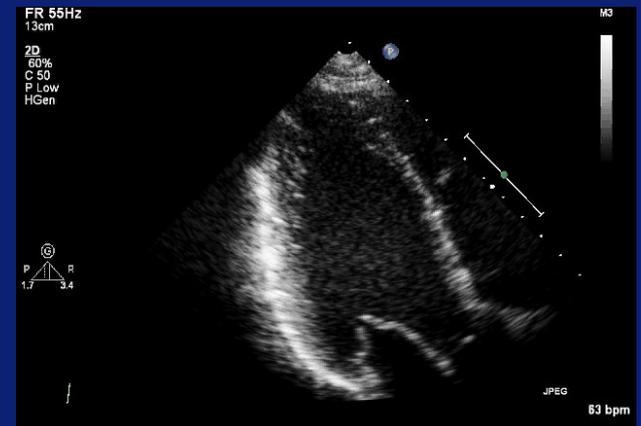
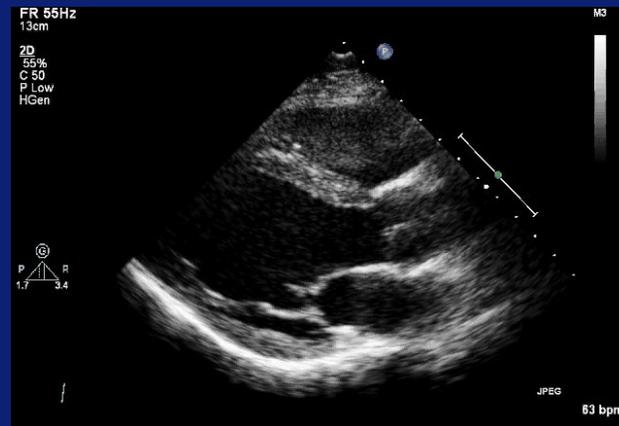
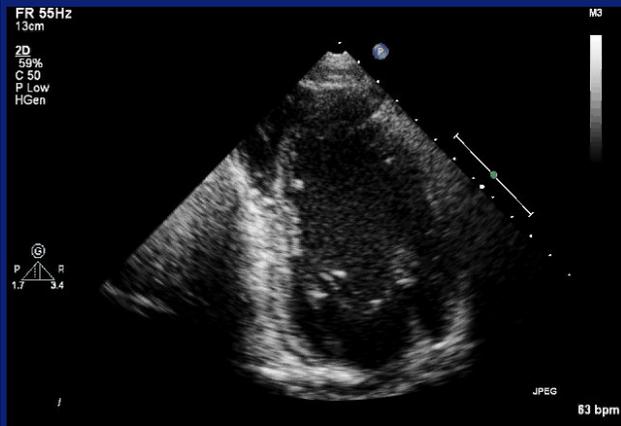
Type I Normale beweging van klepbladen

B Aangeboren cleft

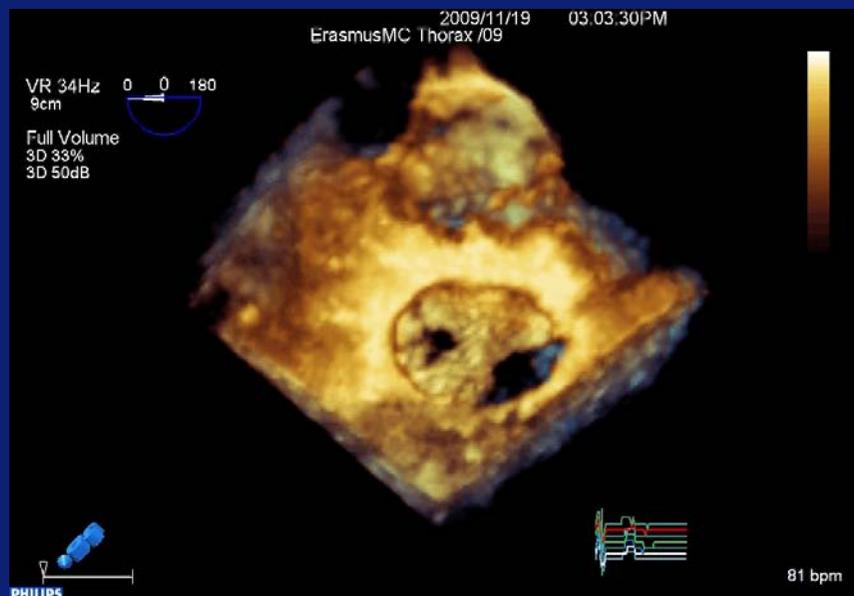
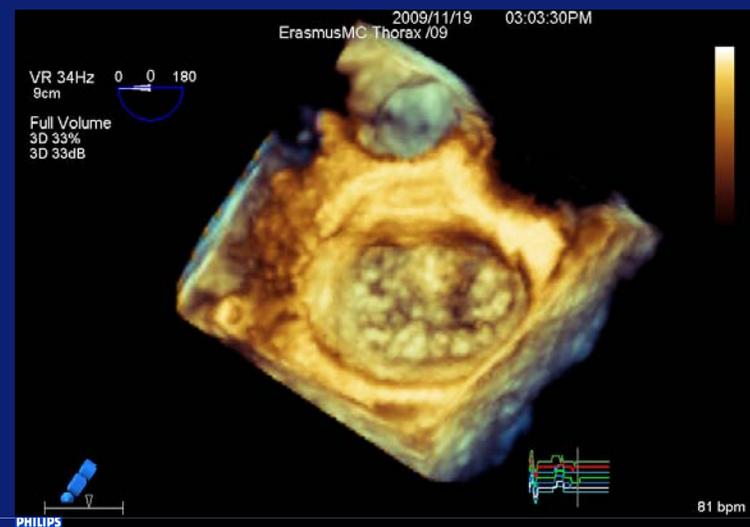
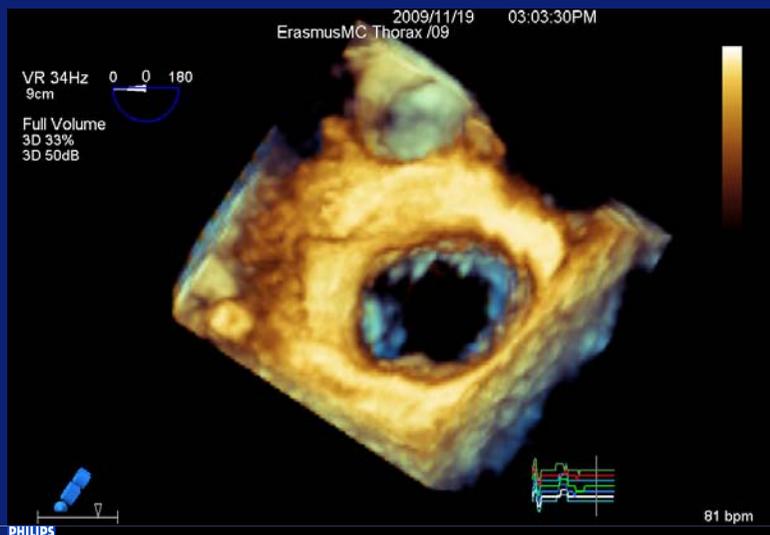
# Type IC Annulus dilatation



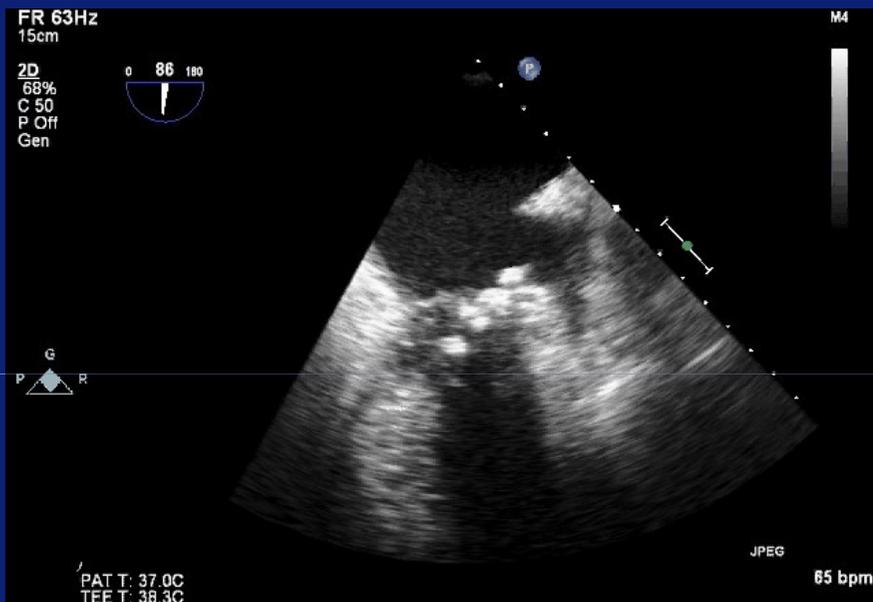
# Type IC Annulus dilatation



# Type IC Annulus dilatation



# Calcification



# Conclusions 3D TEE

- easier to understand (surgeon)
  - faster (only one recording)
  - more accurate (extent)

**change or be changed**

(Jack Welch, former CEO of General Electric)

# Patient practice 1

## Measurement of the 2D annulus

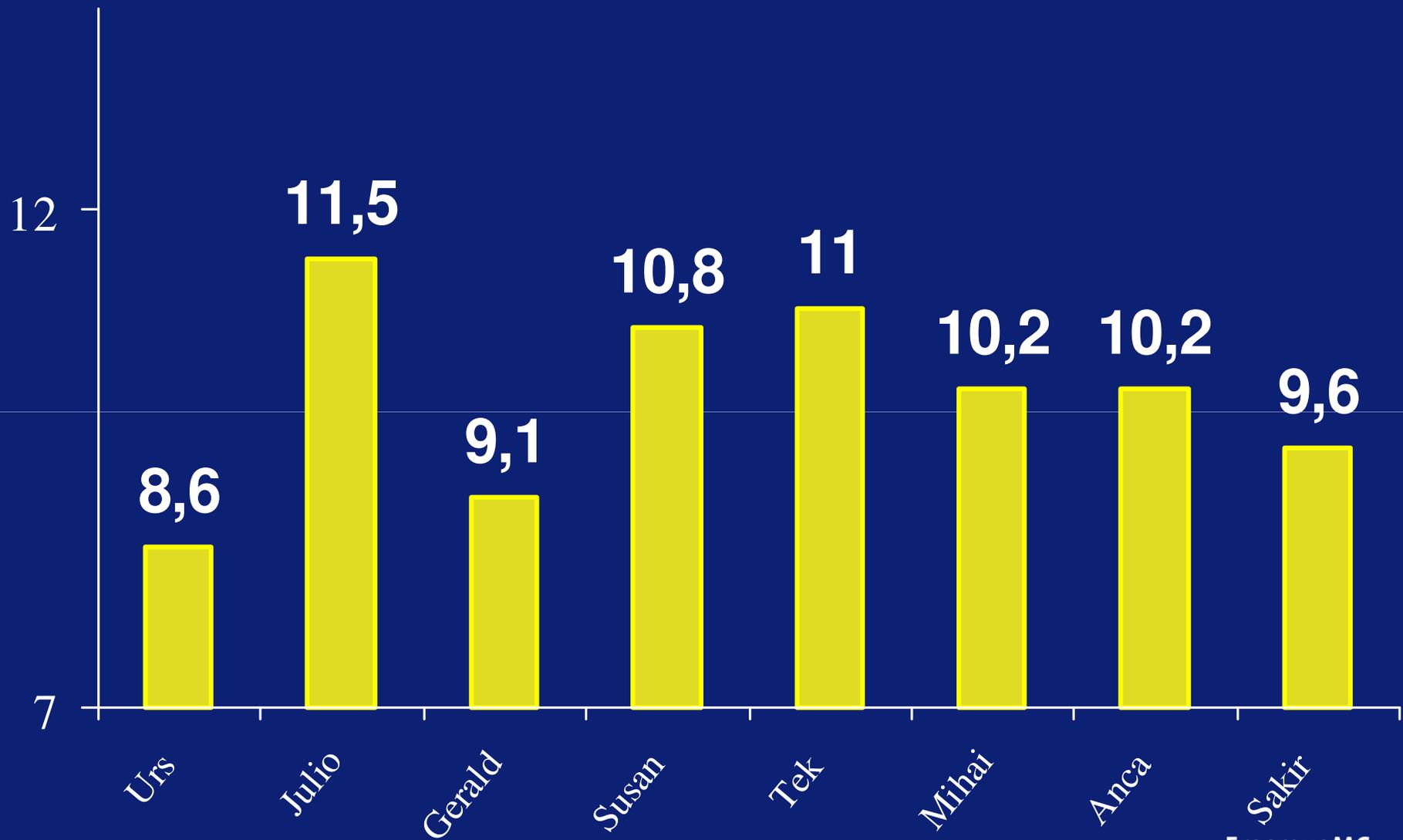
- open folder Keyser on QLAB 2D TEE
- measure the MV annulus according to **your own method** (do not discuss with each other) and note your value

# Patient practice 1

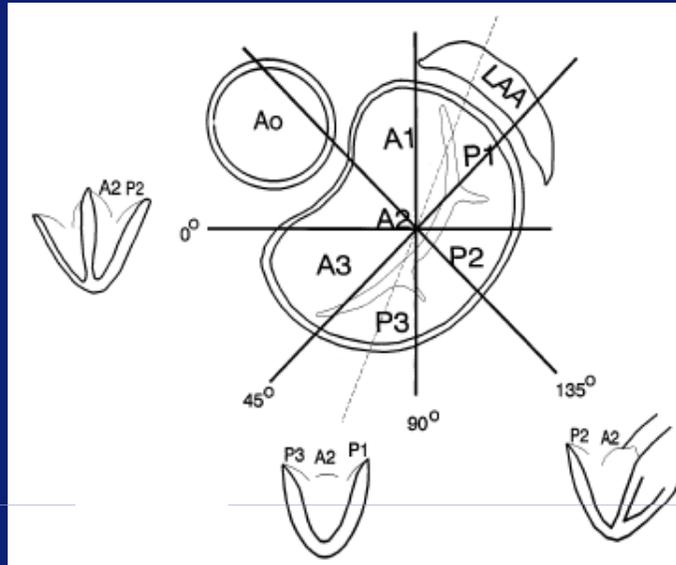
## Measurement of the 3D annulus

- open folder Lips on QLAB (MPR)
- measure the MV annulus area upon instructions of Jacky
  
- open folder Keyser on QLAB (MPR)
- measure the MV annulus area yourself and note your value

# Patient practice 1



# Patient practice 2

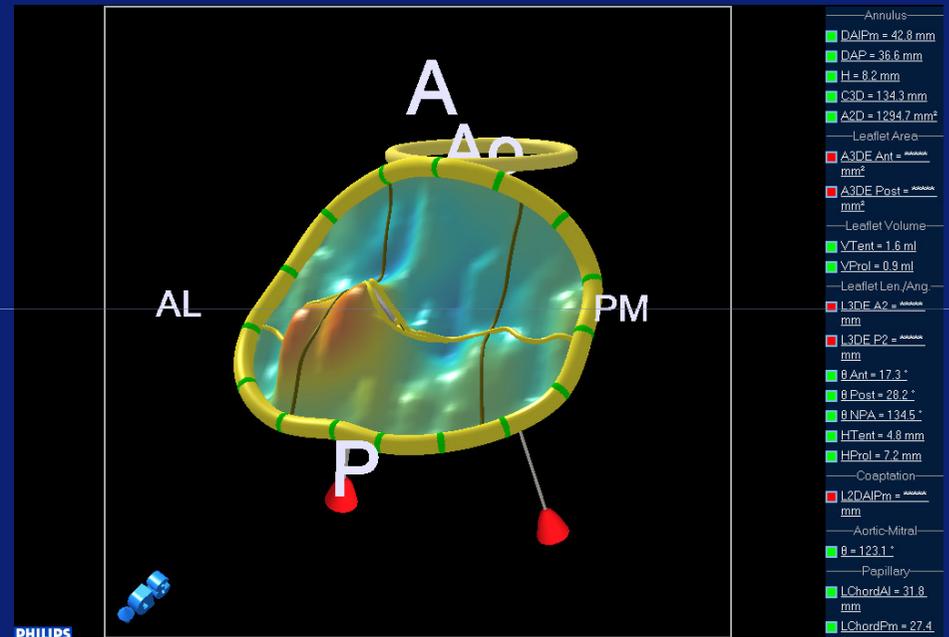
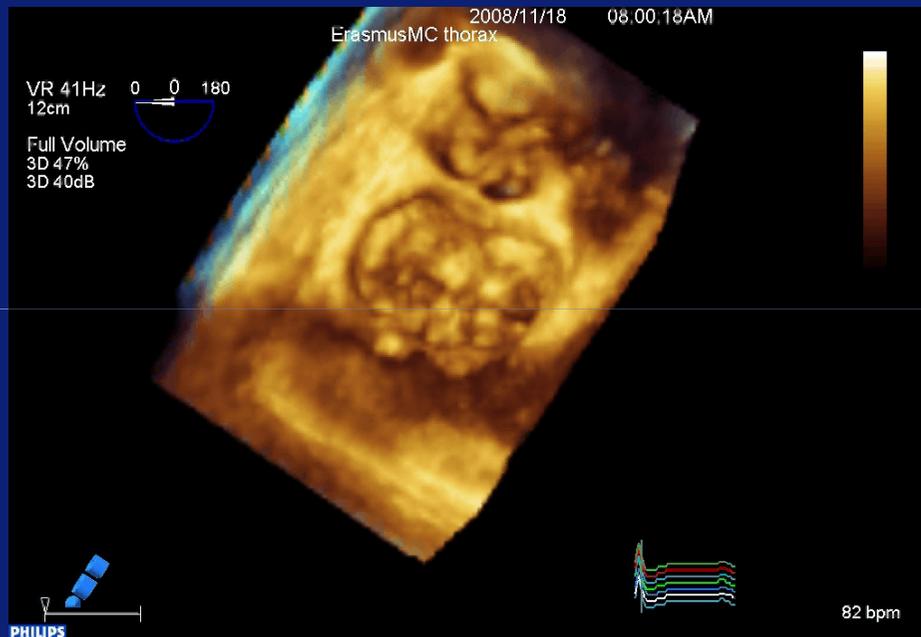


# Patient practice 2

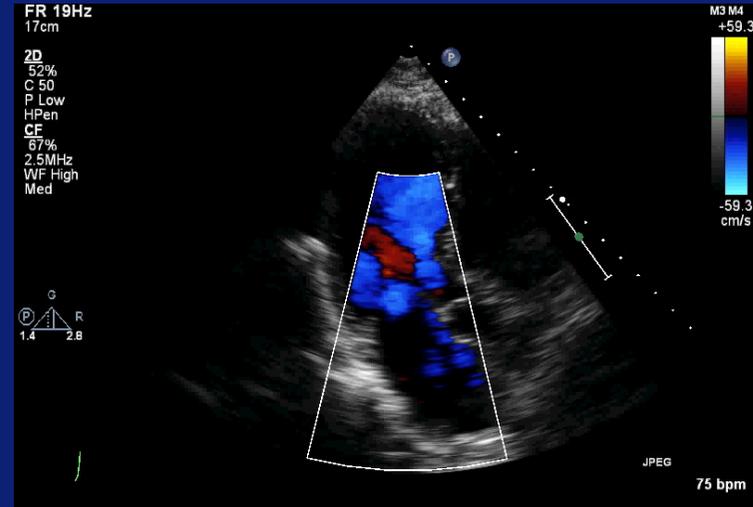
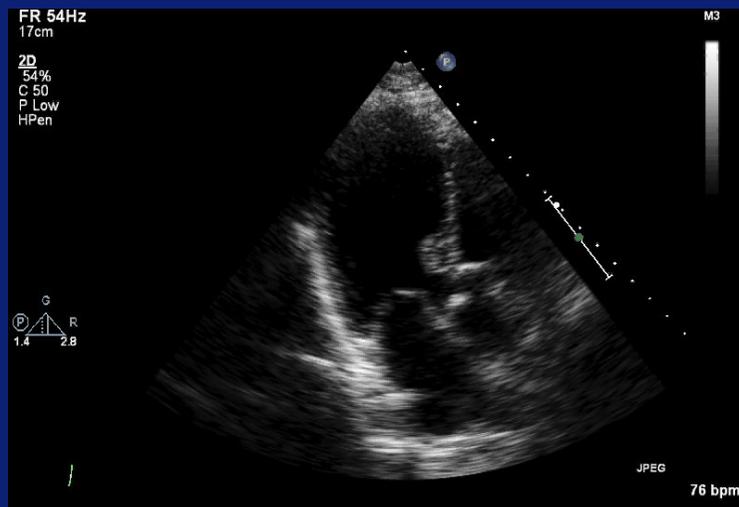
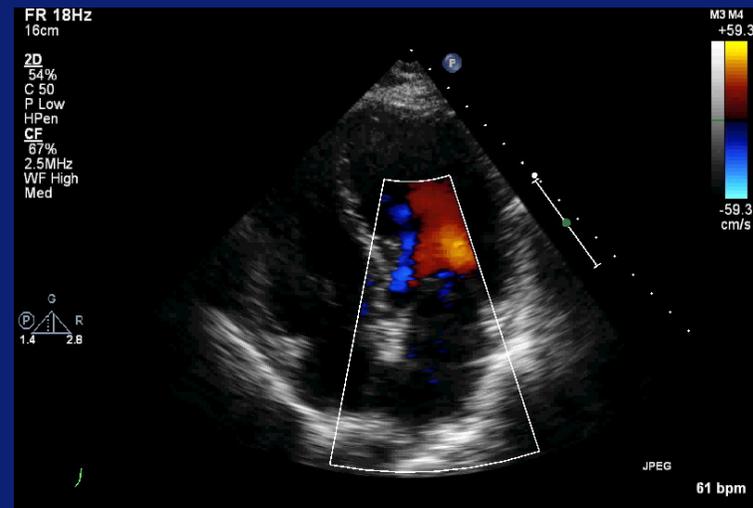
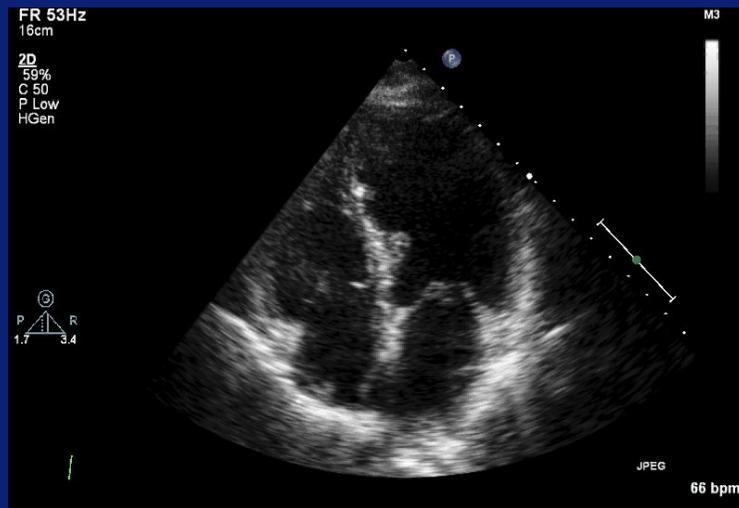
## Mechanism oefenLIPS

- open folder Kraayeveld on QLAB
- find the prolaps yourself

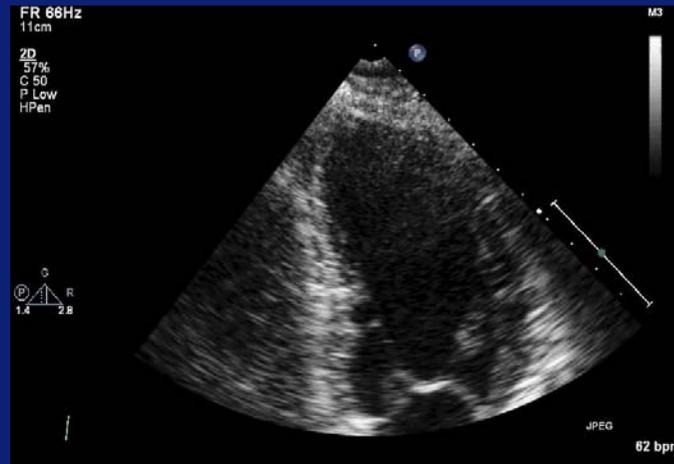
# Patient practice 2 – P2 prolaps



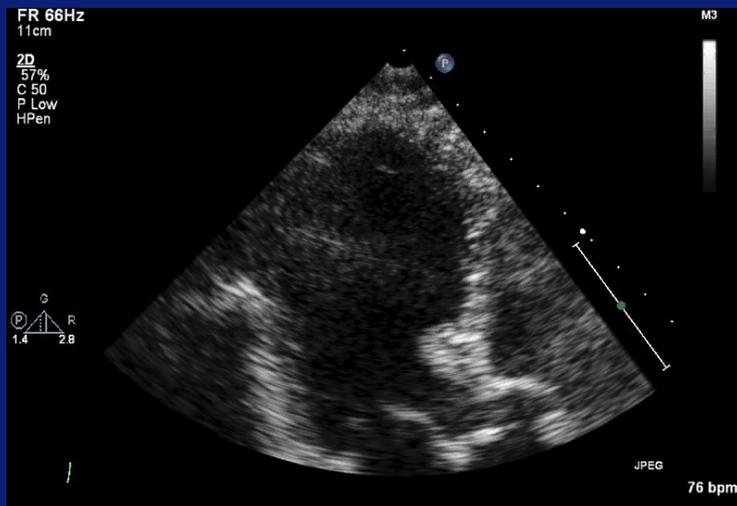
# Patient practice 3



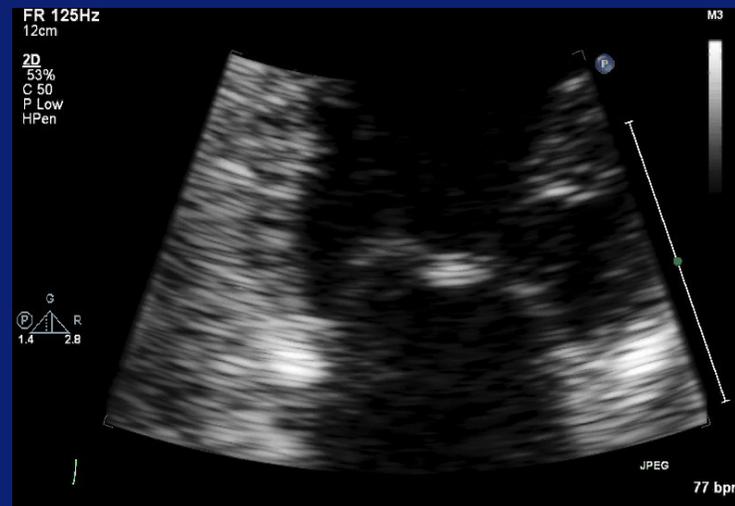
# Patient practice 3



## 4-Chamber



## 3-Chamber



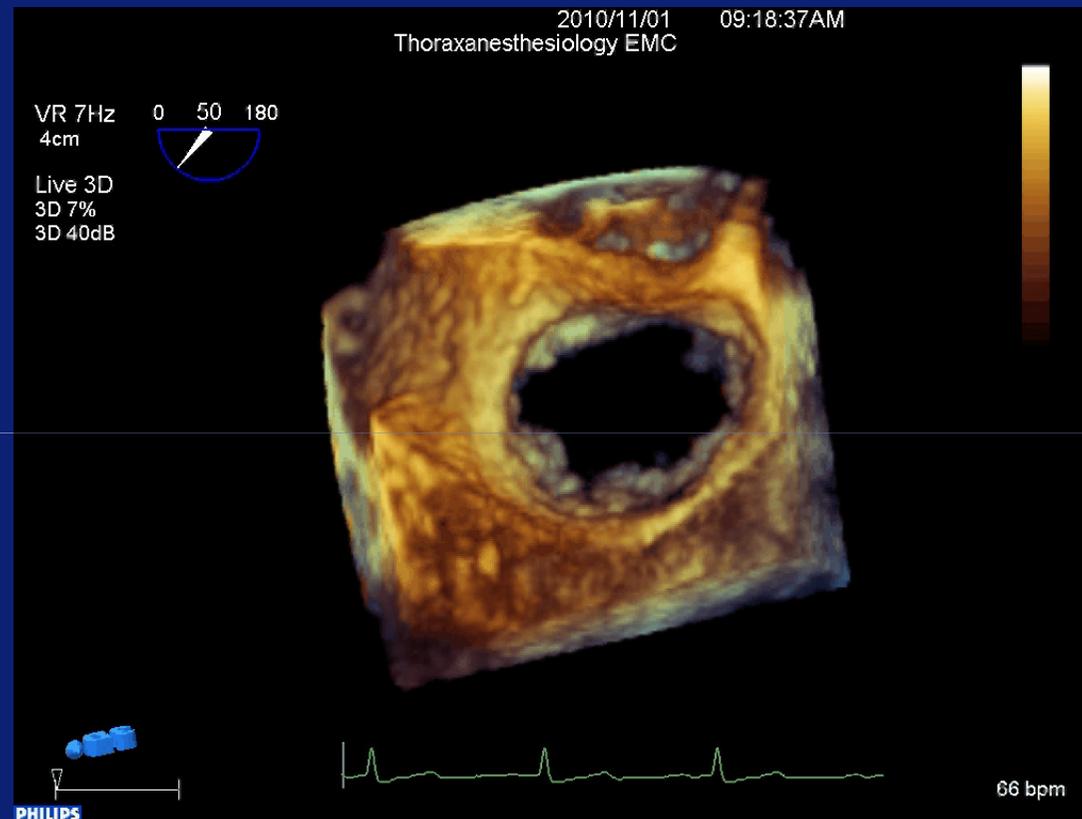
## 2-Chamber

# Patient practice 3

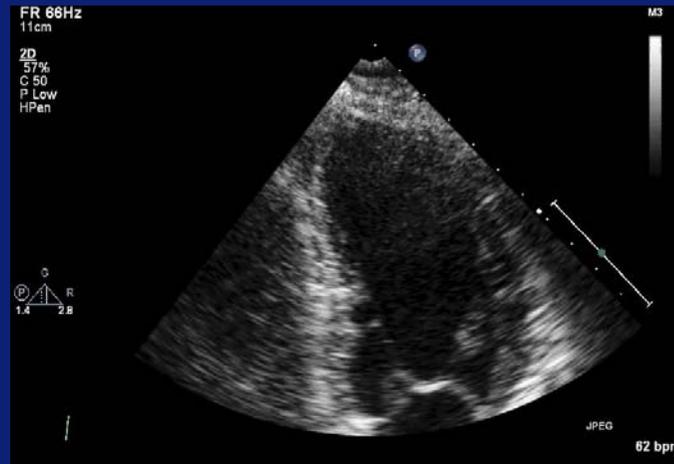
## Mechanism

- open folder Meijvogel on QLAB
- find the prolaps yourself

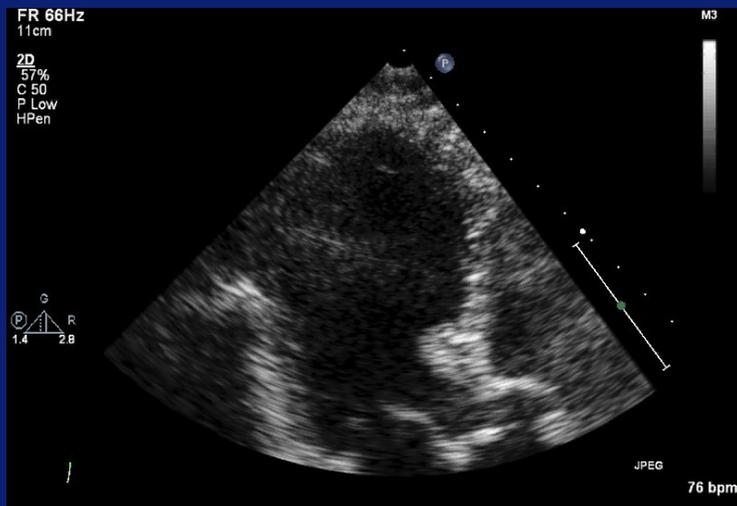
# Patient practice 3 – P3 prolaps



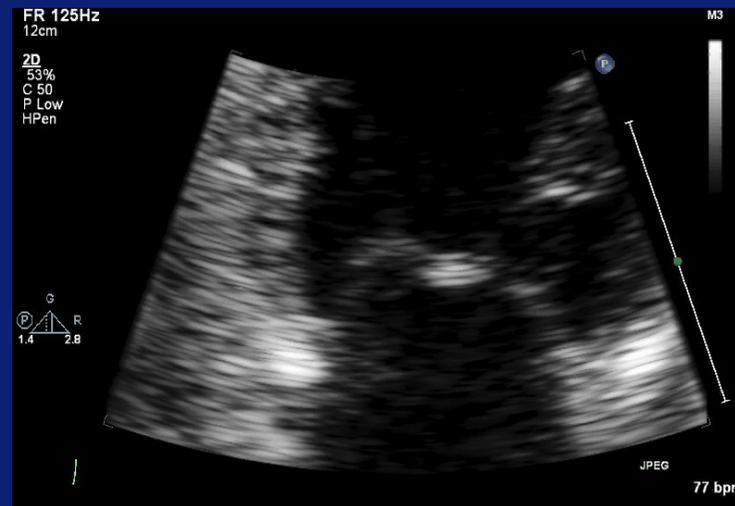
# Patient practice 3



A3 - A2 - P1

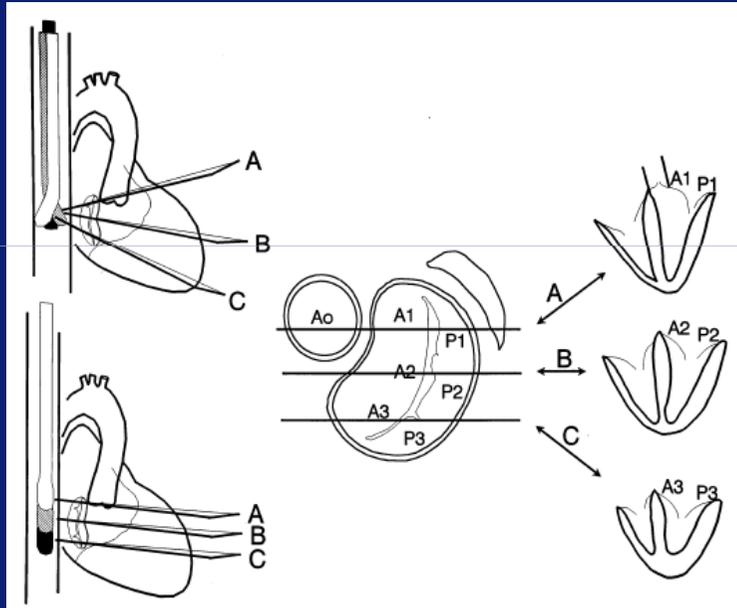


P2 - A2



P3 - A2 - P1

# Patient practice 3



A1 - P1



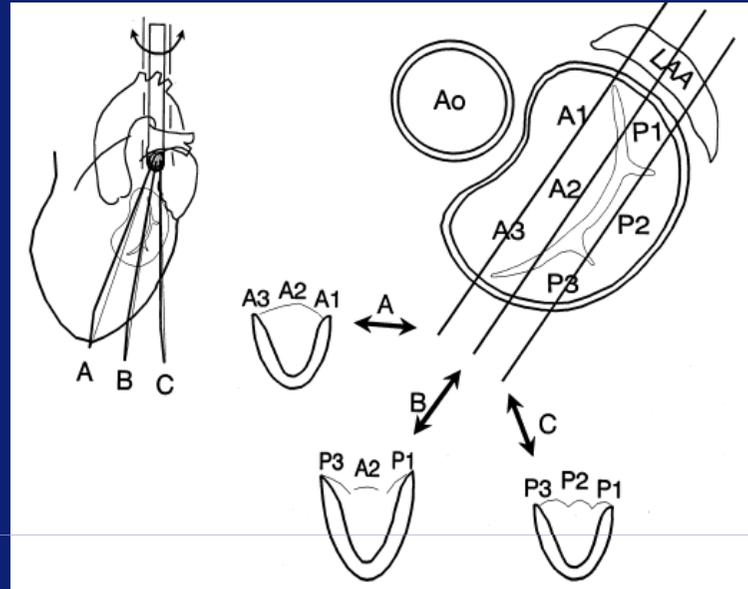
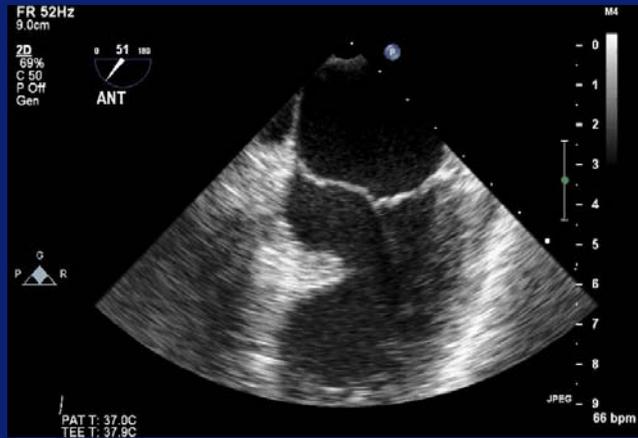
A2 - P2



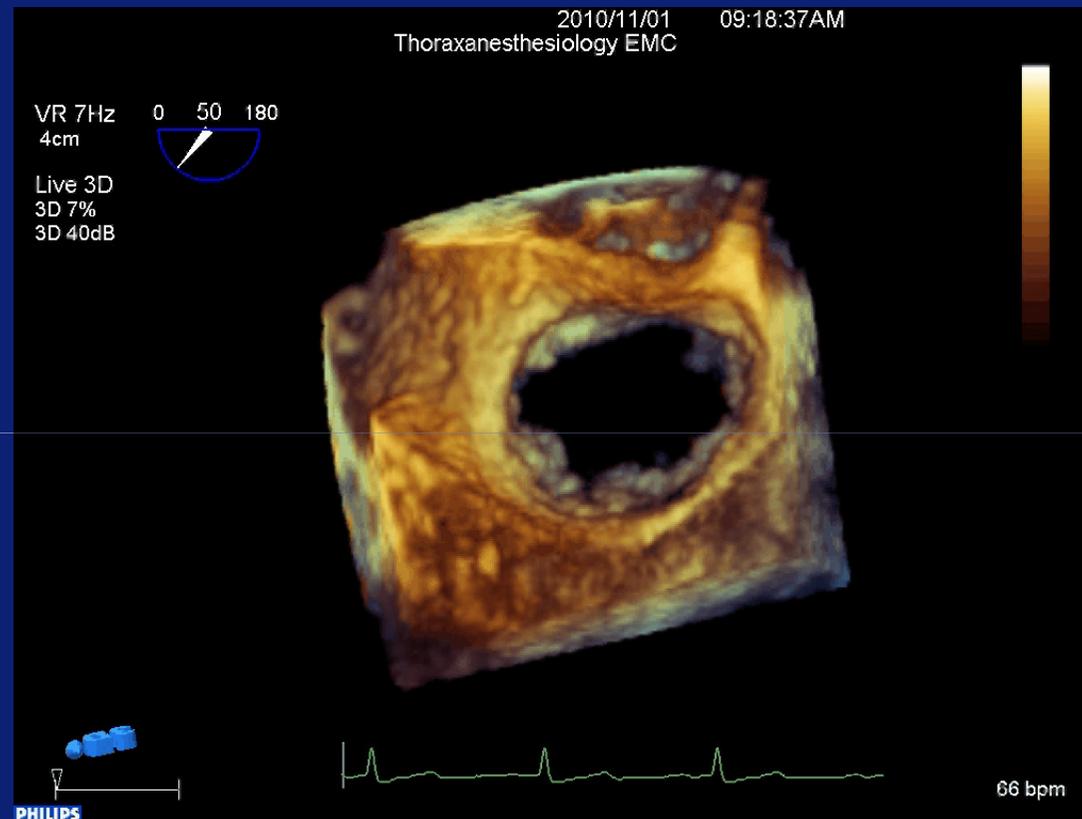
A3 - P3



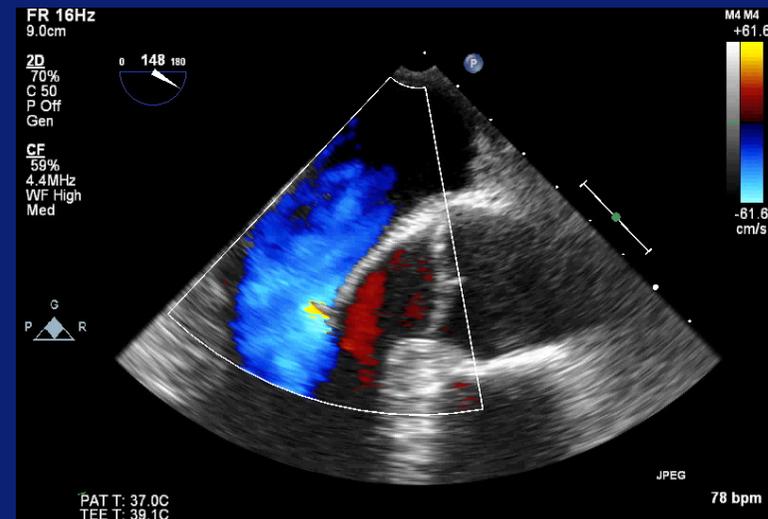
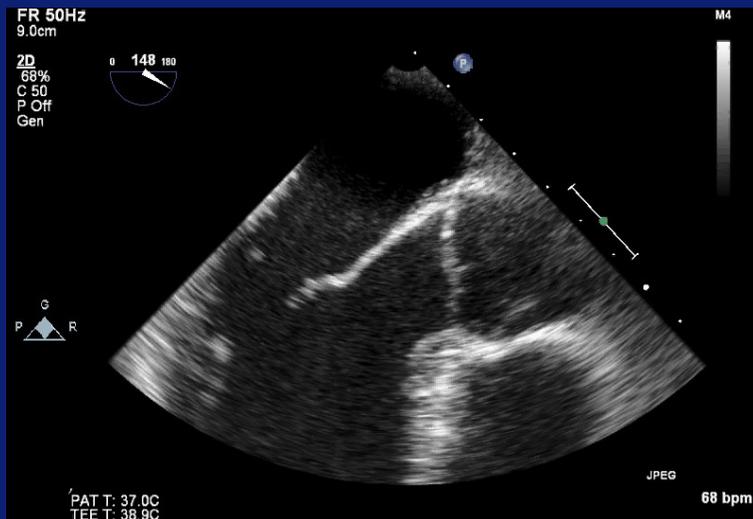
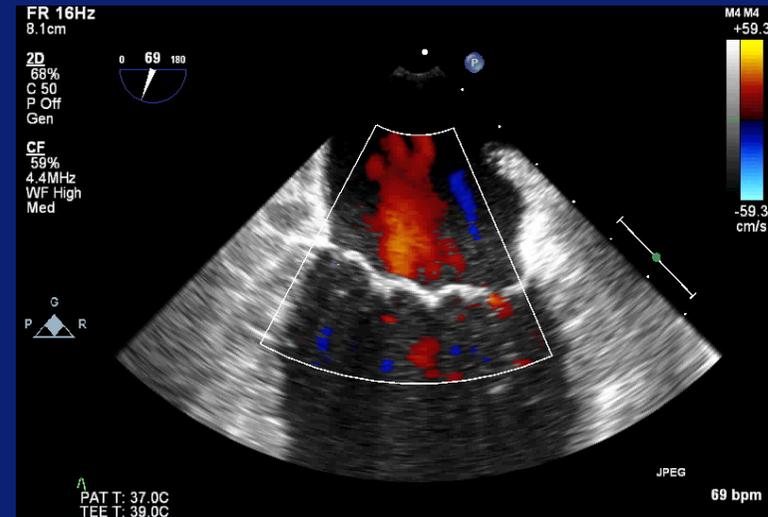
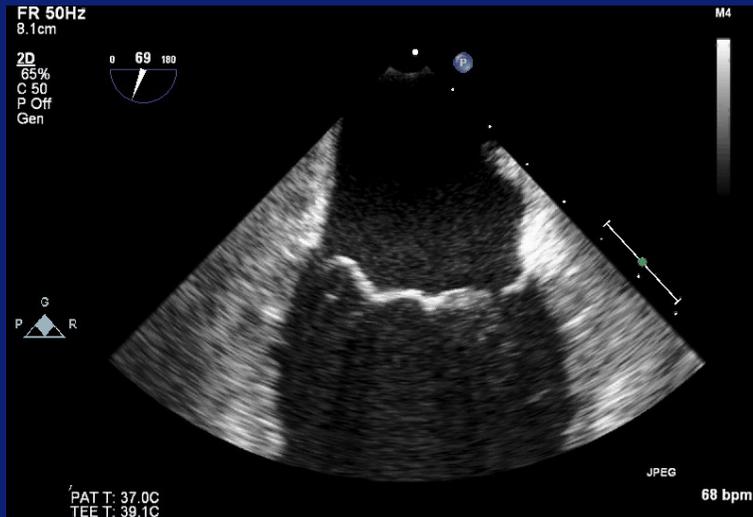
# Patient practice 3



# Patient practice 3 – P3 prolaps



# Patient practice 4

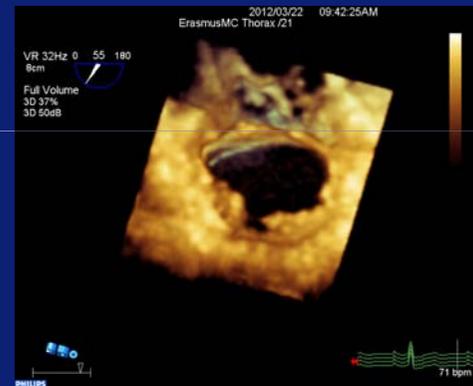
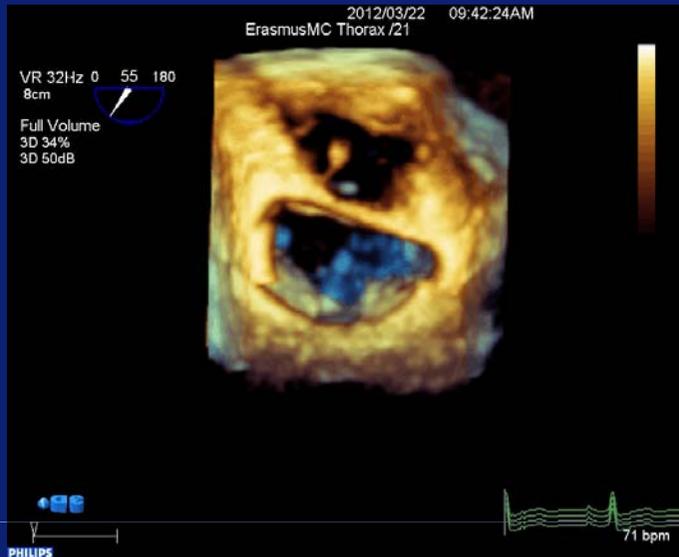


# Patient practice 4

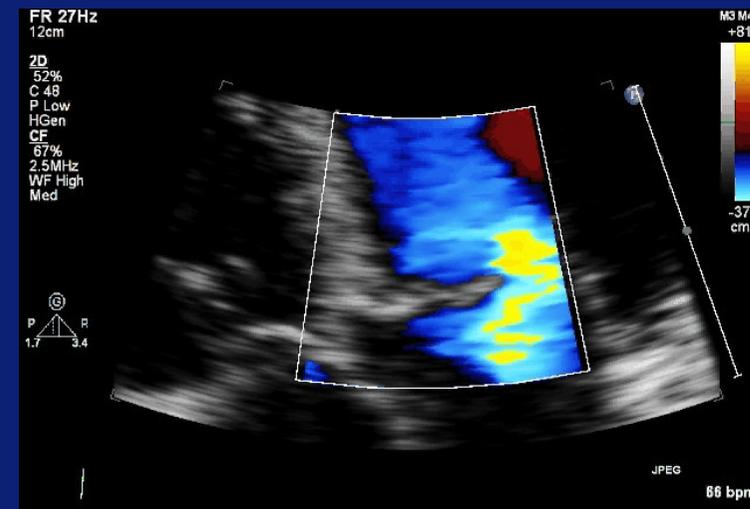
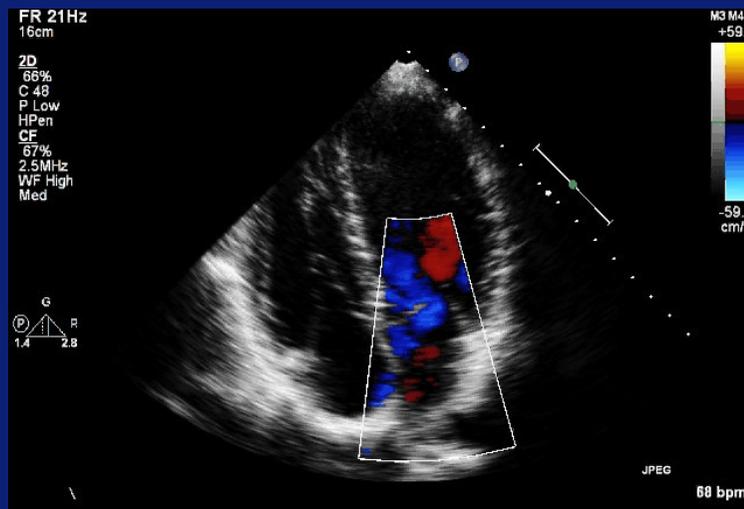
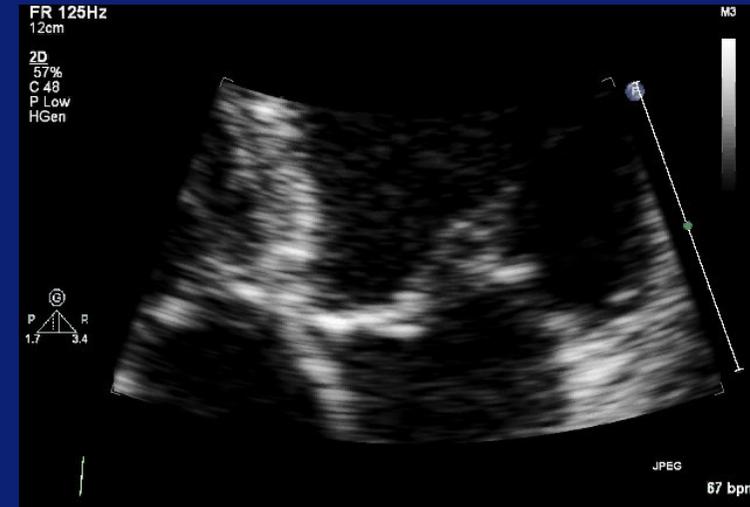
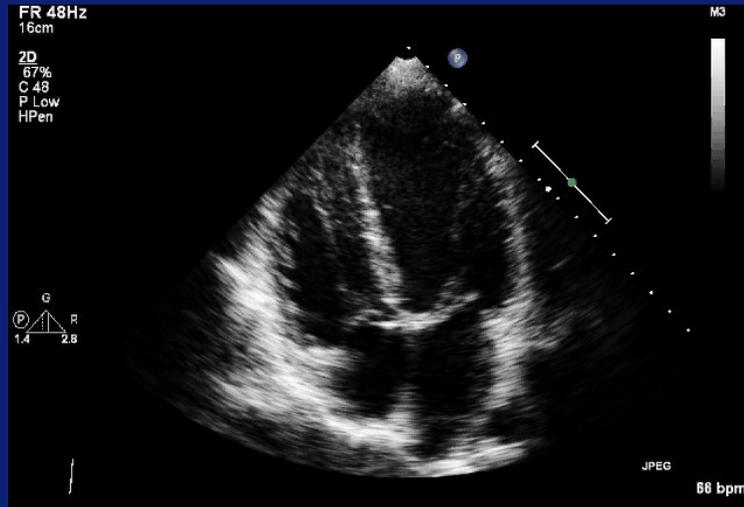
## Mechanism

- open folder Okkerman on QLAB
- find the prolaps or perforation yourself

# Patient practice 4 – P2 perforation



# Patient practice 5

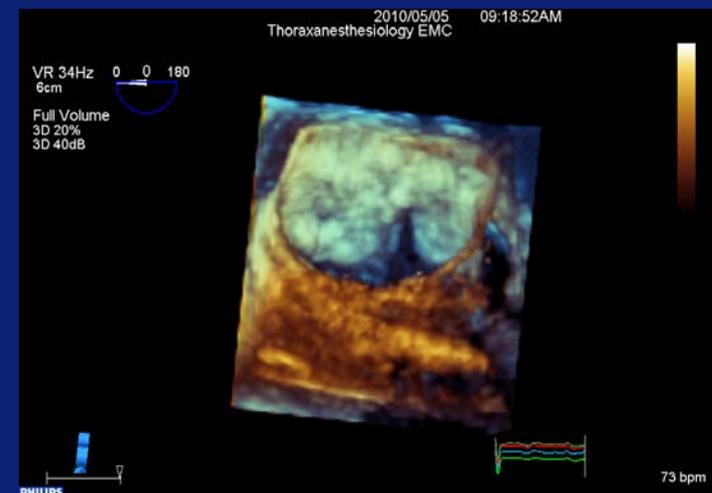
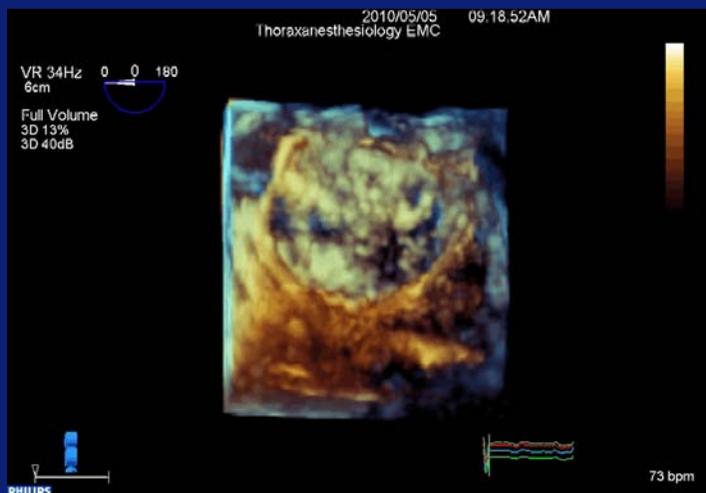
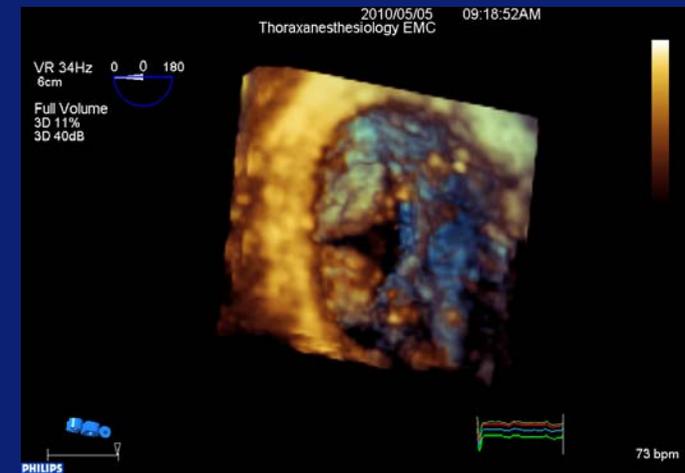


# Patient practice 5

## Mechanism

- open folder vd Knaap on QLAB
- find the mechanism yourself

# Patient practice 5 - congenital cleft



# Patient practice MS 1

Jacky will practice with you  
measurement of a normal MVA from  
a TEE (Lips) and TTE (Haan) study  
+ Osmanovo pre/post balloon)

# Patient practice MS 2

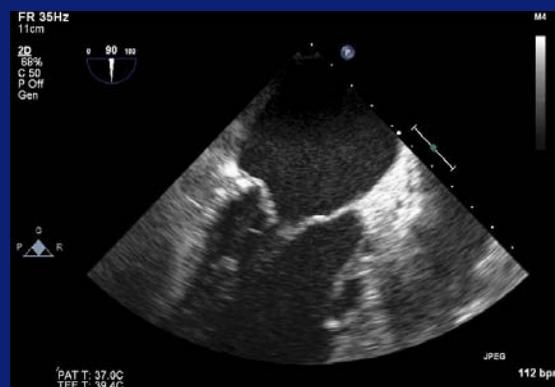
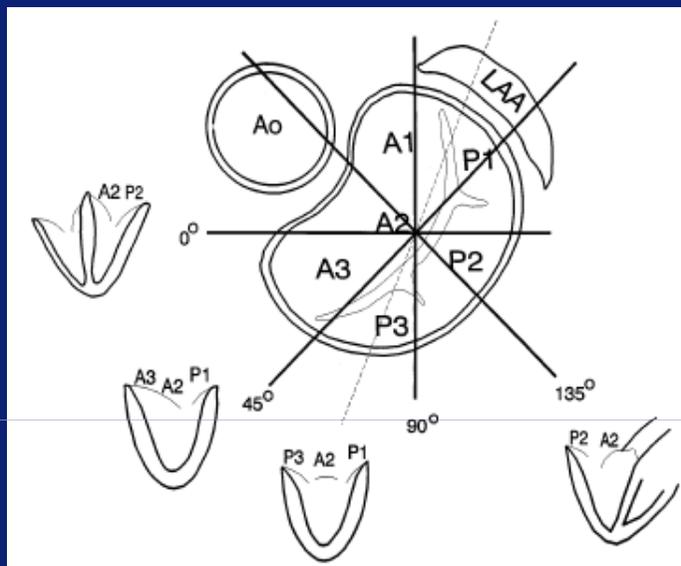
50-year-old-female  
Permanent AF  
Episodes of heart failure  
Currently NYHA 2  
Discrepant findings at TTE

# Patient practice MS2

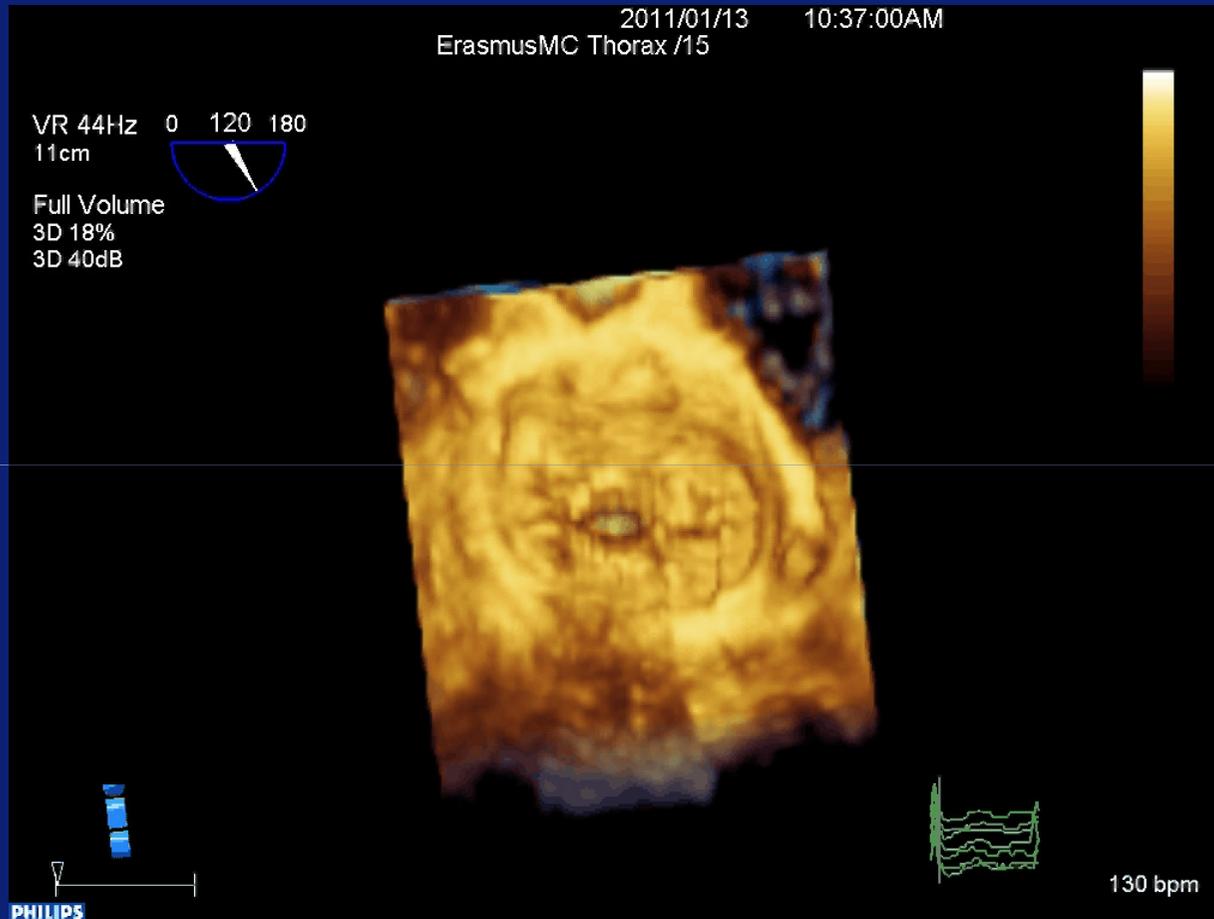
## Mechanism

- open folder Oufkir on QLAB
- measure the MVA yourself

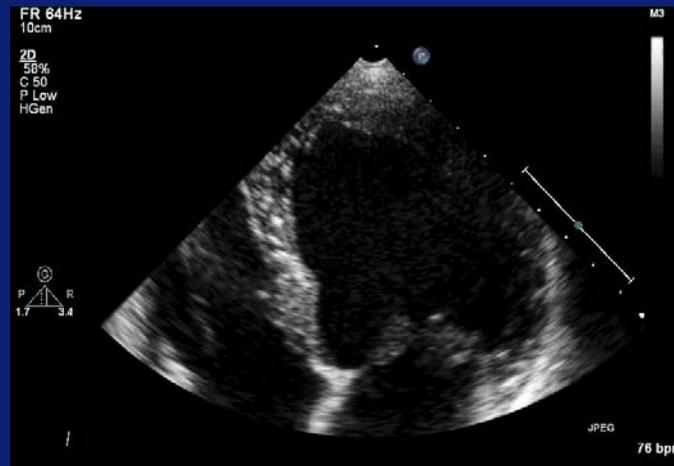
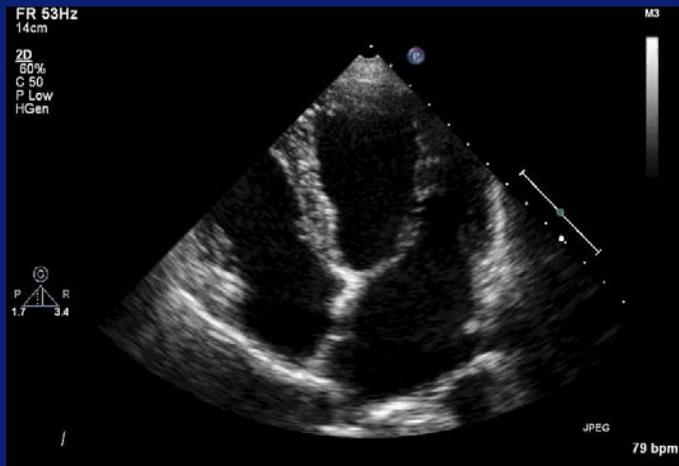
# Patient example XX: scallop P3 ?



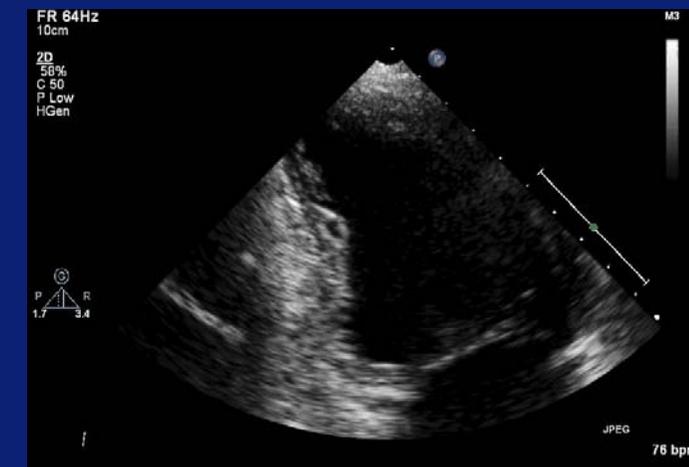
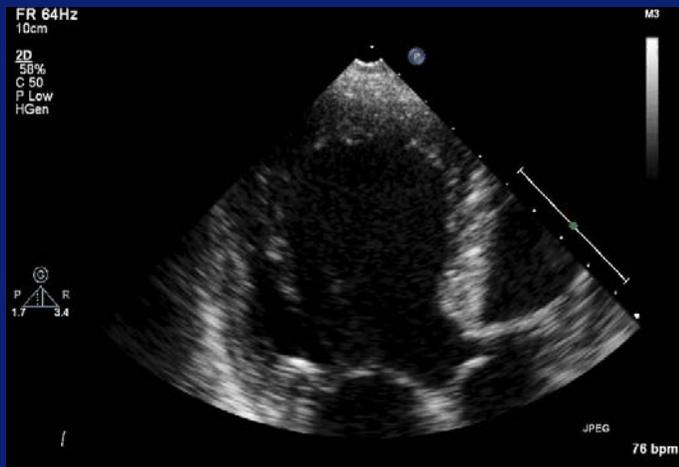
# Patient example XX: scallop P3 ?



# Patient example 3: scallop P3 ?



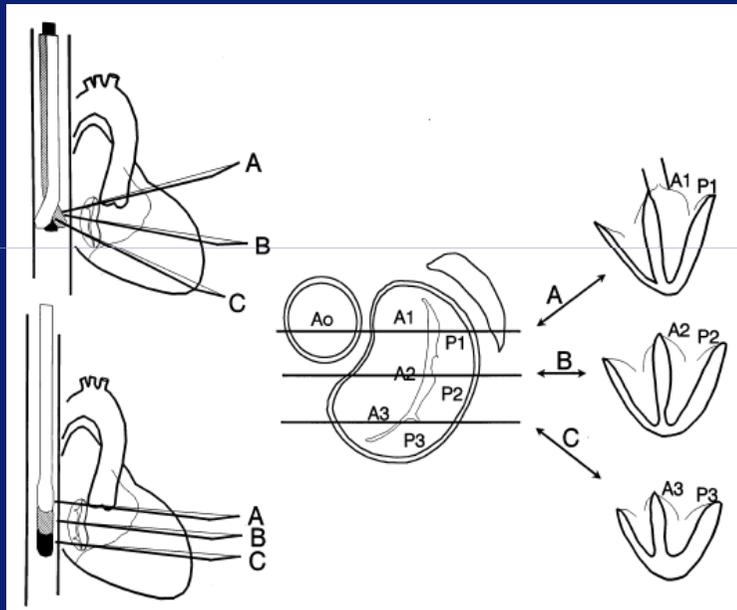
A3 - A2 - P1



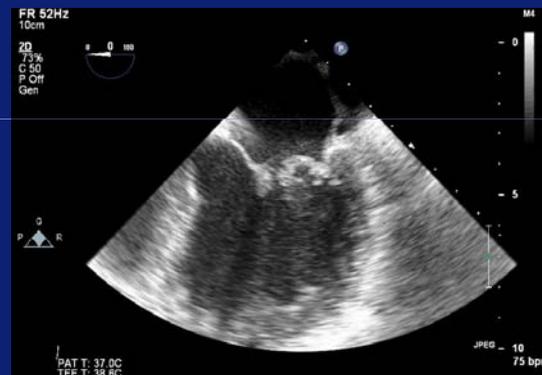
P2 - A2

P3 - A2 - P1

# Patient example 3: scallop P3 ?



A1 - P1

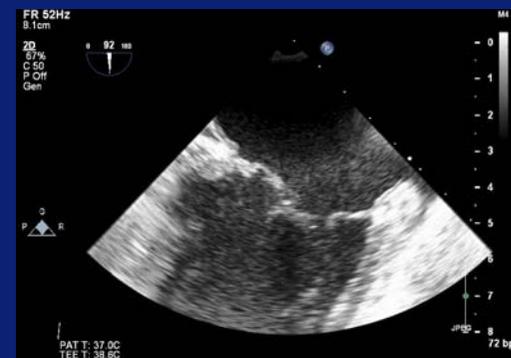
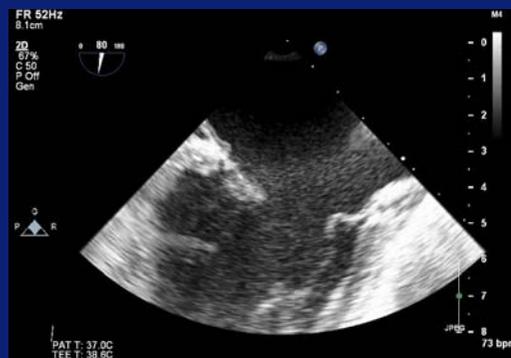
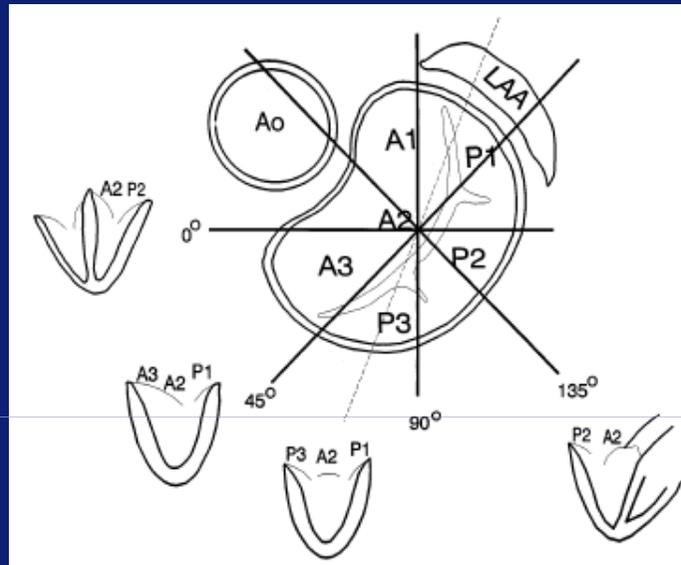


A2 - P2

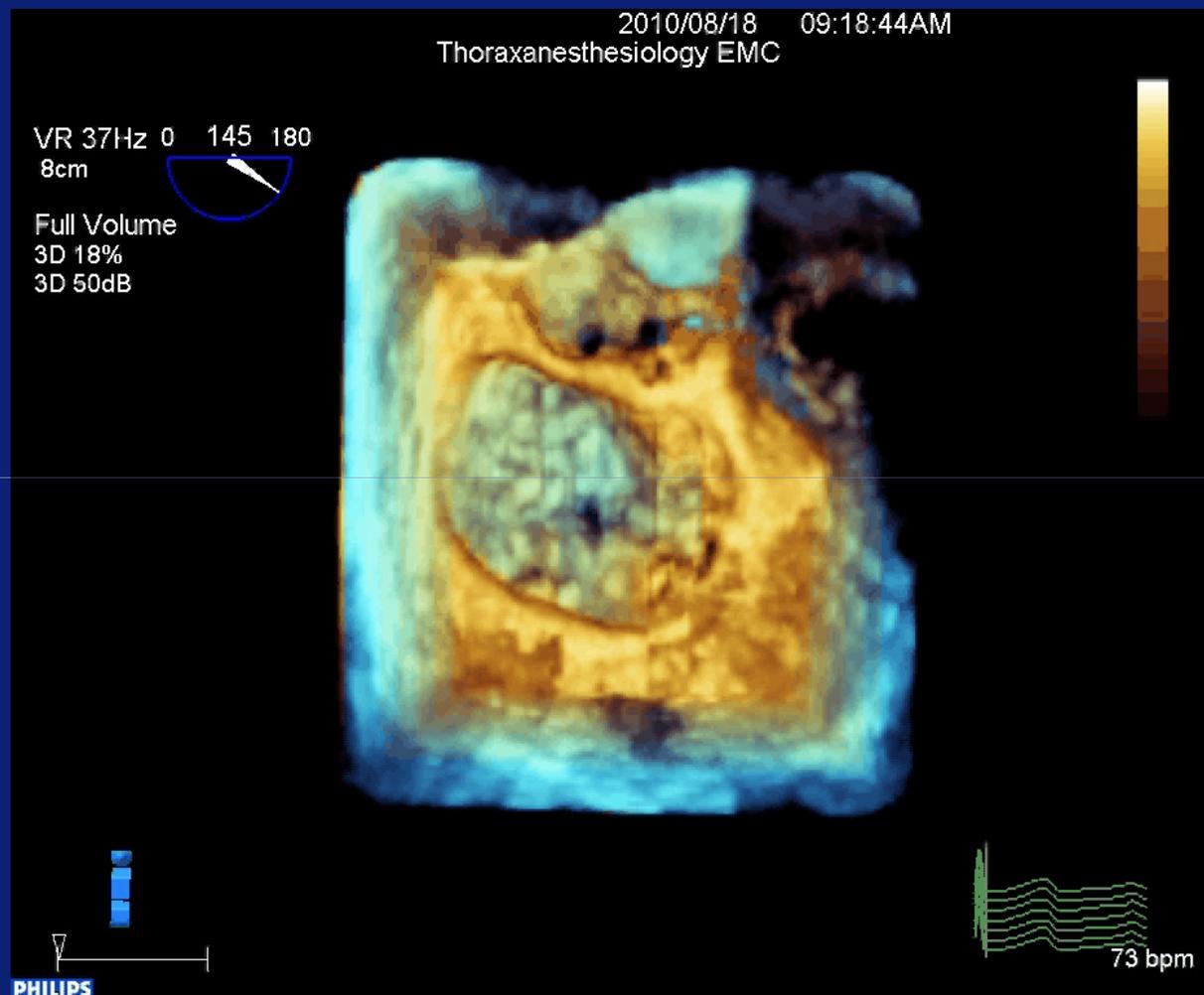


A3 - P3

# Patient example 3: scallop P3 ?



# Patient example 3: scallop P3 ?



# Scallops visualisatie vanuit 3D TEE

## Mitral Valve Anatomy Report

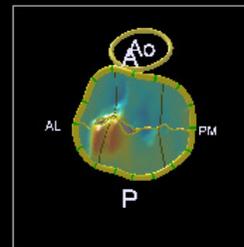
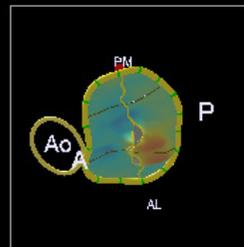
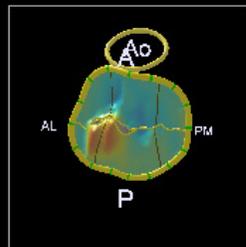
<b>Annulus</b>			<b>Leaflet Volume</b>		
DAIPm	42.8	mm	VTent	1.6	ml
DAP	36.6	mm	VProI	0.9	ml
H	8.2	mm	<b>Leaflet Len./Ang.</b>		
C3D	134.3	mm	θ Ant	17.3	°
A2D	1294.7	mm <sup>2</sup>	θ Post	28.2	°
			θ NPA	134.5	°
			HTent	4.8	mm
			HProI	7.2	mm

### Aortic-Mitral

θ 123.1 °

### Papillary

LChordAI 31.8 mm  
LChordPm 27.4 mm



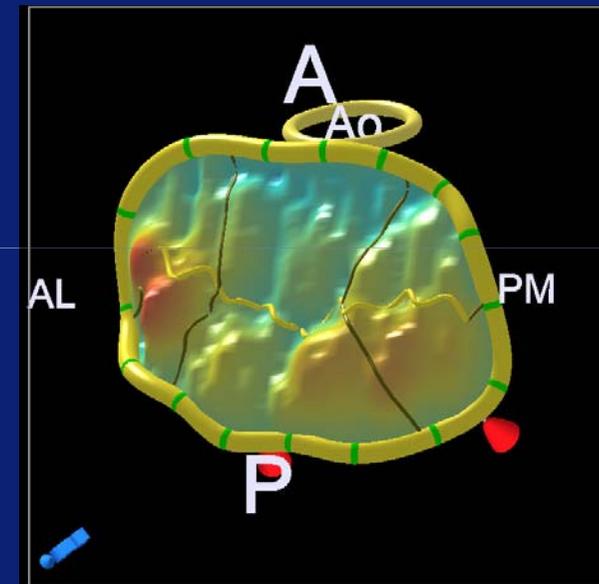
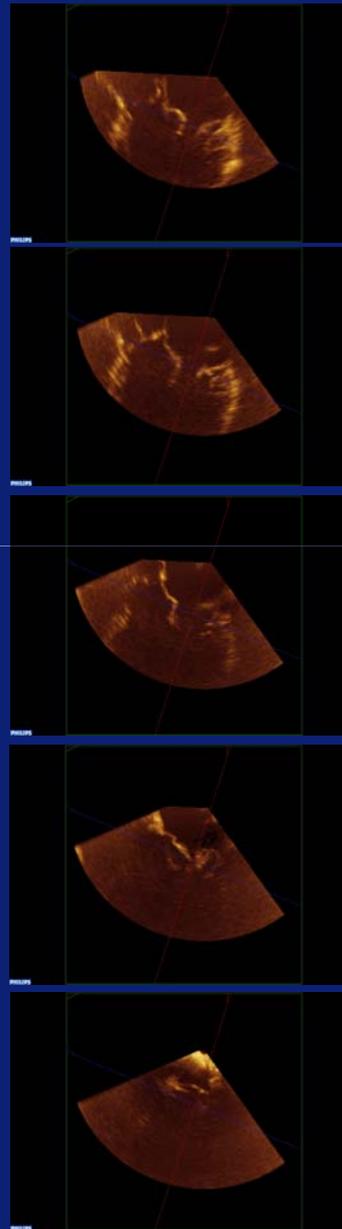
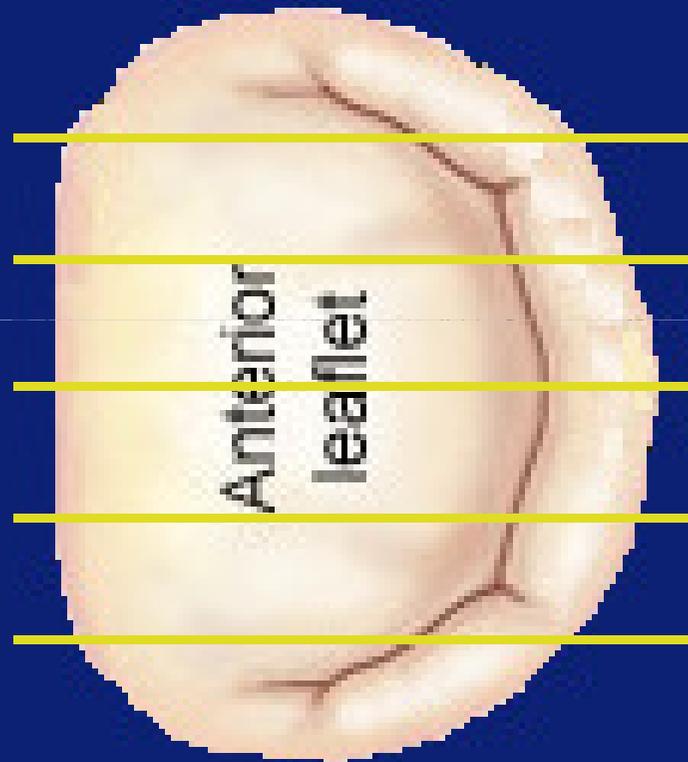
Annulus	
DAIPm = 42.8 mm	
DAP = 36.6 mm	
H = 8.2 mm	
C3D = 134.3 mm	
A2D = 1294.7 mm <sup>2</sup>	
Leaflet Area	
A3DE Ant = <del>mm<sup>2</sup></del>	
A3DE Post = <del>mm<sup>2</sup></del>	
Leaflet Volume	
VTent = 1.6 ml	
VProI = 0.9 ml	
Leaflet Len./Ang.	
L3DE A2 = <del>mm</del>	
L3DE P2 = <del>mm</del>	
θ Ant = 17.3 °	
θ Post = 28.2 °	
θ NPA = 134.5 °	
HTent = 4.8 mm	
HProI = 7.2 mm	
Coaptation	
L2DAIPm = <del>mm</del>	
Aortic-Mitral	
θ = 123.1 °	
Papillary	
LChordAI = 31.8 mm	
LChordPm = 27.4 mm	

PHILIPS

Erasmus MC



# Scallops visualisatie vanuit 3D TEE



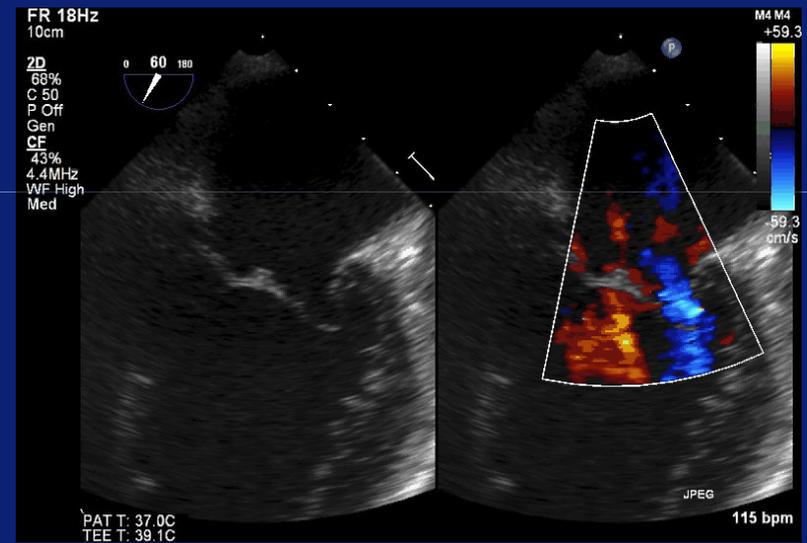
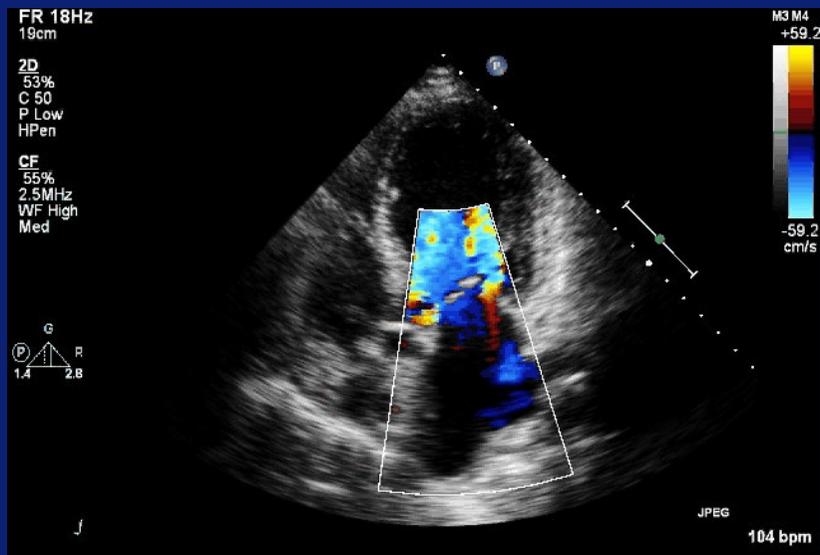
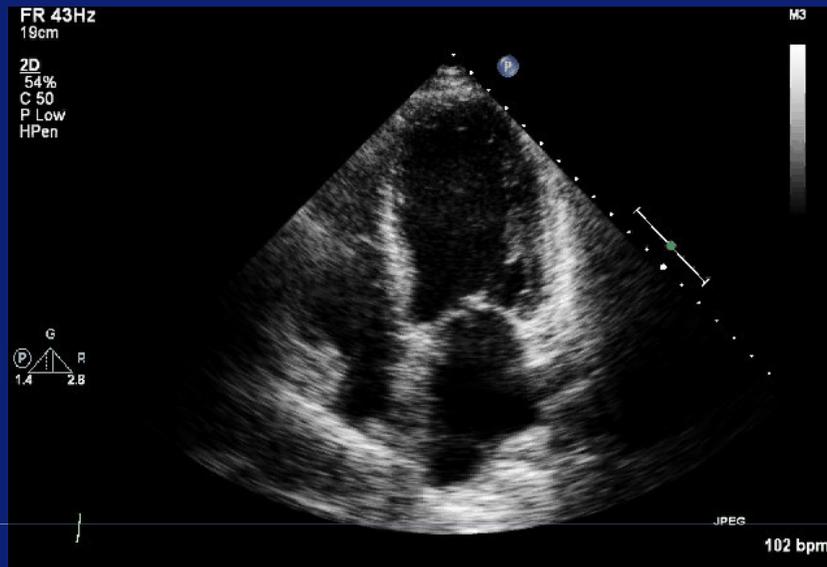
# Pathologie van de mitralisklep

- Type I Normale beweging van klepbladen**
- A Perforatie (endocarditis)
  - B Aangeboren cleft
  - C Gedilateerde annulus zonder restrictie (tethering) van de klepbladen

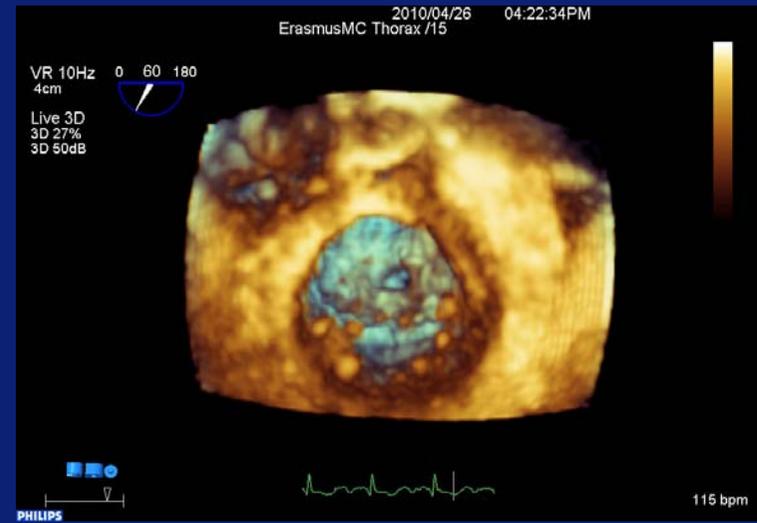
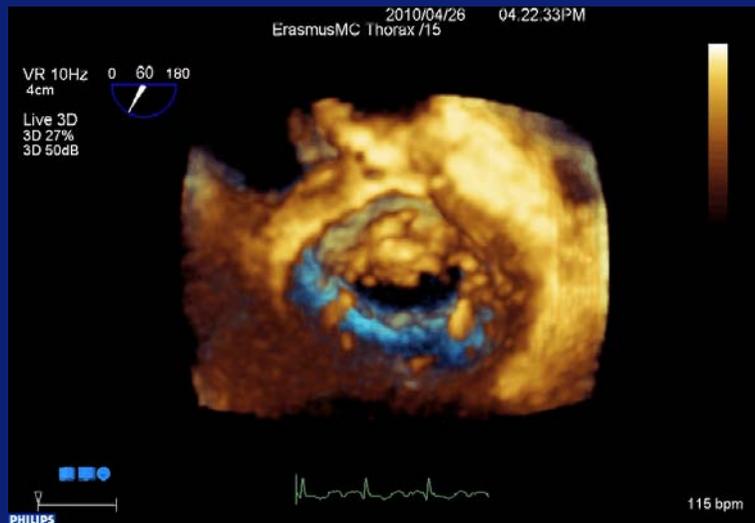
# Pathologie van de mitralisklep

- Type I Normale beweging van klepbladen
  - A Perforatie (endocarditis)

# Type IA Perforation



# Type IA Perforation

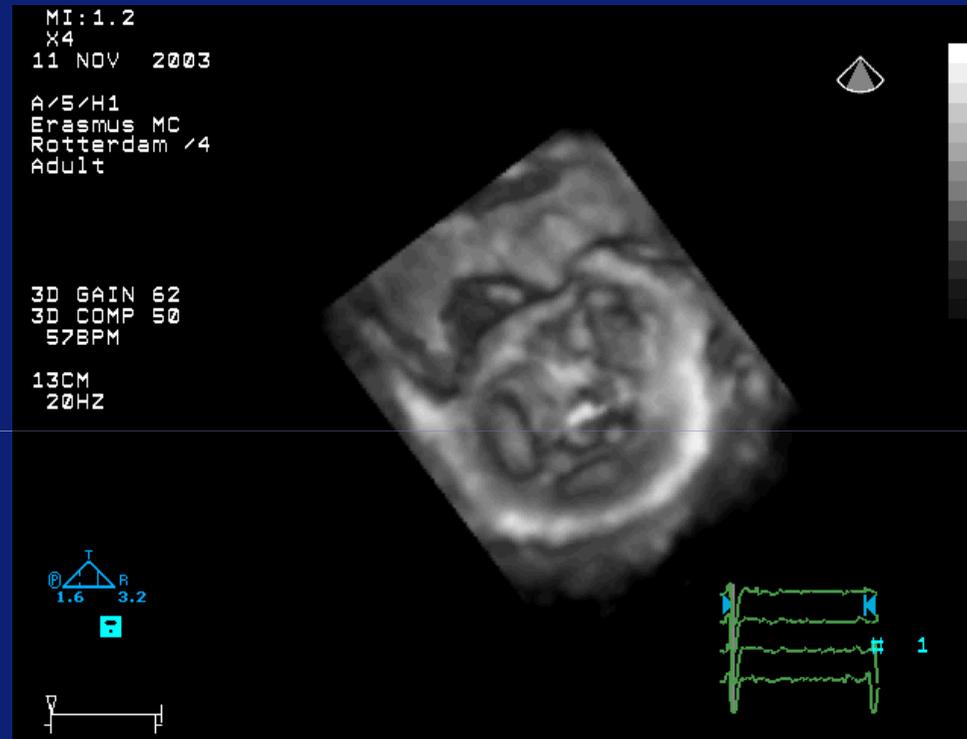


# Pathologie van de mitralisklep

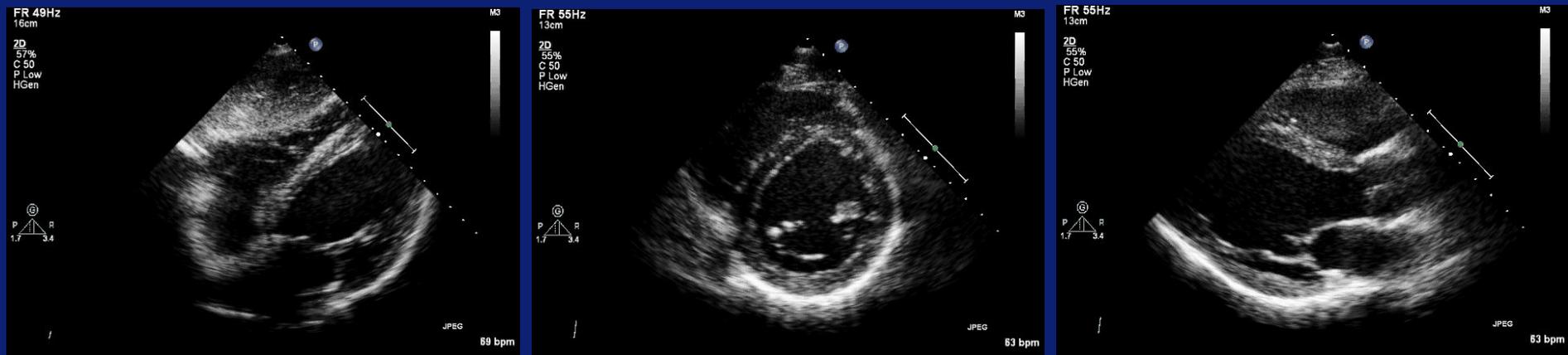
Type I Normale beweging van klepbladen

B Aangeboren cleft

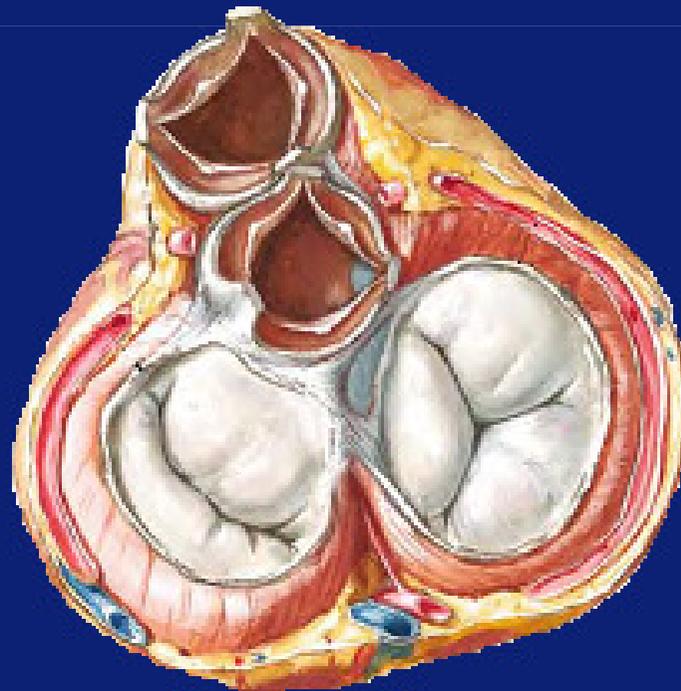
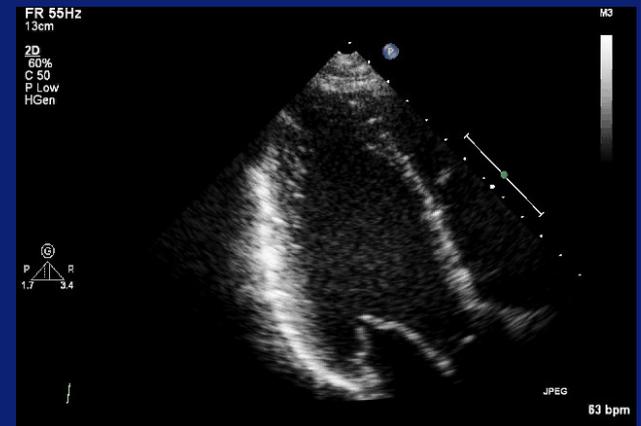
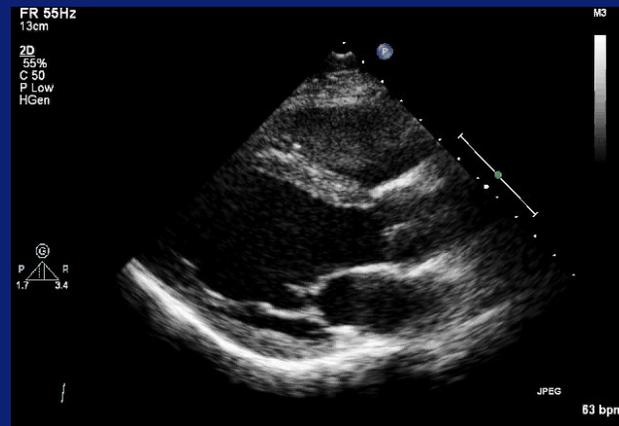
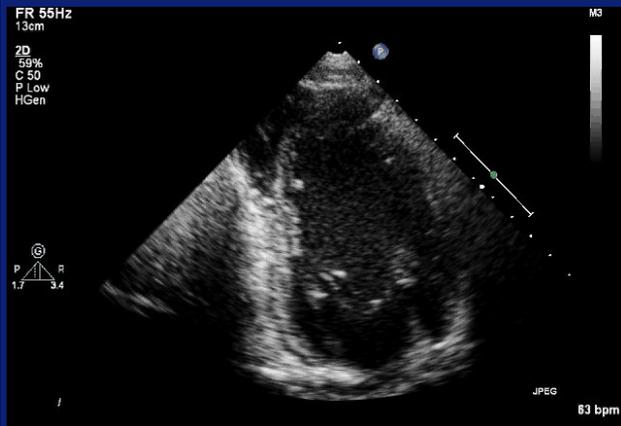
# What can 3D do better?



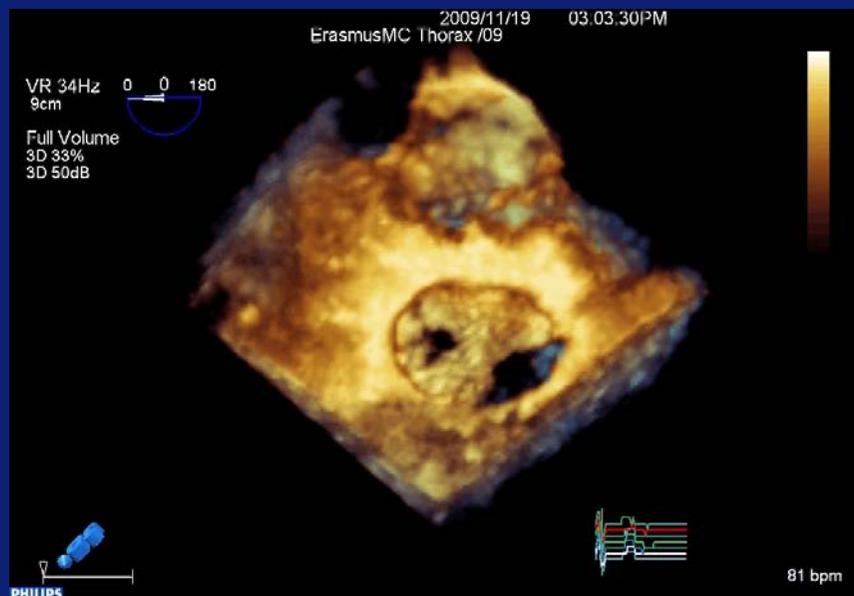
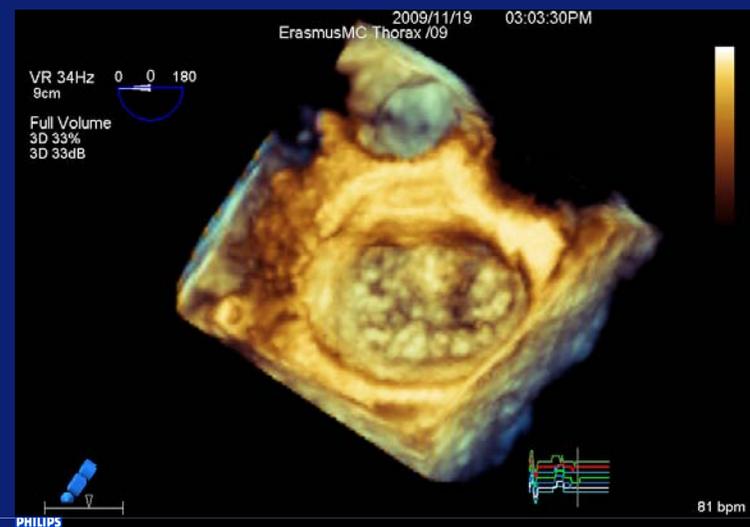
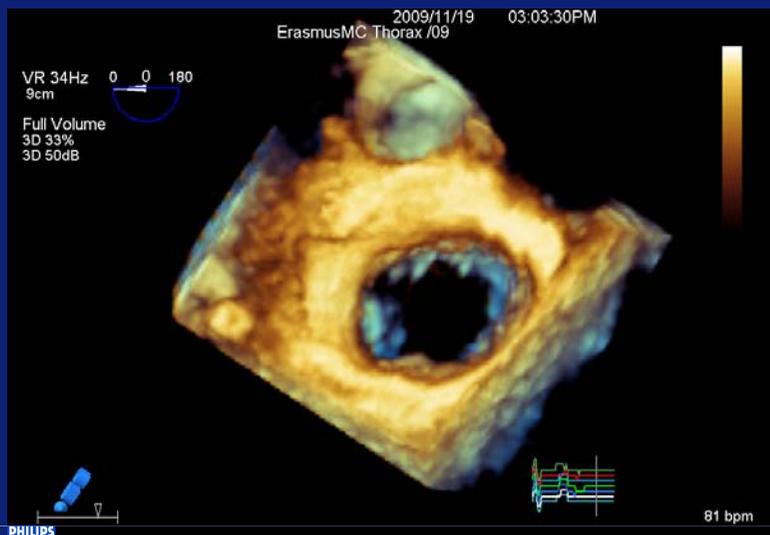
# Type IC Annulus dilatation



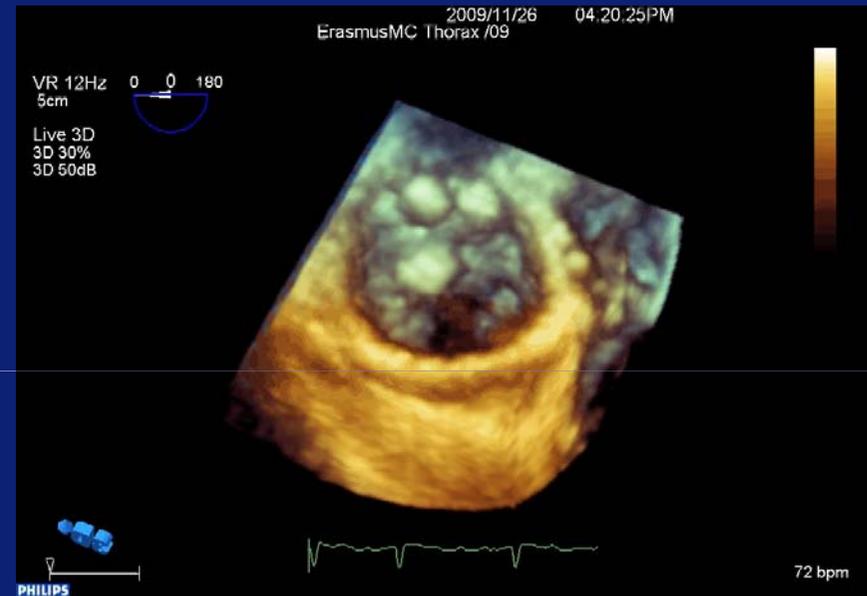
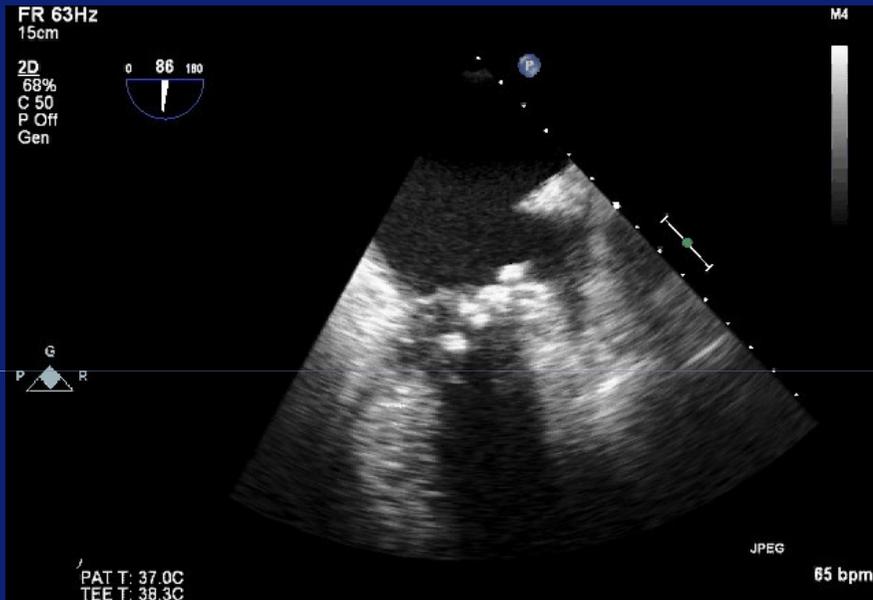
# Type IC Annulus dilatation



# Type IC Annulus dilatation



# Calcification



# Conclusions 3D TEE

- easier to understand (surgeon)
  - faster (only one recording)
  - more accurate (extent)

change or be changed

(Jack Welch, former CEO of General Electric)