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European Association of Cardiovascular Imaging

Valves: Anatomy/Pathology assessment

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Conflict of interest

I am a founder/director of MycardiumAI (for corelab work)

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Introduction

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1) The syllabus/curriculum

2) The reality check

3) Let's do some valves…….

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1) The curriculum

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6.1 Normal valve anatomy

6.2. Basic physiological and pathophysiological principals and CMR sequences

1/ CMR sequences for analyzing valve morphology, quantifying flow, chambers volumes and function (see also section 1 and 3)
2/ Normal valve flow profiles
3/ Aetiology of valve stenosis and regurgitation
4/ Flow patterns of stenosis and regurgitation
5/ Anatomic area, continuity equation and pressure gradients estimation in the assessment of stenosis severity
6/ Severity indices for valve regurgitation assessment
7/ Impact of valve diseases on heart chamber geometry, volumes, function, mass.
8/ Complementary evaluation of the great vessels
9/ Diagnostic accuracy, strengths and weaknesses in comparison with echocardiography, catheterization and computed tomography

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1) The curriculum

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6.3. Assessment of Valve Stenosis

1/ Assessment of mechanisms and aetiology
2/ Flow jet origin and orientation/direction
3/ Strengths, difficulties and limitations: Methods of quantification of stenosis severity
4/ Specific issues for aortic valve stenosis
- LVOT assessment
- Assessment of LV remodeling: volumes, function, wall thickness and mass, LGE fibrosis patterns
- Methods and clinical impact of diastolic function
- Detection/significance of associated LVOT obstruction

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1) The curriculum

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- Relation between aortic and pulmonary outflow anatomy for aortic valve implantation (TAVI)

5/ Specific issues for sub & supravalvular aortic stenosis
- Type and localization of stenosis
- LVOT morphology and size (subvalvular). Aortic root and ascending aorta morphology and size (supravalvular)
- Differentiation of valve stenosis from sub- and supra-valvular stenosis

6/ Specific issues for mitral valve stenosis
- Significance of left atrium size and RV remodeling.
- Left atrial thrombus diagnosis
- Tricuspid and pulmonary valve function

7/ Specific issues for pulmonary stenosis (see Congenital Heart Disease section)

8/ Specific issues for tricuspid valve stenosis
- Significance of right atrium size.
- Venae cavae dimensions

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1) The curriculum

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6.4. Assessment of Valve Regurgitation

1/ Assessment of the mechanisms and aetiology
2/ Regurgitant jet origin and orientation/direction
3/ Strengths, difficulties and limitations of the methods of quantification of the regurgitation severity
4/ Specific issues for mitral regurgitation
- LV geometry, function and late gadolinium enhancement in the mechanism of regurgitation
- Left atrium size, right heart chambers & valves.
- CMR findings and selection of patients for intervention or surgery

5/ Specific issues for aortic regurgitation
- LV remodeling: volumes, function, thickness and mass
- Importance of the complementary study of aorta
- CMR findings and selection of patients for surgery

6/ Specific issues for tricuspid regurgitation
- Significance of right atrium size and RV remodeling
- Venae cavae dimensions

7/ Specific issues for pulmonary regurgitation
- Assessment of RVOT, pulmonary artery, RV remodeling
- CMR findings and selection of patients for intervention

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1) The curriculum

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6.5. Prosthetic heart valves

1/ Specific morphology and signal characteristics for valve prosthetic annulus, biological and mechanical prosthetic valves

2/ Normal and abnormal SSFP flow patterns

3/ CMR and its clinical role in the evaluation of prosthetic heart valves

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Reality check, pt 1:

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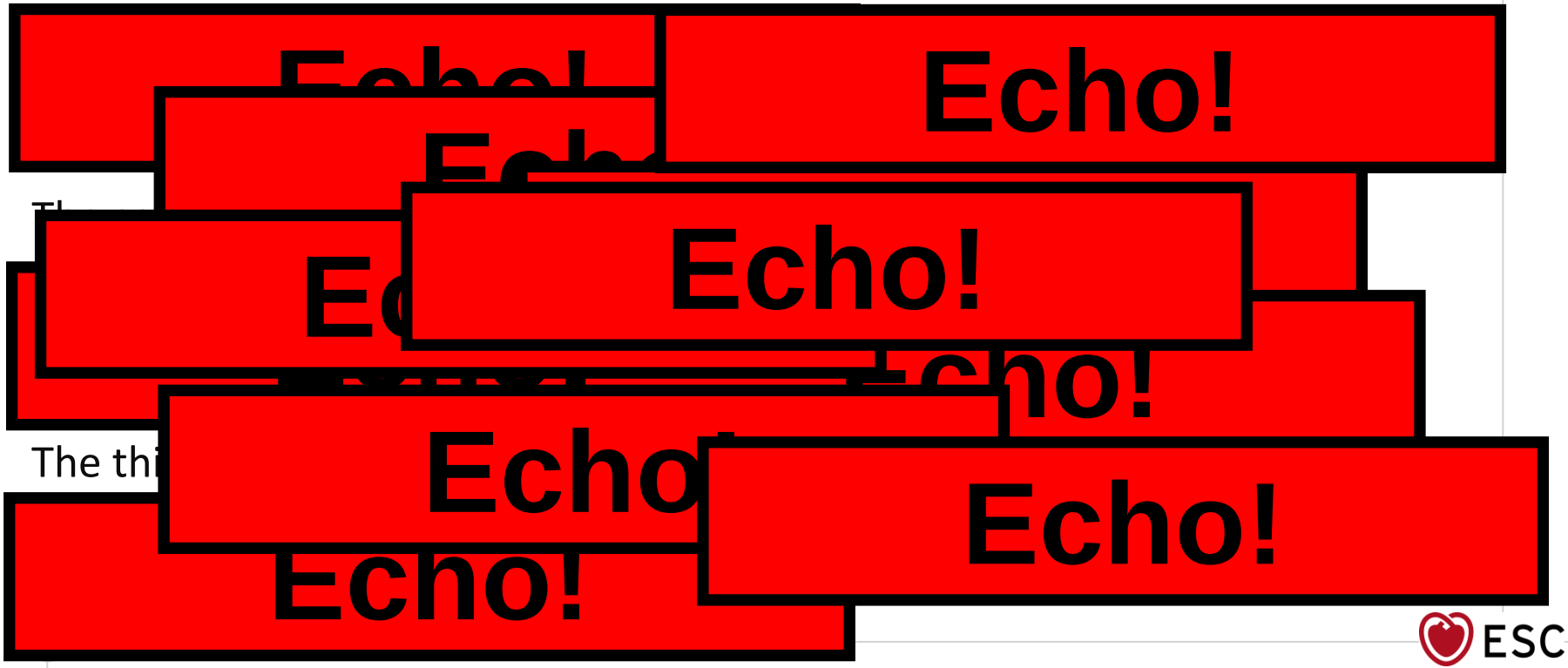
The best test for assessing valves is:



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Reality check, pt 2:

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There are only 4 valves!!!!!!!

The Aortic Valve

The Mitral Valve

The Tricuspid Valve

The Pulmonary Valve

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Reality check, pt 2:

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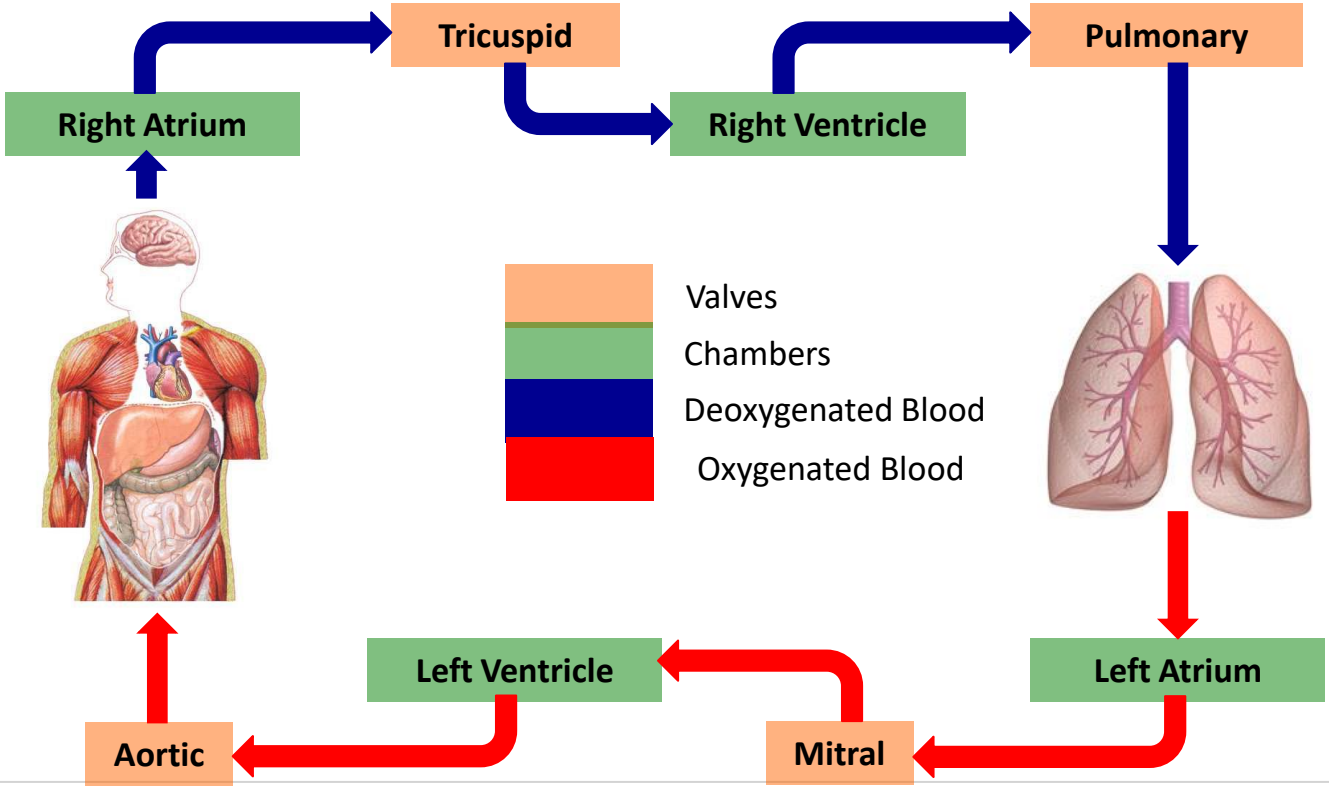

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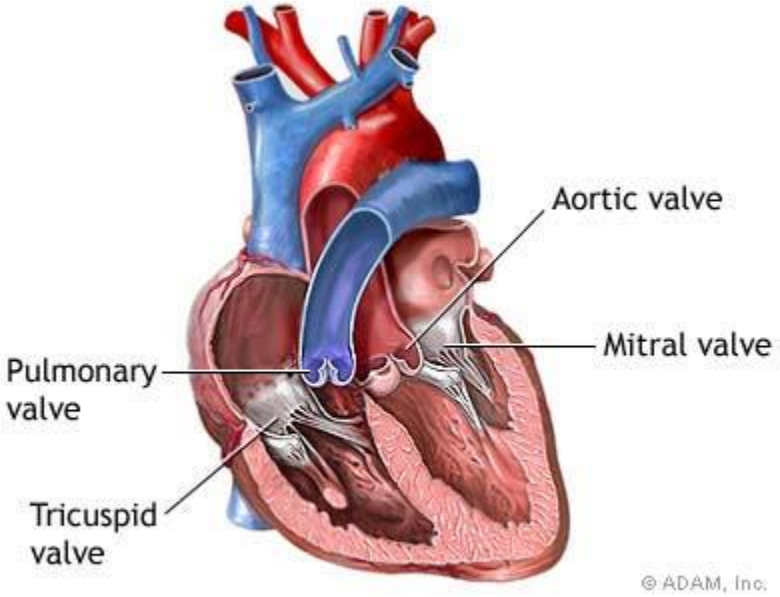

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Reality check, pt 3:

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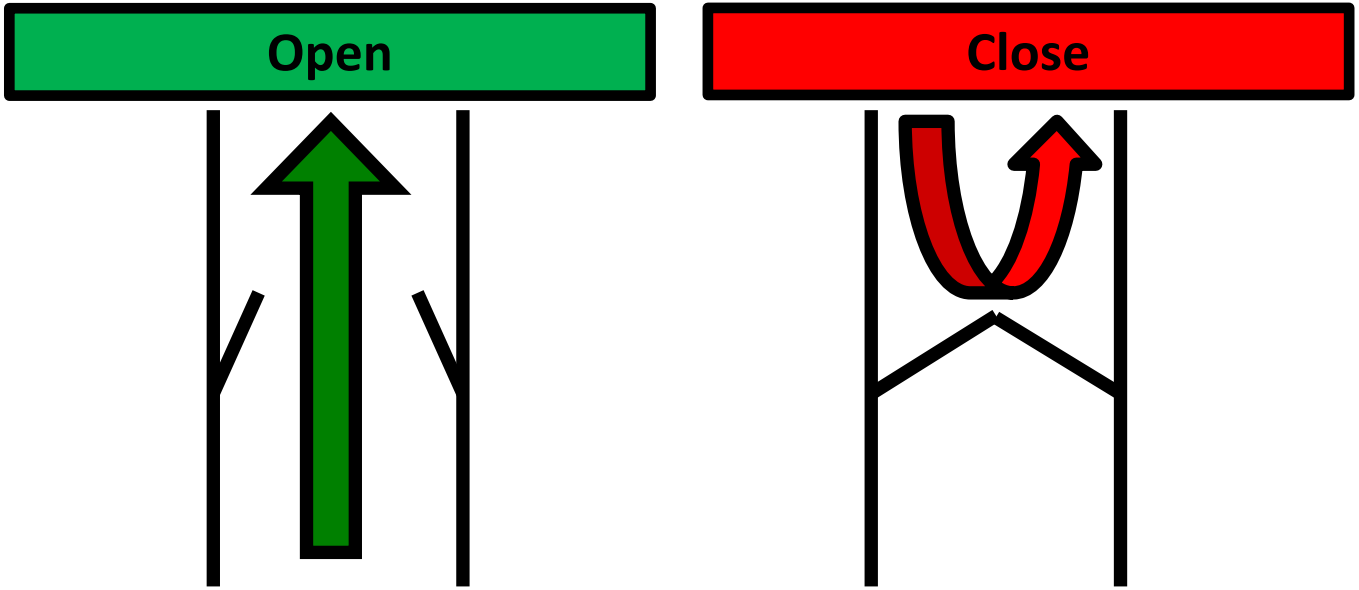
A valve can only do 2 things!!!!



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Reality check, pt 3:

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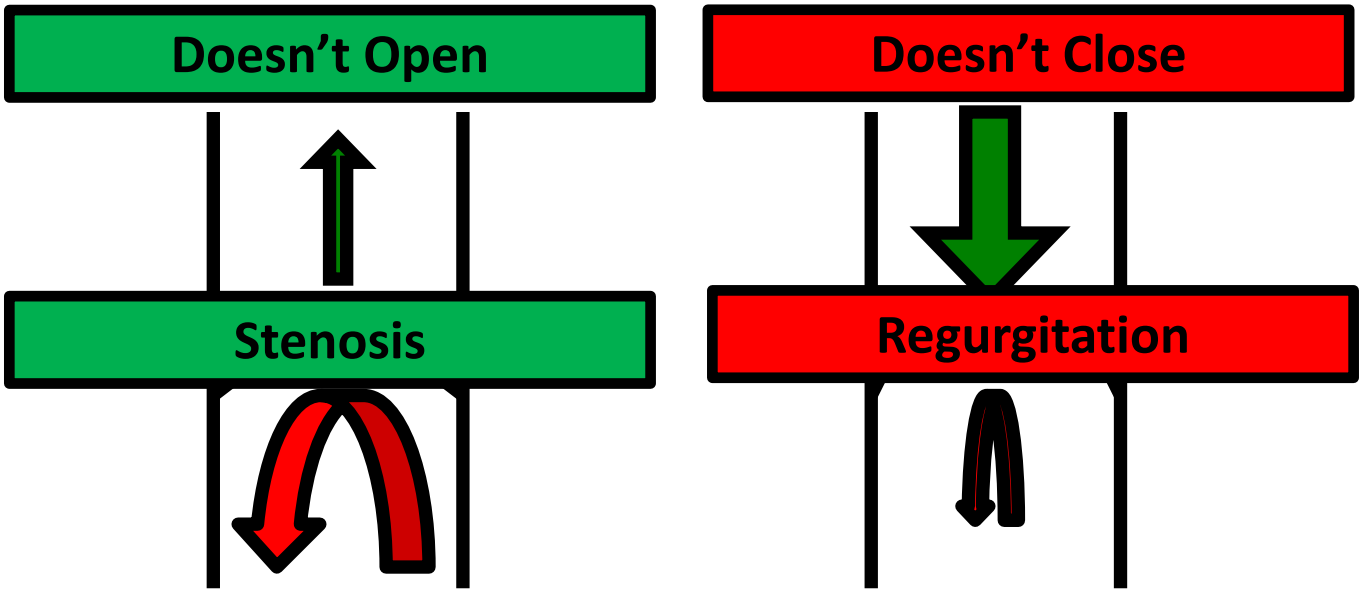
So only 2 things can go wrong!!



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Reality check, pt 4:

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There are therefore 8 conditions!!!!!!!

Aortic
Mitral Stenosis
Tricuspid Steno
Pulm

Lets make this easier!!!!

This is

Mitral
Tricuspid
Pulmo

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Reality check, pt 4:

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But it is easier than this!!!

Aortic Stenosis

Mitral Stenosis

Tricuspid Ste

Pul

A

gurgitation

Tricuspid Regurgitation

Pulmonary Regurgitation

When have you ever seen CMR of this?

Only Cause Rheumatic Valve Disease
Common in 3rd World
Rare in the UK/West

Reality check, pt 4:

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It is even easie

Aortic

~~Mitral Stenosis~~

Tricuspid Steno

Pulm

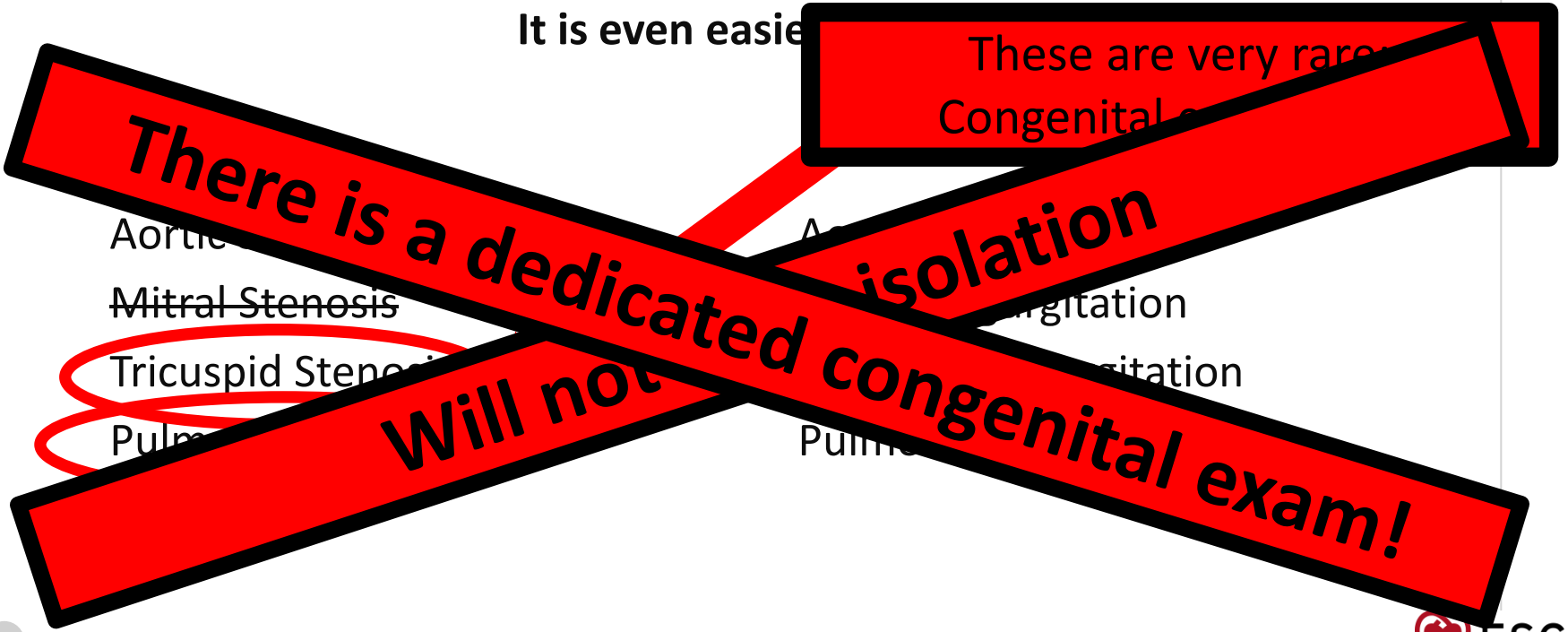
Congenital

A

gitation

itation

Pulm



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make it easier still!!!!!

Again very rare:
Congenital causes
Drug abusers

Aortic Stenosis
~~Mitral Stenosis~~
~~Tricuspid Stenosis~~
~~Pulmonary Stenosis~~

Aortic Regurgitation
Mitral Regurgitation
Tricuspid Regurgitation
Pulmonary Regurgitation

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Common:
Secondary to mitral valve disease
Drug users (endocarditis)
Congenital (Ebsteins)
Carcinoid
Pulmonary hypertension
Very difficult to treat (replacement valves challenging)

Aortic Stenosis
~~Mitral Stenosis~~
~~Tricuspid Stenosis~~
~~Pulmonary Stenosis~~

Aortic Regurgitation
Mitral Regurgitation
Tricuspid Regurgitation
~~Pulmonary Regurgitation~~

Tricuspid regurgitation:

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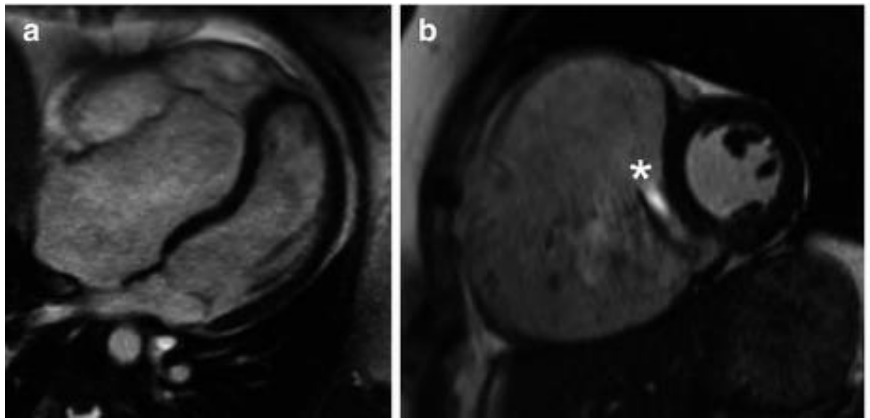
Ebsteins Anomaly:



Tobler D. et al. Cardiac CT and MR for Adult Congenital Heart Disease. Springer, New York, NY

Carcinoid:

Serotonin related:

Flushing

Diarrhoea

Abdominal Pain

Bronchospasm

Nausea/Vomiting

Restrictive cardiomyopathy

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The final 3……

Aortic Stenosis

Aortic Regurgitation

Mitral Regurgitation

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Basic principles…….

Long asymptomatic phases

Risk of infection (endocarditis)

- Untreated endocarditis – 100% mortality

Echo first line in nearly all cases

Treatment

- Replace
- Repair

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Aortic Stenosis

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Aortic Stenosis

Causes

Congenital

Bicuspid Valve

Commissural fusion

Acquired

Rheumatic

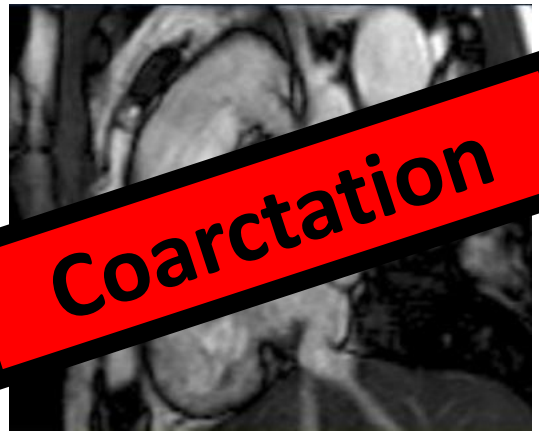
Degenerative Calcific

Bicuspid Valve

This is the commonest cause

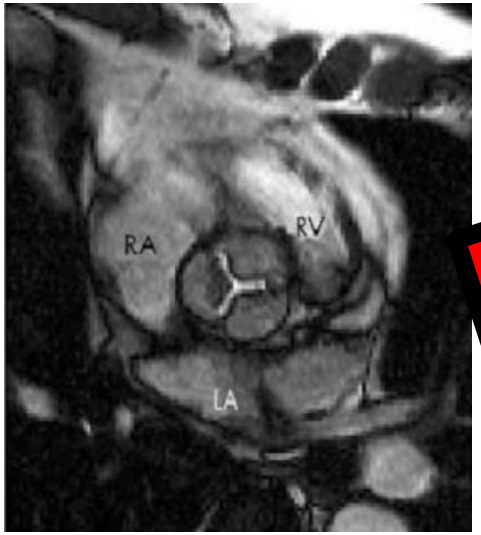
Aortic Stenosis

Bicuspid

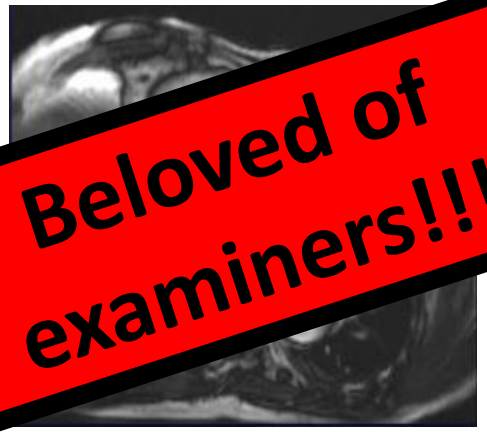


Coarctation

Degenerative



Quadricuspid



Beloved of examiners!!!

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Aortic Stenosis

Symptoms

Asymptomatic

Angina

Syncope

Cardiac Failure

Death

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Aortic Stenosis

Severity

Mean gradient across valve

- >40mmHg is the key

Aortic valve area

- Planimetry
  - Valve area <1.0cm^2

Also asses left ventricular function

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Flow mapping

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Reality check, pt 5:

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There are 2 ways to assess valves:

1) Differential stroke volumes
    - Single valve lesion only
    - Regurgitation only
2) Flow mapping
    - Multiple lesions
    - Stenosis and regurgitation

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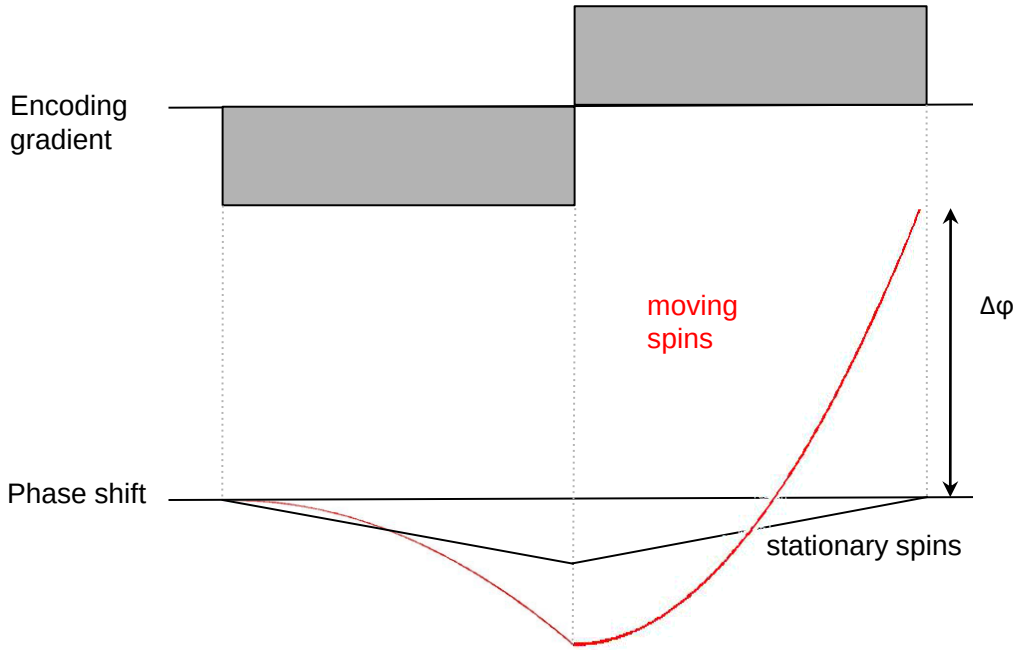
Flow mapping:

On-phase spins
Spin magnetisation vectors are in the same position
(zero angle between vectors)

Off-phase spins
Spin magnetisation vectors have different positions
(non zero angle between vectors)

Courtesy, Redha Boubertakh

Flow mapping: Phase shift Effects



Courtesy, Redha Boubertakh

Flow mapping: Phase shift Effects

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When using bipolar gradient, stationary tissue (spins) acquire no net phase shift ($\Delta\varphi = 0$)

Moving spins (blood) acquire a non zero phase shift:

$\Delta\varphi \propto$ (velocity of spins)

Phase contrast imaging there is a known relationship between

v (velocity)

$\Delta\varphi$ phase angle

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Flow mapping: Pulse sequences

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Quantitative velocity mapping

Fast gradient echo (GRE) / spoiled gradient echo

2D velocity encoding

Slice select direction

Through plane flow

Can do in plane flow with gradients applied to appropriate axis

Can also do full 3D velocity encoding/4D flow

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Flow mapping: Pulse sequences

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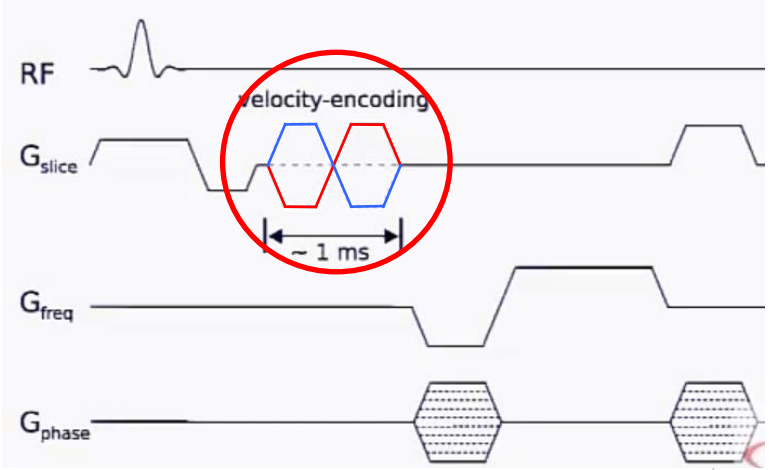
Biploar gradients added to normal imaging sequence

Repeat experiment twice

- Reversed gradients
- Subtract signals from each other
- Now will visualise **only moving spins**



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Flow mapping: Pulse sequences

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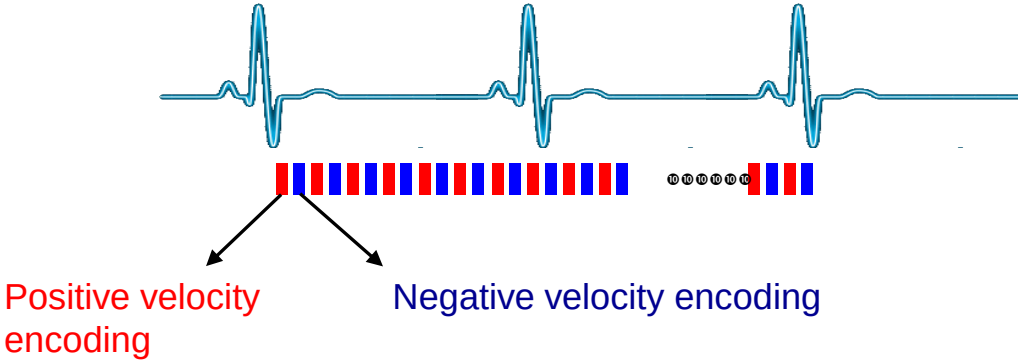
Prospective or retrospective gating

Whole cardiac cycle

Retrospective

Positive and negative velocity encoding

Interleaved (see below)



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Flow mapping: Pulse sequences

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Relationship between velocity and phase

Set/adjusted by ‘VENC’

VENC

Maximum blood flow that will be correctly encoded by the sequence

Gradient amplitude/duration

scanner calculates from selected VENC

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Flow mapping: Velocity encoded images

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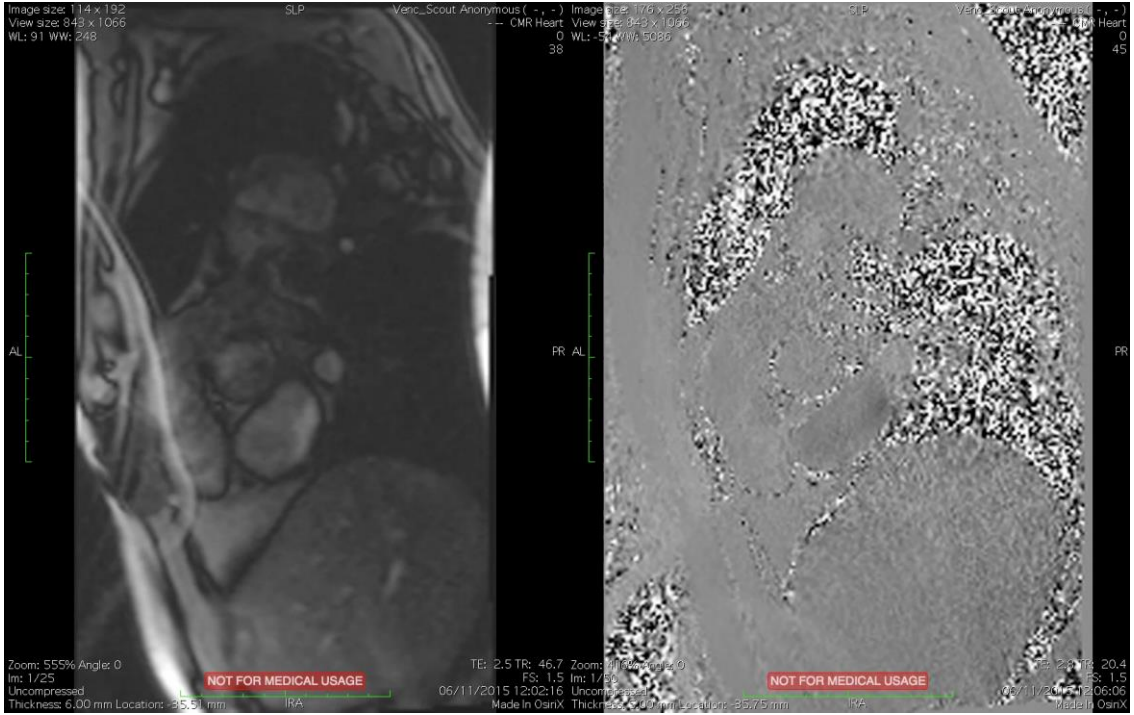

Magnitude image

Velocity image (flow)

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Flow mapping: Velocity encoded images

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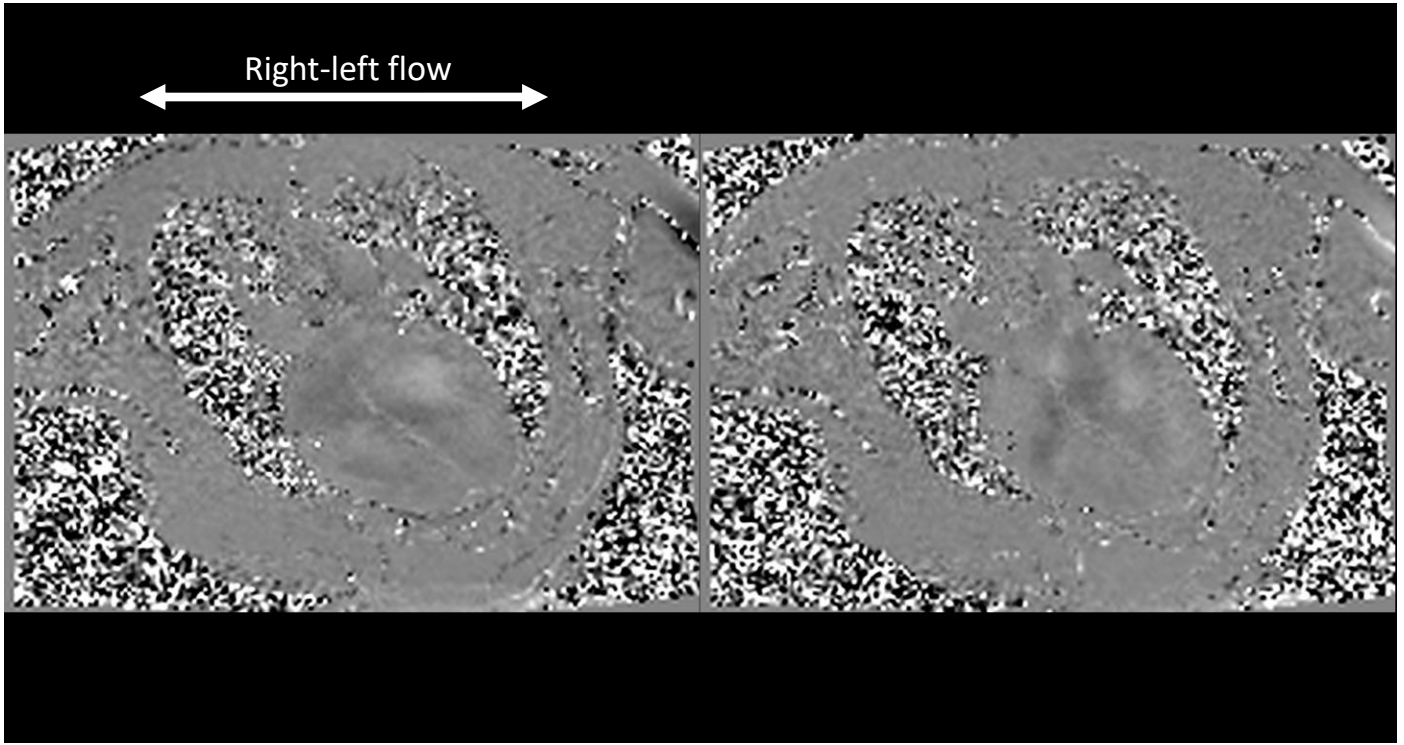

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Flow mapping: Velocity encoded images

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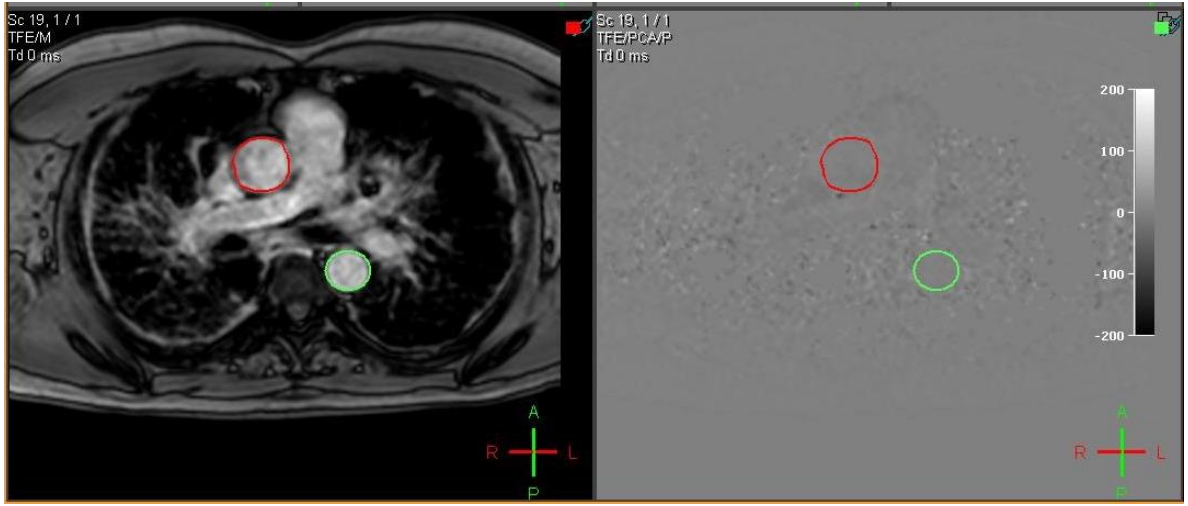
Phase images are used to measure velocity/flow



Magnitude image Velocity image (flow)

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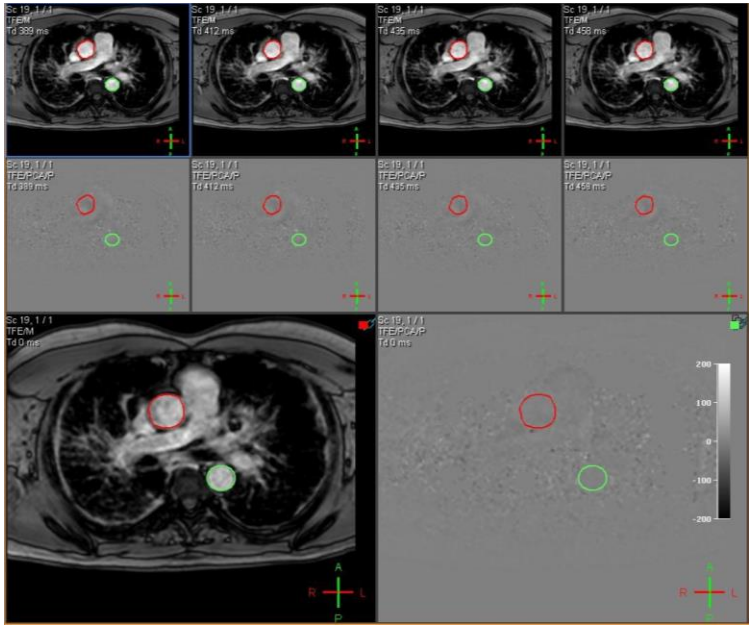
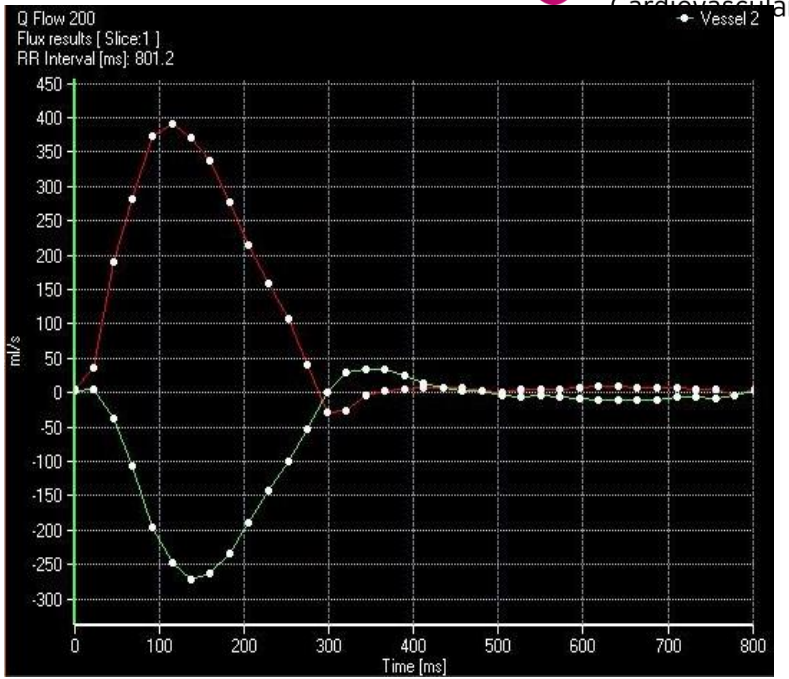
Flow mapping: Flow quantification



Contour propagation
through all cardiac phases



Derived flow quantification time plots

Courtesy, Redha Boubertakh

Flow mapping: Aliasing

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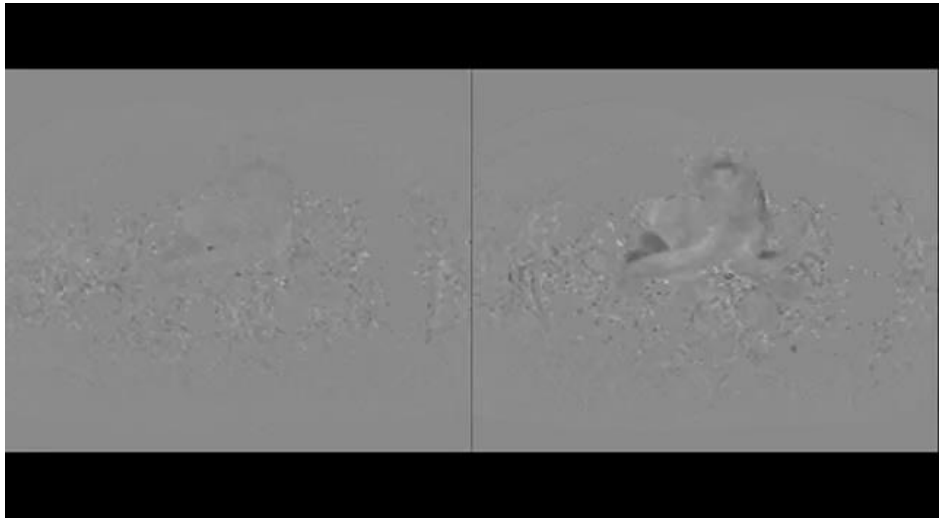
✓



✗

Venc = 200 cm/s Venc = 50 cm/s

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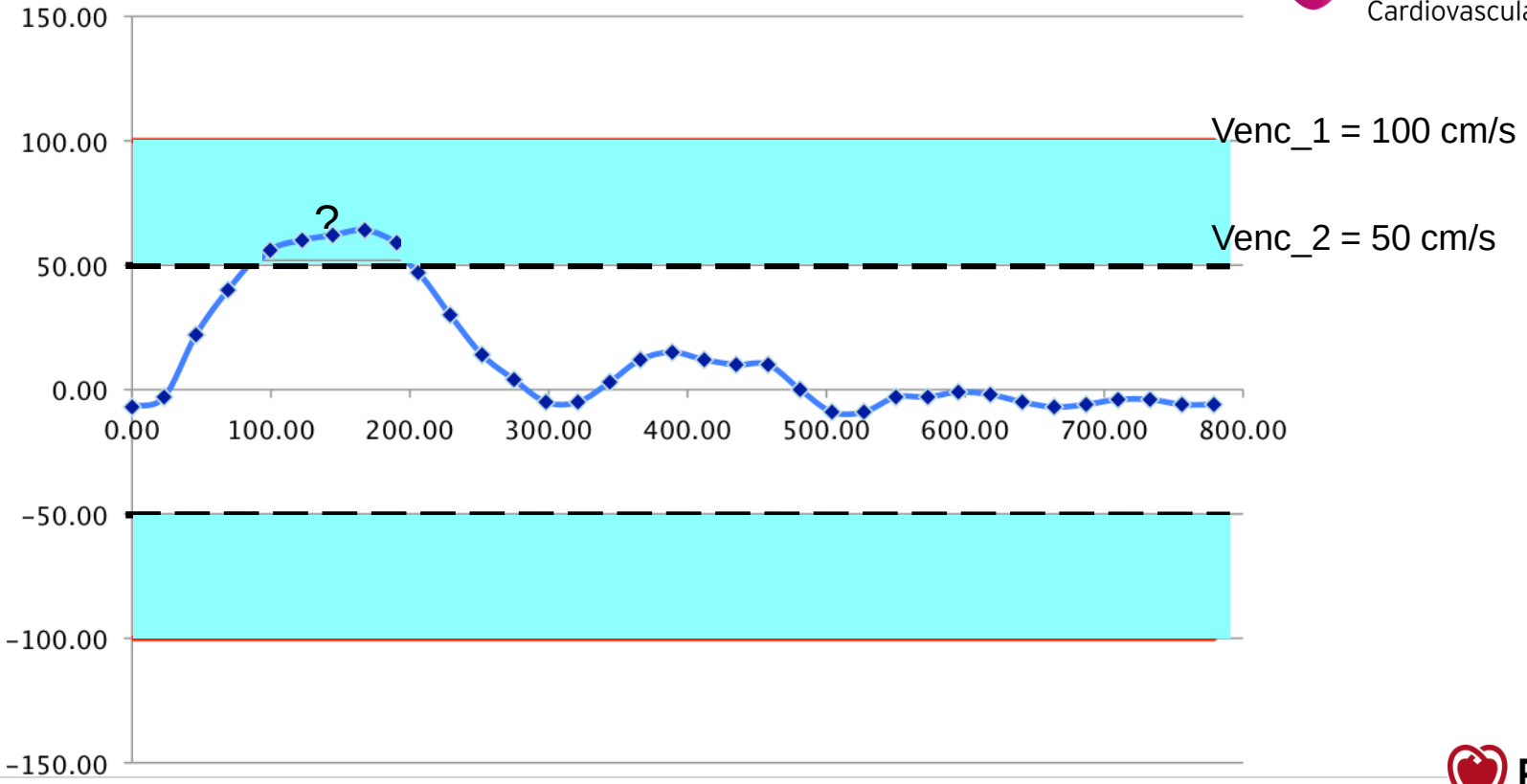
Flow mapping: Aliasing



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Flow mapping: Aliasing

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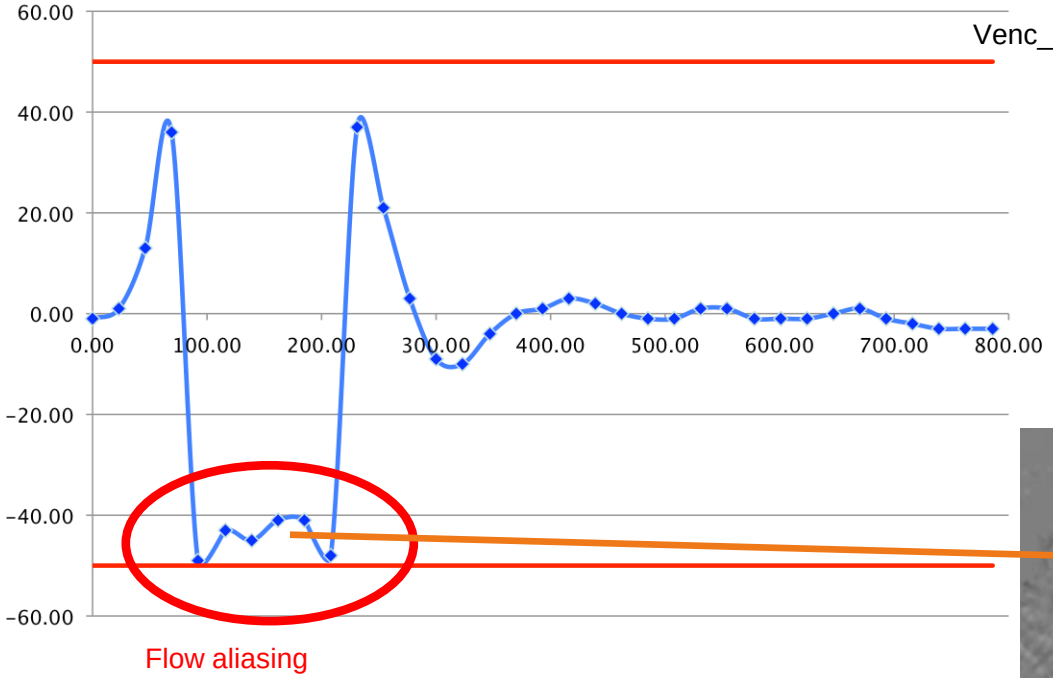

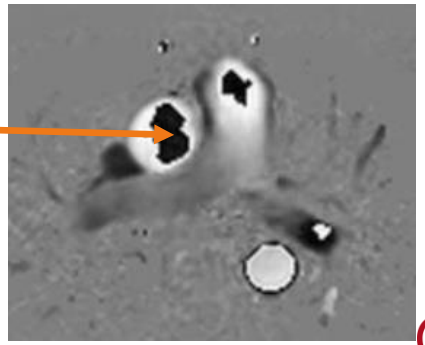

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Flow mapping: VENC Scout

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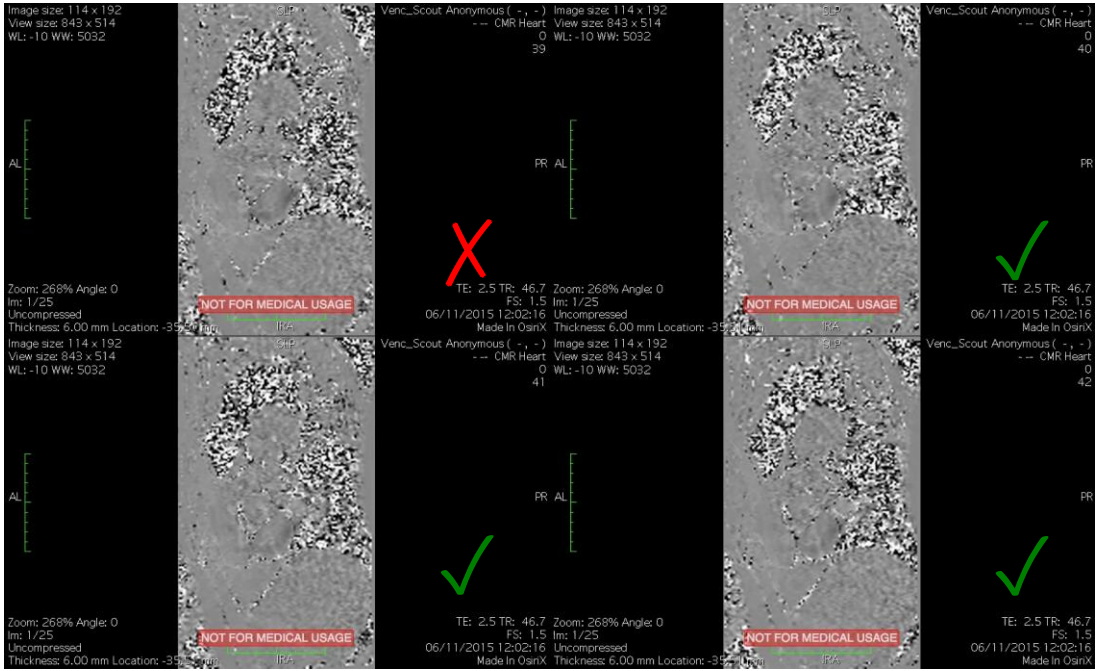
130 cm/s

150 cm/s



180 cm/s

200 cm/s

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Flow mapping: Planning

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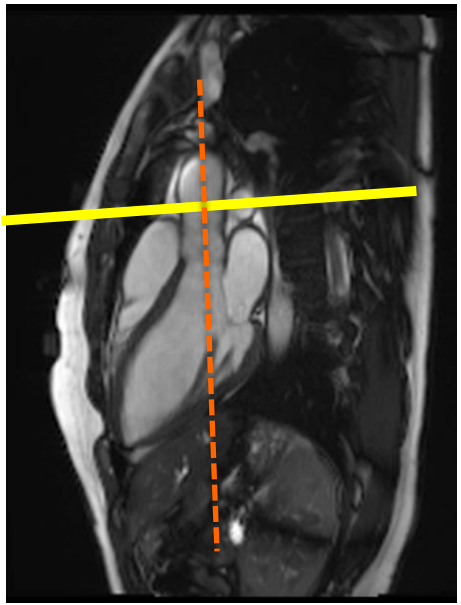
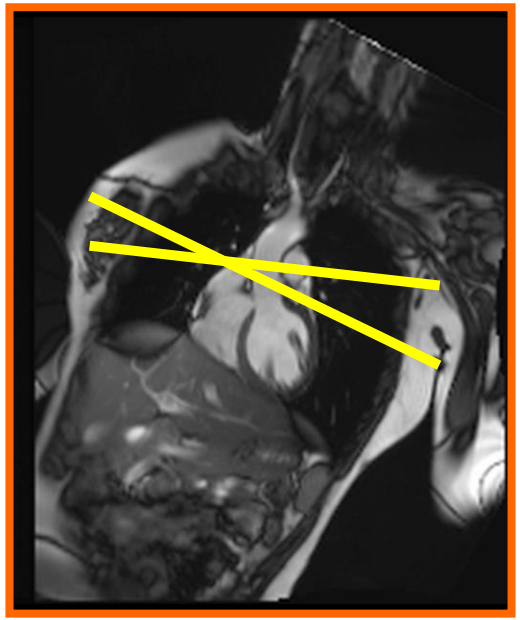


3-chamber view

Shape of Aorta



LVOT view

Courtesy, Redha Boubertakh

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Flow mapping: Accuracy

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Spatial resolution

- Must have sufficient pixels in area of interest
- 16 voxels for 10% accuracy
- **Remember it's the acquired not reconstructed voxel size!!**

Temporal resolution

- At least 60-70ms for pulsatile flow (everything!)

Higher resolution

- Free breathing with multiple signal averages

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Flow mapping: Crib sheet

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Through plane

Perpendicular

Gradient echo

Bipolar

Peak gradient slightly < VENC

Frame rate 50-70ms per frame

Free breathing with multiple signal averages

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Aortic Stenosis

Severity

Flow mapping

Peak gradient

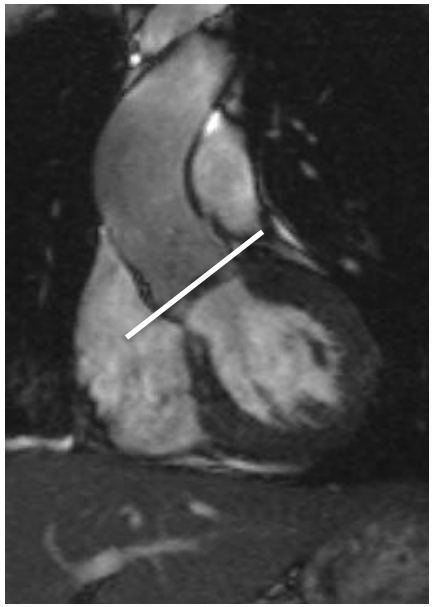
$$mmHg = 4 * v^2$$

VENC to avoid aliasing

Always underestimates cf Doppler

Aortic Stenosis

Severity



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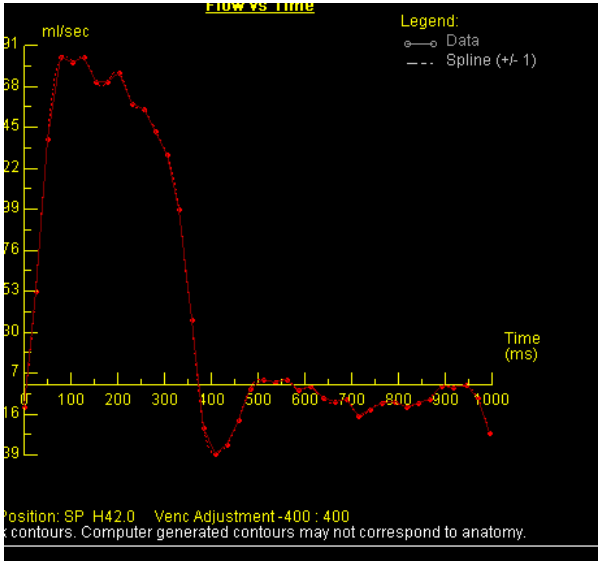
Aortic Stenosis

Severity



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Aortic Regurgitation

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Aortic Regurgitation
Causes

Acute

Rheumatic

Infective endocarditis

Ruptured Sinus Valsa

Trauma

Previous

Aor ion

Ch

Rh

ortitis

Marfans

Osteogenesis Imperfecta

Bicuspid valve

Hypertension

Infective Endocarditis

Rheumatoid Arthritis

There is no one single cause

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Aortic Regurgitation
Symptoms

Acute	Chronic
Weakness	Short of Breath
Short of Breath	Exercise
Hypotension	**All very non specific!**
Angina	Tiredness
	Palpitations

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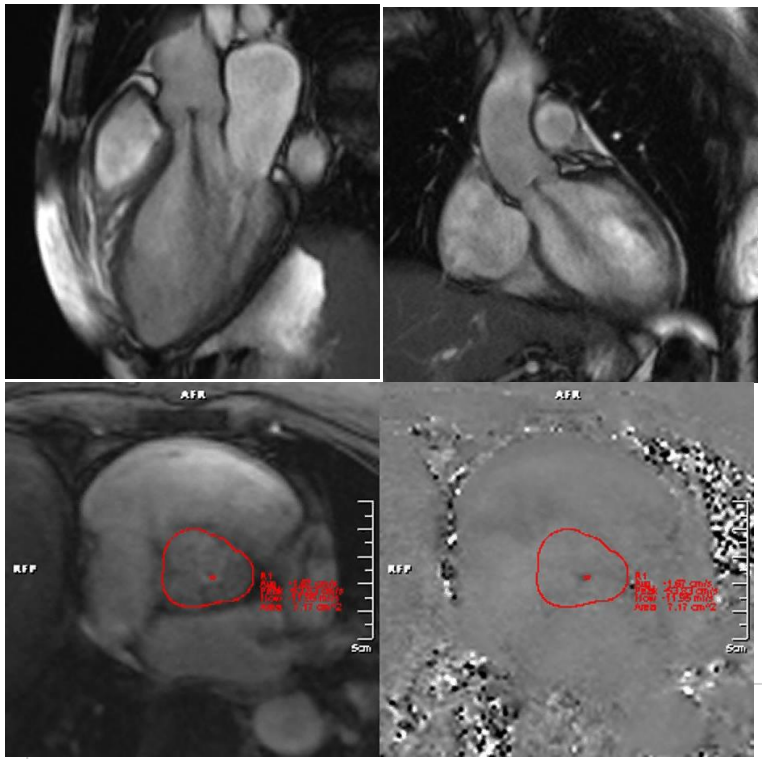
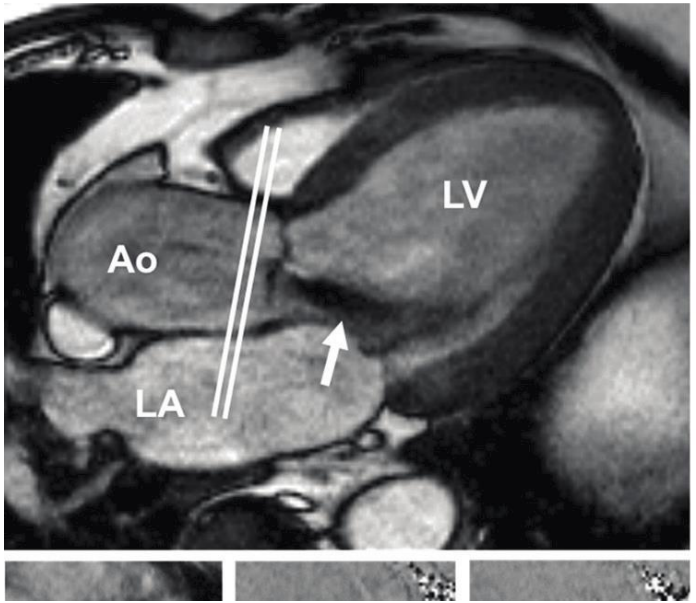
Aortic Regurgitation Severity





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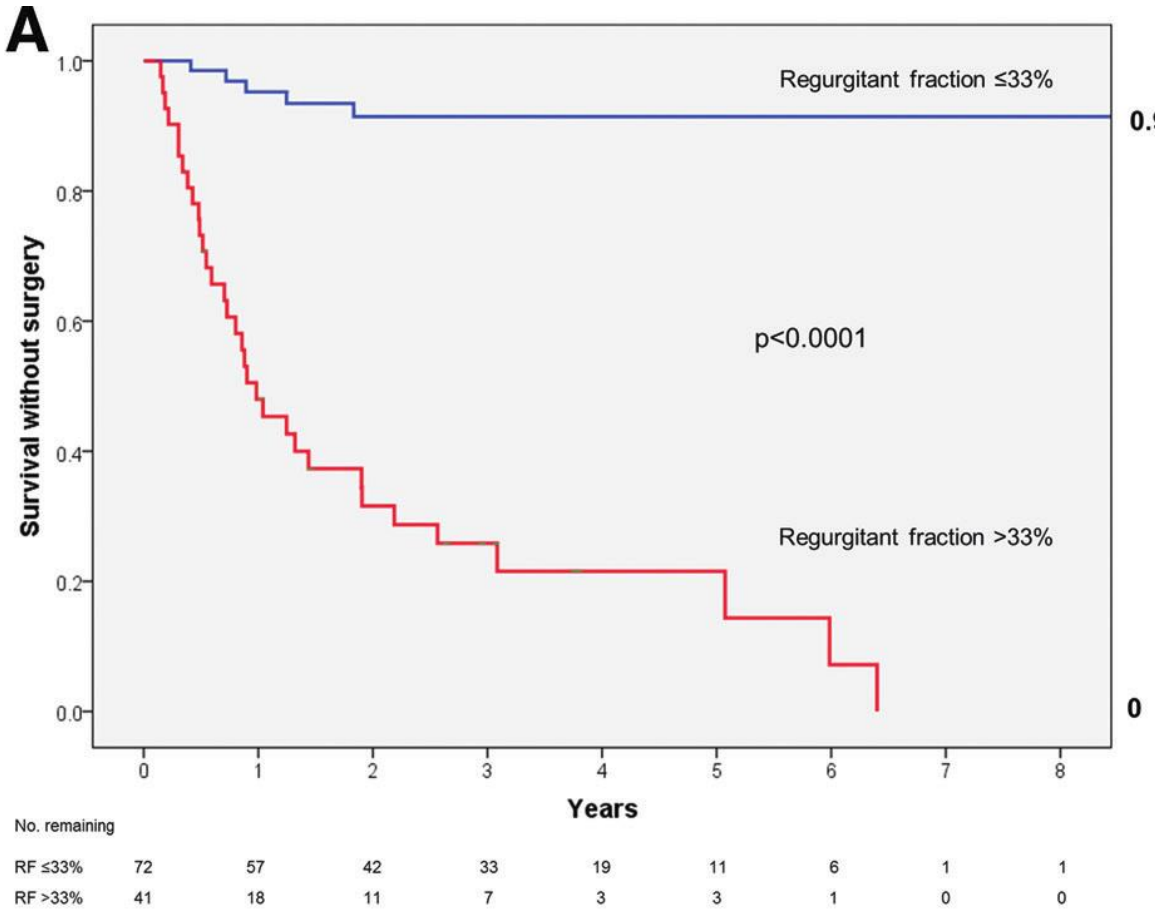

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Myerson et al, Circulation 2012

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Mitral Regurgitation

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Mitral Regurgitation
Causes

Leaflets

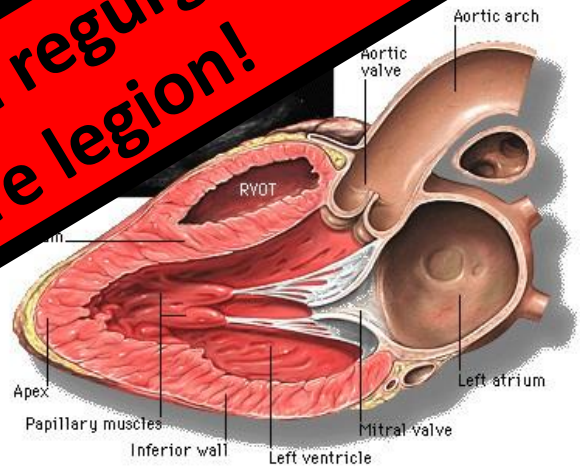
Chordae tendinae

Papillary muscle

Mitral valv

LV

The causes of mitral regurgitation are therefore legion!



Mitral Regurgitation
Symptoms

Weakness

Short of Breath

All very non specific!

AF

Oedema

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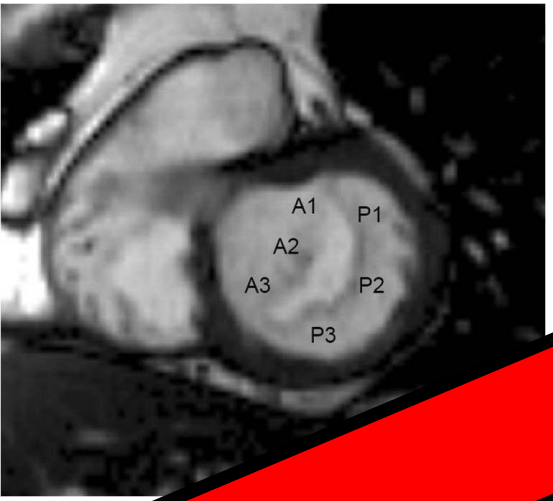
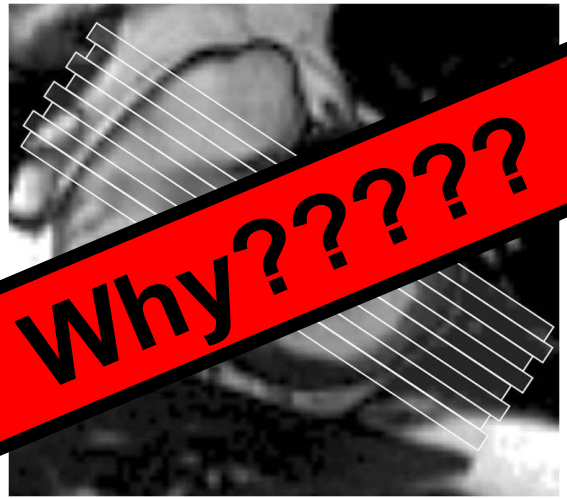
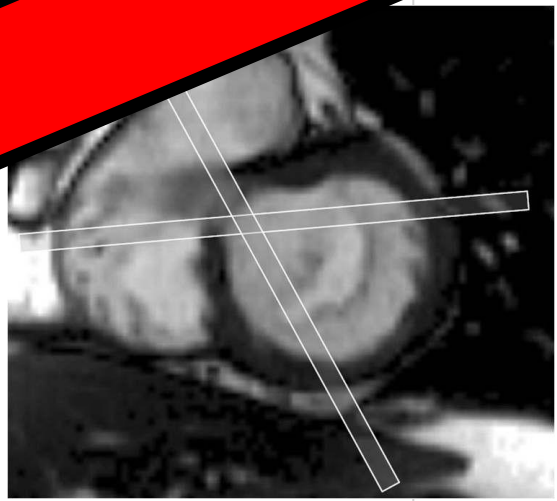
Mitral Regurgitation Severity







Why?????

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And Finally……

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Prosthetic Valves

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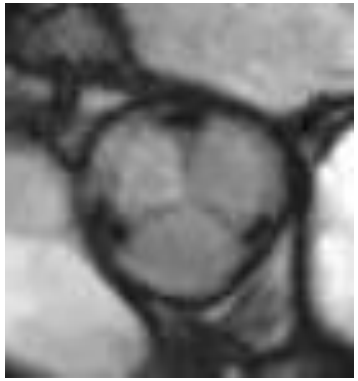
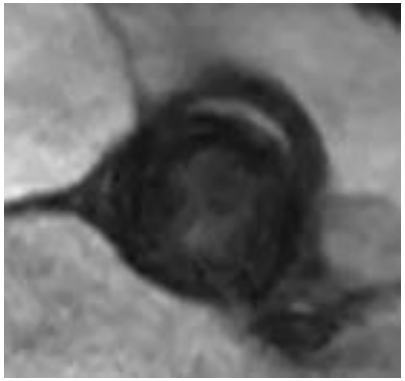
Prosthetic Valves

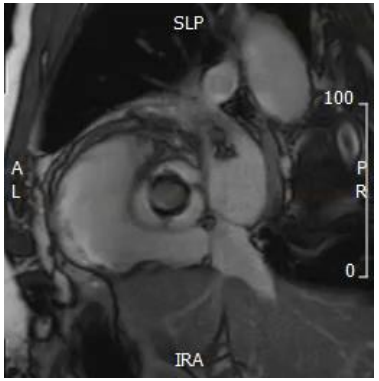
Can assess – more qualitative cf quantitative

All safe at 1.5T and 3.0T

Bioprosthetic easier to assess







Valves: Final Crib

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Echo best test

Can assess peak velocity but always underestimates

Regurgitant fraction and >33% for severe AR

Always look for other things to give diagnosis

Alaising

Mitral valve

A1-3

P1-3

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Conclusion

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1) The syllabus/curriculum

2) The reality check

3) We've done some valves…….

ESC