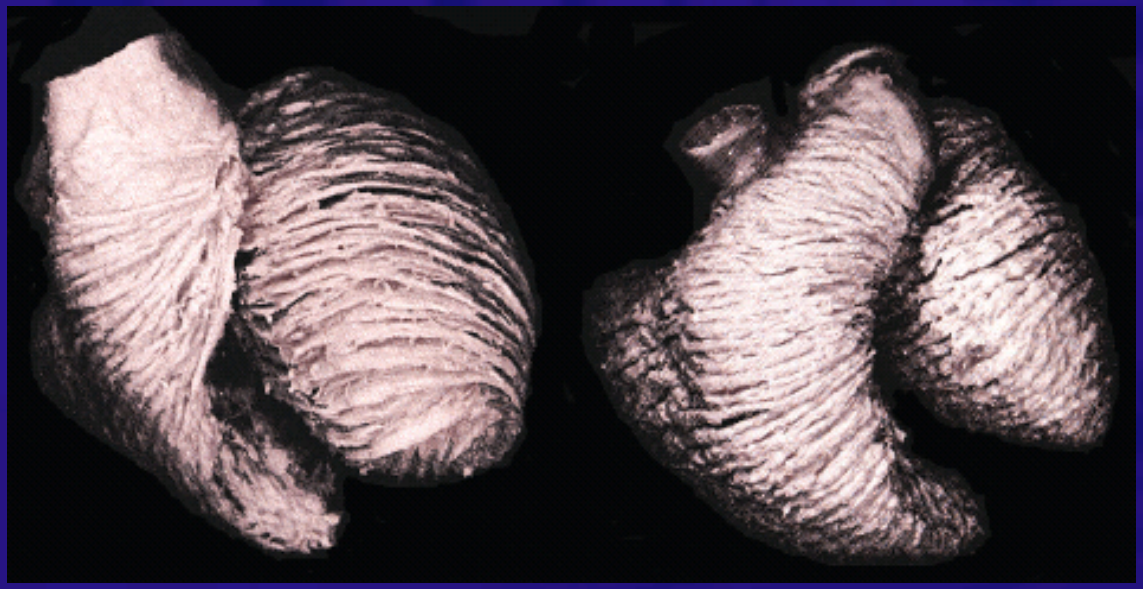
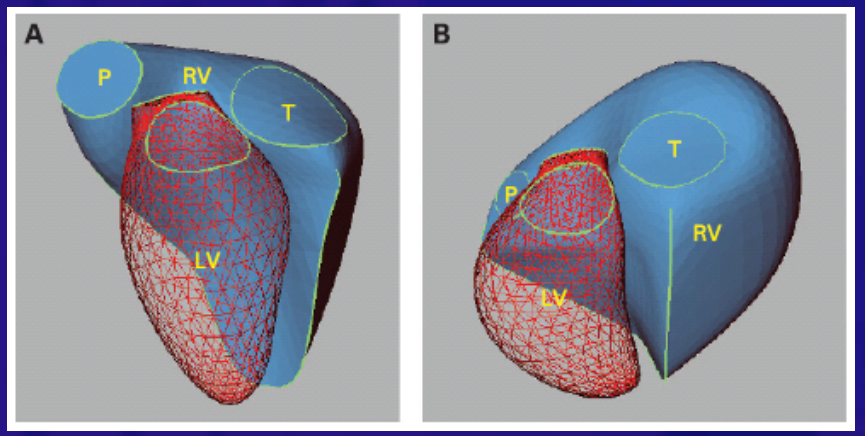
NO SIMPLE GEOMETRIC SHAPE THAT APPROXIMATES THE RV

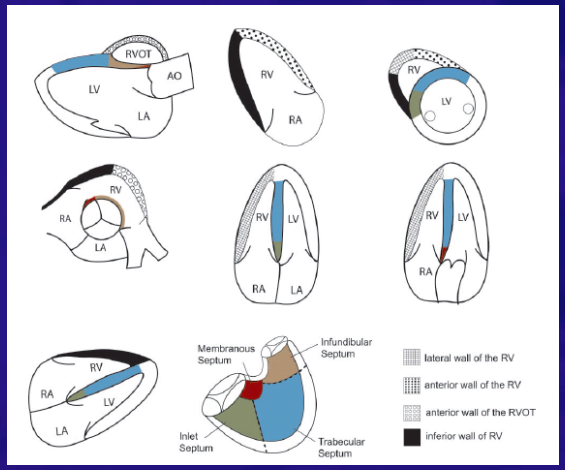
IT'S « WRAPPED AROUND » THE LV IN A U-SHAPED FASHION



ANATOMY

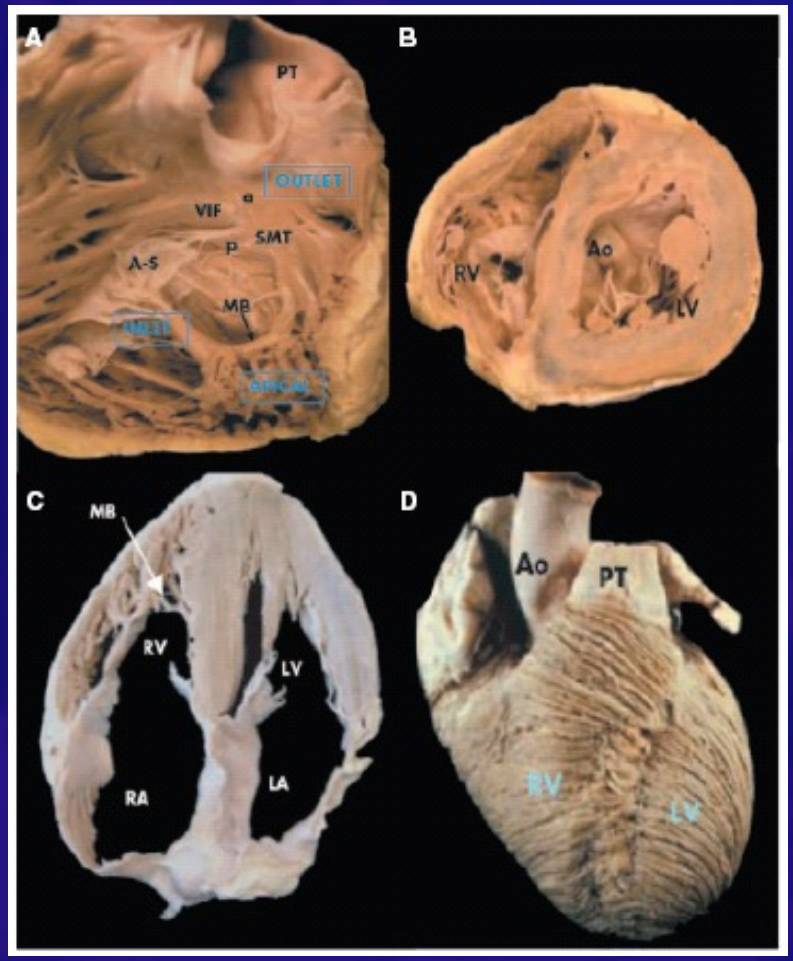
- RV IS THE *MOST ANTERIORLY* SITUATED CARDIAC CHAMBER
- ITS SHAPE IS *COMPLEX*
- RV APPEARS TRIANGULAR (SIDE VIEW) AND CRESCENT SHAPED (CROSS SECTION)
- RV *SHAPE INFLUENCED* BY:
  - INTERVENTRICULAR SEPTUM
  - LOADING AND ELECTRICAL CONDITIONS
- *MULTIPLE LAYERS OF MYOFIBERS*
- THREE MUSCULAR BANDS:
  - PARIETAL BAND
  - SEPTOMARGINAL BAND
  - MODERATOR BAND





ANATOMY

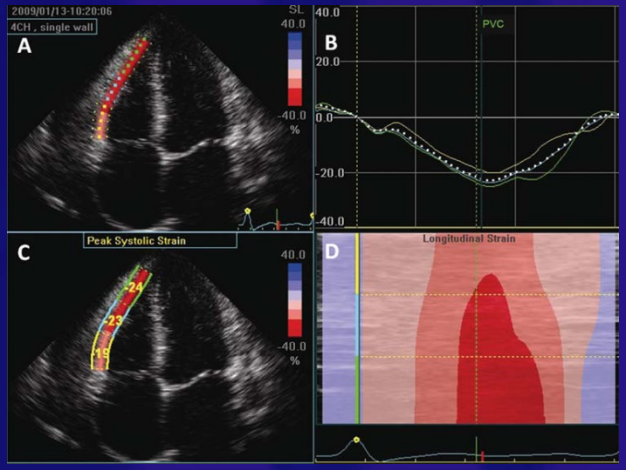
- *THE INLET* WHICH CONSIST IN TRICUSPID VALVE, CHORDAE THENDINAE, AND PAPILLARY MUSCLE
- *THE TRABECULATED APICAL MYOCARDIUM*
- *THE INFUNDIBULUM OR CONUS* THAT CORRESPONDS TO THE SMOOTH OUTFLOW REGION

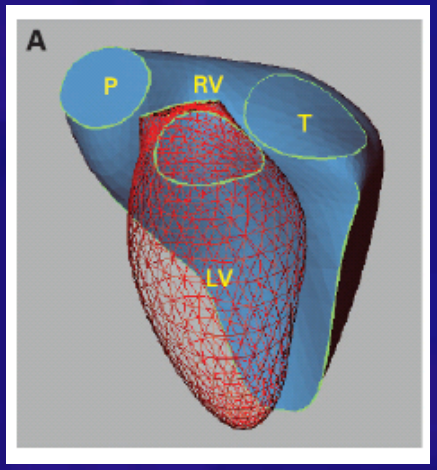


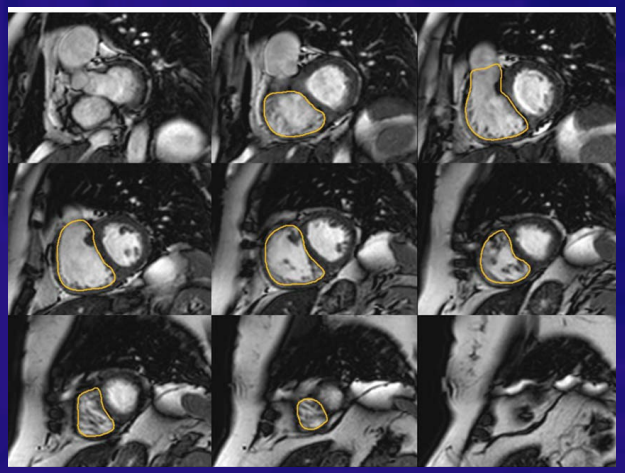
IMAGING IS CHALLENGING

- Complex geometry of RV
- The limited definition of RV endocardial surface caused by the heavily trabeculated myocardium
- The retrosternal position of the RV, which can limit echocardiographic imaging windows
- The marked load dependence of indices of RV function

MULTIMODALITY APROACH TO EVALUATE STRUCTURE AND FUNCTION

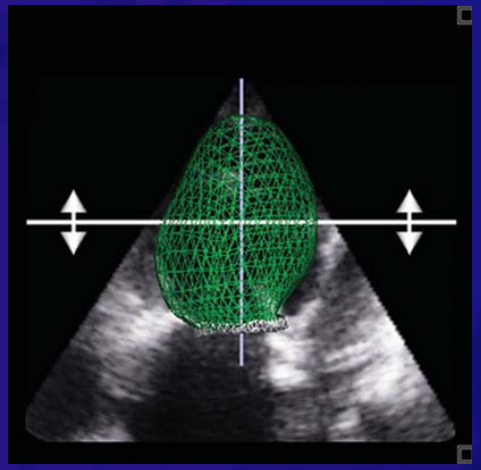


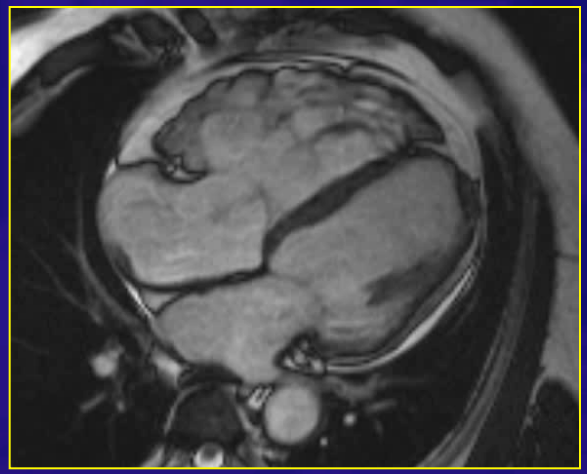




CLINICAL PRACTICE

- *Echocardiography* is the mainstay of evaluation of RV structure and function. Compared with other modalities, it offers the advantages of versatility and availability
- *Cardiac magnetic resonance imaging* (MRI) is increasingly used as a standard tool in the evaluation of RV structure and function.
- MRI is the most accurate method for assessing RV volume and function

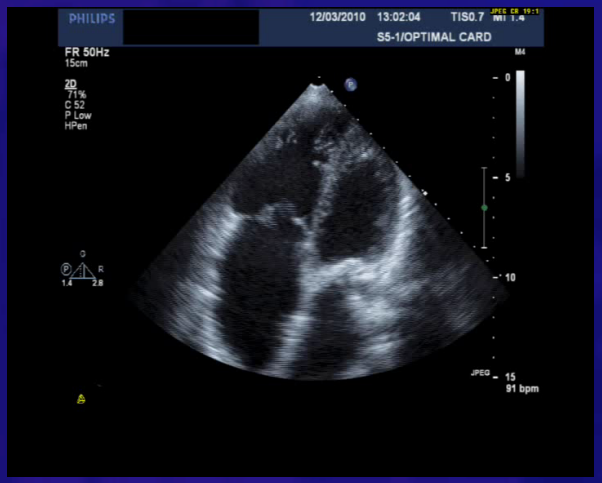


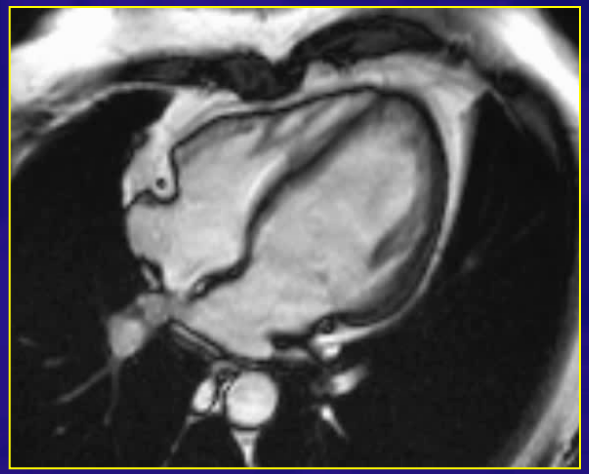


- CMR has emerged as the referenced standard technique to evaluate a large variety of RV disease
- Impact on a patient's prognosis and therapeutic management
- Accurate and reproducible assessement of *function* and *tissue characterisation*

VOLUME: 2D imaging

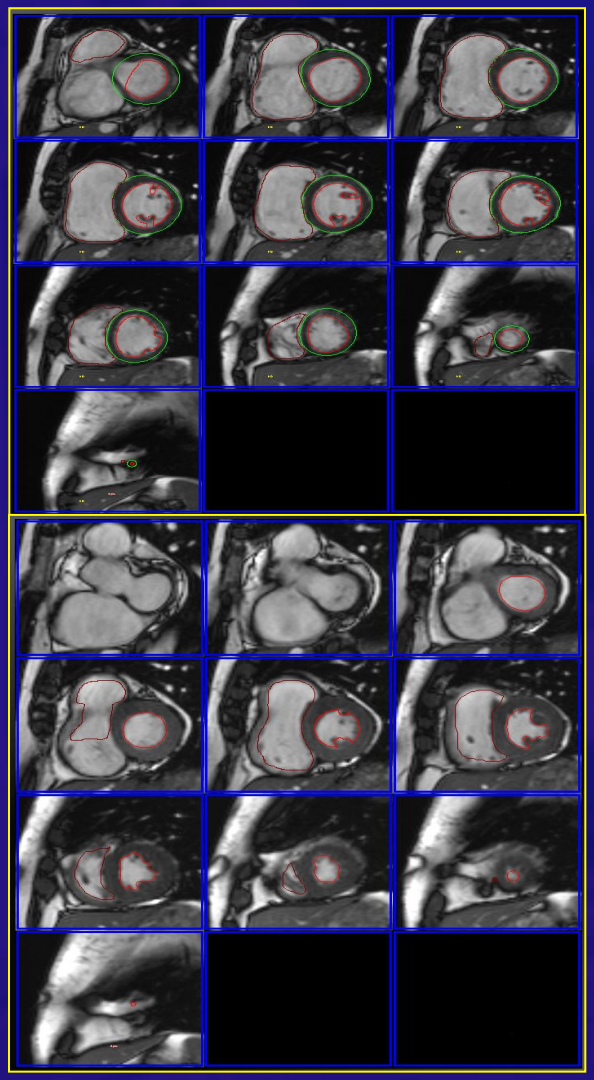
- Two dimensional imaging:
  - performe poorly
  - inaccurate for quantitative analysis
  - current clinical practice is visual assessement to gauge RV size relative to that of LV
- RV is only 2/3 the size of LV in apical 4-chamber
- Failure to include infundibulum (25% of volume)





VOLUME: 3D imaging

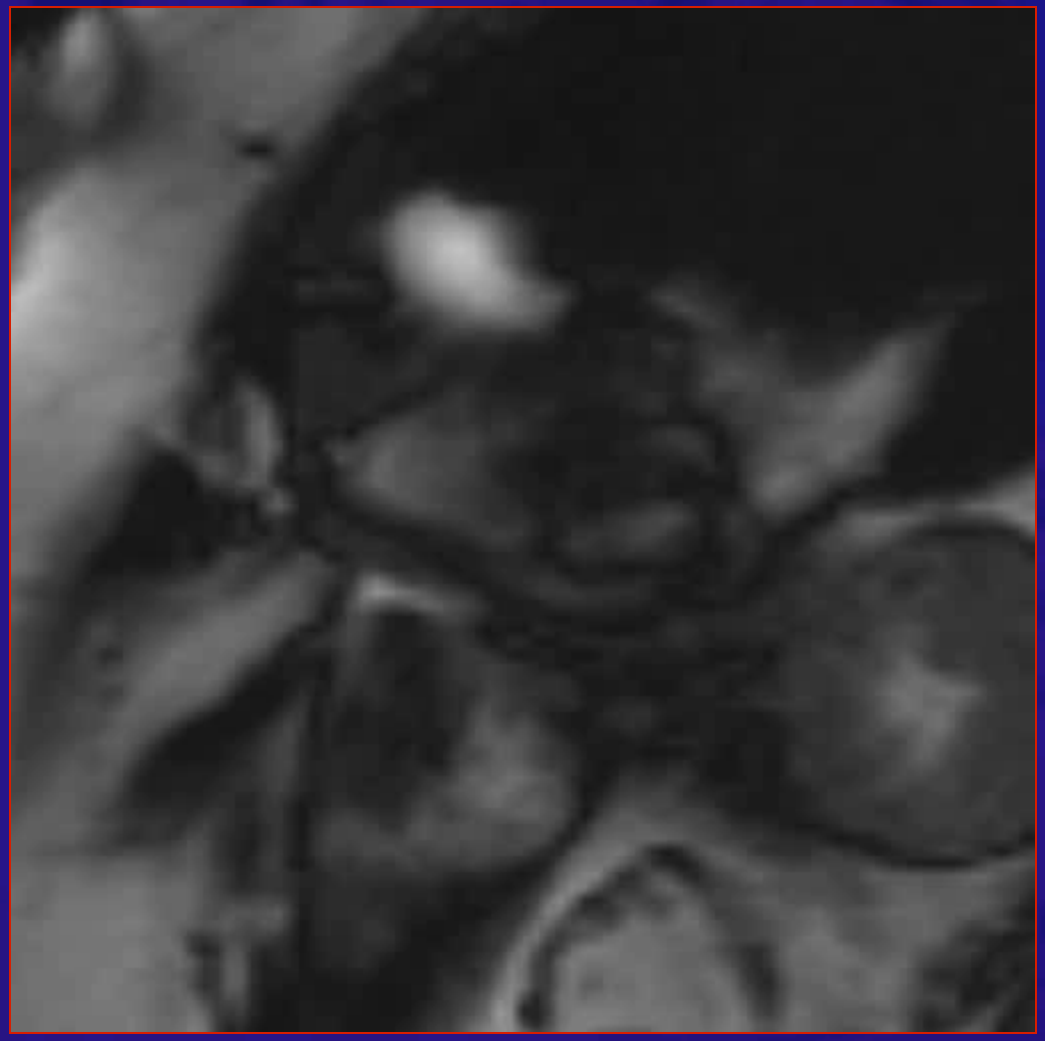
- 3D imaging with analysis using multiple slice technique
- *More accurate*: reliance on geometric modelling is eliminated
- Contours the RV endocardium of each « slice »
- Volume « slice » = area of each slice X slice thickness
- RV volume = summation of volume »slice »

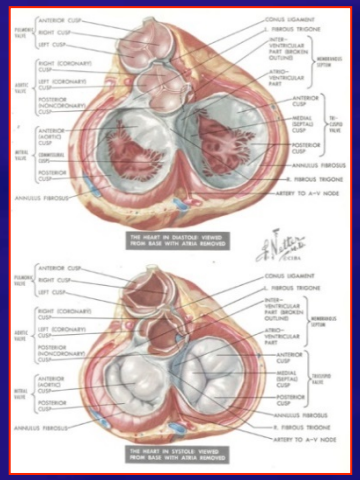


ED phase

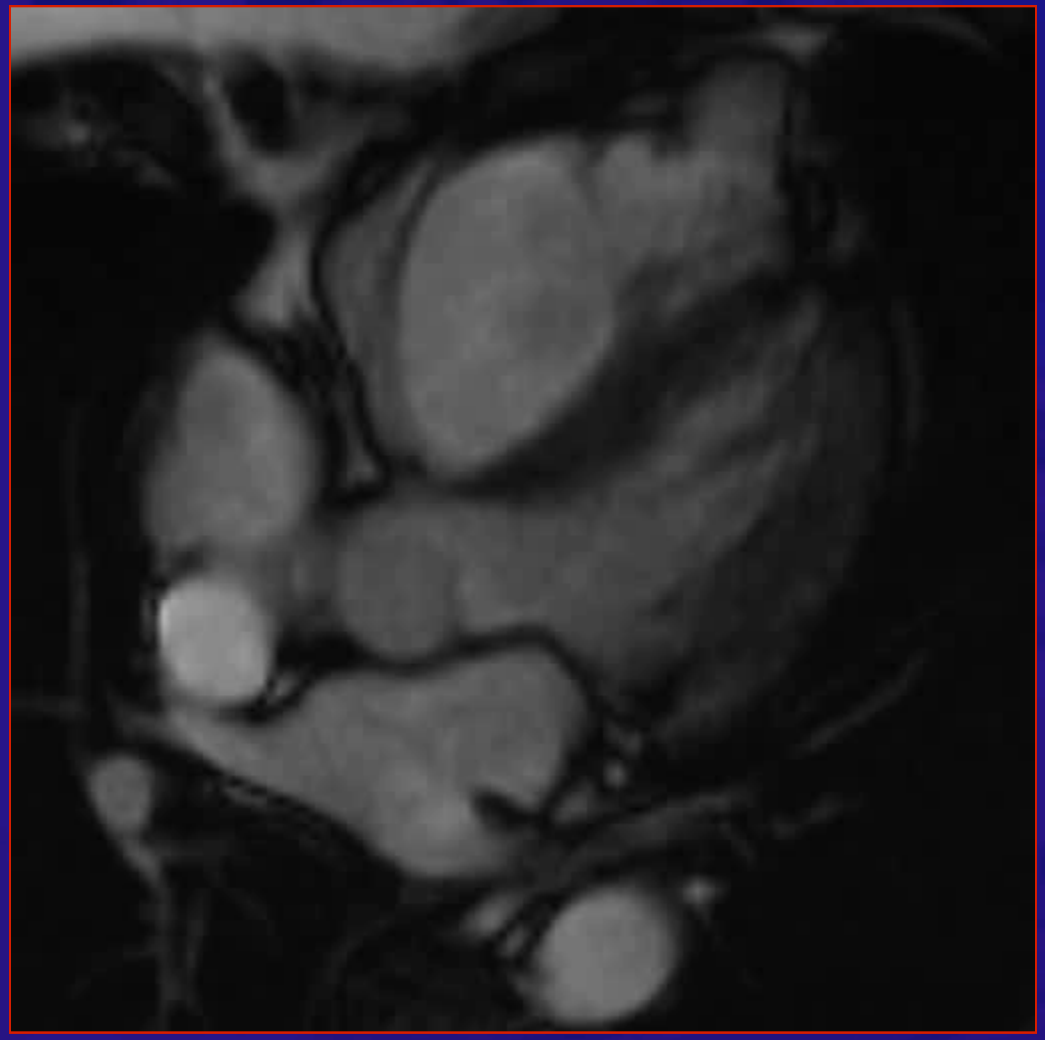
ES phase

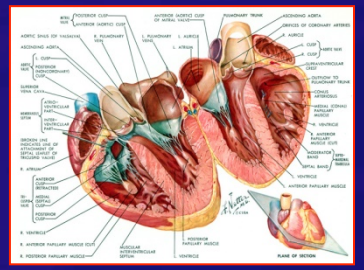
Short axis view



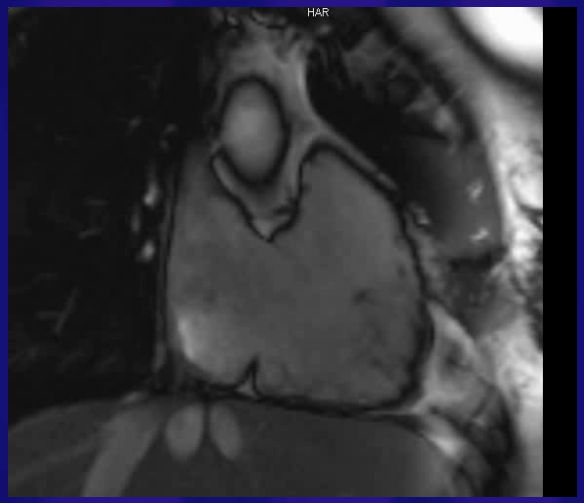


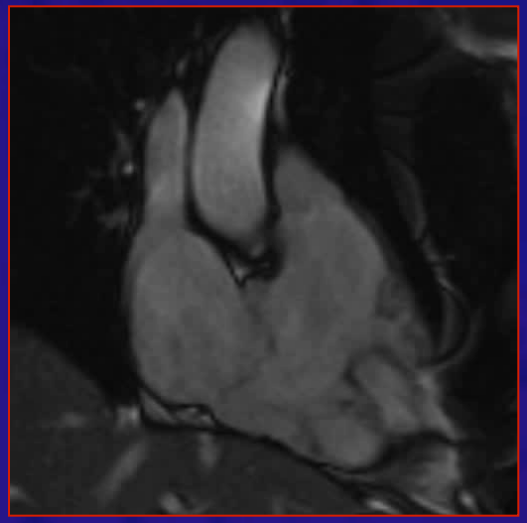
4 chambers view

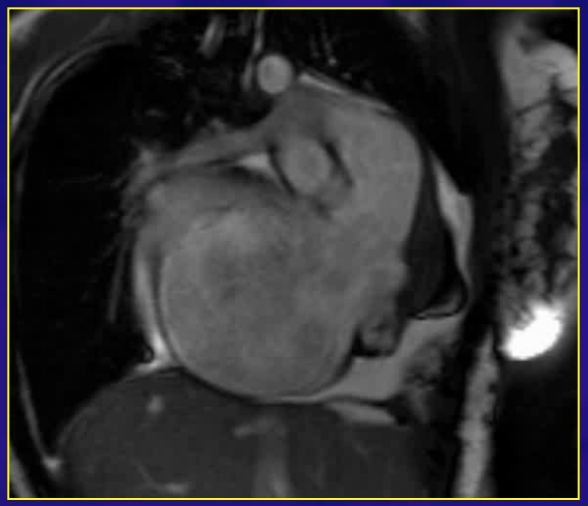


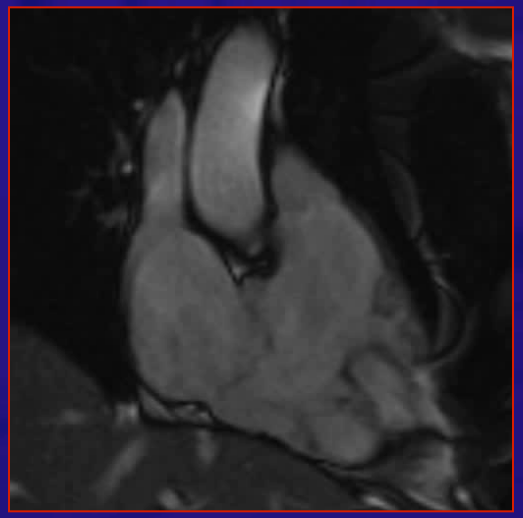


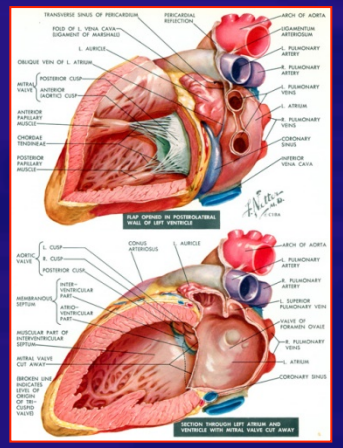
2 chambers view







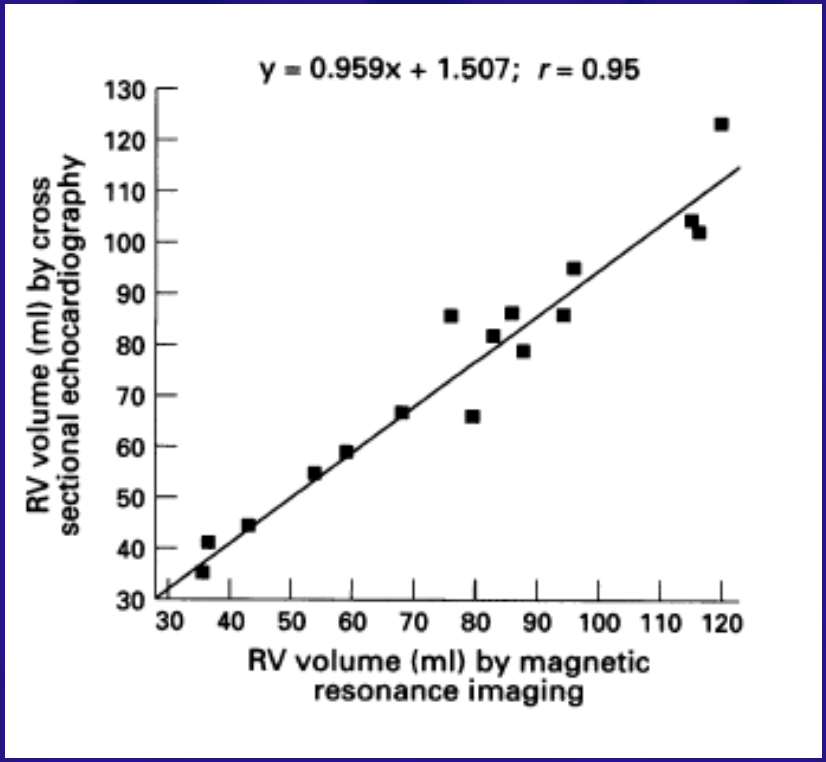




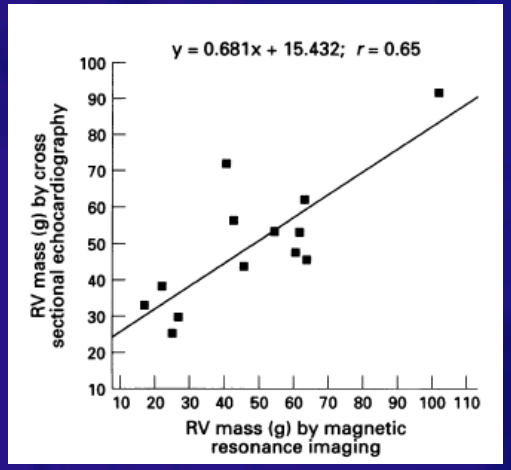
VOLUME: 3D imaging

- Tracing of the RV borders in 8-10 slices at ED et ES phases
- *LIMITATIONS*
- *Automated segmentation*
- Consider
  - *heavy trabeculation of RV*
  - prominent intraventricular structures
  - complex shape

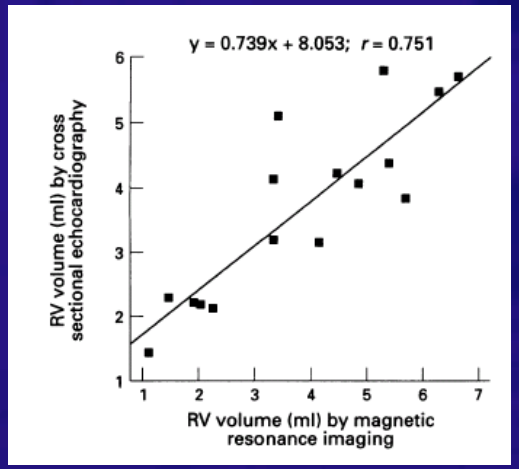
3D echo vs. MRI



END-DIASTOLIC VOLUME



RV MASS



END-SYSTOLIC VOLUME

HEART 1997

RV Ejection Fraction

- RVEF is the most commonly used index of contractility of RV but is highly dependent on loading condition
- Same limitations that volume evaluation
- RVEF lower than LVEF
- Normal range: 47-76%
- RVFA: > 32%

Normal value for RV

	Man	Woman
EF	47-74%	47-80%
EDVI	55-105	48-87 ml/m²
ESVI	16-48	20-32 ml/m²
SV	32-64	27-57 ml/m²

LORENZ CH, 1999

REFERENCE RV VOLUME MASS

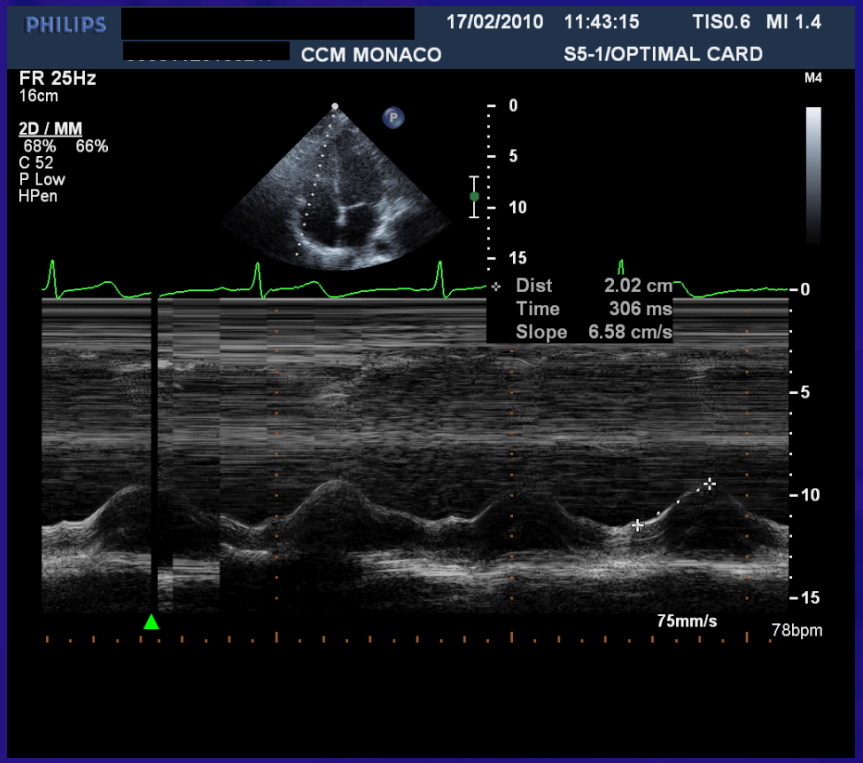
Table 8 RV summary data for all ages (mean ± SD, 95% confidence interval)

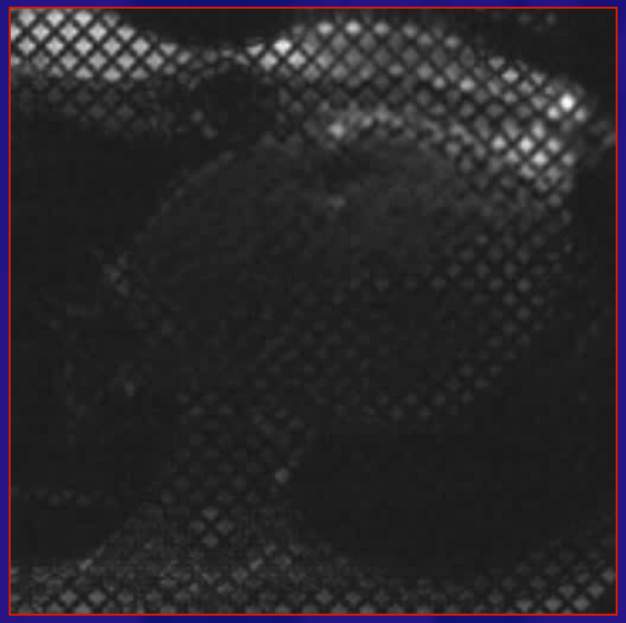
	All	Males	Females
EDV (mL)	144 ± 23 (98, 190)	163 ± 25 (113, 213)	126 ± 21 (84, 168)
EDV/BSA (mL/m^2)	78 ± 11 (57, 99)	83 ± 12 (60, 106)	73 ± 9 (55, 92)
ESV (mL)	50 ± 14 (22, 78)	57 ± 15 (27, 86)	43 ± 13 (17, 69)
ESV/BSA (mL/m^2)	27 ± 7 (13, 41)	29 ± 7 (14, 43)	25 ± 7 (12, 38)
SV (mL)	94 ± 15 (64, 124)	106 ± 17 (72, 140)	83 ± 13 (57, 108)
SV/BSA (mL/m^2)	51 ± 7 (37, 65)	54 ± 8 (38, 70)	48 ± 6 (36, 60)
EF (%)	66 ± 6 (54, 78)	66 ± 6 (53, 78)	66 ± 6 (54, 78)
EF/BSA (%/m^2)	36 ± 5 (27, 45)	34 ± 4 (26, 41)	39 ± 5 (29, 49)
Mass (g)	48 ± 13 (23, 73)	66 ± 14 (38, 94)	48 ± 11 (27, 69)
Mass/BSA (g/m^2)	31 ± 6 (19, 43)	34 ± 7 (20, 47)	28 ± 5 (18, 38)
PFR_E (mL/s)	371 ± 125 (126, 615)	405 ± 137 (137, 674)	337 ± 117 (107, 567)
PFR_E/BSA (mL/m^2)	202 ± 69 (67, 337)	207 ± 70 (68, 345)	197 ± 68 (64, 330)
PFR_E/EDV (/s)	2.6 ± 0.8 (1.0, 4.1)	2.4 ± 0.75 (1.0, 3.9)	2.7 ± 0.85 (1.0, 4.3)
PFR_A (mL/s)	429 ± 168 (99, 759)	489 ± 175 (146, 833)	368 ± 153 (67, 668)
PFR_A/BSA (mL/m^2)	233 ± 93 (50, 415)	250 ± 94 (66, 434)	215 ± 89 (40, 390)
PFR_A/EDV (/s)	3.0 ± 1.0 (1.0, 5.1)	3.1 ± 1.0 (1.0, 5.2)	2.9 ± 1.0 (0.9, 5.0)
PFR_E/PFR_A	0.9 ± 0.47 (-0.1, 1.8)	0.8 ± 0.49 (-0.1, 1.8)	0.9 ± 0.46 (0.0, 1.8)
Septal AVPD (mm)	14 ± 3.6 (6, 21)	15 ± 4.1 (6, 23)	13 ± 3.0 (7, 19)
Septal AVPD/long length (%)	17 ± 4.2 (9, 25)	17 ± 4.5 (8, 26)	17 ± 3.9 (9, 25)
Lateral AVPD (mm)	21 ± 3.9 (13, 29)	22 ± 4.4 (13, 30)	21 ± 3.5 (14, 27)
Lateral AVPD/long length (%)	23 ± 4.0 (15, 31)	23 ± 4.1 (15, 31)	24 ± 4.0 (16, 32)

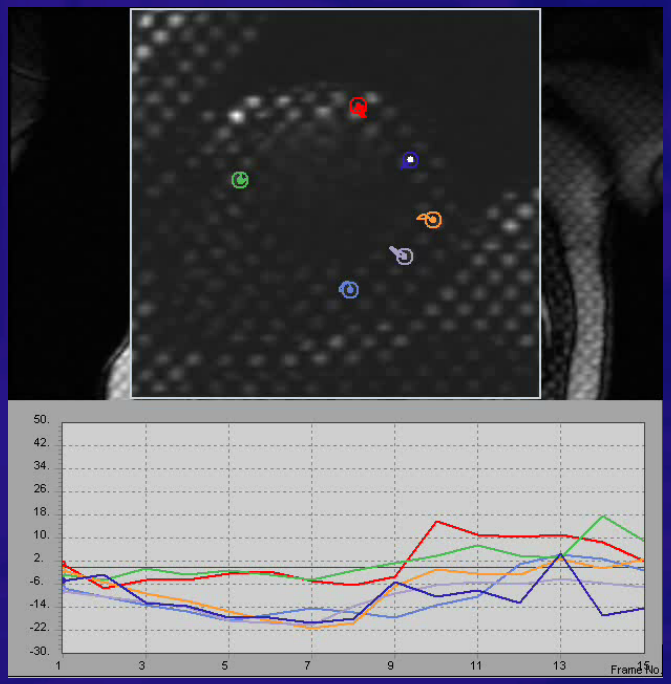
EUR HEART JOURNAL 2006

TAPSE: good correlation with RVEF

- Simple M-mode
- Longitudinal excursion of the lateral tricuspid annulus towards the apex
- Normal value: > 15 mm
- Not limited by endocardial border recognition
- But limitations:
  - ignores the outlet portion and the septal contribution
  - reduced accuracy after cardiac surgery
  - 1D and angle-dependent
  - regional abnormalities neglected



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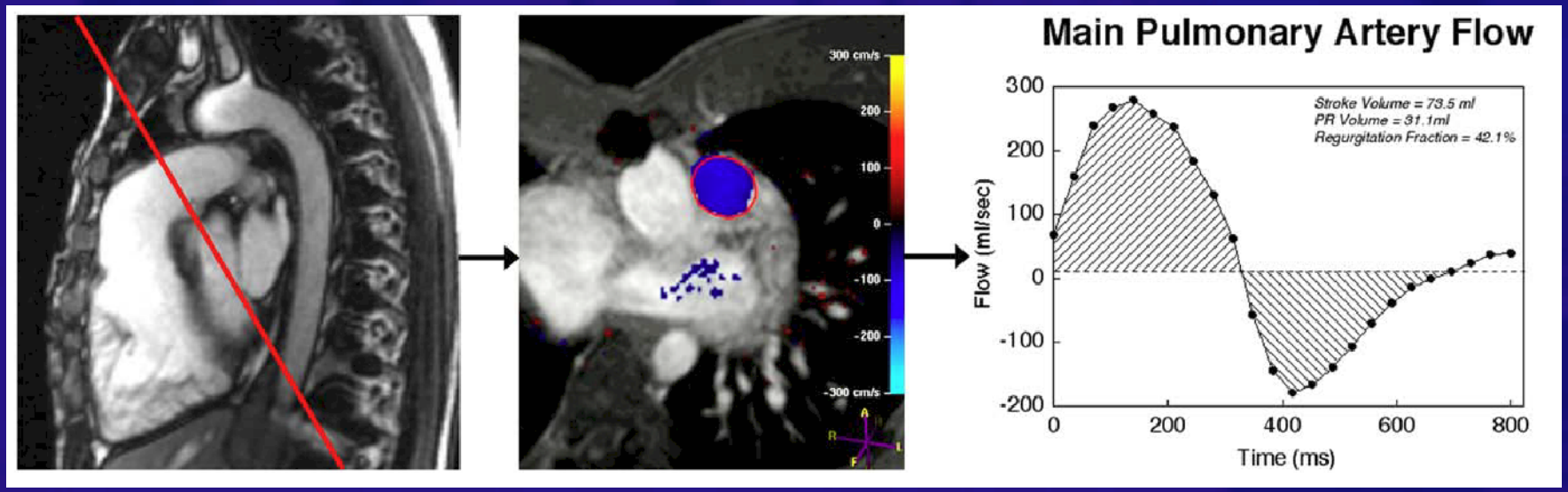
Frame No.

Flow evaluation



The non-ischemic

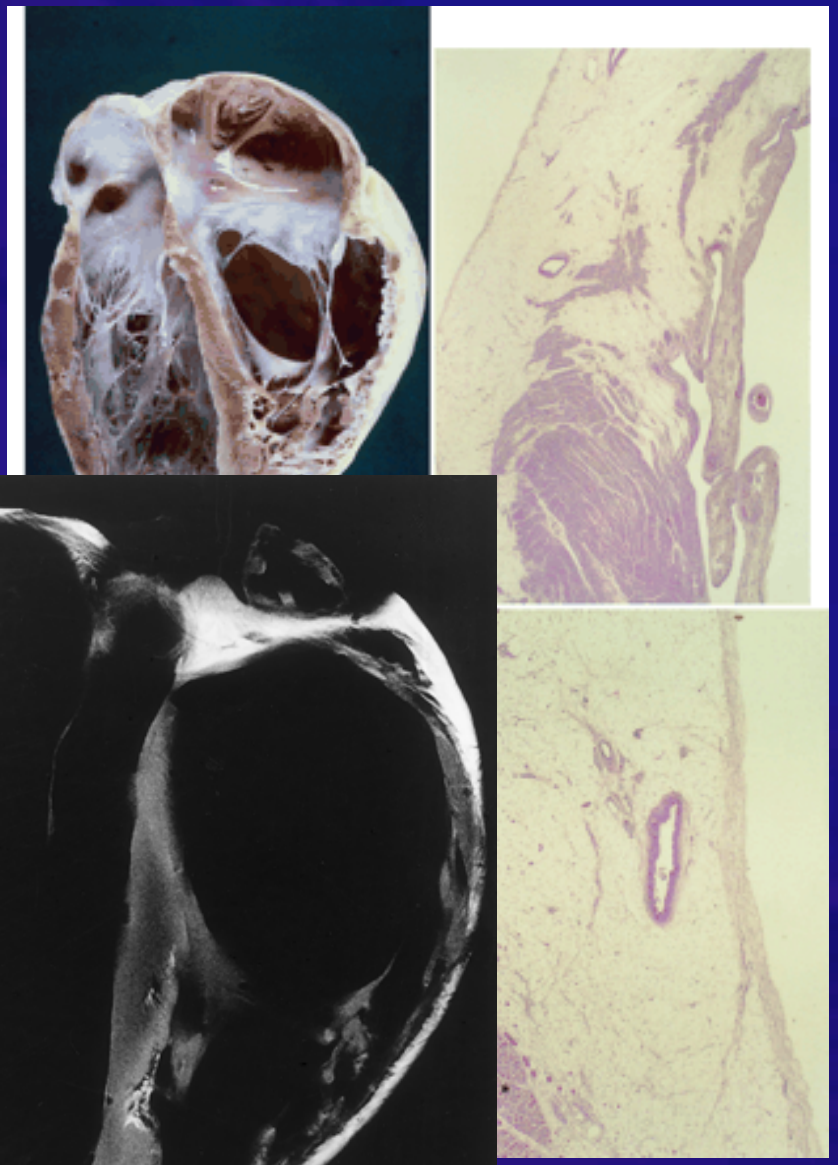
ARVC

PATHOLOGICAL ASPECTS

- Diffuse or segmental loss of the myocardium of the RV free wall and its replacement by fibrofatty tissue
- Frequently transmural
- Triangle of the dysplasia: diaphragmatic, apical and infundibular regions
- The wavefront progression of the process occurs from the subepicardium to the endocardium

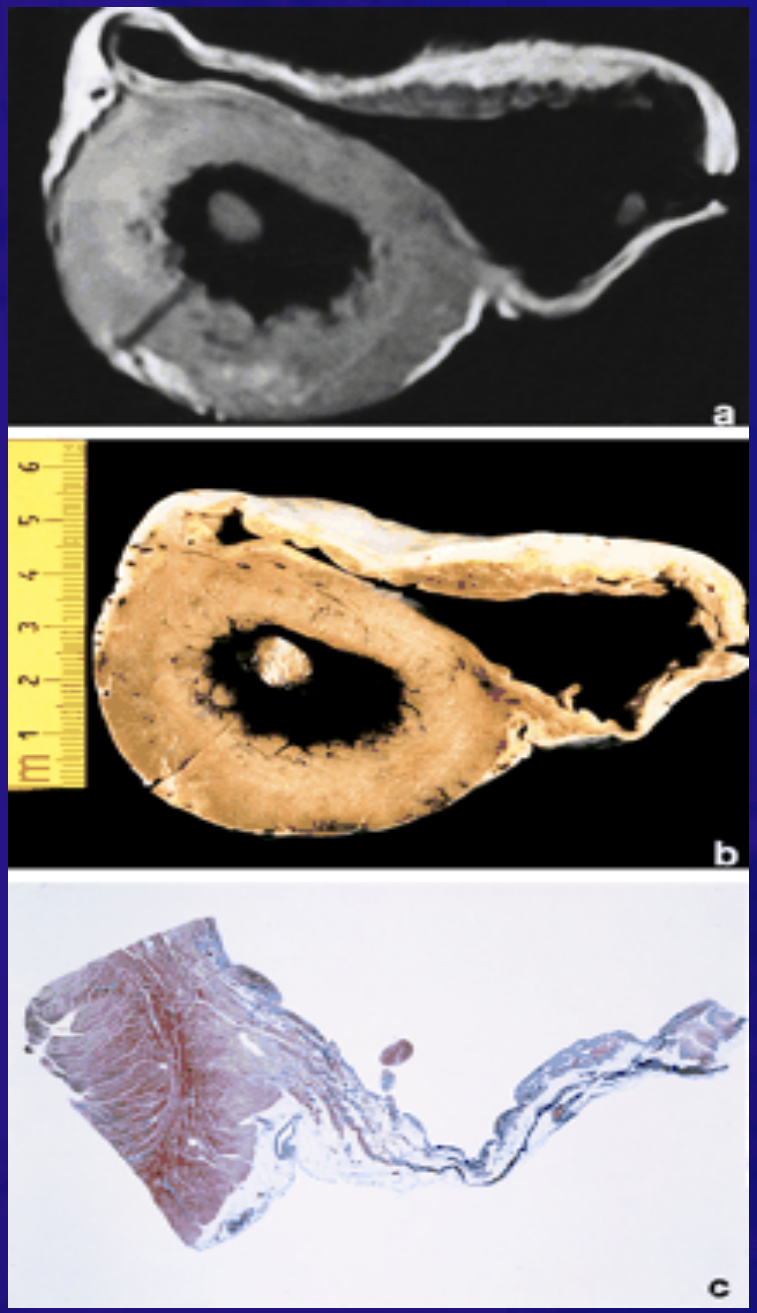
ARVC

- Postmortem MRI
- Extensive hyperintense signal at the level of the RV wall compatible with fat
- Note close relationship between presence of fat at pathology and hyperintense areas at MRI



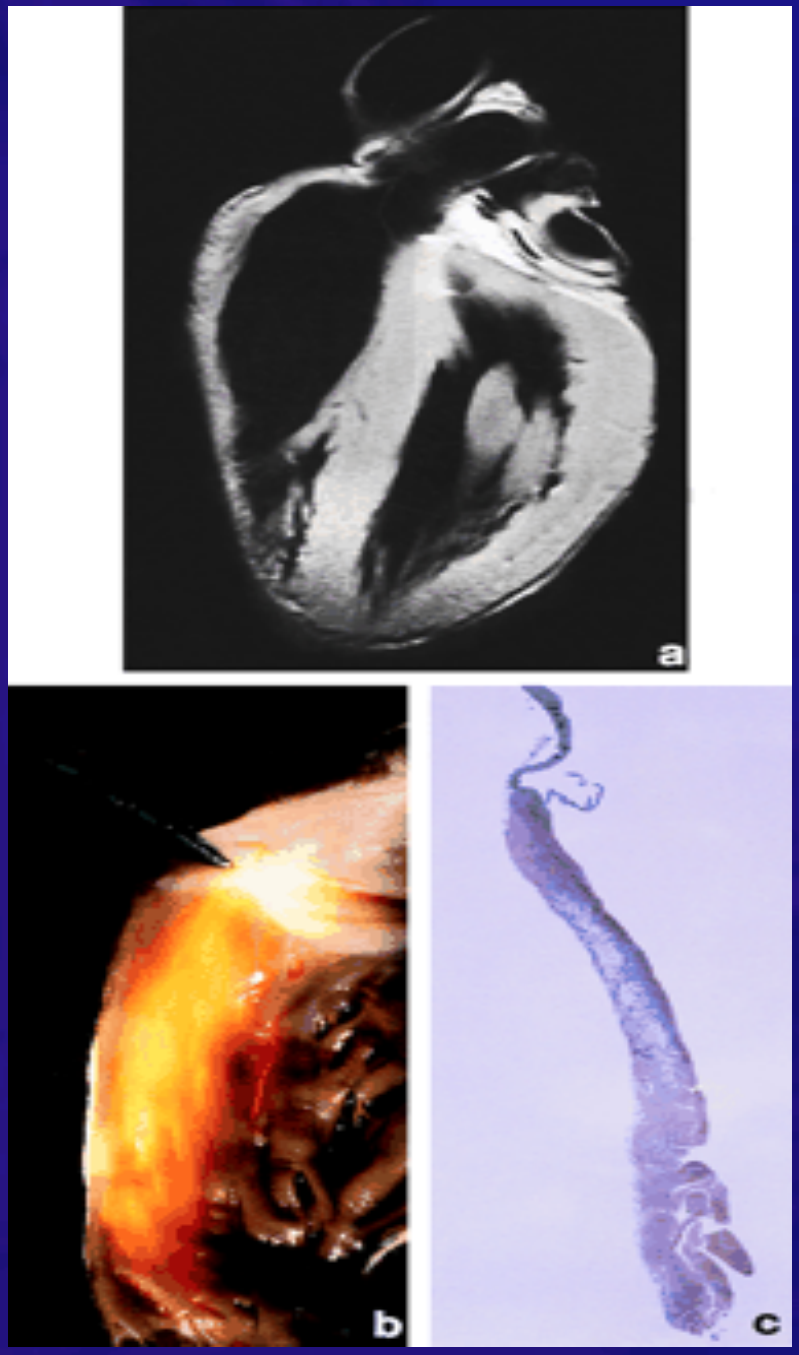
ARVC

- Asymptomatic 17 years old boy died suddenly during a soccer game
- In vitro MRI cross-sectional view
- Uniformly whitish RV free wall ant and inf aneurysm
- Spotty involvement of the posterolateral wall of the LV
- Infundibular and inferior subtricuspidal aneurysm



ARVC

- 26 years old male cyclist died suddenly at rest
- In vitro MRI shows bright streaks in the pulmonary infundibulum
- Fibrofatty replacement



Factor	Major criteria	Minor criteria
Global or regional dysfunction and structural alterations	*Severe dilatation of the RV and reduced RV EF, severe segmental dilatation of the RV, localized RV aneurysm (akinetic or dyskinetic areas with diastolic bulging)*	*Mild dlatation of the RV or reduced RV EF, mild segmental dilatation of the RV, regional RV hypokinesia*
Tissue characterization	*Fibrofatty replacement of RV myocardium at endocardial biopsy*	
Repolarization abnormalities		*Inverted T waves (V2-V3)*
Depolarization or conduction abnormalities	*Epsilon waves or prolonged QRS complex (>110 msec) in V1-V3*	*Late potentials*
Arrhythmias		*VT with LBBB, frequent VES*
Familial history	*Familial disease confirmed at necropsy or surgery*	*Familial history of premature sudden death due to suspected ARVC, familial history (clinical diagnosis based on present criteria)*

REVISED TASK FORCE MR CRITERIA

MAJOR CRITERIA

- Regional RV akinesia or dyskinesia or dyssynchronous contraction

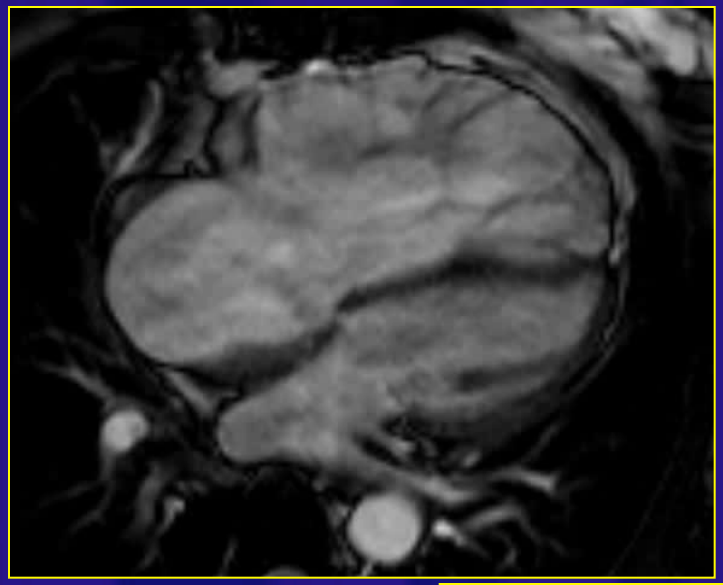
&

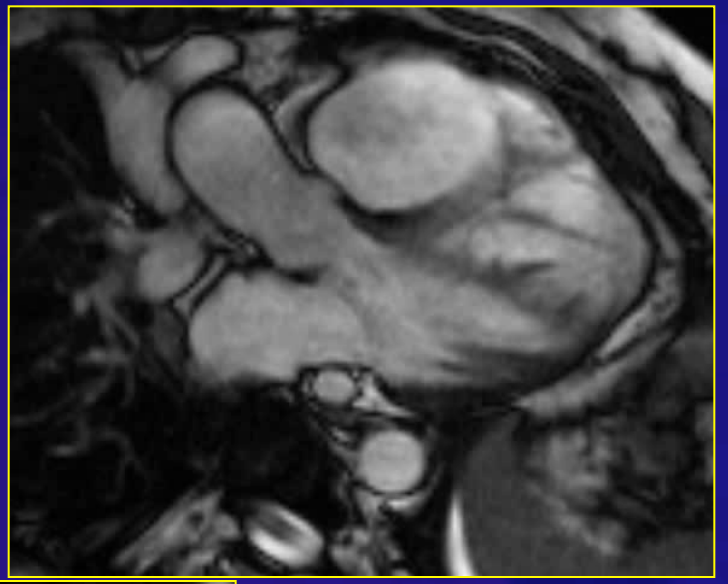
- Ratio of RV end-diastolic volume to BSA > 110 ml/m2

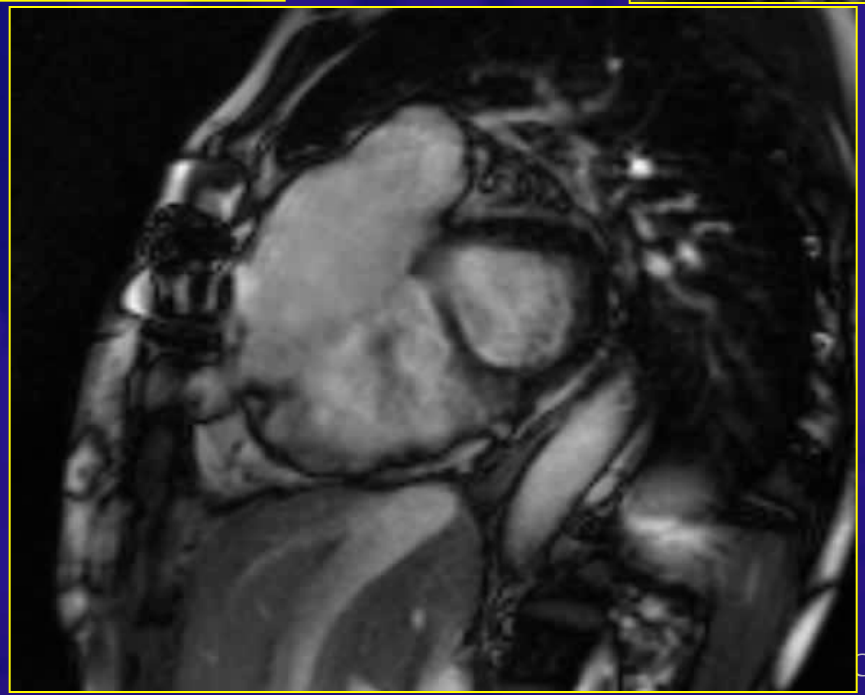
or

- RV ejection fraction < 40%

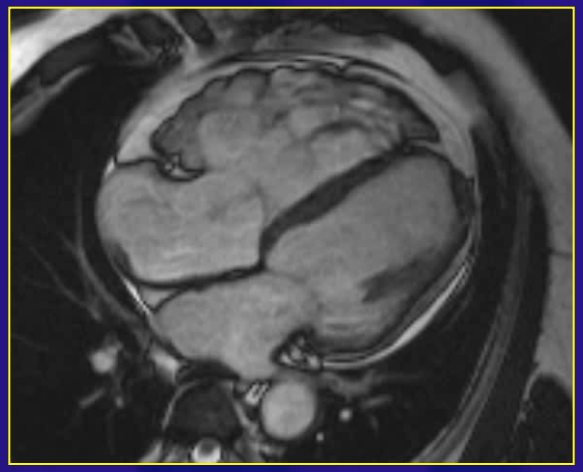
A.R.V.D.

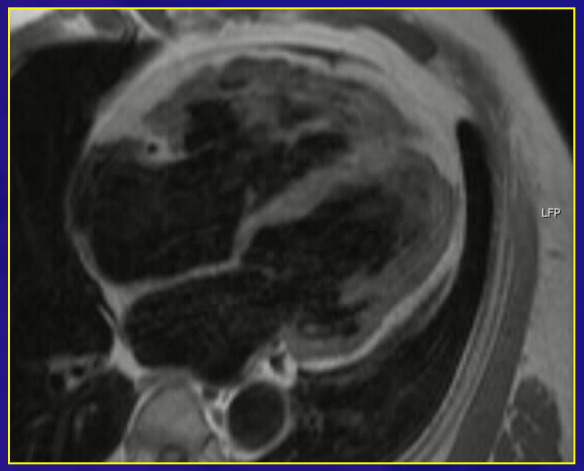
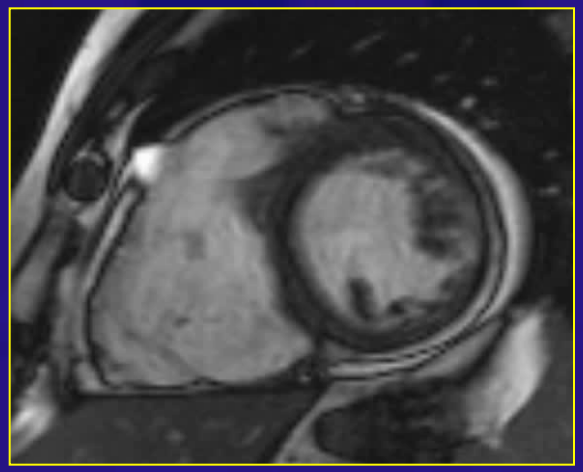


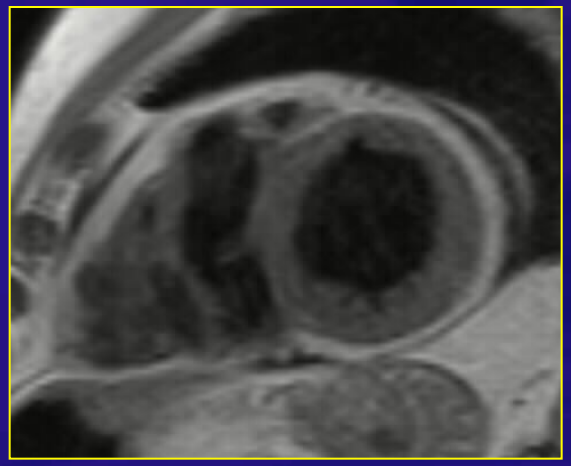




A.R.V.D.





LV 36%
Vol 84-53 ml/m²

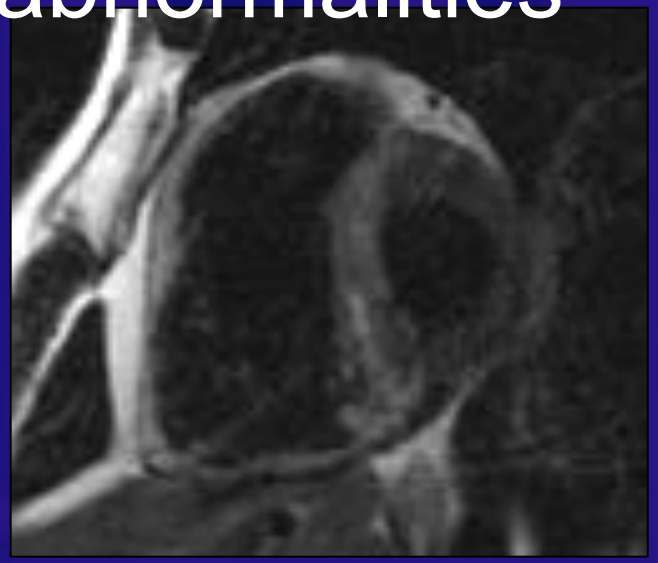
RV 26%
Vol 146-108 ml/m²

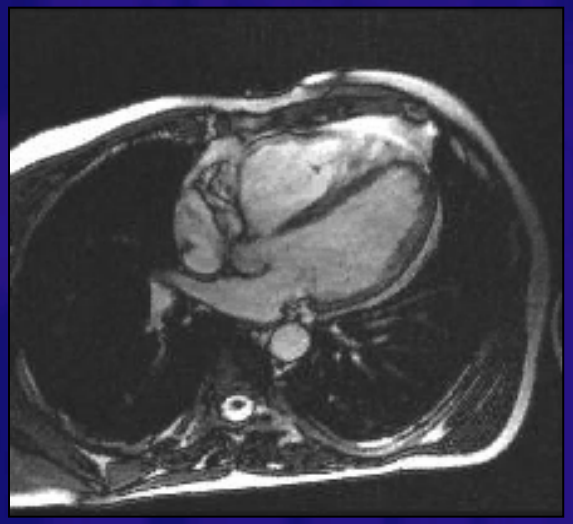
ARVC

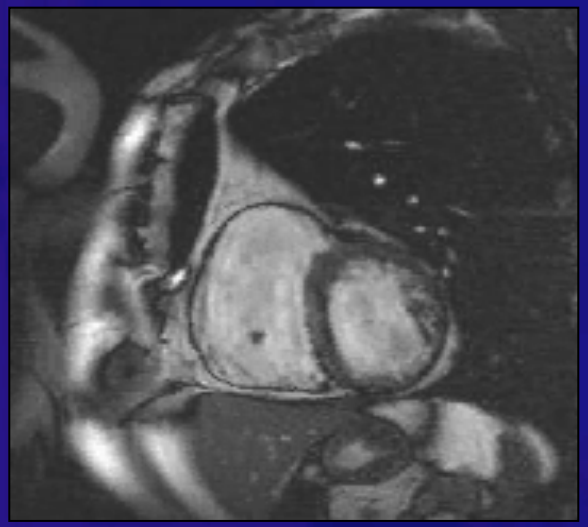
RV motion abnormalities

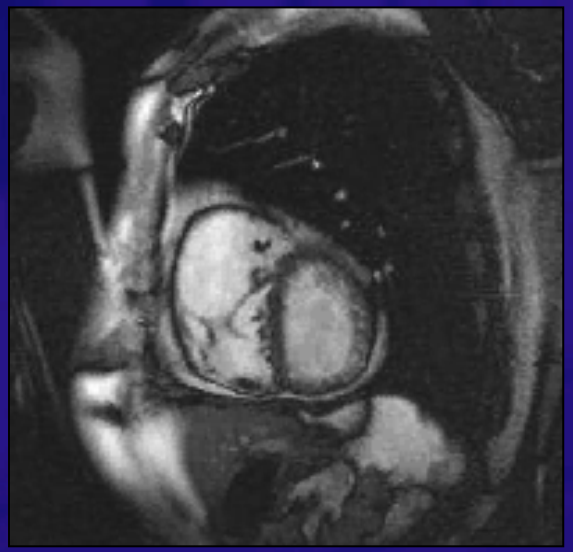
ARVC

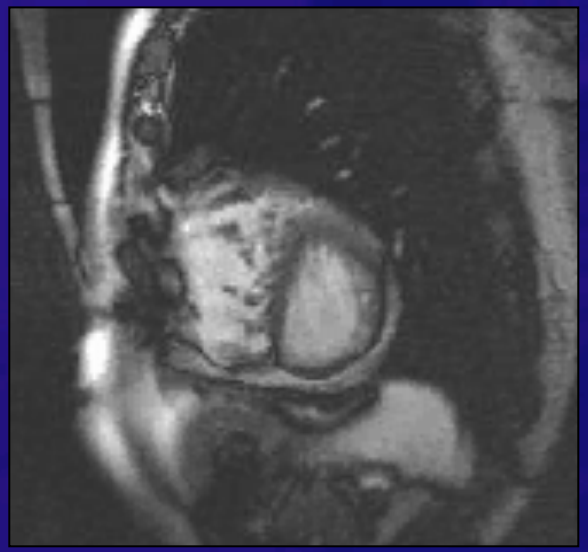
RV motion abnormalities





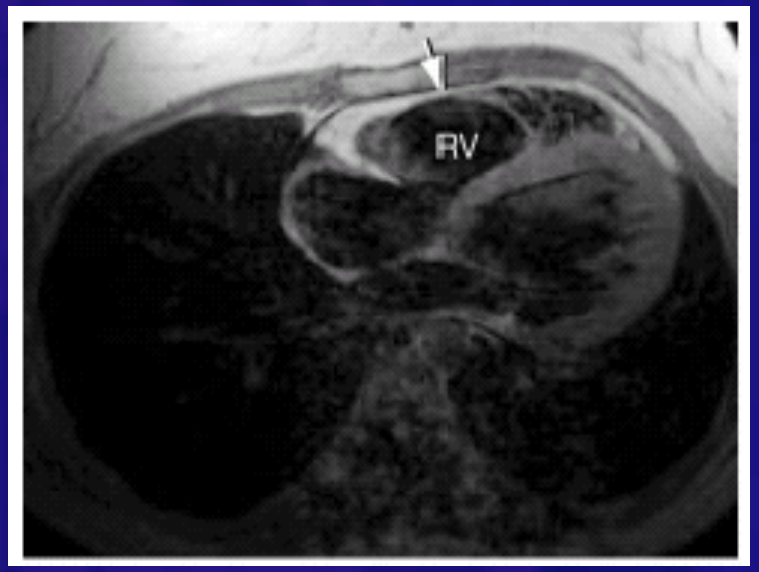


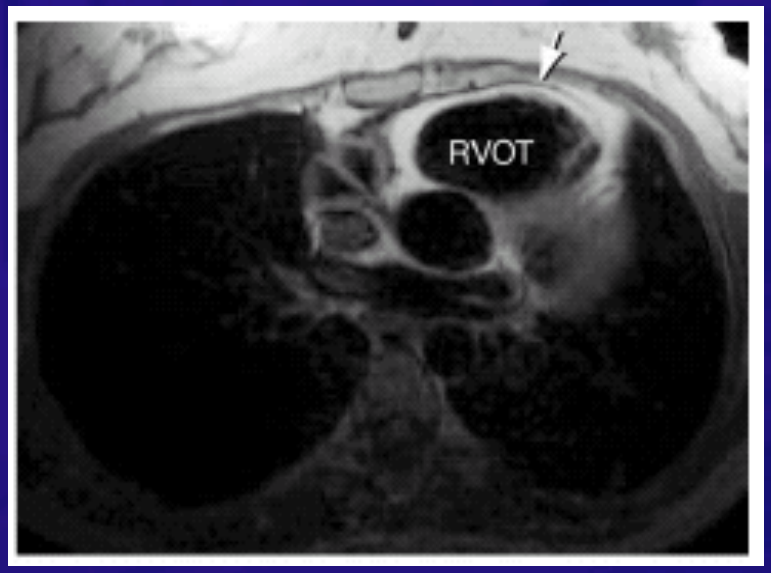




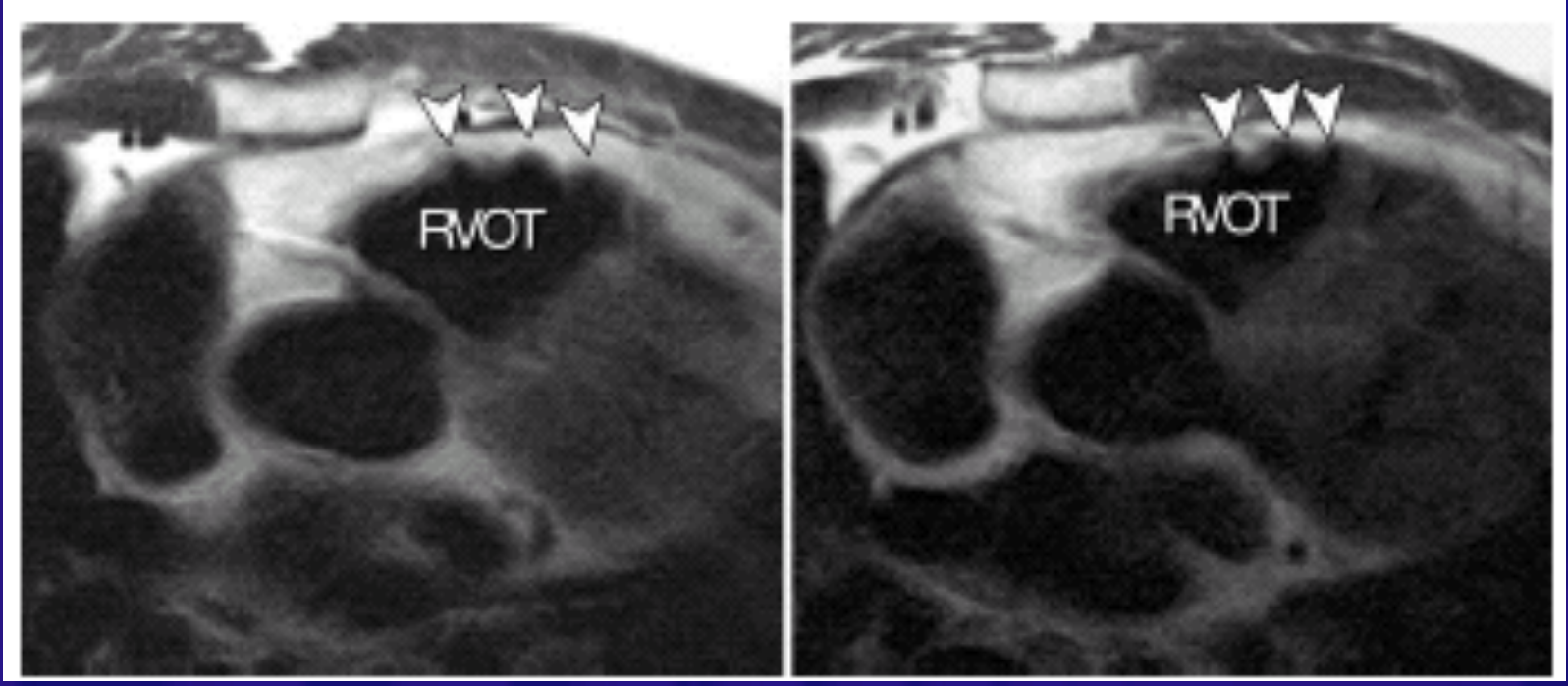
ARVC

- Axial T1-weighted black blood spin-echo images
- Diffuse thinning and fatty replacement of the RV and the RVOT
- These are major criterion for diagnosis of ARVD



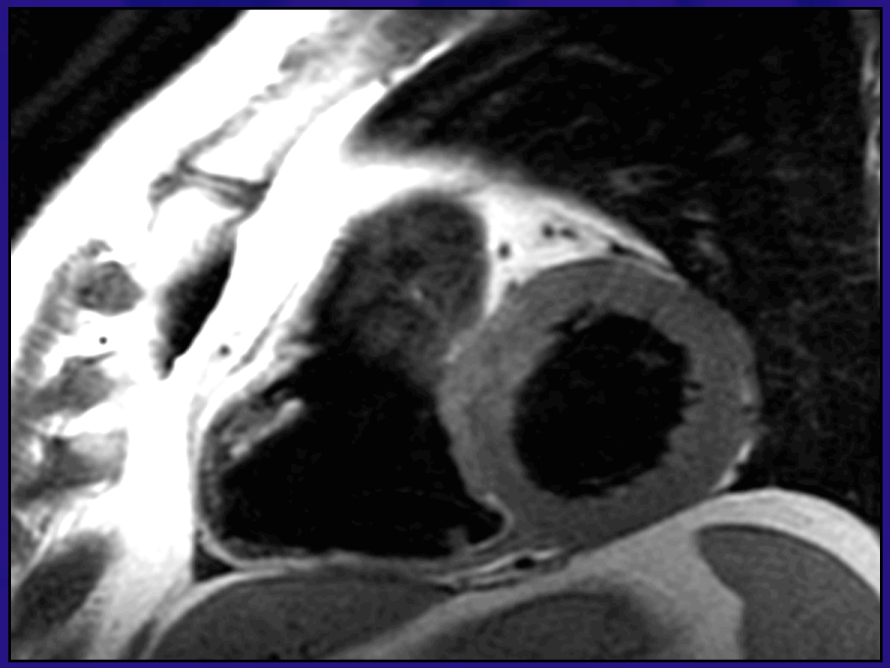


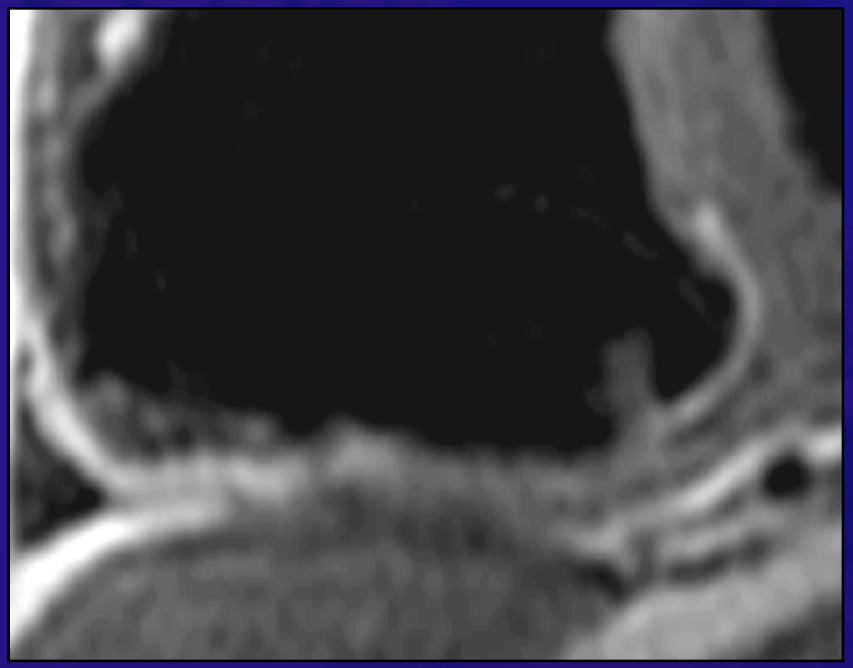
ARVC



- Axial T1-weighted gradient-echo images
- Anterior focal bulging of the RVOT

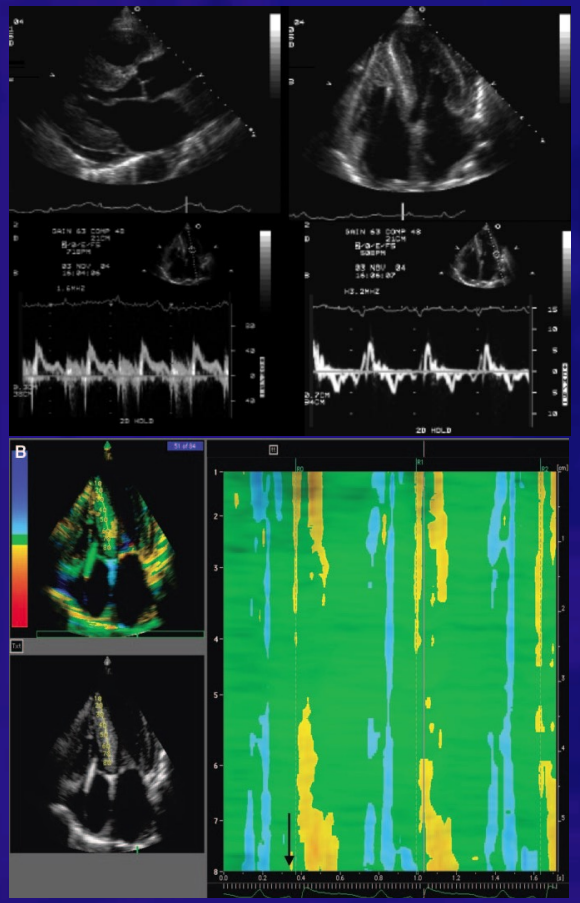
ARVC



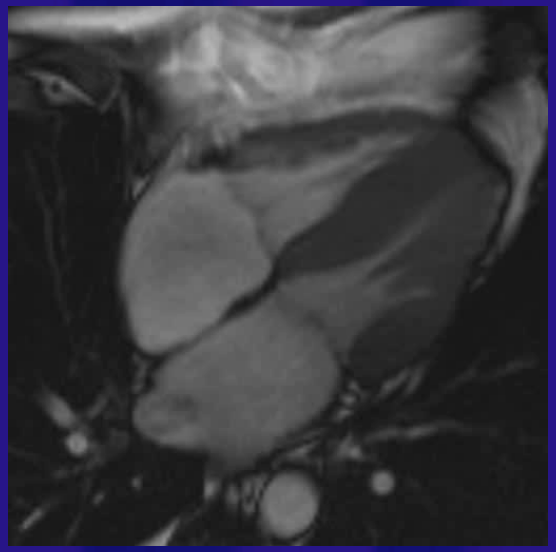


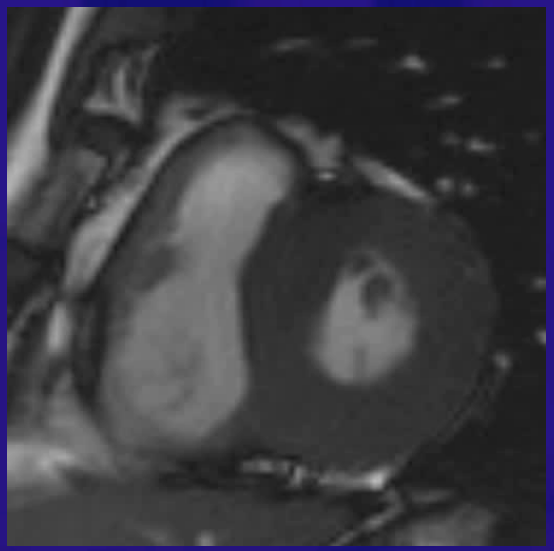
CARDIAC AMYLOIDOSES

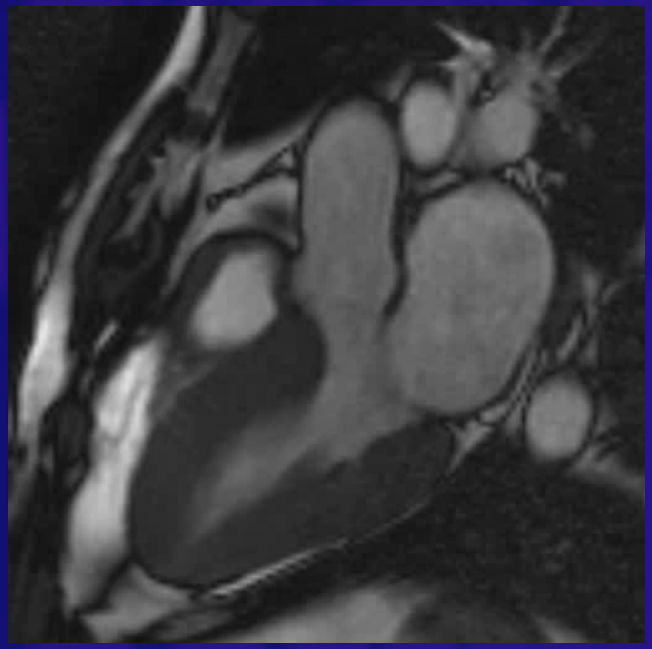
- Multiorgan involvement
- Clinical: CHF to sudden cardiac death
- ECG: low-voltage (infiltration !!!)
- ECHO: « granular sparkling » myocardium
  - biventricular thickening
  - valvular infiltration
  - restrictive pattern (strain)
- Elevated right-sided filling pressure
- *Tissue biopsy required (abdominal fat) and consider cardiac biopsy*



CMR







E.F. 64%

EDVI 56 ml/m2

ESVI 20 ml/m2

Mass 105 g/m2

CI 2.2 l/min

LA 63 ml/m2

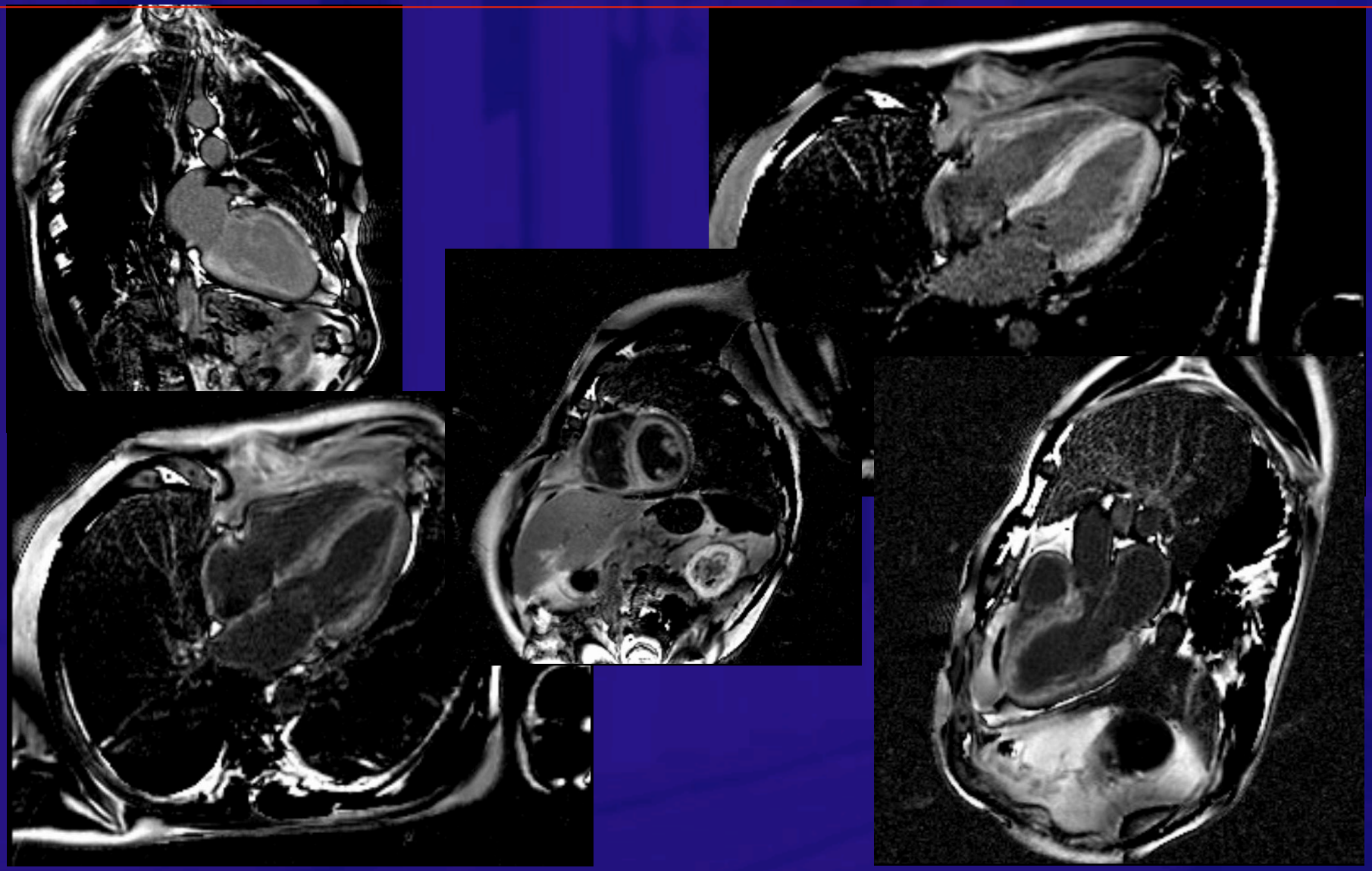
RA 5.6x6 cm.

- Biventricular thickening

- Dilation of atria

- No RV dilation

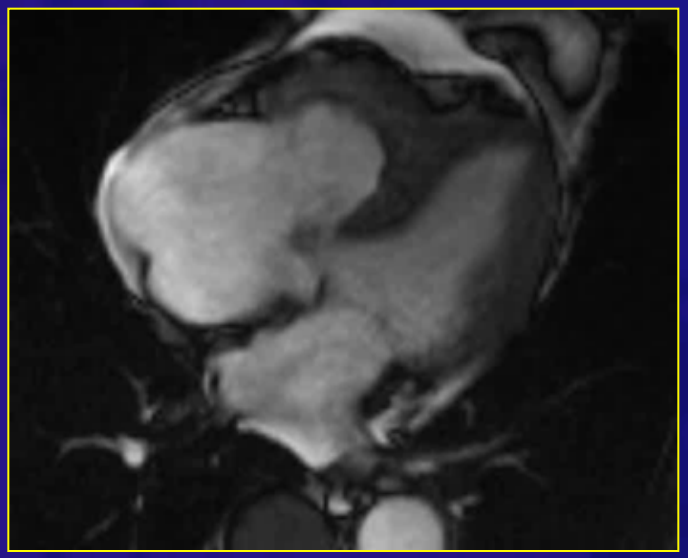
CMR

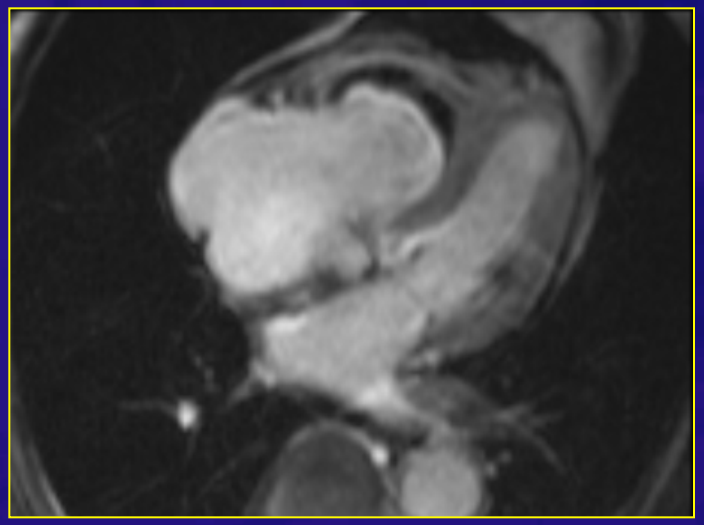


RIGHT HEART FAILURE

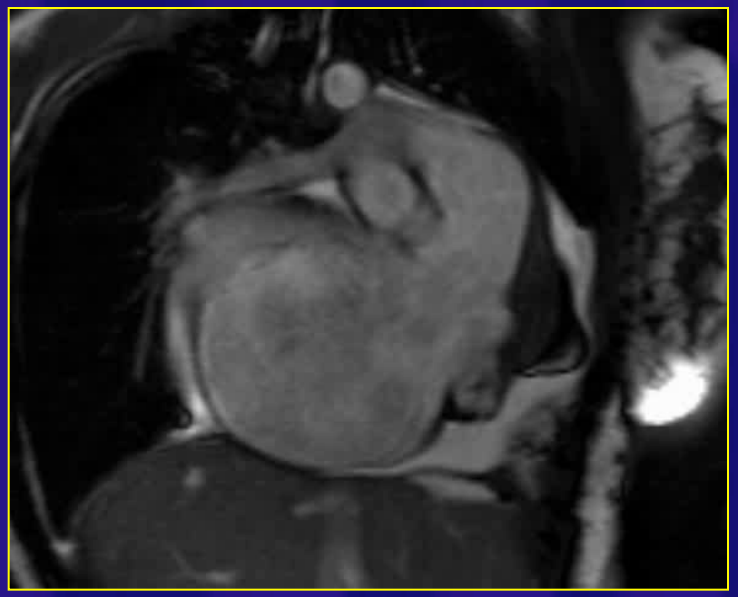
Endomyocardial fibrosis

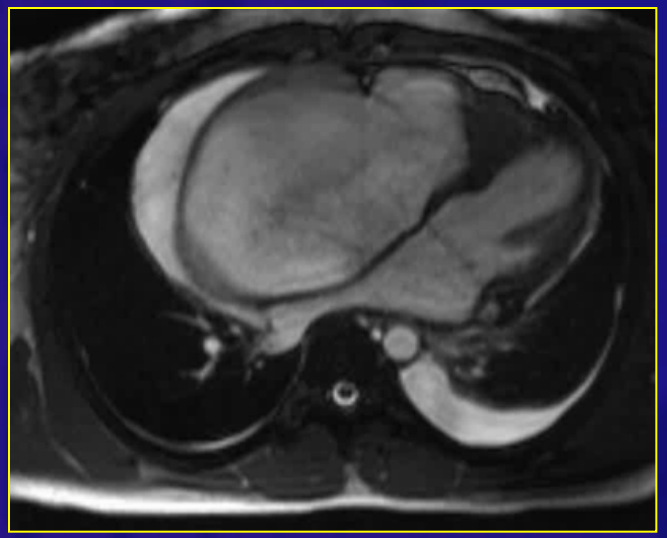
Intense endocardial fibrotic thickening of the apex and subvalvular regions of one or both ventricles that results in obstruction to inflow of blood

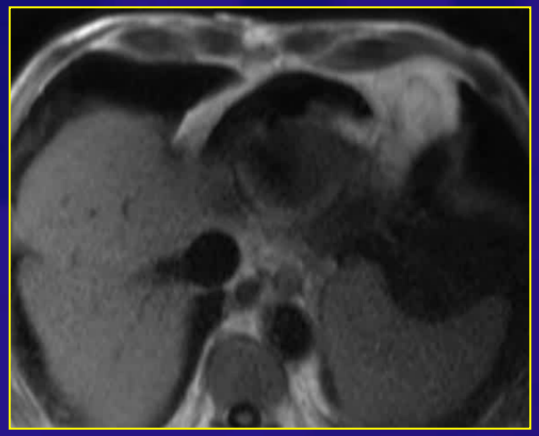


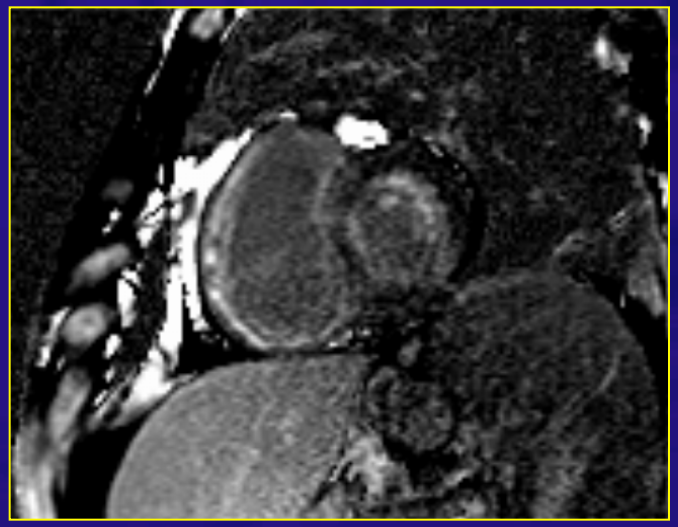


Endomyocardial fibrosis



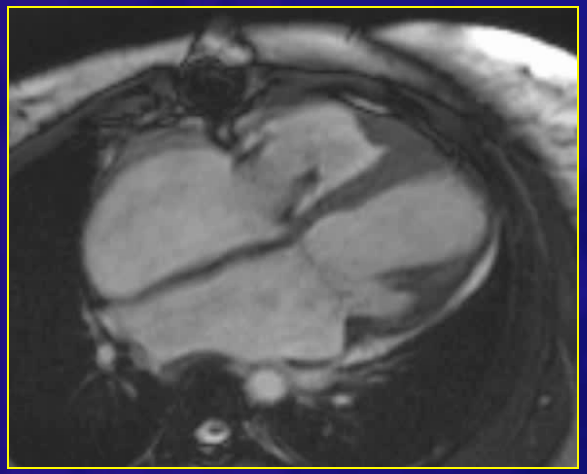


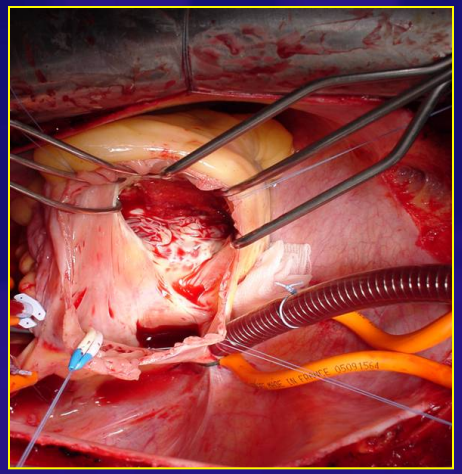




Endomyocardial fibrosis

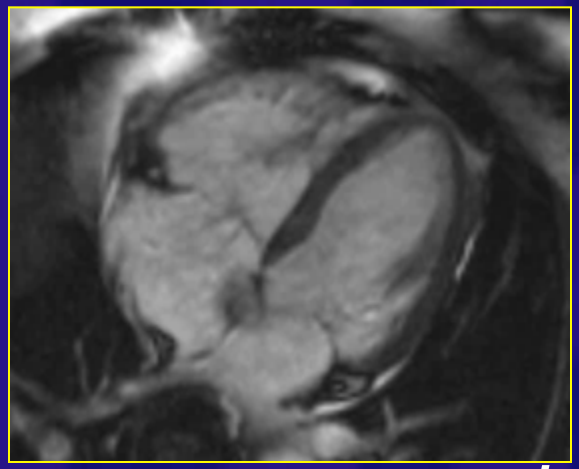
The post operative control

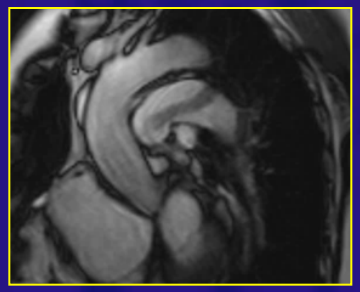




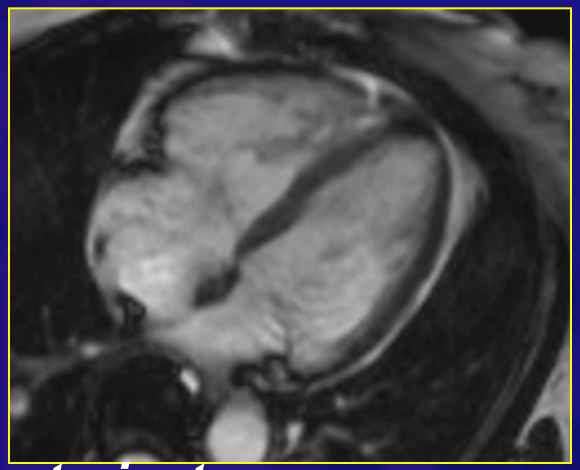
Pulmonary embolism

Initial Study

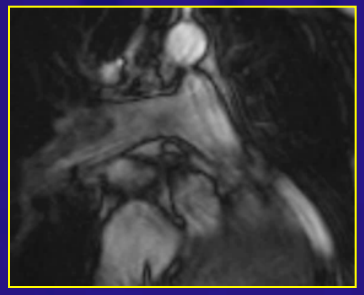




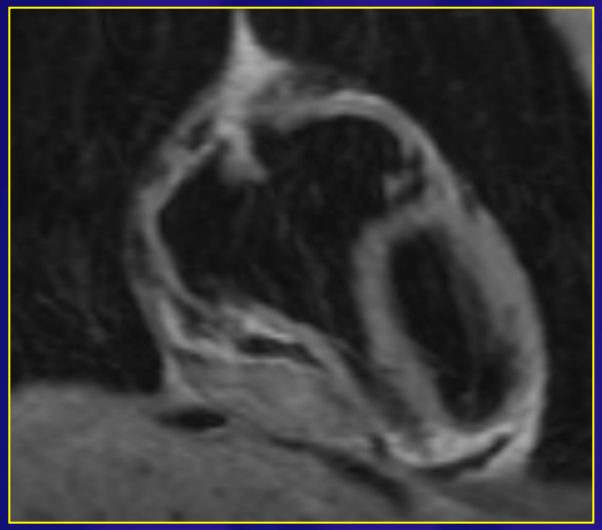
Post operative

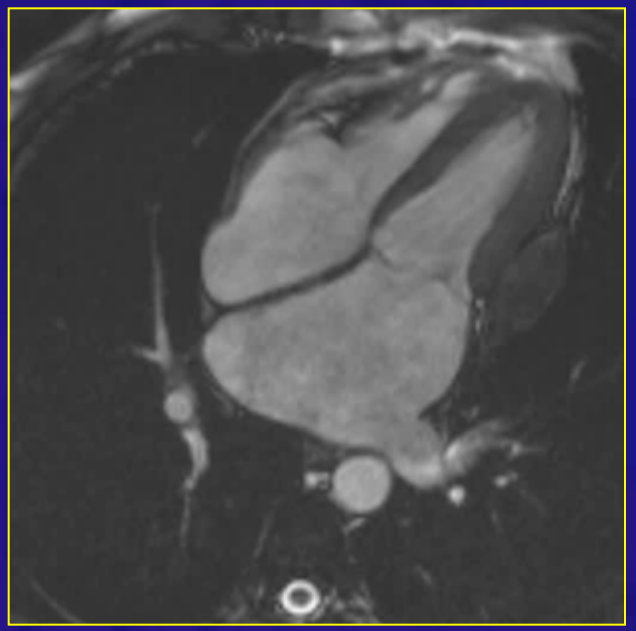


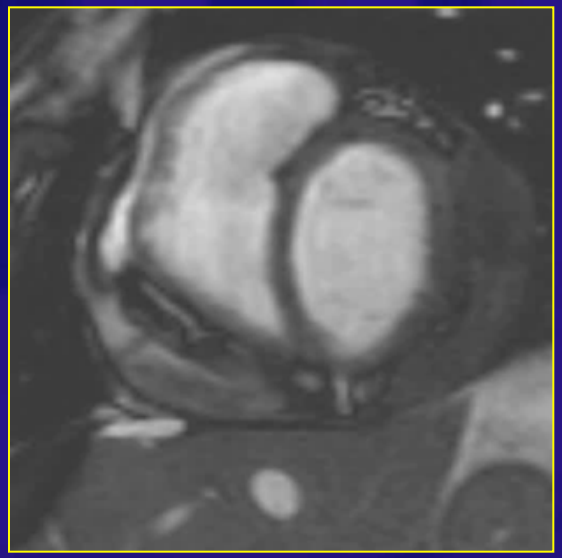
- ***pulmonary thromboendarteriectomy***

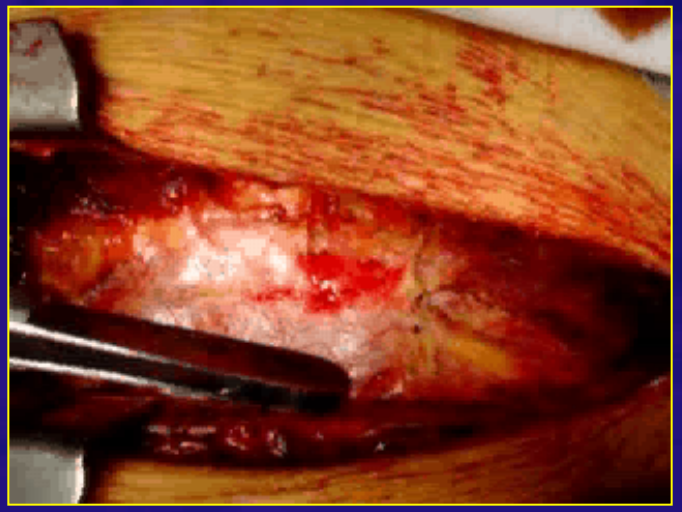


Constrictive pericarditis

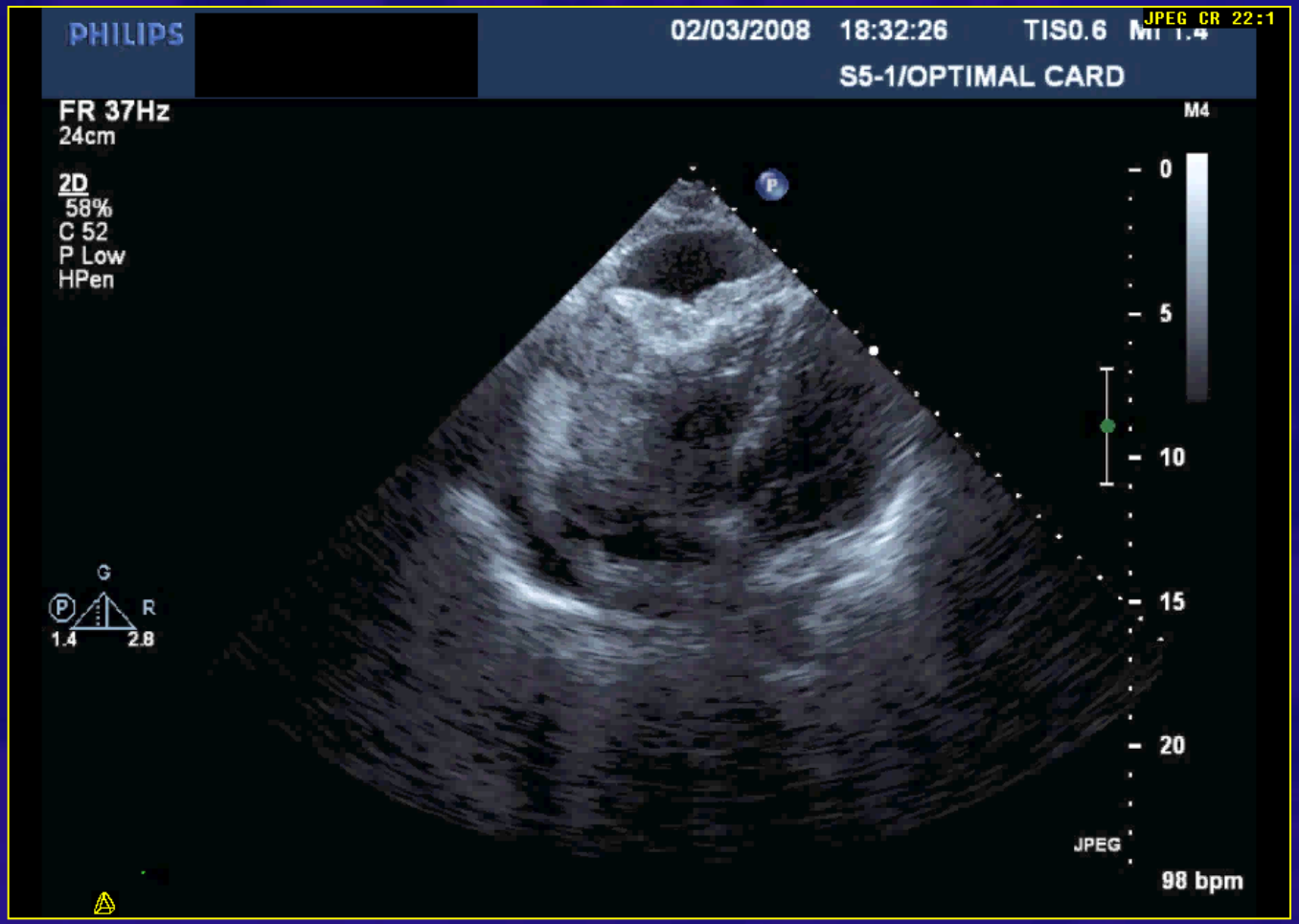




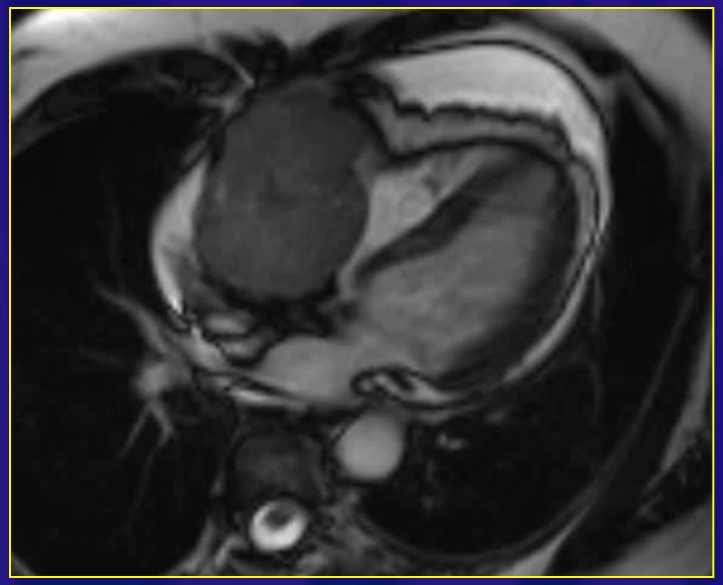


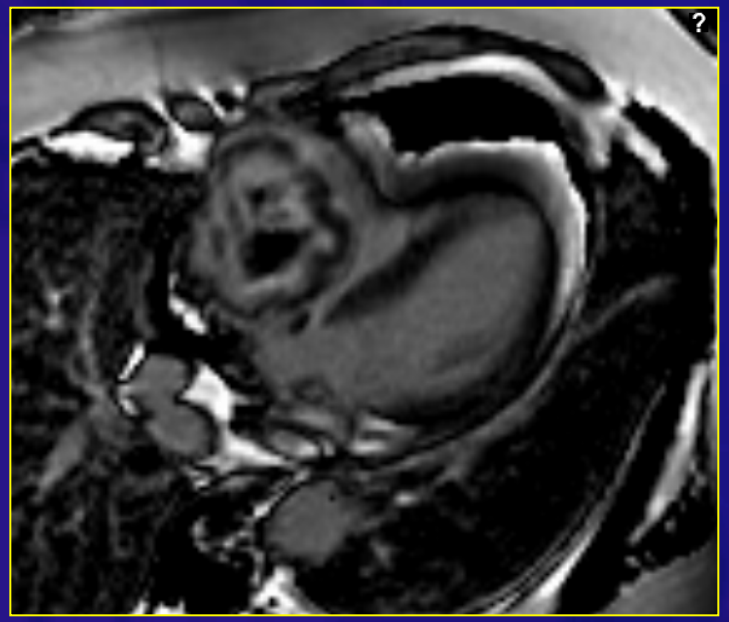


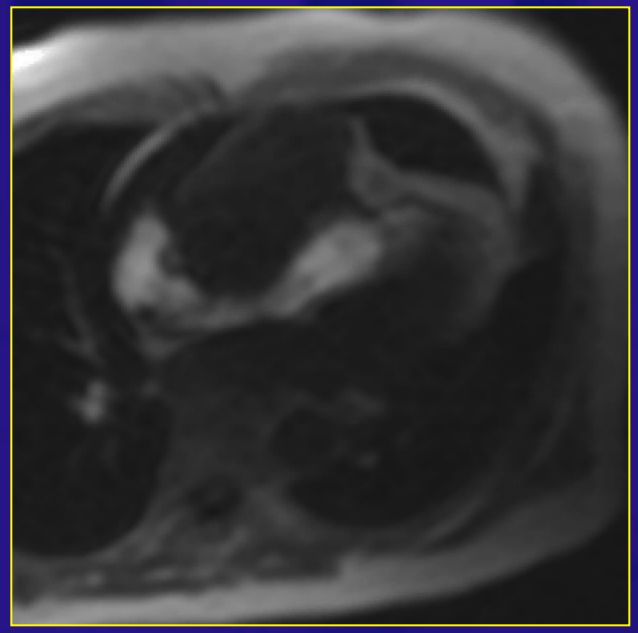
Right mass


PHILIPS
02/03/2008 18:32:26 TIS0.6
JPEG CR 22:1
S5-1/OPTIMAL CARD
FR 37Hz
24cm
2D
58%
C 52
P Low
HPen
M4
0
5
10
15
20
G
P
R
1.4
2.8
JPEG
98 bpm

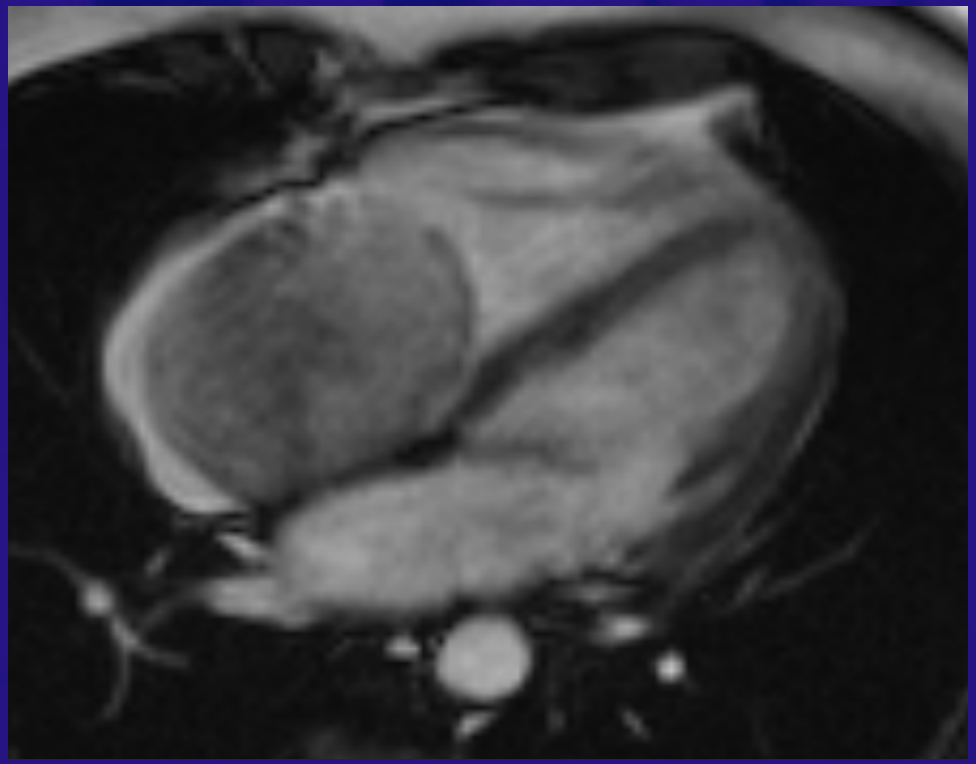
PARAGANGLIOMA

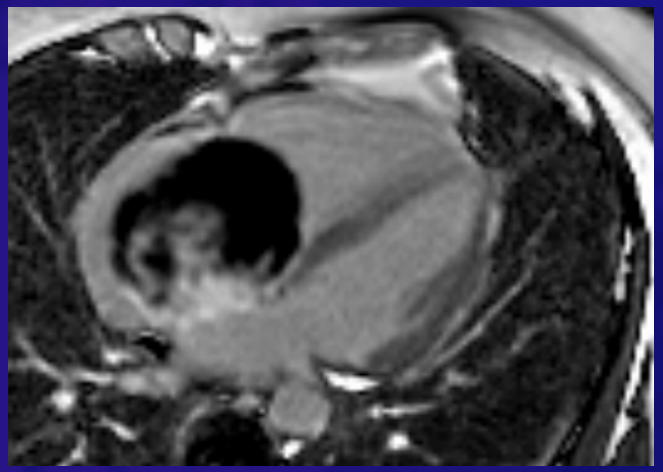


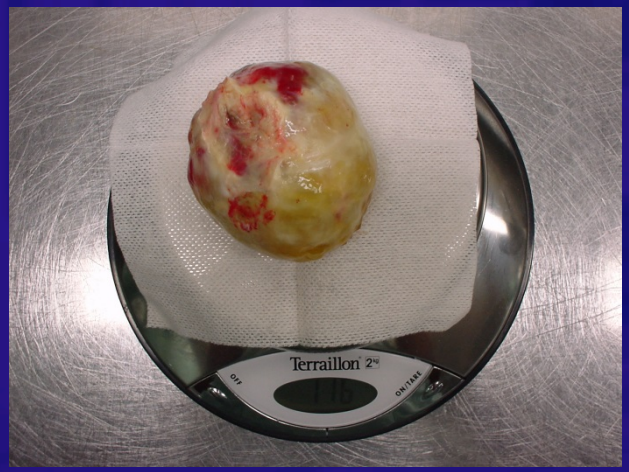




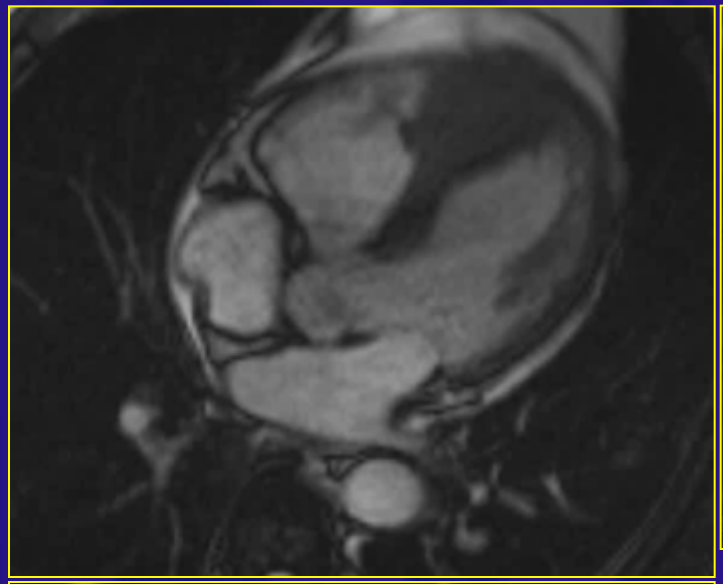
RIGHT ATRIAL MIXOMA

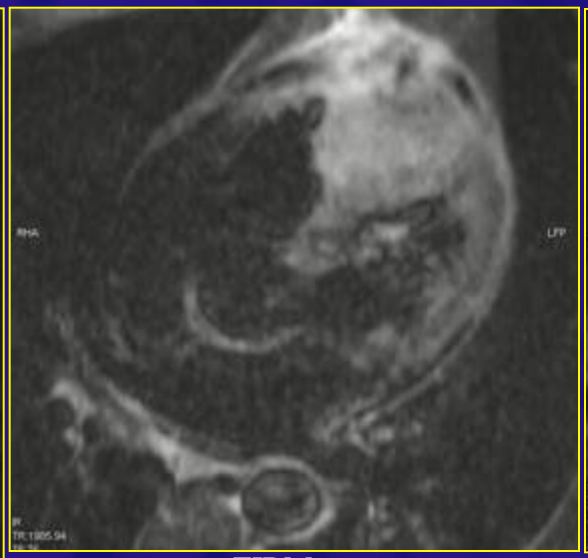




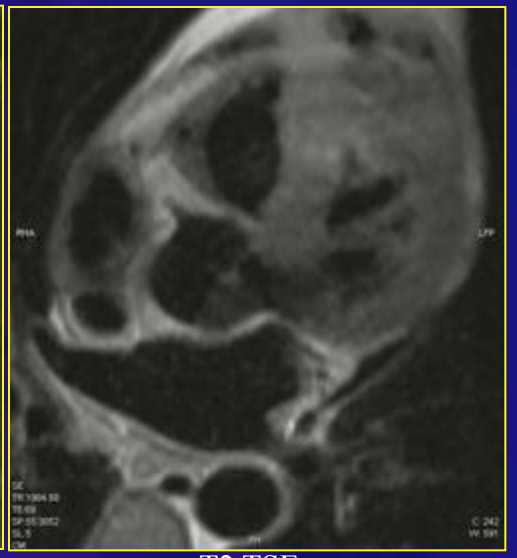


Cardiac Tumor

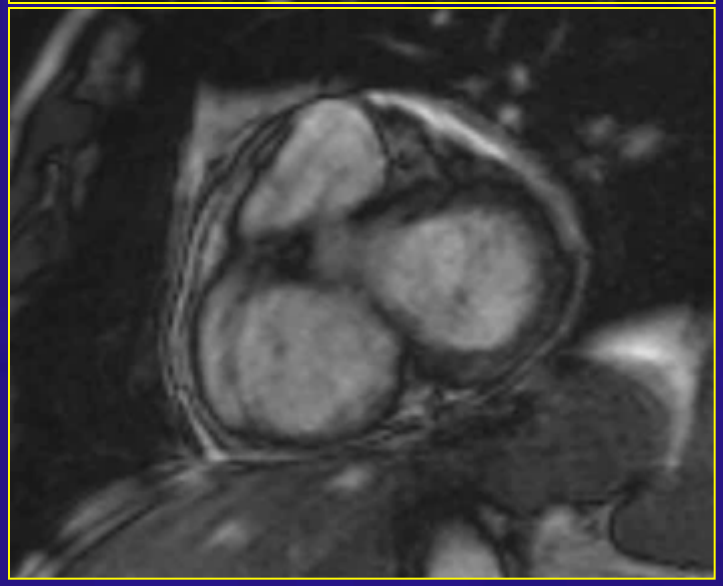




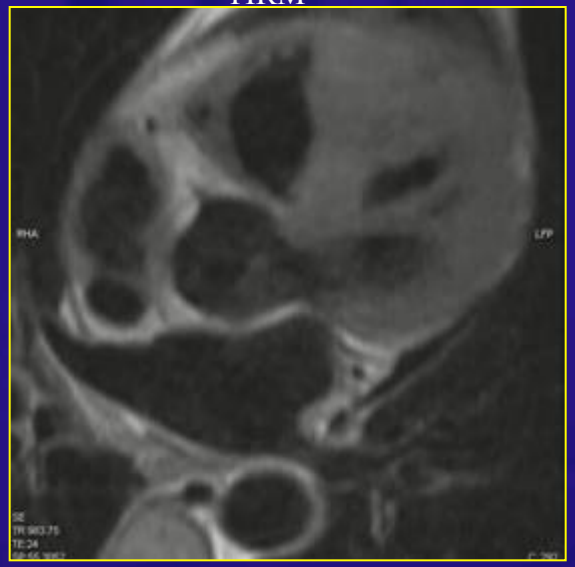
TIRM



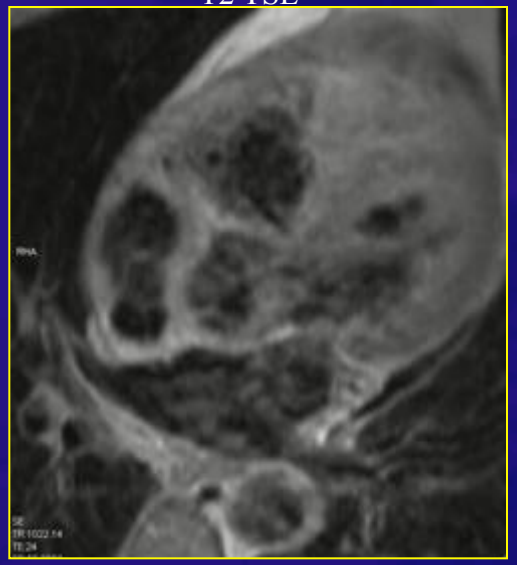
T2 TSE



M 73 y



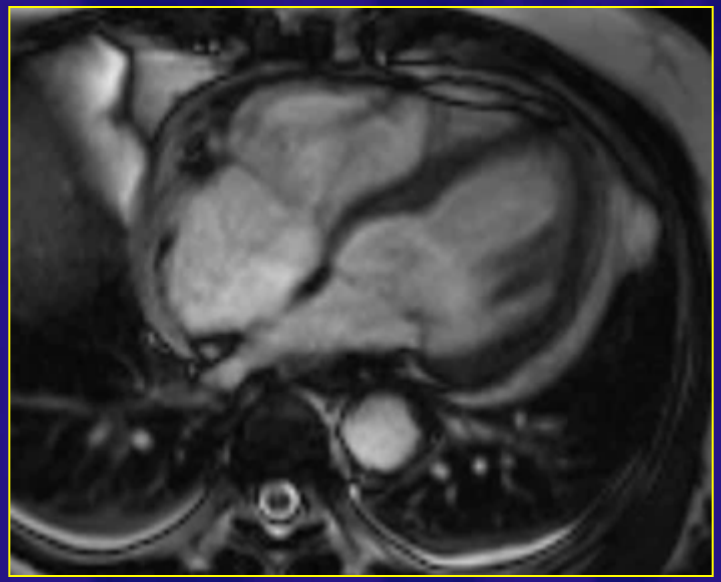
T1 TSE

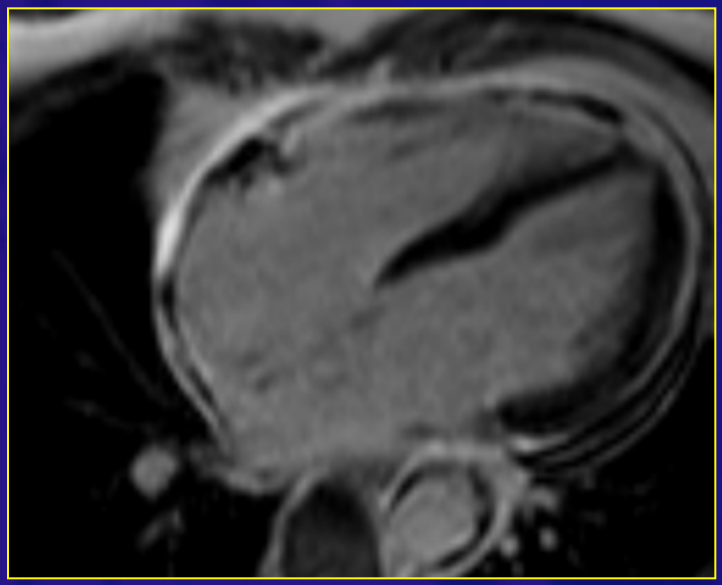


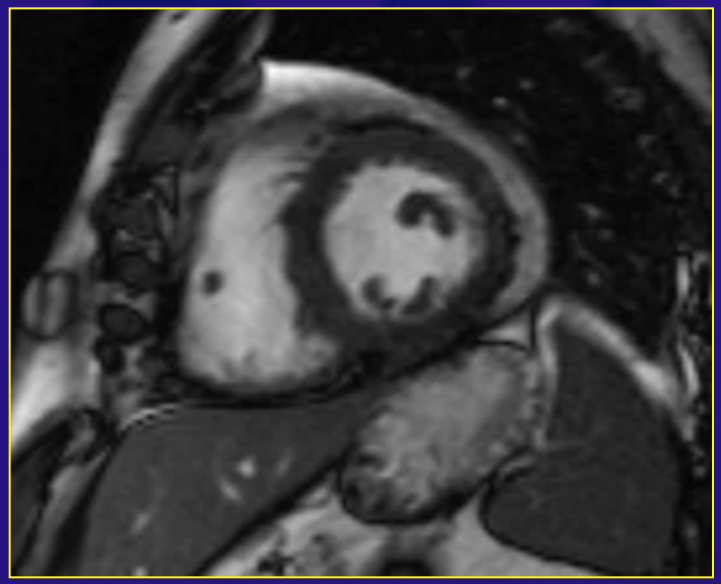
GD T1 TSE

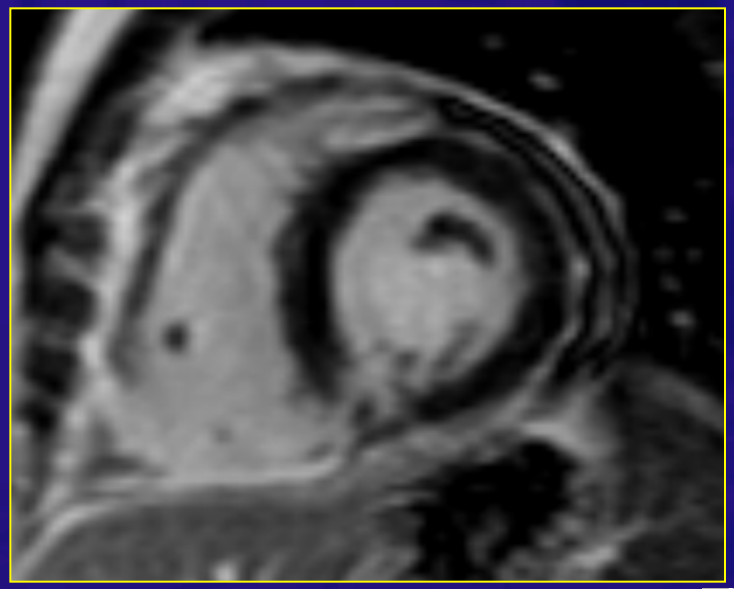
The ischemic

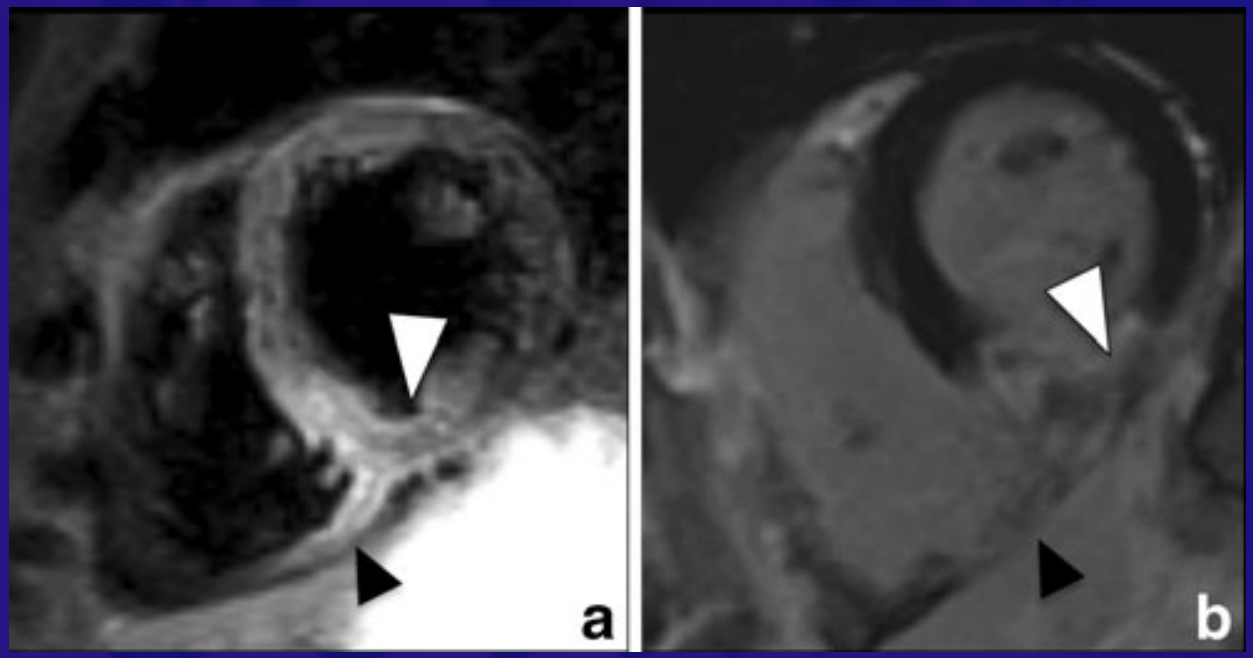
RV myocardial infarction

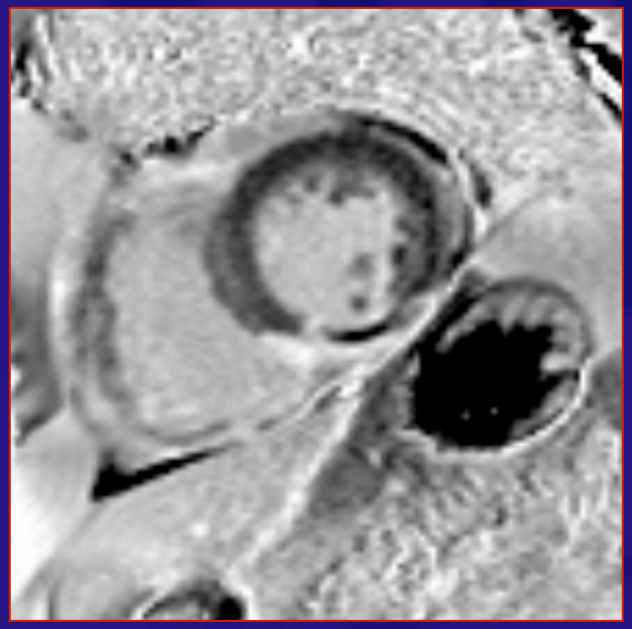








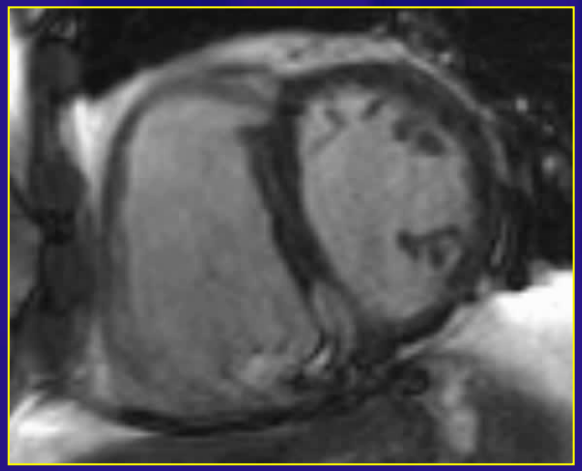


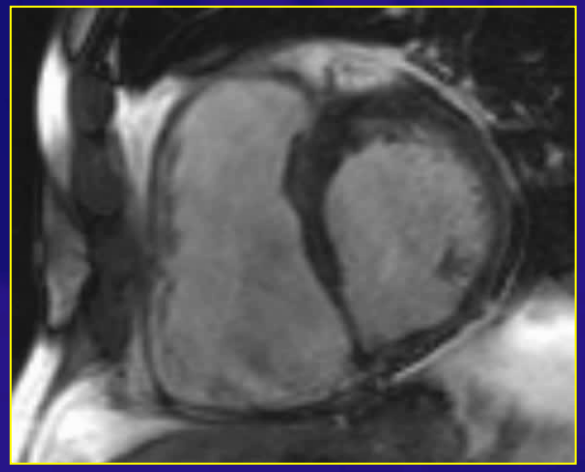


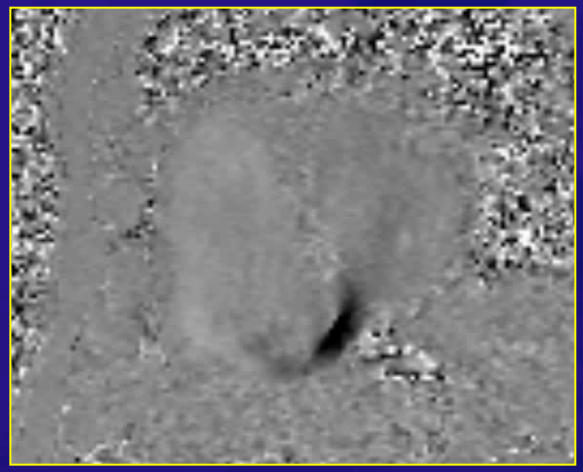
Oedema
and MVO

Myocardial Infarction Complications : VSD

SEPTAL RUPTURE



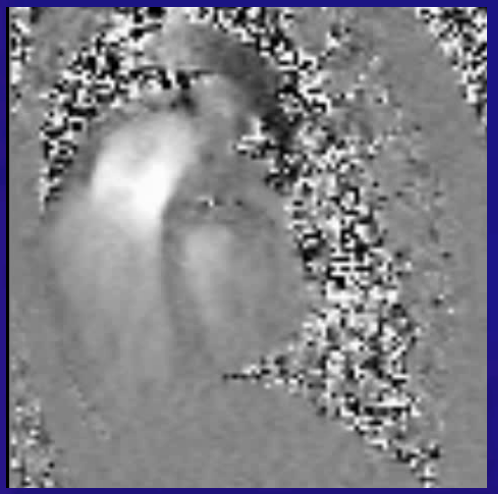




The « congenital diseases »

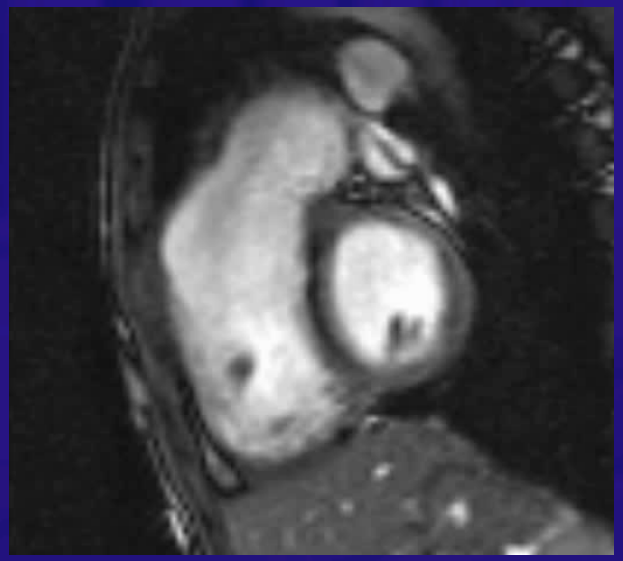
Tetralogy of Fallot
Post operative follow-up:
- timing of surgical intervention

- *Pulmonary regurgitation*



- Re-intervention (pulmonary prosthesis) if
RVEDV > 160 ml/m²
RVESV > 80 ml/m²

- Anatomy of pulmonary branches



RF 63%

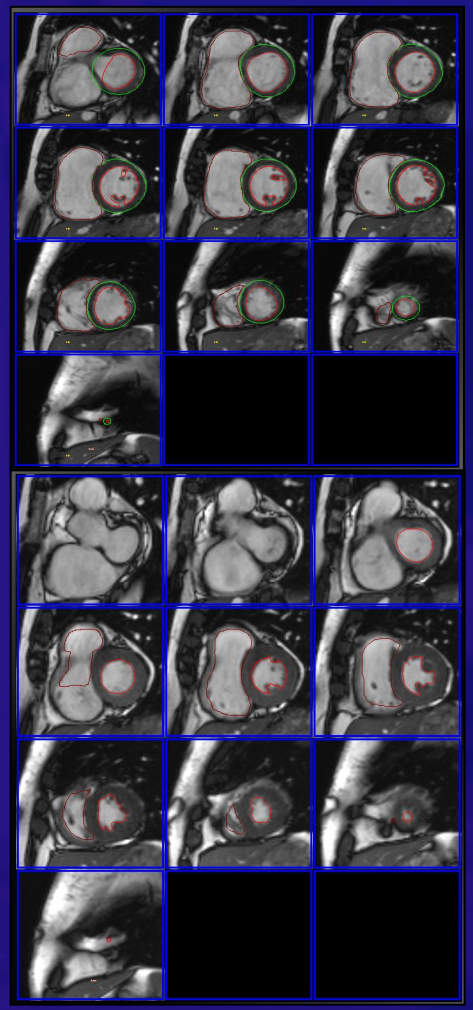
Tetralogy of Fallot

Post operative follow-up:

- timing of surgical intervention (the must or CMR)

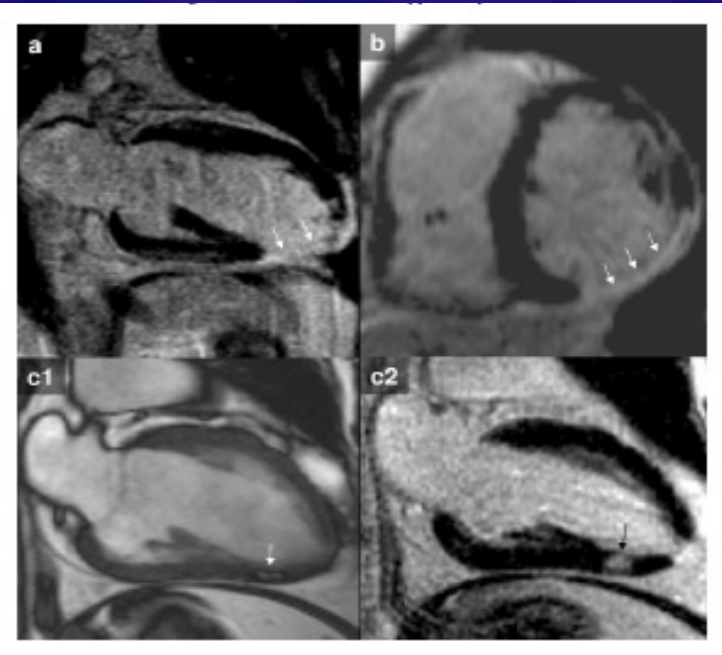
- *The degree of RV dilatation secondary to chronic volume load*

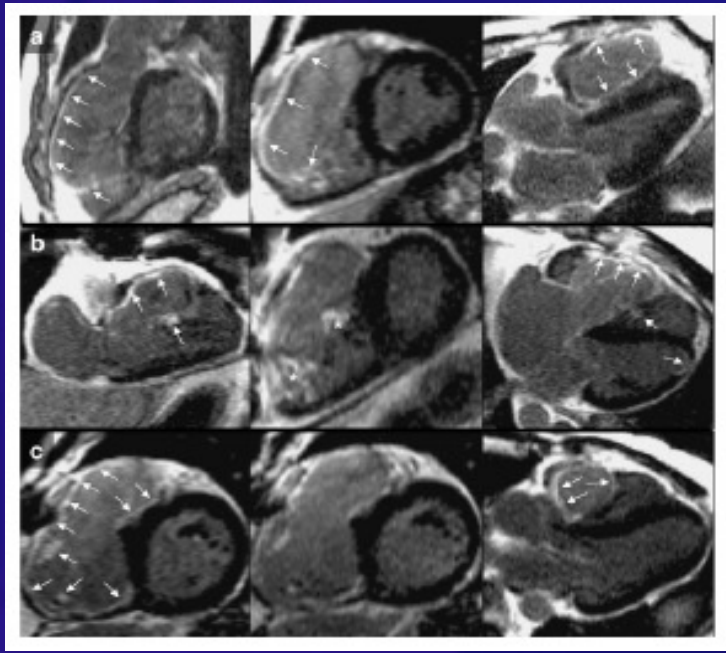
  - RV function and volumes
  - Follow up of aortic regurgitation and sub valvular aortic membranes



Tetralogy of Fallot

Myocardial viability

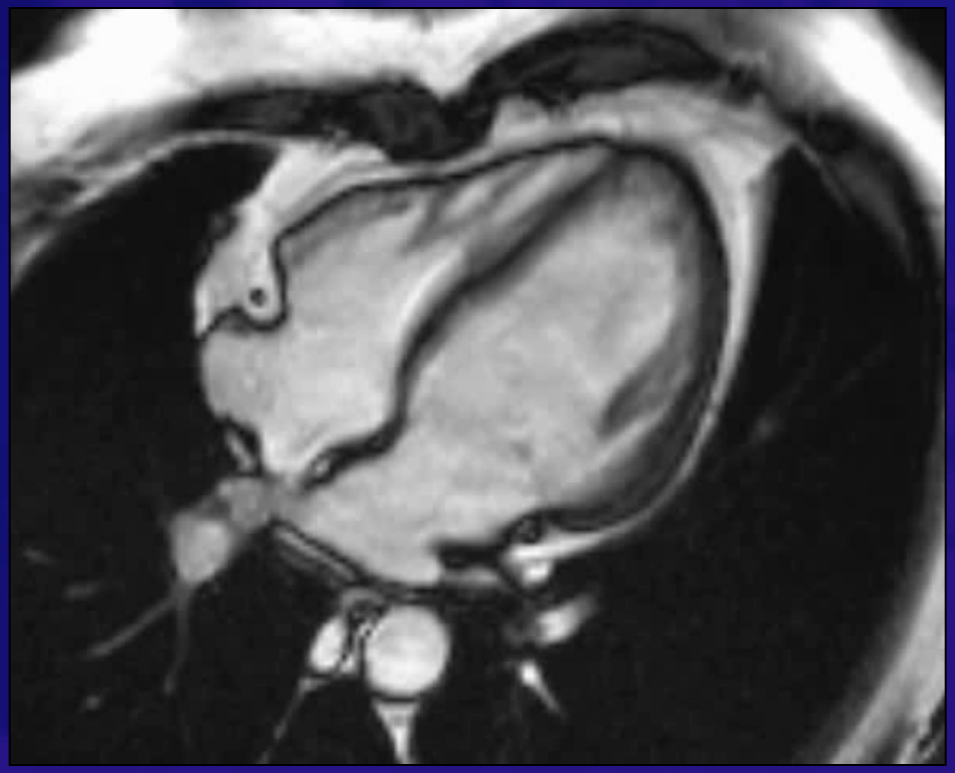




Ventricular fibrosis like a marker of adverse clinical outcome

CIRC 2008

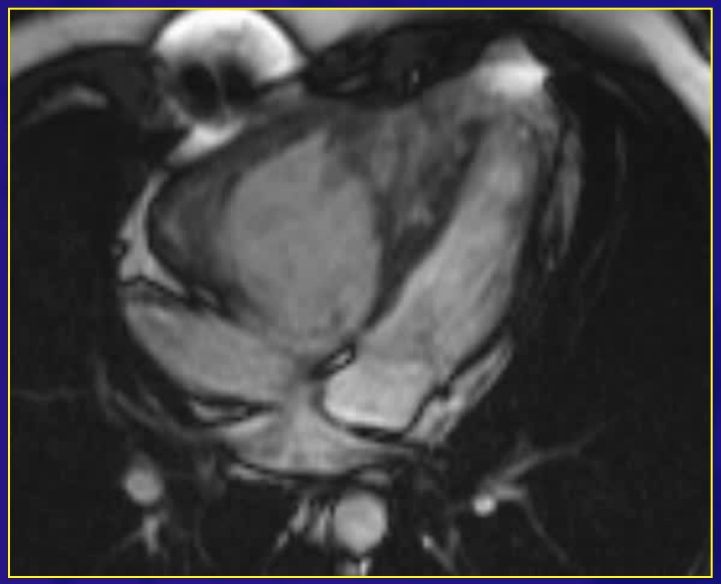
TGA: arterial switch

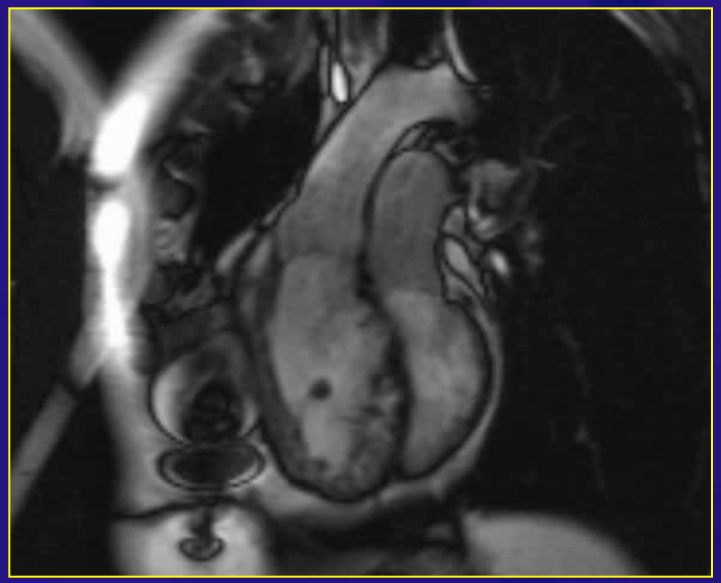


Follow the LV and RV volumes and EF

Mustard for TGA

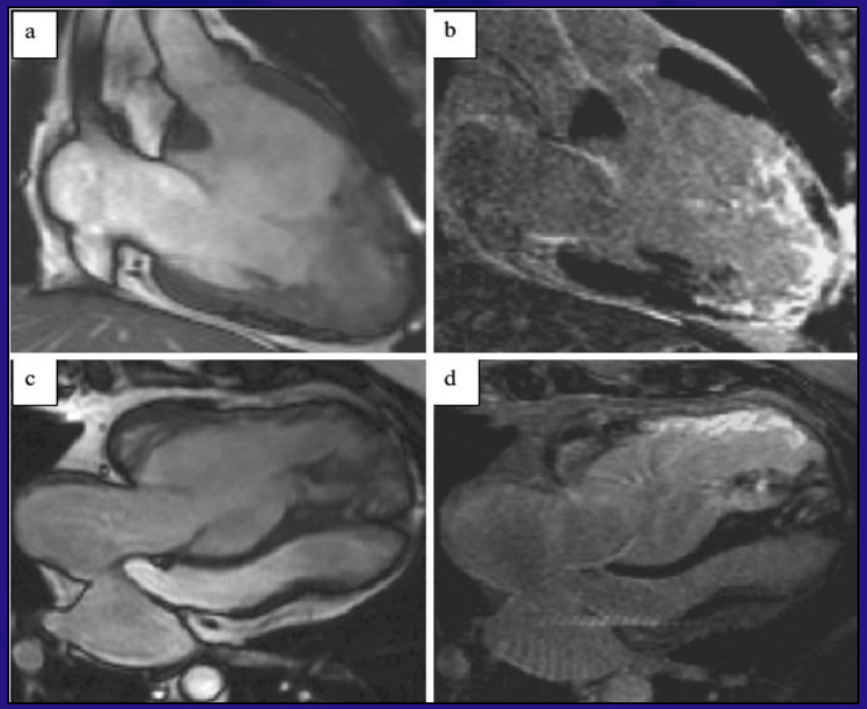
- 34 y man
- Mustard at 1y
- asymptomatic

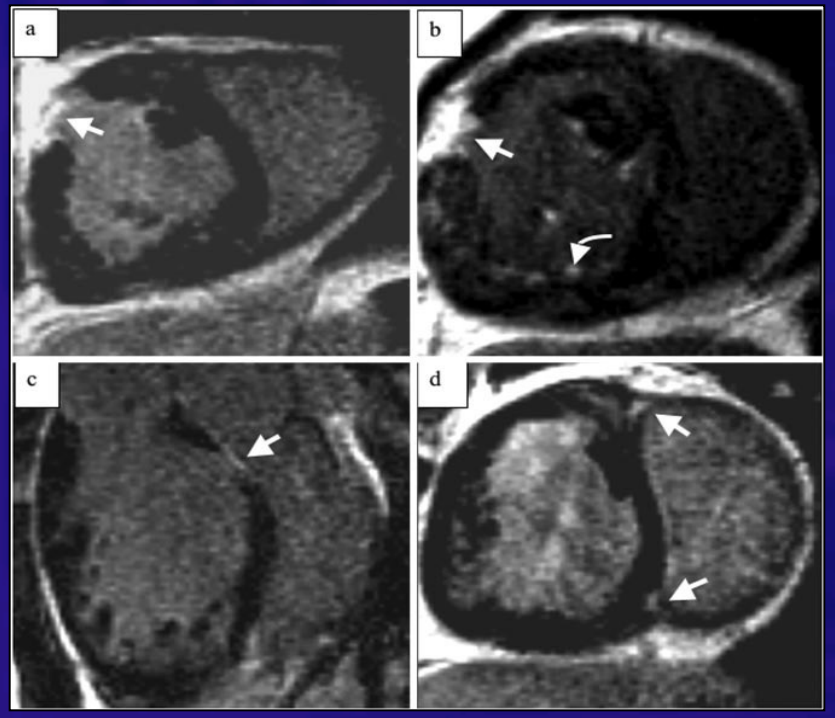




RV:
EF 42%
EDVI 110 ml/m²
ESVI 64 ml/m²

Late enhancement fibrosis like negative prognostic value





CIRC 2008

Double outlet RV

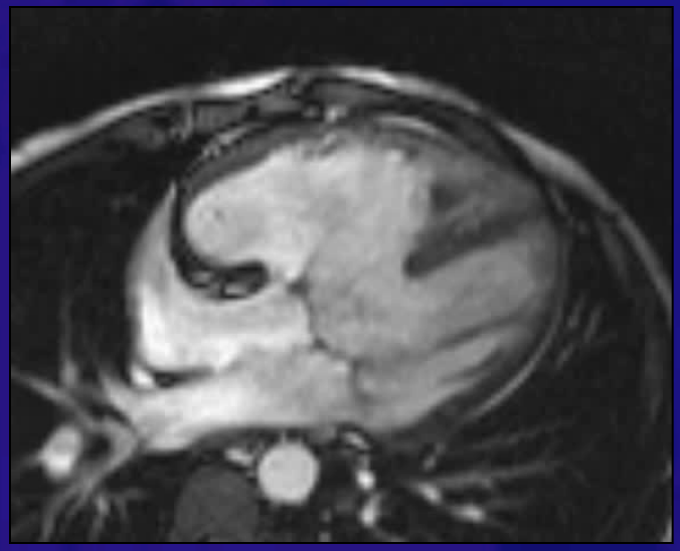
RV is enlarged with huge VSD in the inlet segment

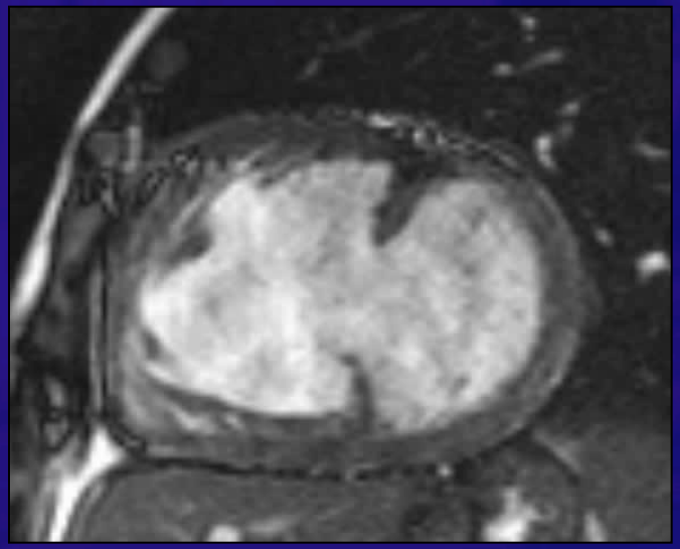
Double outlet right ventricle

Mitral valve regurgitation

A-V concordance

No overriding or straddling of TV and MV



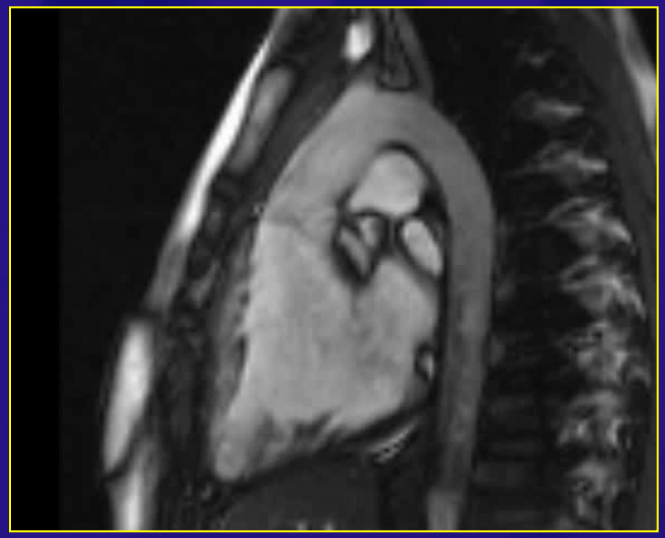


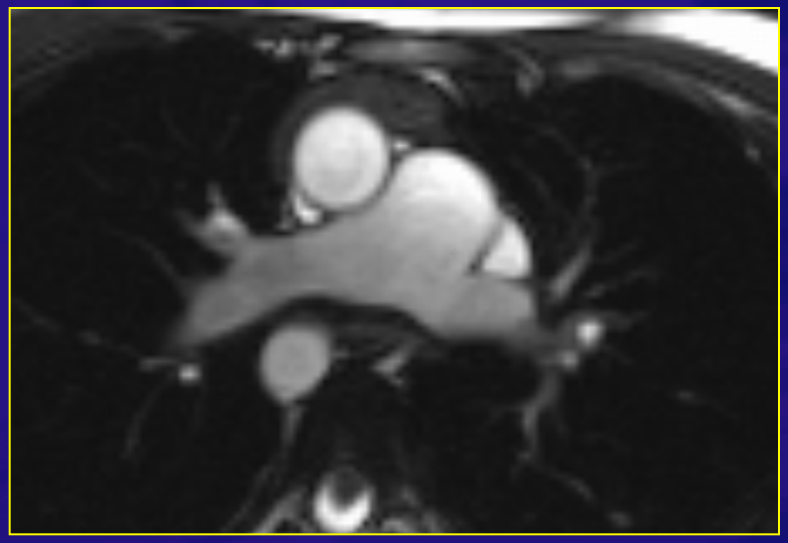
DOUBLE DISCORDANCE

- Fonction of systemic right ventricle
- Study of tricuspid regurgitation
- Study of pulmonary branches

LV-pulm

RV-aorta

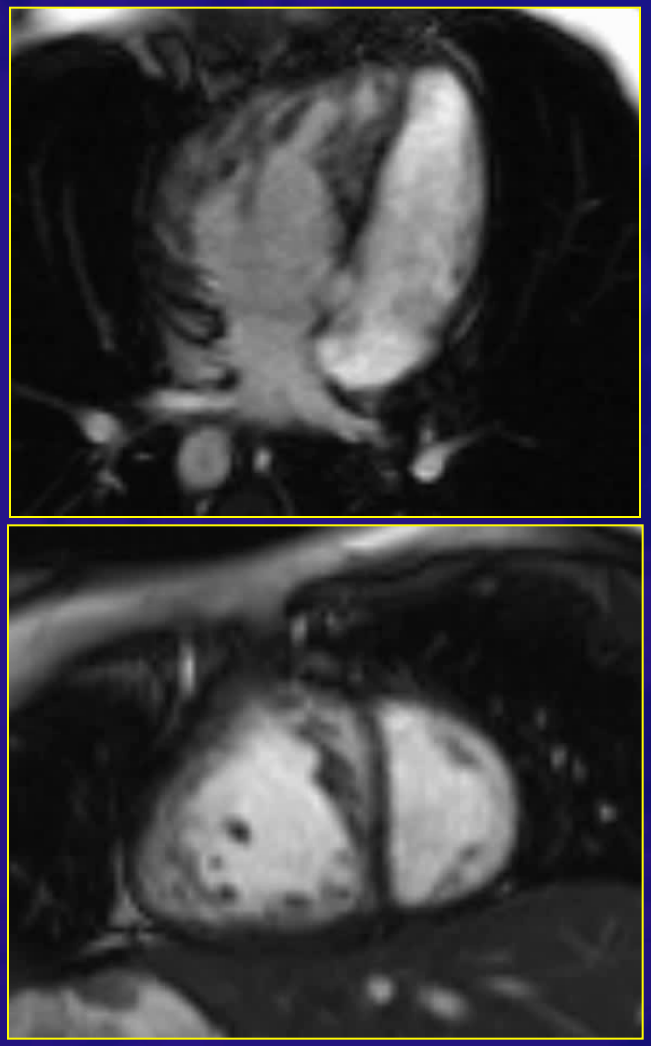




DOUBLE DISCORDANCE

- 11 y boy, asymptomatic.
- Situs inversus
- Levocardie.

RV – EF 40%
EDVI 86 ml/m²
ESVI 51ml/m²



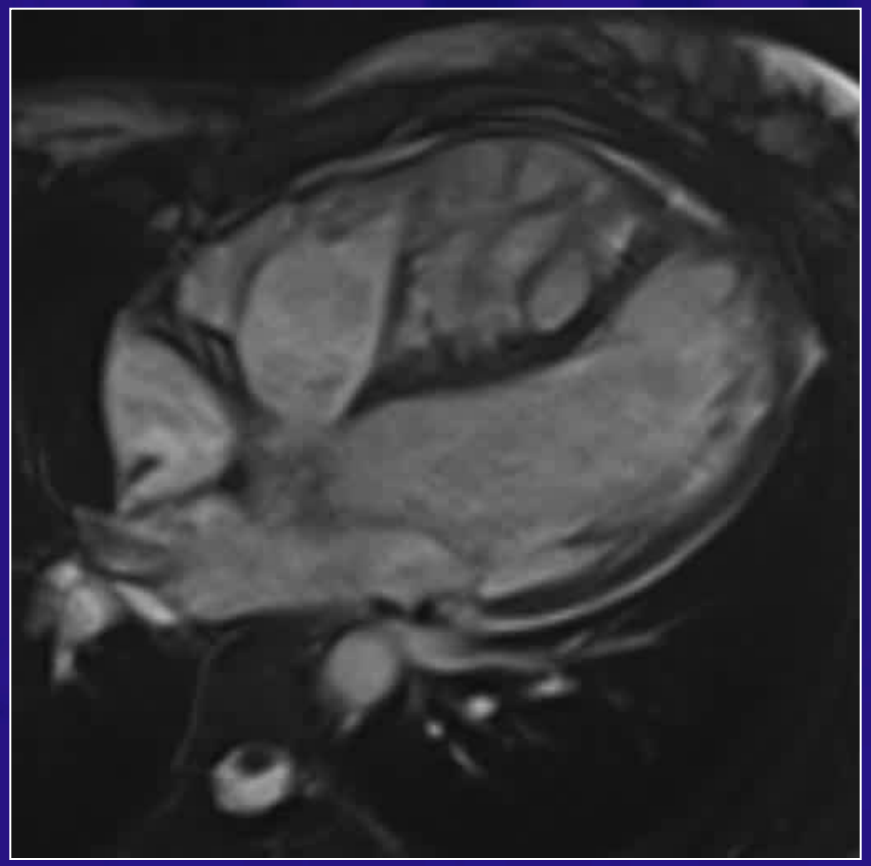
Echography: trabeculation of RV apex : diagnosis of non compaction ?

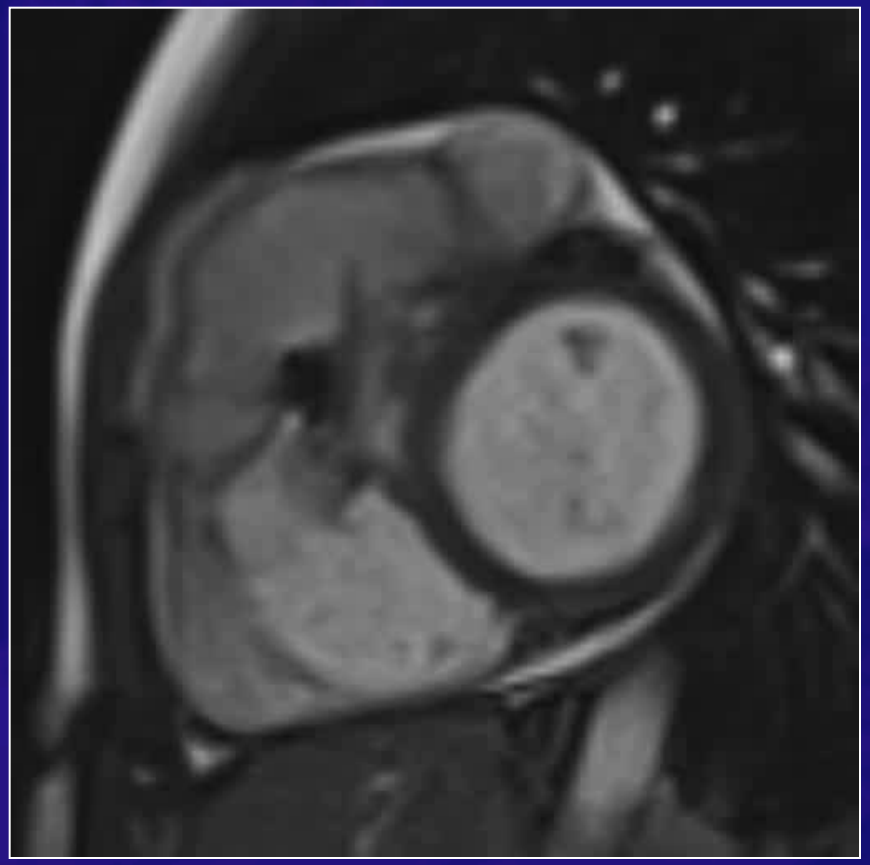
Mlle CH…

jan 2011

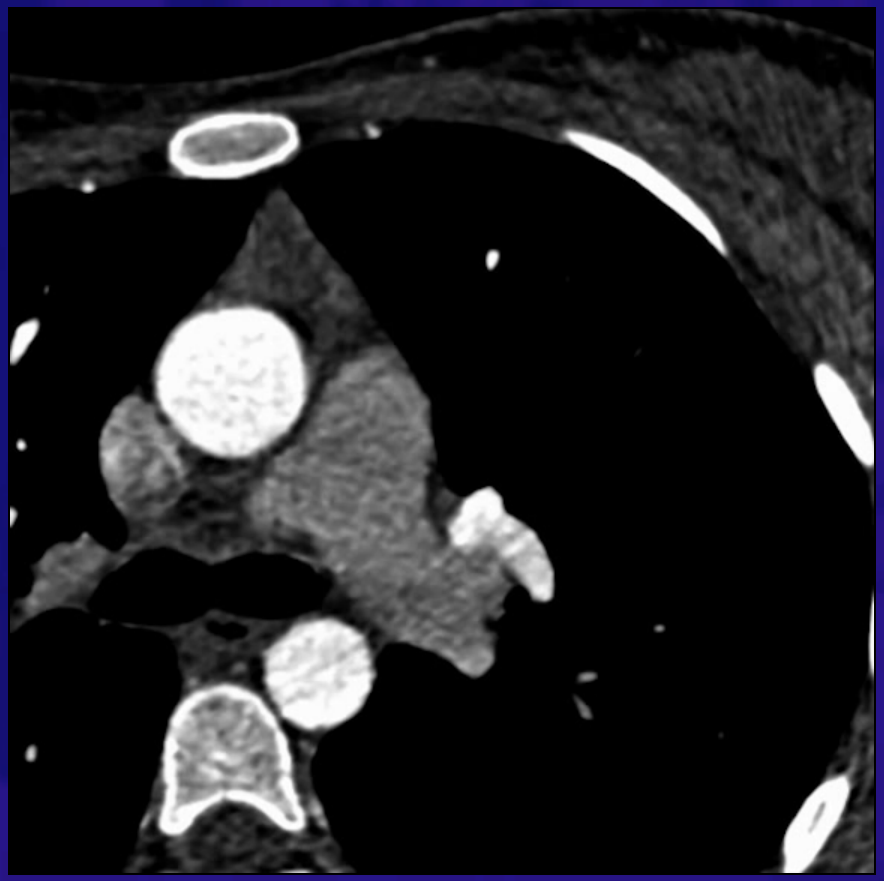
MRI: no *non compaction* RV

but « marecageuse » or swampy aspect of apex due to residual non fonctional fistula

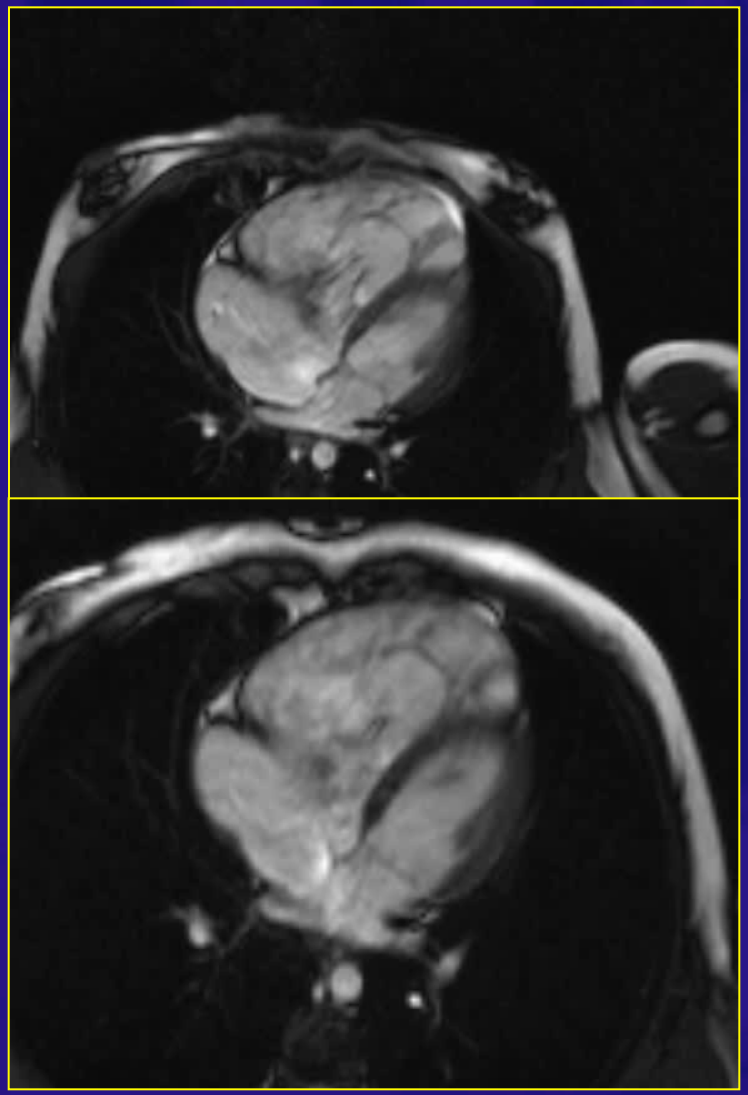


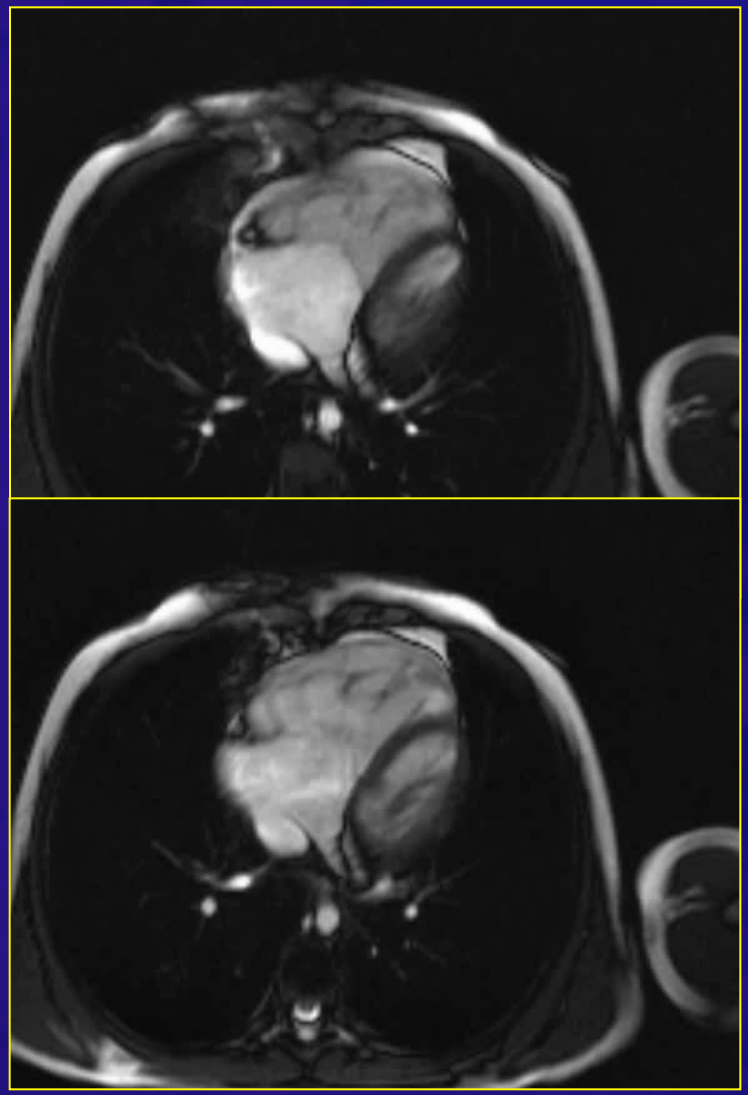


Msct axial

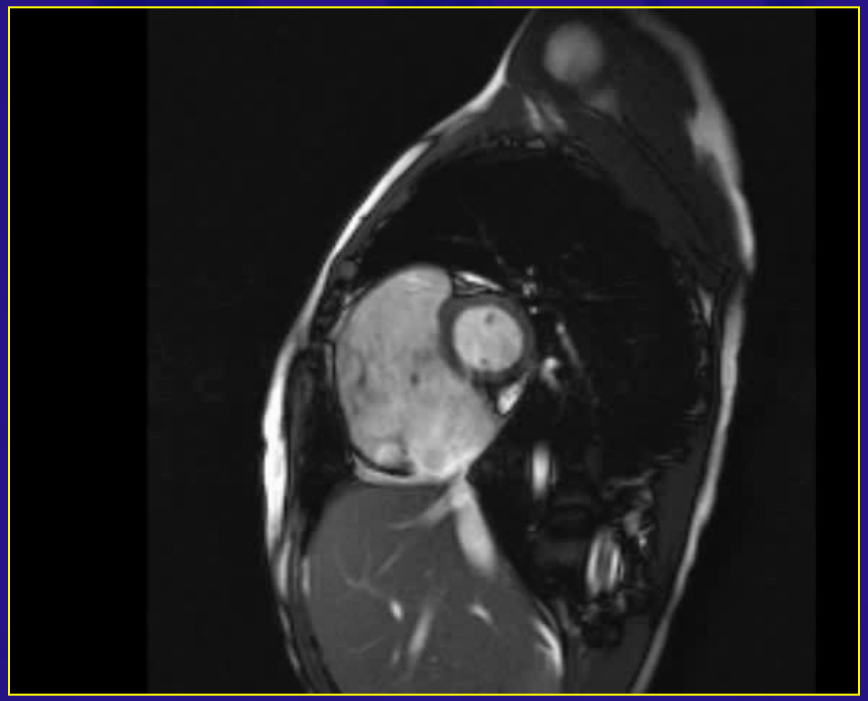


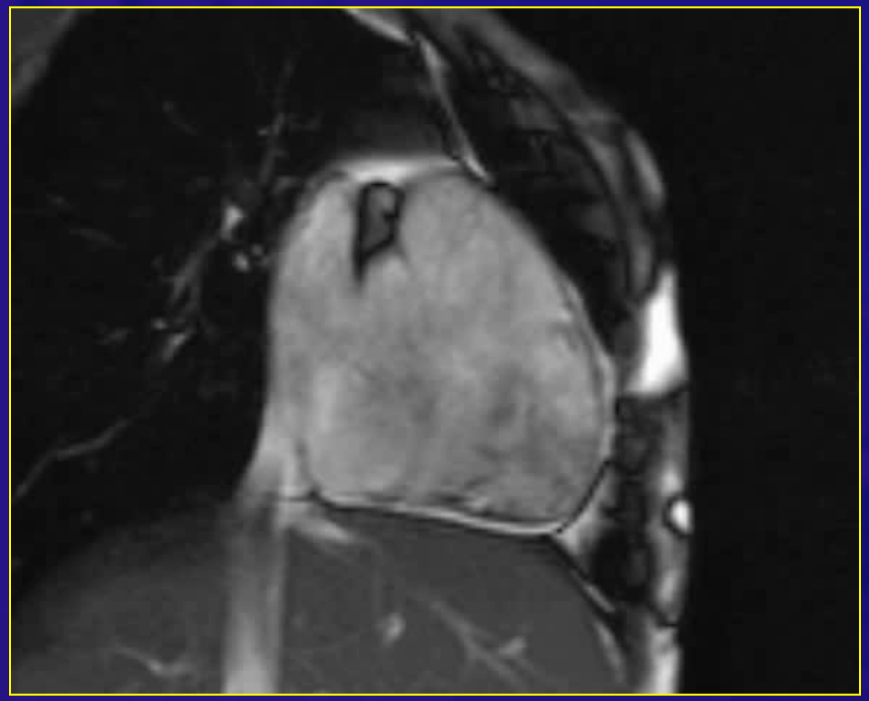
Ebstein



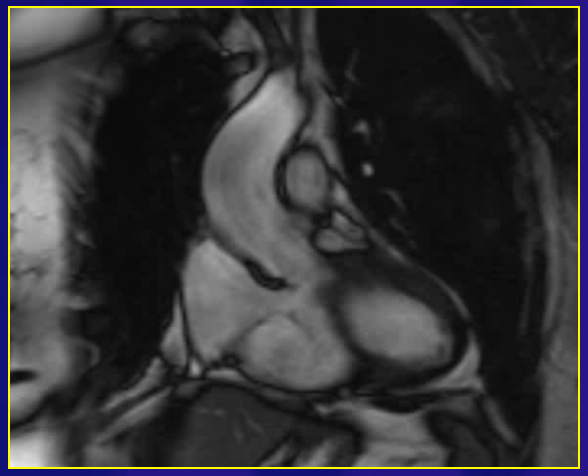


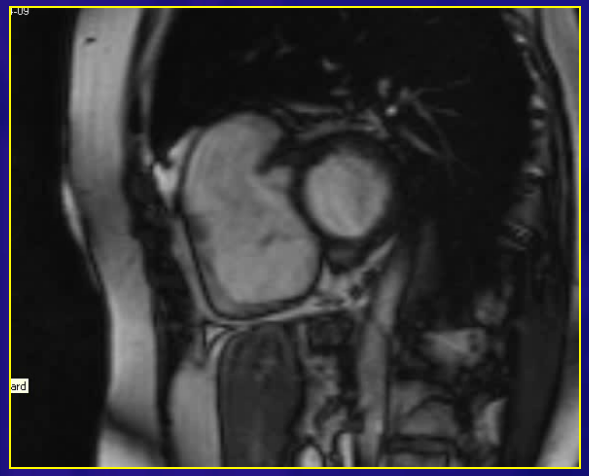
Ebstein

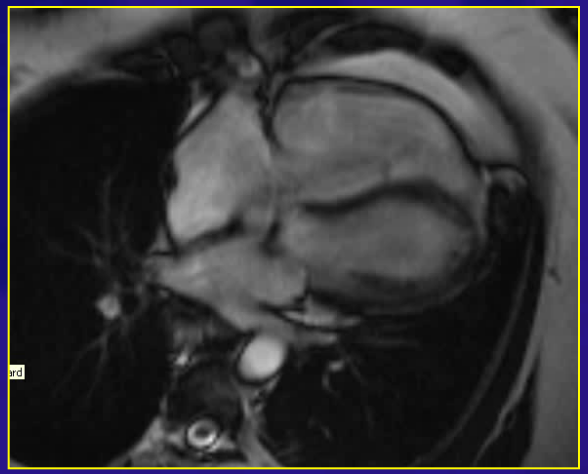


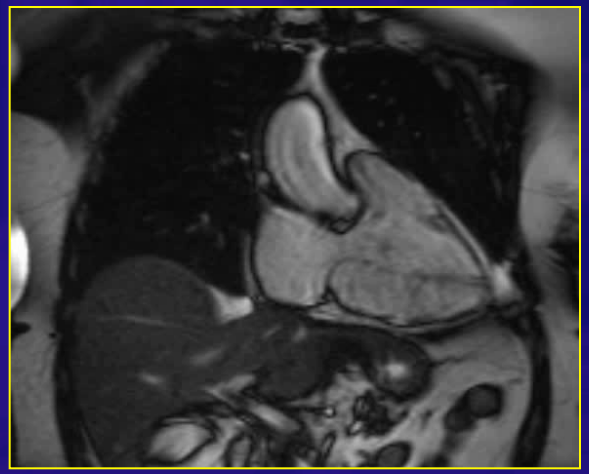


Ebstein's correction

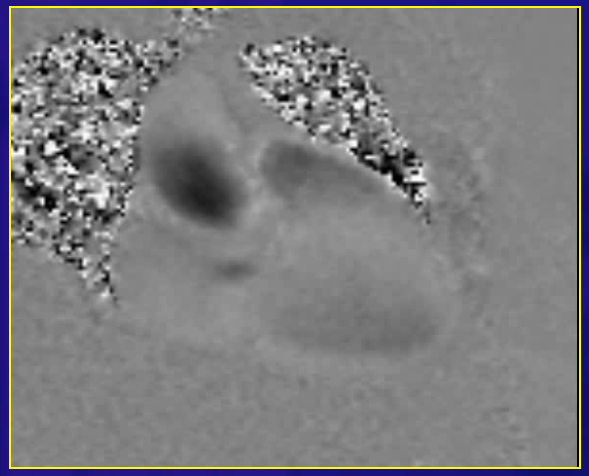


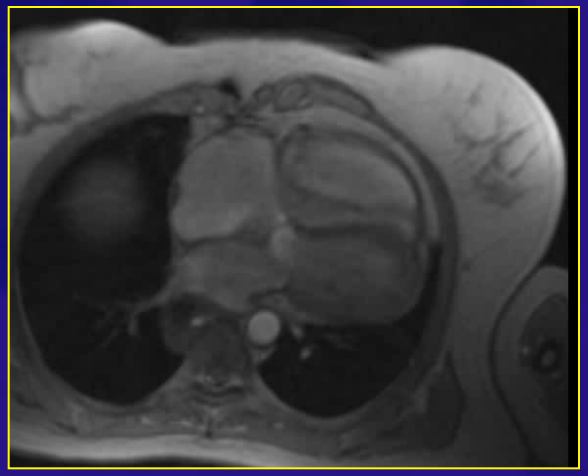


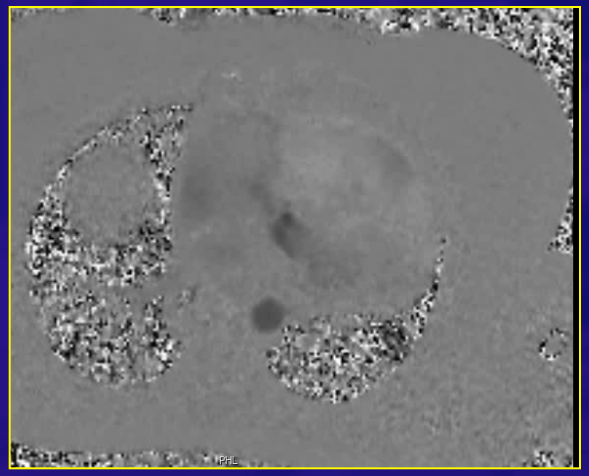




Ebstein's correction



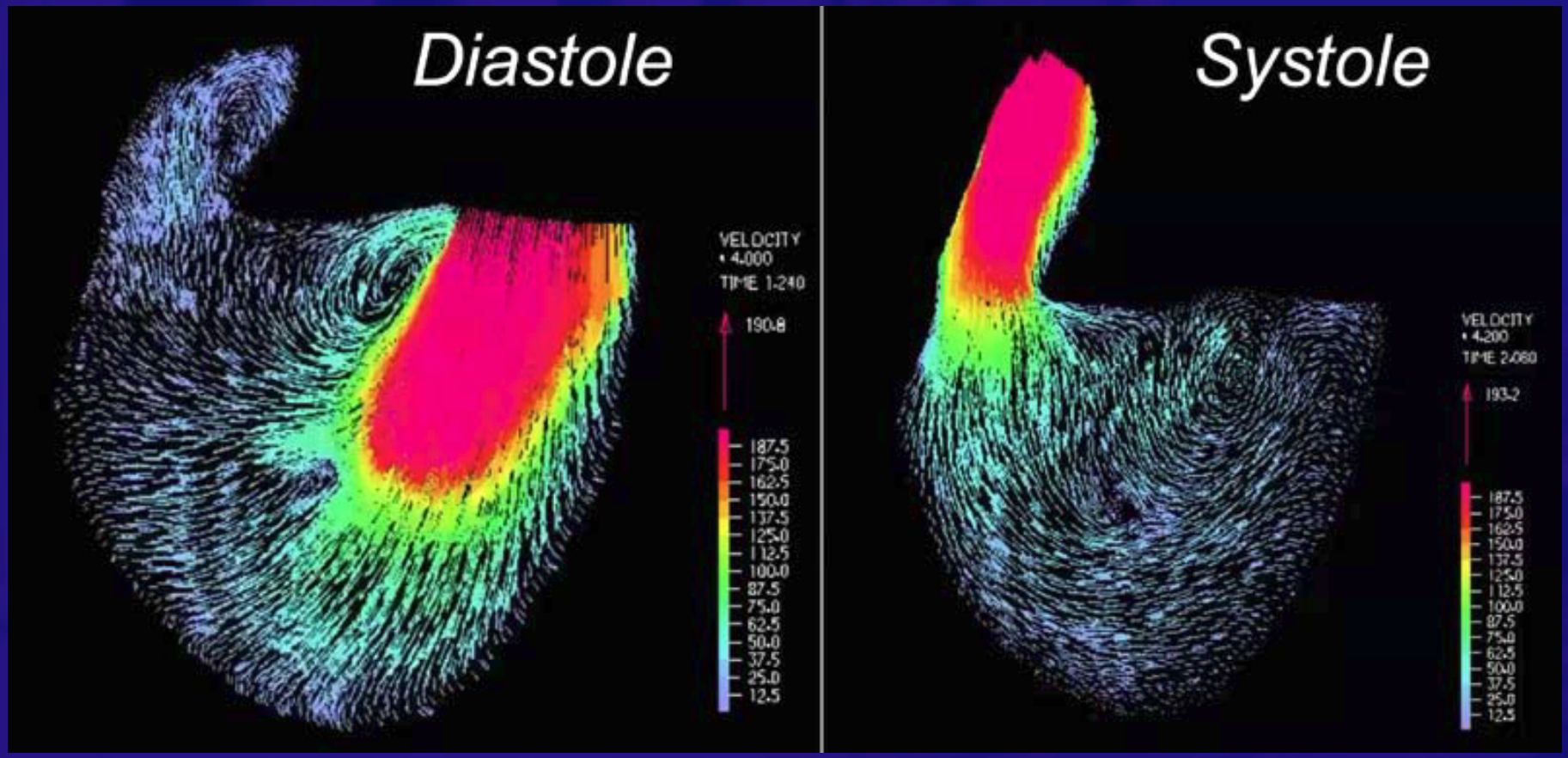




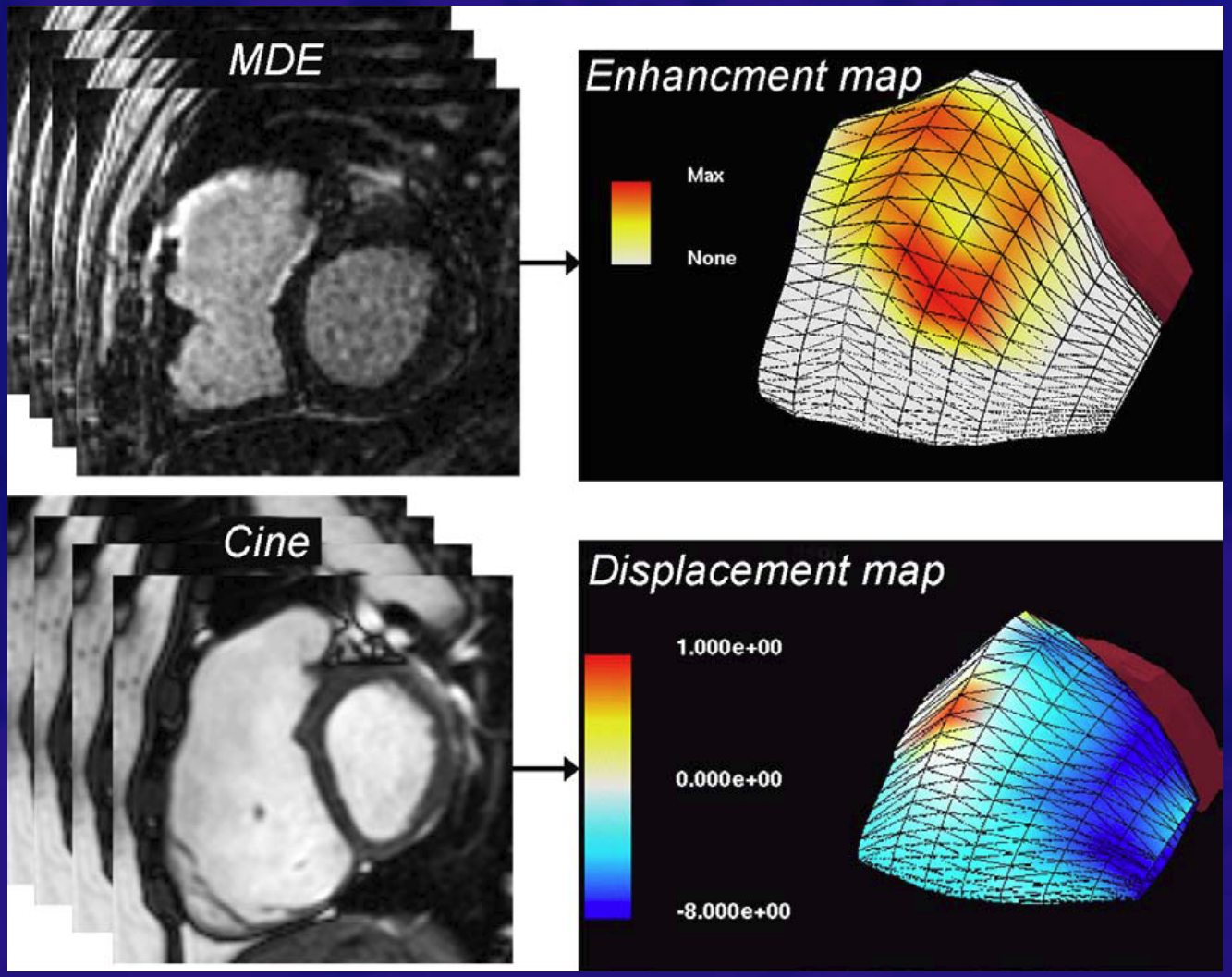
TAKE HOME MESSAGES

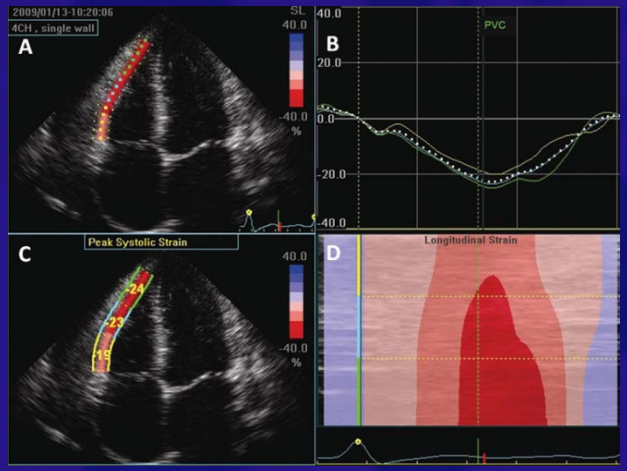
- *Imaging the RV remained clinically challenging*
- *Difficult because of complex structural geometry of RV*
- *MRI is considered the gold standard*
- *3D echocardiography accurate alternative*
- *2D echocardiography good visual assessement in clinical daily practice (TAPSE)*
- *Cath lab. and MSCT*

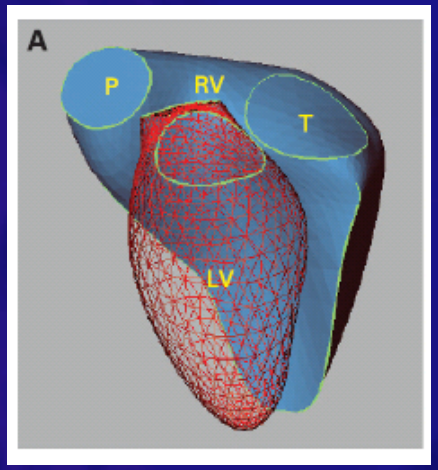
The future


Diastole
VELOCITY
• 4.000
TIME 1.240
190.8
187.5
175.0
162.5
150.0
137.5
125.0
112.5
100.0
87.5
75.0
62.5
50.0
37.5
25.0
12.5
Systole
VELOCITY
• 4.200
TIME 2.080
193.2

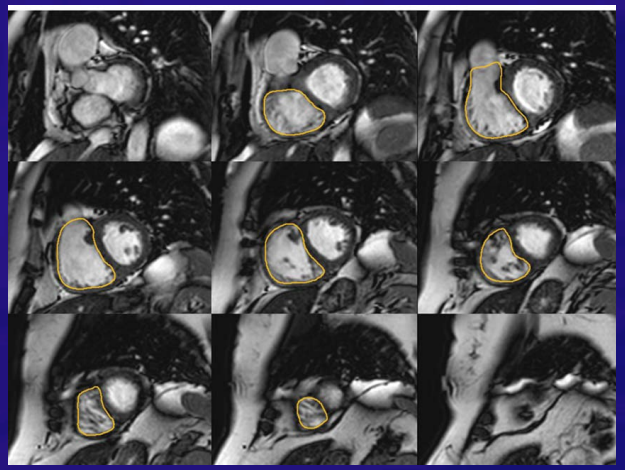
Mapping


MDE
Enhancment map
Max
None
Cine
Displacement map
1.000e+00
0.000e+00
-8.000e+00





MULTIMODALITY APROACH



« THUS THE RIGHT VENTRICLE MAY BE SAID TO BE MADE FOR THE SAKE TO TRASMITTING BLOOD THROUGH THE LUNGS, NOT FOR NOURISHING THEM »

SIR WILLIAM HARVEY 1616

DE MOTU CORDIS