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Exercise Stress Echocardiography

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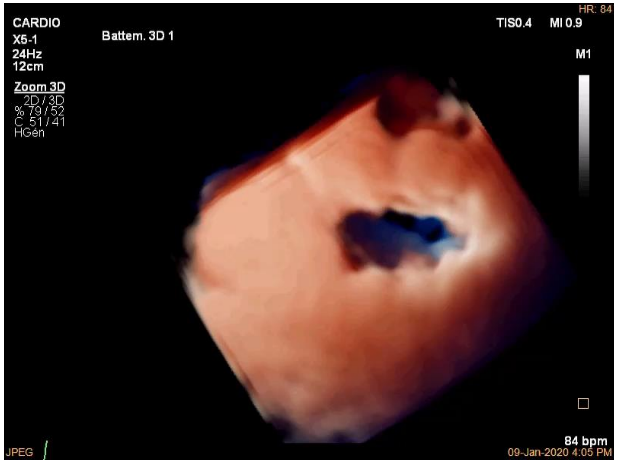
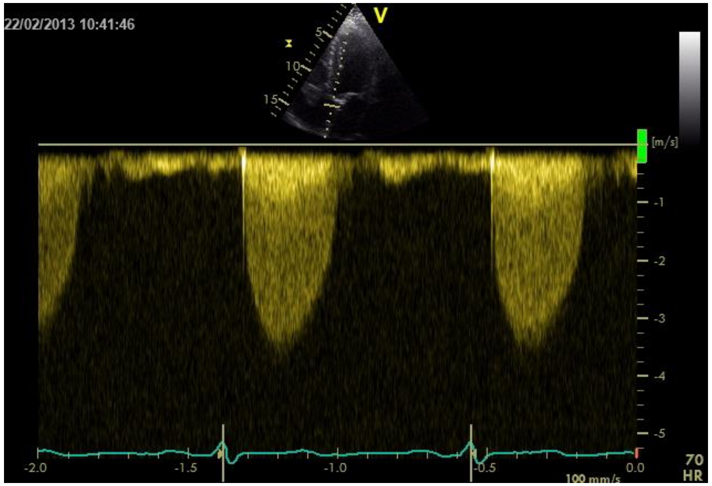
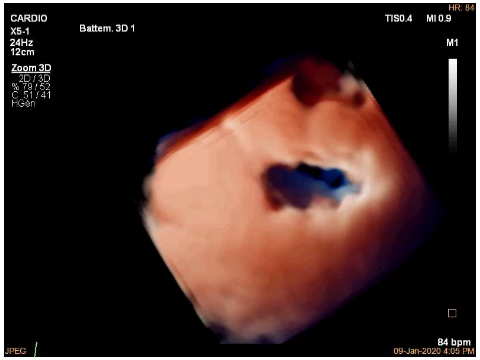
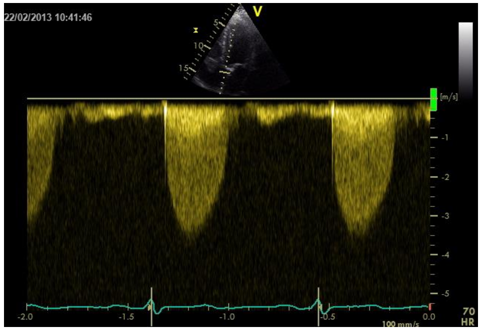


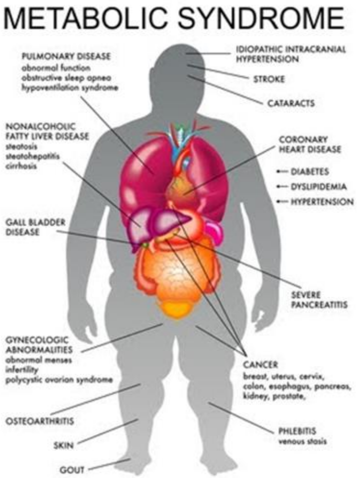
Valvular Heart Disease

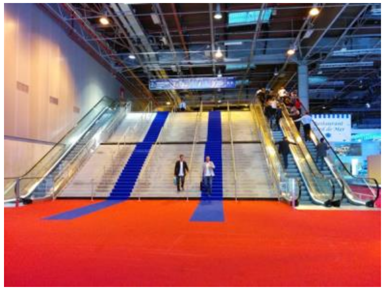


Important issues in patients with VHD









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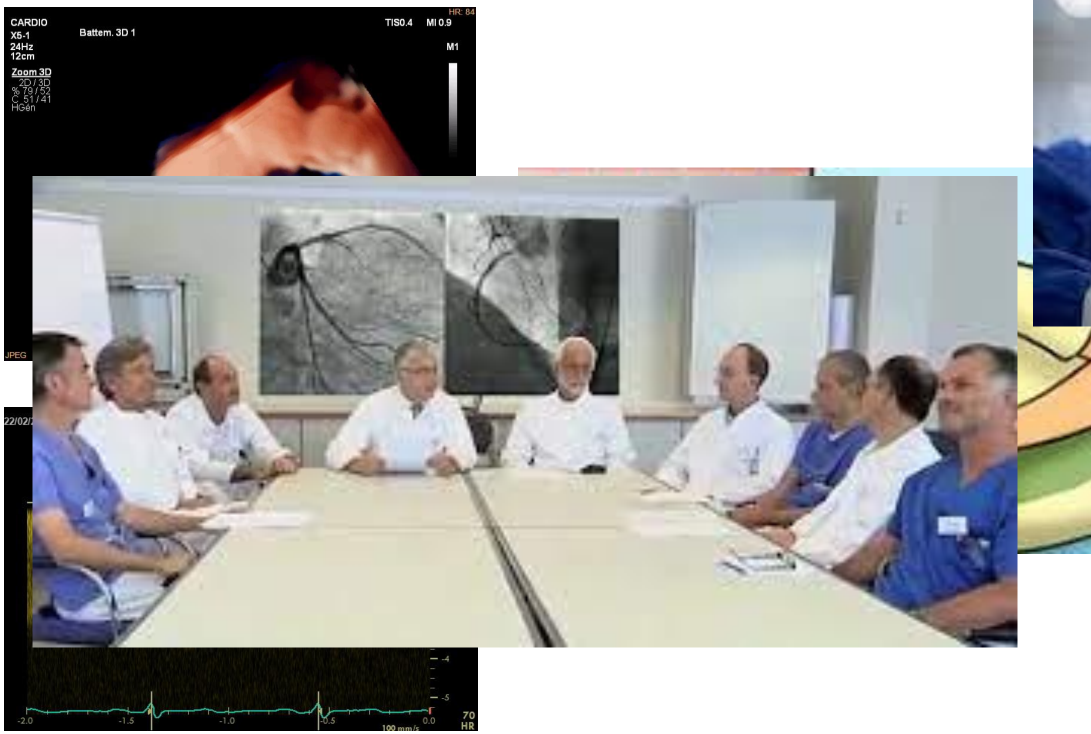
Important issues in p



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Resting evaluation is essential and may be often sufficient

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- **THOROUGH evaluation of symptoms and co-morbid conditions**
- **COMPREHENSIVE resting Doppler echocardiographic examination is only a tool:**
  - **Quantification (severity +++)**
  - **LV remodeling and function**, right ventricle and PASP
  - Mechanisms (and thereby repair faisability)+++
  - Associated valve diseases

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Evaluation of valvular disease during exercise is likely useful

- Discrepancy between the degree of valvular severity at rest and symptoms
- **<u>Equivocal symptoms</u>**
  - To unmask symptoms in patients who claim to be asymptomatic
  - Co-morbid conditions such as COPD or deconditioning that may interfere with signs and symptoms of cardiac disease
- Timing of valve surgery
- (Prognostic value)

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Which echocardiographic measurements may be obtained and how to interpret exercise-induced changes?

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- Conventional exercise testing
  - Exercise time, maximal workload
  - Heart rate, blood pressure, symptoms, EKG, exercise capacity, Borg scale
- Valvular components
- Myocardial response
  - LV systolic response
  - Diastolic reserve and FMR
- Pulmonary pressures

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EACVI/ASE CLINICAL RECOMMENDATIONS

The Clinical Use of Stress Echocardiography in Non-Ischaemic Heart Disease: Recommendations from the European Association of Cardiovascular Imaging and the American Society of Echocardiography

Key Points

In the SE laboratory, a variety of parameters may be assessed: ventricular function, valvular gradients and regurgitant flows, left and right heart haemodynamics including pulmonary artery systolic pressure, and ventricular volumes. As it is not feasible to assess all possible parameters during stress, the variables of potential diagnostic interest should be prioritized for the individual patient based on the perceived importance of each. Physiology determines the choice of the stress and the key echocardiographic variables of interest. Exercise is the test of choice for most applications. Bicycle ergometer stress testing is optimal for obtaining Doppler data during exercise, but patient endurance is generally less than with treadmill exercise unless the patient has trained cycling muscles. Dobutamine is the preferred alternative modality for the evaluation of contractile reserve (as in dilated cardiomyopathy or aortic valve stenosis with LV dysfunction). Vasodilation is the preferred modality for the evaluation of coronary flow reserve, which can provide prognostically relevant information in cardiomyopathy.

J Am Soc Echocard, 2017

	Northern Europe (n=327)	Western Europe (n=1493)	Eastern Europe (n=1901)	Southern Europe (n=1340)	North Africa (n=158)
Multiple left-sided	76 (23.2)	325 (21.8)	510 (26.8)	344 (25.7)	42 (26.6)
Isolated right-sided	8 (2.4)	37 (2.5)	38 (2.0)	51 (3.8)	9 (5.7)
Type of valve disease					
Degenerative	241/324 (74.4)	1188/1461 (81.3)	1135/1832 (62.0)	862/1311 (65.8)	22/157 (14.0)
Rheumatic	12/324 (3.7)	59/1461 (4.0)	252/1832 (13.8)	163/1311 (12.4)	113/157 (72.0)
Congenital	20/324 (6.2)	49/1461 (3.4)	157/1832 (8.6)	78/1311 (5.9)	5/157 (3.2)
Prior endocarditis/inflammatory	1/324 (0.3)	12/1461 (0.8)	19/1832 (1.1)	8/1311 (0.6)	3/157 (1.9)
Other*	50/324 (15.6)	153/1461 (10.5)	269/1832 (14.7)	200/1311 (15.3)	14/157 (8.9)
Investigations, n (%)					
2D strain analysis	10 (3.1)	211 (14.1)	89 (4.7)	94 (7.0)	3 (1.9)
3D transthoracic echocardiography	22 (6.7)	207 (13.9)	133 (7.0)	100 (7.5)	22 (13.9)
Transesophageal echocardiography	62 (19.0)	396/1492 (26.5)	411 (21.6)	173 (12.9)	26 (16.5)
Stress test					
All patients	16 (4.9)	81 (5.4)	16 (0.8)	40 (3.0)	0 (0)
NYHA class I	0/38 (0)	30/287 (10.5)	8/283 (2.8)	16/311 (5.1)	0/45 (0)
Cardiac/vascular CT scan	63 (19.3)	462 (30.9)	203 (10.7)	163 (12.2)	6 (3.8)
Cardiac magnetic resonance	5 (1.5)	49 (3.3)	11 (0.6)	28 (2.1)	5 (3.2)
Coronary angiography	202 (61.8)	1015 (68.0)	1045 (55.0)	540 (40.3)	24 (15.2)
Cardiac catheterization	25 (7.6)	237 (15.9)	101 (5.3)	91 (6.8)	8 (5.1)

Iung et al, Circulation, 2019

European Heart Journal – Cardiovascular Imaging (2014) 15, 158–163
doi:10.1093/ehjci/jet082

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Stress echocardiography in clinical practice: a United Kingdom National Health Service Survey on behalf of the British Society of Echocardiography

Sanjeev Bhattacharyya[1], Omar Chehab[1], Rajdeep Khattar[1], Guy Lloyd[2], and Roxy Senior[1,3]*, on behalf of the British Society of Echocardiography

Table 3 Indications for SE in valvular heart disease

Units which perform stress echo for assessment of valvular heart disease	n (%)
Low-flow, low-gradient aortic stenosis	81 (95.3)
Asymptomatic severe aortic stenosis	34 (40)
Asymptomatic severe mitral regurgitation	26 (30.6)
Asymptomatic severe mitral stenosis	21 (24.7)
Symptomatic mild/moderate mitral regurgitation	32 (37.6)
Symptomatic mild/moderate mitral stenosis	24 (28.2)
Asymptomatic severe aortic regurgitation	15 (17.6)

Battacharyya et al, Eur Heart J VCI, 2013

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Conventional exercise test in asymptomatic AVS (no symptoms and normal LVEF)

<u>Exercise-induced symptoms</u>

Negative predictive value 87 %
<u>Positive predictive value 57 %</u>
Positive predictive value 79 % (physically active patients < 70 y.o.)

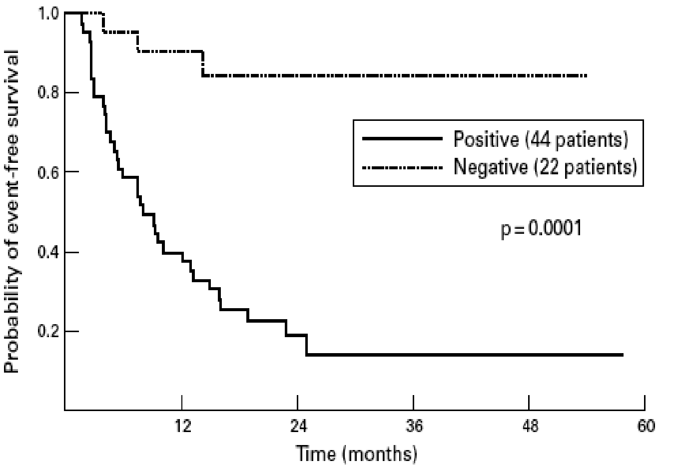

Figure 3 Kaplan–Meier life table analysis for probability of event-free survival over 60 months for patients with asymptomatic severe aortic stenosis, according to positive or negative results of exercise testing.

Amato et al, Heart, 2001 - Das et al, Eur Heart J, 2005

B) Asymptomatic patients with severe aortic stenosis		
Intervention is recommended in asymptomatic patients with severe aortic stenosis and systolic LV dysfunction (LVEF <50%) without another cause.[9,238,239]	I	B
Intervention is recommended in asymptomatic patients with severe aortic stenosis and demonstrable symptoms on exercise testing.	I	C
Intervention should be considered in asymptomatic patients with severe aortic stenosis and systolic LV dysfunction (LVEF <55%) without another cause.[9,240,241]	IIa	B
Intervention should be considered in asymptomatic patients with severe aortic stenosis and a sustained fall in BP (>20 mmHg) during exercise testing.	IIa	C

Vahanian et al, Eur Heart J, 2021

MYOCARDIAL COMPONENTS
LV abnormal response to exercise in severe AVS

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Table 1 Predictors of abnormal exercise test

Variables	Normal test $n = 68$	Abnormal test $n = 60$	P
LV ejection fraction (%)	6.6 ± 7.8	0.9 ± 8.2	<0.0001
Aortic valve area (cm^2)	0.11 ± 0.19	0.04 ± 0.17	0.032
Peak aortic pressure gradient (mmHg)	17 ± 13	24 ± 17	0.019
Mean aortic pressure gradient (mmHg)	10.5 ± 7	18 ± 11	<0.0001
Mean aortic pressure gradient 17 mmHg	12 (18%)	35 (58%)	<0.0001

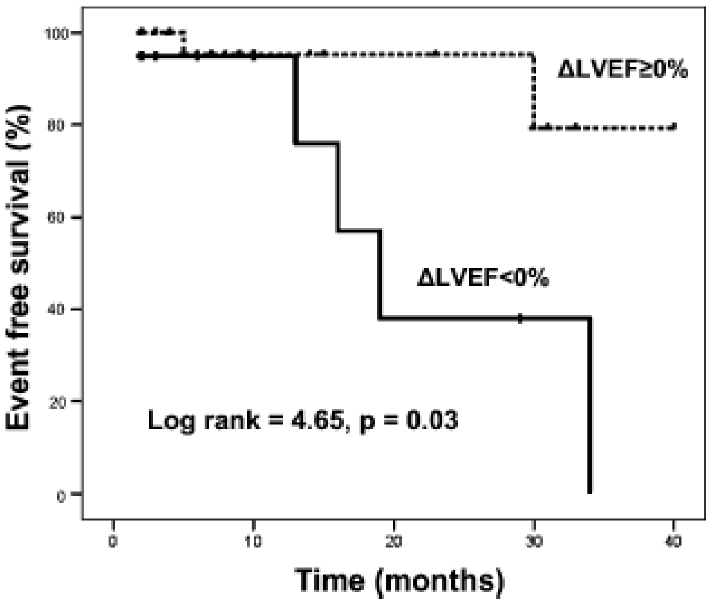
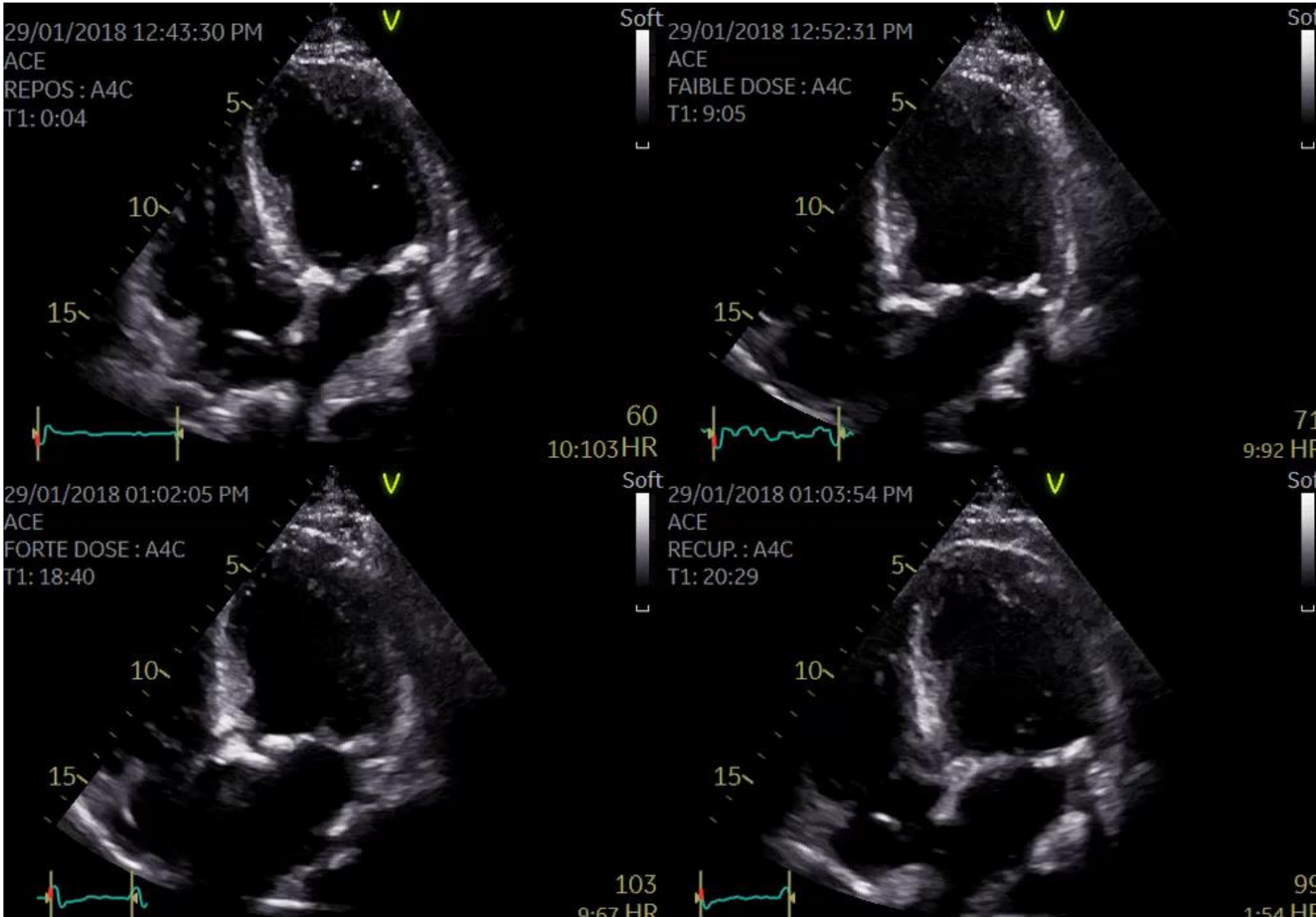
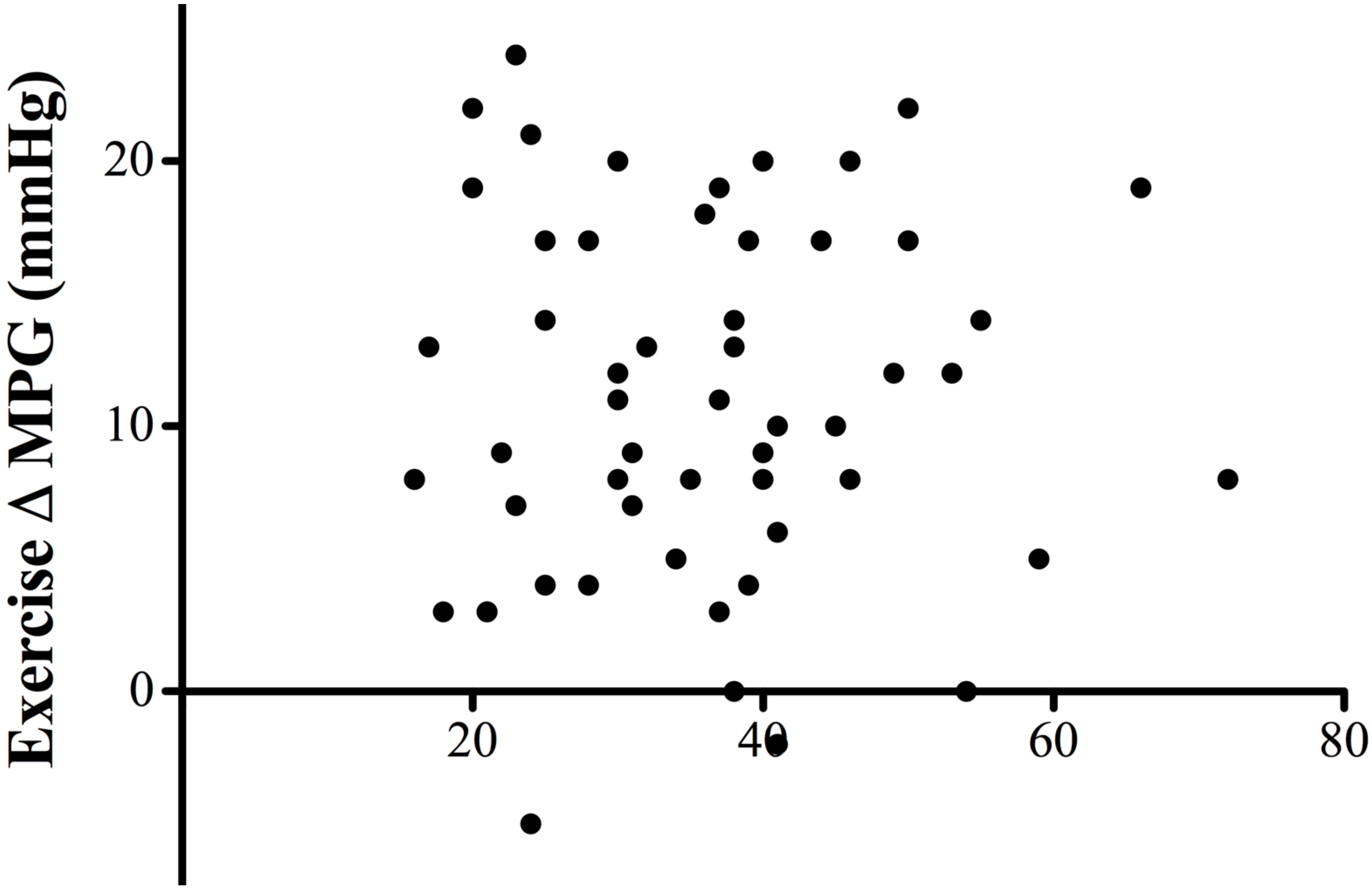


Figure 1. *Event-free survival according to the LV response to exercise.*

Lancellotti et *al*, *European Journal of Echocardiography*, 2008
Maréchaux *et al*, *Echocardiography*, 2007


29/01/2018 12:43:30 PM
ACE
REPOS : A4C
T1: 0:04
Soft
V
5
10
15
60
10:103 HR
29/01/2018 12:52:31 PM
ACE
FAIBLE DOSE : A4C
T1: 9:05
Soft
V
5
10
15
71
9:92 HR
29/01/2018 01:02:05 PM
ACE
FORTE DOSE : A4C
T1: 18:40
Soft
V
5
10
15
103
9:67 HR
29/01/2018 01:03:54 PM
ACE
RECUP. : A4C
T1: 20:29
Soft
V
5
10
15
99
1:54 HR

Valvular components



Ringle *et al*, ACVD, 2017

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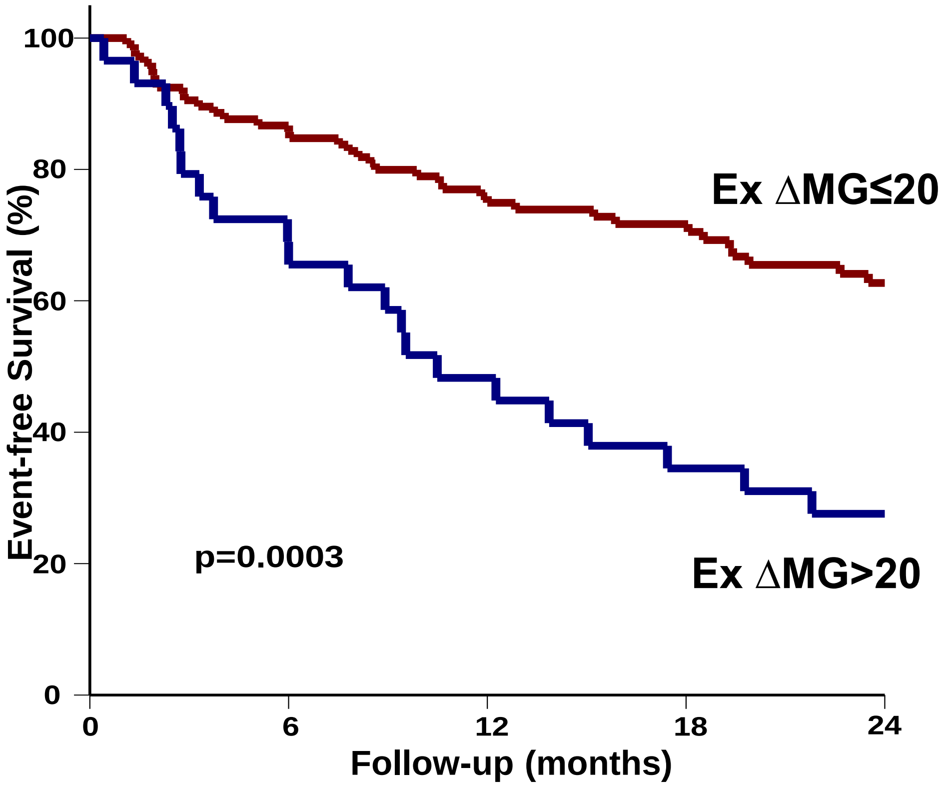
Event-free Survival



Maréchaux *et al*, *Eur Heart J*, 2010

Clinical case

Table 3 **Multivariate analysis of association between baseline variables entered in continuous format and event risk in the whole cohort (*n* = 135), in patients with severe aortic stenosis (*n* = 72), and in those with moderate aortic stenosis (*n* = 63)**

Variables)	Increment category	Whole cohort (*n* = 135)		Severe aortic stenosis (*n* = 72)		Moderate aortic stenosis (*n* = 63)	
		HR (95% CI)	*P*-value	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Age (years)	10 years increase	1.27 (1.06–1.53)	0.01	1.17 (0.94–1.47)	0.16	1.82 (1.26–2.78)	0.001
Diabetes	Yes	3.61 (1.49–7.83)	0.006	3.75 (1.39–9.12)	0.01	–	–
Rest systolic blood pressure	10 mmHg increase	1.07 (0.92–1.22)	0.36	–	–	1.17 (0.90–1.49)	0.23
LV mass index (g/m^2)	10 g/m^2 increase	1.08 (1.00–1.15)	0.06	1.12 (1.01–1.22)	0.02	–	–
Rest mean gradient (mmHg)	10 mmHg increase	1.50 (1.27–1.77)	<0.0001	1.32 (1.05–1.86)	0.02	1.72 (1.03–2.86)	0.04
Exercise Δ mean gradient (mmHg)	10 mmHg increase	1.67 (1.32–2.13)	<0.0001	1.49 (1.12–2.00)	0.008	2.08 (1.26–3.56)	0.004
Exercise LV ejection fraction (%)	10% decrease	1.20 (0.94–1.54)	0.15	1.22 (0.88–1.67)	0.23	–	–

The variables marked by superscript 'a' in *Table* 2 were entered in the multivariate model for the whole cohort. We selected the same variables to construct the models in the subsets of patients with severe and moderate aortic stenosis. However, the variables were entered in these models only if the *P*-value was <0.1 on univariate analysis in the given subset.
The hazard ratios reflect the increase in risk of event per increment category.

Maréchaux *et al*, *Eur Heart J*, 2010

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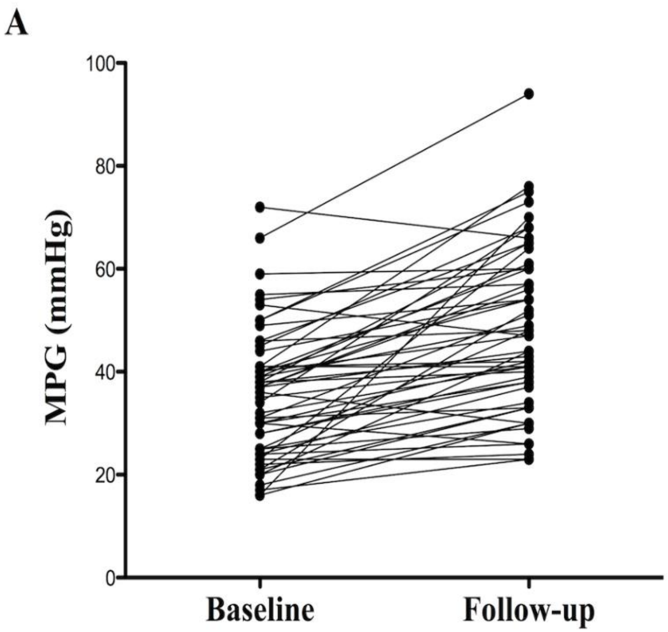
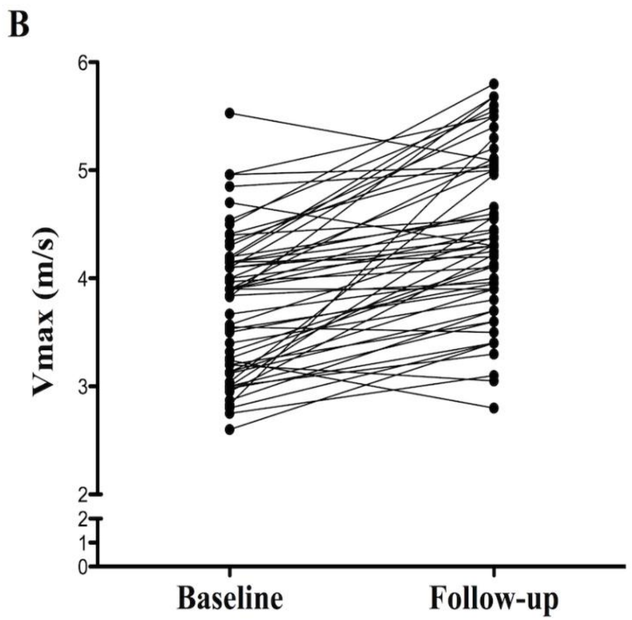
Echo d'effort et progression de la sténose?



55 patients with moderate to severe AS

Echocardiographic FU: 1.6 [1.1-3.2] years



Ringle, Levy et al, ACVD, 2017

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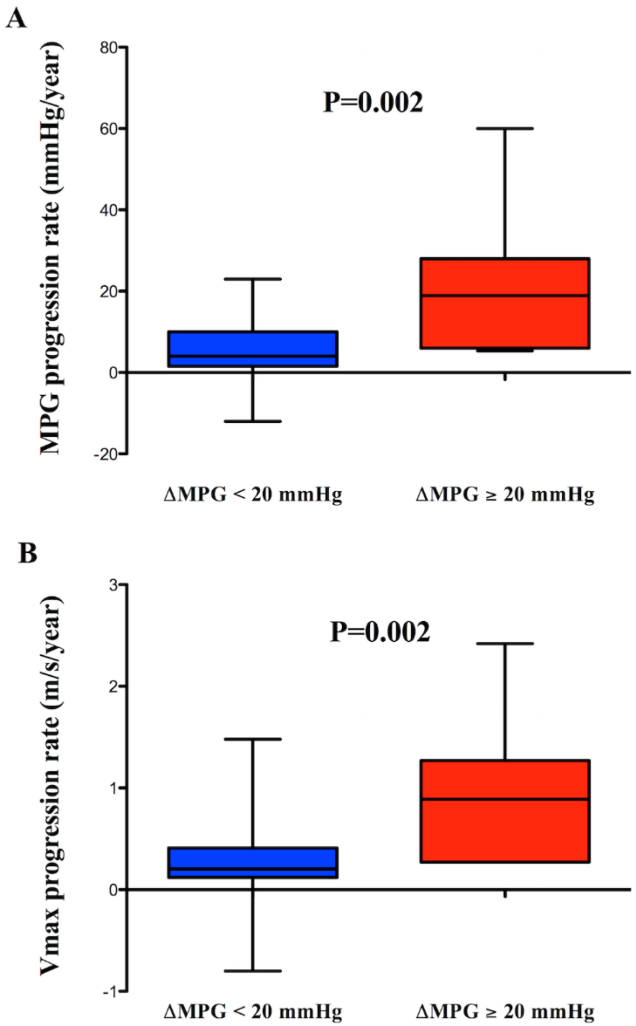
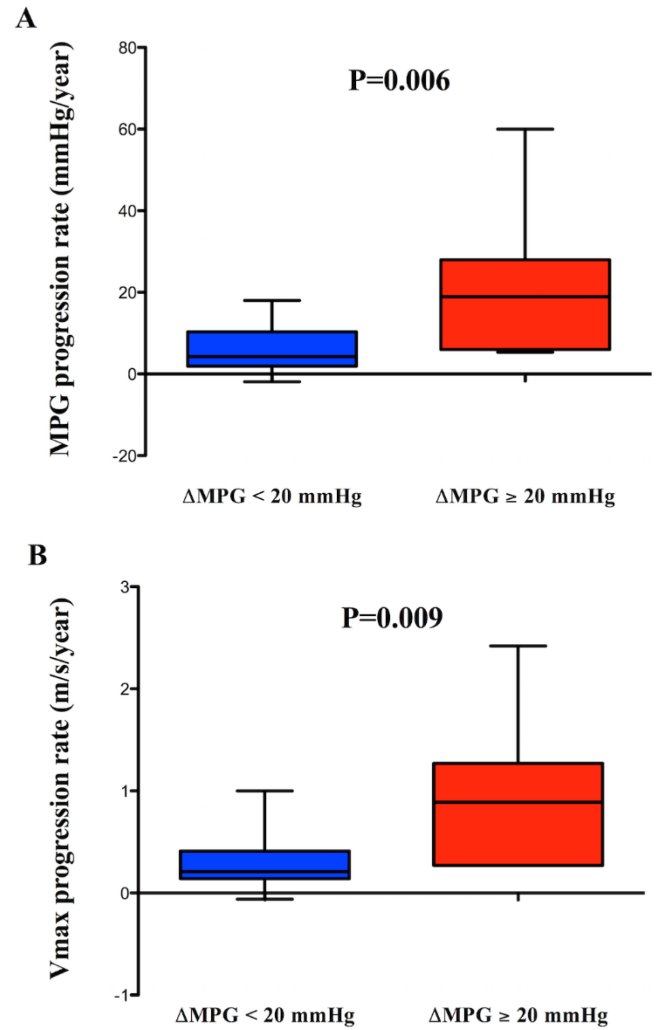


Severe AS
25 patients



Moderate AS
30 patients

Ringle, Levy et al, ACVD, 2017

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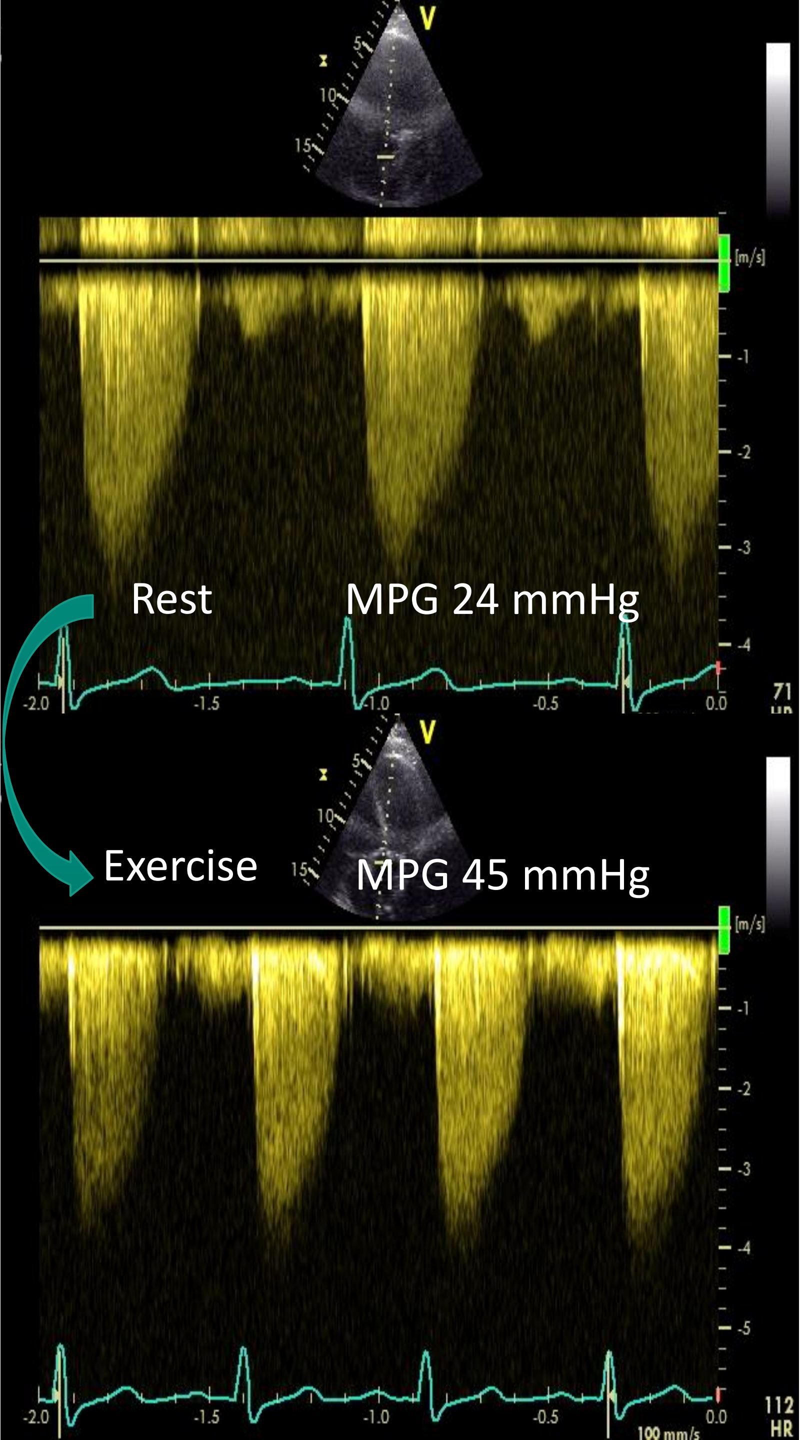

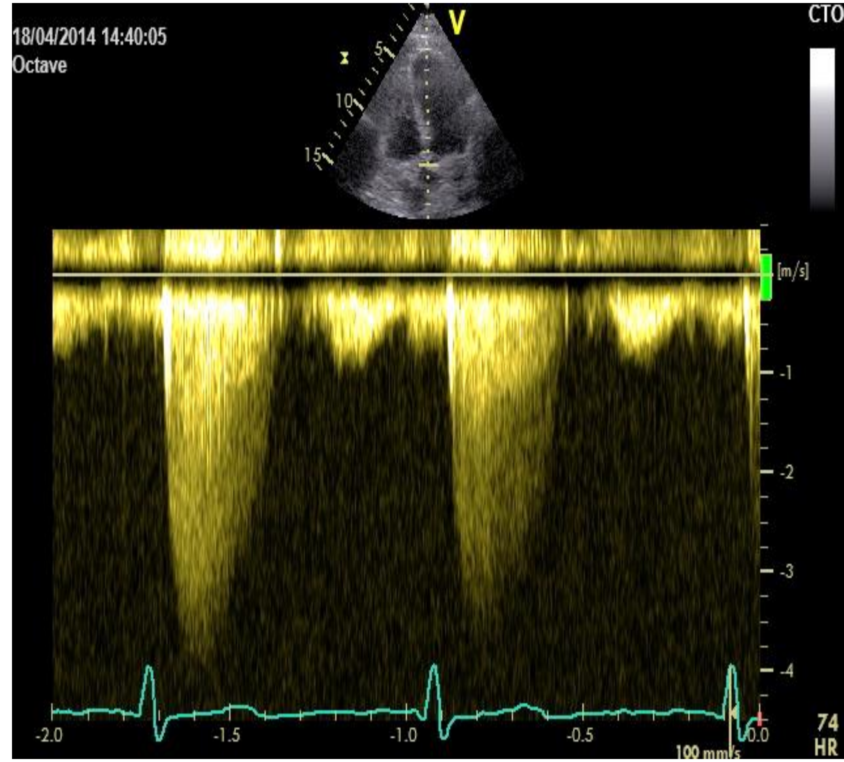

1-year follow up rest MPG 37 mmHg

MPG progression rate: 13 mmHg/y

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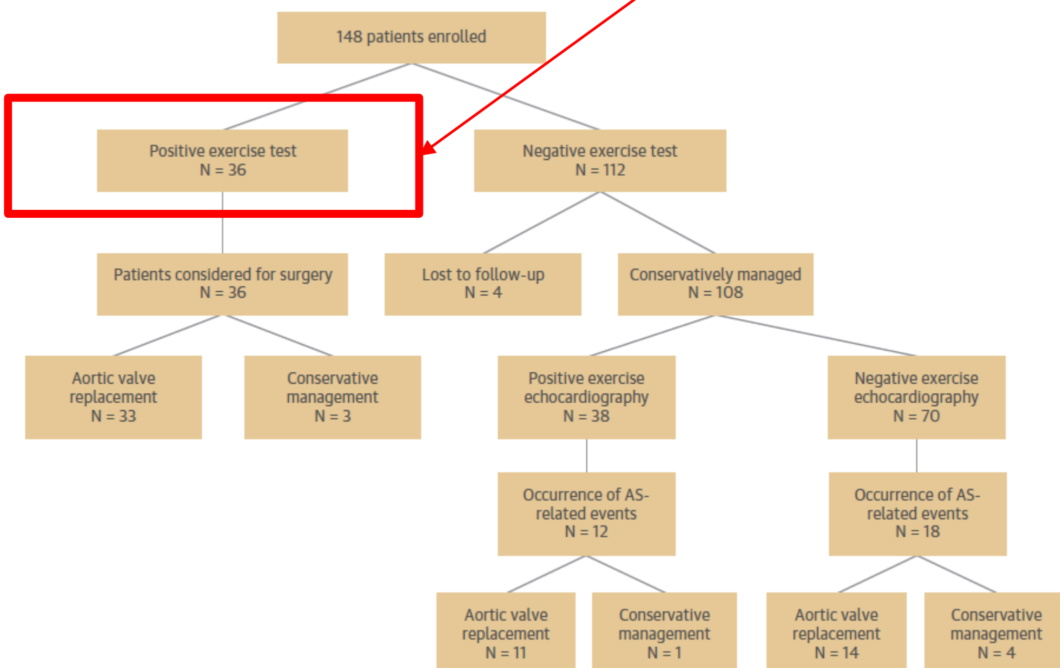
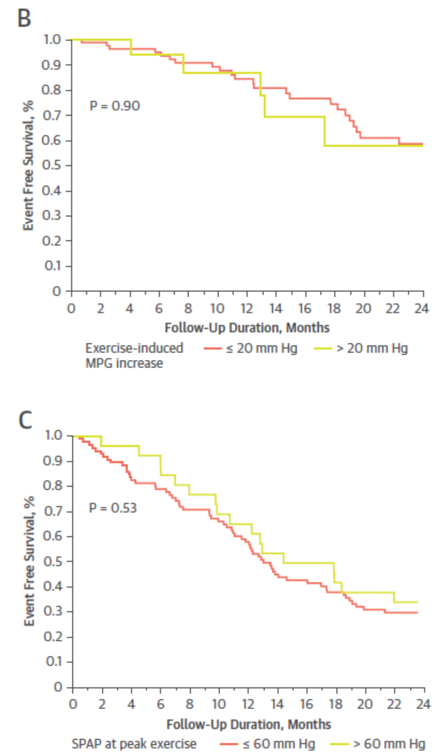
Prognostic Value of Exercise-Stress Echocardiography in Asymptomatic Patients With Aortic Valve Stenosis

- Neither MPG increase >20 mm Hg nor peak SPAP >60 mm Hg was predictive of occurrence of AS-related events
- Positive exercise test: LV systolic dysfunction or WMSA



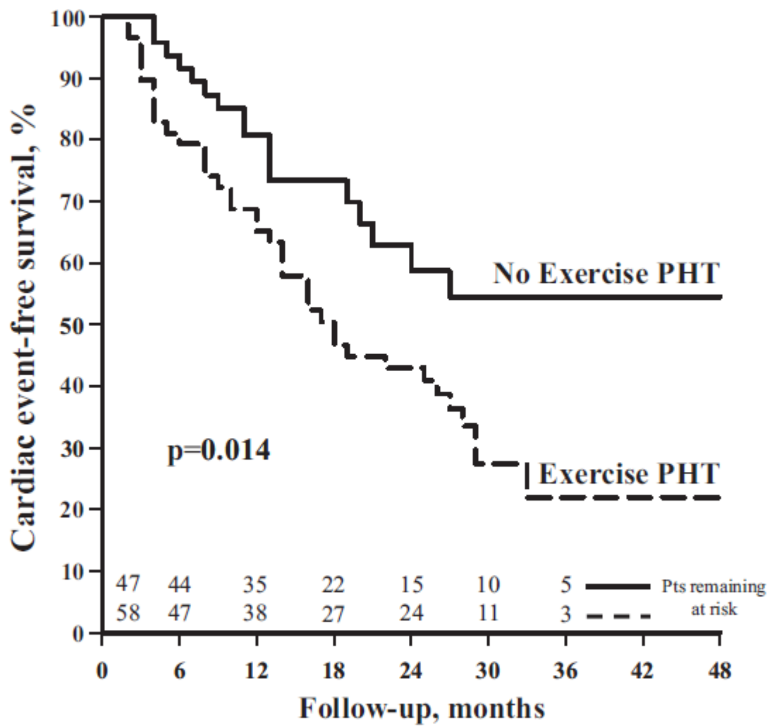


J Am Coll Cardiol Img 2018;11:787–95

Exercise echocardiography allows the assessment of systolic pulmonary artery pressure response

- Technical issue: faint Doppler tracing in asymptomatic patients…
- Interpretation of pulmonary pressure may be difficult in older hypertensive people, patients with history of pulmonary embolism, COPD…

*In asymptomatic severe **AS** patients, exercise PHT is associated with a 2-fold increased risk of cardiac event*



Clinical case

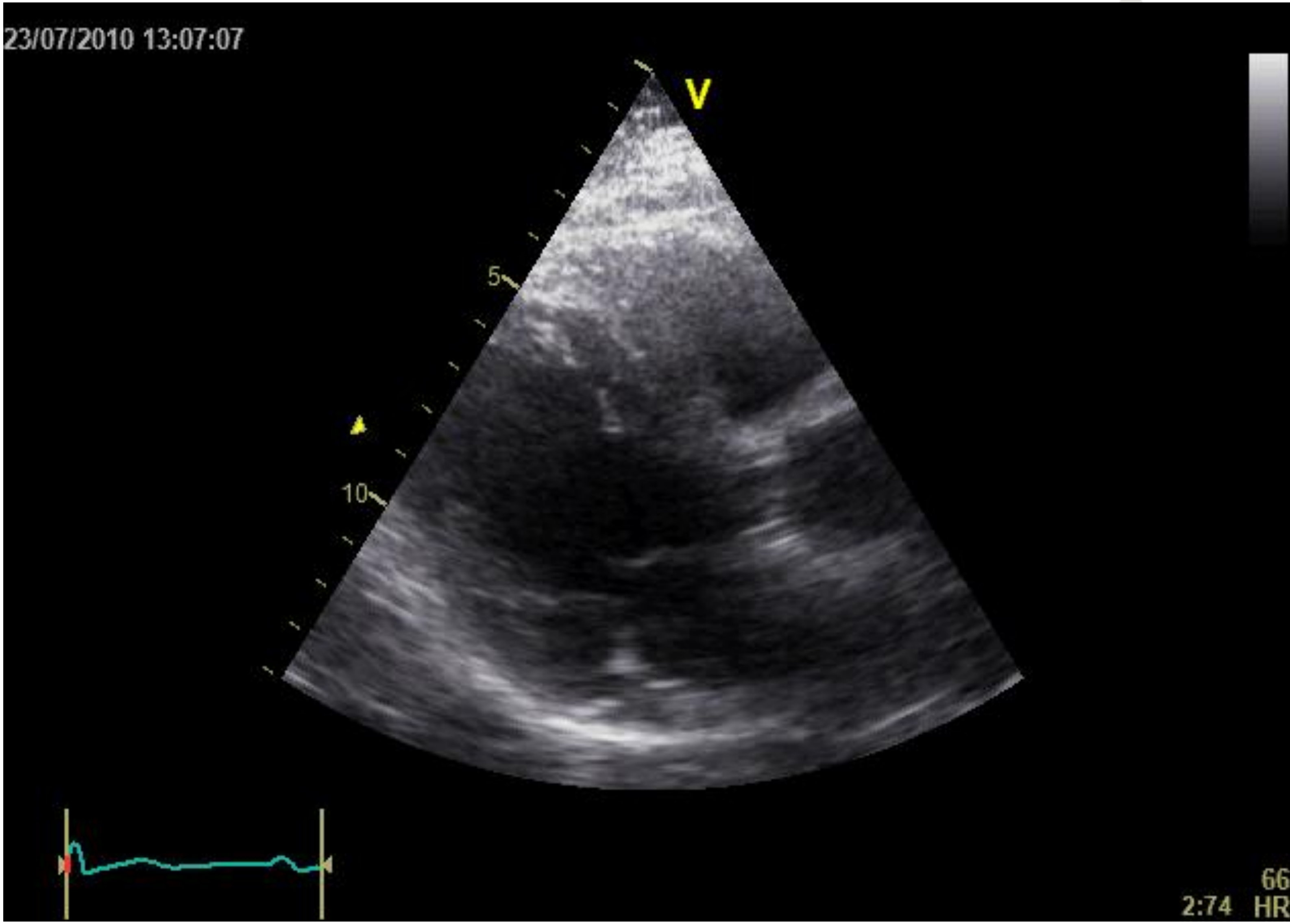
75 yo patient (2010)

No symptoms

No medical history

Systolic murmur

Echocardiography: AS

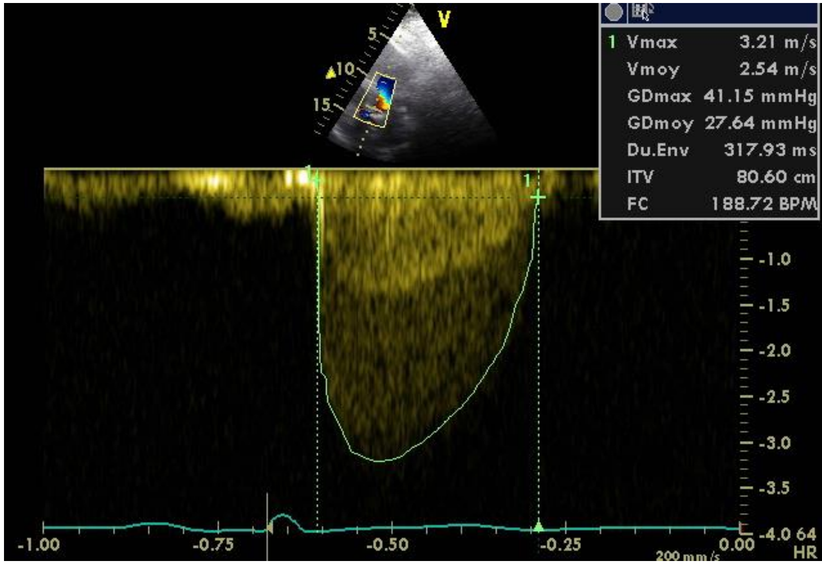

23/07/2010 13:07:07
V
5
10
66
2:74 HR

Clinical case

MPG 28 mmHg, Av-vel 3.20 m/s

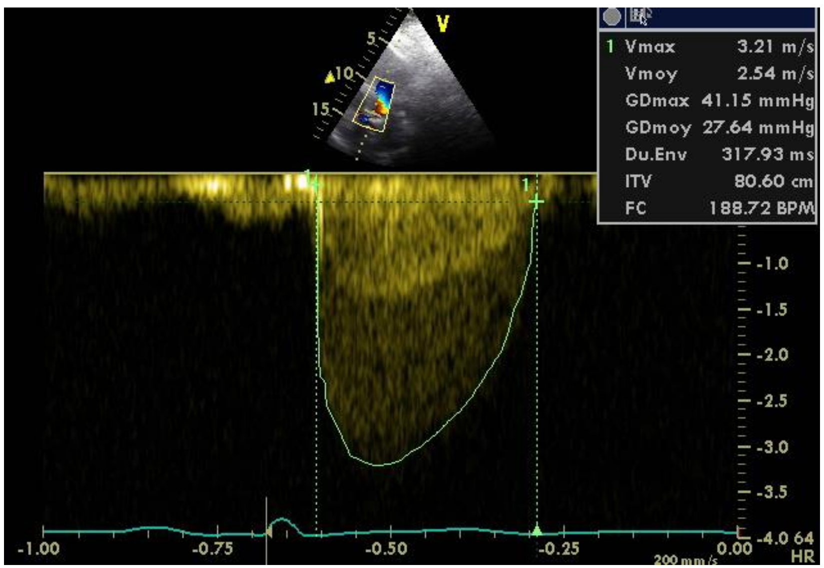
Aortic valve area 1.1 cm²

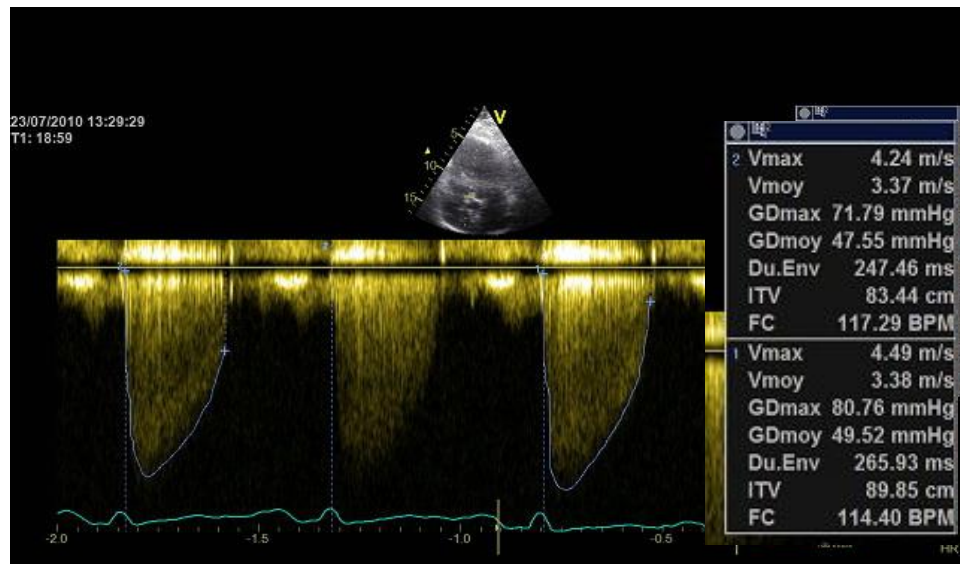
Moderate AS



Exercise Stress Echocardiography

- SBP increases from 140 to 180 mmHg
- HR increases from 64 to 117 bpm
- Exercise duration 8 minutes 40 s, 100 Watts
- Leg fatigue
- LV EF increases from 0.65 to 0.72
- MPG increases from 28 to 49 mmHg





Clinical case

One year follow up

AV-vel 3.9 m/s

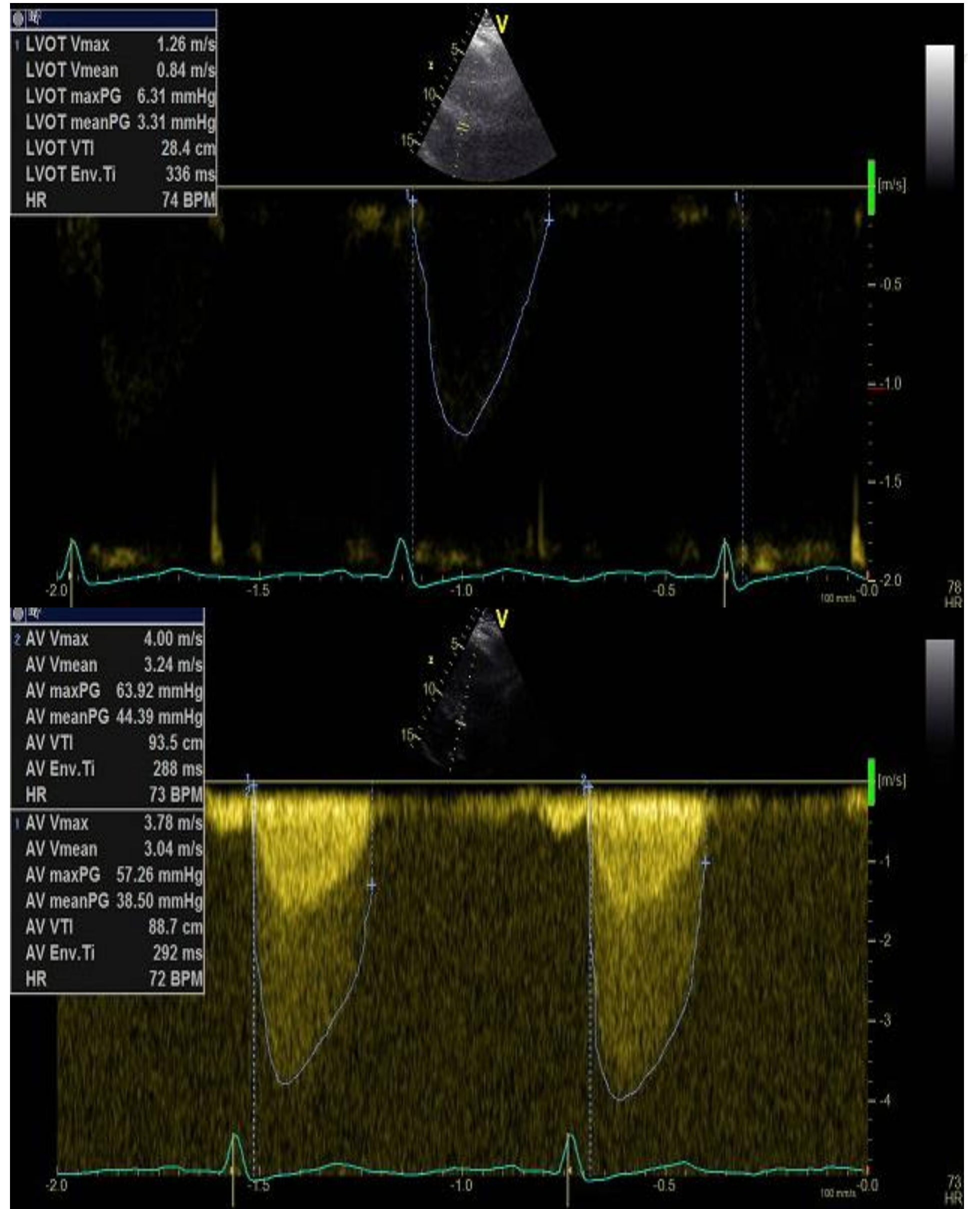
MPG 42 mmHg

PI 0.29

SAo 0.9 cm^2

Severe AS

Increase in AV-vel 0.7 m/s/y



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Clinical case 10/2011

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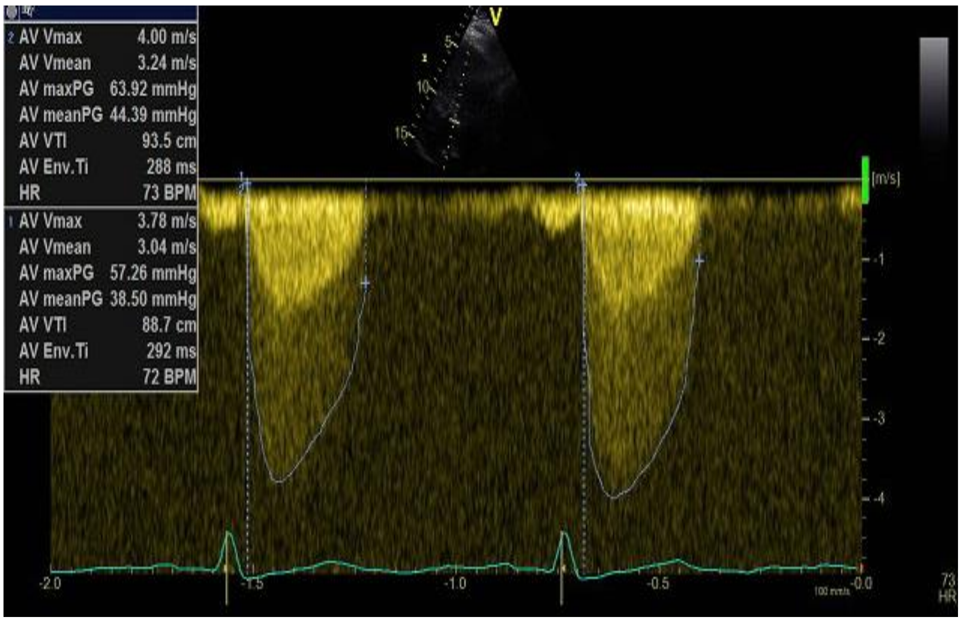

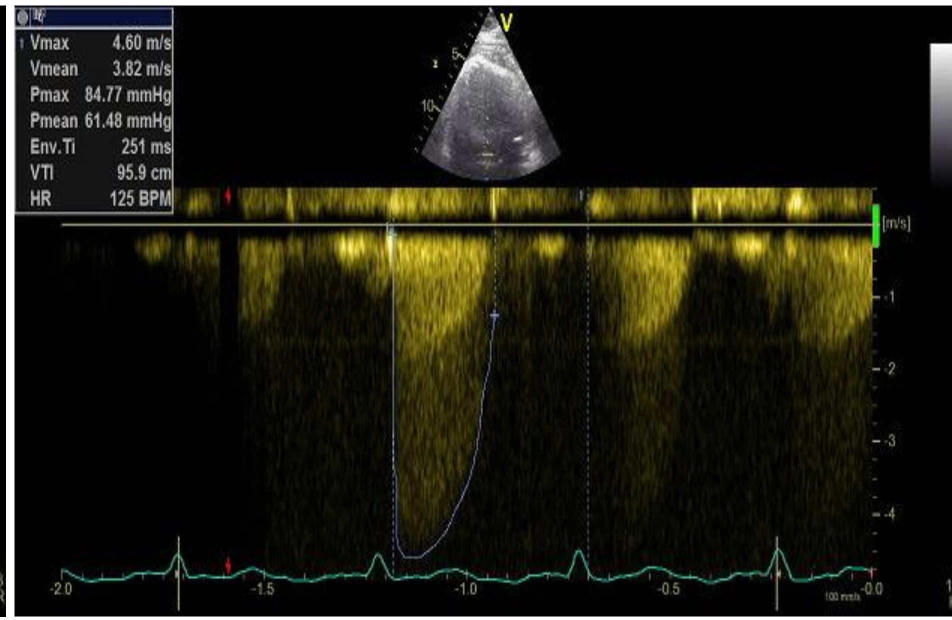

Δ GM 20 mmHg

Exercise duration 8 min

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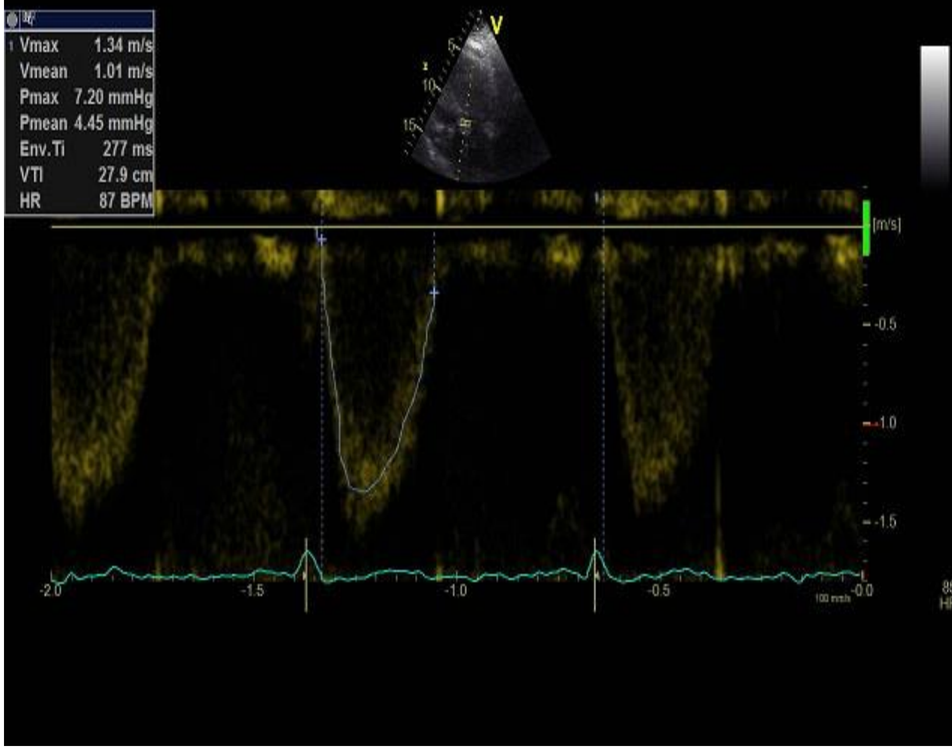
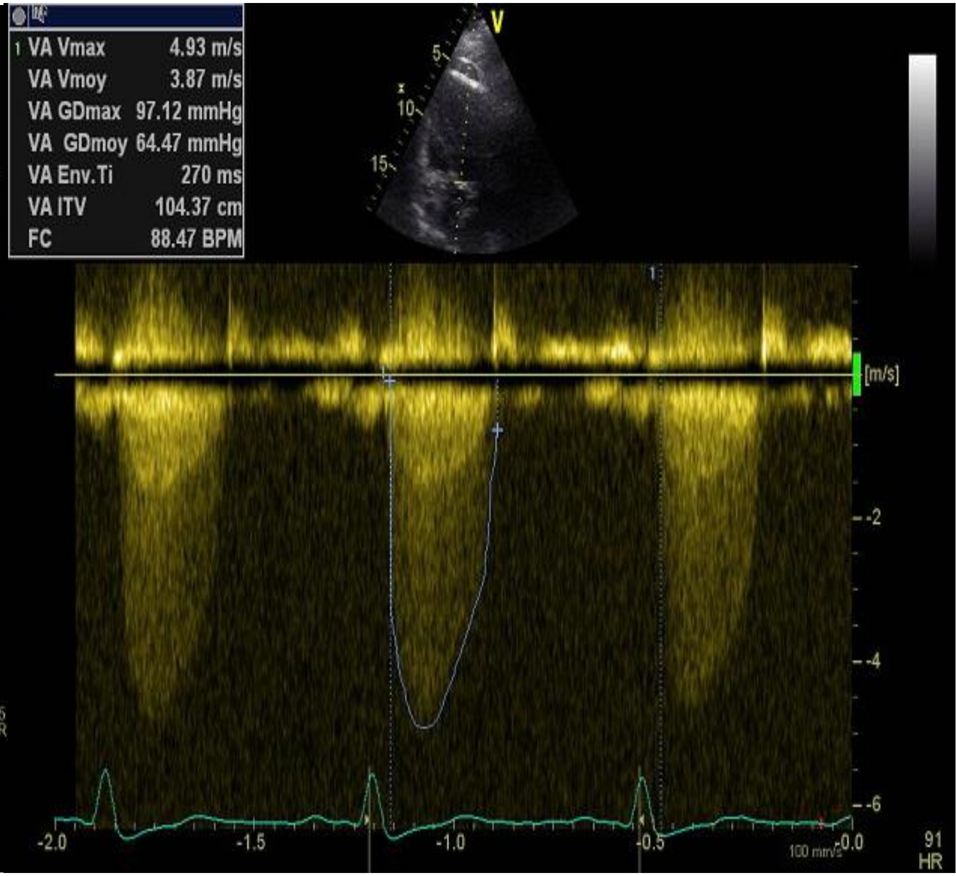
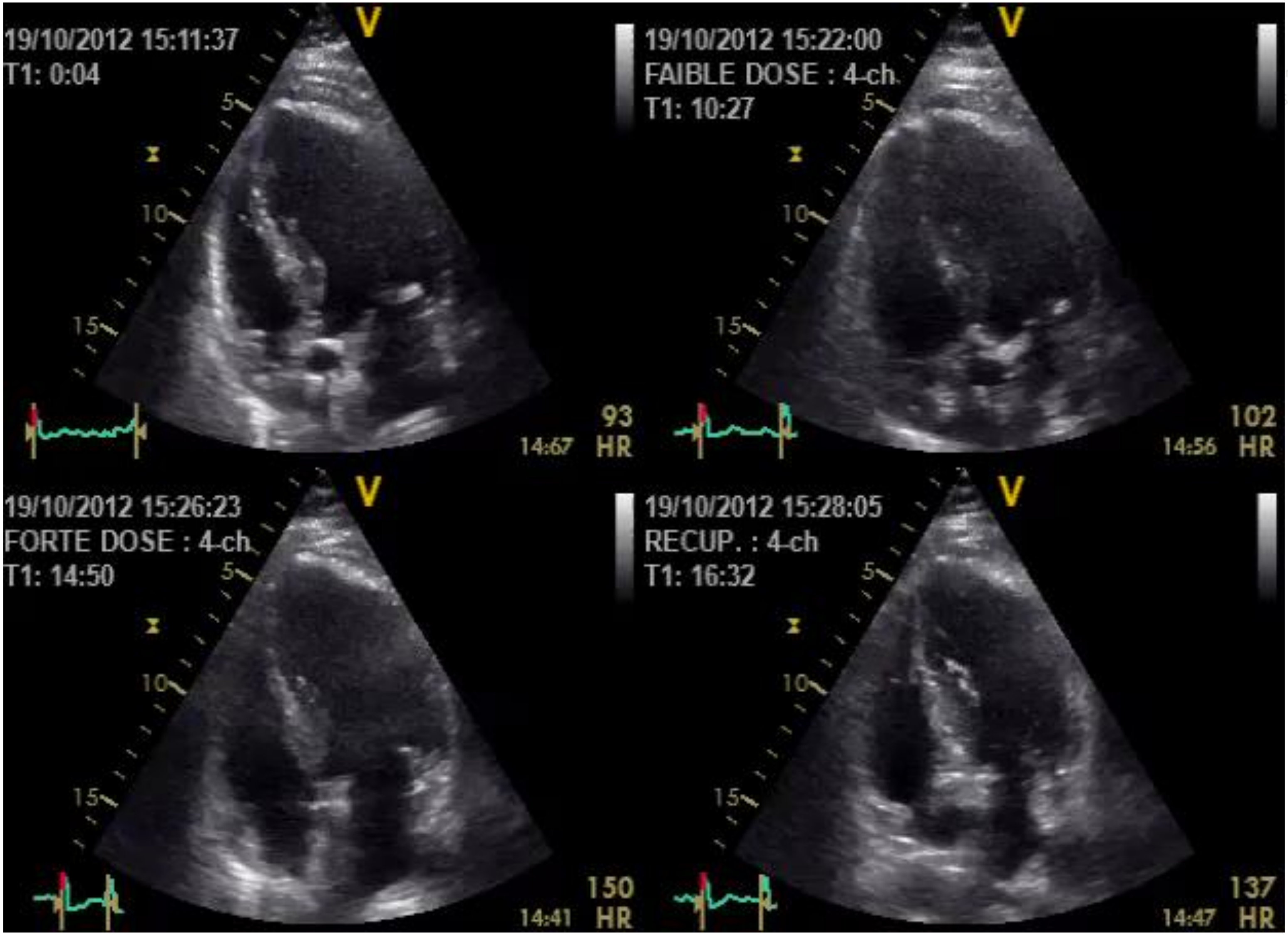
Cas 2 Echo d'effort 10/2012
2 year f/u

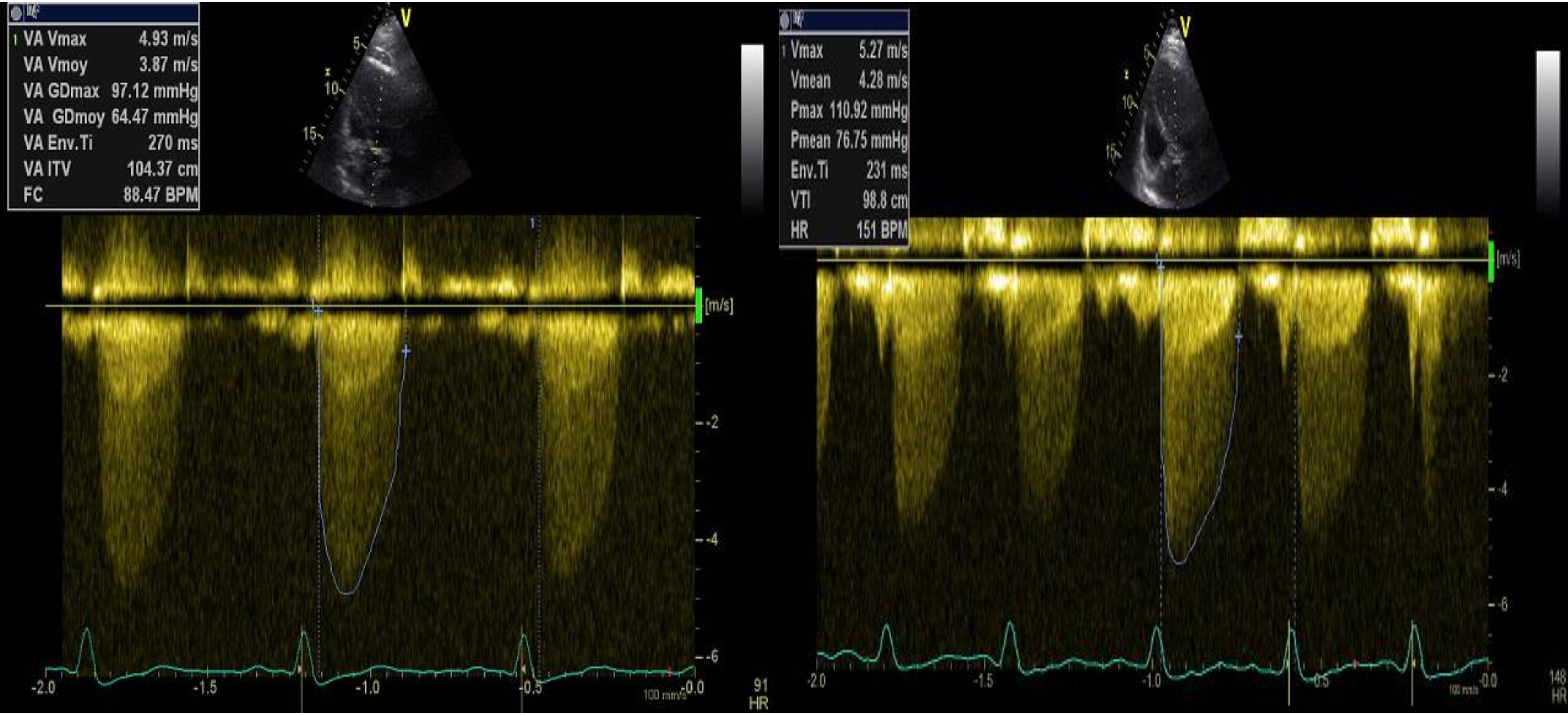




AV-vel 4.83 m/s, PI 0.24, AVA 0.85 cm^2



- Exercise duration 5 min
- Shortness of breath
- Afterload mismatch



Δ GM 14 mmHg

Referred for AVR after preoperative evaluation

Exercise echo in moderate to severe AS

Negative exercise test

Positive exercise test

LV functional reserve
ΔMPG $\leq$ 20 mmHg
Preserved AV compliance

→

LV functional reserve
ΔMPG > 20 mmHg
Decreased AV compliance

→

Afterload mismatch
Low increase or
decrease in MPG

Exercise Stress Echocardiography

53 years old patient

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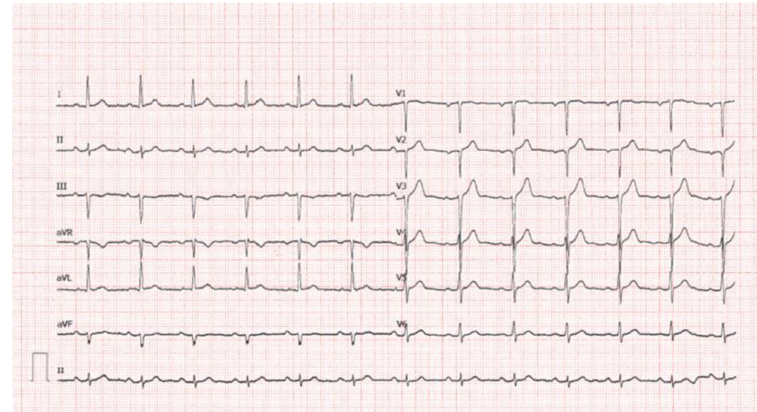
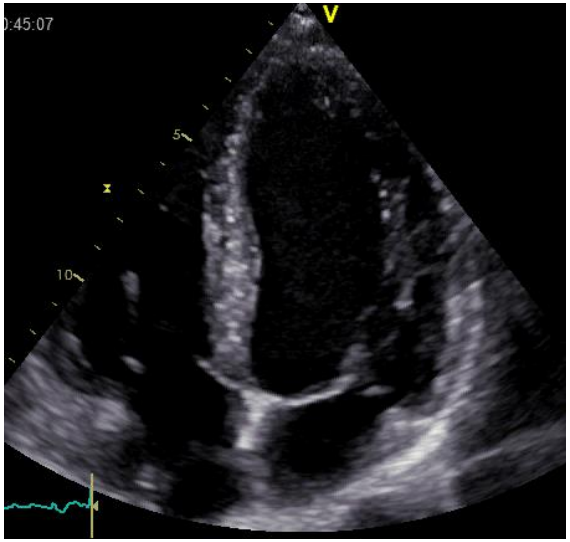
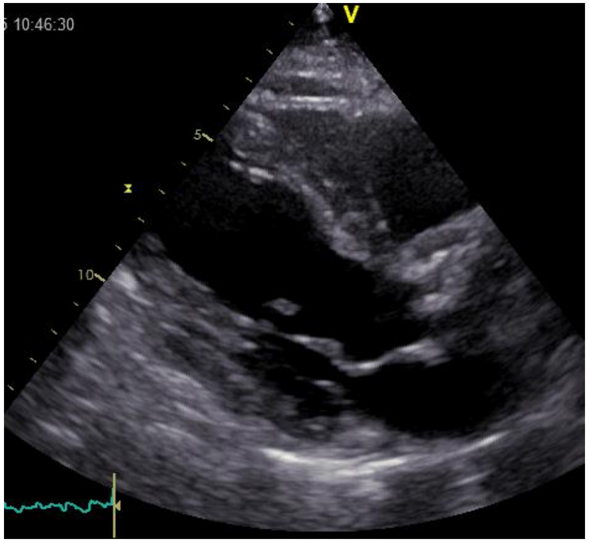
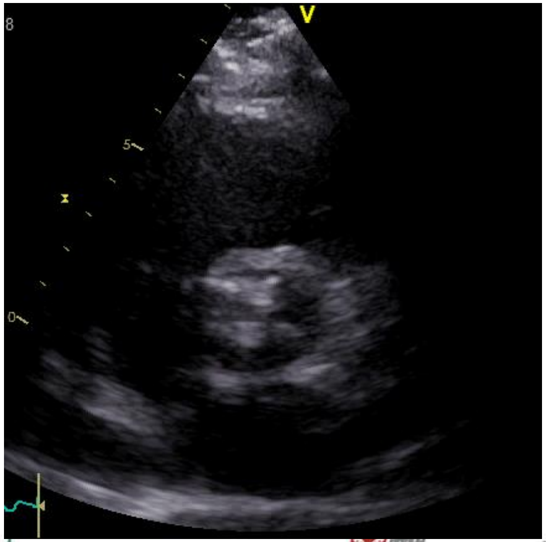
Exercise induced syncope during running
History of moderate AS, bicuspid valve
6 to 8 h exercise/week (crossfit)









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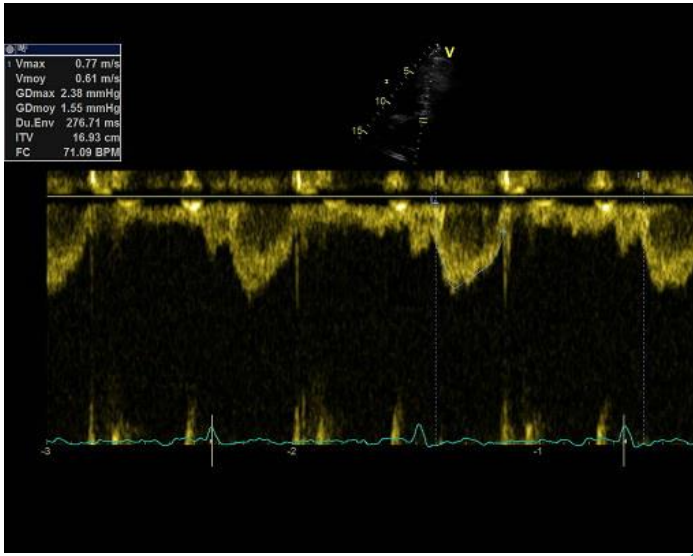
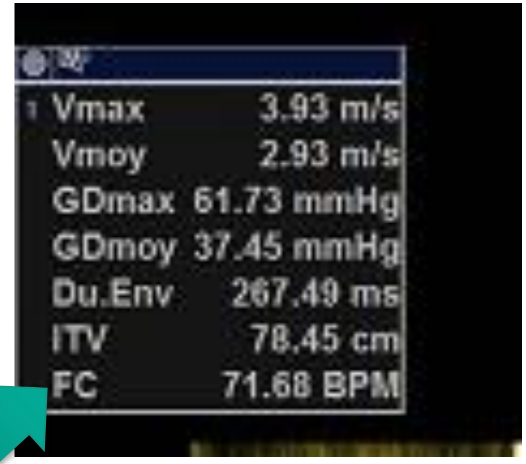
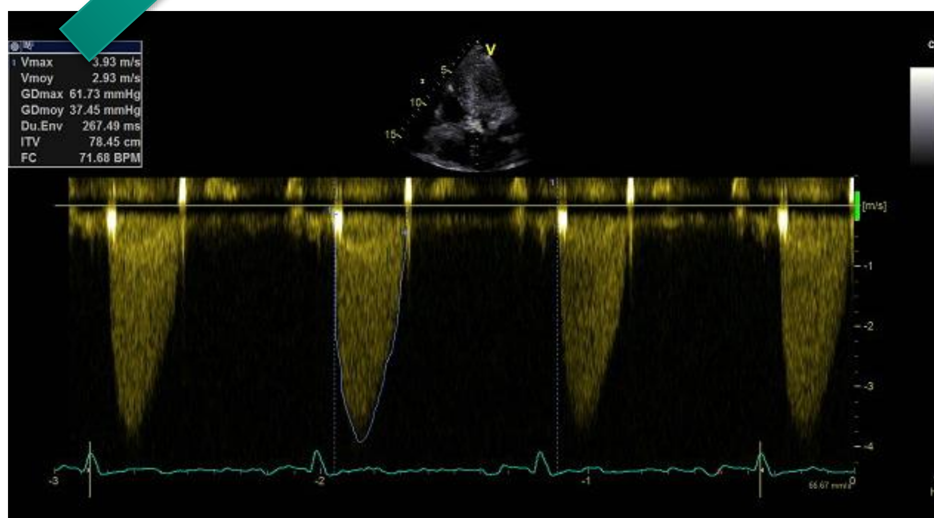
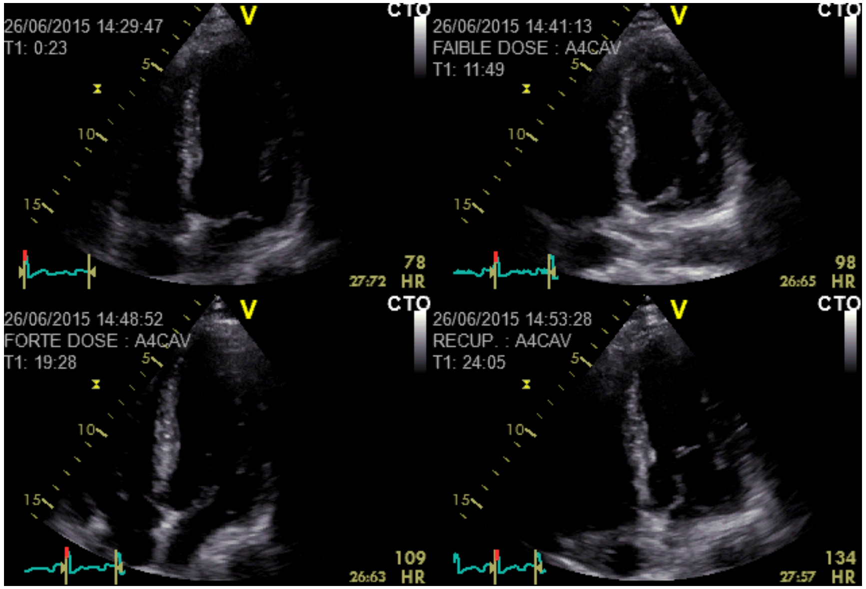

Vmax 0.77 m/s
Vmoy 0.61 m/s
GDmax 2.38 mmHg
GDmoy 1.55 mmHg
Du.Env 276.71 ms
ITV 16.93 cm
FC 71.09 BPM

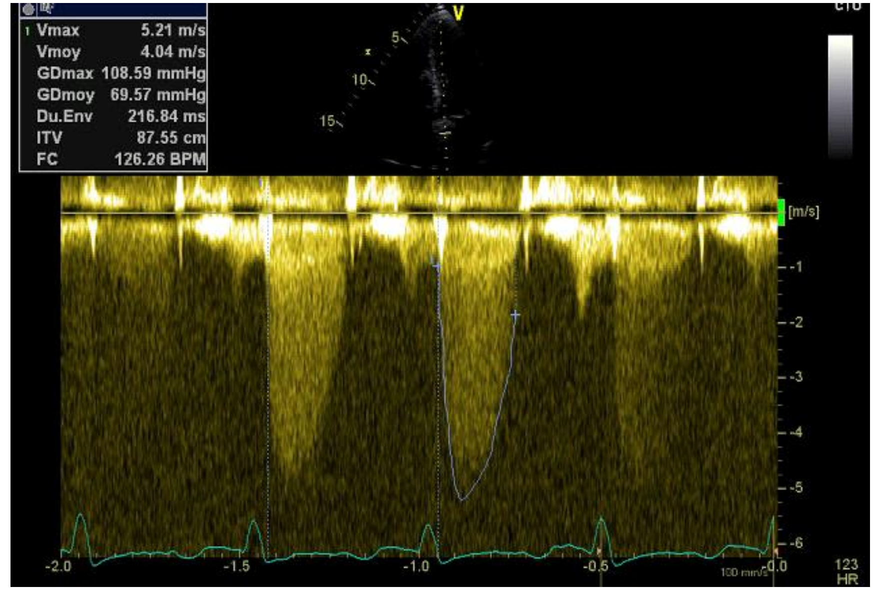

Vmax 3.93 m/s
Vmoy 2.93 m/s
GDmax 61.73 mmHg
GDmoy 37.45 mmHg
Du.Env 267.49 ms
ITV 78.45 cm
FC 71.68 BPM

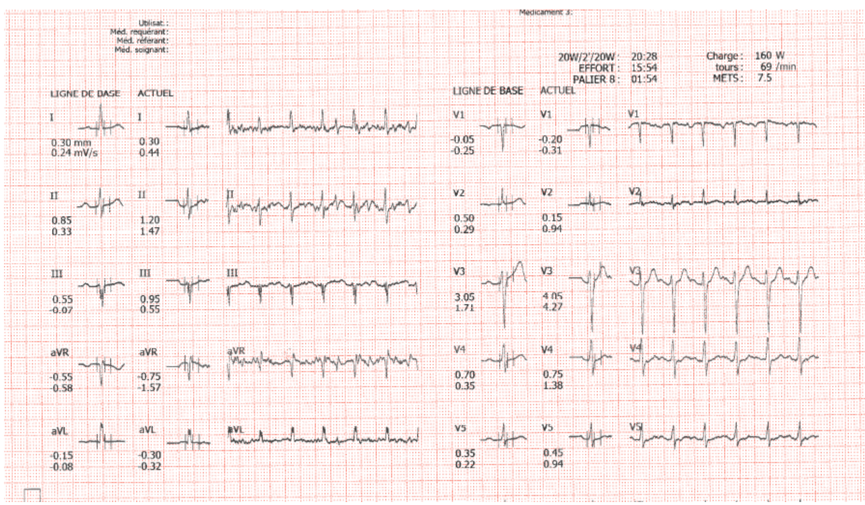
AVA 1,1cm2


Vmax 3.93 m/s
Vmoy 2.93 m/s
GDmax 61.73 mmHg
GDmoy 37.45 mmHg
Du.Env 267.49 ms
ITV 78.45 cm
FC 71.68 BPM
[m/s]

Exercise echocardiography

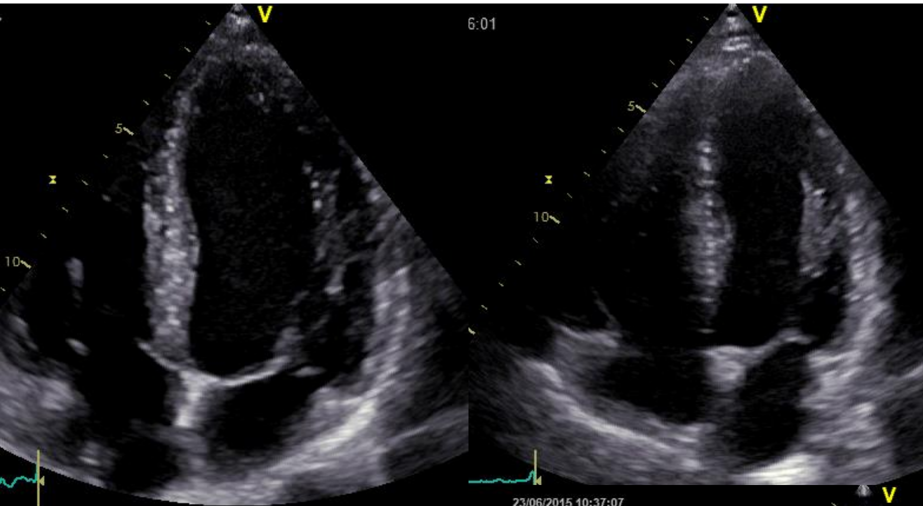






160W, 80% Maximal HR
No increase in SBP

Postoperative echocardiography



The Clinical Use of Stress Echocardiography in Non-Ischaemic Heart Disease: Recommendations from the European Association of Cardiovascular Imaging and the American Society of Echocardiography

Key Points

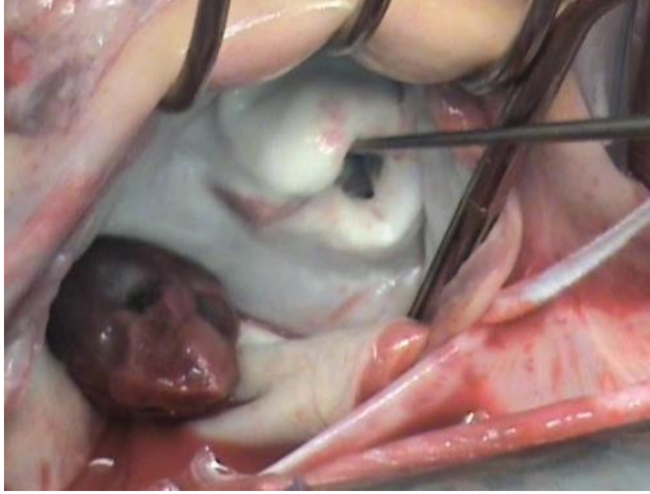
In patients with asymptomatic severe AS, exercise SE may uncover the development of symptoms, necessitating consideration for AVR. The main risk markers are a marked (>18–20 mmHg) increase in mean pressure gradient, a deterioration of LV systolic function, the lack of LV functional reserve, and the development of PH (SPAP > 60 mmHg) during exercise. These markers can also be used to adjust the timing of follow-up in patients with moderate AS.

Exercise testing may unmask symptoms and is recommended for risk stratification of asymptomatic patients with severe aortic stenosis.[172] Exercise echocardiography provides additional prognostic information by assessing the increase in mean pressure gradient and change in LV function.[173]

Vahanian et al, ESC guidelines, 2021

Mitral stenosis

Clinical case



- 69 yo patient, overweight
- 5 years exposure to benfluorex (MEDIATOR)
- NYHA functional class IIa
- Echocardiography +/- exercise stress echo

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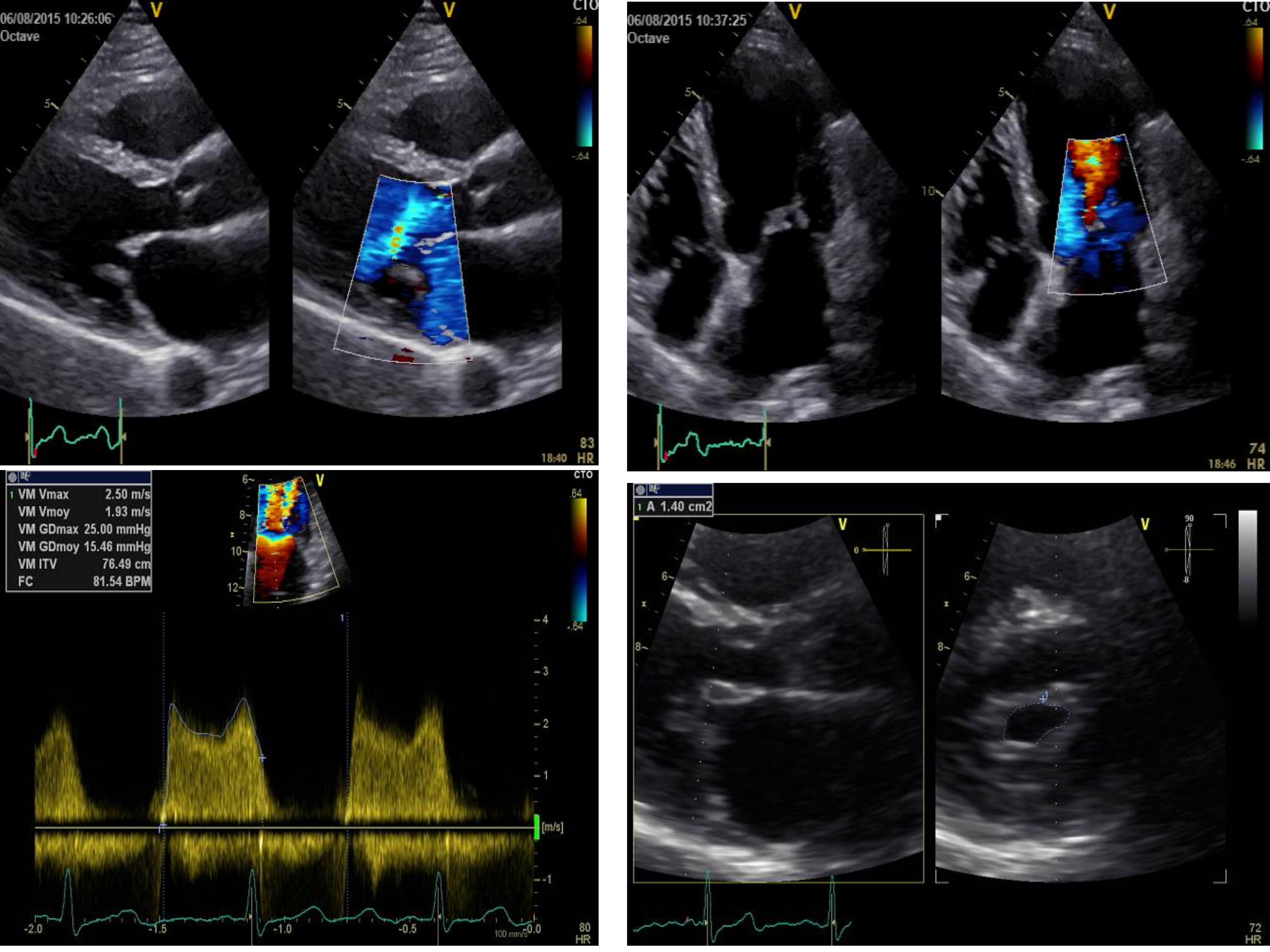
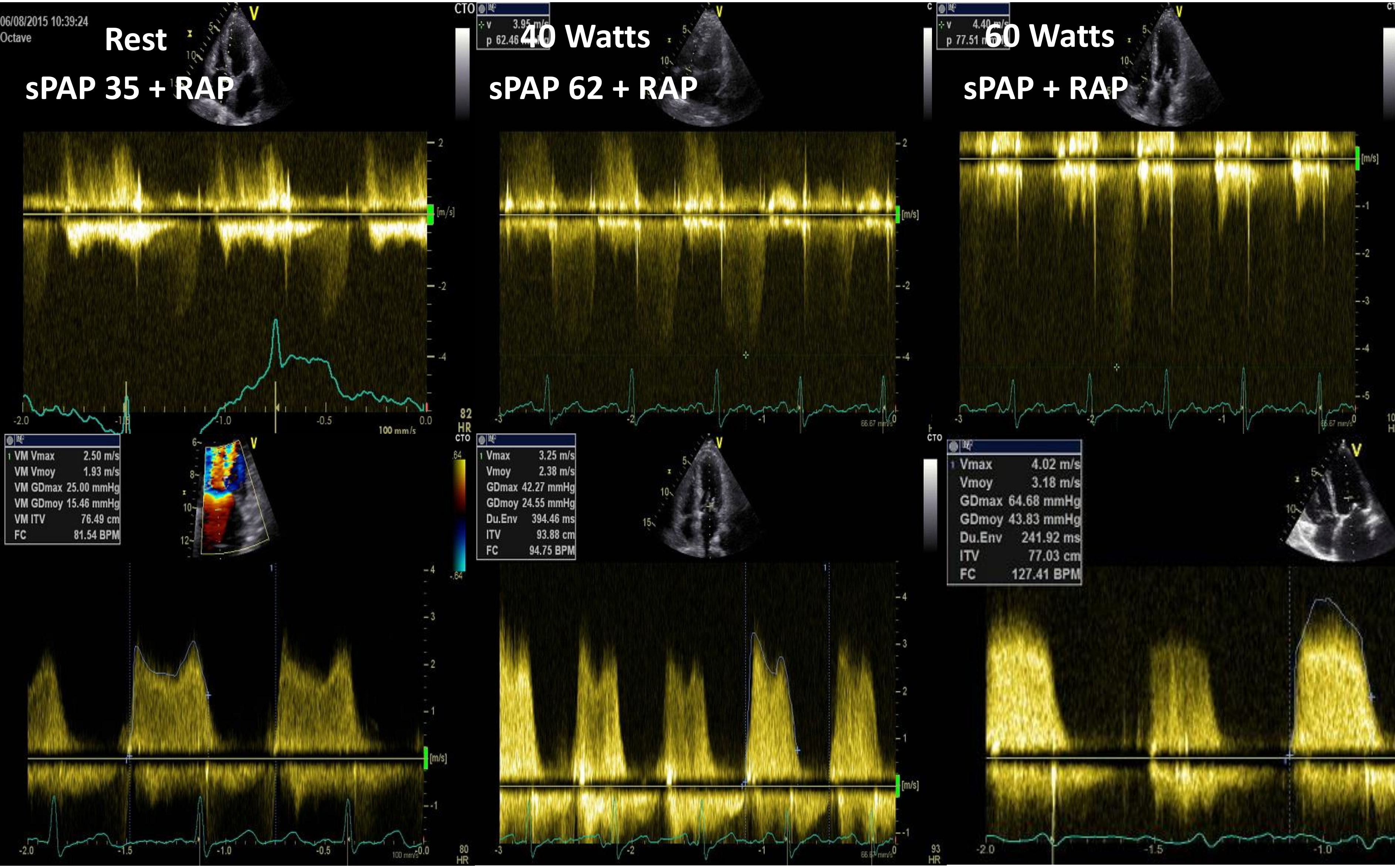

06/08/2015 10:26:06
Octave
18:40
83
HR
06/08/2015 10:37:25
Octave
18:46
74
HR
VM Vmax 2.50 m/s
VM Vmoy 1.93 m/s
VM GDmax 25.00 mmHg
VM GDmoy 15.46 mmHg
VM ITV 76.49 cm
FC 81.54 BPM
[m/s]
100 mm/s
80
HR
A 1.40 cm2
72
HR



Exercise induced dyspnea
Feasability of PMC

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Early Hemodynamic Changes Versus Peak Values: What Is More Useful to Predict Occurrence of Dyspnea During Stress Echocardiography in Patients with Asymptomatic Mitral Stenosis?

Eric Brochet, MD, Delphine Détaint, MD, Olivier Fondard, MD, Amale Tazi-Mezalek, MD, David Messika-Zeitoun, MD, Bernard Iung, MD, and Alec Vahanian, MD, *Paris, France*

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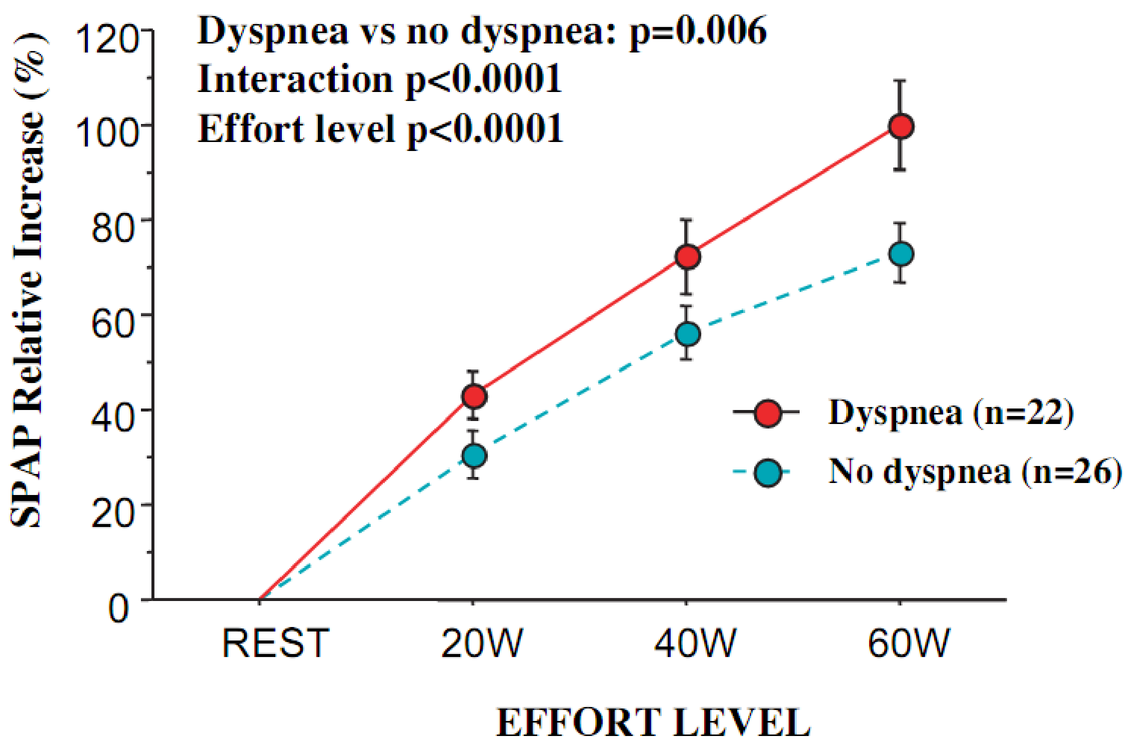

ORs of developing dyspnea

Threshold	OR (95% CI)	*P* value
Peak SPAP ≥60 mm Hg	1.37 (0.67–3.15)	.40
Increase in rest SPAP at 60W ≥90%	2.31 (1.21–4.85)	.02

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The increase in sPAP during exercise may be physiological

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- The sPAP increases during exercise until cardiac output reaches 2.5 to 3 times its resting value.

- TPG=mean PAP-downstream pressure

mean PAP-downstream pressure=(PVR/cardiac output)

mean PAP=(PVR/cardiac output)+downstream pressure

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Pulmonary hypertension during exercise

Table 2 Level of pulmonary artery systolic pressure at rest, at first workload step (25 W), at peak exercise, and peak exercise-induced increase in pulmonary artery systolic pressure within each range of age

	All ($n = 70$)	Age 20–30 ($n = 13$)	Age 30–40 ($n = 10$)	Age 40–50 ($n = 14$)	Age 50–60 ($n = 12$)	Age 60–70 ($n = 11$)	Age 70–80 ($n = 10$)
PASP at rest (mmHg)	27 ± 4	27 ± 4	29 ± 3	28 ± 3	26 ± 4	27 ± 4	28 ± 6
PASP at first workload step (mmHg)	34 ± 6	31 ± 4	33 ± 5	34 ± 4	31 ± 6	37 ± 9	37 ± 5
PASP at peak exercise (mmHg)	51 ± 9	45 ± 7	51 ± 6	52 ± 9	53 ± 4	54 ± 12*	58 ± 7*
Increase in PASP (mmHg)	27 ± 8	22 ± 8	24 ± 7	27 ± 10	29 ± 5	29 ± 9	30 ± 8

*No significant differences between strata except for PASP at peak exercise: $P = 0.01$.

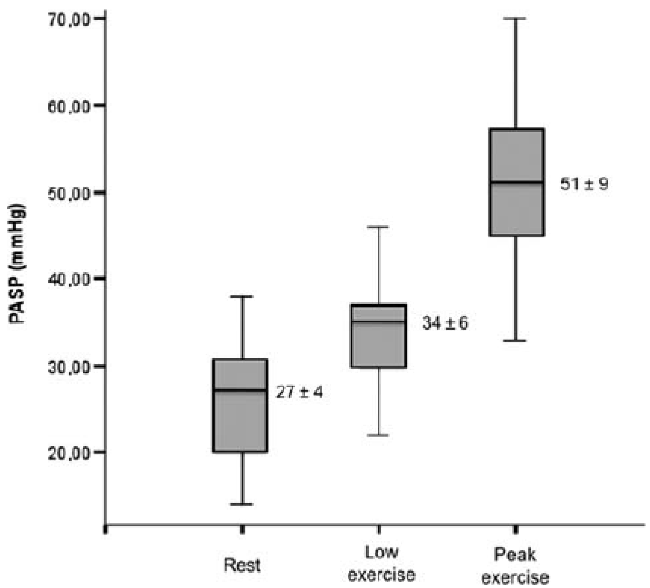
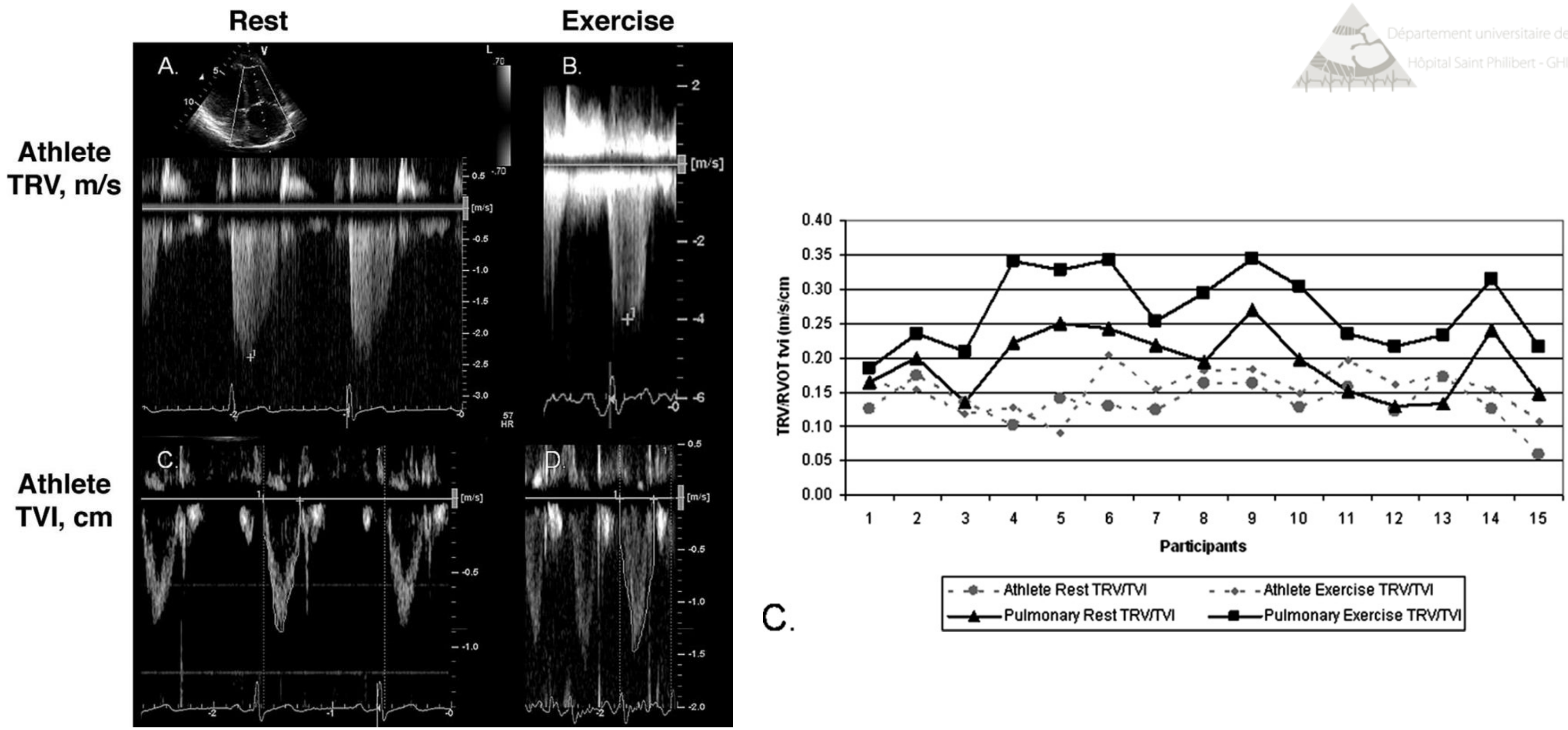


Figure 1 Increase in pulmonary artery pressure during exercise in the 70 healthy individuals of the study. Solid horizontal line indicates mean values; hatched box, quartiles; and vertical line, highest and lowest values.

sPAP > 60 mmHg is frequent at peak exercise in patients with good exercise capacity and older than 60

sPAP > 60 mmHg at low workload in a young patient should be considered as abnormal

Mahjoub, Levy et al, *Eur J Echocard*, 2009



TRV / RVOT VTI < 0.2 = Normal PVR

Bidart et al, *J Am Soc Echocard*, 2006

Key Points

SE is indicated to reveal symptoms and assess haemodynamic consequences of MS—based on the gradient and SPAP increase during stress—in patients with discordance between symptoms and stenosis severity. Exercise SE is preferred for SPAP assessment. MS should be considered severe if exertion results in a mean gradient >15 mmHg and SPAP >60 mmHg.

stenosis. Exercise echocardiography may provide objective information by assessing changes in mitral gradient and pulmonary artery pressure and is superior to DSE. Echocardiography plays an important role in

Vahanian et al, Eur Heart J, 2021

Mitral regurgitation

Primary mitral regurgitation (prolapse)

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CARDIOVASCULAR MEDICINE

Functional and prognostic implications of left ventricular contractile reserve in patients with asymptomatic severe mitral regurgitation

R Lee, B Haluska, D Y Leung, C Case, J Mundy, T H Marwick

Heart 2005;91:1407–1412. doi: 10.1136/hrt.2004.047613

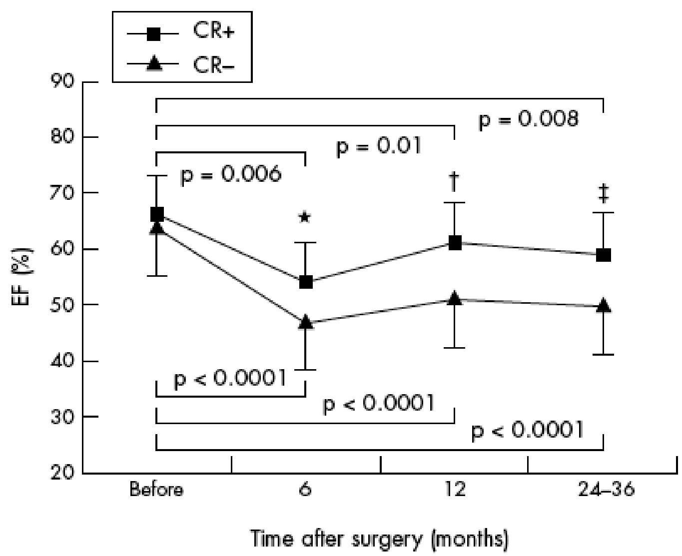

Figure 1 Follow up ejection fraction (EF) in surgically treated patients with (CR+) and without contractile reserve (CR–). EF expressed as mean (SD). *p = 0.16; †p = 0.02; ‡p = 0.008.

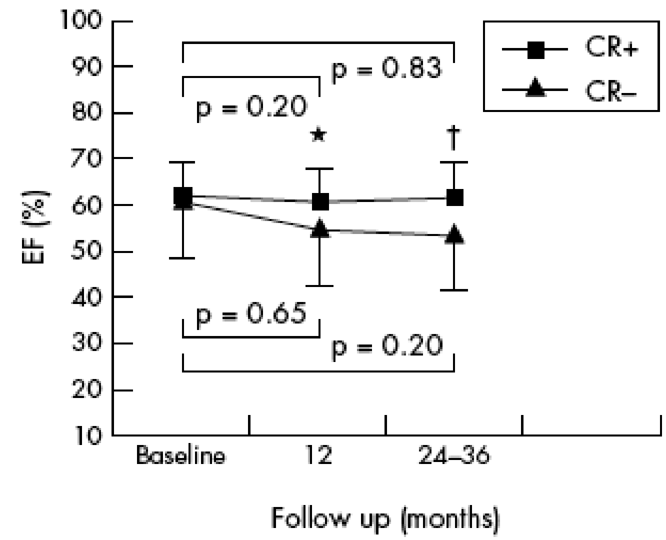

Figure 2 Follow up EF in medically treated CR+ and CR– patients. EF expressed as mean (SD). *p = 0.37; †p = 0.06.

Lee et al, *Heart*, 2005

3+, 4+
Asymptomatic organic MR
CR = Δ LV EF ≥ 4% from rest to peak exercise

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CARDIOVASCULAR MEDICINE

Functional and prognostic implications of left ventricular contractile reserve in patients with asymptomatic severe mitral regurgitation

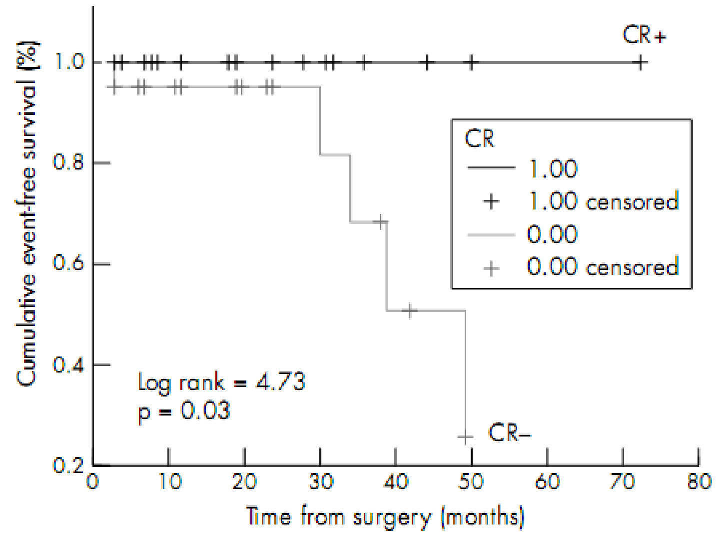
R Lee, B Haluska, D Y Leung, C Case, J Mundy, T H Marwick

Heart 2005;91:1407–1412. doi: 10.1136/hrt.2004.047613

Table 2 Baseline rest and exercise echocardiographic measurements in CR+ and CR− patients

Variable	CR+ (n = 45)	CR− (n = 26)	p Value
Rest			
LVEDD (cm)	5.8 (0.7)	5.8 (0.8)	0.97
LVESD (cm)	3.3 (0.4)	3.4 (0.6)	0.48
LVEDVrest (ml)	118 (35)	122 (43)	0.70
LVESVrest (ml)	43 (16)	44 (19)	0.85
EFrest (%)	64 (7)	64 (7)	0.86
Exercise			
LVEDVexe (ml)	103 (37)	95 (27)	0.38
LVESVexe (ml)	27 (14)	42 (13)	<0.0001
EFexe (%)	74 (8)	56 (8)	<0.0001
ΔEF (%)	10 (6)	−8 (9)	<0.0001
Peak RPP (×1000)	28 (6)	27 (6)	0.45
Functional capacity			
METS	7.8 (3.6)	5.1 (1.5)	0.001
VO_2max (ml/kg/min)	24.8 (9.9)	15.8 (6.0)	0.004

Values are mean (SD).
ΔEF, ejection fraction increment with exercise; EFexe, ejection fraction with exercise; EFrest, ejection fraction at rest; LVEDD, end diastolic diameter; LVEDVexe, end diastolic volume with exercise; LVEDVrest, end diastolic volume at rest; LVESD, end systolic diameter; LVESVexe, end systolic volume with exercise; LVESVrest, end systolic volume at rest; METS, metabolic equivalents; RPP, rate–pressure product; VO_2max, maximum oxygen consumption.



Number at risk:						
CR+	19	14	10	6	3	1
CR−	22	16	11	6	3	1

Figure 4 Event-free survival in surgically treated CR+ and CR− patients.

Lee et al, *Heart*, 2005

3+, 4+
Asymptomatic organic MR
CR = Δ LV EF ≥ 4% from rest to peak exercise

Speckle tracking for reproducible assessment of LV function?

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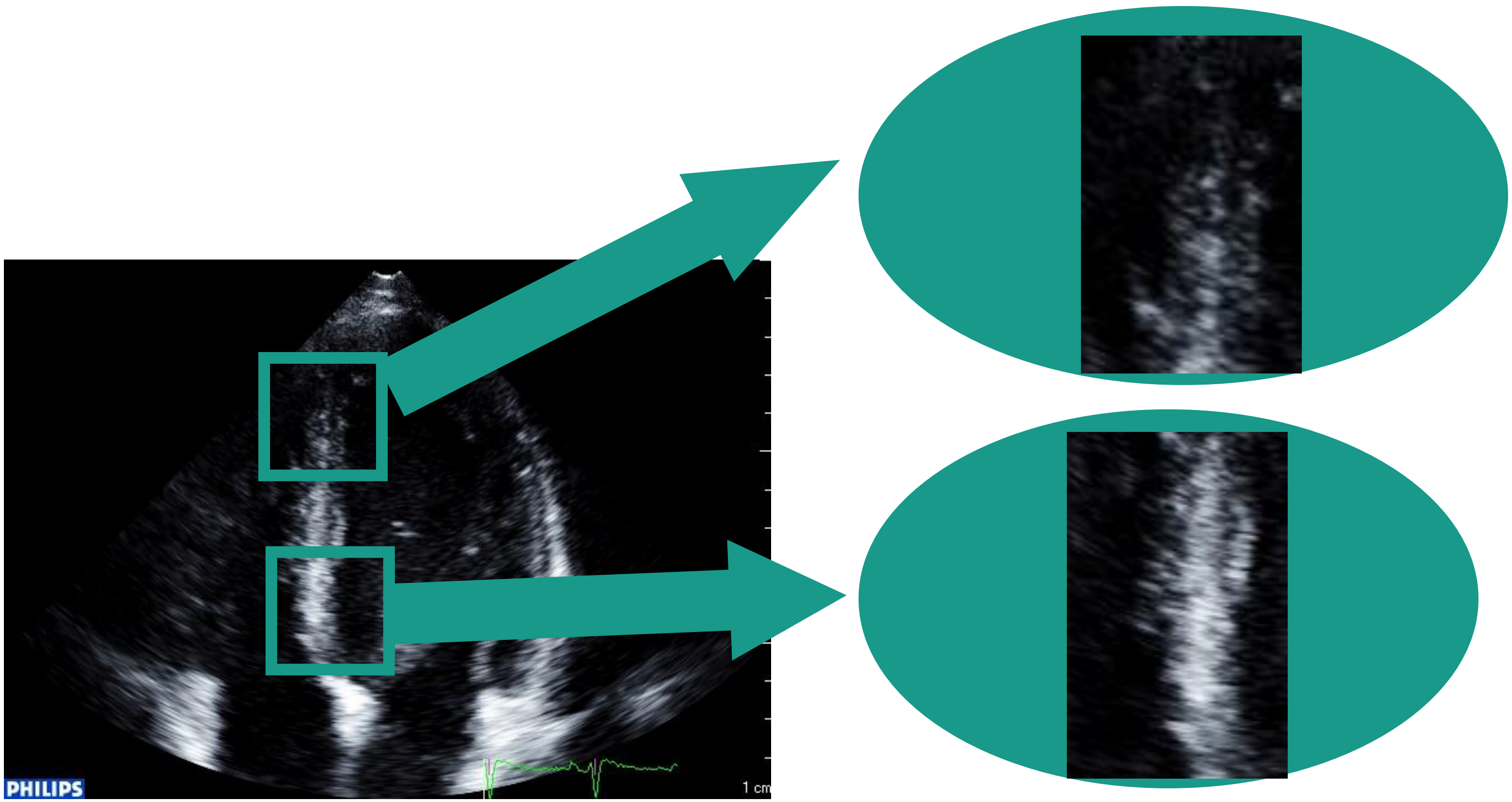

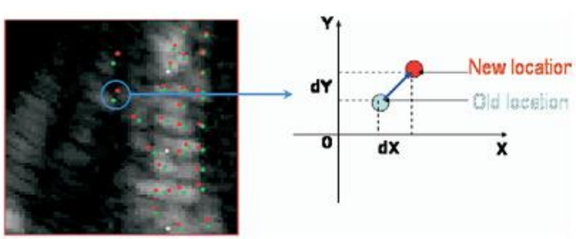

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Importance of Left Ventricular Longitudinal Function and Functional Reserve in Patients With Degenerative Mitral Regurgitation: Assessment by Two-Dimensional Speckle Tracking

Patrizio Lancellotti, MD, PhD, Bernard Cosyns, MD, Dimitris Zacharakis, MD, Emilio Attena, MD, Guy Van Camp, MD, PhD, Olivier Gach, MD, Marc Radermecker, MD, PhD, and Luc A. Piérard, MD, PhD, *Liège, Braine l'Alleud, and Brussels, Belgium*

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93 patients, degenerative MR
ERO > 30 mm2
LV EF > 60%, LVESD < 45 mm

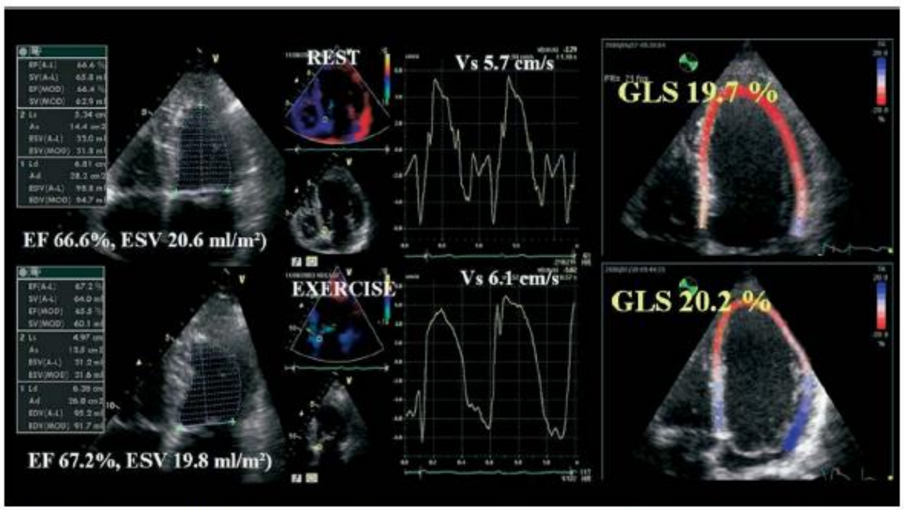

Figure 1 Example of a patient with limited contractile recruitment during exercise. During test, LV ejection fraction (EF), peak systolic velocity, and GLS changed slightly. *EDV*, End-diastolic volume; *ESV*, end-systolic volume. Color figure online.

Table 3 Determinants of postoperative LV ejection fraction

Data at inclusion	Postoperative LV ejection fraction ≥ 50% (n = 17)	Postoperative LV ejection fraction < 50% (n = 13)	*P* value
Rest			
Left atrial volume (mL)	67 ± 20	94 ± 28	.008
LV ejection fraction (%)	67 ± 6	67 ± 5.5	NS
Peak systolic velocity (cm/s)	6.2 ± 1.7	6.1 ± 1.5	NS
GLS (%)	19.8 ± 3.2	17.9 ± 2.7	.044
Exercise			
LV end-systolic volume (mL)	33 ± 12	42 ± 20	NS
LV ejection fraction (%)	71 ± 9	63 ± 11	.05
Peak systolic velocity	8.9 ± 2.2	7.8 ± 2.3	NS
GLS (%)	23.4 ± 4.7	17.1 ± 4.4	.0009
Exercise-induced changes			
LV ejection fraction (%)	4.3 ± 8.8	−3.2 ± 7.1	.018
Peak systolic velocity (cm/s)	2.7 ± 2.4	1.7 ± 1.5	NS
GLS (%)	3.6 ± 3.9	−0.8 ± 3.9	.005

Delta GLS 1.9%

Longitudinal strain, apical 4- and 2-chamber views

Lancellotti et al, *J Am Soc Echocard*, 2008

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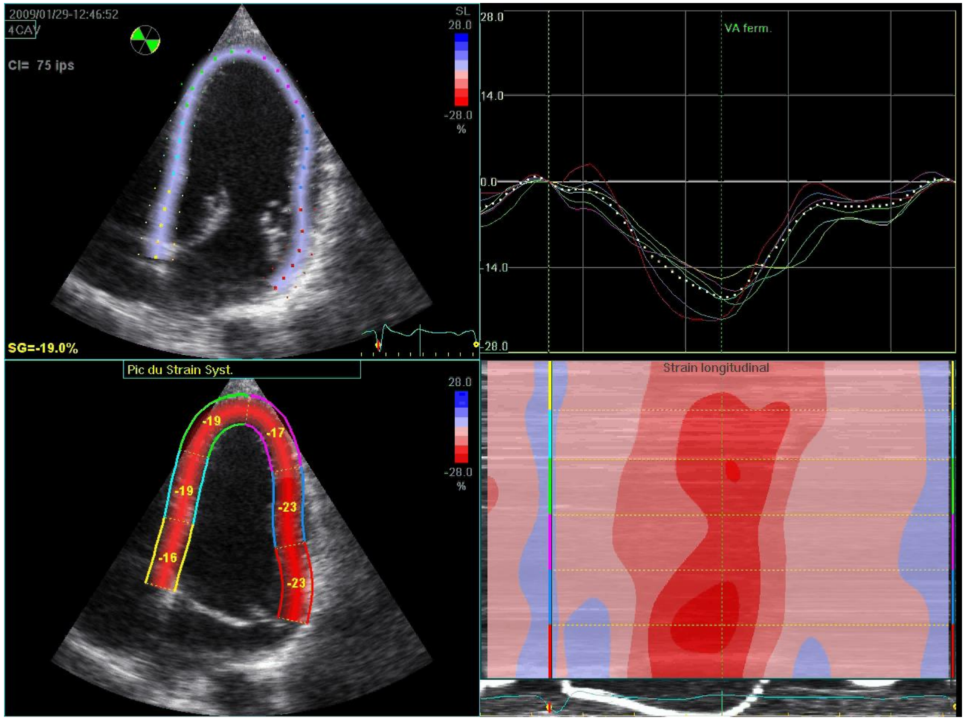

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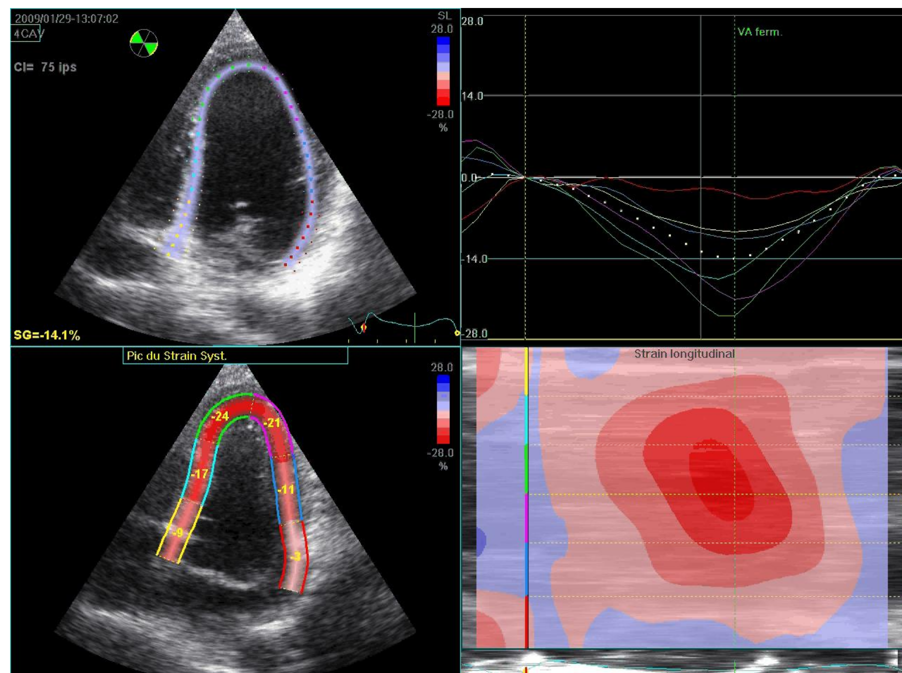
EXERCISE



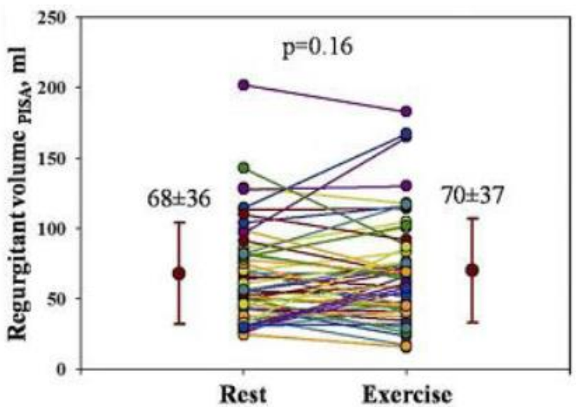
REST

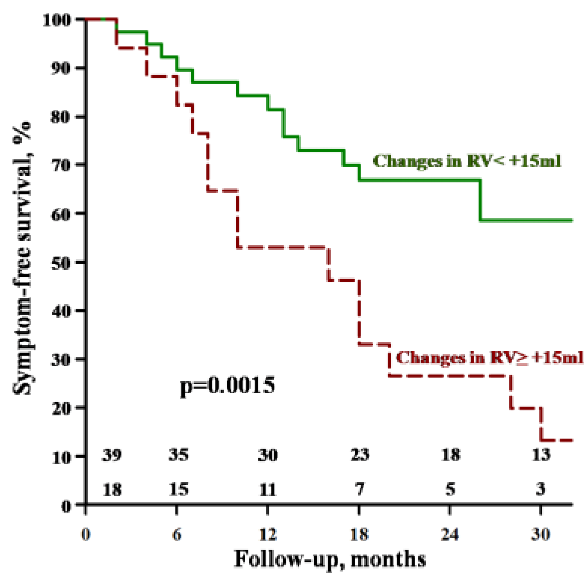
Valvular Heart Disease

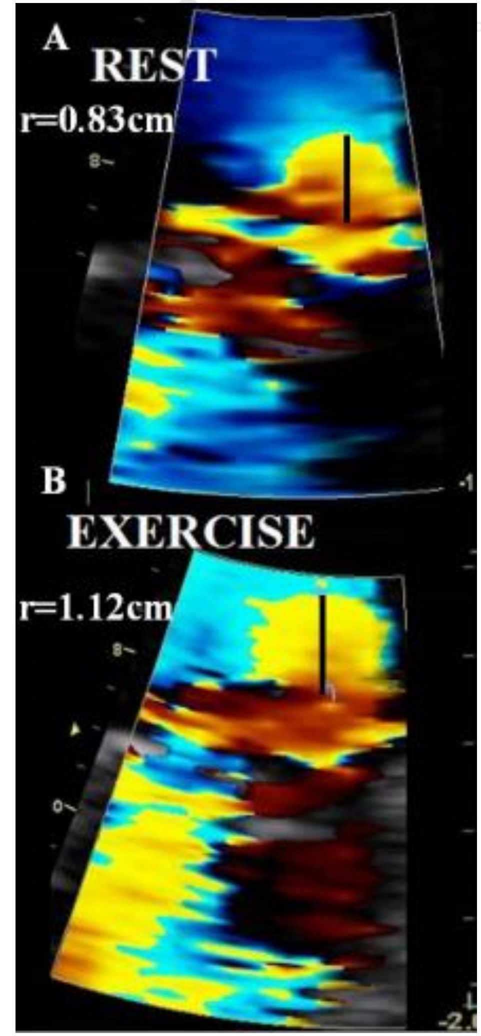
Exercise-Induced Changes in Degenerative Mitral Regurgitation

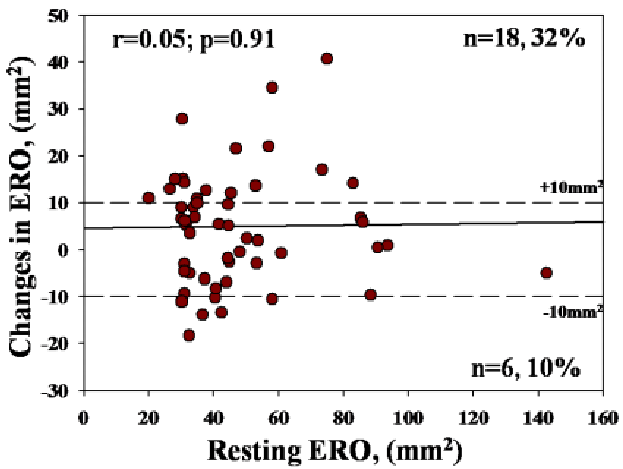
Julien Magne, PHD, Patrizio Lancellotti, MD, PHD, Luc A. Piérard, MD, PHD
Liège, Belgium

61 patients,
moderate to severe MR









Magne et al, *J Am Coll Cardiol*, 2010

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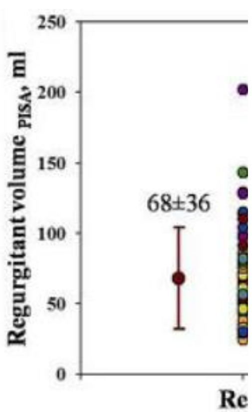
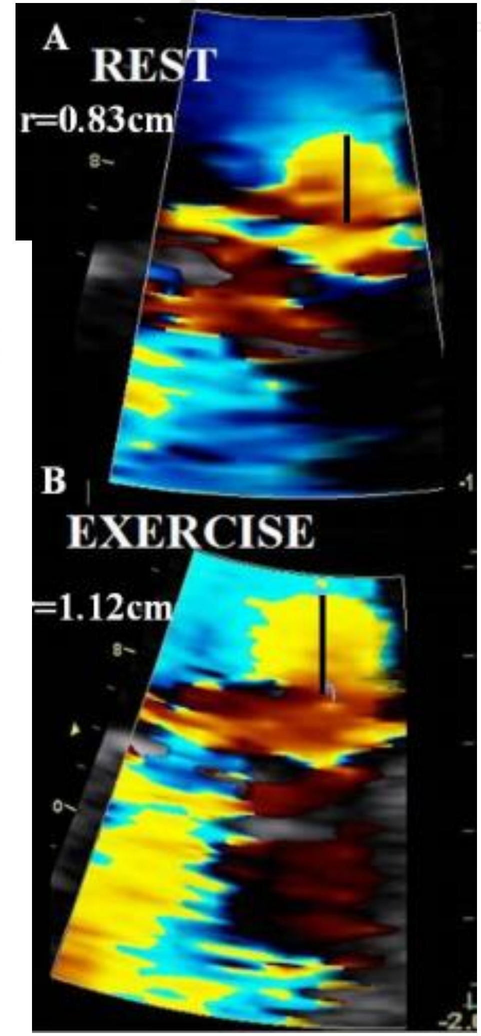
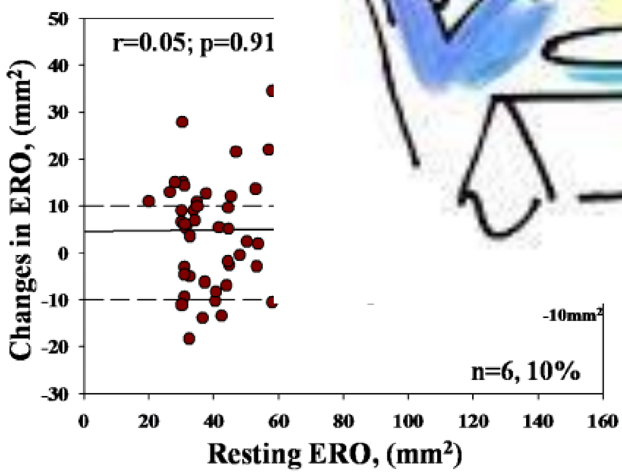
Valvular Heart Disease

Exercise-Induced Changes in Degenerative Mitral Regurgitation

Julien Magne, PHD, Patrizio Lancellotti, MD, PHD, Luc A. Piérard, MD, PHD
Liège, Belgium







Magne et al, *J Am Coll Cardiol*, 2010

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Exercise Pulmonary Hypertension in Asymptomatic Degenerative Mitral Regurgitation

Julien Magne, PhD; Patrizio Lancellotti, MD, PhD, FESC; Luc A. Piérard, MD, PhD, FESC

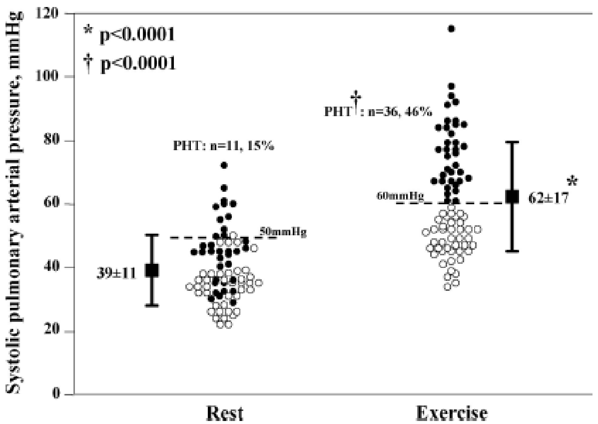
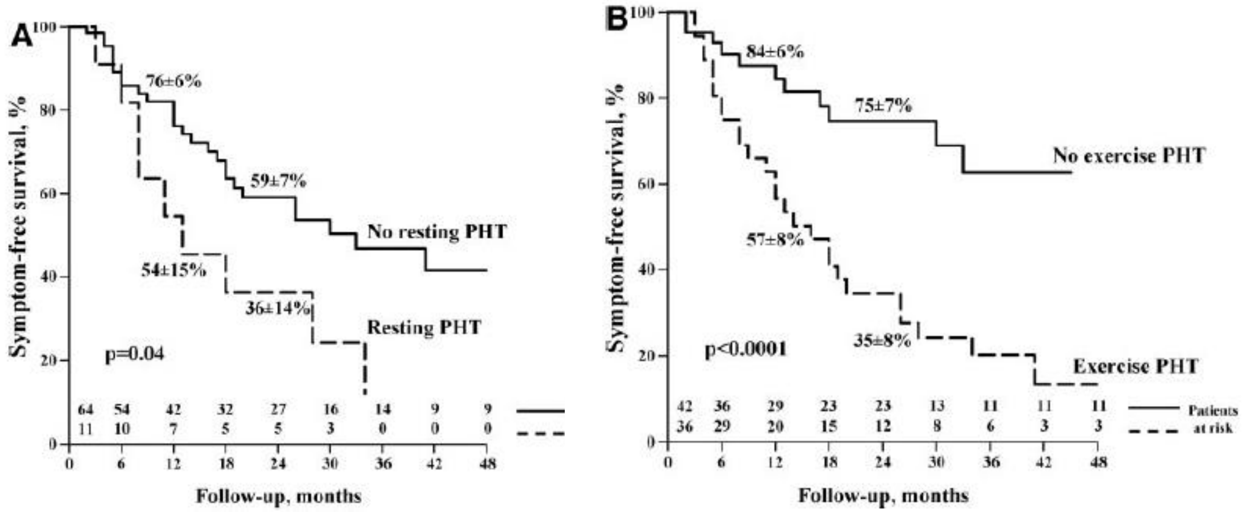
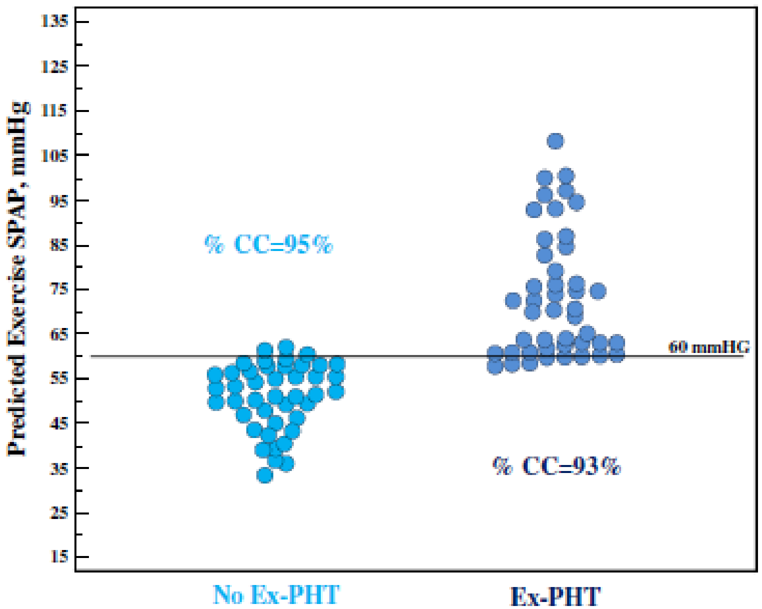


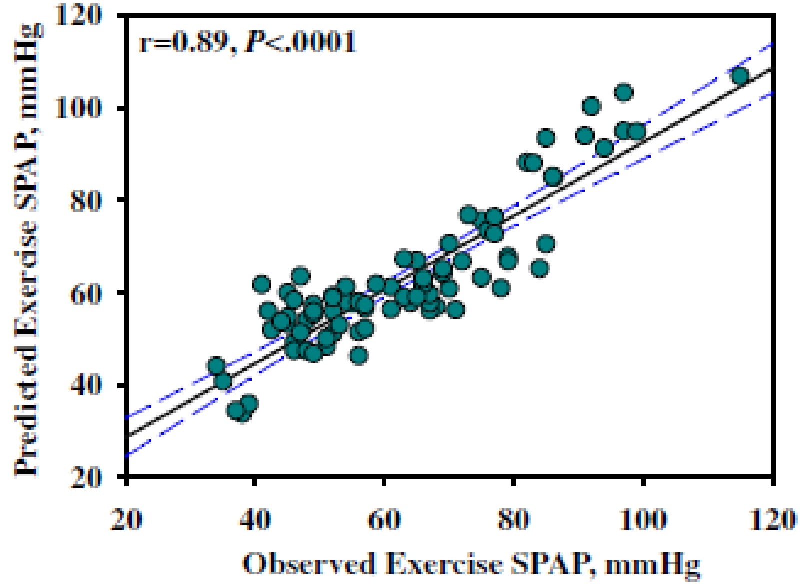
Figure 1. SPAP at rest and during exercise in the whole cohort Solid circles identify patients with exercise PHT; squares and bars represent mean±SD. The number and percent indicate the number and percentage of patients with PHT at rest and during exercise. Dotted lines indicate threshold of PHT. *Significant difference between rest and exercise SPAP. †Significant difference between the frequency of resting and exercise PHT.



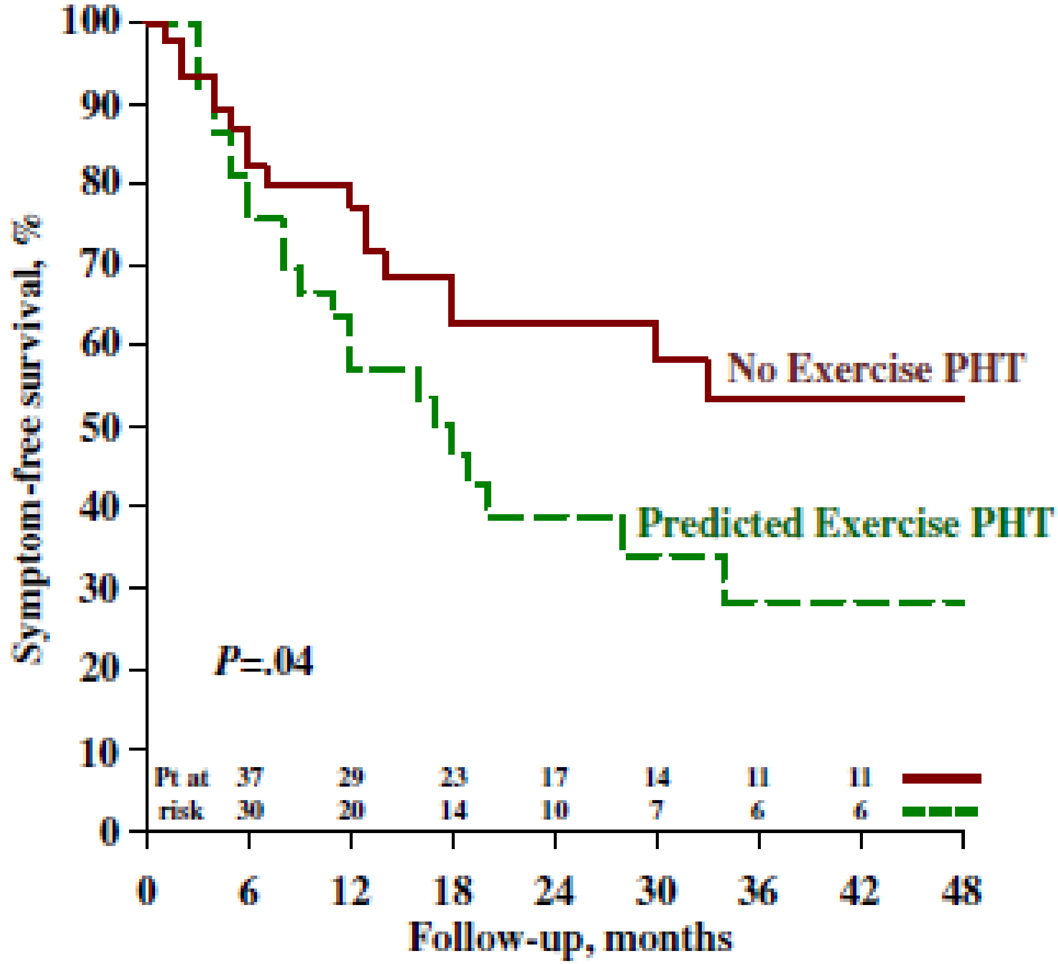
Prediction of Exercise Pulmonary Hypertension in Asymptomatic Degenerative Mitral Regurgitation

Julien Magne, PhD, Patrizio Lancellotti, MD, PhD, Kim O'Connor, MD, Caroline M. Van de Heyning, MD, Catherine Szymanski, MD, and Luc A. Piérard, MD, PhD, *Liège, Belgium; Quebec, Quebec, Canada*





$$Predicted\ Exercise\ SPAP = 0.13 \times Age + 0.05 \times LVED\ Vol + 0.7 \times E/Ea\ ratio - \frac{TP\ Sa}{10} + 51 mm\ Hg.$$

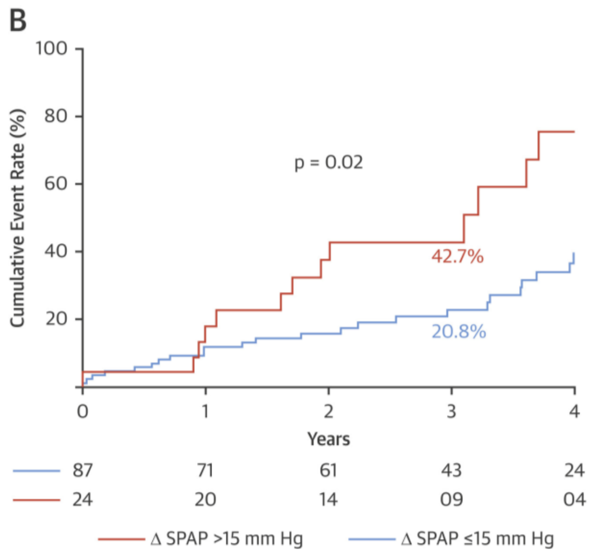


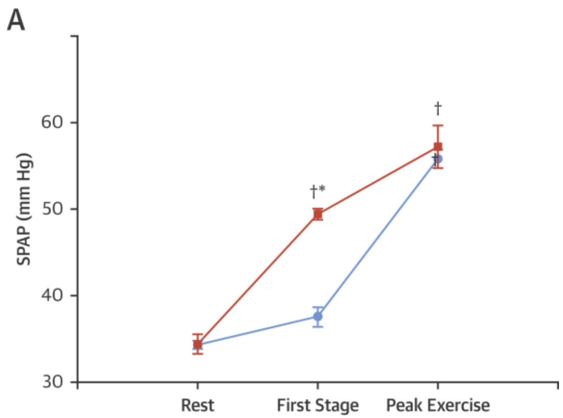
$$Predicted\ Exercise\ SPAP = 0.13 \times Age + 0.05 \times LVED\ Vol + 0.7 \times E/Ea\ ratio - \frac{TP.Sa}{10} + 51 mm\ Hg.$$

Magne et al, *J Am Soc Echocard*, 2011

Exercise pulmonary pressure in organic MR?

Asymptomatic patients with organic MR presenting an abrupt increase in SPAP >15 mm Hg at a low level of exercise have 2-fold increase in the risk of cardiac events





J Am Coll Cardiol 2018;71(6):700-1

Clinical case

Département universitaire de cardiologie
Hôpital Saint Philibert - GHICL

- 64 yo, patient
- Exercise induced dyspnea
- Migraine (Ergotamine), history of LAD stenting
- MR/prolapse
- Discrepancy between leak severity and dyspnea
- Referred for exercise stress echocardiography

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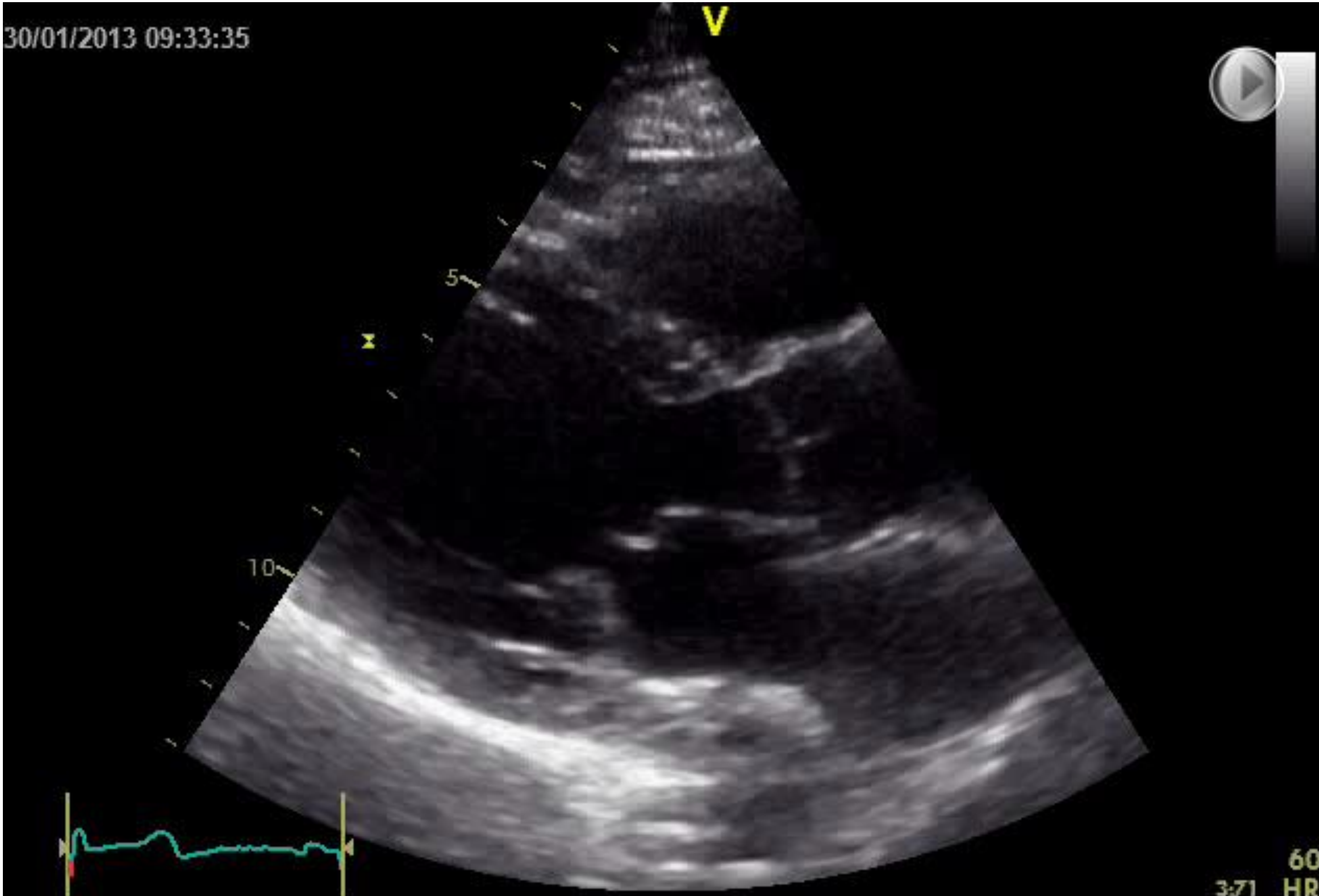
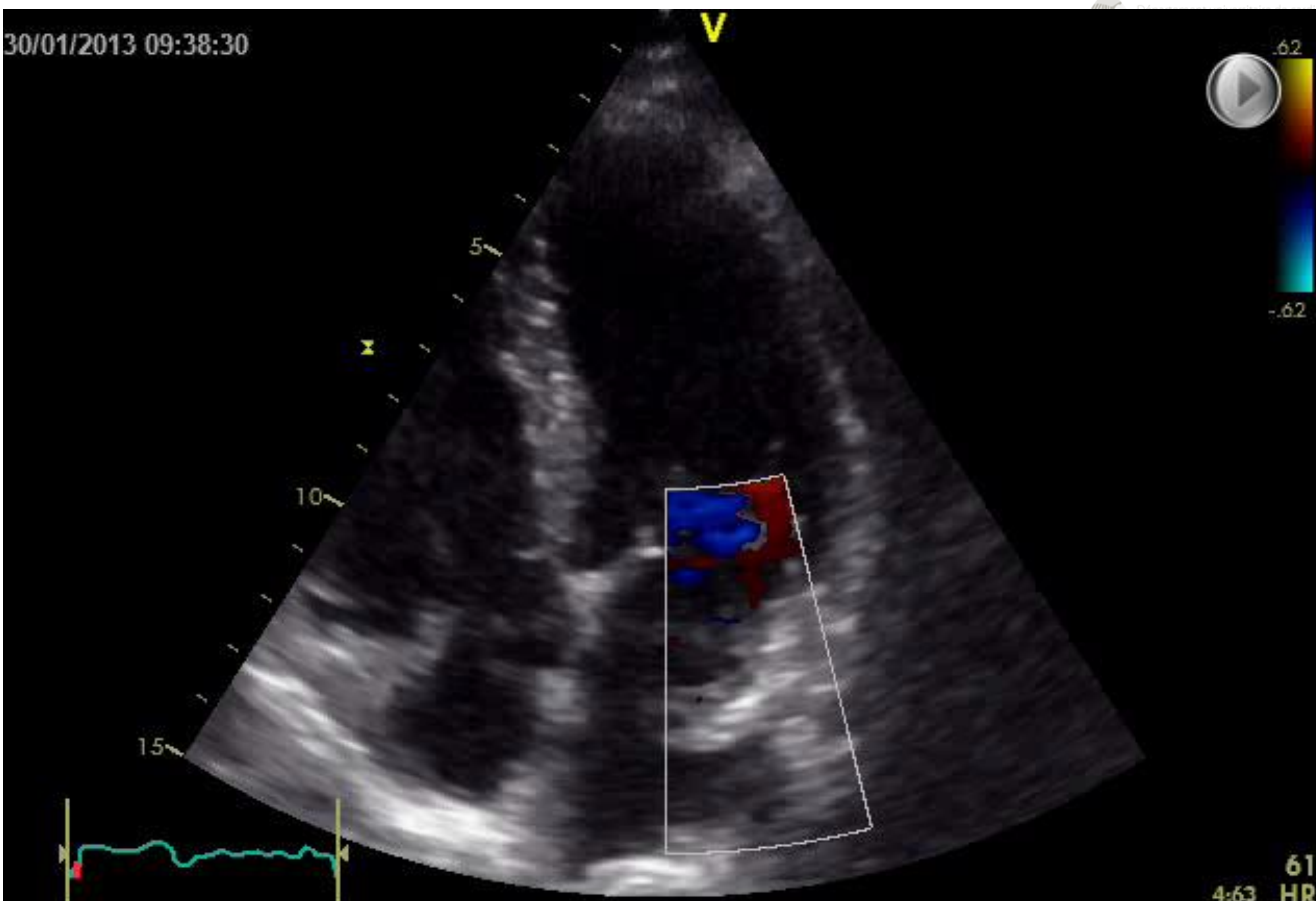
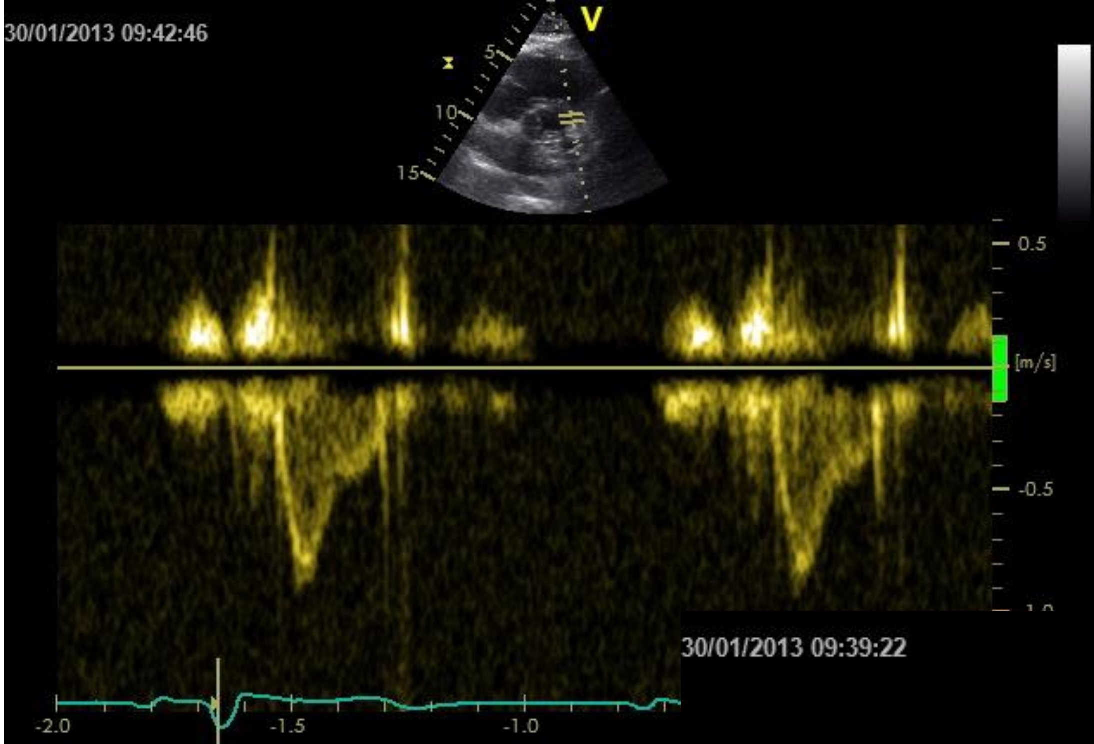
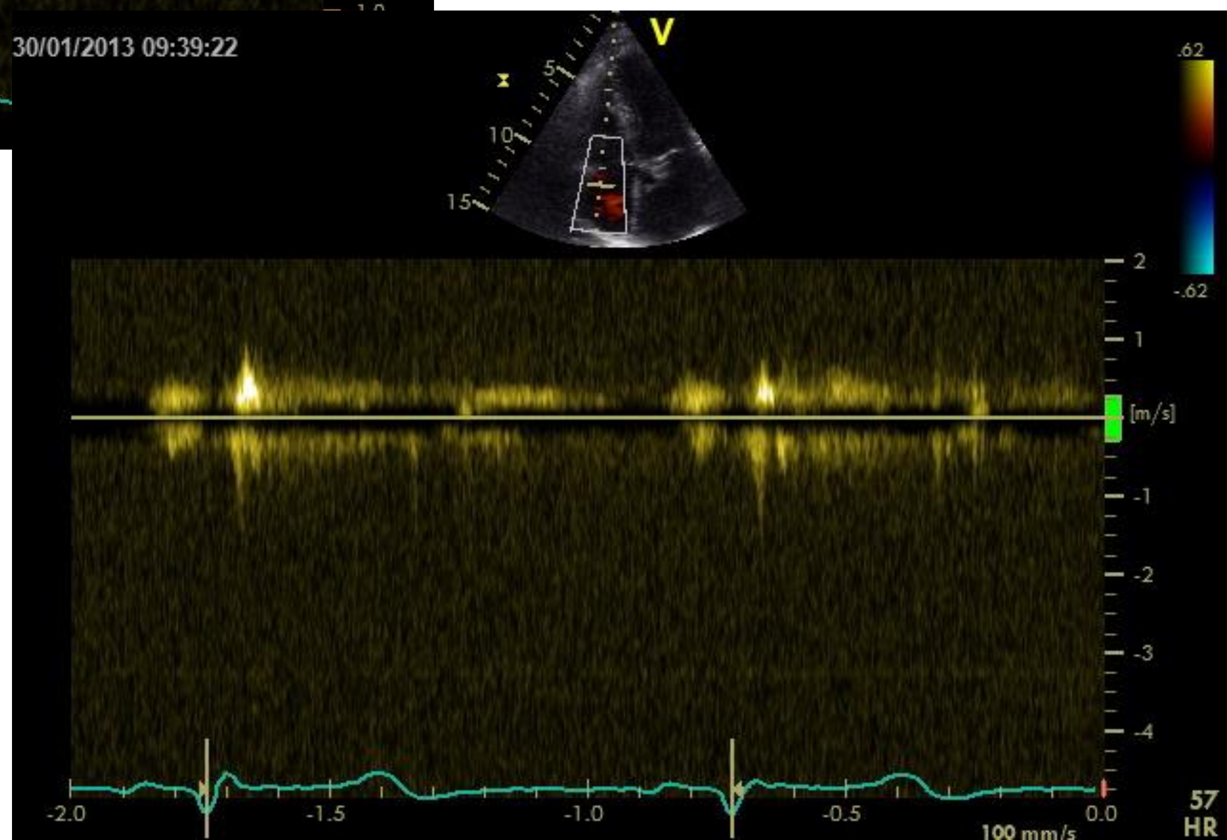
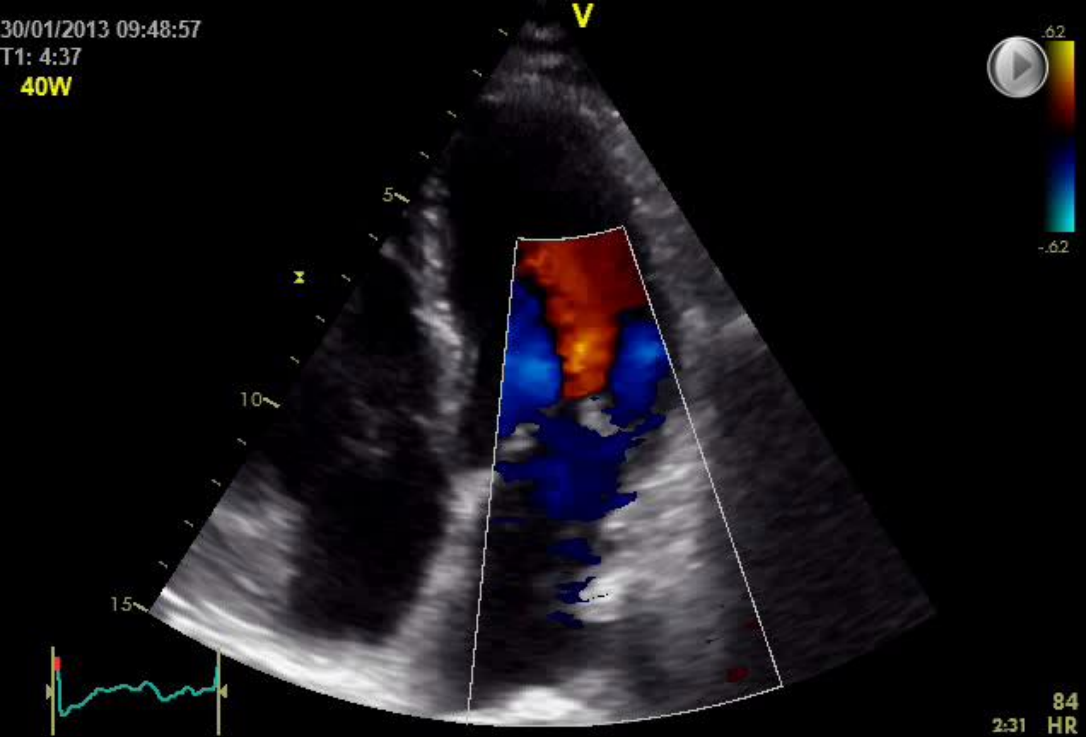
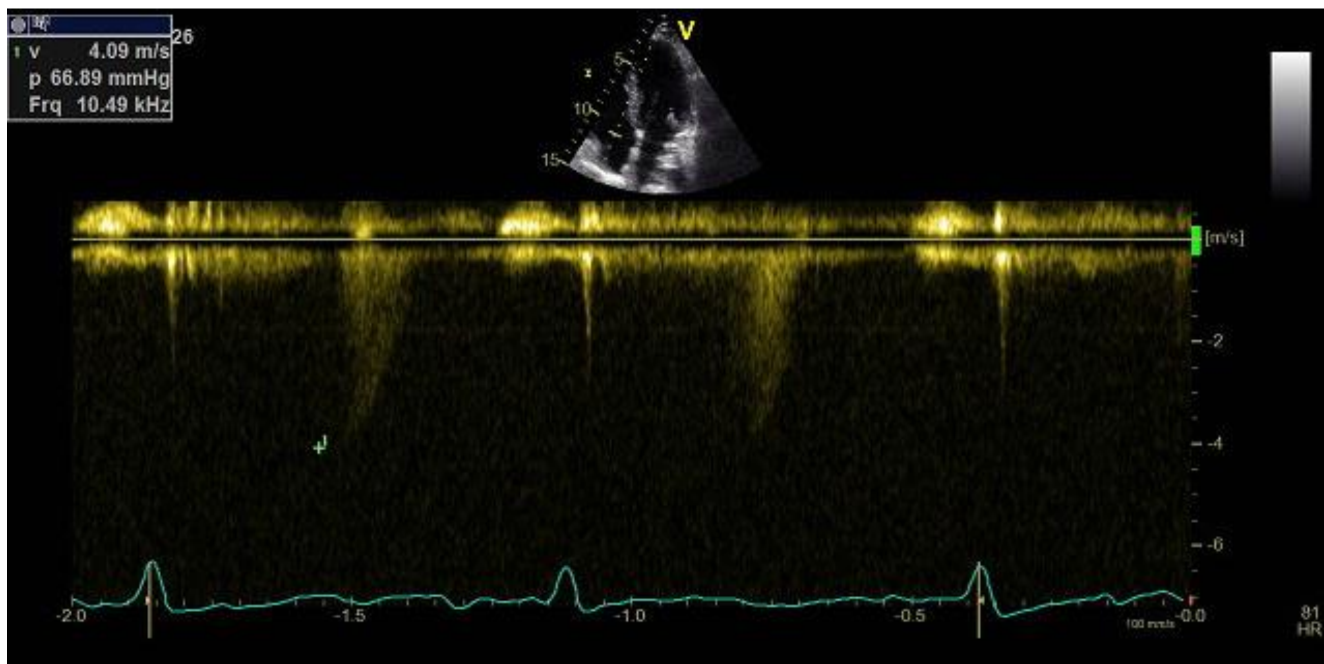

30/01/2013 09:33:35
V
5
10
60
3:71
HR


30/01/2013 09:38:30
V
.62
-.62
5
10
15
61
4:63
HR


30/01/2013 09:42:46
V
5
10
15
0.5
[m/s]
-0.5
-2.0
-1.5
-1.0


30/01/2013 09:39:22
V
5
10
15
.62
-.62
2
1
[m/s]
-1
-2
-3
-4
-2.0
-1.5
-1.0
-0.5
0.0
100 mm/s
57
HR


30/01/2013 09:48:57
T1: 4:37
40W
V
.62
-.62
5
10
15
84
HR
2:31


v 4.09 m/s
p 66.89 mmHg
Frq 10.49 kHz
26
V
[m/s]
-2
-4
-6
-2.0
-1.5
-1.0
-0.5
-0.0
81
HR

=>Pulmonary Hypertension

- Ergotamine
- KT: mPAP 30 mmHg, PCPW 7 mmHg
- Mutliples distal pulmonary embolism

Key Points

Exercise SE provides information about disease severity and individual outcome in MR. MR severity, SPAP, and left and right ventricular contractile reserve should be evaluated according to the clinical context. An increase by ≥1 grade in MR (from moderate-to-severe MR), an SPAP ≥ 60 mmHg, and a lack of contractile reserve (<5% increase in EF or <2% increment in global longitudinal strain) are markers of poor prognosis.

Exercise echocardiography permits evaluation of changes in mitral regurgitant volume and pulmonary pressures during peak exercise and is particularly helpful in patients with discordant symptoms and regurgitation grade at rest.[280,281] In asymptomatic patients with severe PMR and non-dilated LV and LA, low BNP values are associated with low mortality and can be useful during follow-up.[41,282]

Vahanian et al, ESC guidelines, 2021

Restrictive mitral regurgitation
Secondary mitral regurgitation

Clinical case

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- 72 yo woman
- High SBP, catamenial migraine
- No diabetes
- 3 episodes of pulmonary oedema
- Severe exercise induced dyspnea
- Quantification of MR variable
- Normal coronary angiography and renal arteries

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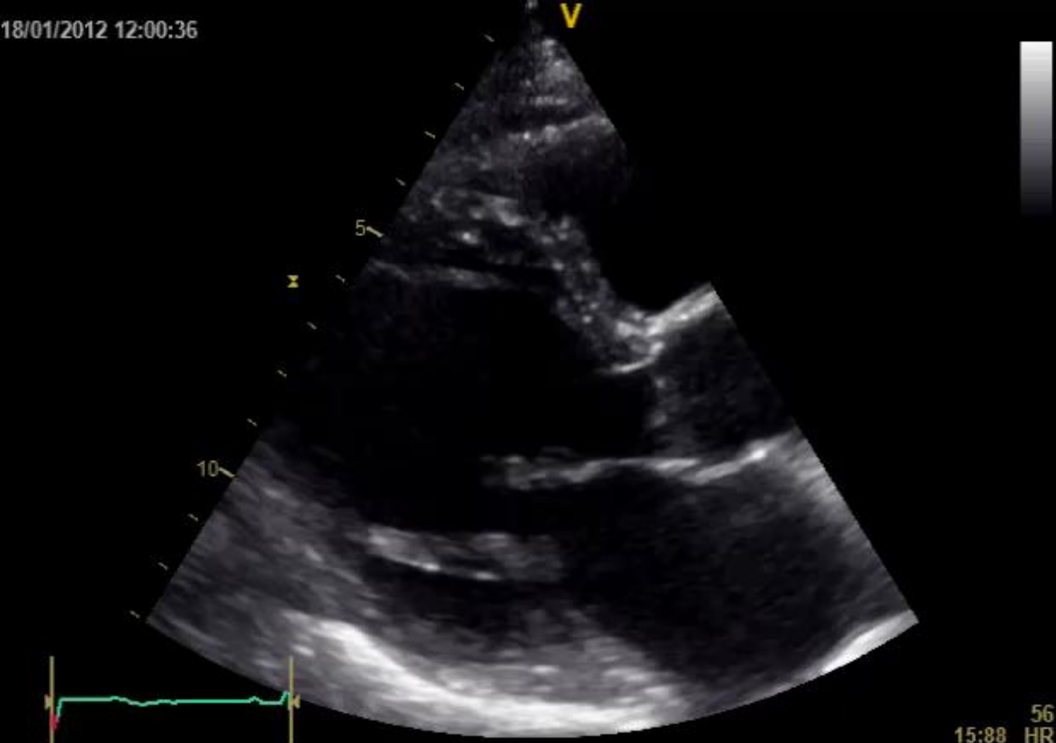
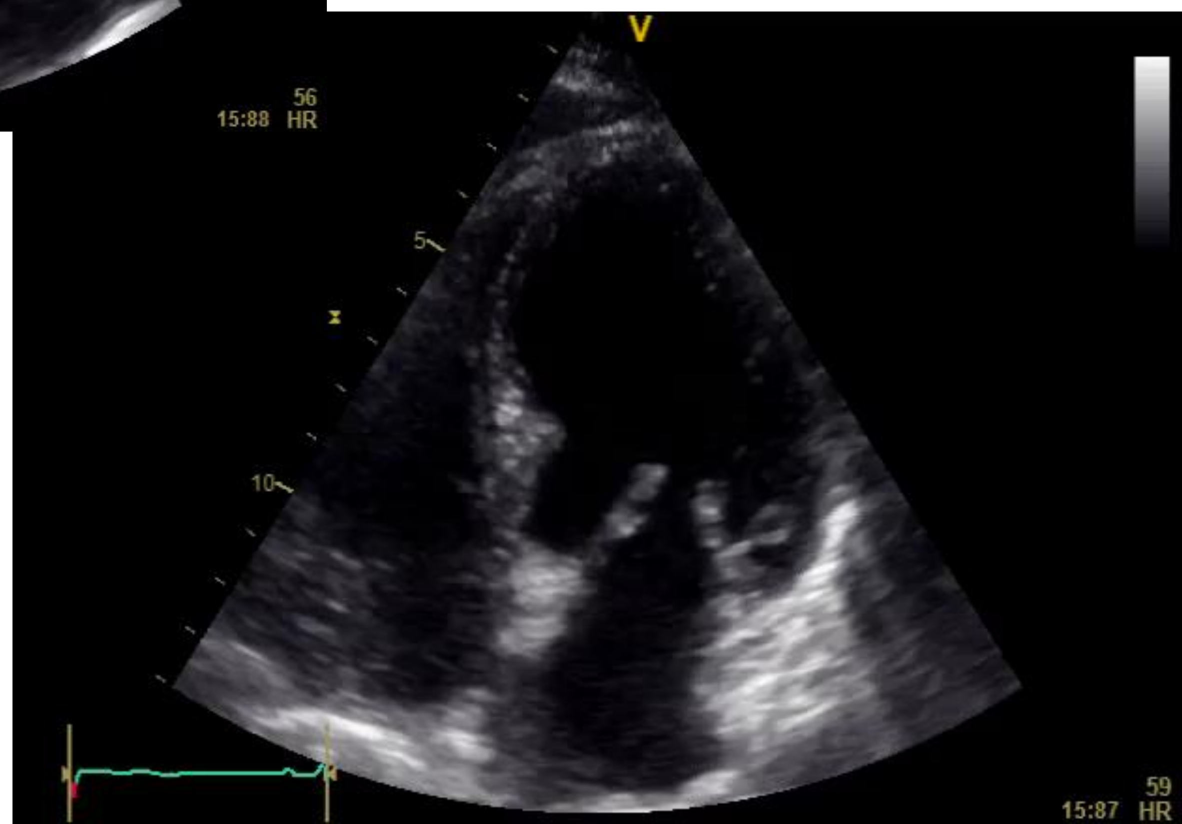
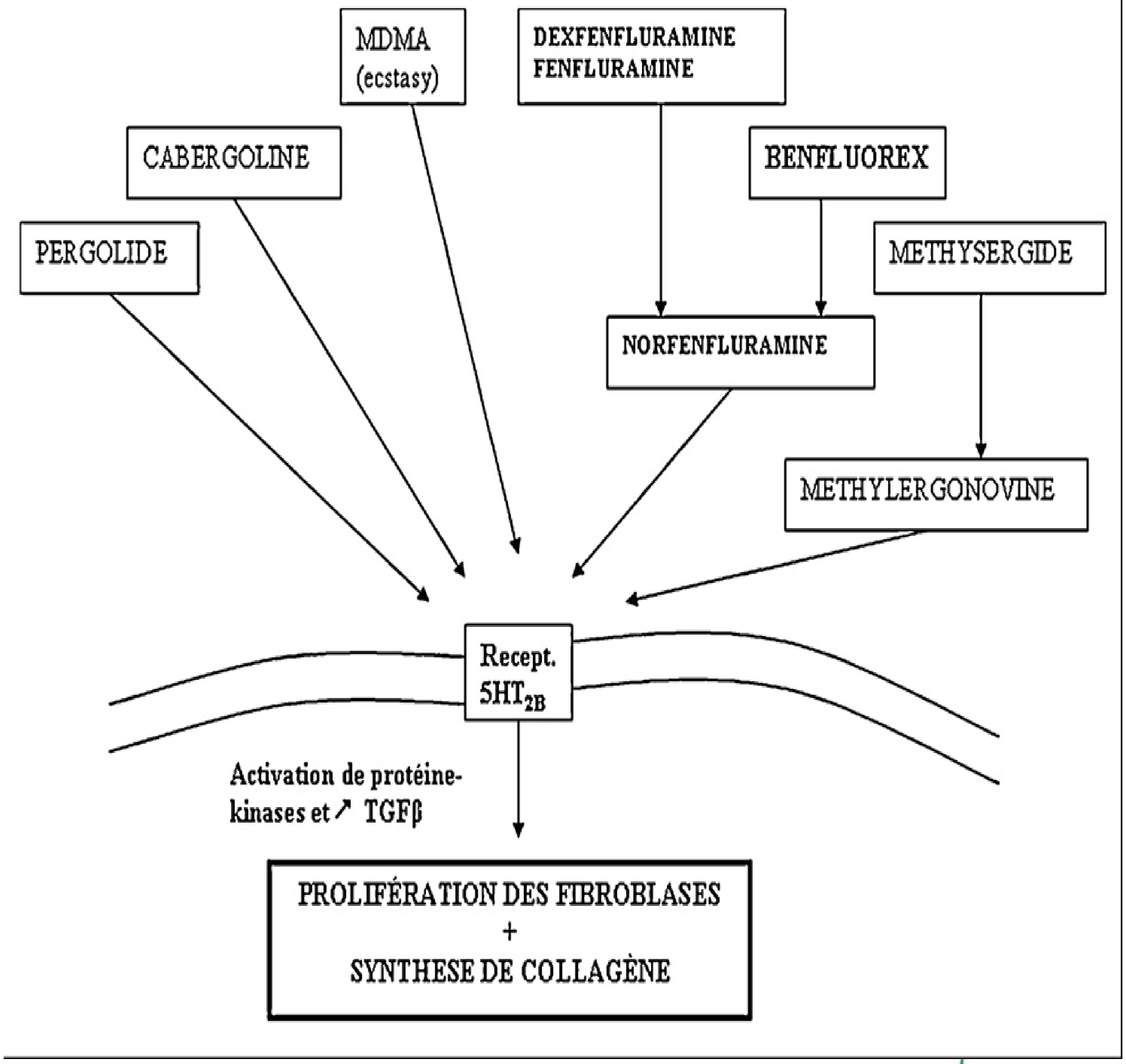
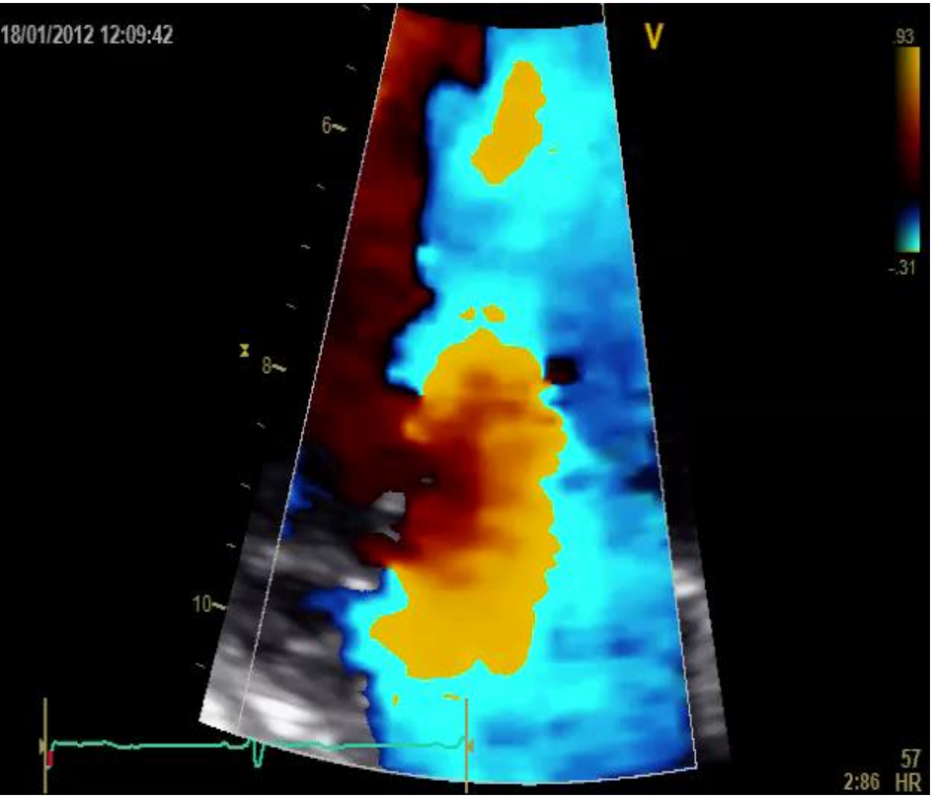
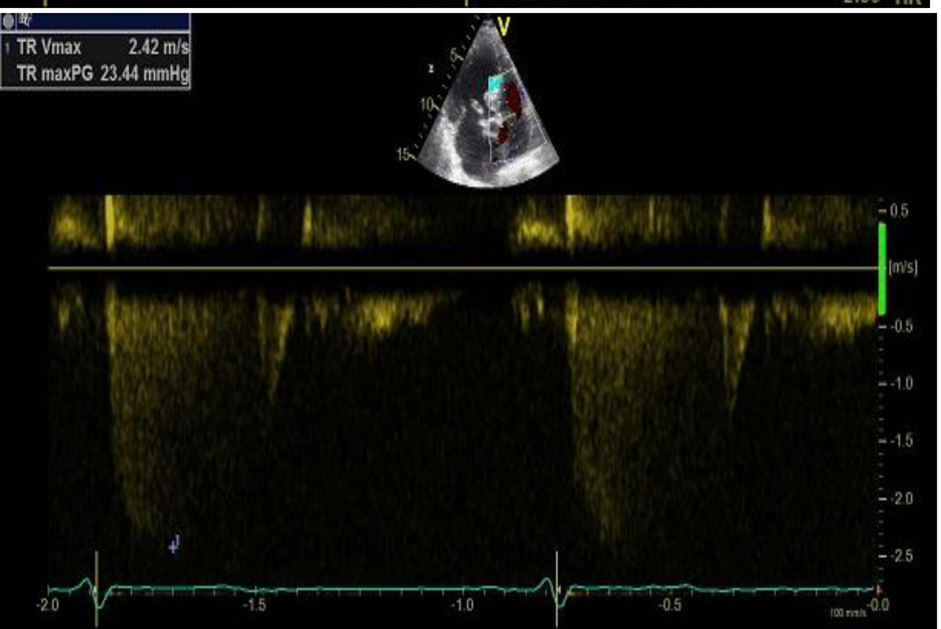

18/01/2012 12:00:36
V
5
10
56
15:88 HR

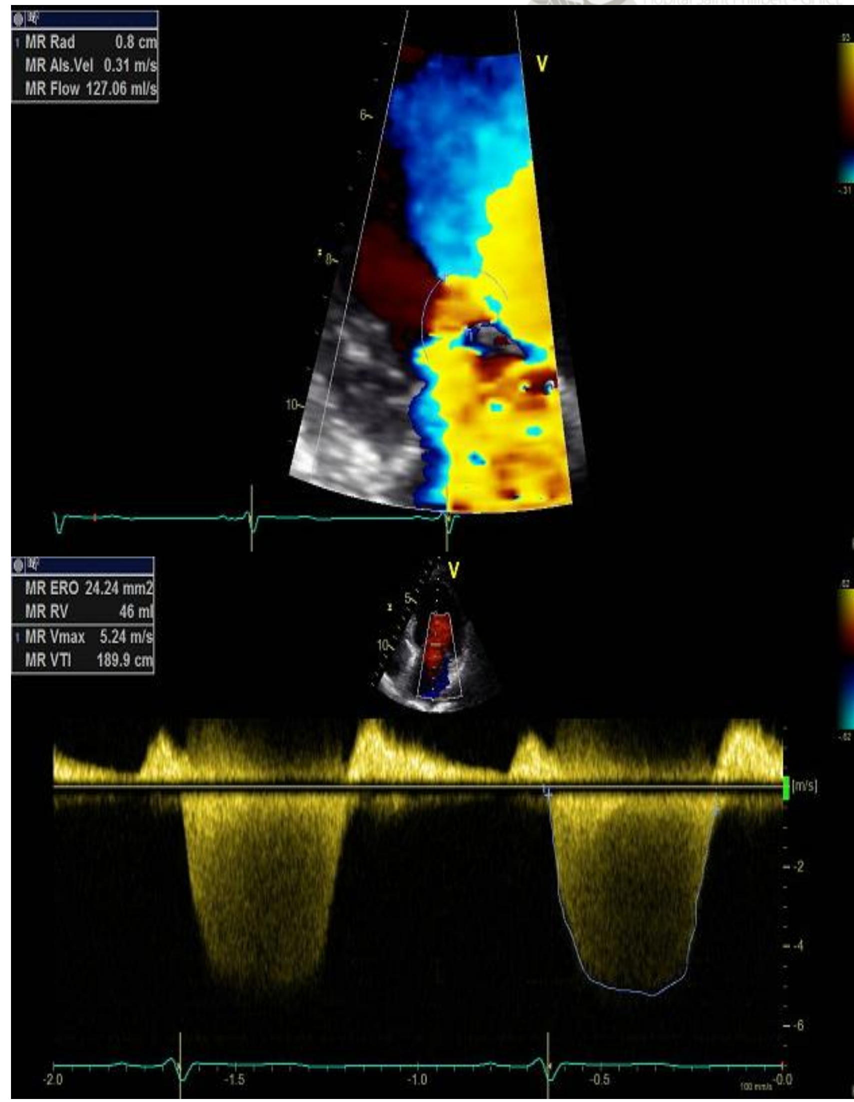

V
5
10
59
15:87 HR


MDMA
(ecstasy)
DEXFENFLURAMINE
FENFLURAMINE
CABERGOLINE
BENFLUOREX
PERGOLIDE
METHYSERGIDE
NORFENFLURAMINE
METHYLERGONOVINE
Recept.
5HT2B
Activation de protéine-kinases et ↗ TGFβ
PROLIFÉRATION DES FIBROBLASES
+
SYNTHESE DE COLLAGÈNE

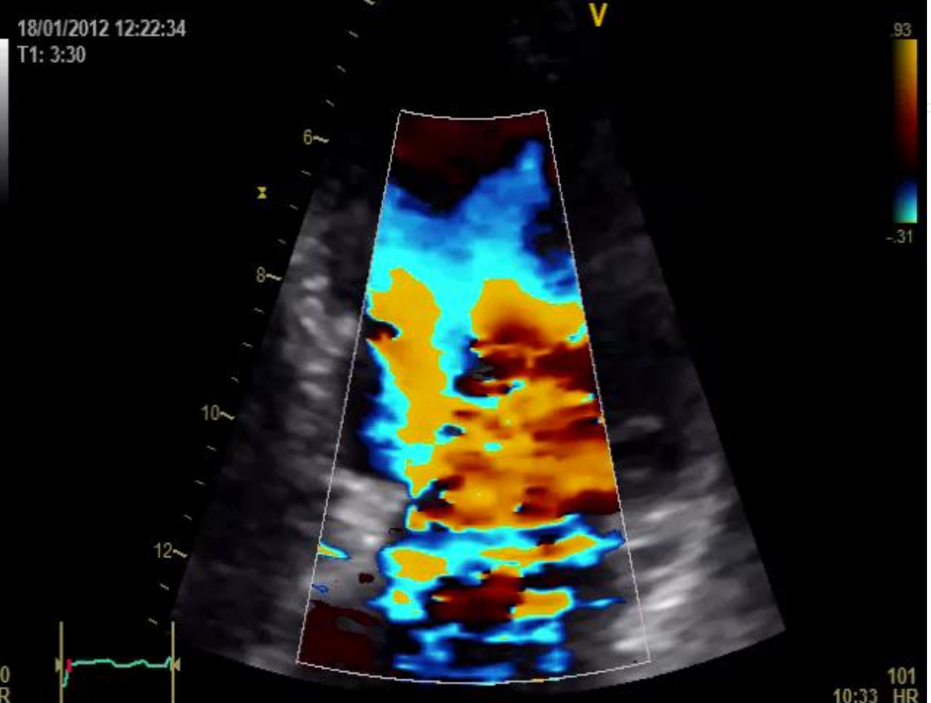
Ergotamine

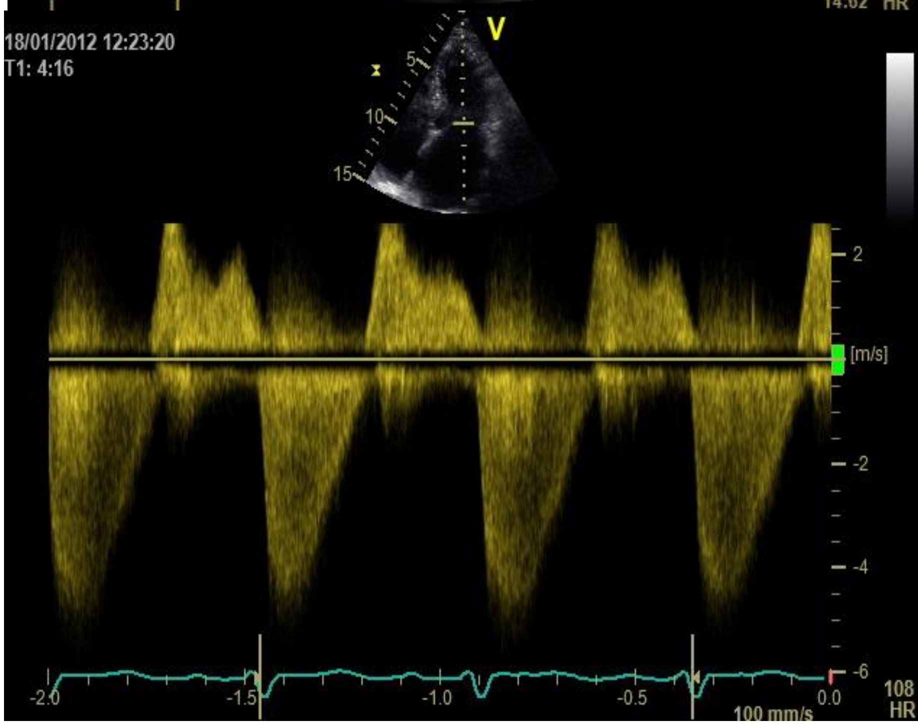

18/01/2012 12:09:42
V
.93
-.31
6
8
10
57
2:86 HR


TR Vmax 2.42 m/s
TR maxPG 23.44 mmHg
V
10
15
0.5
[m/s]
-0.5
-1.0
-1.5
-2.0
-2.5
-2.0
-1.5
-1.0
-0.5
-0.0


MR Rad 0.8 cm
MR Als.Vel 0.31 m/s
MR Flow 127.06 ml/s
V
6
8
10
57
HR
MR ERO 24.24 mm2
MR RV 46 ml
MR Vmax 5.24 m/s
MR VTI 189.9 cm
[m/s]
-2
-4
-6
-2.0
-1.5
-1.0
-0.5
-0.0
58
HR

- Exercise echocardiography





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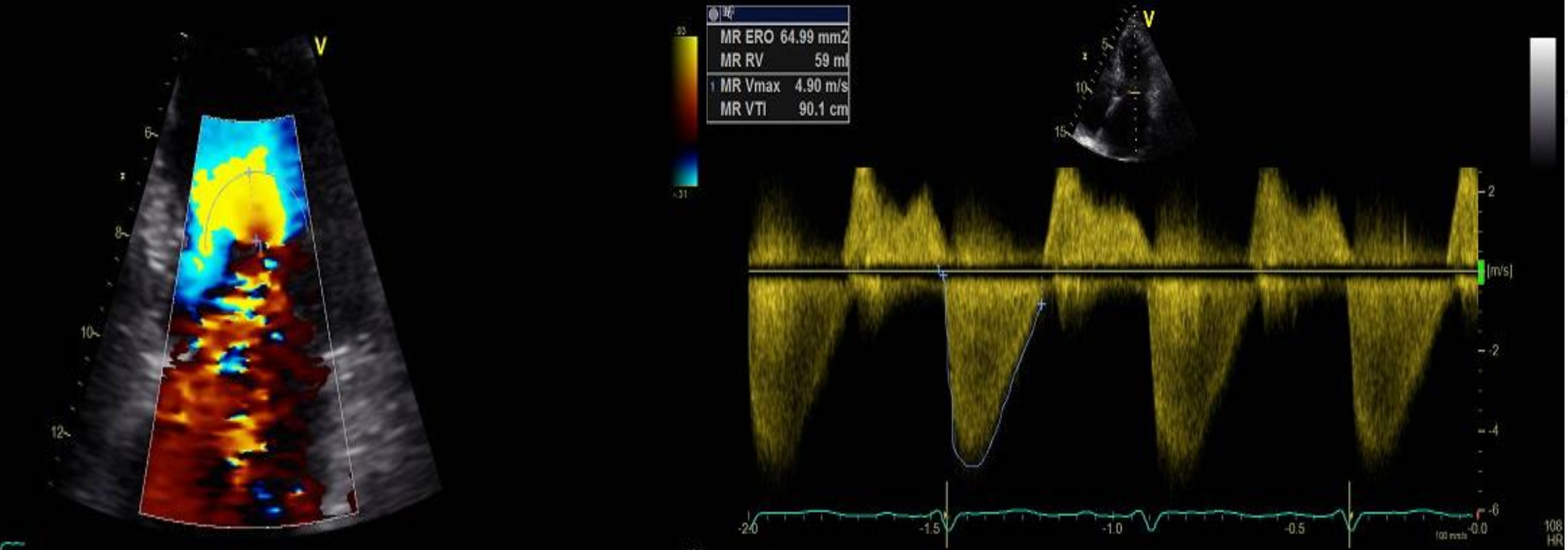

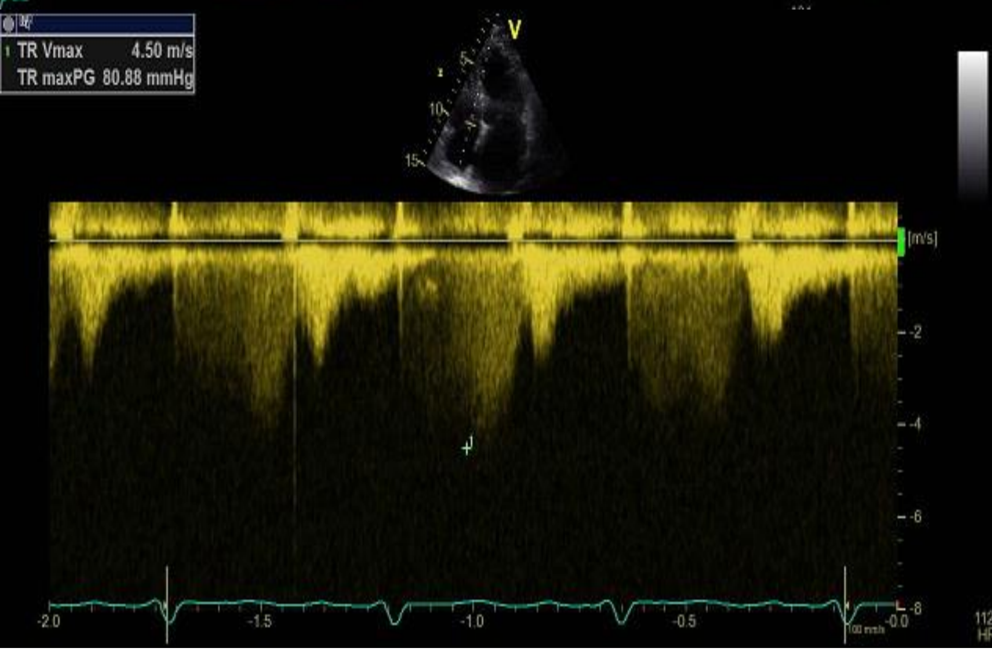

Worsening of MR which becames torential

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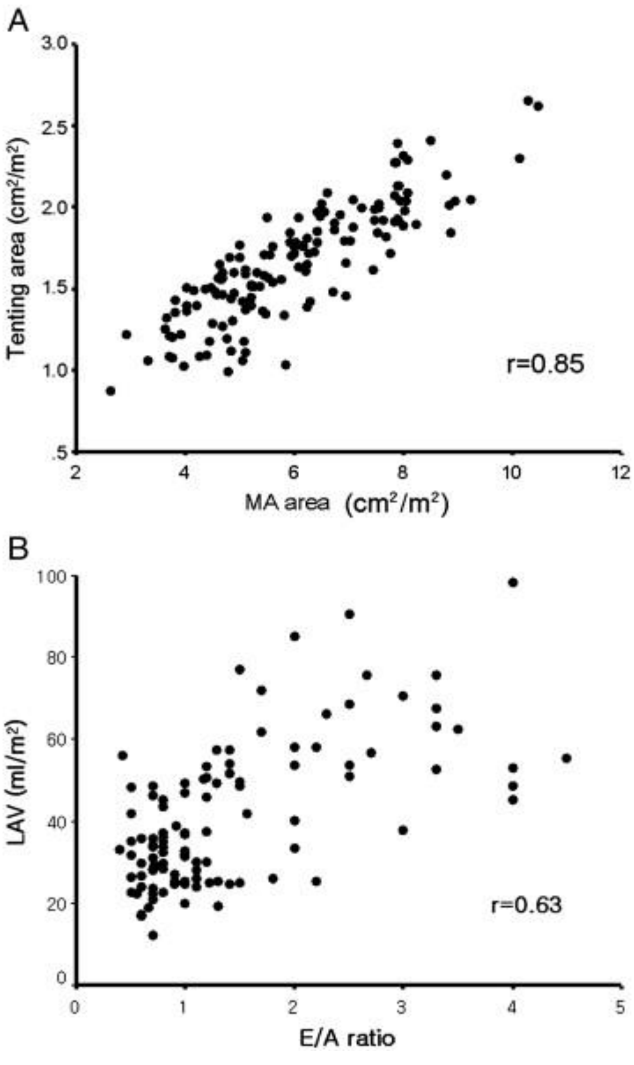
Insights?

Major importance of loading conditions in MR

Before unloading therapy

After unloading therapy

Importance of cardiac load condition in functional MR



Diastolic dysfunction and left atrial enlargement as contributing factors to functional mitral regurgitation in dilated cardiomyopathy: data from the Acorn trial.

Park et al., *Am Heart J*, 2007

Importance of cardiac load condition in functional MR

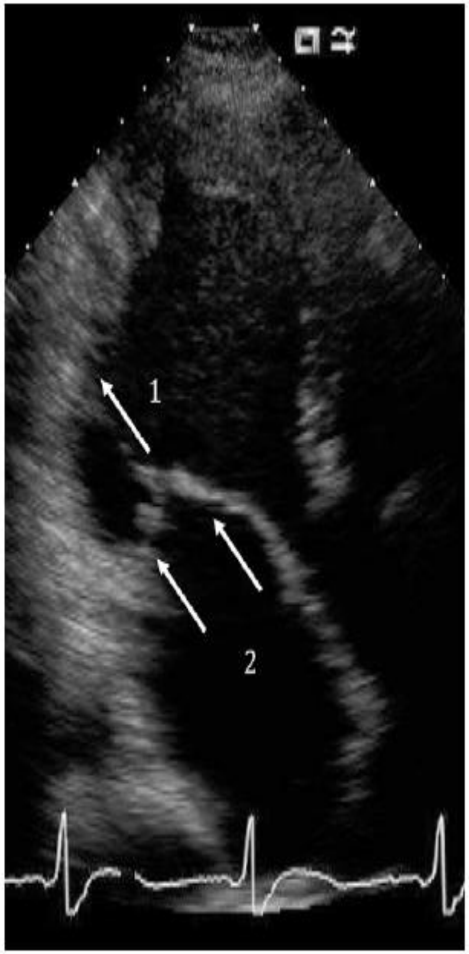


Figure 4 Apical long axis view illustrating that mitral tenting area may result from tethering forces (local LV remodelling, arrow 1) and pushing forces (increased LA pressure and size, arrows 2).

Noninvasively estimated left atrial pressure by the E/Ea ratio is a key determinant of mitral valve tenting in functional mitral regurgitation.

Maréchaux et al. Heart 2010

83 yo patient, APO

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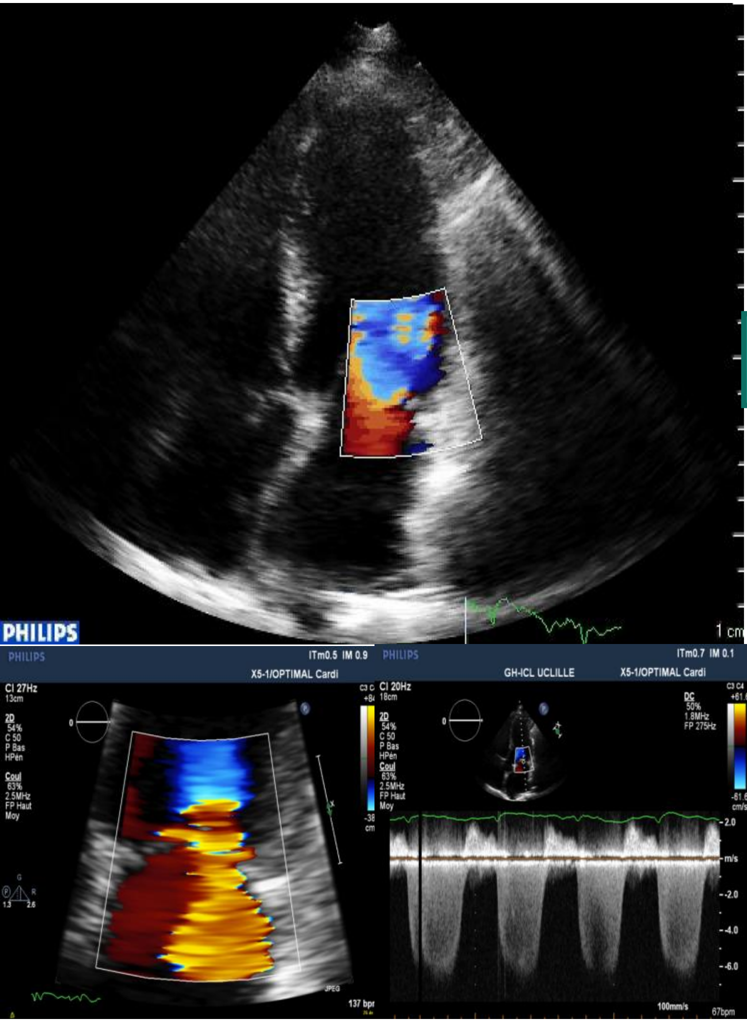
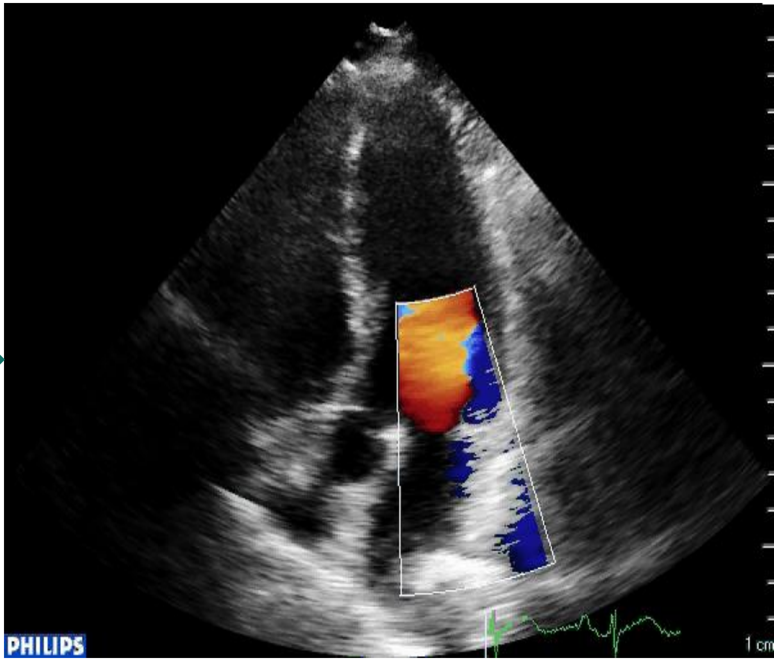


Diuretics
Nitrates



Ennezat, Maréchaux et al, Journal of Cardiac Failure, 2014

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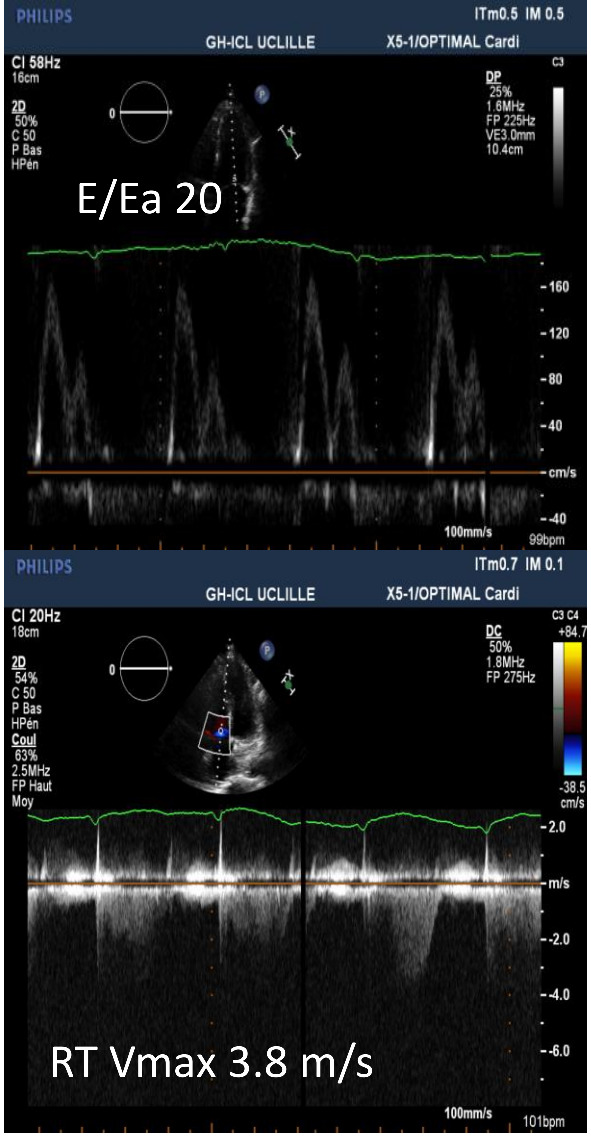
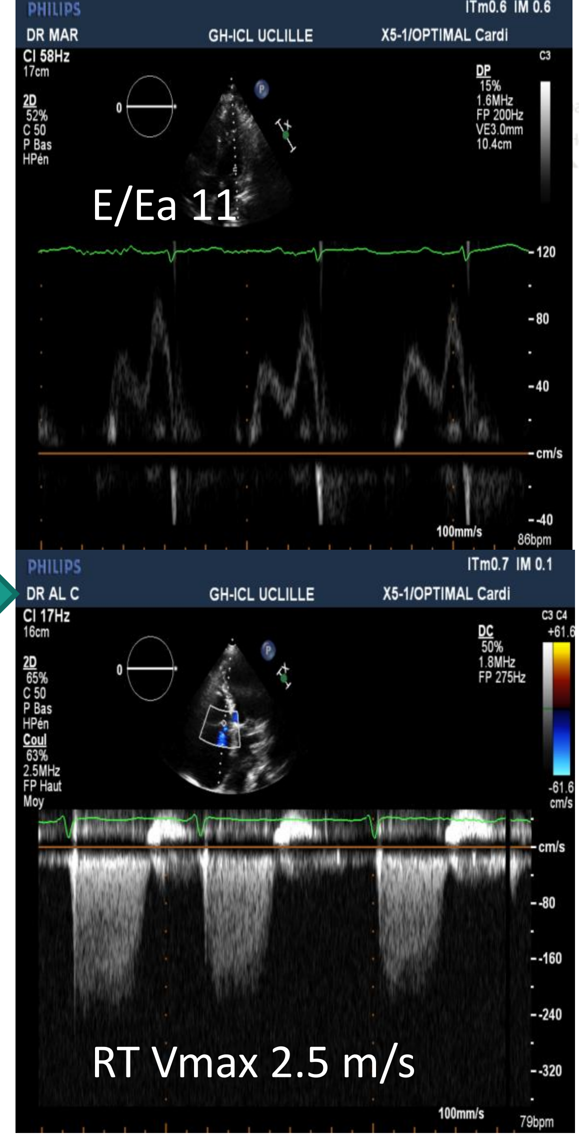


Diuretics
Nitrates



Ennezat, Maréchaux et al, Journal of Cardiac Failure, 2014

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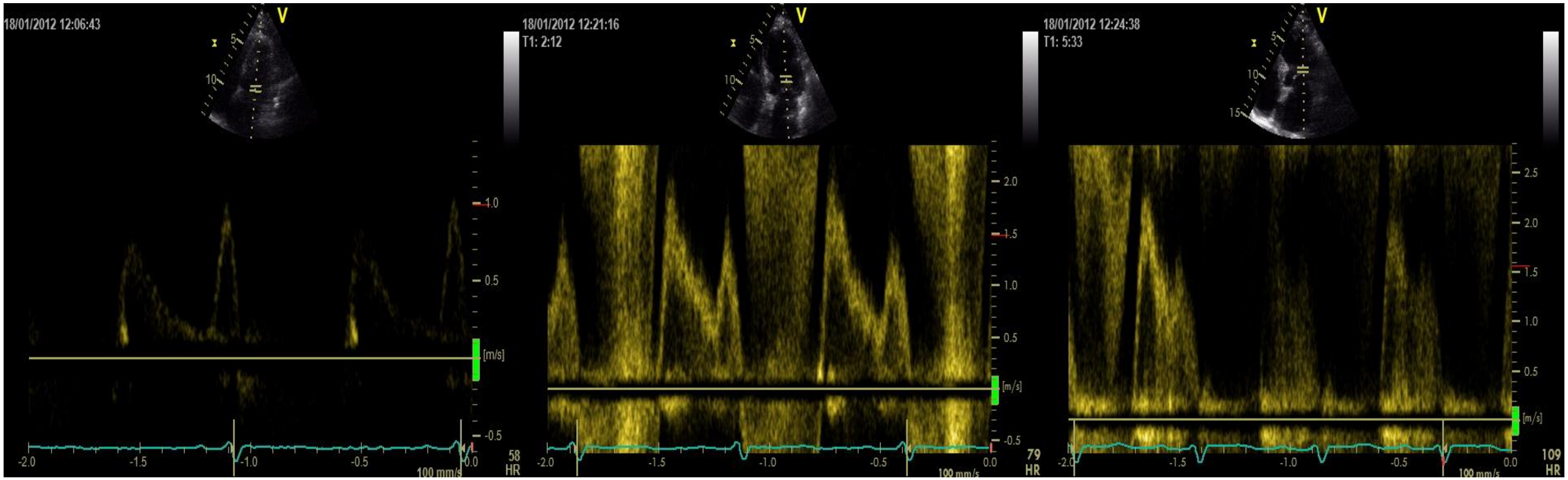
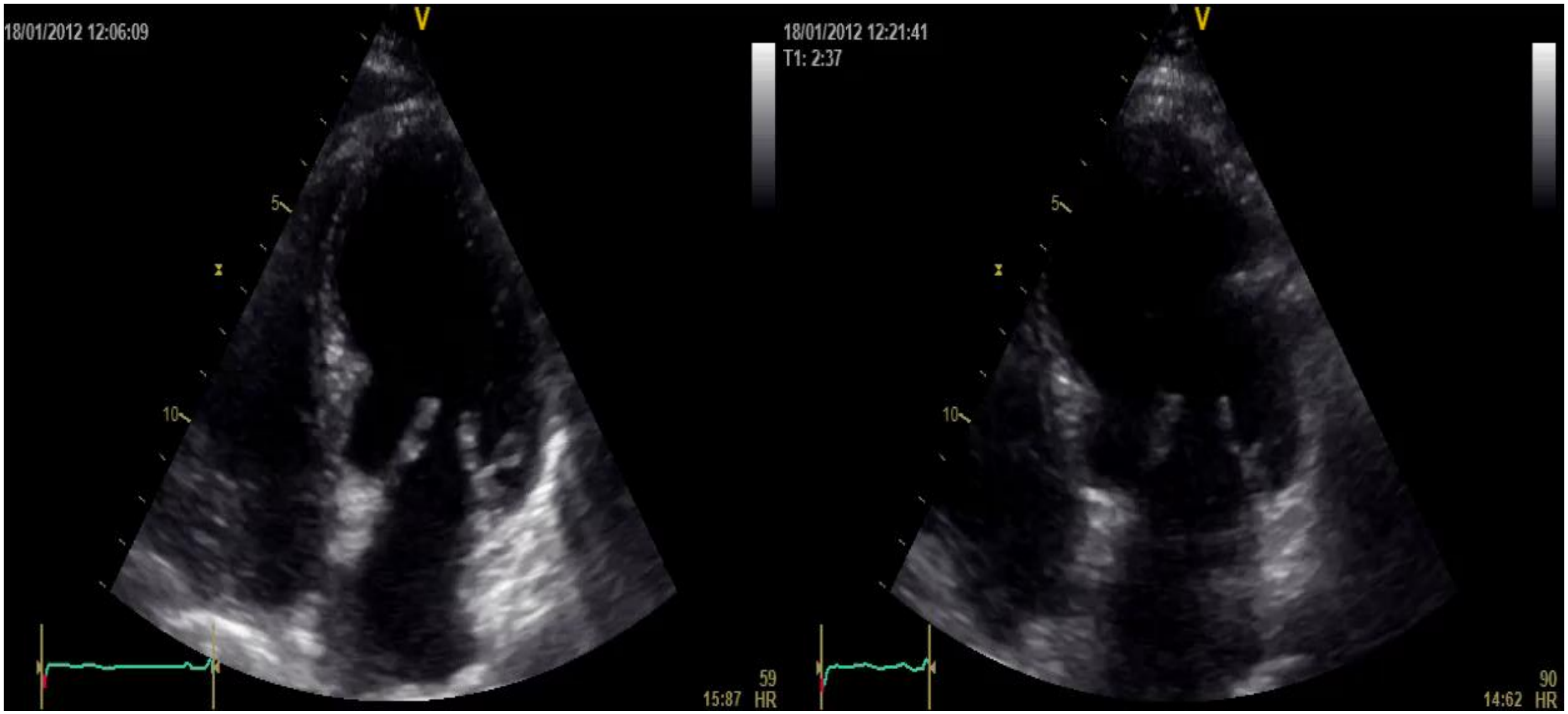
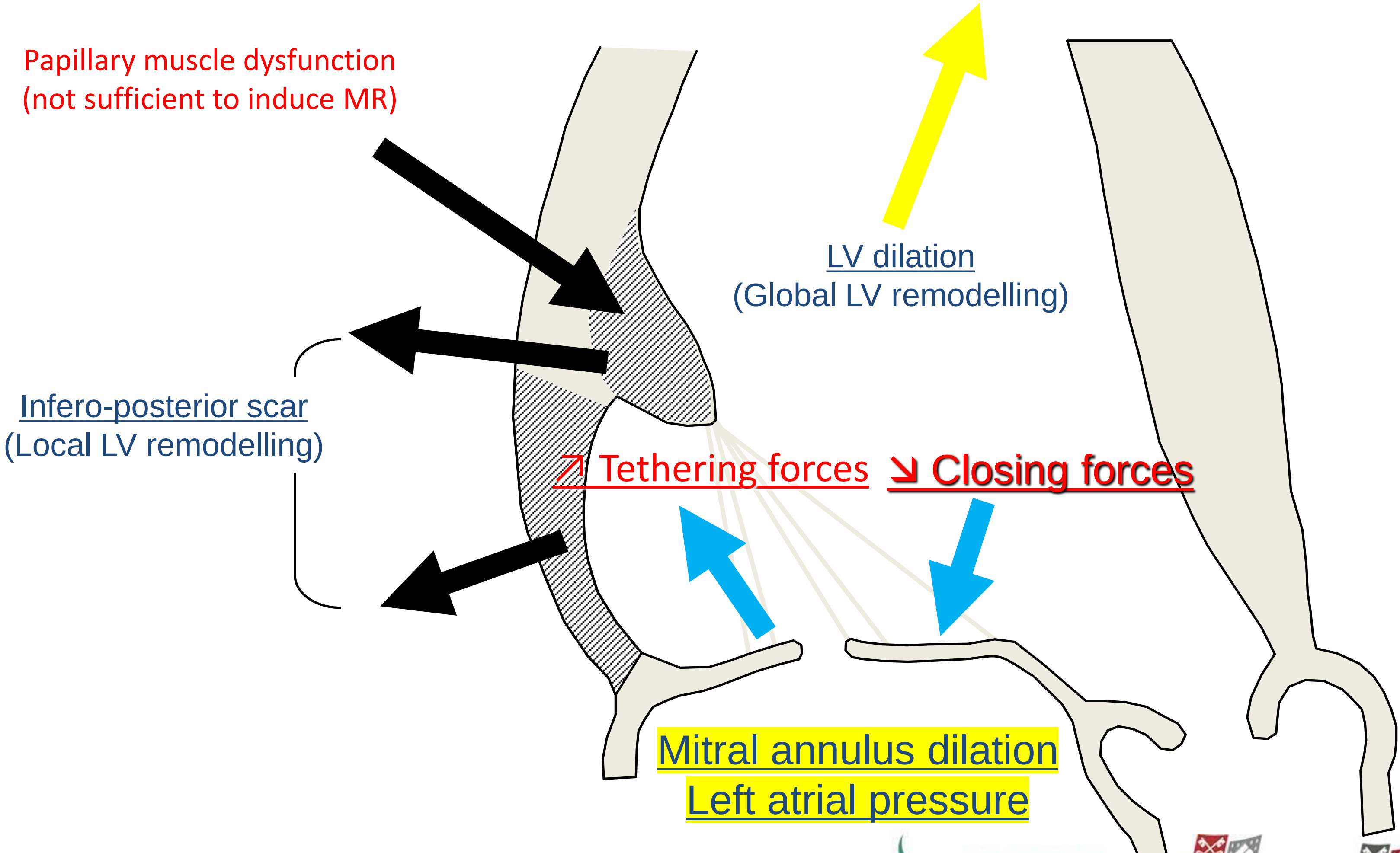
Assessment of LV diastolic function during exercise



Rest 25 Watts 45 Watts


18/01/2012 12:06:09
V
5
10
15:87
59
HR
18/01/2012 12:21:41
T1: 2:37
V
5
10
14:62
90
HR

Insights into functional MR



Mikal et al, *Circulation*, 1971
He et al, *Circulation*, 1997

Patient with LV systolic dysfunction
Secondary MR

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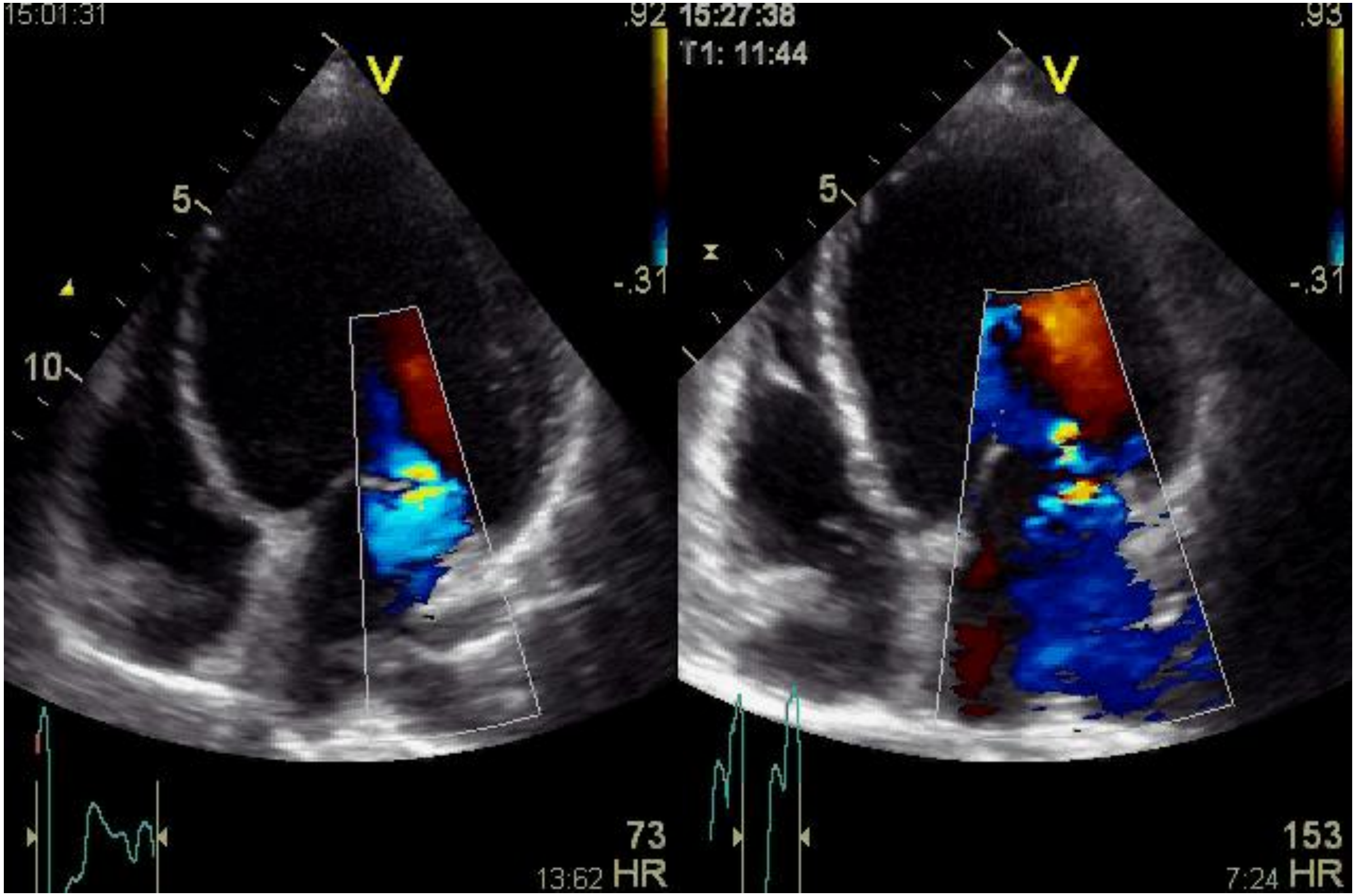

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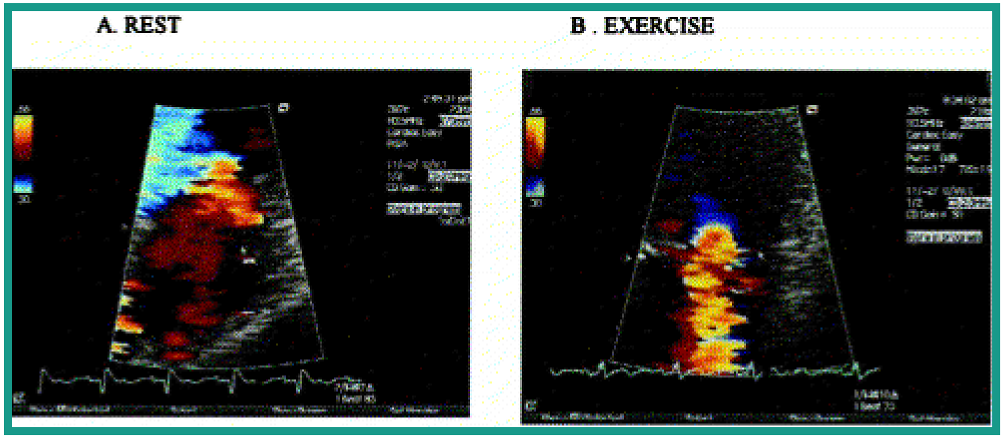
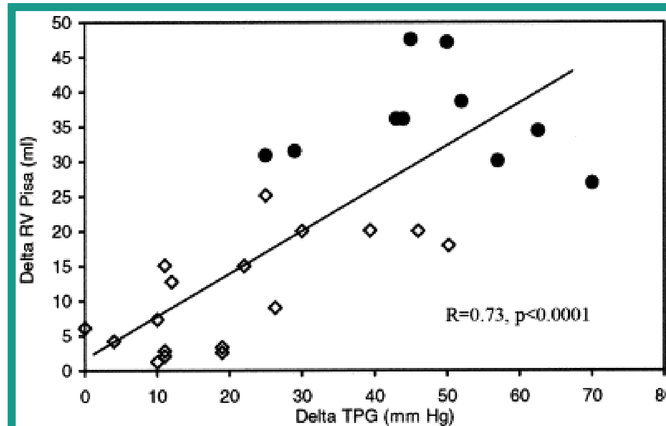
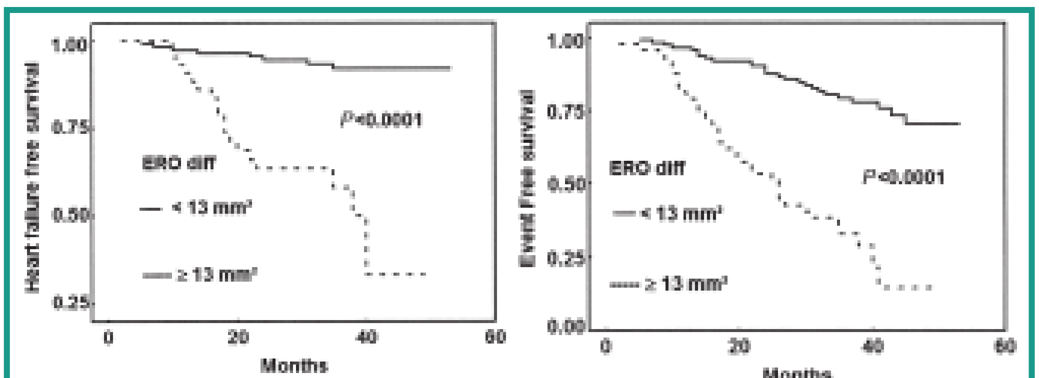
Ischemic/Functional MR

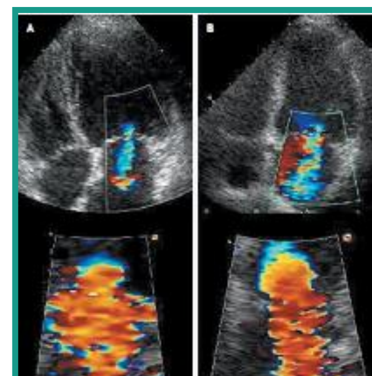
- Ischemic mitral regurgitation severity may increase during exercise
- A large increase in mitral ERO (Δ ERO ≥ 13 mm^2) has been associated to a recent history of acute pulmonary edema, pulmonary hypertension during exercise and a poor prognosis

RV: 21ml **RV: 39 ml**









Quantitation of Functional Mitral Regurgitation During Bicycle Exercise in Patients With Heart Failure
Frédéric Lebrun, MD, Patrizio Lancellotti, MD, Luc A. Piérard, MD, PhD, FESC

Long-term outcome of patients with heart failure and dynamic functional mitral regurgitation
Patrizio Lancellotti[1*], Paul L. Gérard[2], and Luc A. Piérard[1*]

The Role of Ischemic Mitral Regurgitation in the Pathogenesis of Acute Pulmonary Edema
Luc A. Piérard, M.D., Ph.D., and Patrizio Lancellotti, M.D.

Ischemic/Functional MR

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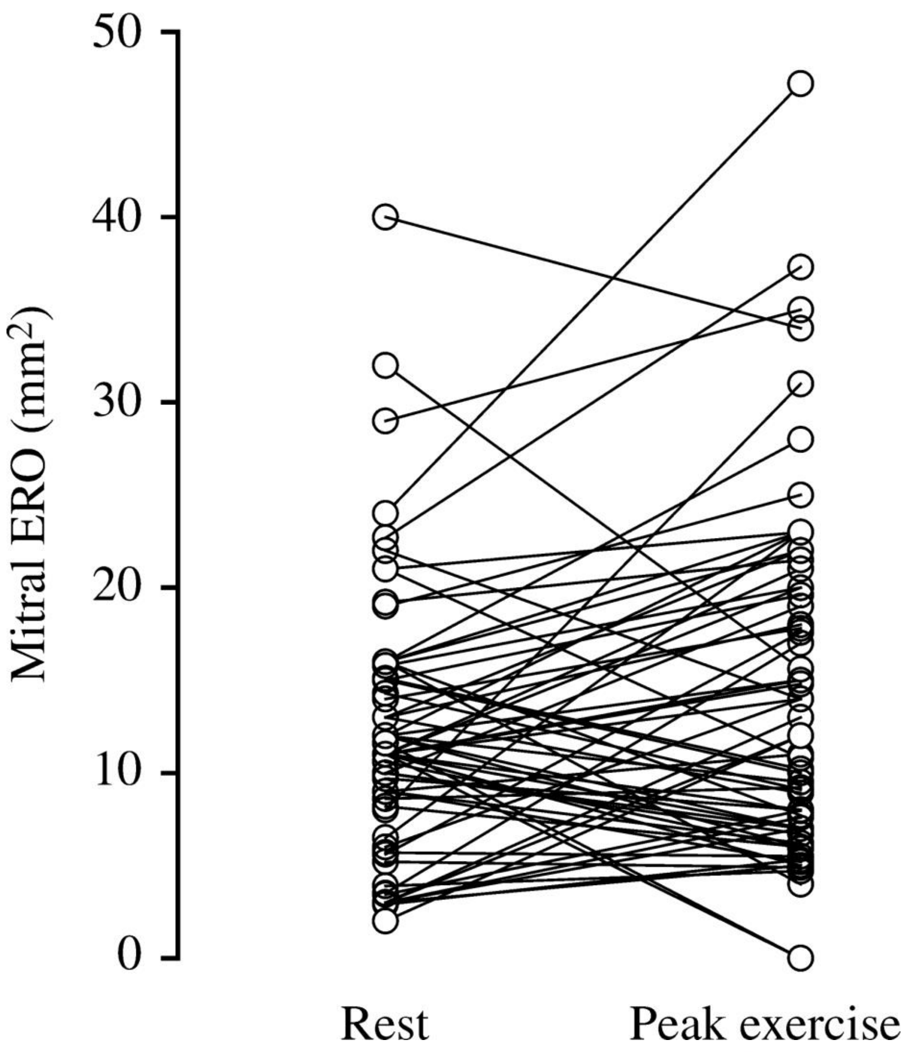

Individual changes in mitral ERO between rest and peak exercise.

Ennezat, Marechaux et al. Eur Heart J 2006;27:679-683

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Role of myocardial dyssynchrony

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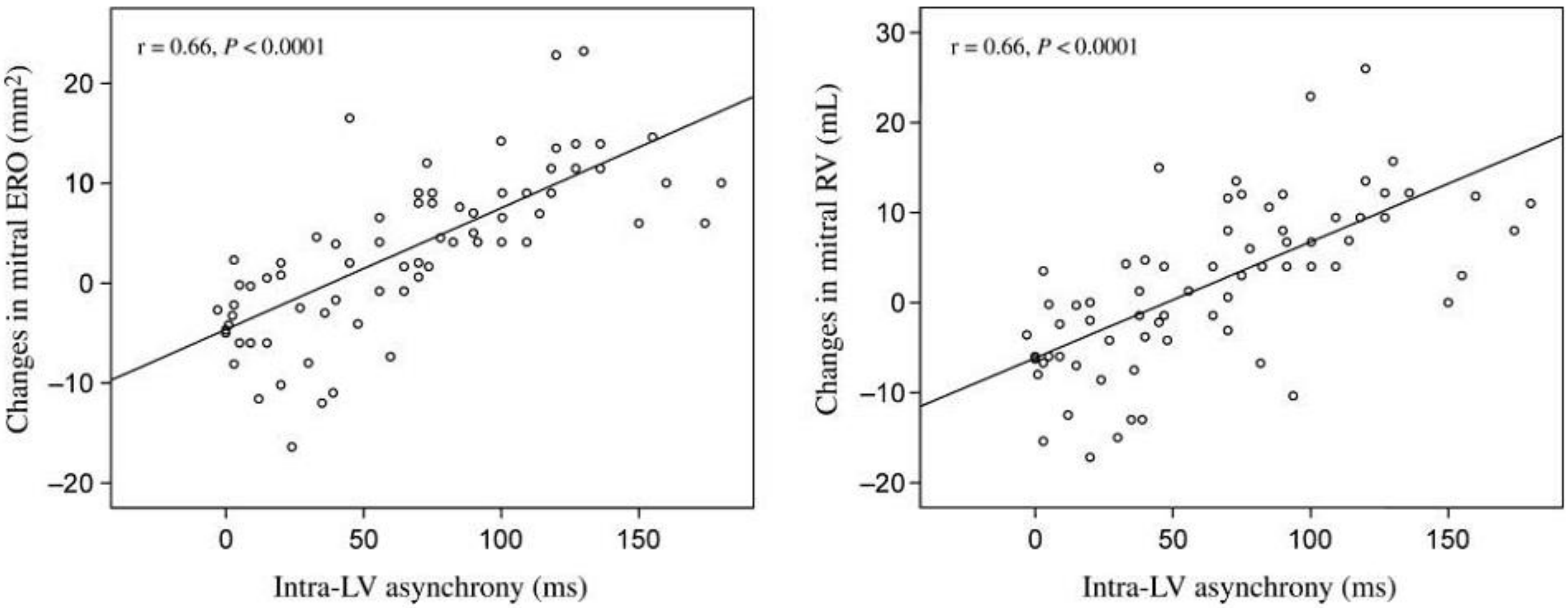

Ennezat, Maréchaux et al, *European Heart Journal*, 2006

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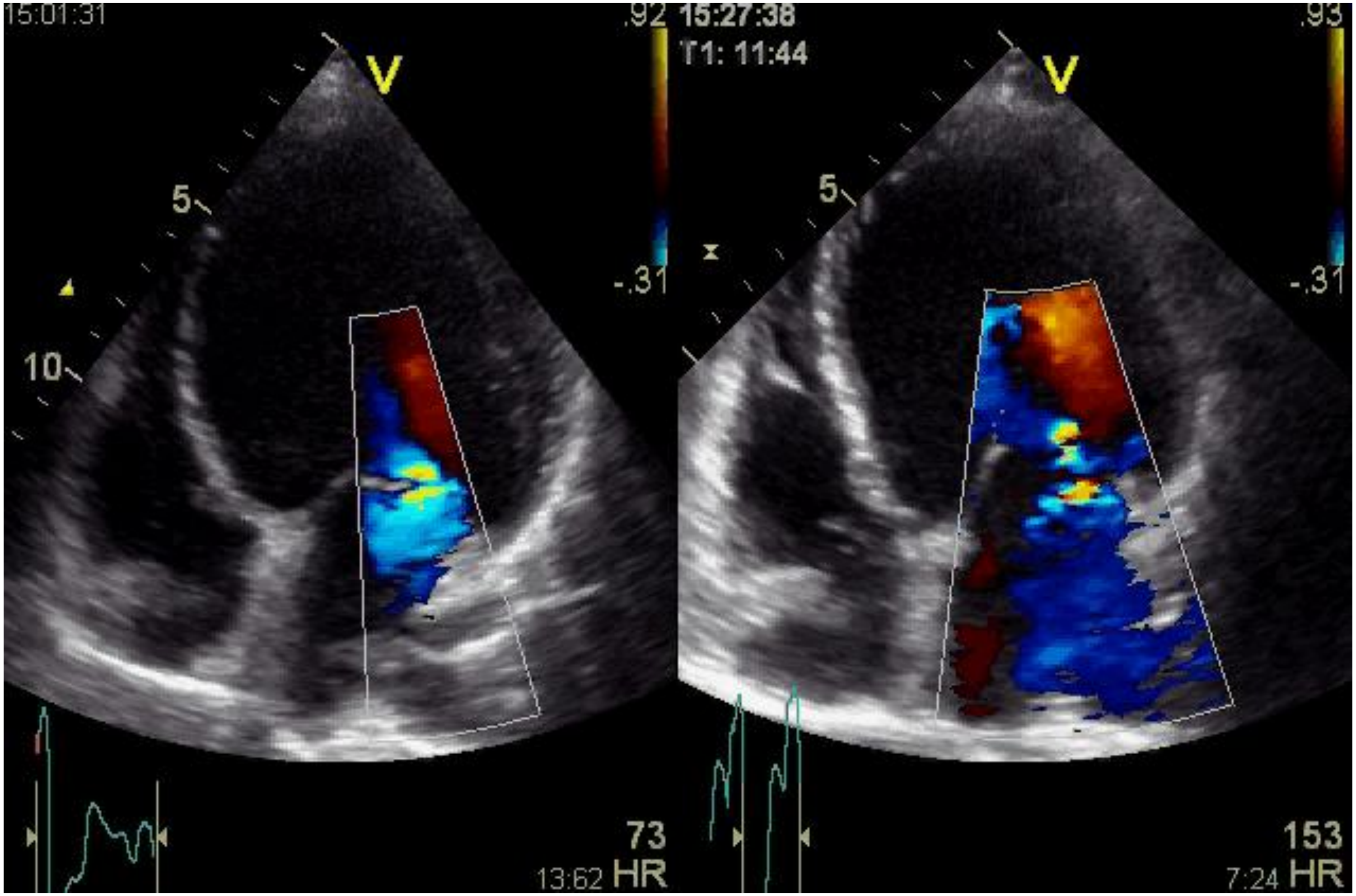
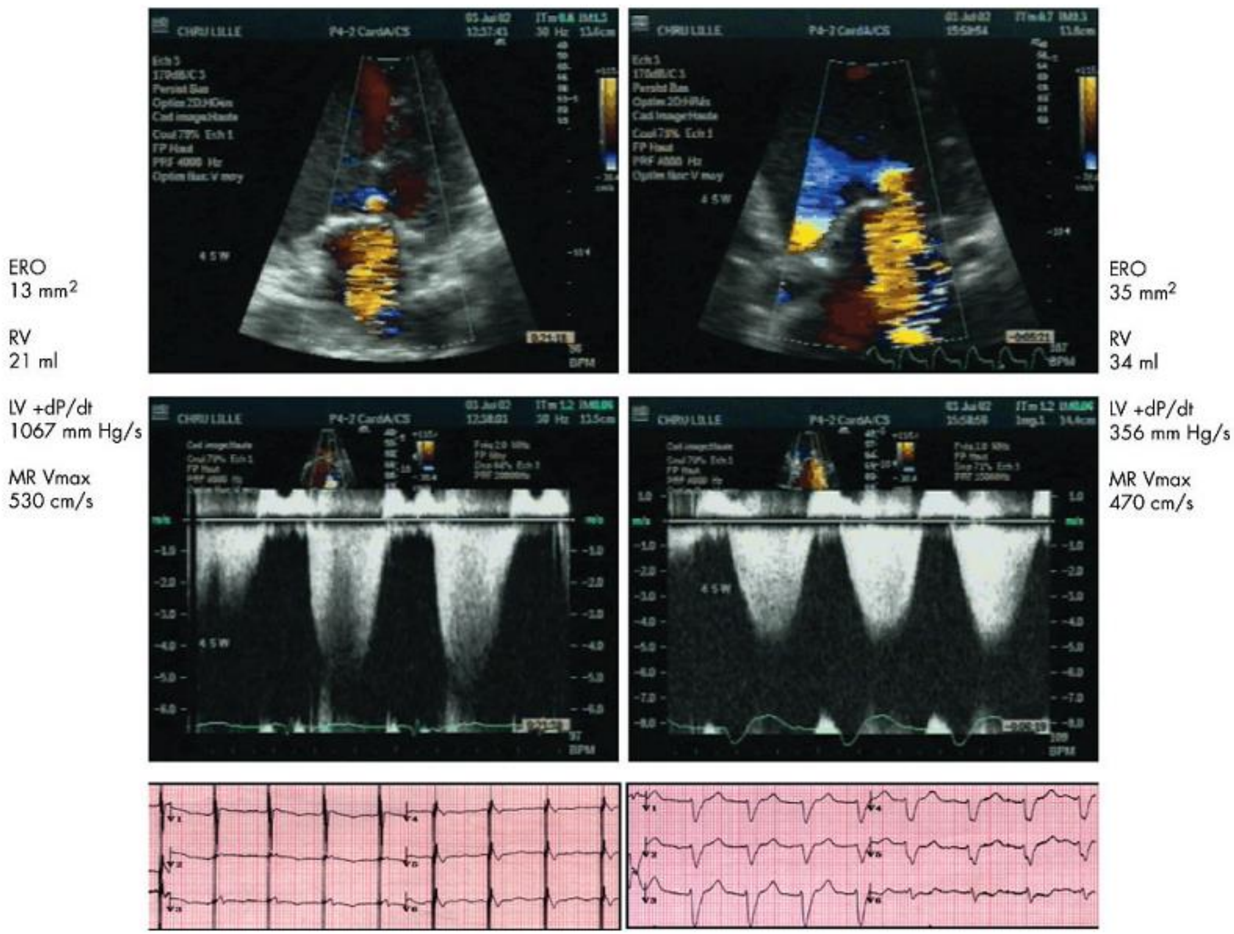
Role of myocardial dyssynchrony



Patients with an activation delay: LBBB, RV pacing

Cardiac resynchronisation therapy reduces functional mitral regurgitation during dynamic exercise in patients with chronic heart failure: an acute echocardiographic study



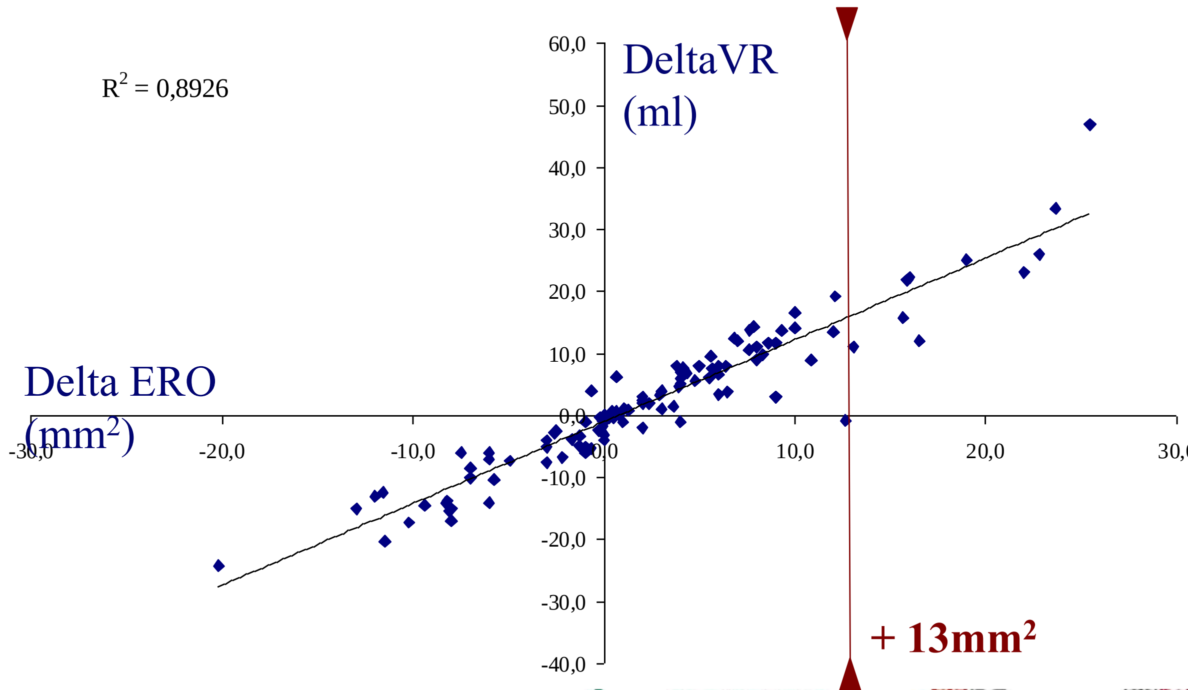
Ennezat et al, *Heart* 2005
Marechaux et al, *JASE*, 2009

Collaborative study Lille - clinique universitaire St Luc, Bruxelles

120 patients with ischemic LV systolic dysfunction

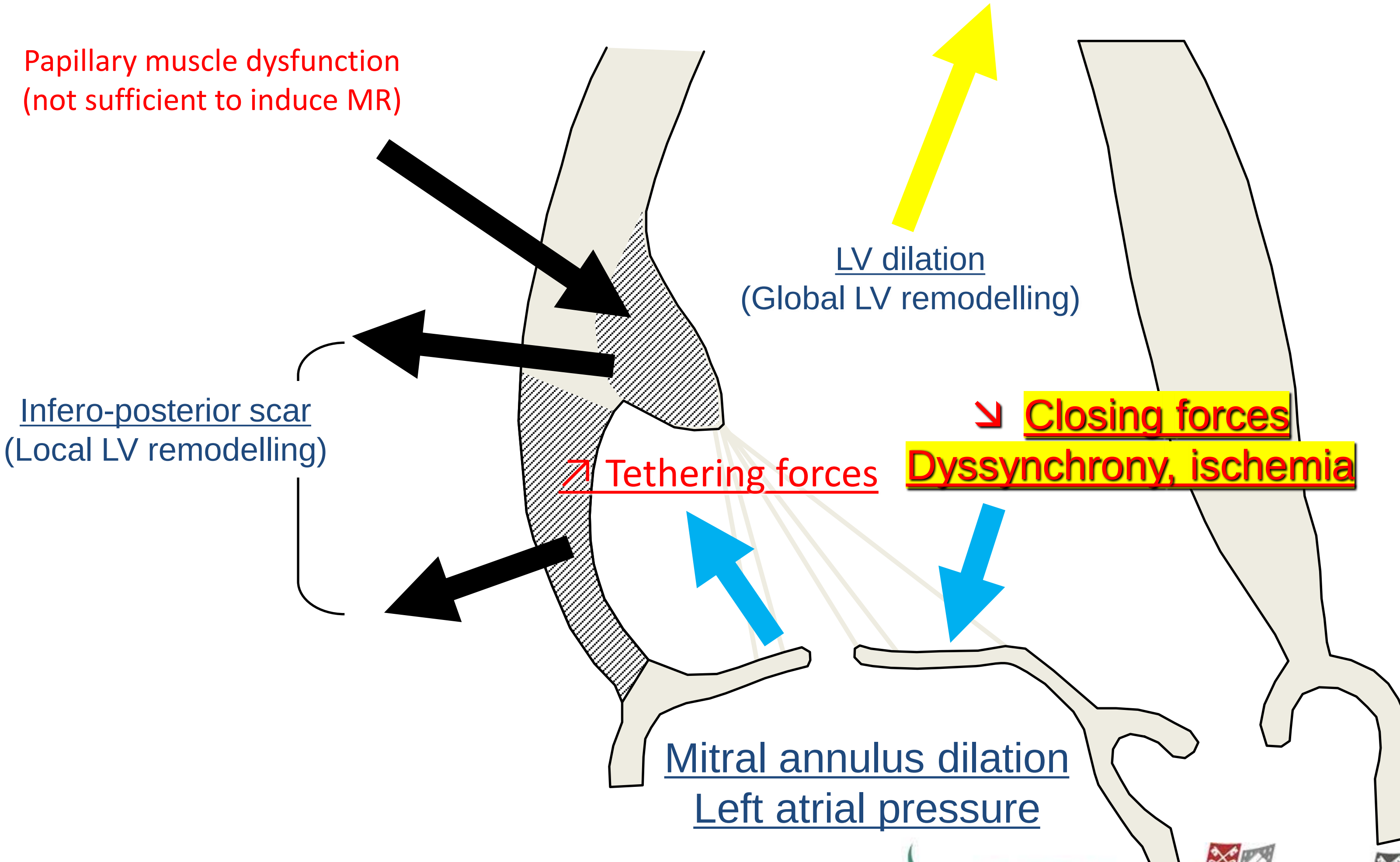
Changes in ERO > 13 mm² uncommon (8.3%)

Large increase in ERO correlates with exercise induced wall motion abnormalities (60% when Δ ERO > 13 mm2)



Le Poulain de Waroux et *al*, unpublished data

Insights into functional MR



Mikal et al, *Circulation*, 1971
He et al, *Circulation*, 1997

Exercise echocardiography in valvular heart disease

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Hôpital Saint Philibert - GHICL

- Resting evaluation in valvular heart disease (clinical and Doppler echocardiography)
- Importance of the assessment of functional capacity
- No longitudinal data available
- Multiple valves diseases?: no guidelines
- Correlation between exercise symptoms and changes in ventricular and valvular function and pulmonary pressure
- Expertise (high reproducibility and feasibility in trained centers – heart valve centers)
- Additional value compared with other data (biomarkers, CT, MRI, peak VO2, exercise right catheterism…..)

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Hypertrophic cardiomyopathy
LVOT obstruction

Clinical case

52 yo patient
History of mitral valve repair, with annuloplasty (27 mm), quadrangular resection, 15 years ago
Bisoprolol 5 mg/d
Lipothymia/vertigo during exercise (climbing stairs)
Normal ECG, Holter ECG: no abnormality
What do you consider?

Exercise stress echocardiography

- 170 Watts
- 86% maximal HR
- Leg fatigue

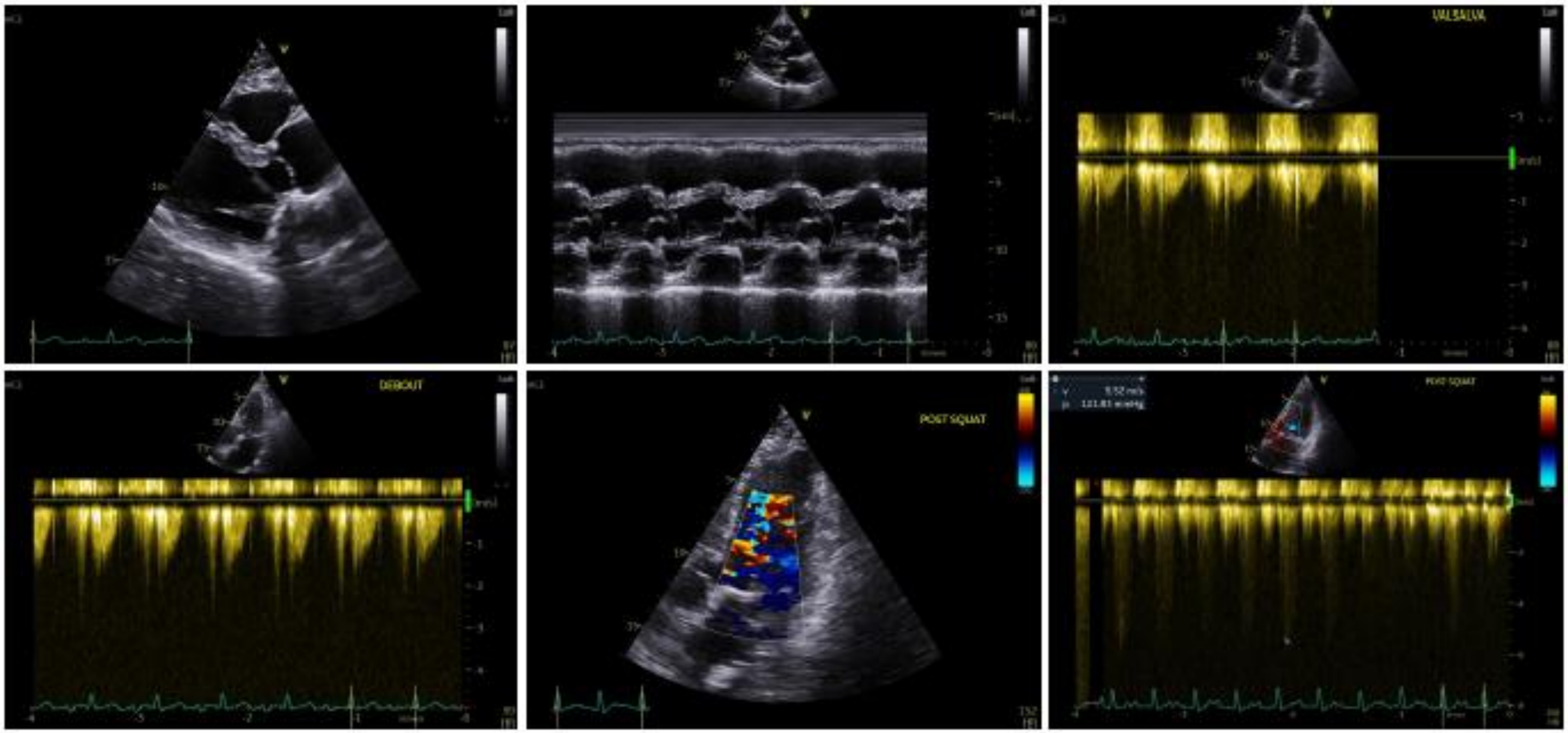
- No LVOT obstruction at peak or after exercise

- What is your conclusion?

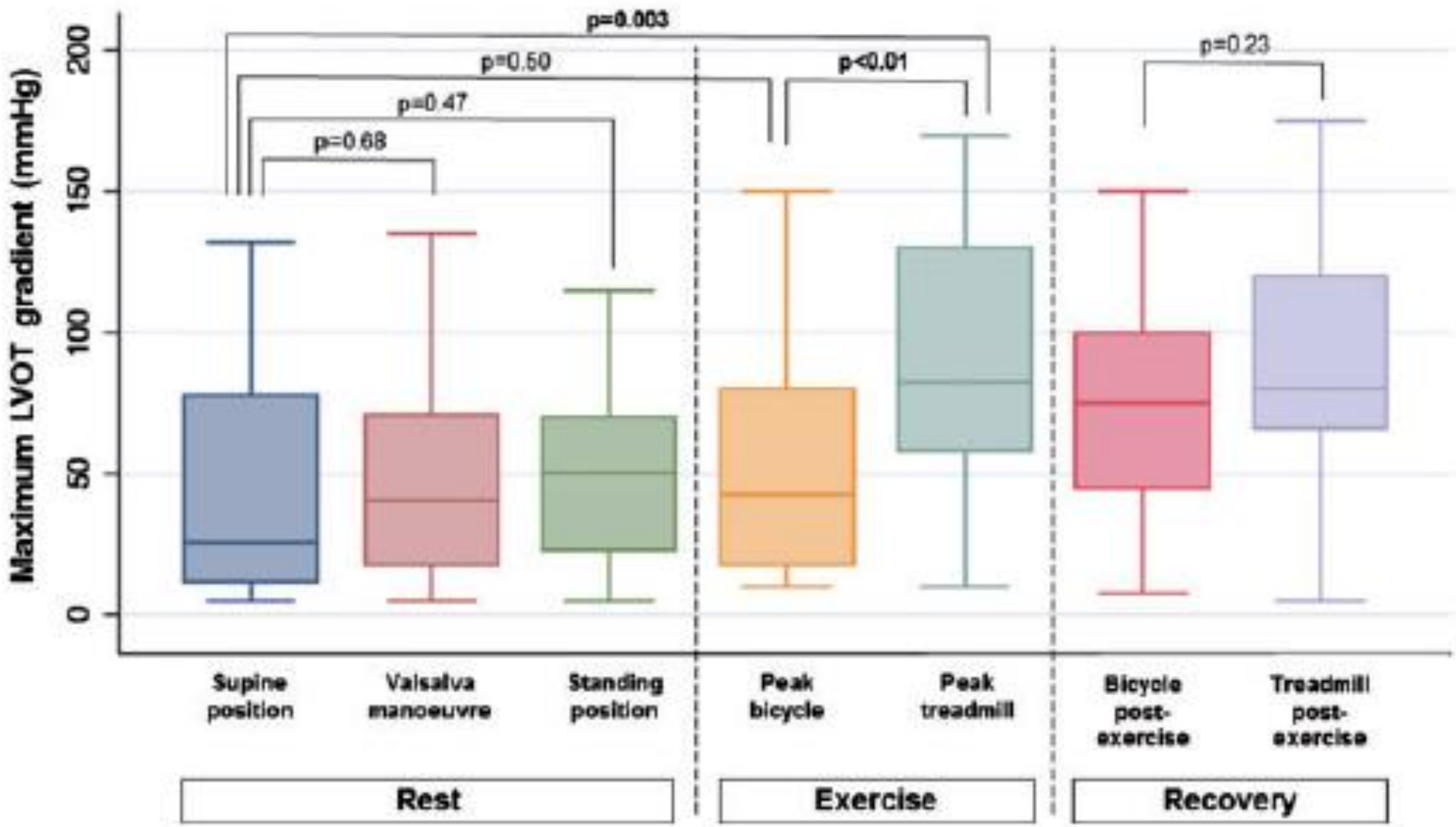
LVOT obstruction after 10 squats

Symptoms are reproductible after 10 squats

Peak LVOT obstruction 130 mmHg!



Hydratation, normal amount of salt
Avoid alcohool, high amounts of sugar
Nadolol



Reant P et al, ACVD, 2018

ExEcho in HCM/LVOT obstruction

- Semi supine ExEcho is less sensitive than exercise performed upright

- Take Home message: upright if semi supine echo does not allow to explain symptoms

Ischemic Heart Disease Semiology

60 yo male

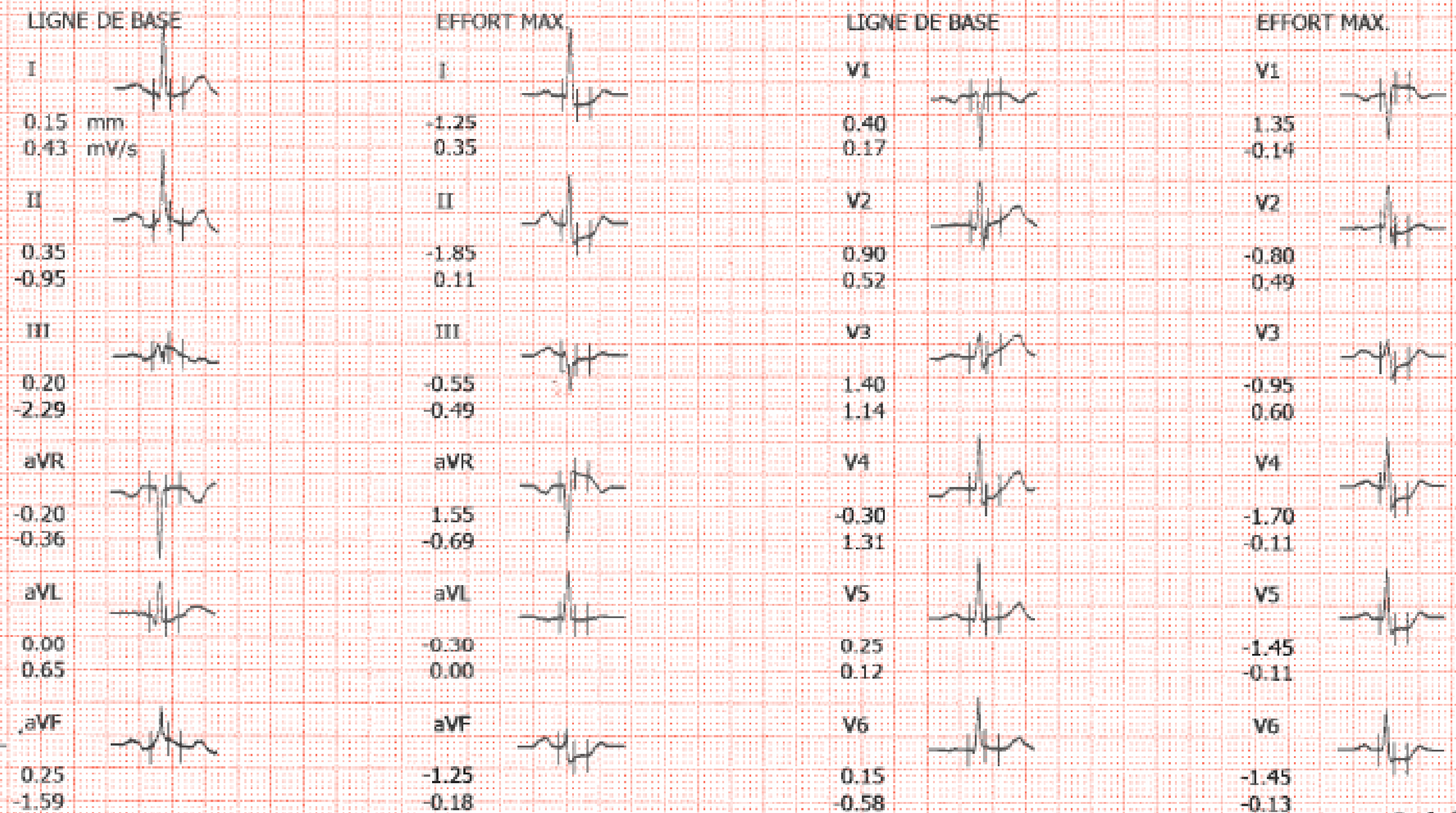
- IHD, stent RCA 10 years ago
- Diabetes, hypertension, dyslipidemia
- Exercise stress echo for atypical chest pain
- 6 :34, workload 80 W, 77% max HR

Max. FC : 123 /min = 77 % de FC cible 160 /min (LIGNE DE BASE: 81 /min)
TA max. : 210/90 mmHg (LIGNE DE BASE: 140/80 mmHg)
Max. RPP/100 : 258 mmHg/min (EFFORT 06:30)
Maximum ST : -2.05 mm (V4, EFFORT: 05:56)
Niveau ST (EFFORT MAX.) : -1.85 mm (II, EFFORT: 06:34)

20W/2'/20W : 08:59
PRETEST : 00:07
EFFORT : 06:34
RECUP. : 02:18

Charge max. : 80 W
METS : 4.1

Total complexes QRS : 951 BIGV : 1 EV : 22 ESSV : 15



GE MAC1600 1.0.4 HEART V5.2.2.1 25 mm/s 10 mm/mV FRF 0.16 Hz 50 Hz Bref résumé Effort 1/1

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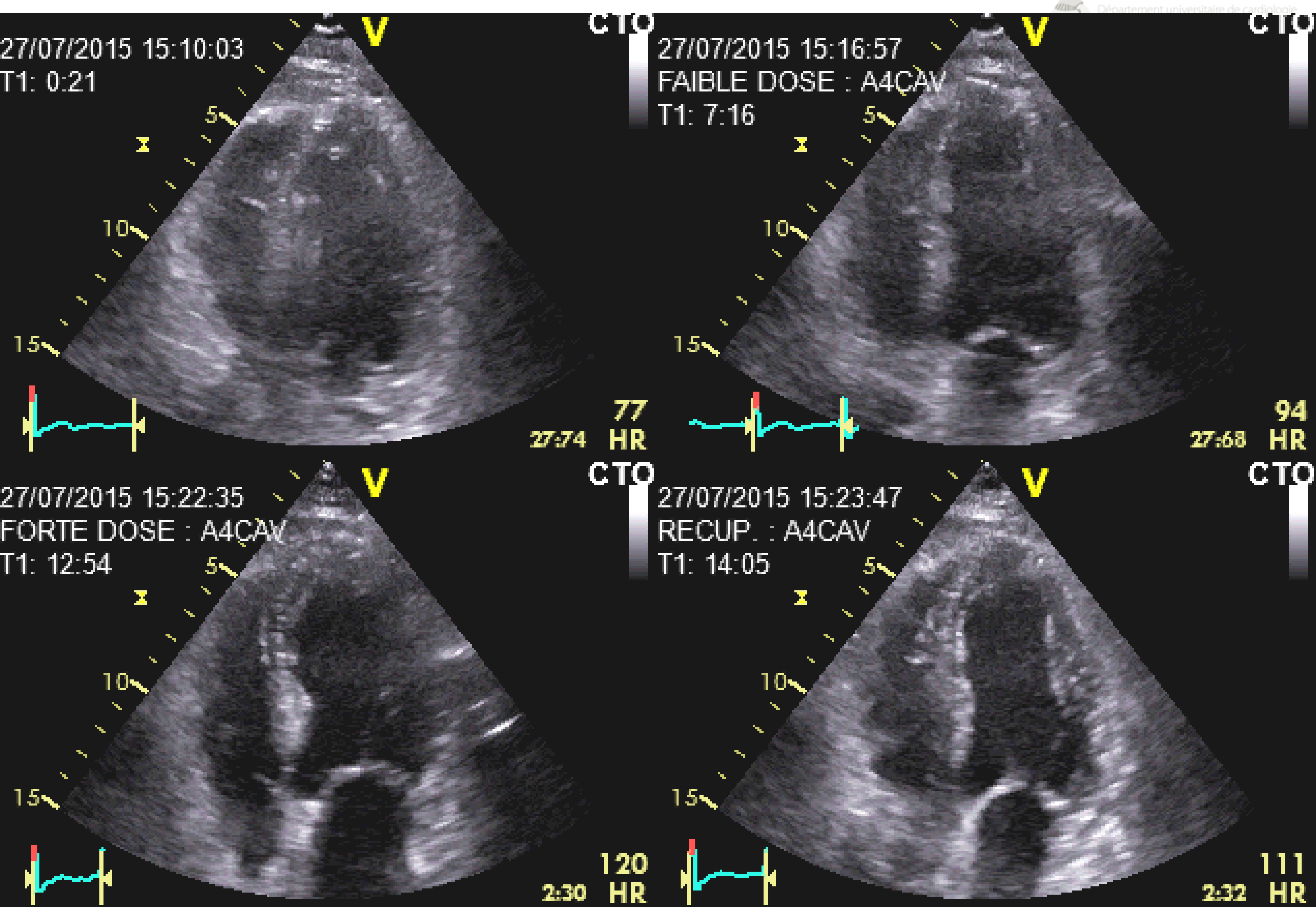

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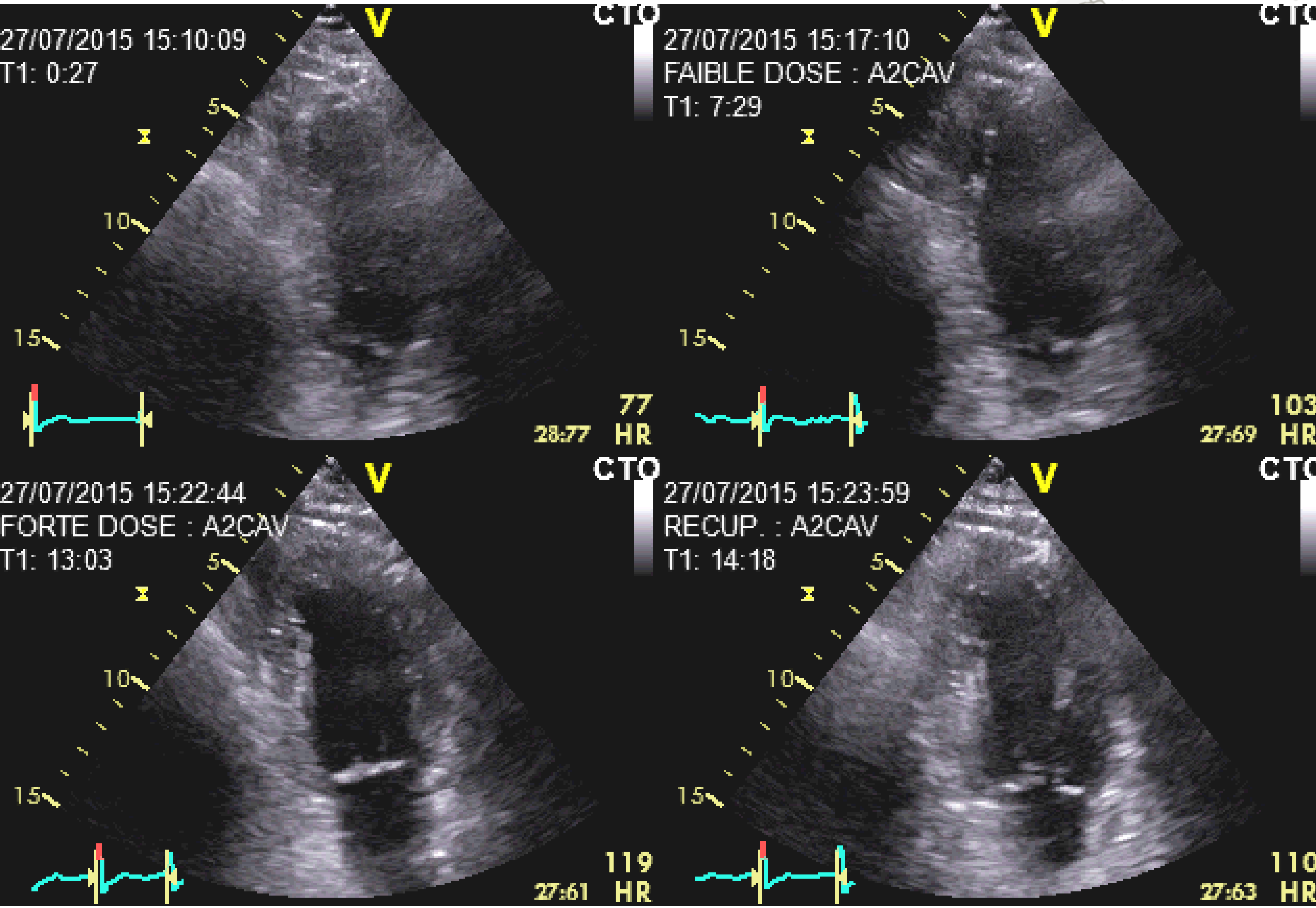
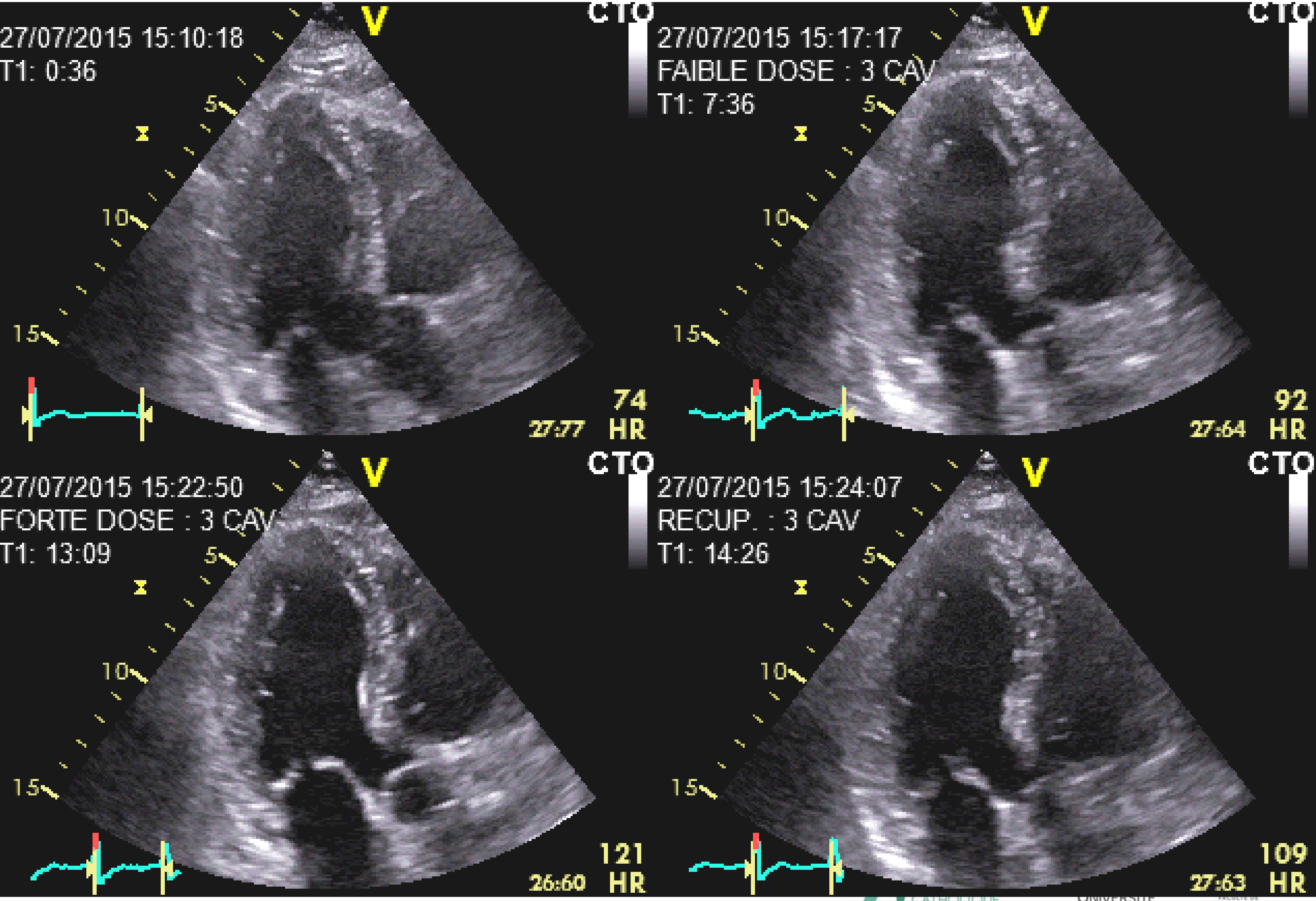
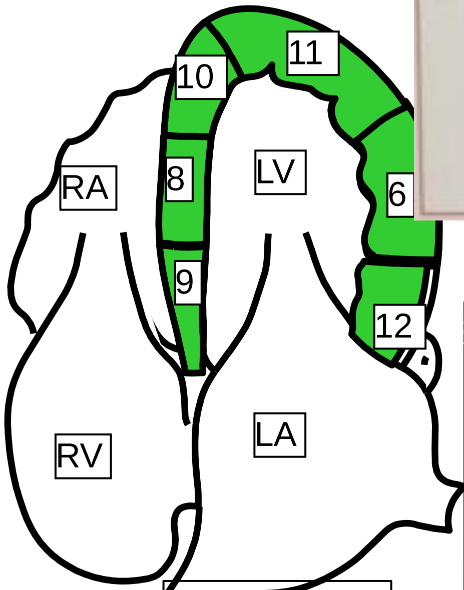
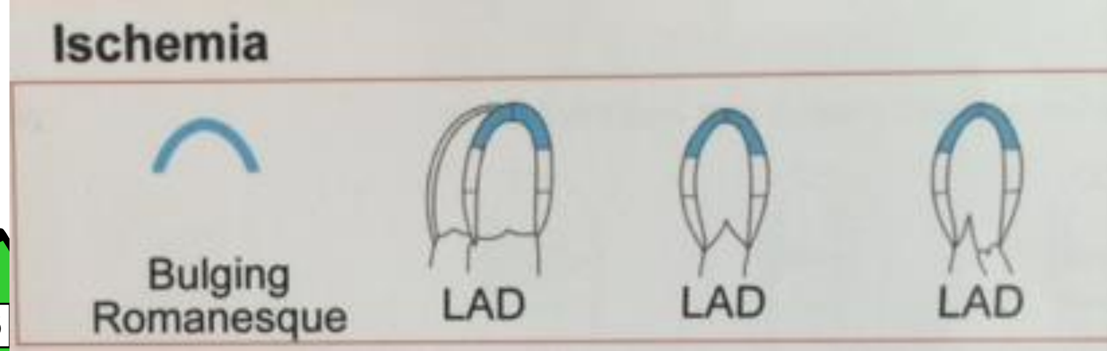


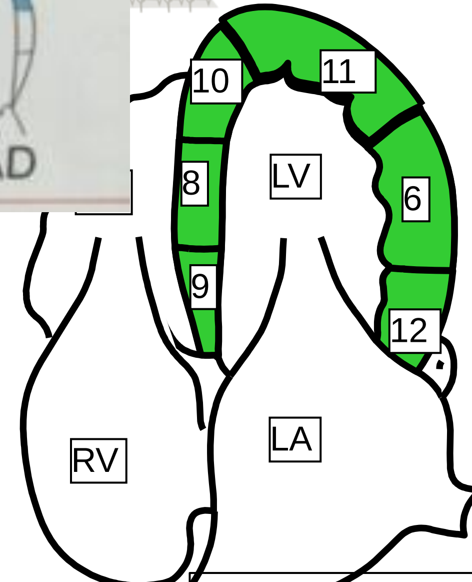

27/07/2015 15:10:18
T1: 0:36
74
27:77 HR
27/07/2015 15:17:17
FAIBLE DOSE : 3 CAV
T1: 7:36
92
27:64 HR
27/07/2015 15:22:50
FORTE DOSE : 3 CAV
T1: 13:09
121
26:60 HR
27/07/2015 15:24:07
RECUP. : 3 CAV
T1: 14:26
109
27:63 HR

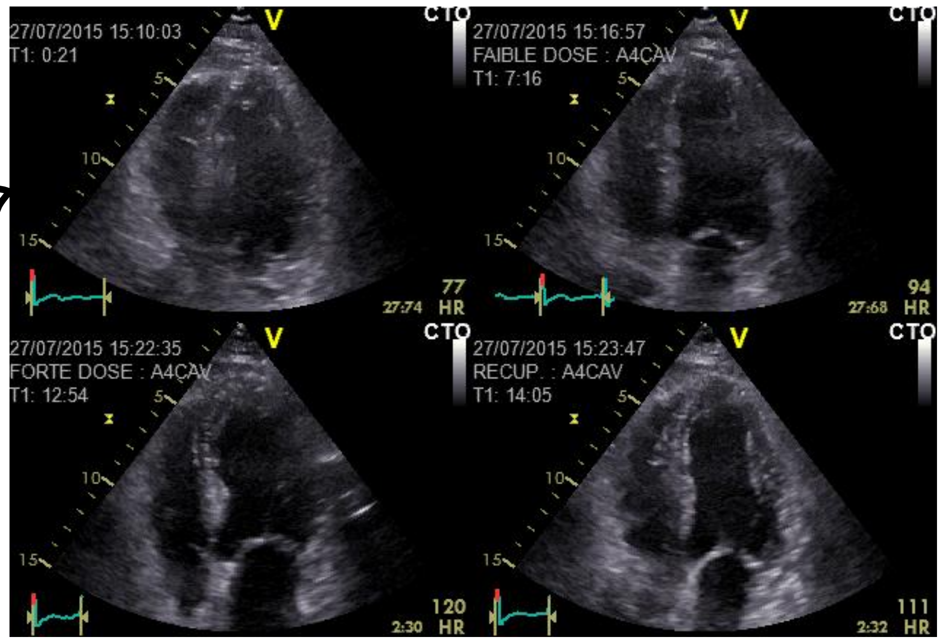
Base



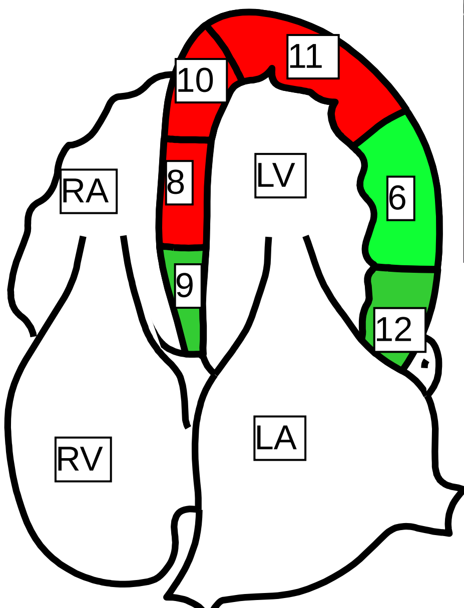


Faible effort

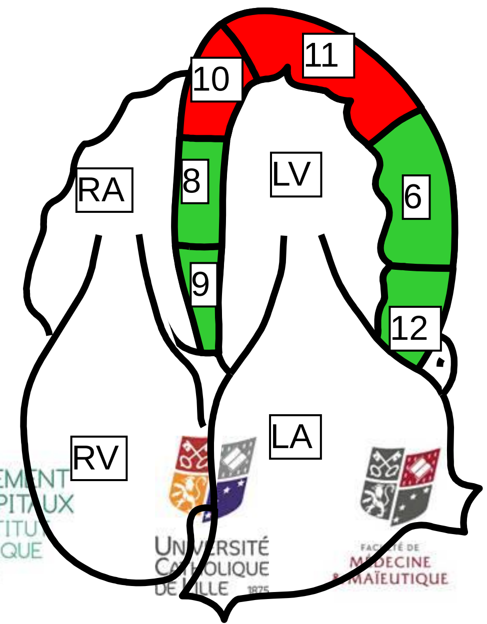




Pic Effort



Récup



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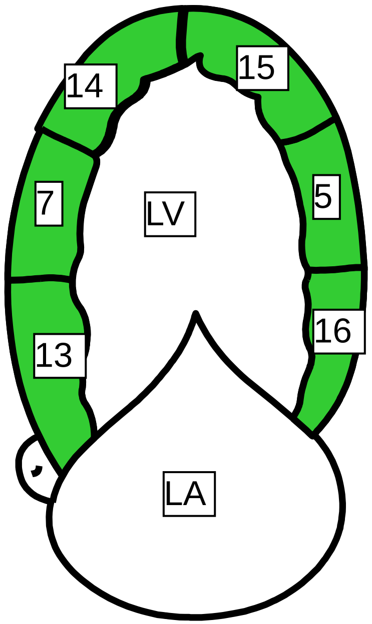
Base



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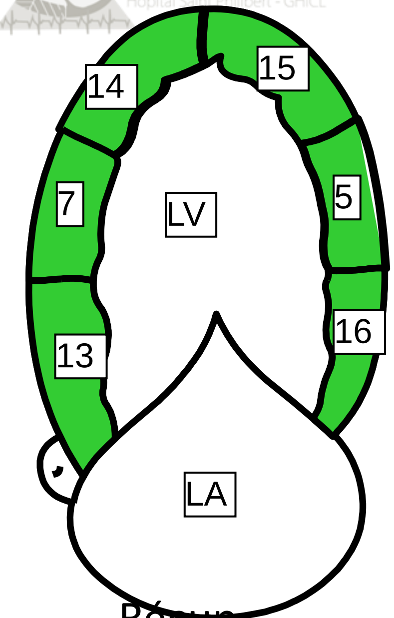

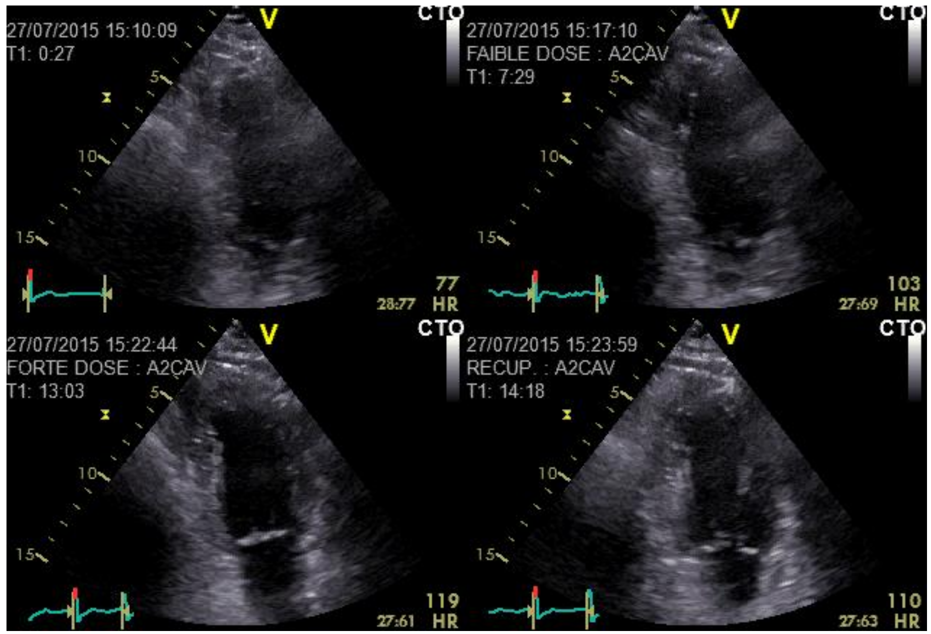

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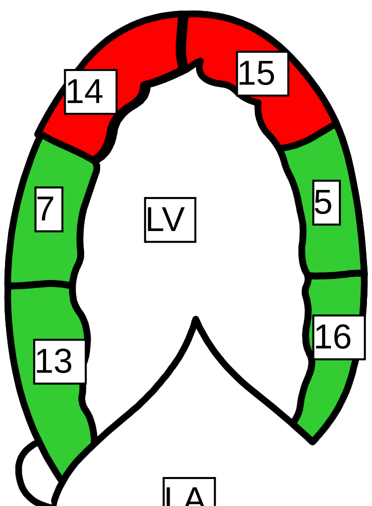

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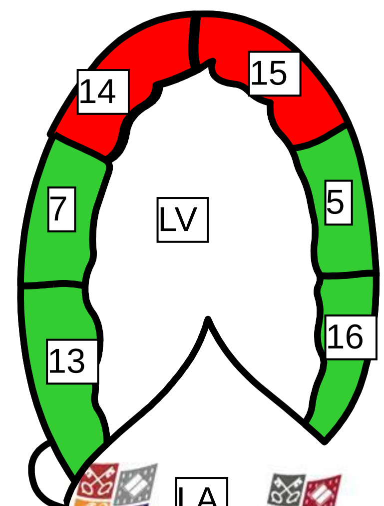

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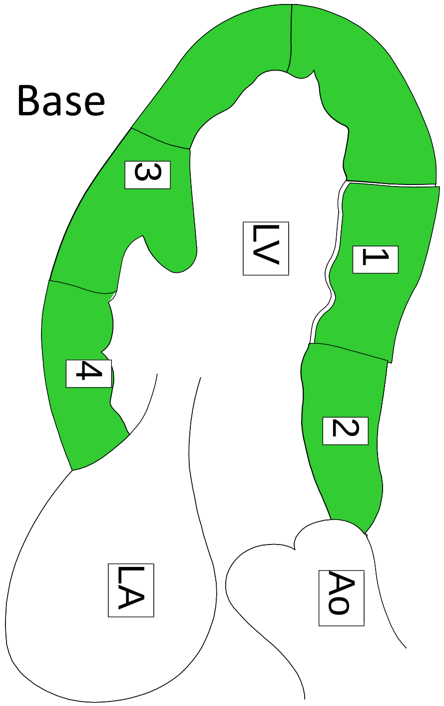

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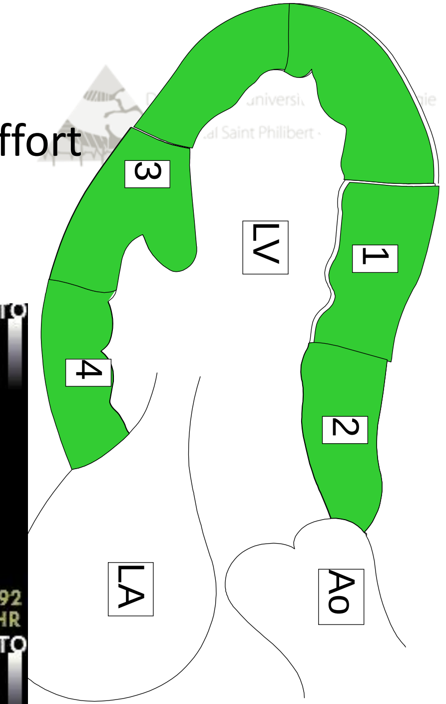

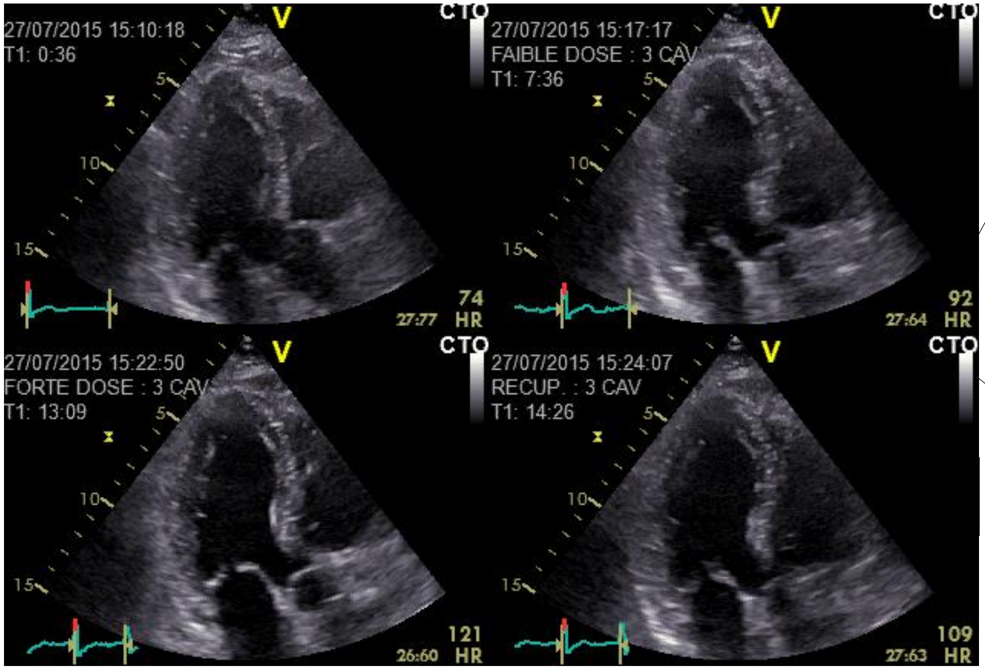

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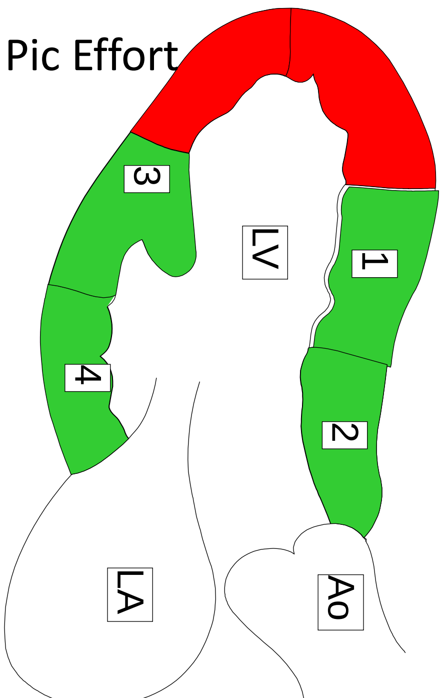

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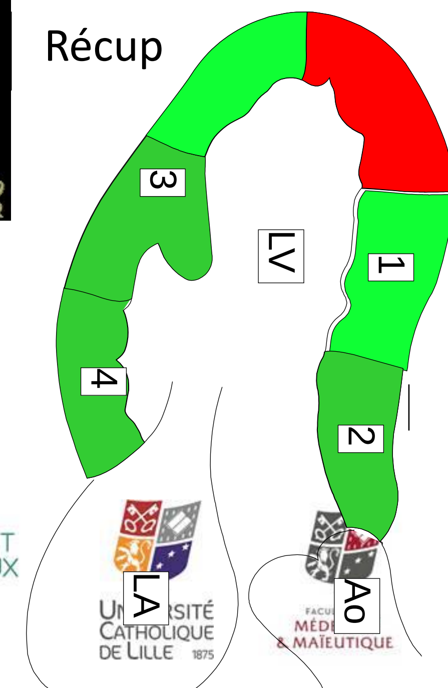

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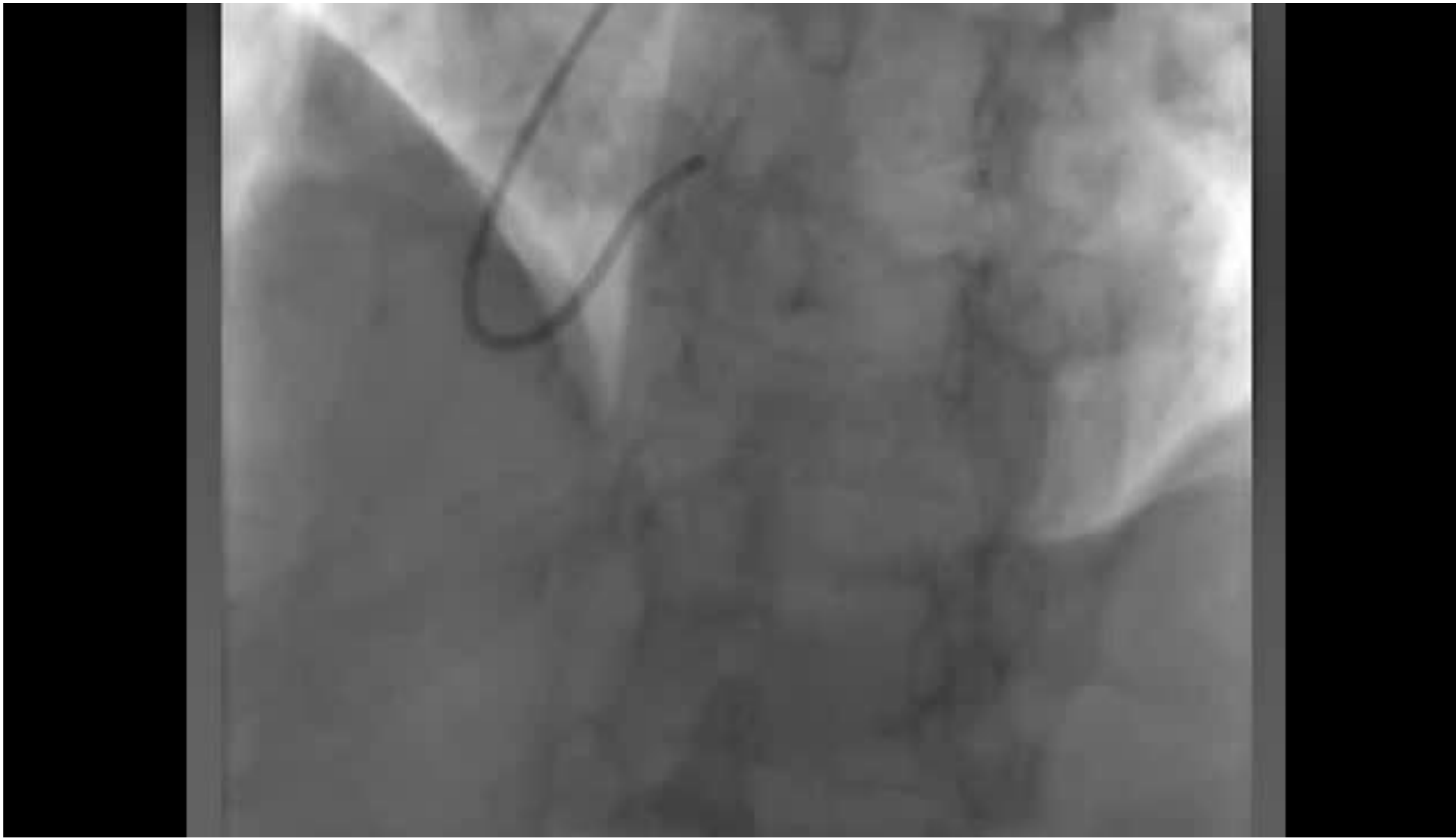

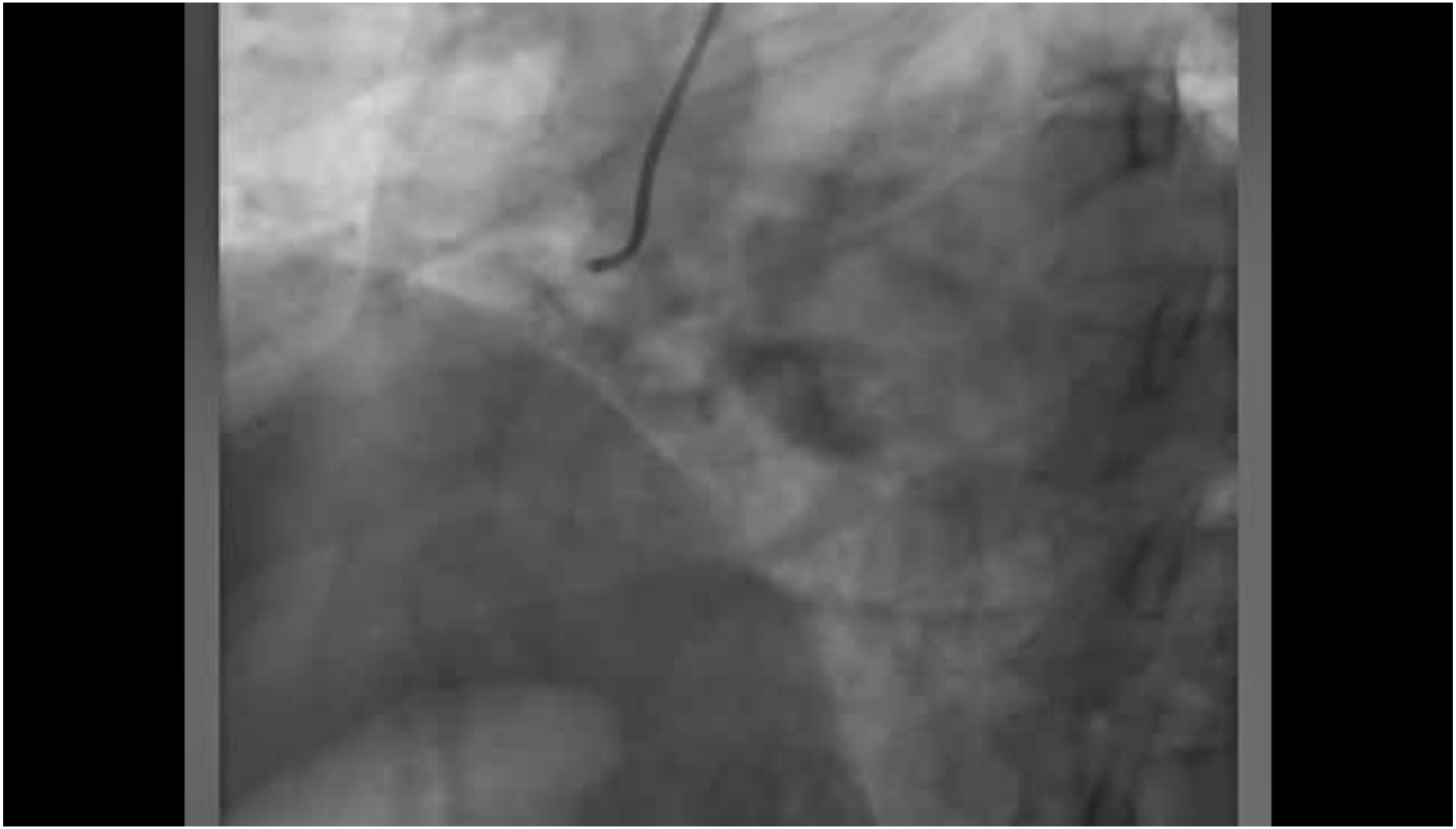

73 yo woman

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- ACS, RCA desobtruction, NS lesions Cx and LAD
- Asymptomatic
- 7min24
- Systolic BP 185/80 mmHg
- 97% max HR
- Workload 80W
- Fatigue

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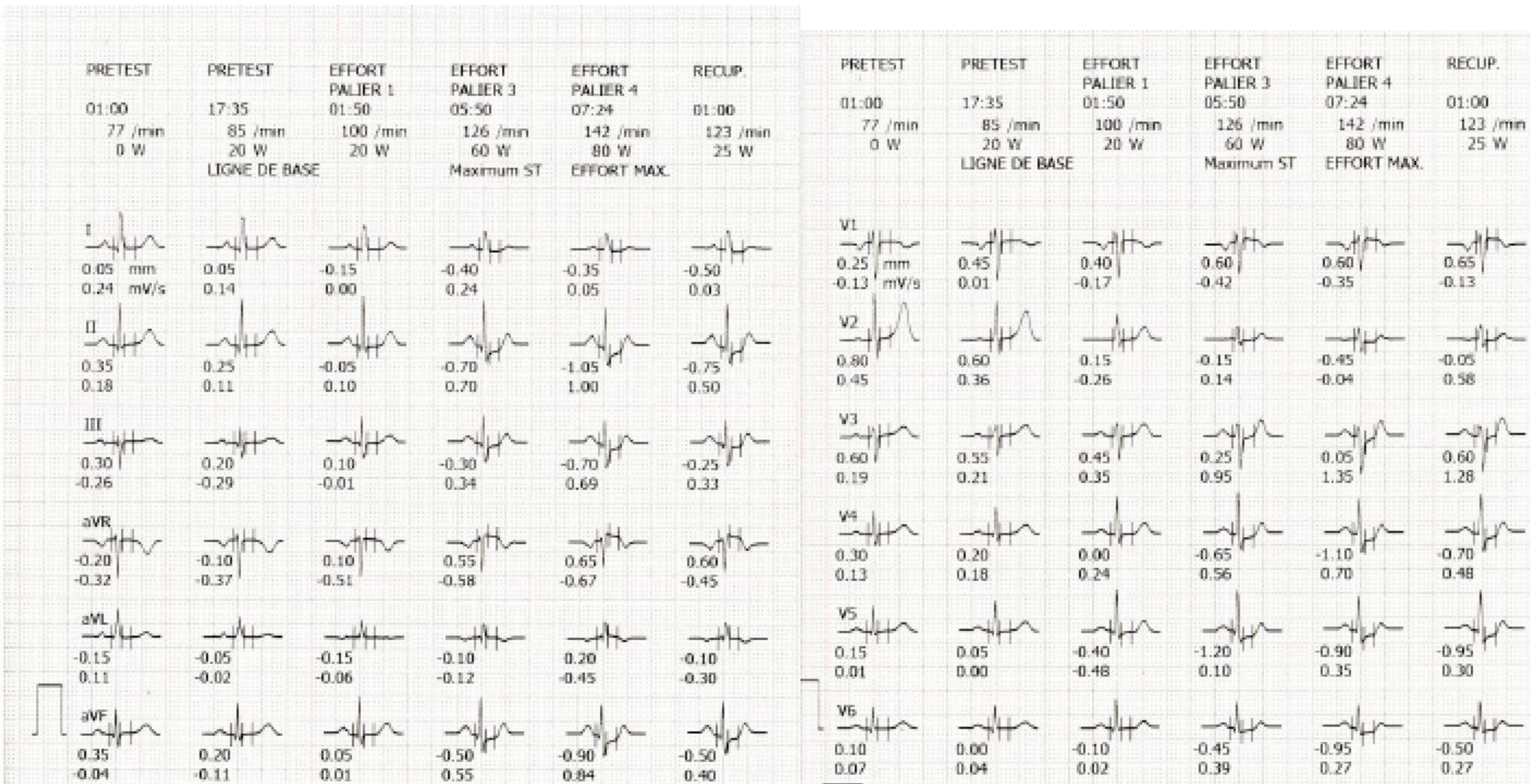

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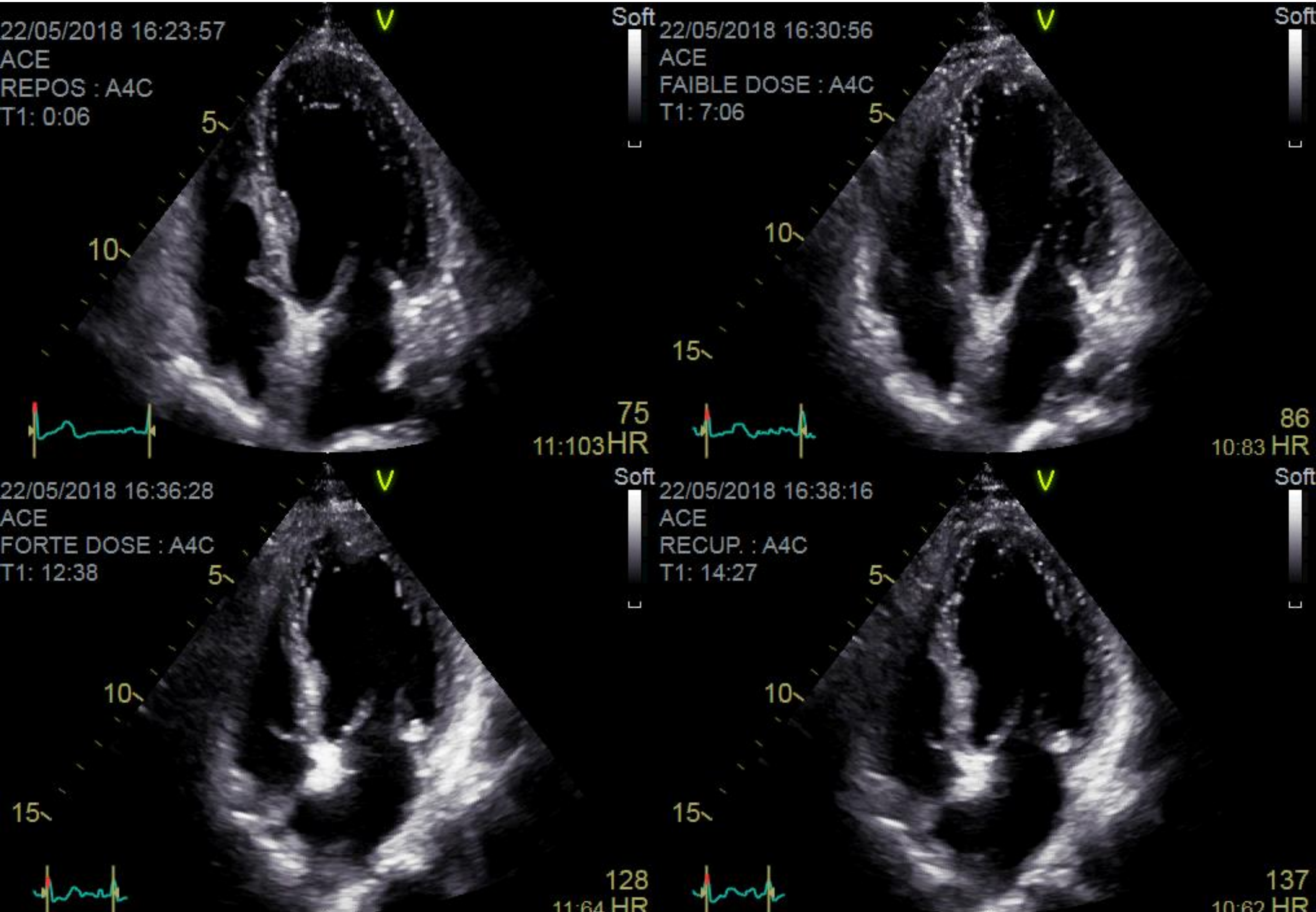
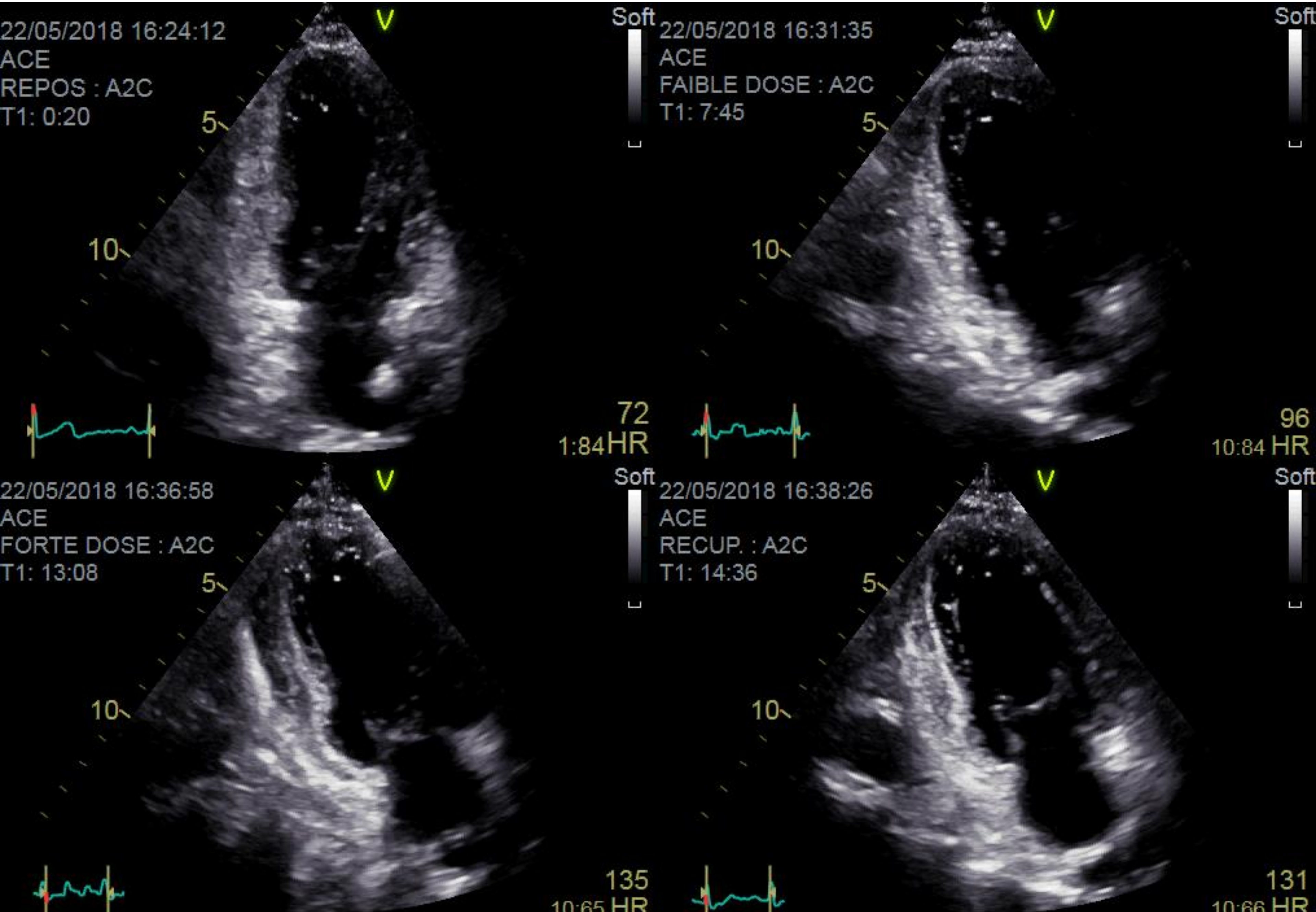

22/05/2018 16:23:57
ACE
REPOS : A4C
T1: 0:06
75
11:103HR
22/05/2018 16:30:56
ACE
FAIBLE DOSE : A4C
T1: 7:06
86
10:83 HR
22/05/2018 16:36:28
ACE
FORTE DOSE : A4C
T1: 12:38
128
11:64 HR
22/05/2018 16:38:16
ACE
RECUP. : A4C
T1: 14:27
137
10:62 HR


22/05/2018 16:24:12
ACE
REPOS : A2C
T1: 0:20
V
Soft
5
10
72
1:84 HR
22/05/2018 16:31:35
ACE
FAIBLE DOSE : A2C
T1: 7:45
V
Soft
5
10
96
10:84 HR
22/05/2018 16:36:58
ACE
FORTE DOSE : A2C
T1: 13:08
V
Soft
5
10
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T1: 14:36
V
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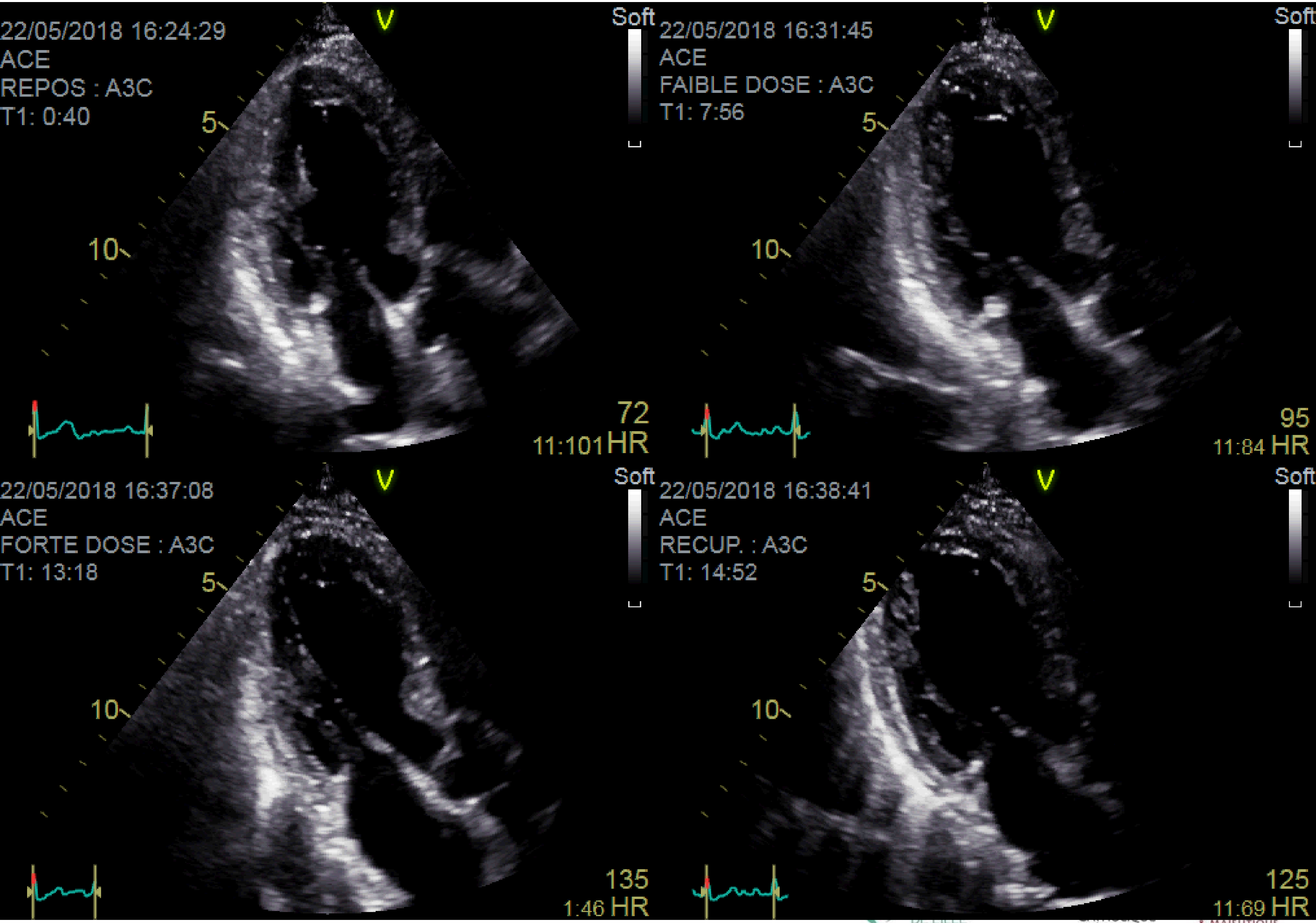
5
10
131
10:66 HR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REPOS : A3C
T1: 0:40
Soft
72
11:101 HR
22/05/2018 16:31:45
ACE
FAIBLE DOSE : A3C
T1: 7:56
Soft
95
11:84 HR
22/05/2018 16:37:08
ACE
FORTE DOSE : A3C
T1: 13:18
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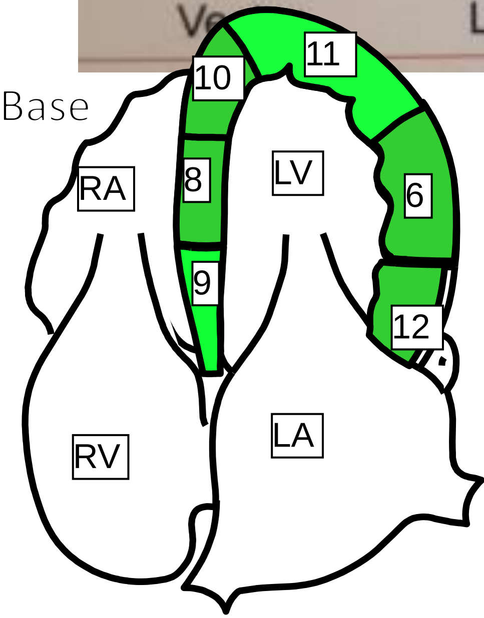
Soft
125
11:69 HR

Base



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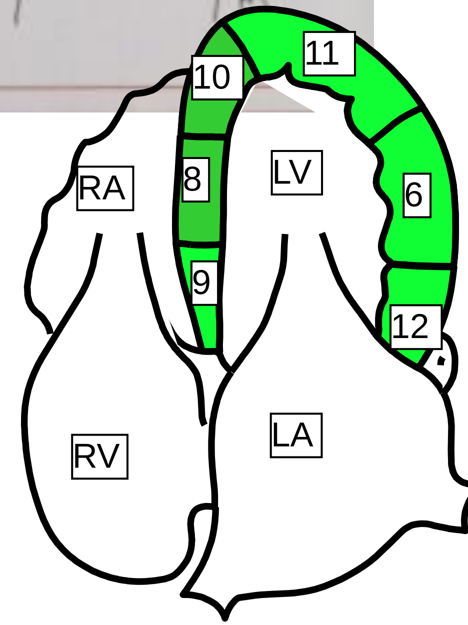

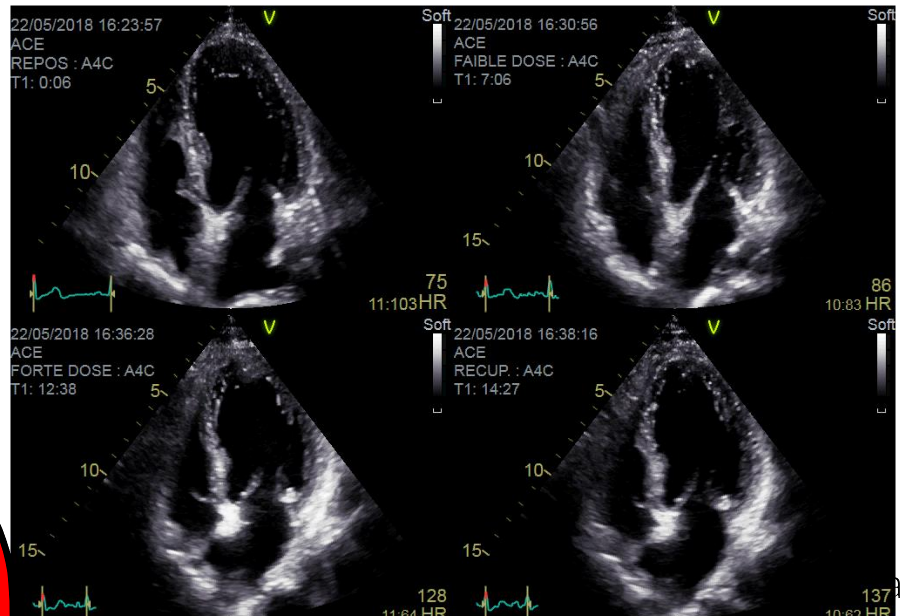

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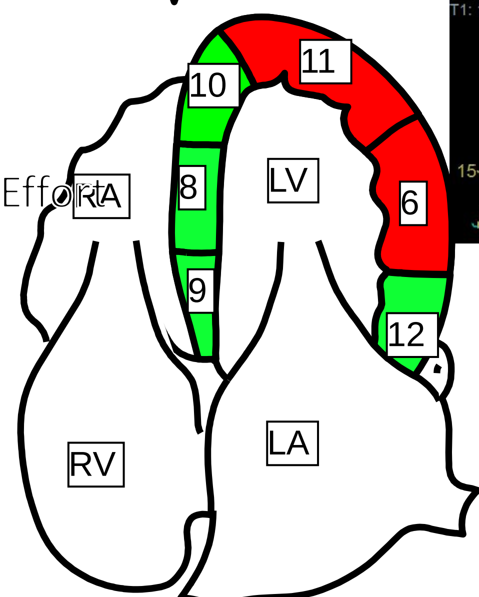

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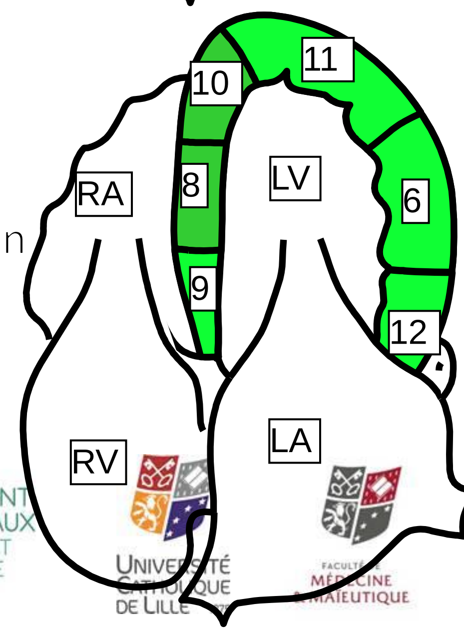

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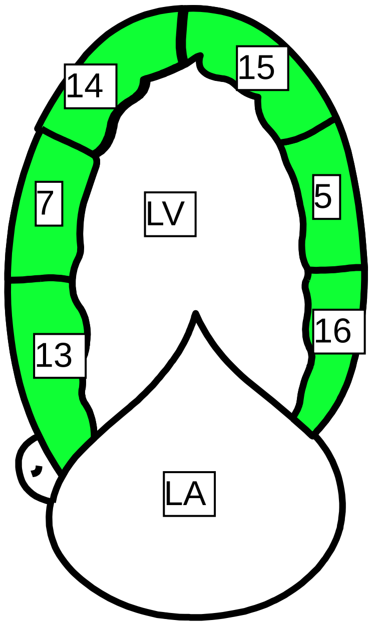

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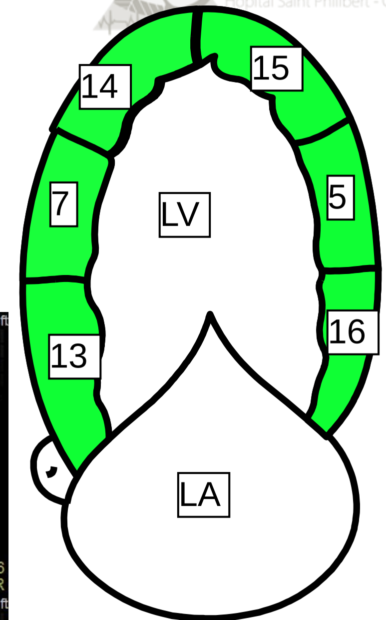

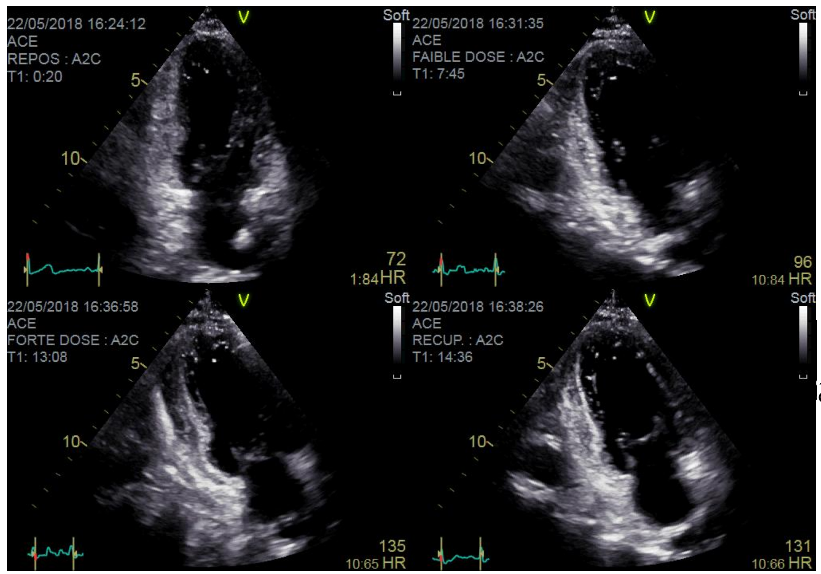

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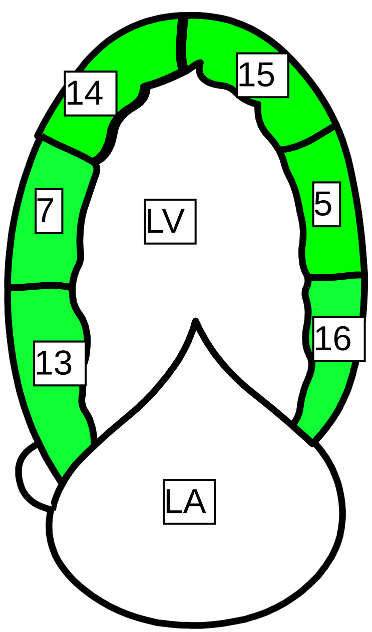

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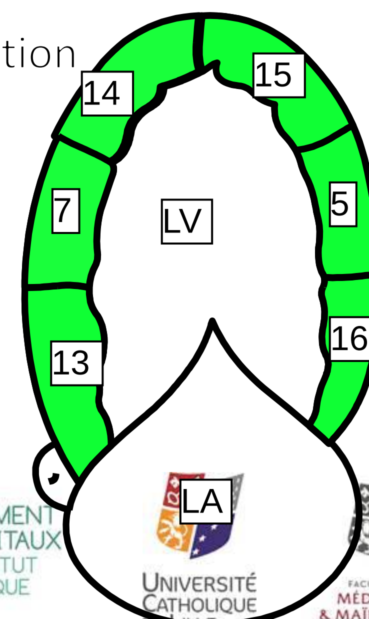

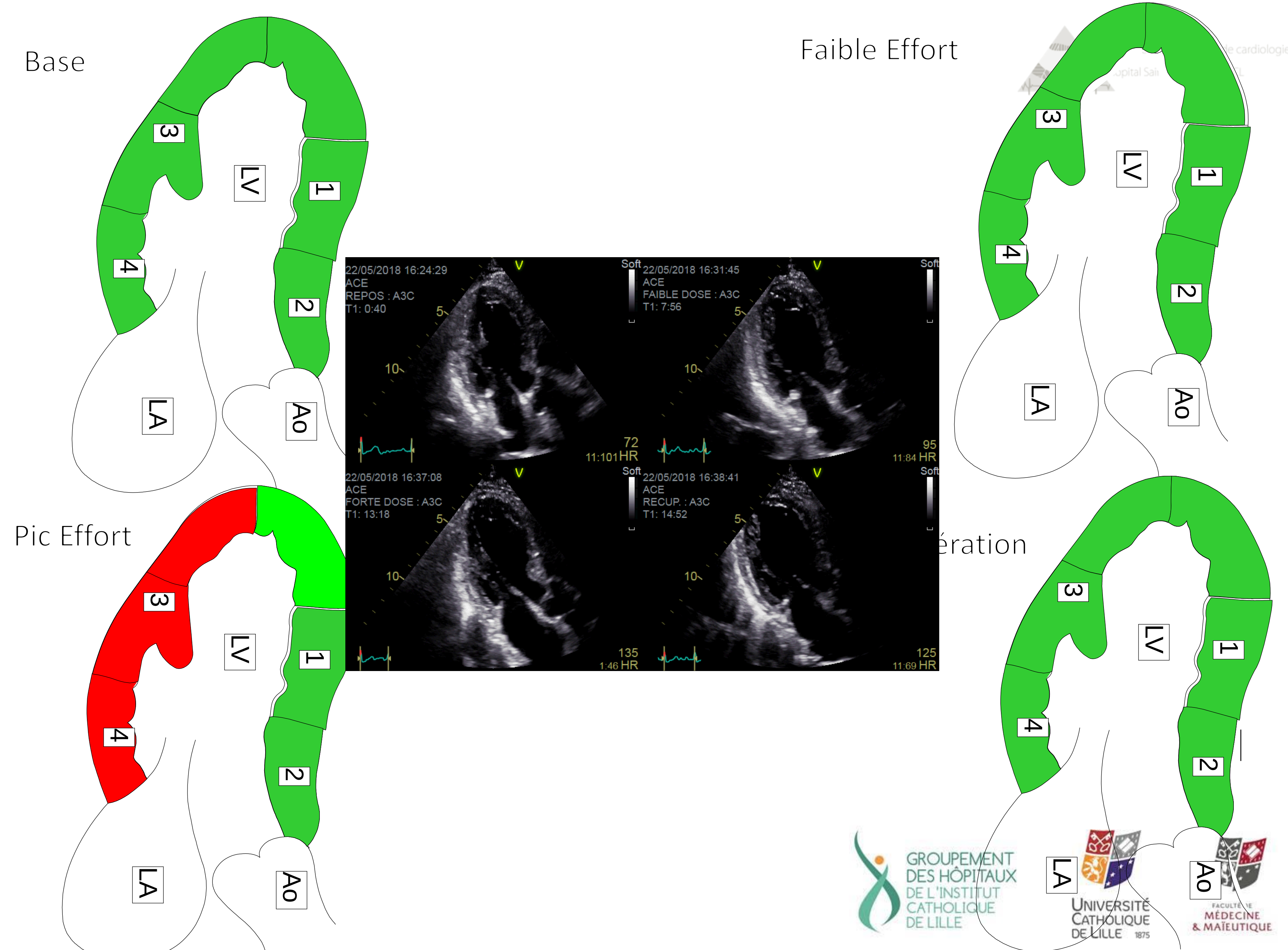

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Improving stress echocardiography accuracy for detecting left circumflex artery stenosis: a new echocardiographic sign?

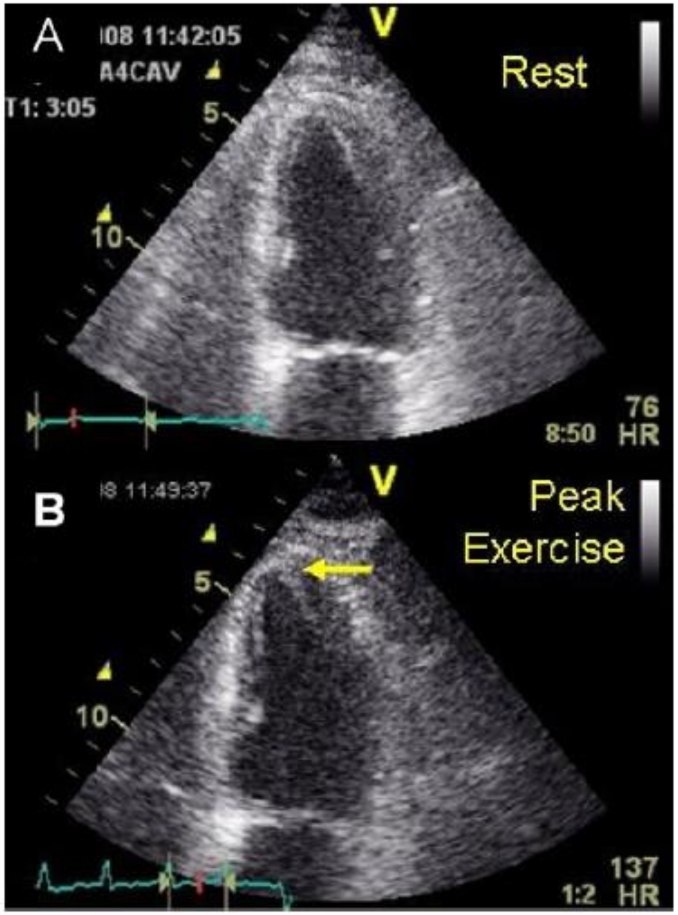
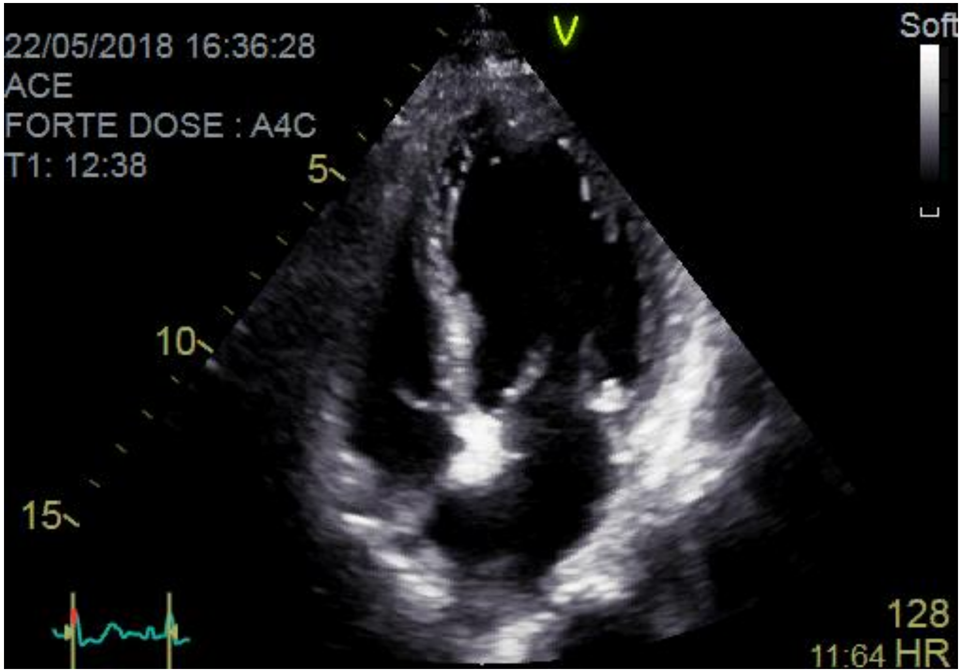


Figure 1. Exercise echocardiography: four-chamber view at rest (A) and at peak exercise (end-systole) (B). The characteristic RA-HA sign is observed at peak stress with lateral motion of the apex towards the right.

ascension du segment apico-latéral et/ou un déplacement horizontal de la pointe vers la droite en incidence apicale 3 ou 4 cavités au pic du stress.



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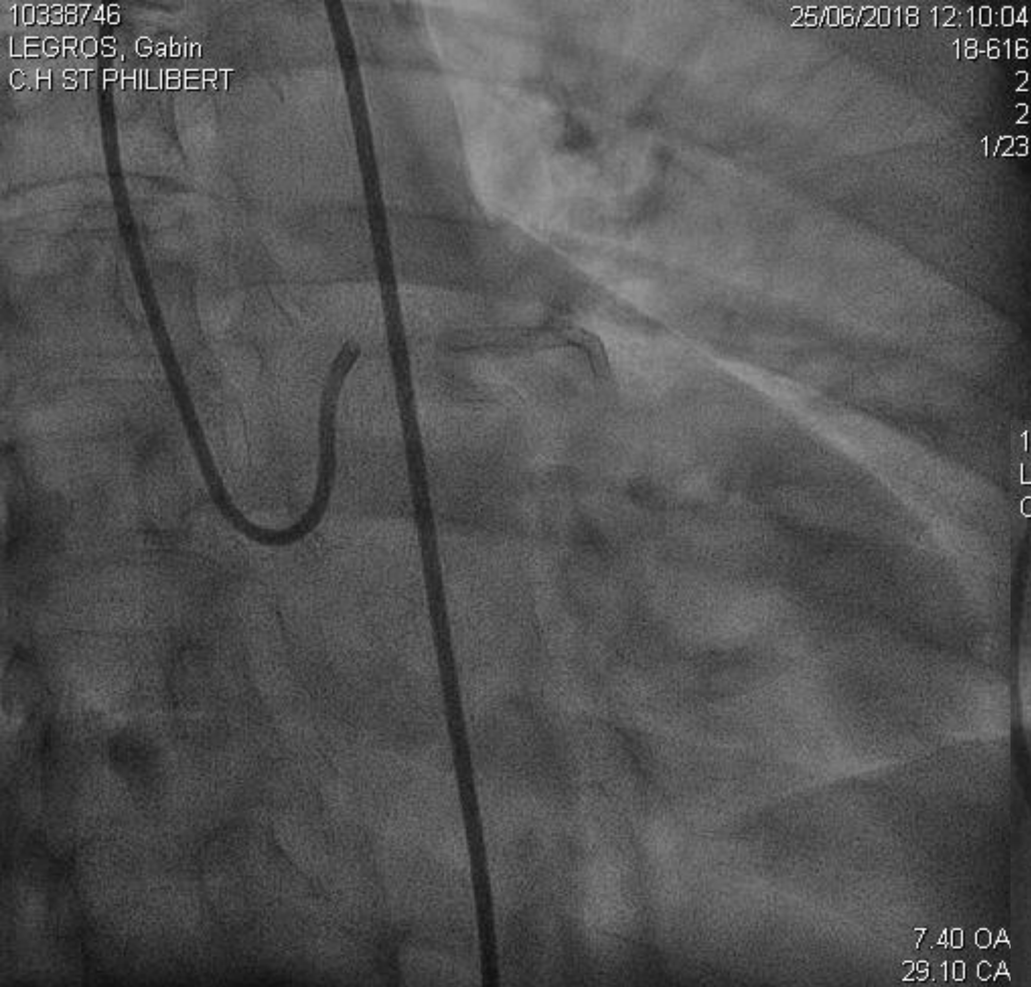
Improving stress echocardiography accuracy for detecting left circumflex artery stenosis: a new echocardiographic sign?

Table 4 Diagnostic performance of the RA-HA sign.

Coronary artery	Reader	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV (%)	NPV (%)
LAD	Senior 1	33.3 (20.4—49.1)	65.6 (46.8—80.8)	57.7	41.1
	Senior 2	31.1 (18.6—46.8)	65.6 (46.8—80.8)	56.0	40.4
LCx	Senior 1	70.0 (50.4—84.6)	89.4 (76.1—96.0)	80.8	82.4
	Senior 2	66.7 (47.1—82.1)	89.4 (76.1—96.0)	80.0	80.8
RCA	Senior 1	48.1 (29.2—67.6)	74.0 (59.4—84.9)	50.0	72.6
	Senior 2	44.4 (26.0—64.4)	74.0 (59.4—84.9)	48.0	71.2

Diagnostic performance of RA-HA sign (for the two senior readers) to detect significant stenosis of the LAD, LCx or RCA, irrespective of whether the patient had single, double or triple vessel disease. CI: confidence interval; LAD: left anterior descending coronary artery; LCx: left circumflex artery; NPV: negative predictive value; PPV: positive predictive value; RA-HA: Rise of the Apical lateral wall and/or Horizontal displacement of the Apex towards the septum; RCA: right coronary artery.

Chauvel C, Abergel E et al, ACVD, 2012


10338746
LEGROS, Gabin
C.H ST PHILIBERT
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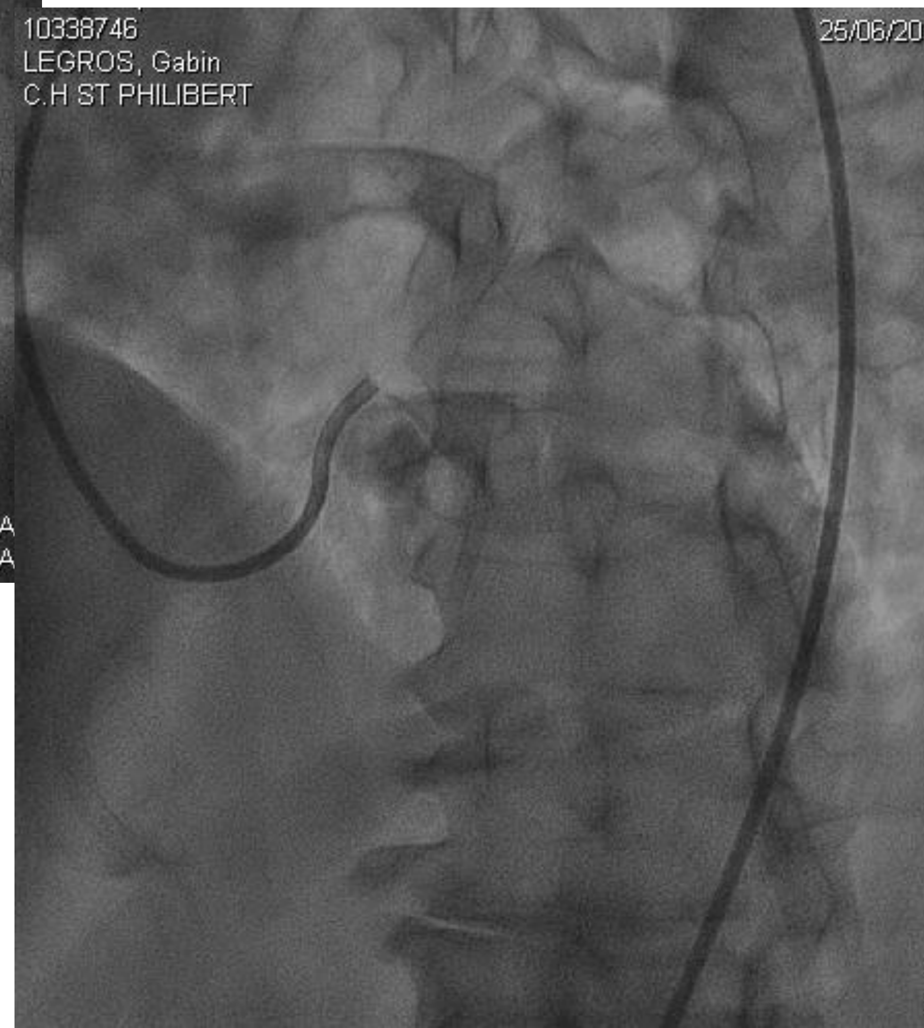
18-616
2
2
1/23
7.40 OA
29.10 CA


10338746
LEGROS, Gabin
C.H ST PHILIBERT
25/06/20

Thank you for your attention

GHICL – heart valve center, echocardiography laboratories, cardiology and ICU departments

<u>GHICL Heart Team</u>
Dr Alexandre Altes
Dr Ludovic Appert
Dr Camille Binda
Dr Jean Philippe Bonnet
Dr Anne-Laure Castel
Dr Vincent Decourcelle
Dr Marie Decroocq
Dr François Delelis
Dr Helene Dumortier
Dr Caroline Le Goffic
Pr Pierre Graux
Dr Tiphaine Leblond
Dr Yves Guyomar
Dr Gabin Legros
Dr Blandine Leman
Dr Aymeric Menet
Dr Farid Nedjari
Dr Clémence Riolet
Dr Nicolas Thellier
Dr Guillaume Viart
Pr André Vincentelli – Dr Valentin Lobuyck (CHU Lille)
Pr Sylvestre Marechaux

The echocardiography laboratory of the GHICL is certified « advanced echo lab » by the European Association for Cardiovascular Imaging (EACVI) until 2023 https://www.escardio.org/Education/Career-Development/Accreditation/EACVI-Laboratory-accreditation/Accredited-Laboratories

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Filiale d'Imagerie Cardiovasculaire
de la Société Française de Cardiologie

EACVI
European Association of Cardiovascular Imaging

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