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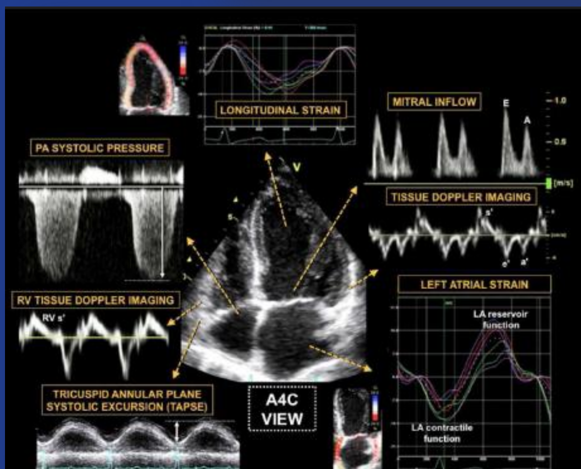
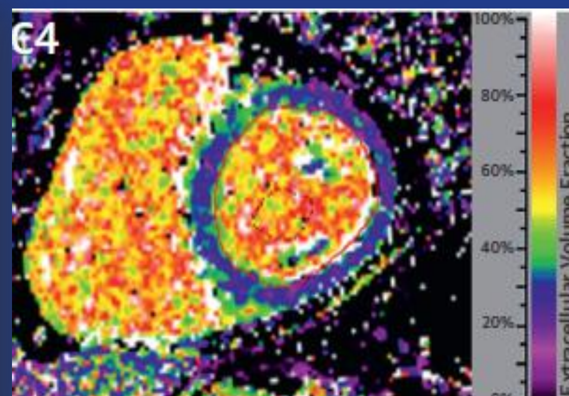




Ipertensione e imaging di diagnostica ecocardiografica

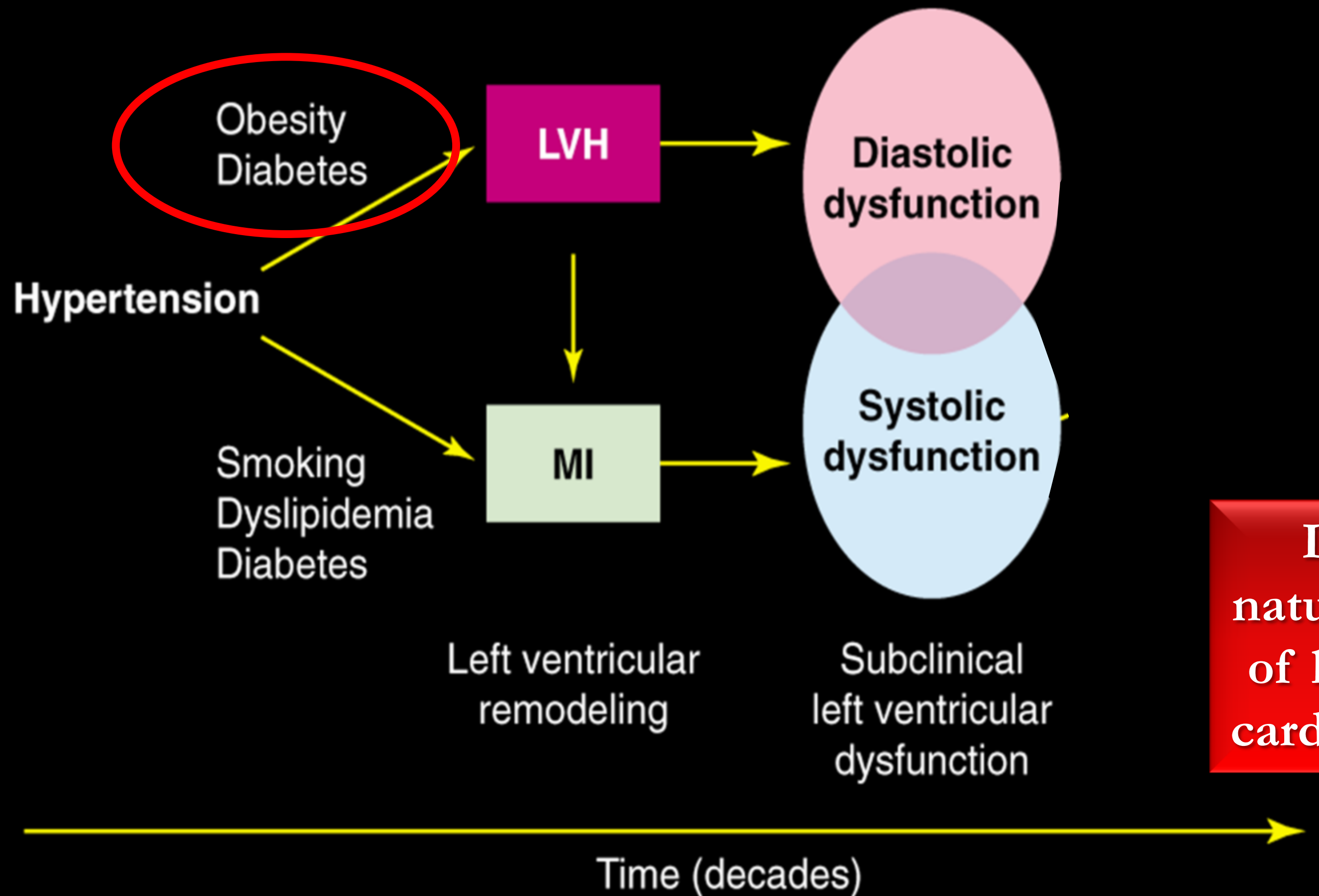
Gabriella Locorotondo, MD PhD
U.O. Diagnostica Cardiologica Non Invasiva
Fondazione Policlinico Universitario A. Gemelli Roma

Conflicts of interest

Nothing to disclose

The natural history of hypertension

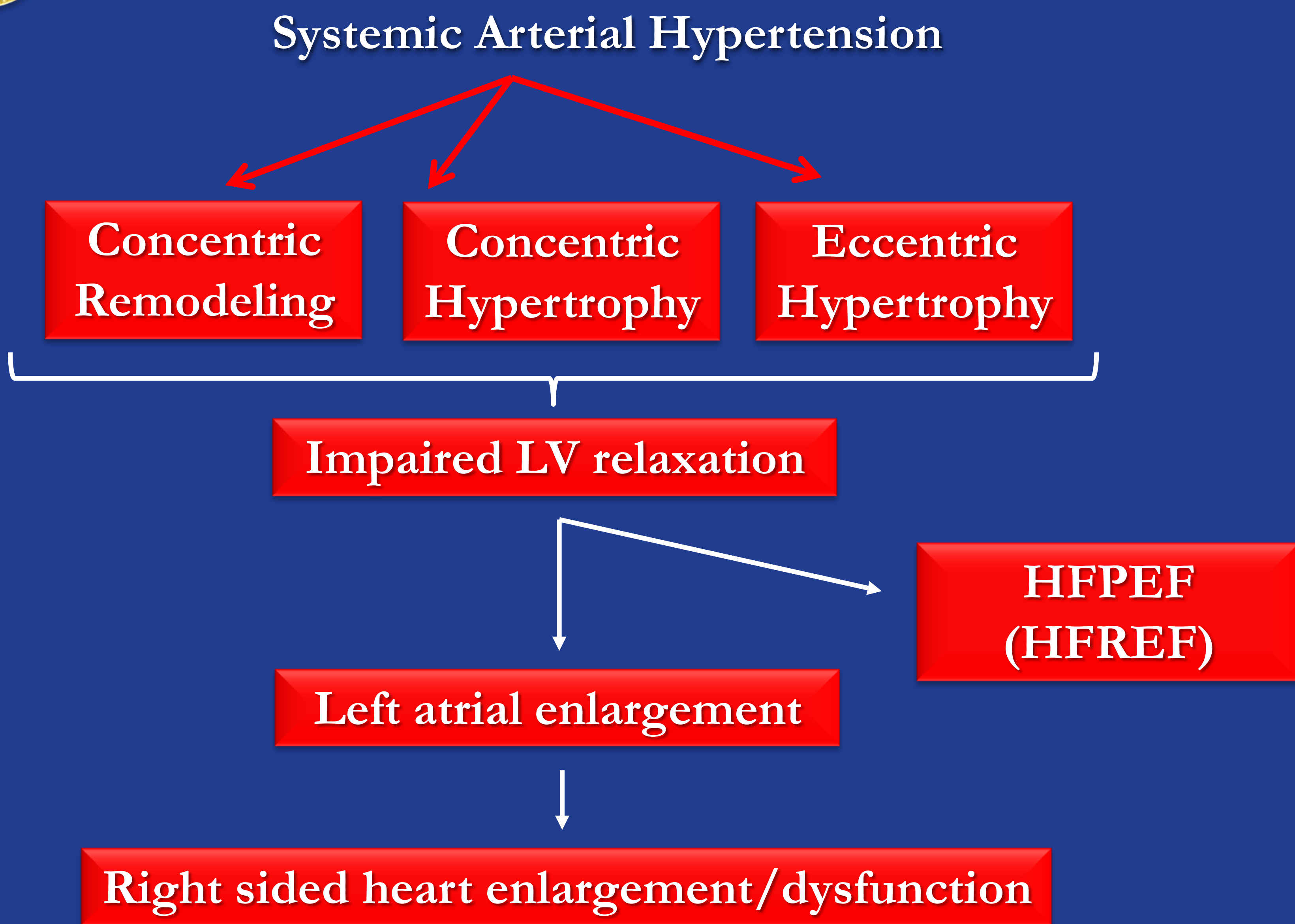
Compensation | Decompensation | Failure



Is HFPEF natural evolution of hypertensive cardiomyopathy?

Vasan RS, Levy D. *Arch Intern Med.* 1996;56:1789-1796.

The «overload cascade»



ESC European Society of Cardiology
European Heart Journal (2018) **39**, 3021–3104
doi:10.1093/eurheartj/ehy339

ESC/ESH GUIDELINES

2018 ESC/ESH Guidelines for the management of arterial hypertension

The Task Force for the management of arterial hypertension of the European Society of Cardiology (ESC) and the European Society of Hypertension (ESH)

Table 4 Factors influencing cardiovascular risk in patients with hypertension

Demographic characteristics and laboratory parameters
Sex[a] (men >women)
Age[a]
Smoking (current or past history)[a]
Total cholesterol[a] and HDL-C
Uric acid
Diabetes[a]
Overweight or obesity
Family history of premature CVD (men aged <55 years and women aged <
Family or parental history of early-onset hypertension
Early-onset menopause
Sedentary lifestyle
Psychosocial and socioeconomic factors
Heart rate (resting values >80 beats/min)

Asymptomatic HMOD
Arterial stiffening: Pulse pressure (in older people) ≥60 mmHg Carotid–femoral PWV >10 m/s
ECG LVH (Sokolow–Lyon index >35 mm, or R in aVL ≥11 mm; Cornell voltage duration product >2440 mm.ms, or Cornell voltage >28 mm in men or >20 mm in women)
Echocardiographic LVH [LV mass index: men >50 $g/m^{2.7}$; women >47 $g/m^{2.7}$ (height in $m^{2.7}$); indexation for BSA may be used in normal-weight patients; LV mass/BSA g/m^2 >115 (men) and >95 (women)]
Microalbuminuria (30–300 mg/24 h), or elevated albumin–creatinine ratio (30–300 mg/g; 3.4–34 mg/mmol) (preferentially on morning spot urine)[b]
Moderate CKD with eGFR >30–59 mL/min/1.73 m^2 (BSA) or severe CKD eGFR <30 mL/min/1.73 m^2 [b]
Ankle-brachial index <0.9
Advanced retinopathy: haemorrhages or exudates, papilloedema
Established CV or renal disease
Cerebrovascular disease: ischaemic stroke, cerebral haemorrhage, TIA
CAD: myocardial infarction, angina, myocardial revascularization
Presence of atheromatous plaque on imaging
Heart failure, including HFpEF
Peripheral artery disease
Atrial fibrillation

ESC European Society of Cardiology
European Heart Journal (2018) 39, 3021–3104
doi:10.1093/eurheartj/ehy339
ESC/ESH GUIDELINES

2018 ESC/ESH Guidelines for the management of arterial hypertension

Table 5 Ten year cardiovascular risk categories (Systematic COronary Risk Evaluation system)

The presence of HMOD is unlikely to influence treatment, as these patients should already receive lifestyle interventions, BP-lowering medications, statins, and in some cases antiplatelet therapy, to reduce their risk

The main advantage of detecting HMOD is that it may reclassify a patient's risk assessment from low to moderate or from moderate to high risk

Recommendations	Class	Level
Echocardiography: • Is recommended in hypertensive patients when there are ECG abnormalities or signs or symptoms of LV dysfunction.[42,134]	I	B
• May be considered when the detection of LVH may influence treatment decisions.[42,134]	IIb	B

Moderate CKD eGFR 30-59 mL/min/1.73 m²)

...0%

≥1 to <5%

...g to this categor...

<1%

The ECG is not a particularly sensitive method of detecting LVH and its sensitivity varies according to body weight

Too late!

Should we initiate treatment when BP is high-normal (130–139/85–89 mmHg)?

ESC European Society of Cardiology
European Heart Journal (2018) 39, 3021–3104
doi:10.1093/eurheartj/ehy339
ESC/ESH GUIDELINES

2018 ESC/ESH Guidelines for the management of arterial hypertension

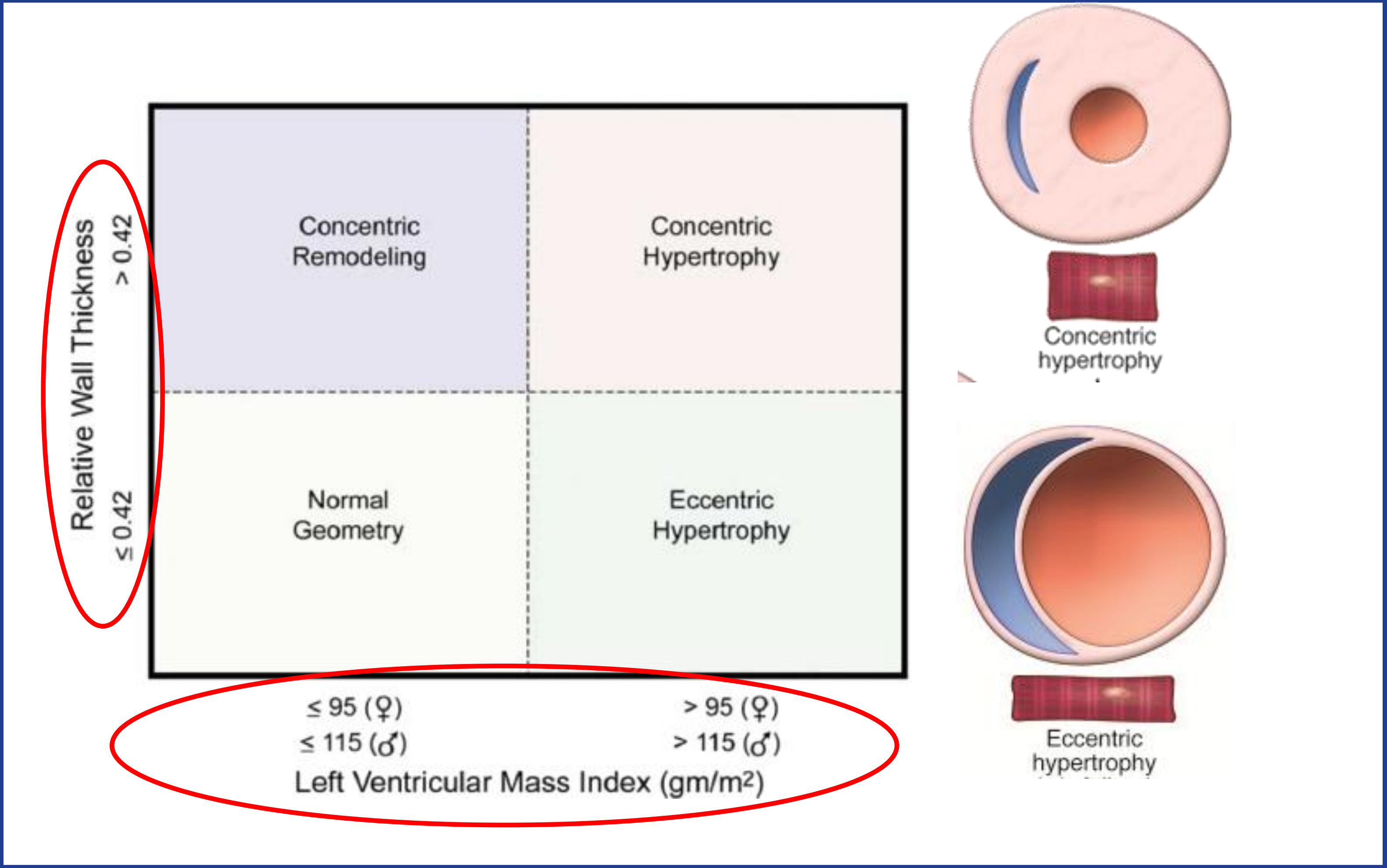
The Task Force for the management of arterial hypertension of the European Society of Cardiology (ESC) and the European Society of Hypertension (ESH)

Table 17 Echocardiographic definitions of left ventricular hypertrophy, concentric geometry, left ventricular chamber size, and left atrial dilatation

Parameter	Measure	Abnormality threshold
LVH	LV mass/height$^{2.7}$ (g/m$^{2.7}$)	>50 (men)
		>47 (women)
LVH[a]	LV mass/BSA (g/m^2)	>115 (men)
		>95 (women)
LV concentric geometry	RWT	≥0.43
LV chamber size	LV end-diastolic diameter/height (cm/m)	>3.4 (men)
		>3.3 (women)
Left atrial size (elliptical)	Left atrial volume/height^2 (mL/m^2)	>18.5 (men)
		>16.5 (women)

Diastolic dysfunction can be further evaluated by a combination of transmitral flow and tissue Doppler studies.

How can we quantify LV remodeling?



Echocardiographic Determination of Left Ventricular Mass in Man

Anatomic Validation of the Method

Richard B. Devereux, M.D., and Nathaniel Reichek, M.D.

With the technical assistance of Patricia J. Klunder

CIRCULATION

Vol 55, No 4, April 1977

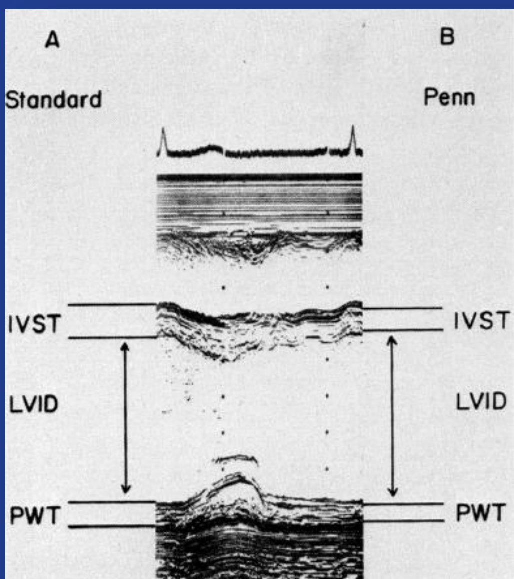
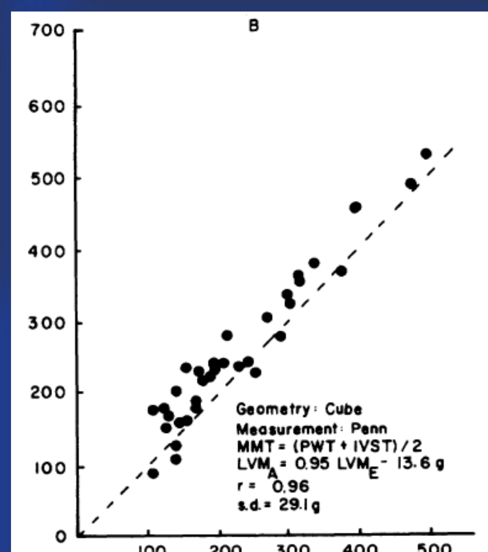


Table 1. *Comparison of Echocardiographic Estimates of Left Ventricular Mass with Actual Postmortem Ventricular Weight*

Convention	Geometry	MMT	Regression equation	SD	r
S	Cube	(PWT + IVST)/2	$LVM_A = 0.7\ LVM_E + 2.4$ g	42.2 g	0.92
S	Cube	PWT	$LVM_A = 0.67\ LVM_E + 22.0$ g	54.8 g	0.86
S	R	(PWT + IVST)/2	$LVM_A = 0.68\ LVM_E + 31.8$ g	43.7 g	0.91
S	R	PWT	$LVM_A = 0.65\ LVM_E + 49.4$ g	55.1 g	0.86
P	Cube	(PWT + IVST)/2	$LVM_A = 0.95\ LVM_E - 13.6$ g	29.1 g	0.96
P	Cube	PWT	$LVM_A = 0.95\ LVM_E - 0.7$ g	37.8 g	0.93
P	R	(PWT + IVST)/2	$LVM_A = 0.91\ LVM_E + 19.3$ g	31.5 g	0.96
P	R	PWT	$LVM_A = 0.91\ LVM_E + 30.0$ g	39.7 g	0.93



$$\text{Anatomic LVM} = 1.04\ ([LVID_p + PWT_p + IVST_p]^3 - [LVID_p]^3) - 13.6\ \text{g.}$$

GUIDELINES AND STANDARDS

Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

Journal of the American Society of Echocardiography
January 2015

LV Mass and LV Mass Index

CALCULATION

Input

LVEDD [ ] mm Height [ ] cm
IVSd [ ] mm Weight [ ] kg
PWd [ ] mm Gender ◉ Male ○ Female

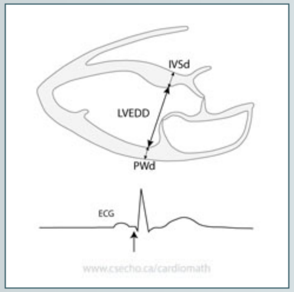
Calculate
Clear

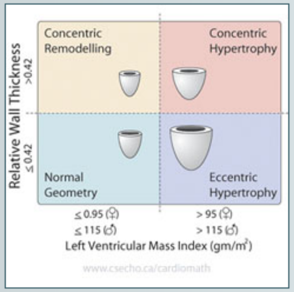
Result

LV Mass g
LV Mass Index g/m^2
RWT

▲ TOP

ILLUSTRATIONS





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INFORMATION

Reference Ranges & Partition Values for LV Mass Indexed To BSA (g/m^2)

	Female	Male
Reference Range	43-95	49-115
Mildly Abnormal	96-108	116-131
Moderately Abnormal	109-121	132-148
Severely Abnormal	≥122	≥149

LV Mass and LV Mass Index

Left ventricular mass and left ventricular mass indexed to body surface area estimated by LV cavity dimension and wall thickness at end-diastole.

Relative wall thickness (RWT) allows further classification of LV mass increase as either concentric hypertrophy (RWT >0.42) or eccentric hypertrophy (RWT ≤0.42).

LV Mass (g) = 0.8{1.04[([LVEDD + IVSd +PWd]^3 - LVEDD^3)]} + 0.6

$$RWT = \frac{2 * PWd}{LVEDD}$$

4·[(IVS
T)^3−LVID^3] + 0.6g

Table 6 Normal ranges for LV mass indices

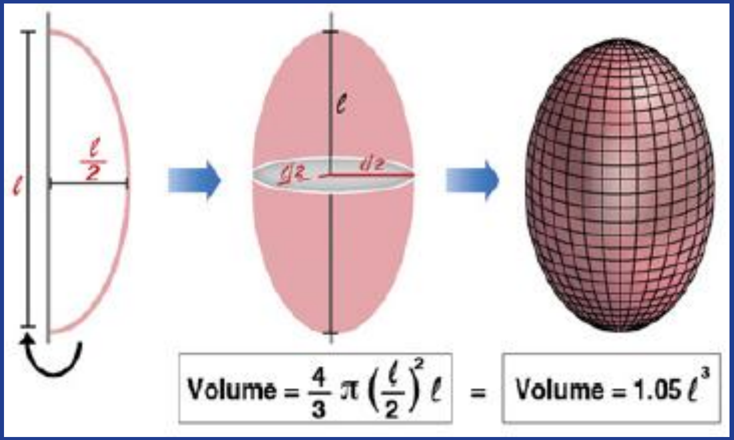
	Women	Men
Linear method		
LV mass (g)	67–162	88–224
LV mass/BSA (g/m^2)	***43–95***	***49–115***
Relative wall thickness (cm)	0.22–0.42	0.24–0.42
Septal thickness (cm)	***0.6–0.9***	***0.6–1.0***
Posterior wall thickness (cm)	***0.6–0.9***	***0.6–1.0***
2D method		
LV mass (g)	66–150	96–200
LV mass/BSA (g/m^2)	***44–88***	***50–102***

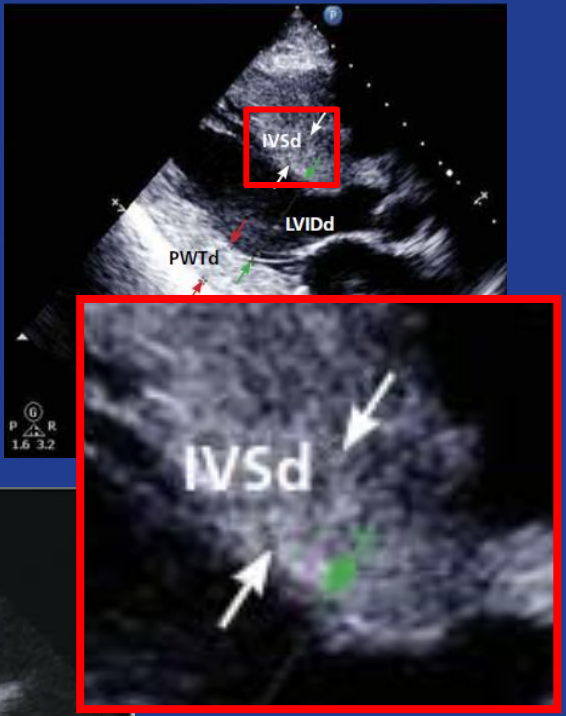
ength:
ss = 1.05

$$\left\{\left[\frac{5}{6}A_1(a+d+t)\right] - \left[\frac{5}{6}A_2(a+d)\right]\right\}$$

Limits of LV mass assessment by echo

$$LVM + 0.8 \times \left[1.05\left(IVST+LVID+PWT\right)^3 - \left(LVID\right)^3\right] + 0.8\ g$$





Intraclass Correlation Coefficient (ICC):	LVDD	0.87 – 0.97
	IVST	0.50 – 0.85
	PWT	0.65 – 0.83

Are increased LV mass and LV hypertrophy interchangeable concepts?

Man, age 65 yrs
Weight 70 Kg - Height 160 cm
BSA 1.73 m2

EDD 40 mm – IVS 14 mm – PW 13 mm
LV mass 197 g
LV
RV

Concentric remodeling

LVMi 55 g/m2
Concentric hyperthrophy

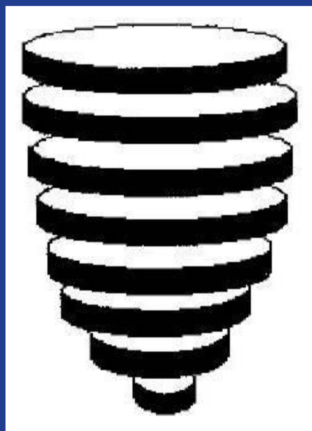
Woman, age 70 yrs
Weight 80 Kg - Height 155 cm
BSA 1.79 m2

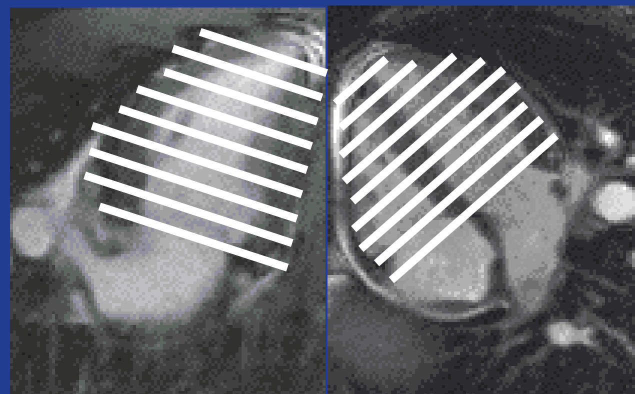
EDD 49 mm – IVS 10 mm – PW 10 mm
LV mass 175 g
LV n
RWT

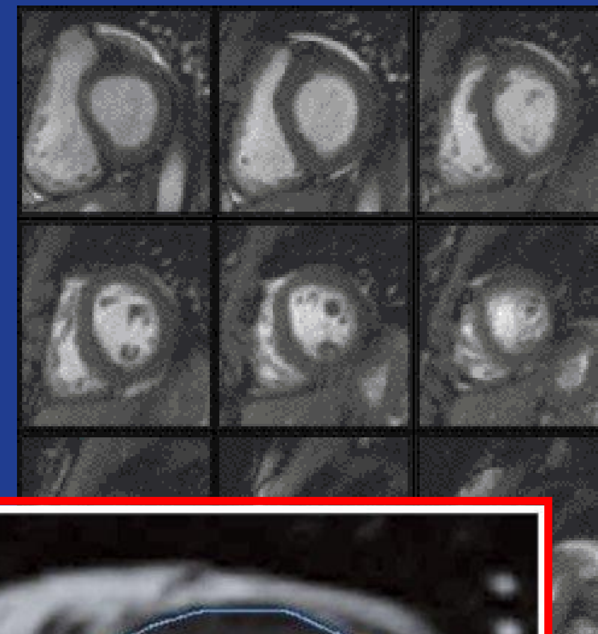
Eccentric hypertrophy

What about papillary muscles?

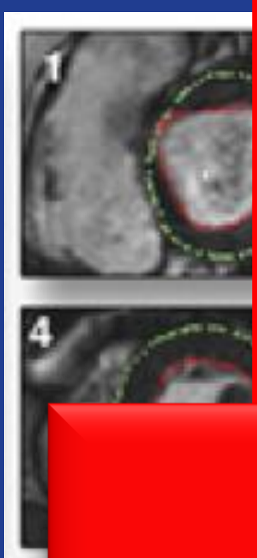
LV mass assessment by CMR

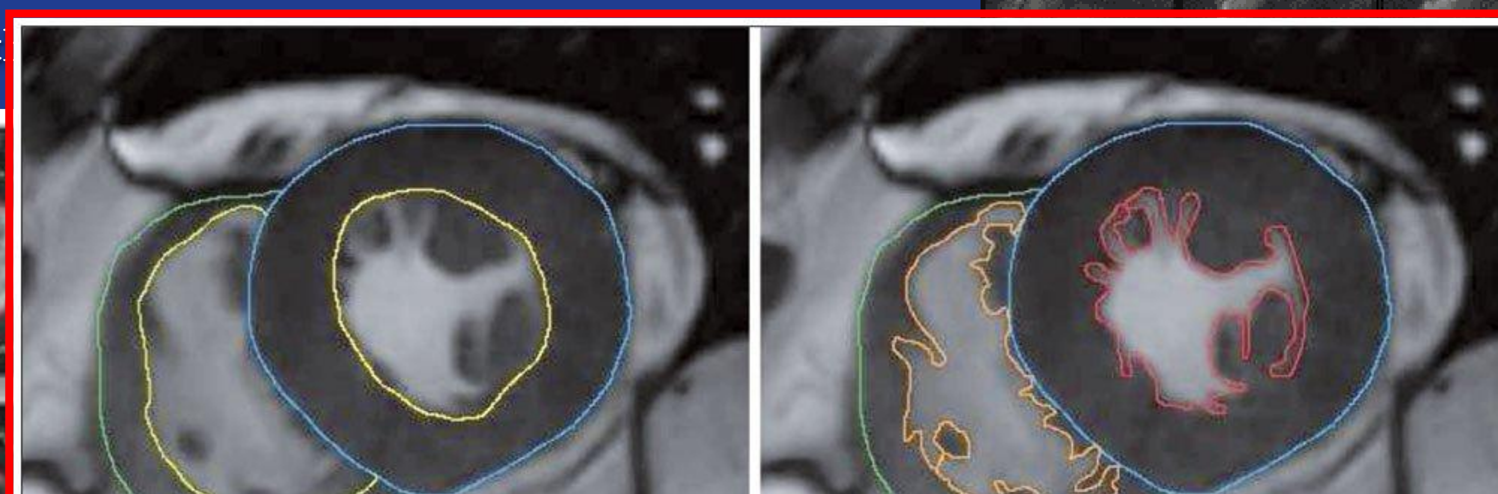






Slice t





5 g

Intraclass Correlation Coefficient (ICC): 0.99
Intrareader reproducibility 0.5 ± 11%
Interscan average difference of 0.32 g ± 20 g

Are Echo and CMR interchangeable in assessing LV mass?

Magnetic resonance imaging compared to echocardiography to assess left ventricular mass in the hypertensive patient

Peter B. Bottini, Albert A. Carr ✉, L. Michael Prisant, Fred W. Flickinger, Jerry D. Allison, John S. Gottdiener

American Journal of Hypertension, Volume 8, Issue 3, 1 March 1995, Pages 221–228, https://doi.org/10.1016/0895-7061(94)00178-E

Published: 01 March 1995 **Article history** ▾

MRI LVM estimates were within 17.5 g (95% CI) of the true LVM. The linear agreement between MRI and ECHO estimates of LVM could be described by the equation MRI = 0.61 × ECHO + 49.57 ($r = 0.63$, $P < .01$). The precision of LVM by MRI (11 g) was over twice that observed with ECHO (26 g). The reliability of MRI LVM estimates was more consistent (±8 g) than that for ECHO (±49 g).

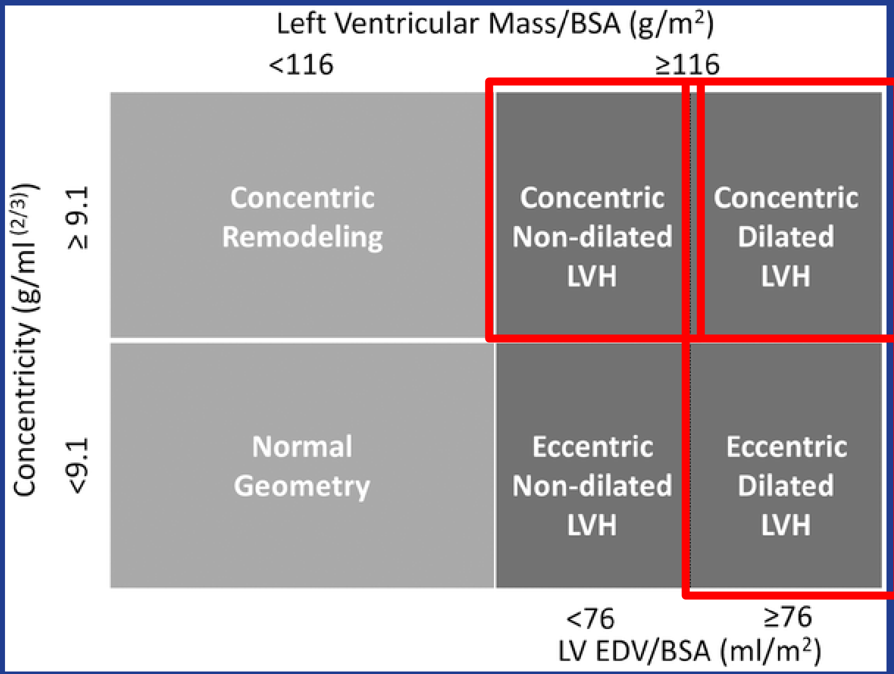
MRI appears to be a more precise and reliable method for measuring LVM, and would be more suitable than ECHO for the clinical evaluation of the individual patient.

Why do we still use Echo to assess LV mass?

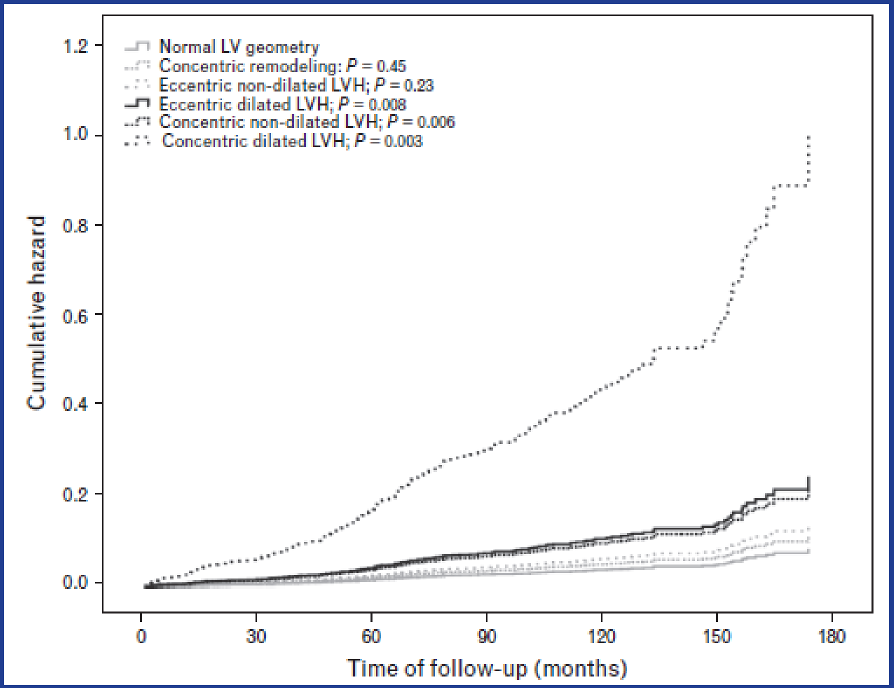
Table 18 Sensitivity to detect treatment-induced changes, reproducibility and operator independence, time to changes, and prognostic value of changes provided by markers of hypertension-mediated organ damage

Marker of HMOD	Sensitivity to changes	Reproducibility and operator independence	Time to changes	Prognostic value of the change
LVH by ECG	Low	High	Moderate (>6 months)	Yes
LVH by echocardiogram	Moderate	Moderate	Moderate (>6 months)	Yes
LVH by CMR	High	High	Moderate (>6 months)	No data
eGFR	Moderate	High	Very slow (years)	Yes
Urinary protein excretion	High	Moderate	Fast (weeks to months)	Moderate
Carotid IMT	Very low	Low	Slow (>12 months)	No
PWV	High	Low	Fast (weeks to months)	Limited data
Ankle-brachial index	Low	Moderate	Slow (>12 months)	Moderate

New classification based on LV volumes!



Results: Independent of confounders, eccentric dilated LVH, concentric nondilated LVH and concentric dilated LVH were associated with higher cardiovascular risk (hazard ratios between 2 and 9, all $P < 0.01$), mostly depending on the magnitude of LVM index. A volume load was present especially in dilated forms of LVH, the extent of which was important in the determination of harmful types of left ventricular geometry.



De Simone G, J Hypertension 2015

Sex-related differences in hypertensive organ damage

TOD	Men	Women
Cardiac		
LV hypertrophy	+	– Regression more difficult
Concentric geometry	+	++
Ejection fraction	+	higher values
Diastolic dysfunction	+	+
Left atrial enlargment	+	±
Renal		
Glomerular filtration rate	Slower decrease with aging	Higher prevalence of reduced eGFR in postmenopausal women
Albuminuria prevalence	Higher	Lower
Vascular		
Carotid plaques	Increased prevalence	– (more positive remodeling?)
Carotid distensibility	Reduced	Reduced in postmenopausal women
Aortic stiffness PWV	Increased	Lower values in women
Augmentation index	Increased	Higher increase
Small arteries (subcutaneous tissue) media to lumen (M/L) ratio	++	+++, after adjusting for confounders
Retinal vessels Increased W/L ratio	+	+

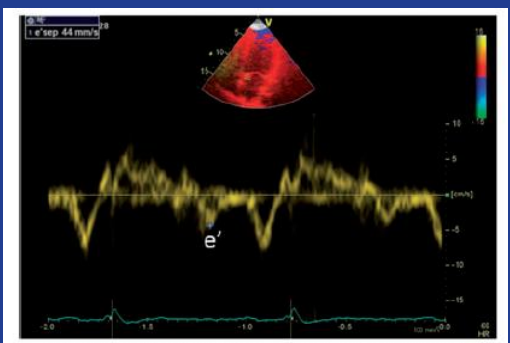
Muiesan ML, High Blood Pressure & Cardiovascular Prevention 2018

ESC European Society of Cardiology
European Heart Journal - Cardiovascular Imaging (2017) 18, 945–960
doi:10.1093/ehjci/jex094
EACVI/ESH CONSENSUS PAPER

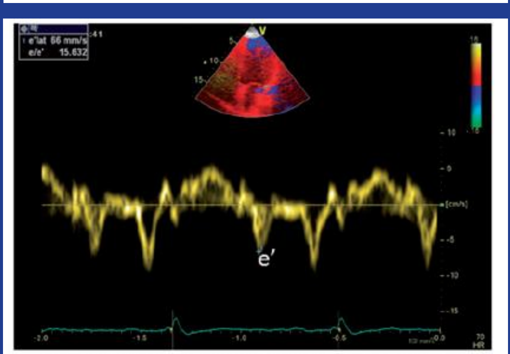
Non-invasive cardiovascular imaging for evaluating subclinical target organ damage in hypertensive patients

A consensus paper from the European Association of Cardiovascular Imaging (EACVI), the European Society of Cardiology Council on Hypertension, and the European Society of Hypertension (ESH)

Pasquale Perrone-Filardi[1]*, Antonio Coca[2], Maurizio Galderisi[1], Stefania Paolillo[3], Francisco Alpendurada[4], Giovanni de Simone[5], Erwan Donal[6], Thomas Kahan[7], Giuseppe Mancia[8], Josep Redon[9], Roland Schmieder[10], Bryan Williams[11], and Enrico Agabiti-Rosei[12]



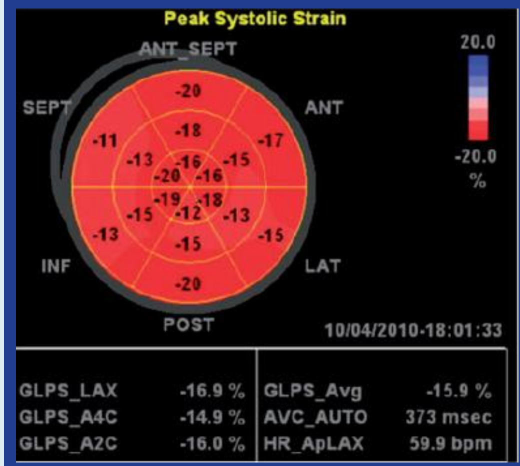
Pulsed Tissue Doppler of septal mitral annulus



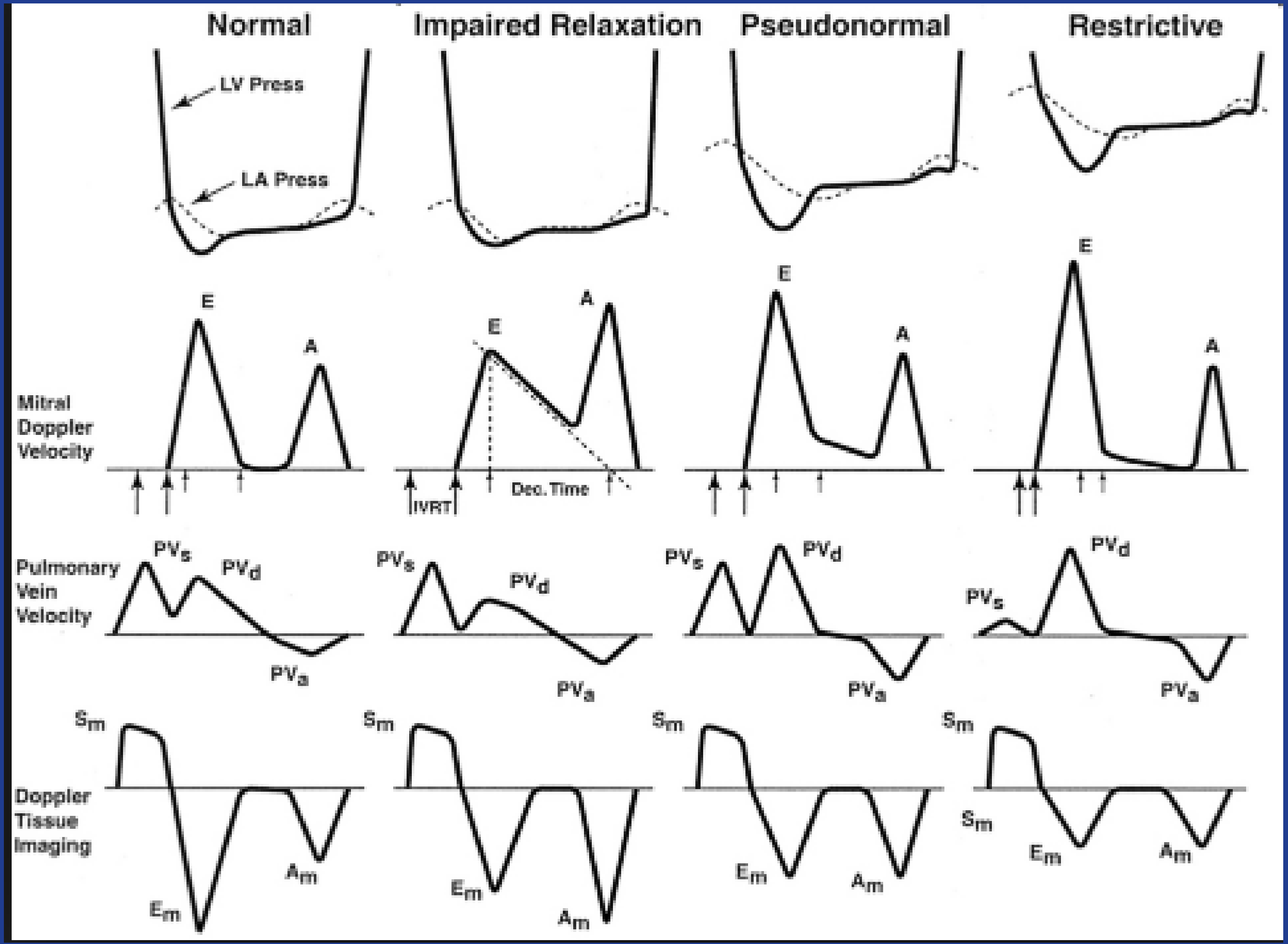
Pulsed Tissue Doppler of lateral mitral annulus

Table 2 Echocardiographic parameters (and their cut-off values of abnormalcy) of cardiac damage in arterial hypertension

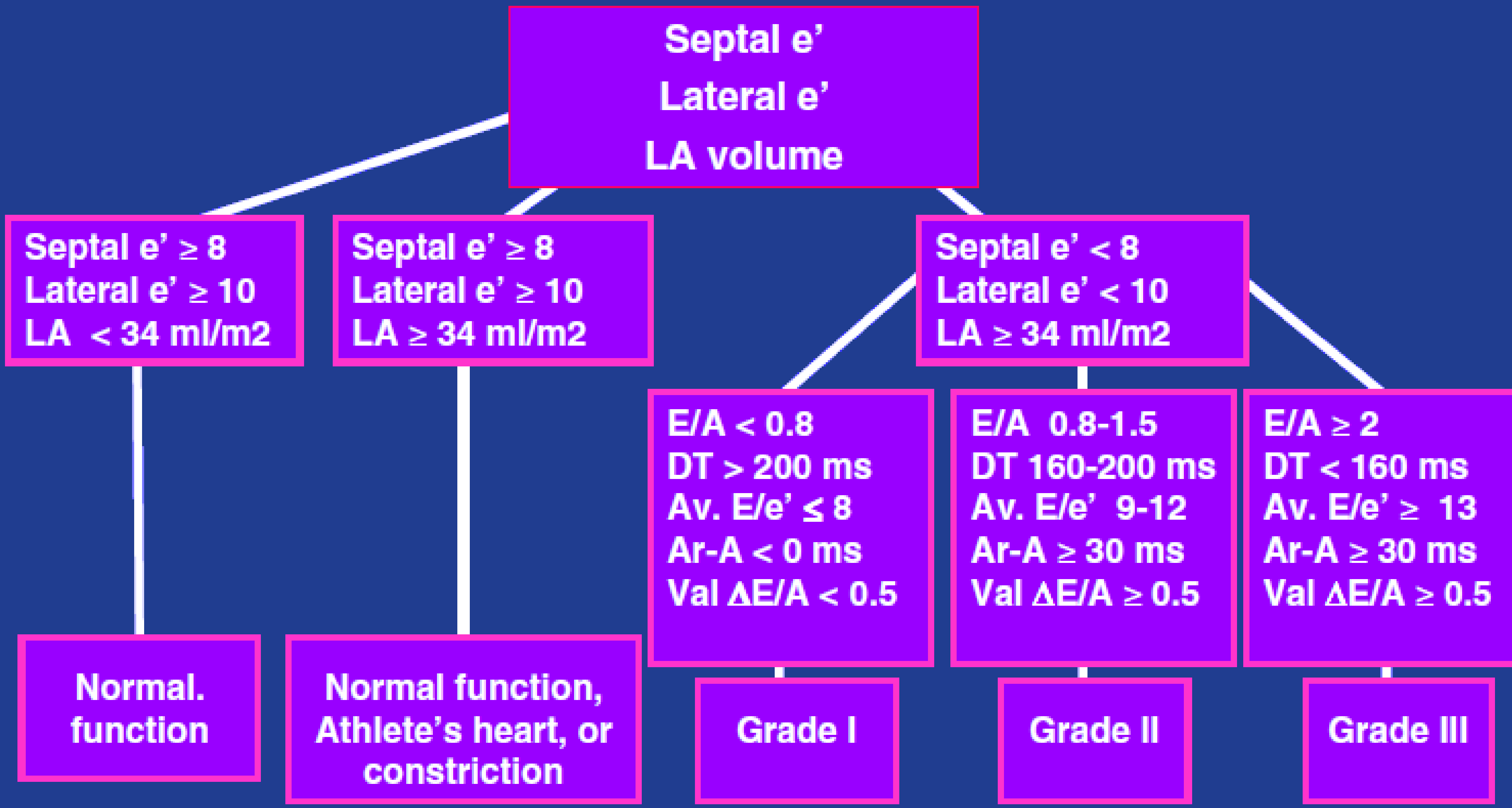
Echo parameter	Type of cardiac damage	Abnormal if
LVM/height (g/m$^{2.7}$)	LVH	> 47W, > 50M
LVM/BSA (g/m^2)	LVH	>95 W, >115 M
RWTd	LV concentric geometry	≥ 0.43
Septal annular e′ velocity (cm/s)	LVDD	<7
Lateral annular e′ velocity (cm/s)	LVDD	<10
E/e′ average ratio	Elevated LVFP	>14
LAVi (mL/m^2)	Elevated LVFP	>34
GLS (%)	LV systolic dysfunction	<20



Assessment of diastolic dysfunction: a long history with multiple changes

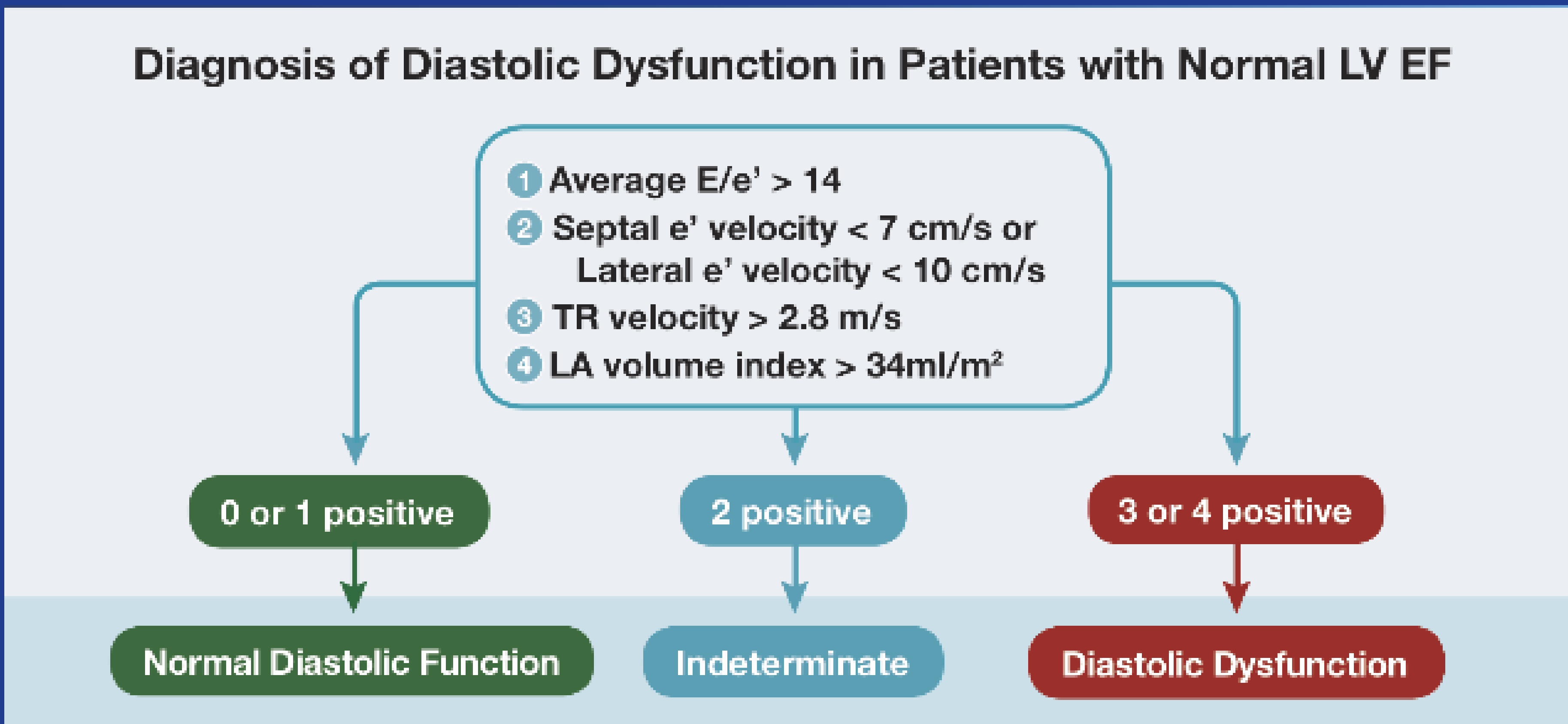


Recommendations for the Evaluation of LV Diastolic Function by Echo (ASE 2009)



Nagueh SF, JASE 2009

Recommendations for the Evaluation of LV Diastolic Function by Echo (ASE/EACVI 2016)



Nagueh SF, JASE 2016

Reference ranges for normal cardiac Doppler data: results from the NORRE Study

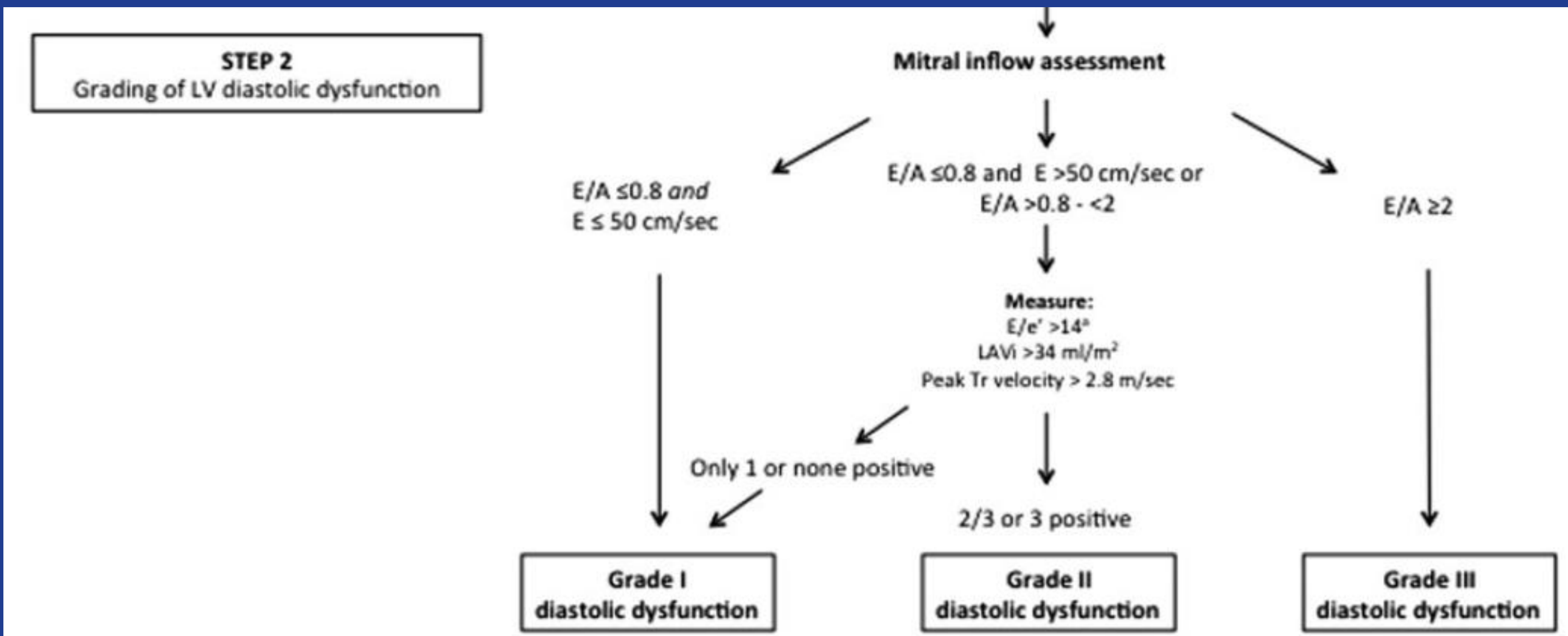
Table 3 Left ventricular diastolic parameters according to age and gender

Parameters	20–40 years				40–60 years				≥60 years			
	Total Mean ± SD	Total 95% CI	Male Mean ± SD	Female Mean ± SD	Total Mean ± SD	Total 95% CI	Male Mean ± SD	Female Mean ± SD	Total Mean ± SD	Total 95% CI	Male Mean ± SD	Female Mean ± SD
Pulse Doppler at the mitral valve												
E wave velocity (cm/s)	0.82 ± 0.16	0.53–1.22	0.79 ± 0.14	0.84 ± 0.17	0.75 ± 0.17	0.46–1.13	0.72 ± 0.16	0.77 ± 0.17	0.70 ± 0.16	0.39–1.03	0.67 ± 0.15	0.72 ± 0.17
A wave velocity (cm/s)	0.50 ± 0.13	0.30–0.87	0.50 ± 0.13	0.51 ± 0.12	0.62 ± 0.15	0.37–0.97	0.61 ± 0.15	0.63 ± 0.14	0.74 ± 0.16	0.40–1.04	0.73 ± 0.16	0.76 ± 0.16
E wave deceleration time (ms)	178.2 ± 43.1	105.2–269.0	179.8 ± 46.4	176.7 ± 40.1	187.6 ± 45.5	114.6–288.1	186.6 ± 52.8	188.2 ± 39.8	208.9 ± 62.7	114.0–385.9	217.5 ± 69.7	201.5 ± 55.7
E/A ratio	1.71 ± 0.52	0.89–3.18	1.69 ± 0.52	1.72 ± 0.52	1.24 ± 0.39	0.71 - 2.27	1.22 ± 0.31	1.26 ± 0.43	0.98 ± 0.29	0.53–1.80	0.96 ± 0.27	0.99 ± 0.31
E/Ea ratio												
Septal *E/e'*	6.9 ± 1.6	4.4–10.6	6.9 ± 1.7	6.9 ± 1.6	8.1 ± 2.3	4.3–13.2	7.8 ± 2.4	8.2 ± 2.2	9.7 ± 2.8	5.0–16.9	9.8 ± 3.0	9.7 ± 2.6
Lateral *E/e'*	5.1 ± 1.3	3.1–8.5	5.0 ± 1.3	5.2 ± 1.3	6.3 ± 2.2	3.7–12.0	6.1 ± 2.2	6.5 ± 2.3	7.8 ± 2.2	4.2–12.8	7.6 ± 2.1	7.9 ± 2.2
Average septal and lateral *E/e'*	5.8 ± 1.3	3.6–9.1	5.8 ± 1.4	5.9 ± 1.3	7.0 ± 2.1	4.2–11.5	6.7 ± 2.1	7.2 ± 2.0	8.5 ± 2.2	4.6–13.5	8.4 ± 2.2	8.6 ± 2.2
Average *E/e'*	5.6 ± 1.1	3.7–7.9	5.6 ± 1.2	5.5 ± 1.0	6.8 ± 1.8	4.0–11.6	6.7 ± 1.8	6.9 ± 1.9	8.3 ± 2.2	4.4–14.8	8.1 ± 2.3	8.6 ± 2.2

Caballero L, EHJ – Cardiovasc Im 2015

ESC European Society of Cardiology
European Heart Journal - Cardiovascular Imaging (2017) **18**, 945–960
doi:10.1093/ehjci/jex094
EACVI/ESH CONSENSUS PAPER

Non-invasive cardiovascular imaging for evaluating subclinical target organ damage in hypertensive patients



IPERTENSIONE ARTERIOSA

dalle Linee Guida alla Terapia di Associazione

ROMA, 22 - 23 MARZO 2019

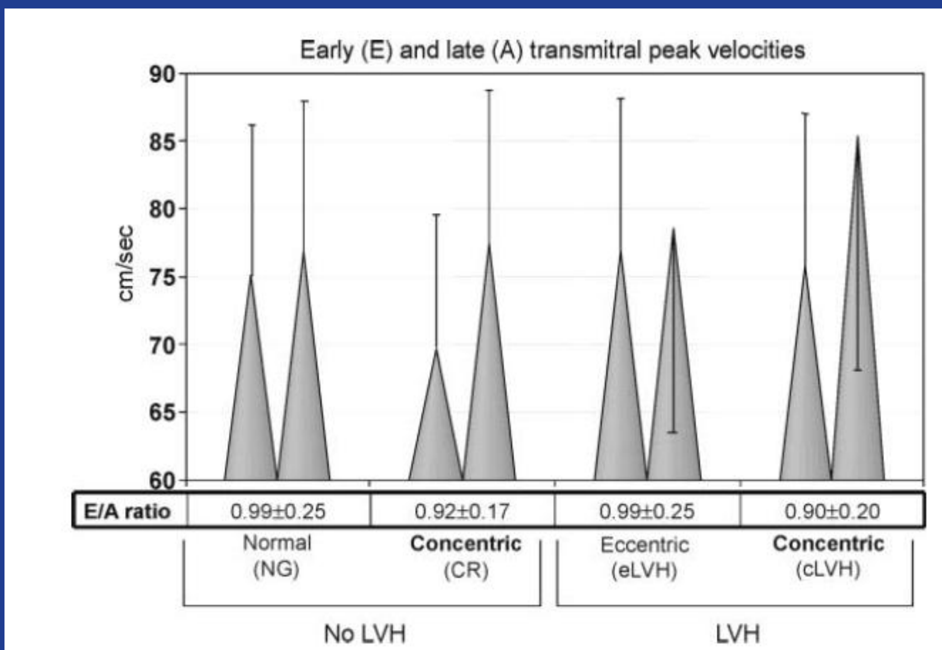
What is the exact relationship between hypertension, LVH and diastolic dysfunction?

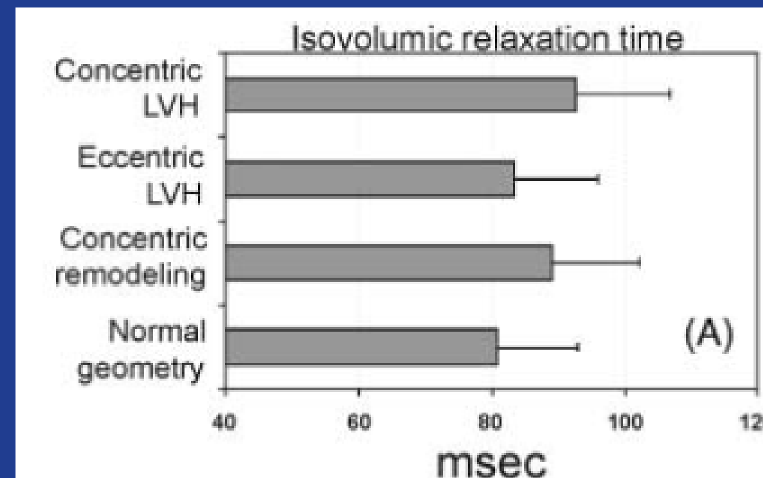
Are there novel echocardiographic indexes to diagnose subclinical dysfunction?

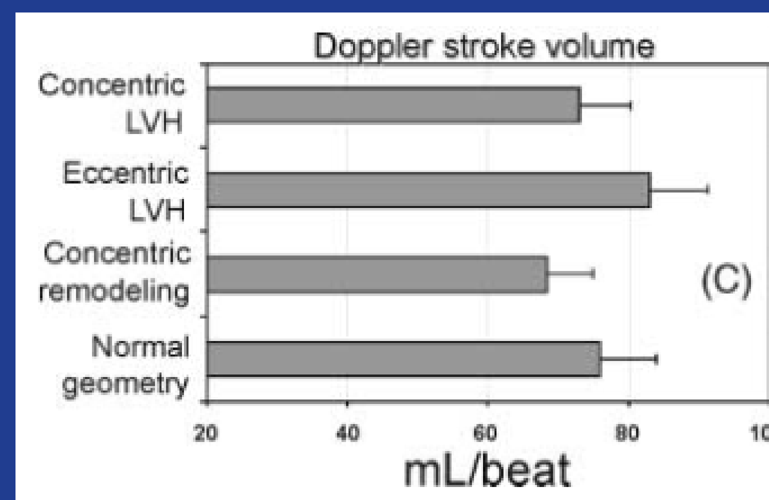
What about HFPEF? Is it the natural evolution of hypertensive LVH?

LV concentric geometry is associated with impaired relaxation in hypertension: the HyperGEN study

1384 pts with hypertension, obesity and type II diabetes



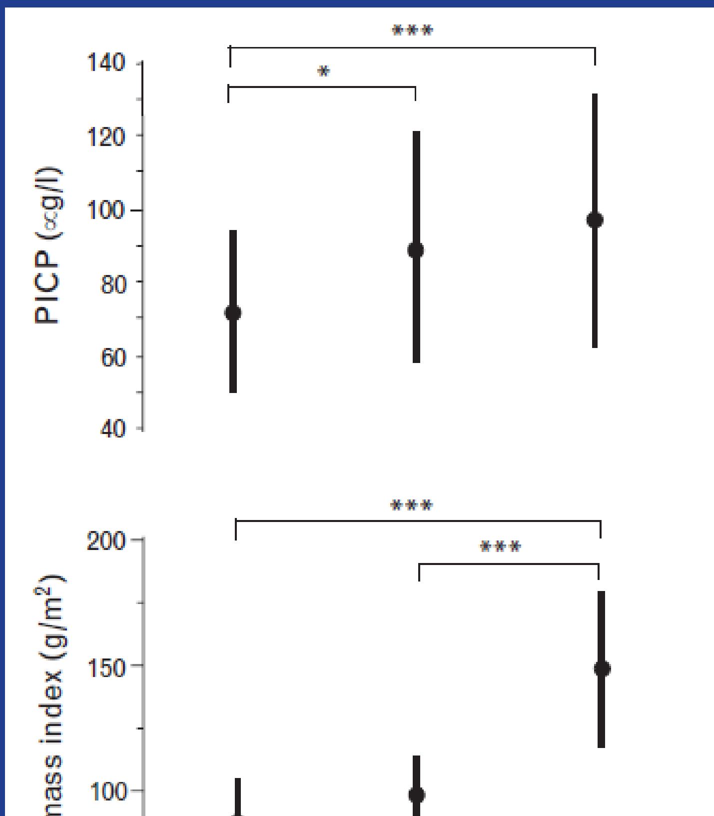


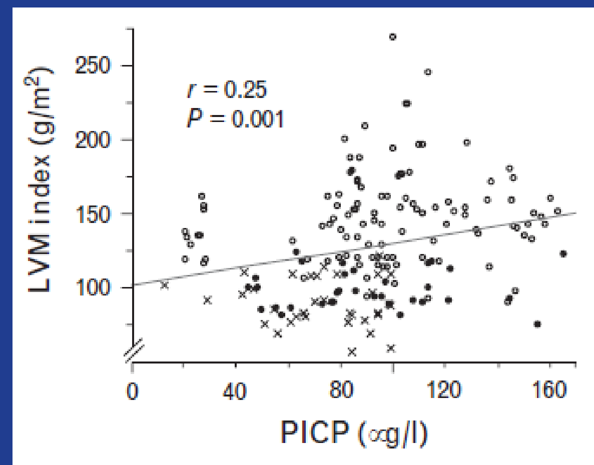


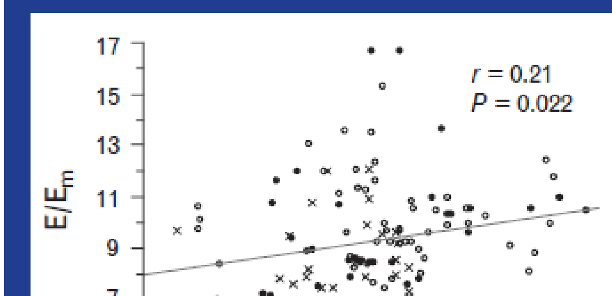
De Simone G, EHJ 2005

Myocardial fibrosis and diastolic dysfunction in hypertension: results from the Swedish Irbesartan LV Hypertrophy Investigation versus Atenolol (SILVHIA)

114 subjects with HTN LVH, 38 subjects with HTN non-LVH, 38 normotensive controls







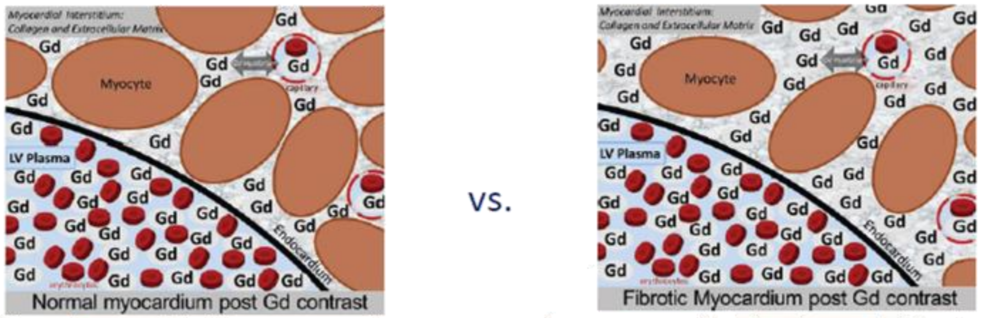
In a multivariate model, these results for PICP levels were confirmed for SBP and DBP. The relationship with LVM index was attenuated.

No relationship between PICP levels and LV geometry

No relationship

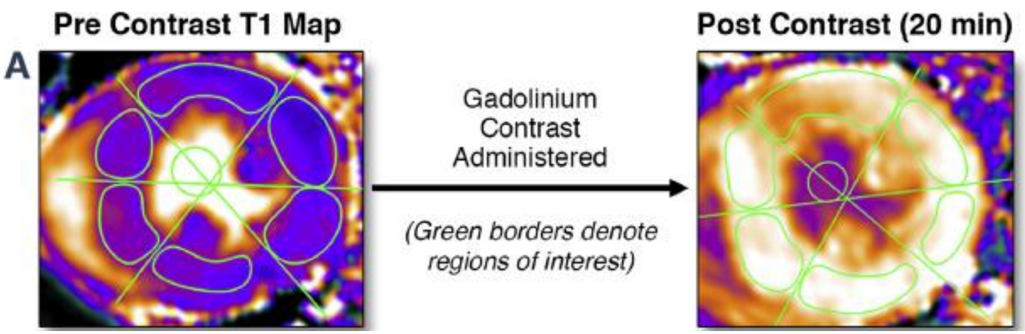
Treatment with irbesartan or atenolol reduced PICP levels, and the relative reductions in PICP were greater than the relative changes observed in LVM, suggesting that these changes are not mutually interrelated.

CMR-derived T1 mapping for diffuse myocardial fibrosis / extracellular volume

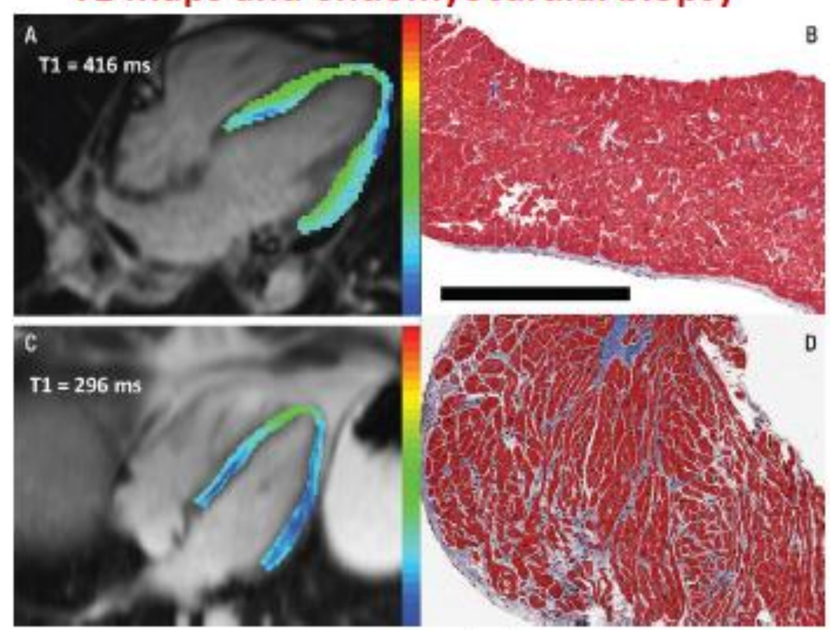


Wong
Circ 2012

ECV myocardium = [R1myocardium] / [R1bloodpool] * *(1-Ht)*



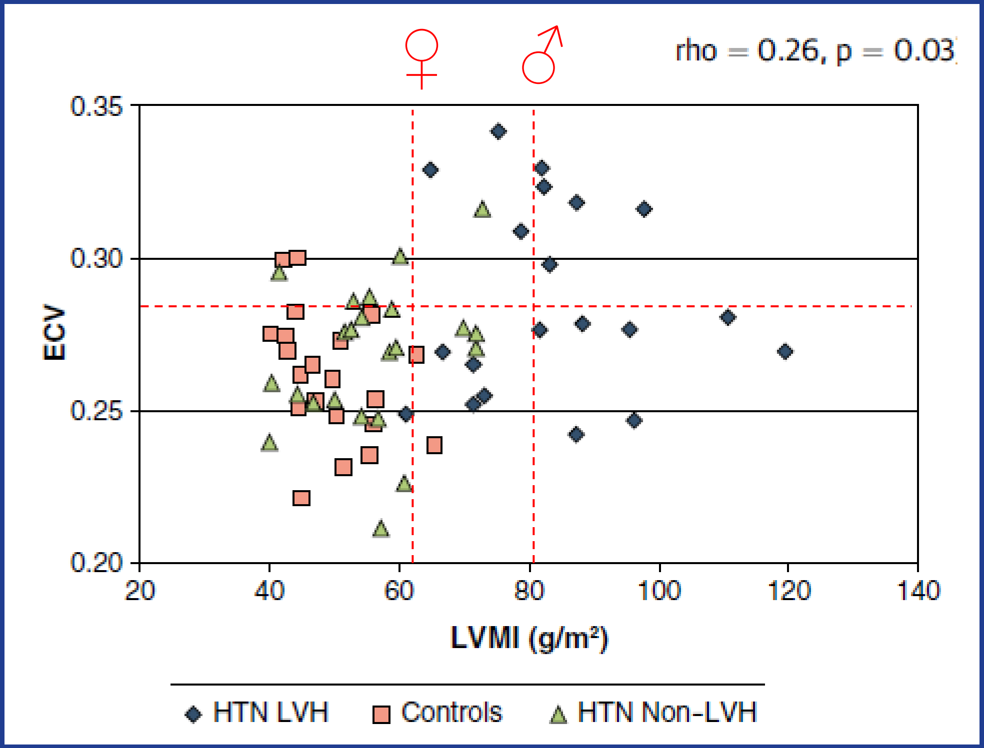
T1 maps and endomyocardial biopsy



Radiology. 2012;265:724-732

Increased Extracellular Volume and Altered Mechanics Are Associated With LVH in Hypertensive Heart Disease, Not Hypertension Alone

20 subjects with HTN LVH, 23 subjects with HTN non-LVH, 22 normotensive controls



Certain HTN LVH subjects with relatively lower LVMI had significantly higher levels of ECV (>0.30)

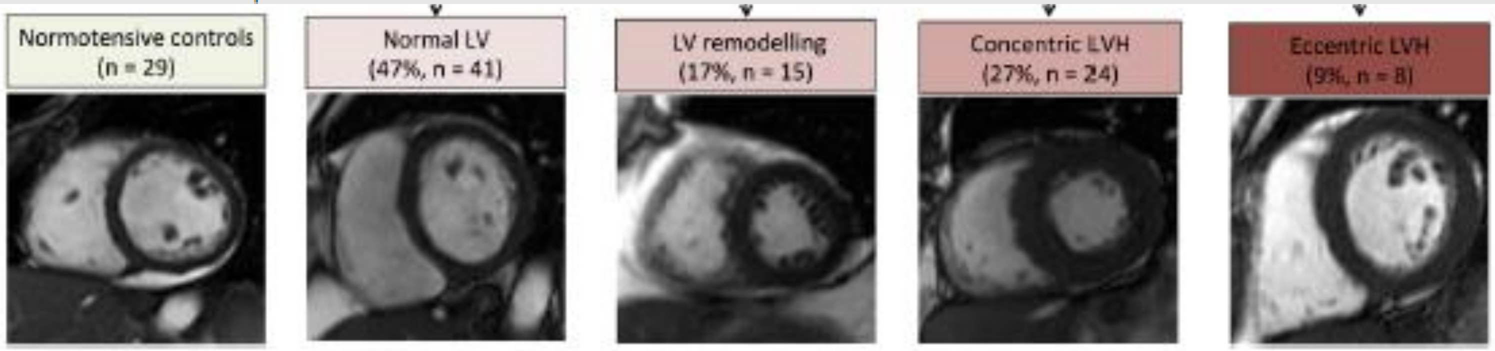
Kuruvilla S, JACC Cardiovasc Im 2015

Myocardial interstitial fibrosis varies across hypertensive LV phenotypes with functional consequences.

Table 4 T1-mapping, myocardial strain and aortic function data corrected for covariates* for hypertensive subjects

	Hypertensive subjects (n=88)			
	Normal indexed LVM (n=56)		Elevated indexed LVM (n=32)	
	Normal LV (n=41)	Concentric remodelling (n=15)	Concentric LVH (n=24)	Eccentric LVH (n=8)
T1-mapping				
Native T1 (ms)	1031±6	1025±10	1054±8*1	1067±15*2
Extracellular volume fraction (%)	27±1	26±1	29±1*3	30±1*4
Circumferential myocardial function				
Peak strain (%)	−16.9±0.5	−17.4±0.8	−16.1±0.6	−14.2±1.1*5
Peak systolic strain rate (%/s)	−104±4	−120±7	−99±5*6	−76±10*7
Peak diastolic strain rate (%/s)	95±4	97±6	85±5	80±8
Aortic function				
Compliance (mm^2/mm Hg)	1.61±0.19	0.93±0.28*8	1.73±0.23	1.47±0.40
Distensibility (mm^2/mm Hg ×10^3)	2.27±0.26	1.05±0.39*9	2.04±0.30	1.57±0.55

*Multiple linear regression accounting for the covariates of age, gender, body mass index, diabetes, office systolic blood pressure and diastolic blood pressure and number of antihypertensive medications. Data are presented as mean±SE.



Rodrigues JCL, et al. Heart 2016

Myocardial extracellular volume fraction quantified by CMR is increased in hypertension and associated with left ventricular remodeling

134 subjects with HTN (40 with LGE, 94 without LGE) vs 97 normotensive controls

Clinical	Control (n = 97)	Total (n = 134)	t/Z	p	LGE− (n = 94)	LGE+ (n = 40)	t	p
Age (y)	50.1 ± 16.3	53.5 ± 13.8	−1.717	0.088	51.6 ± 14.2	58.1 ± 11.8	−2.550	0.012
Sex, M (%)	69 (71.1)	124 (92.5)	18.755	<0.001	87 (92.6)	37 (92.5)	0.011	0.992
BMI	23.43 ± 3.7	26.46 ± 4.28	−5.614	<0.001	26.41 ± 4.11	26.60 ± 4.68	−0.241	0.810
Body area (m^2)	1.73 ± 0.17	1.92 ± 0.18	−8.460	<0.001	1.93 ± 0.17	1.90 ± 0.19	1.172	0.243
Max SBP (mmHg)	114 ± 12	167 ± 13	−30.593	<0.001	159 ± 9	183 ± 5	−19.875	<0.001
Max DBP (mmHg)	76 ± 9	102 ± 7	−24.740	<0.001	99 ± 4	110 ± 3	−17.228	<0.001
Smoker, n (%)	12 (12.4)	39 (29.1)	−3.020	0.003	29 (30.9)	10 (25.0)	−0.680	0.497
Diabetes, n (%)	16 (16.5)	39 (29.1)	−2.216	0.027	28 (29.8)	11 (27.5)	−0.266	0.790
Dyslipidaemia, n (%)	24 (24.7)	49 (36.6)	−1.904	0.057	39 (41.5)	11 (27.5)	−1.807	0.071
Current medication								
No cardiovascular medication, n (%)	97	5 (3.7)	/	/	4 (4.3)	1 (2.5)	/	/
Beta-blocker, n (%)	0	122 (91.0)	/	/	85 (90.4)	37 (92.5)	/	/
Calcium channel blocker, n (%)	0	21 (15.7)	/	/	15 (16.0)	6 (15.0)	/	/
Angiotensin II receptor blocker, n (%)	0	44 (32.8)	/	/	31 (33.0)	11 (27.5)	/	/
ACE inhibitor, n (%)	0	69 (51.5)	/	/	48 (51.1)	21 (52.5)	/	/
Diuretic, n (%)	0	49 (36.6)	/	/	14 (14.9)	35 (87.5)	/	/
Other, n (%)	0	13 (9.7)	/	/	5 (5.3)	8 (20.0)	/	/

Wang S, Eur Rad 2017

JACC: CARDIOVASCULAR IMAGING
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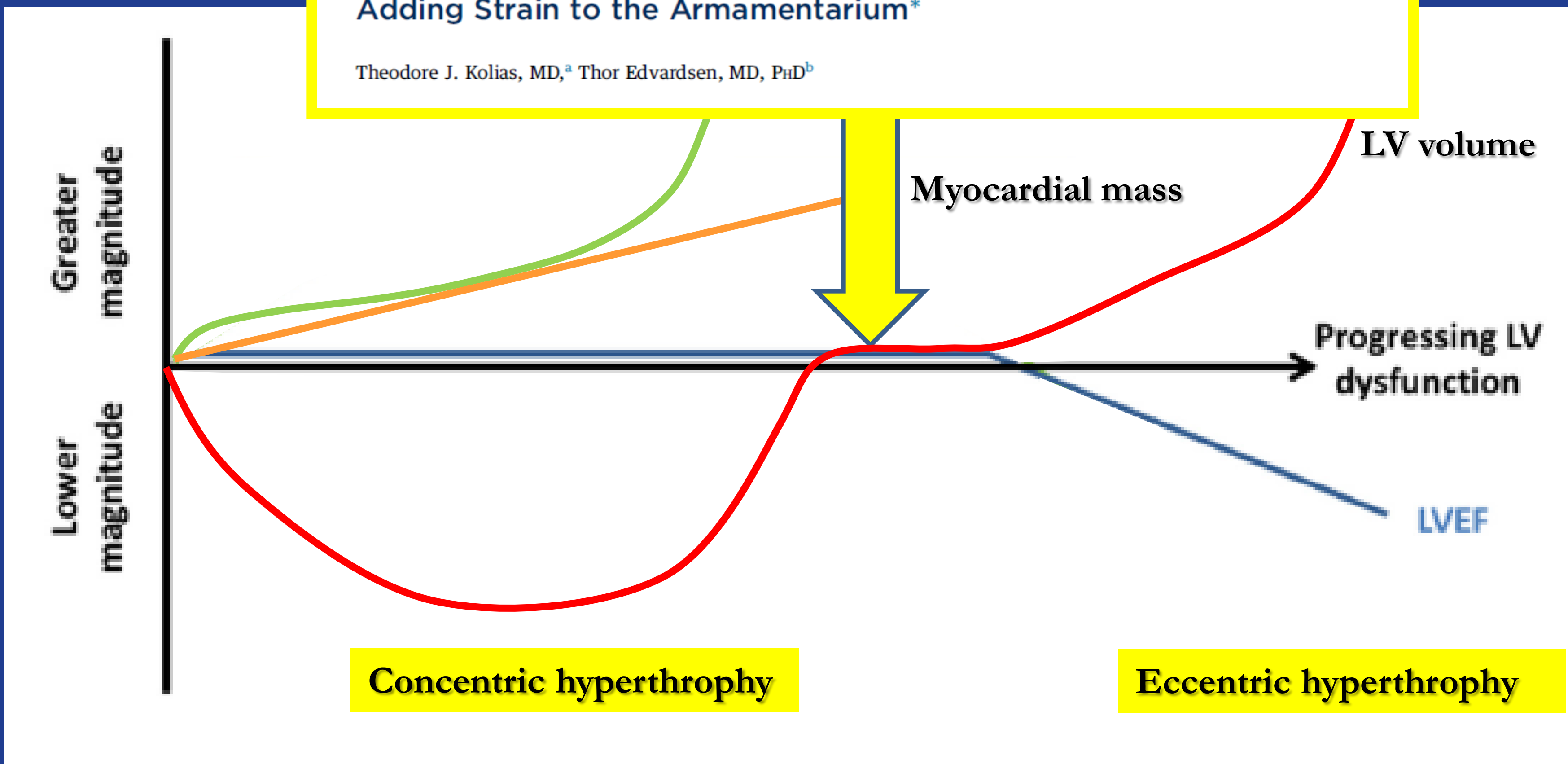
http://dx.doi.org/10.1016/j.jcmg.2015.10.029

EDITORIAL COMMENT

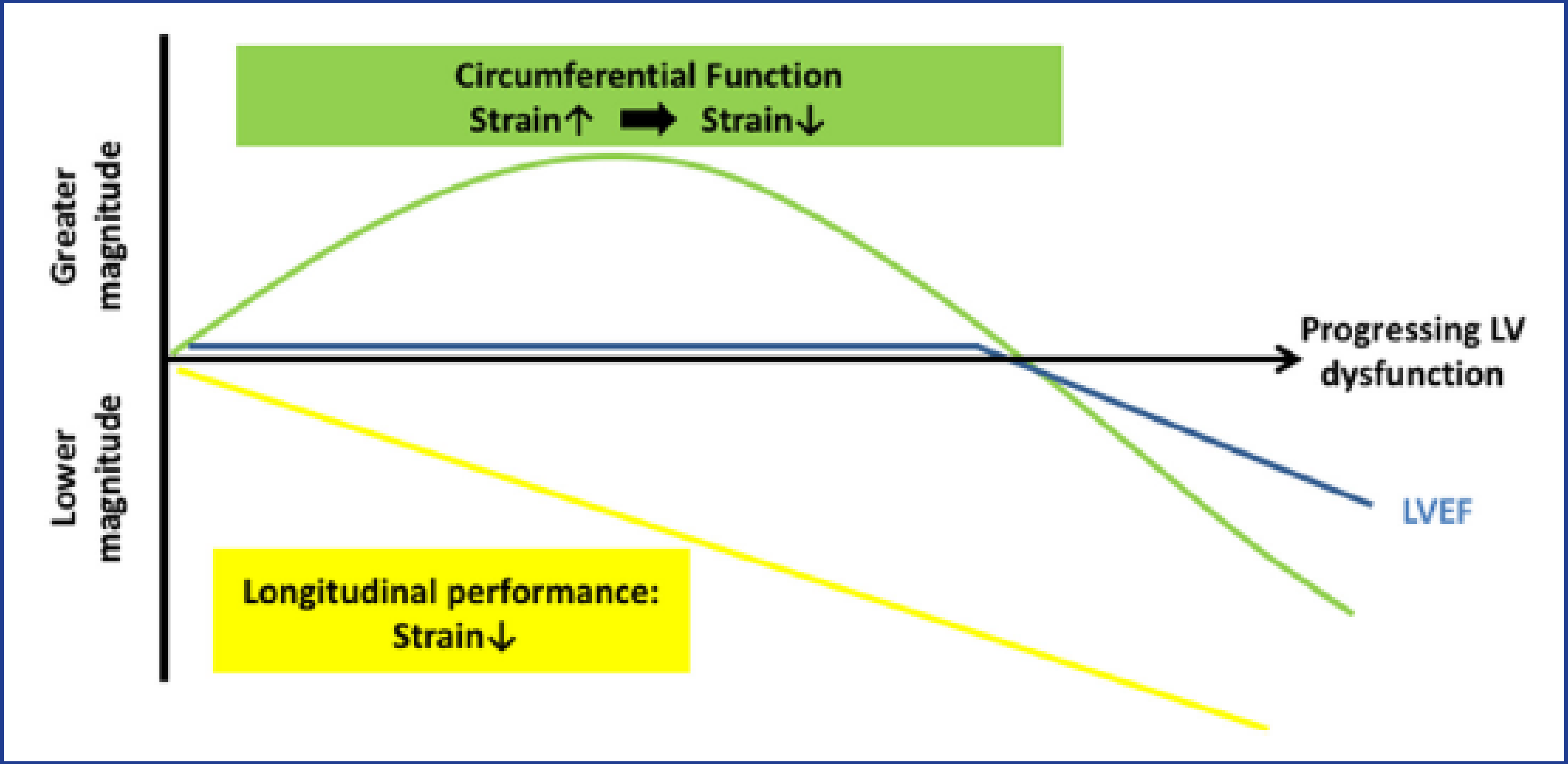
Beyond Ejection Fraction

Adding Strain to the Armamentarium*

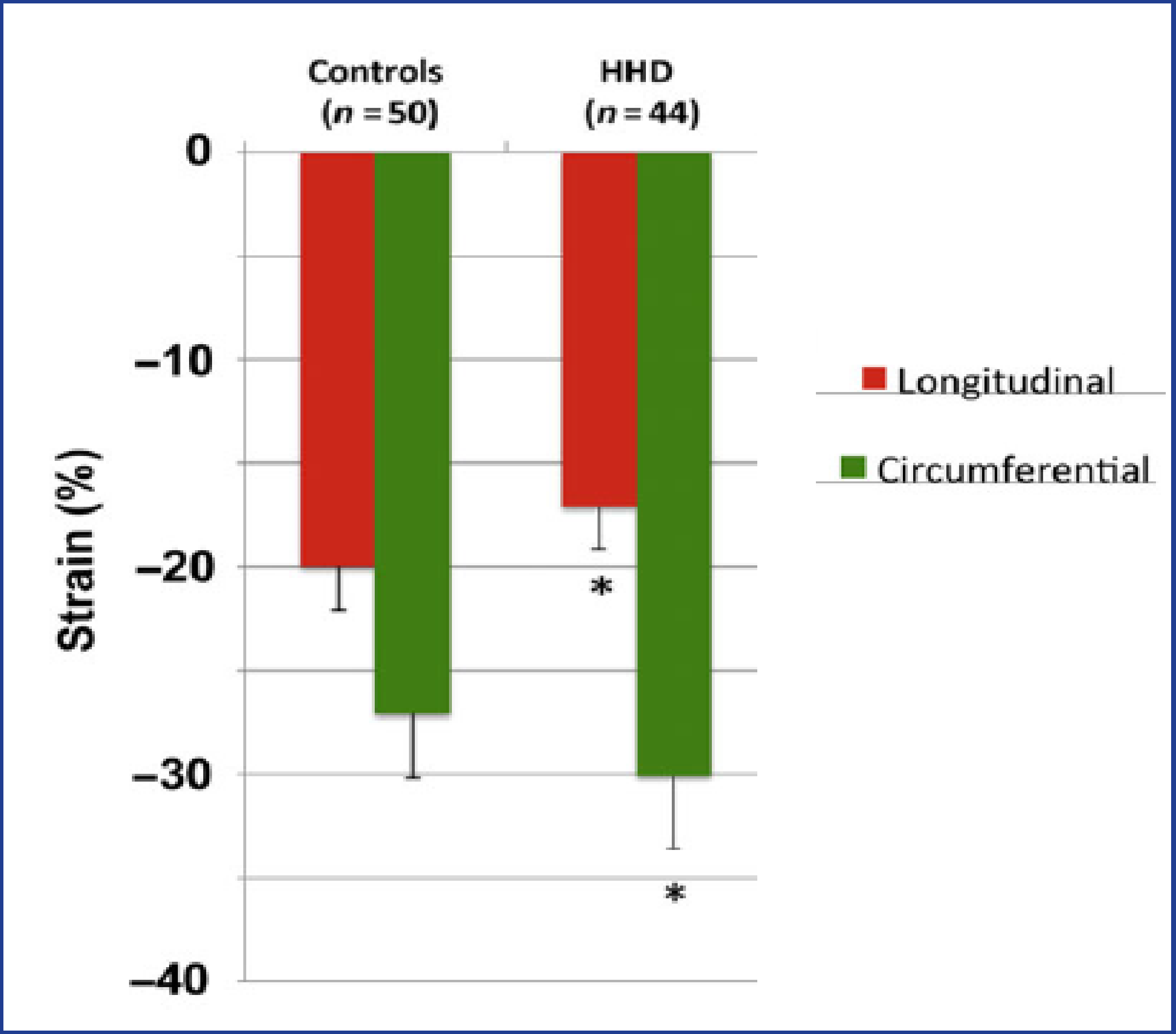
Theodore J. Kolias, MD,[a] Thor Edvardsen, MD, PhD[b]



Novel echocardiographic indexes to early diagnose evolution towards HF

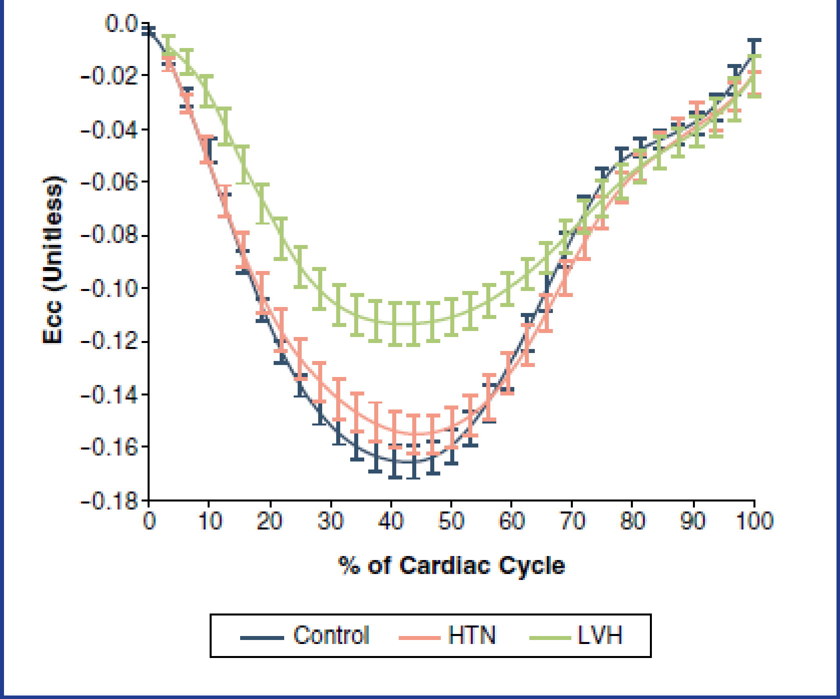


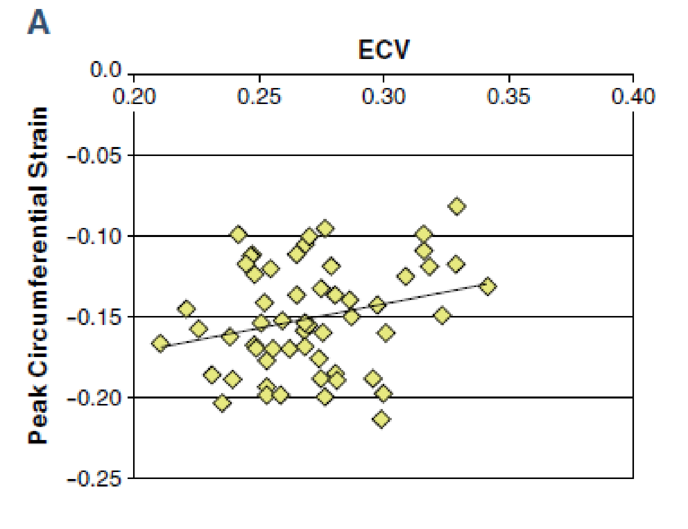
Speckle Tracking Echo in hypertensive cardiomyopathy

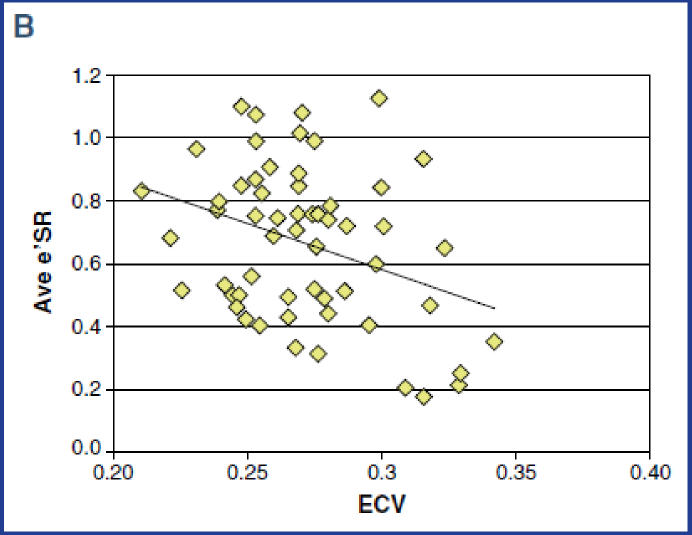


Smiseth OA, Eur Heart J 2016

Increased Extracellular Volume and Altered Mechanics Are Associated With LVH in Hypertensive Heart Disease, Not Hypertension Alone







Kuruvilla S, JACC Cardiovasc Im 2015

Prognostic Implications of LV Strain Risk Score in Asymptomatic Patients With Hypertensive Heart Disease

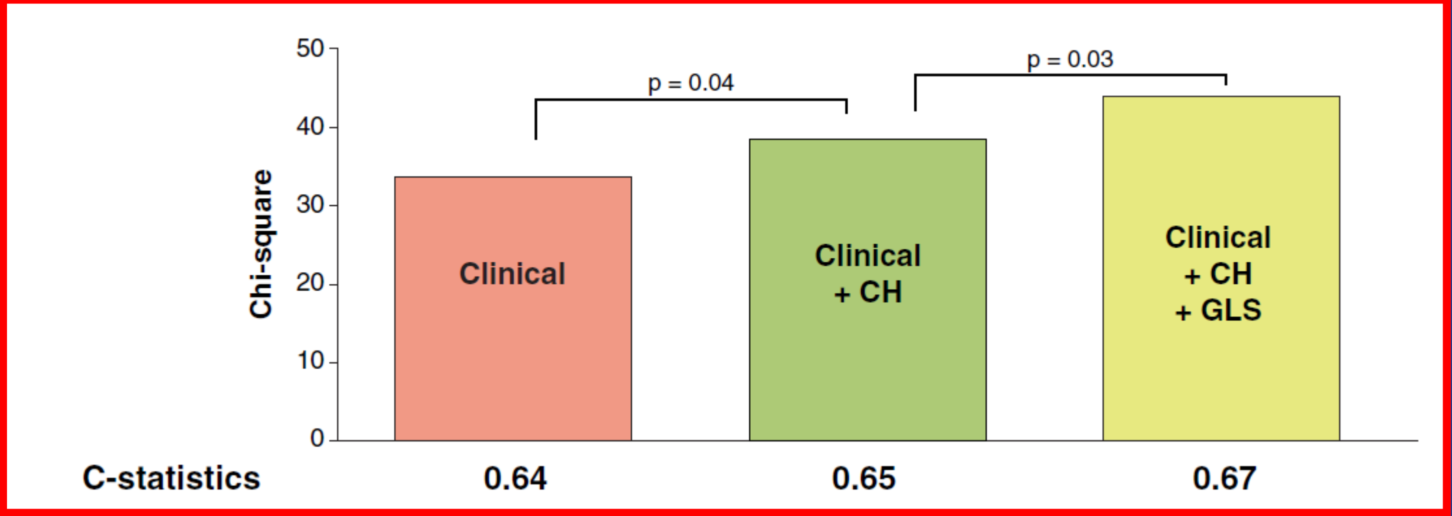
TABLE 3 Characteristics Independently Associated With MACE (Multivariable Cox Regression)

	Clinical Model (Model Chi-Square, 45.1; C Statistic, 0.68) HR (95% CI), p Value	Echo Model (Model Chi-Square, 31.9; C Statistic, 0.64) HR (95% CI), p Value
Age, yrs	**1.03 (1.01-1.05), $p < 0.01$**	**1.04 (1.01-1.06), $p < 0.01$**
Male	1.01 (0.62-1.64), $p = 0.96$	1.05 (0.64-1.73), $p = 0.83$
Heart rate, beats/min	1.00 (0.99-1.01), $p = 0.90$	1.01 (1.00-1.02), $p = 0.21$
Systolic blood pressure, mm Hg	**0.99 (0.97-1.00), $p = 0.02$**	
Atrial fibrillation	**1.82 (1.05-3.15), $p = 0.03$**	
β-blockers	1.58 (0.93-2.70), $p = 0.09$	
Concentric hypertrophy		**1.75 (1.08-2.84), $p = 0.02$**
LA volume index, ml/m^2		1.00 (0.99-1.02), $p = 0.79$
E/e′		1.03 (0.98-1.08), $p = 0.20$
LV global longitudinal strain, %	**1.08 (1.00-1.16), $p = 0.045$**	**1.08 (1.01-1.17), $p = 0.04$**

Saito M, JACC Cardiovasc Imag 2016

Prognostic Implications of LV Strain Risk Score in Asymptomatic Patients With Hypertensive Heart Disease

This score seemed to be more effective for predicting HF-specific outcome, a finding that is concordant with the implied association between asymptomatic LV dysfunction and the onset of HF.



Saito M, JACC Cardiovasc Imag 2016

European Heart Journal (2016) **37**, 2129–2200
doi:10.1093/eurheartj/ehw128

ESC GUIDELINES

2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure

The Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC)

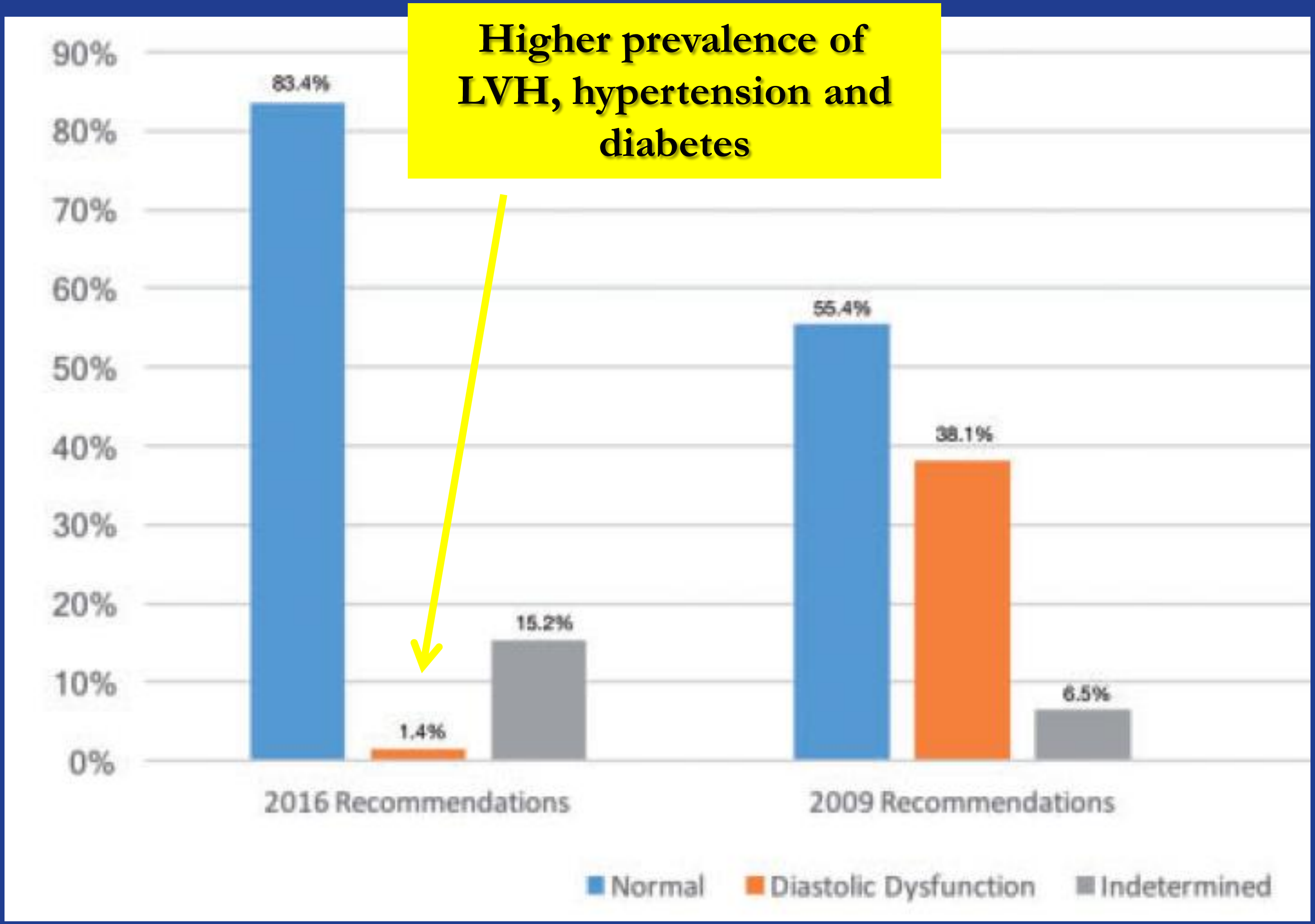
Type of HF		HFrEF	HFmrEF	HFpEF
CRITERIA	1	Symptoms ± Signs[a]	Symptoms ± Signs[a]	Symptoms ± Signs[a]
	2	LVEF <40%	LVEF 40–49%	LVEF ≥50%
	3	–	1. Elevated levels of natriuretic peptides[b]; 2. At least one additional criterion: a. relevant structural heart disease (LVH and/or LAE), b. diastolic dysfunction (for details see Section 4.3.2).	1. Elevated levels of natriuretic peptides[b]; 2. At least one additional criterion: a. relevant structural heart disease (LVH and/or LAE), b. diastolic dysfunction (for details see Section 4.3.2).

cause for the clinical presentation. Key structural alterations are a left atrial volume index (LAVI) >34 mL/m^2 or a left ventricular mass index (LVMI) ≥ 115 g/m^2 for males and ≥ 95 g/m^2 for females.[65,67,72] Key functional alterations are an E/e′ ≥ 13 and a mean e′ septal and lateral wall <9 cm/s.[65,67,70,72,80–84] Other (indir-

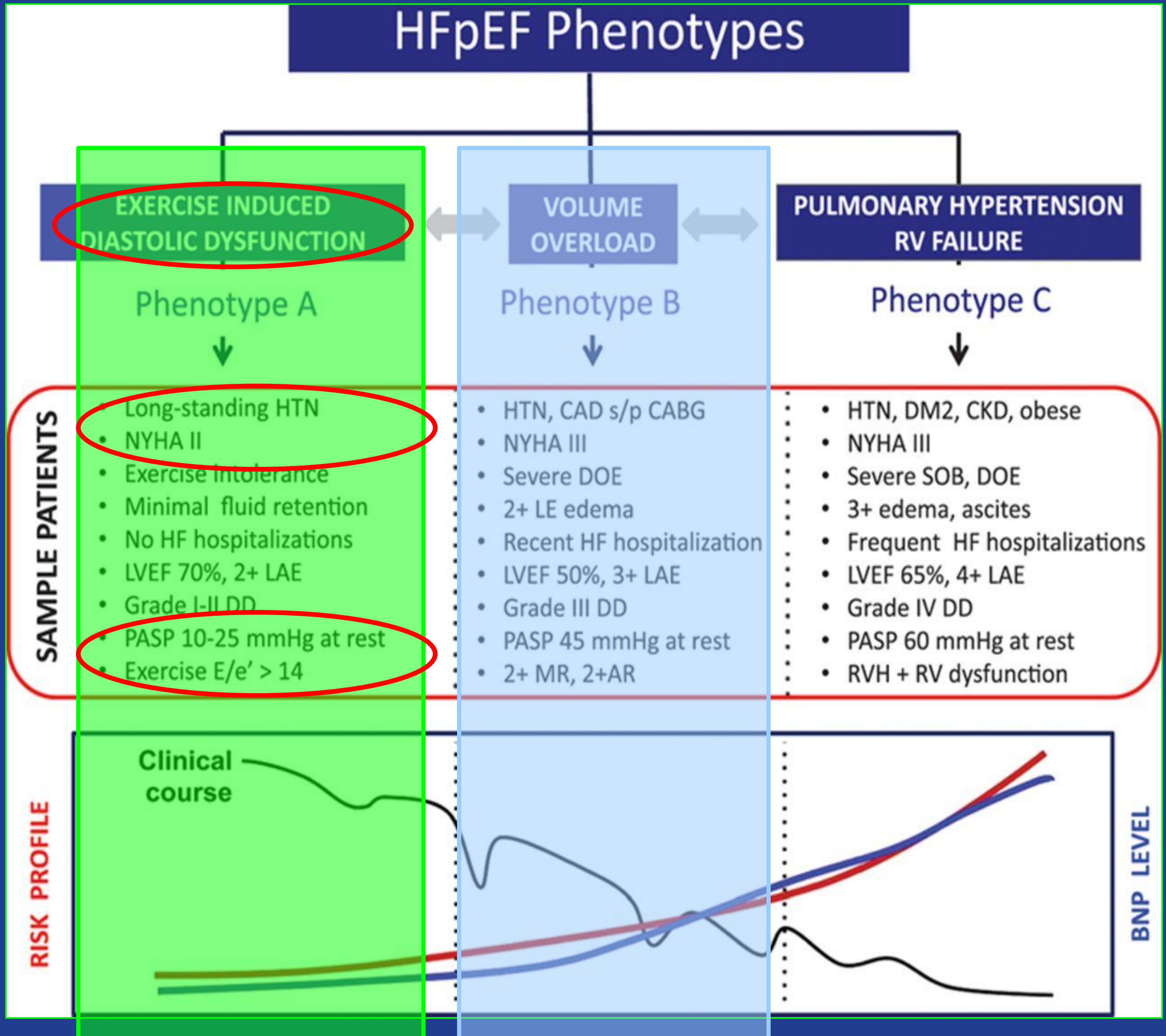
Not LA diameter!

Not E/A ratio!

Impact of the 2016 ASE/EACVI recommendations on the prevalence of diastolic dysfunction

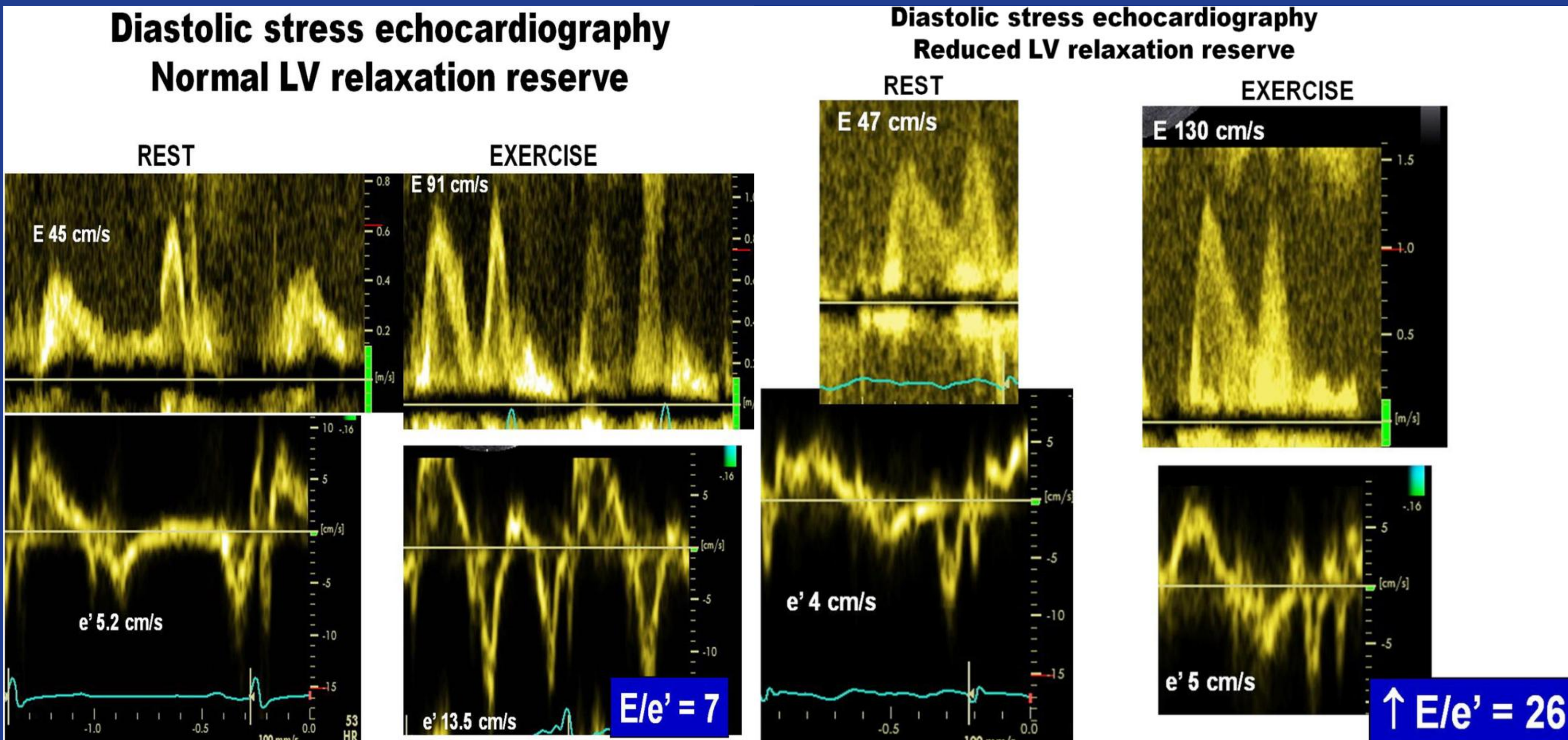


Almeida JG, EHJ – Cardiovasc Im 2018



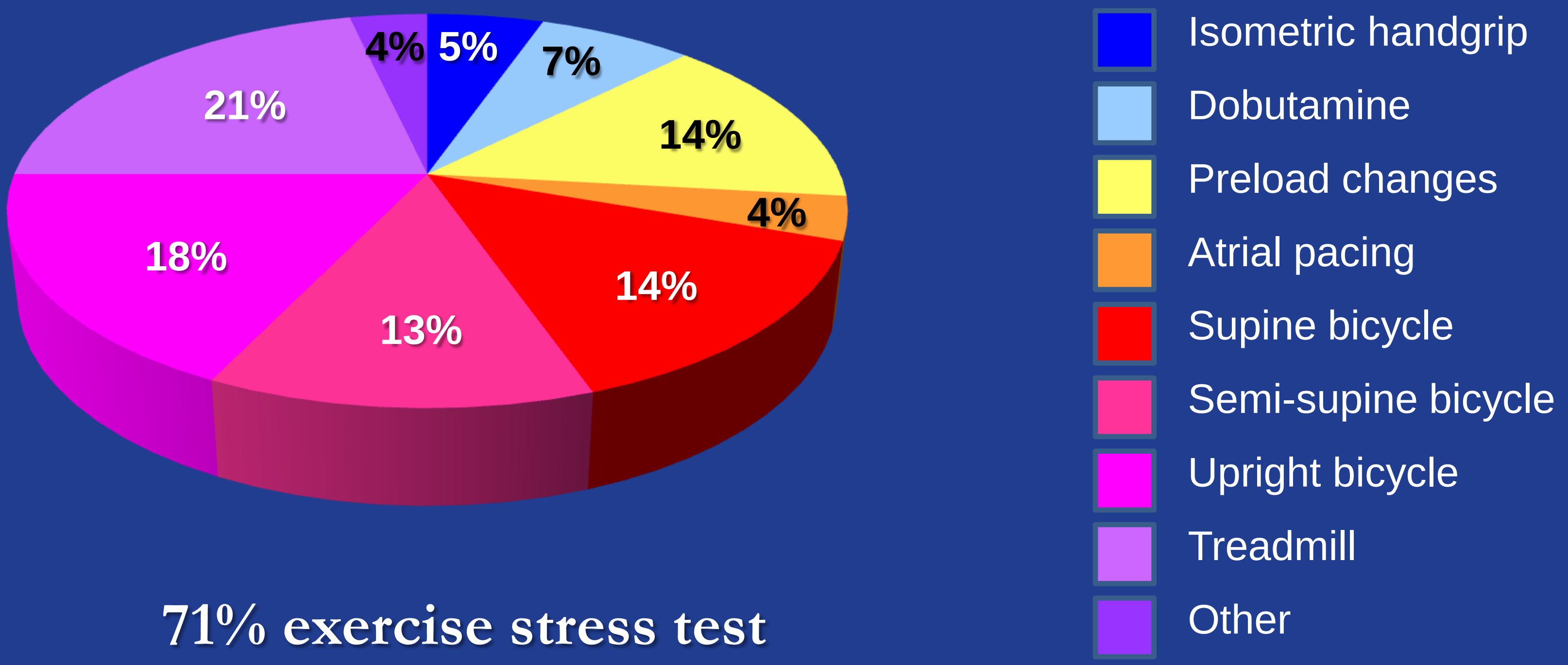
Guazzi M, Circulation 2014

Unmasking HFpEF by stress test!



Penicka et al, Heart 2014

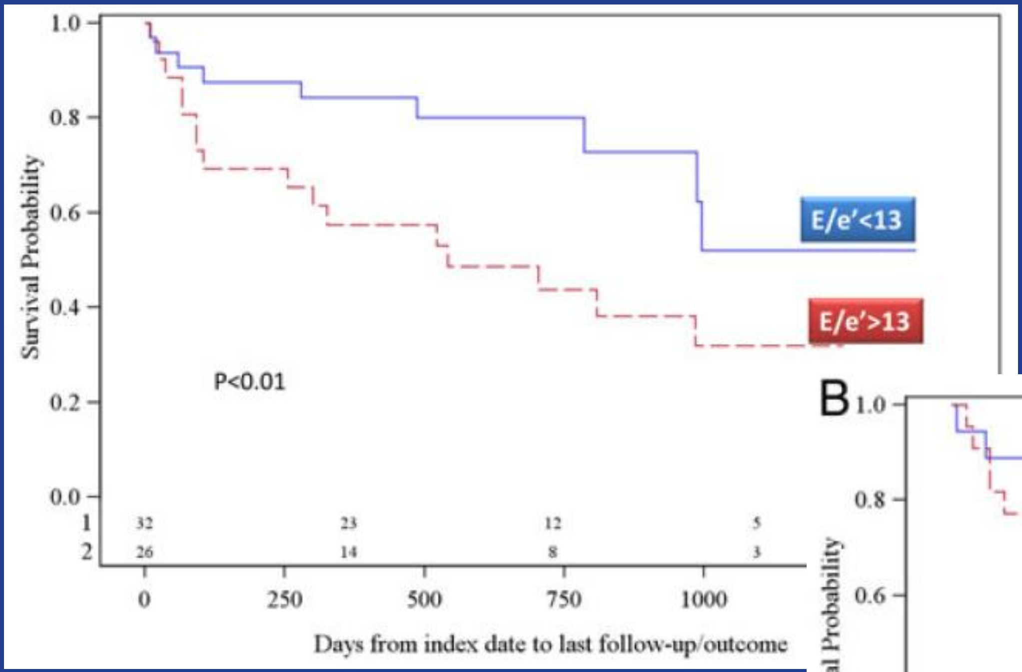
A systematic review of diastolic stress test in HFpEF

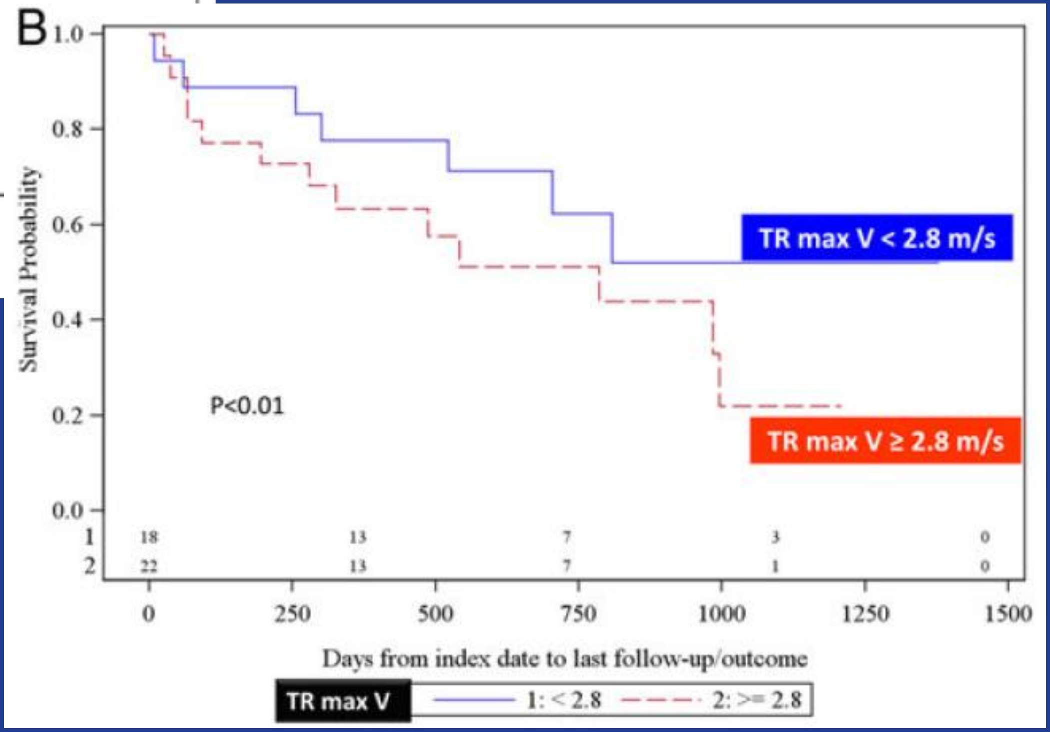


71% exercise stress test

Erdei T, Eur J Heart Failure 2014

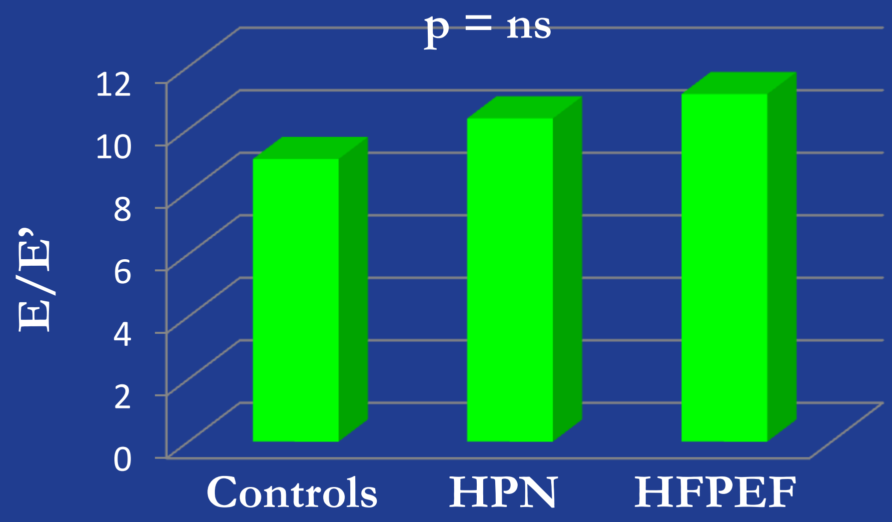
Value of exercise echocardiography in HFpEF: a substudy from the KaRen study

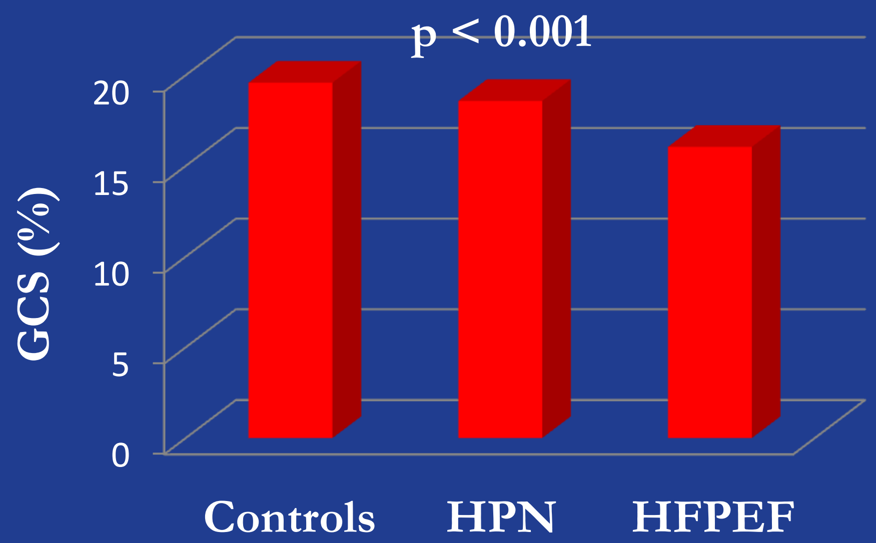


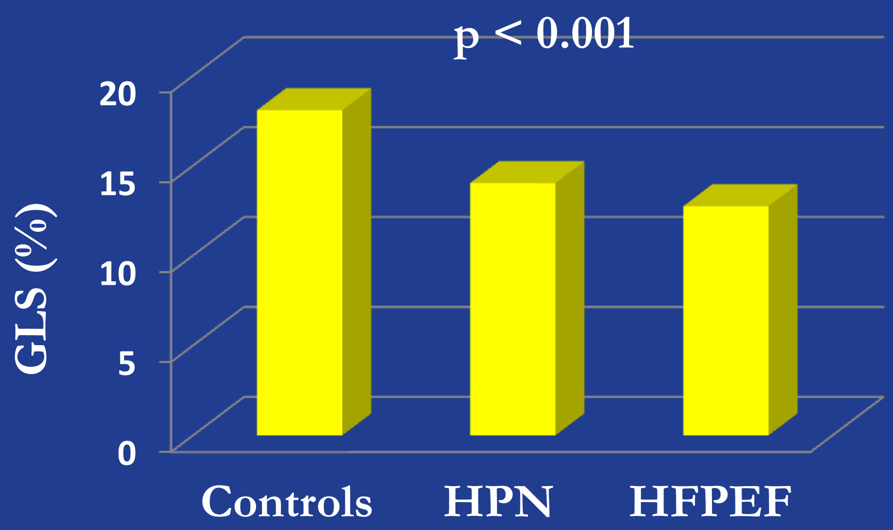


Donal E, EHJ – Cardiovasc Im 2016

GLS and ECV correctly stratify between normal, hypertensive and HFpEF patients

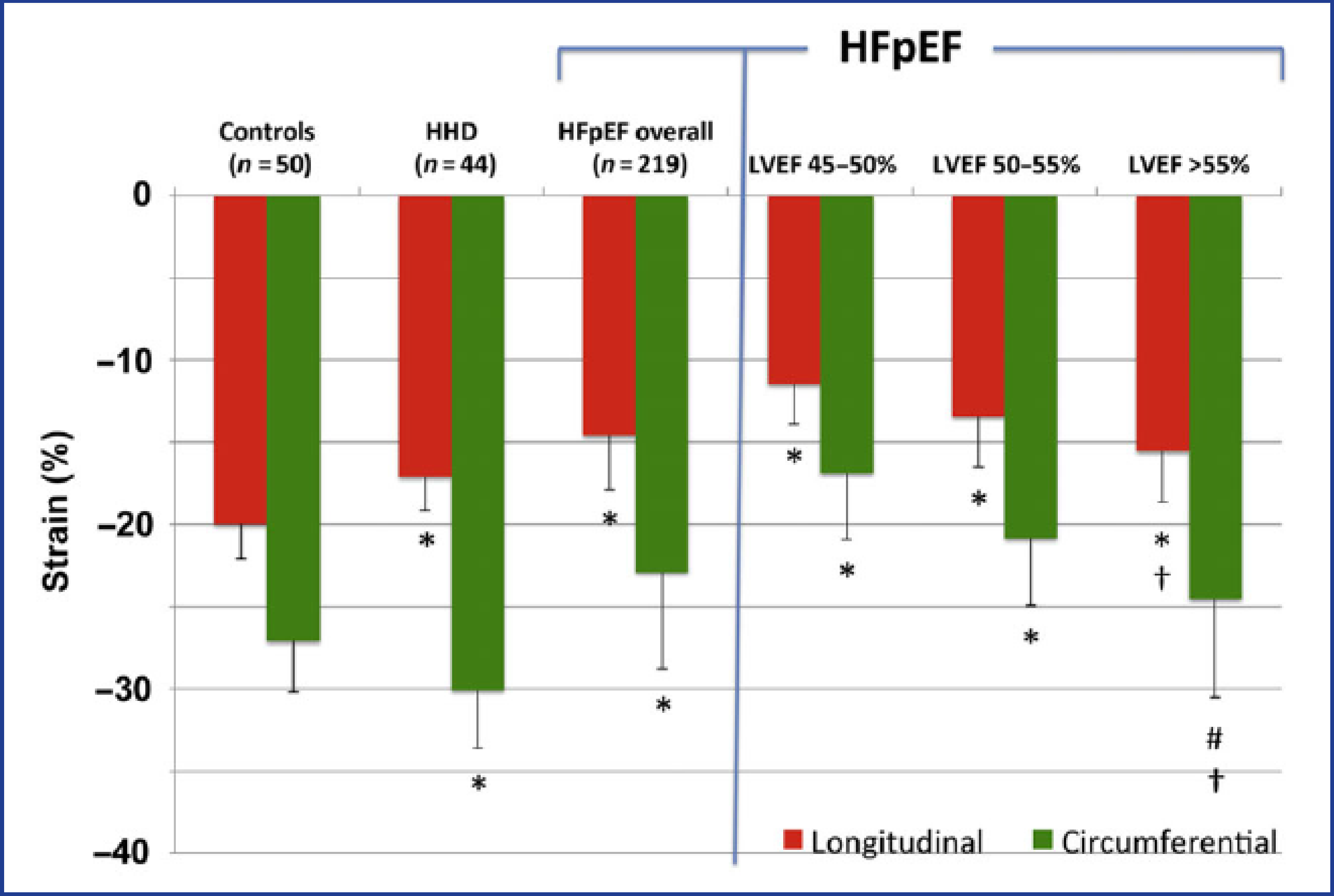






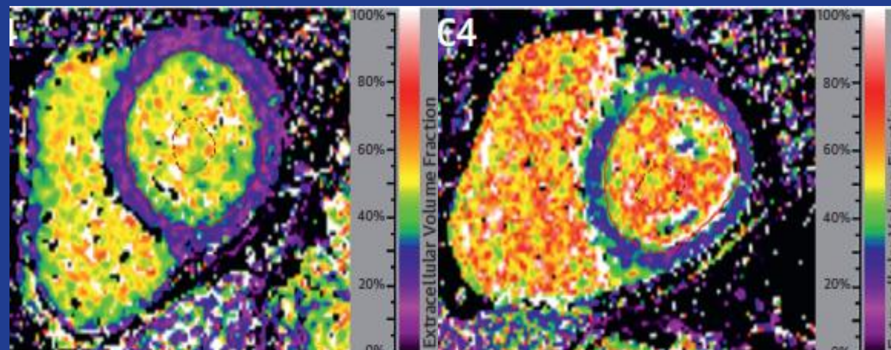
Modified from Mordi IF, J Am Coll Cardiol Img 2018

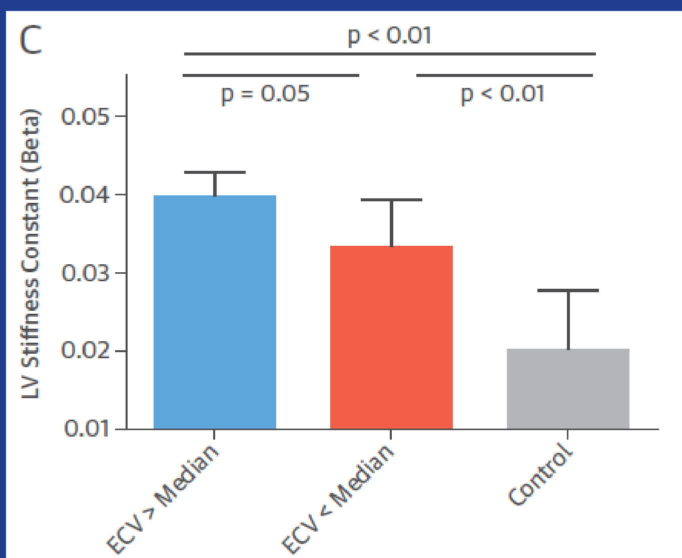
Role of GLS in HFpEF

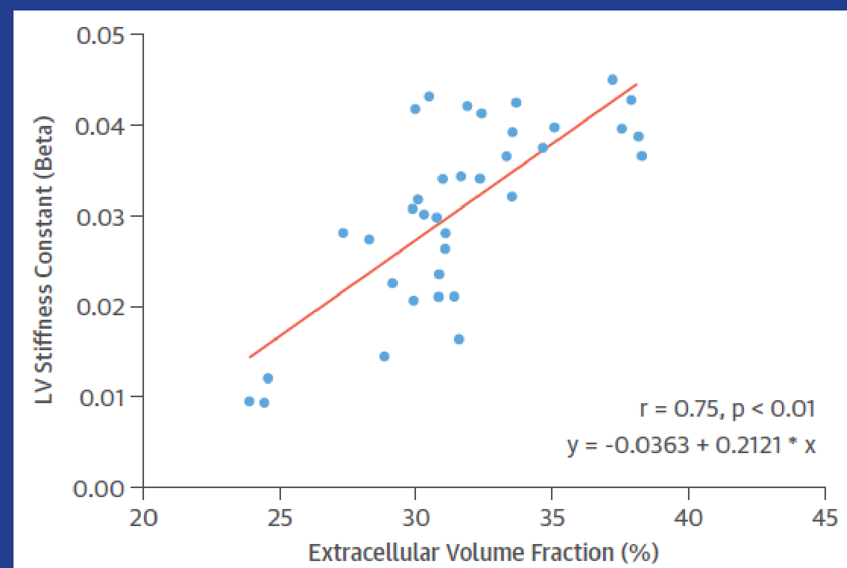


Smiseth OA, Eur Heart J 2016

Extracellular Volume Fraction for Characterization of Patients With HFpEF

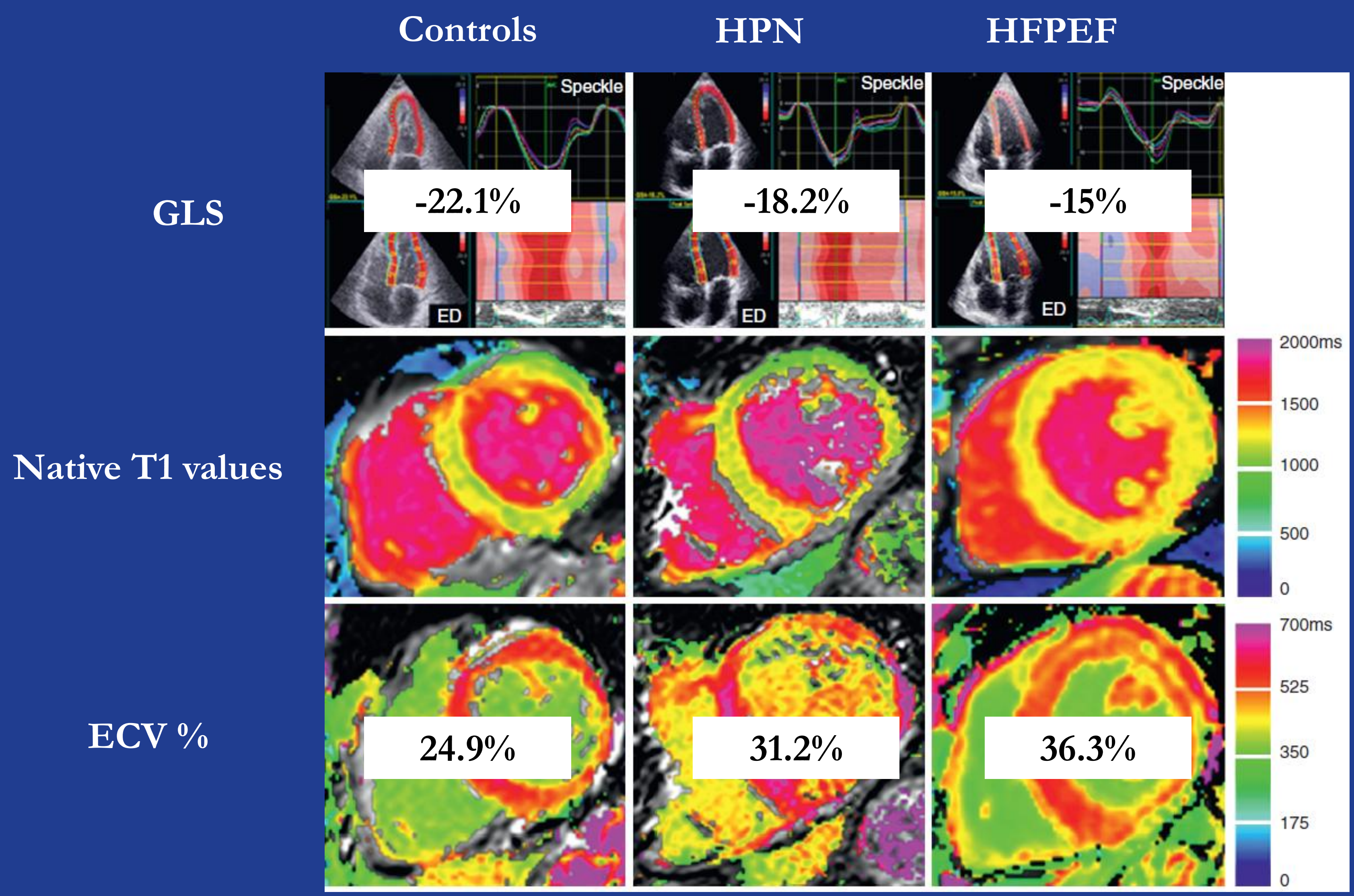






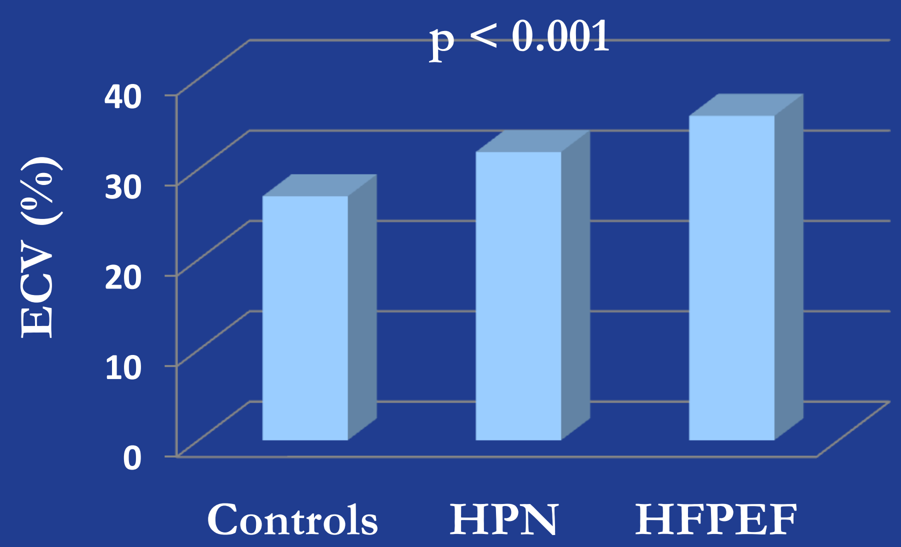
Rommel, K.-P. et al.
J Am Coll Cardiol. 2016

GLS and ECV correctly stratify between normal, hypertensive and HFpEF patients



Mordi IF, J Am Coll Cardiol Img 2018

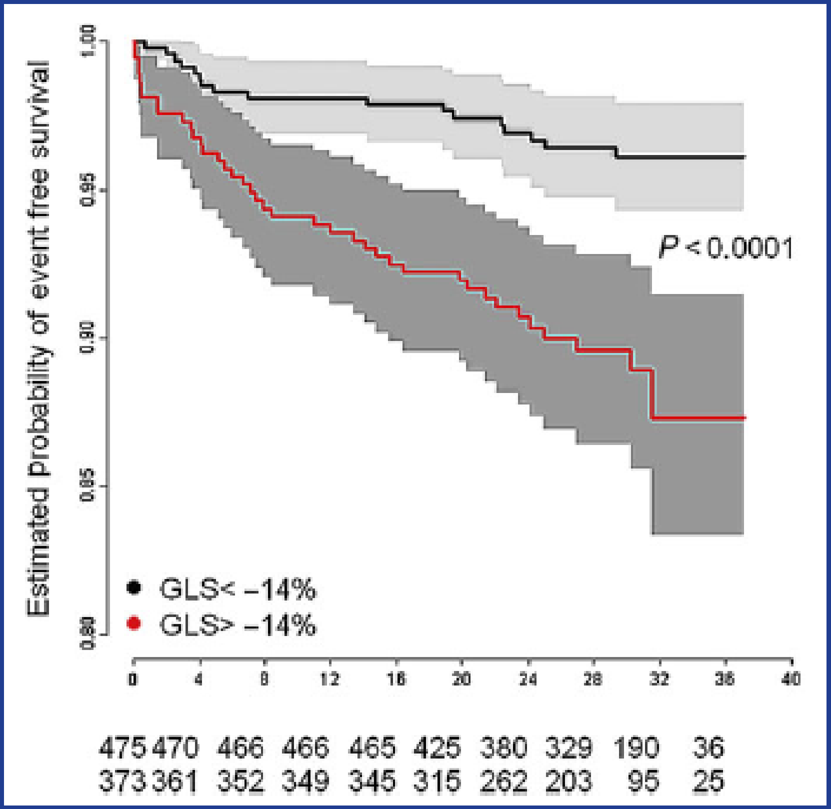
GLS and ECV correctly stratify between normal, hypertensive and HFpEF patients

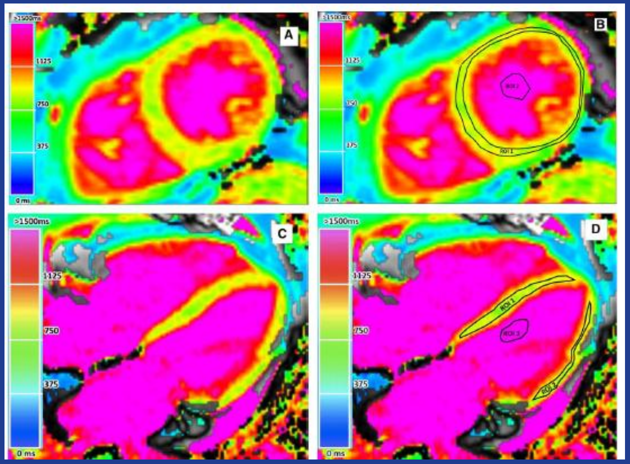


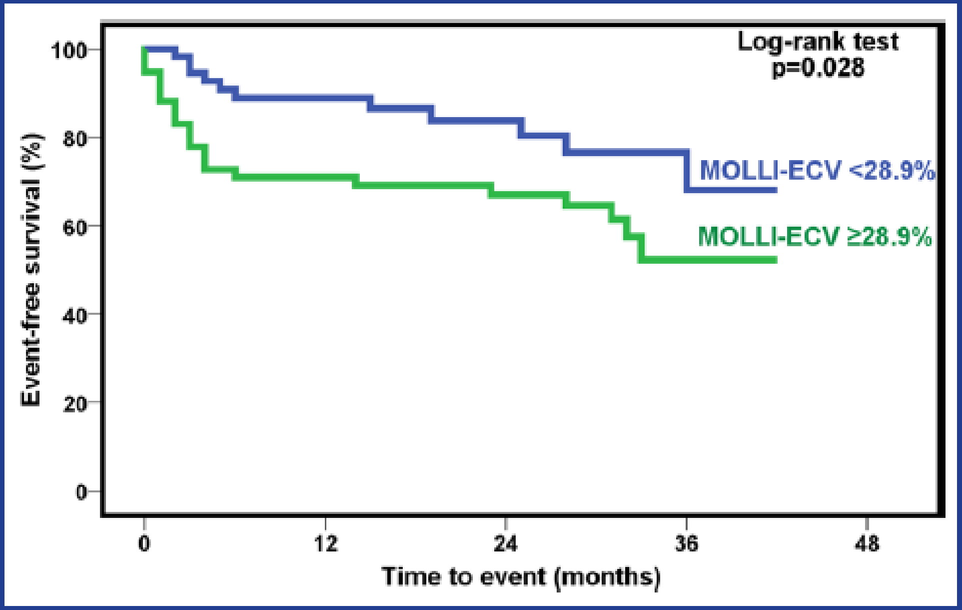
	HFpEF Patients (n = 62)	Hypertensive Patients (n = 22)	Control Subjects (n = 28)	p Value
LVEF, %	66.7 ± 9.3	65.6 ± 6.7	64.3 ± 4.3	0.42
LVEDVi	67.8 ± 17.5	64.8 ± 11.7	60.6 ± 23.3	0.06
LVESVi	23.2 ± 12.1	17.5 ± 7.7	23.1 ± 11.9	0.82
LVMi	70.8 ± 20.2*	107.2 ± 23.1†	69.2 ± 23.2*	**<0.001**
cGCS, %	−15.10 ± 2.62	−16.23 ± 3.81	−18.50 ± 1.21†	**0.045**
Native T_1, ms	1,218 ± 78	1,185 ± 58	1,194 ± 29	0.06
ECV, %	35.9 ± 5.0*	31.9 ± 5.2†	27.0 ± 4.3*†	**<0.001**

Modified from Mordi IF, J Am Coll Cardiol Img 2018

Prognostic role of GLS and ECV in HFpEF







Smiseth OA, Eur Heart J 2016

Duca F, Circ Cardiovasc Imaging. 2016

Progression of hypertension to LVH and HFpEF?

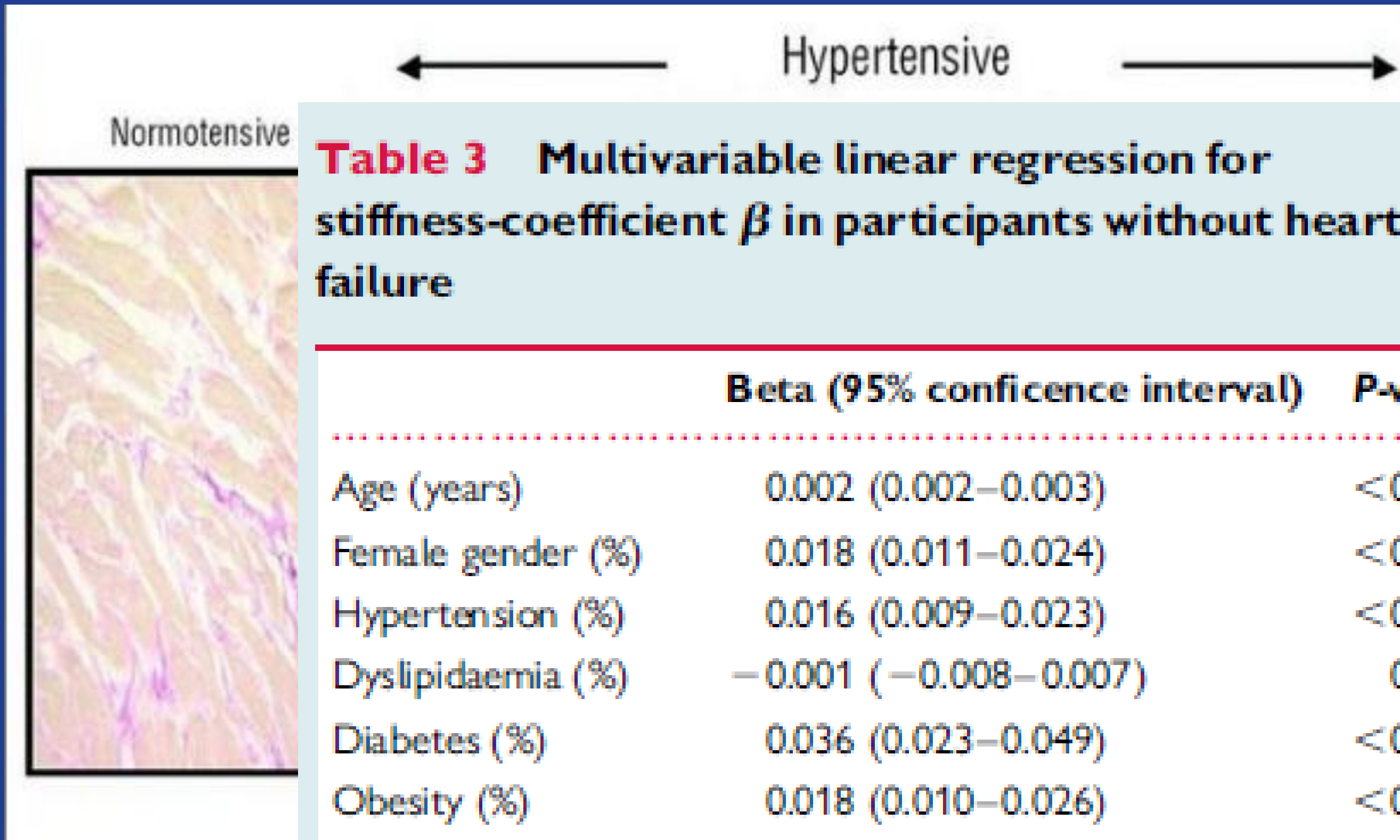
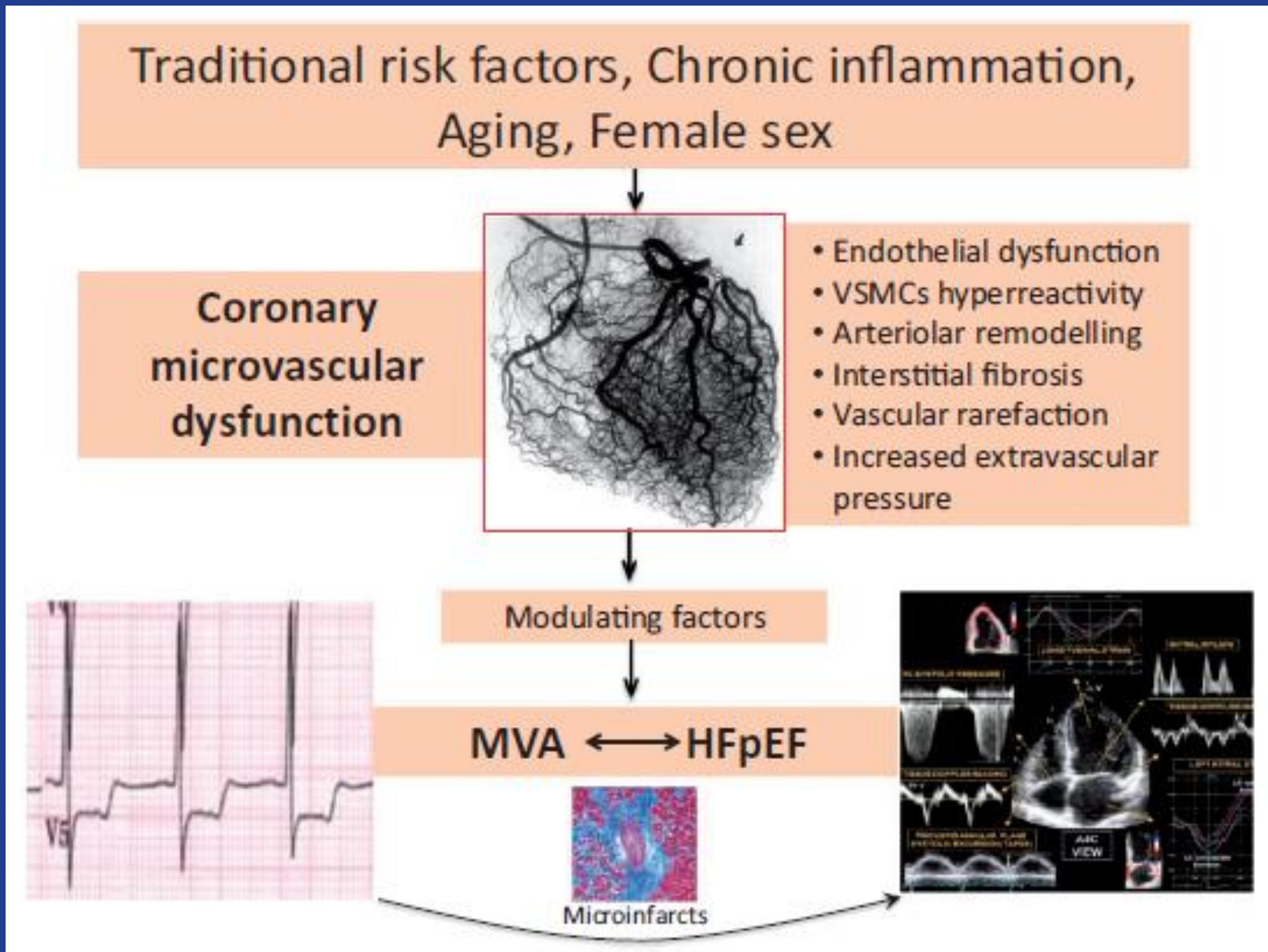


Table 3 Multivariable linear regression for stiffness-coefficient β in participants without heart failure

	Beta (95% conficence interval)	P-value
Age (years)	0.002 (0.002–0.003)	<0.001
Female gender (%)	0.018 (0.011–0.024)	<0.001
Hypertension (%)	0.016 (0.009–0.023)	<0.001
Dyslipidaemia (%)	−0.001 (−0.008–0.007)	0.80
Diabetes (%)	0.036 (0.023–0.049)	<0.001
Obesity (%)	0.018 (0.010–0.026)	<0.001
Current smoking (%)	0.007 (−0.001–0.016)	0.076
eGFR (mL/kg/min)	0.0001 (−0.0004, 0.0002)	0.59

Schwarzl M, Eur Heart J 2016

The common soil hypothesis from microvascular angina and HFpEF: a paradigm shift



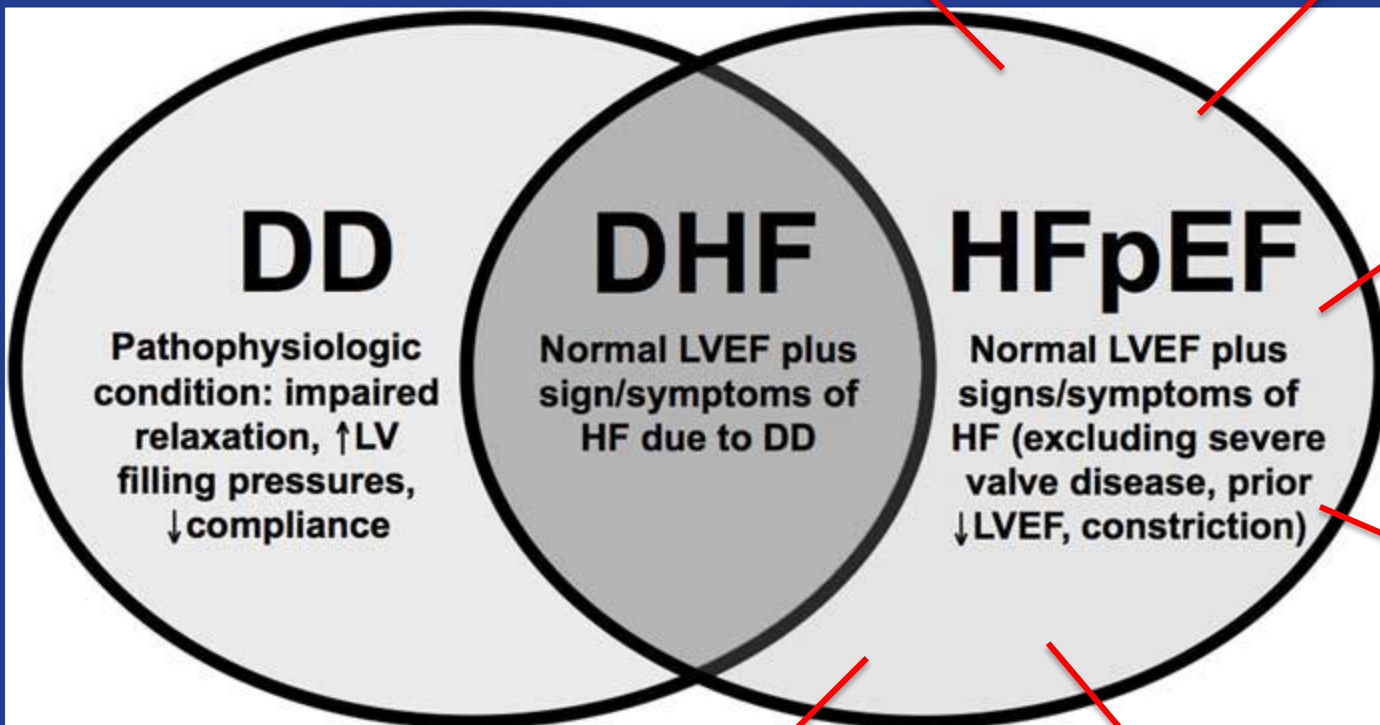
Crea F, Eur Heart J 2016

Take-home messages (3)

Longitudinal LV systolic dysfunction

Abnormal ventricular-arterial coupling

Pulmonary hypertension

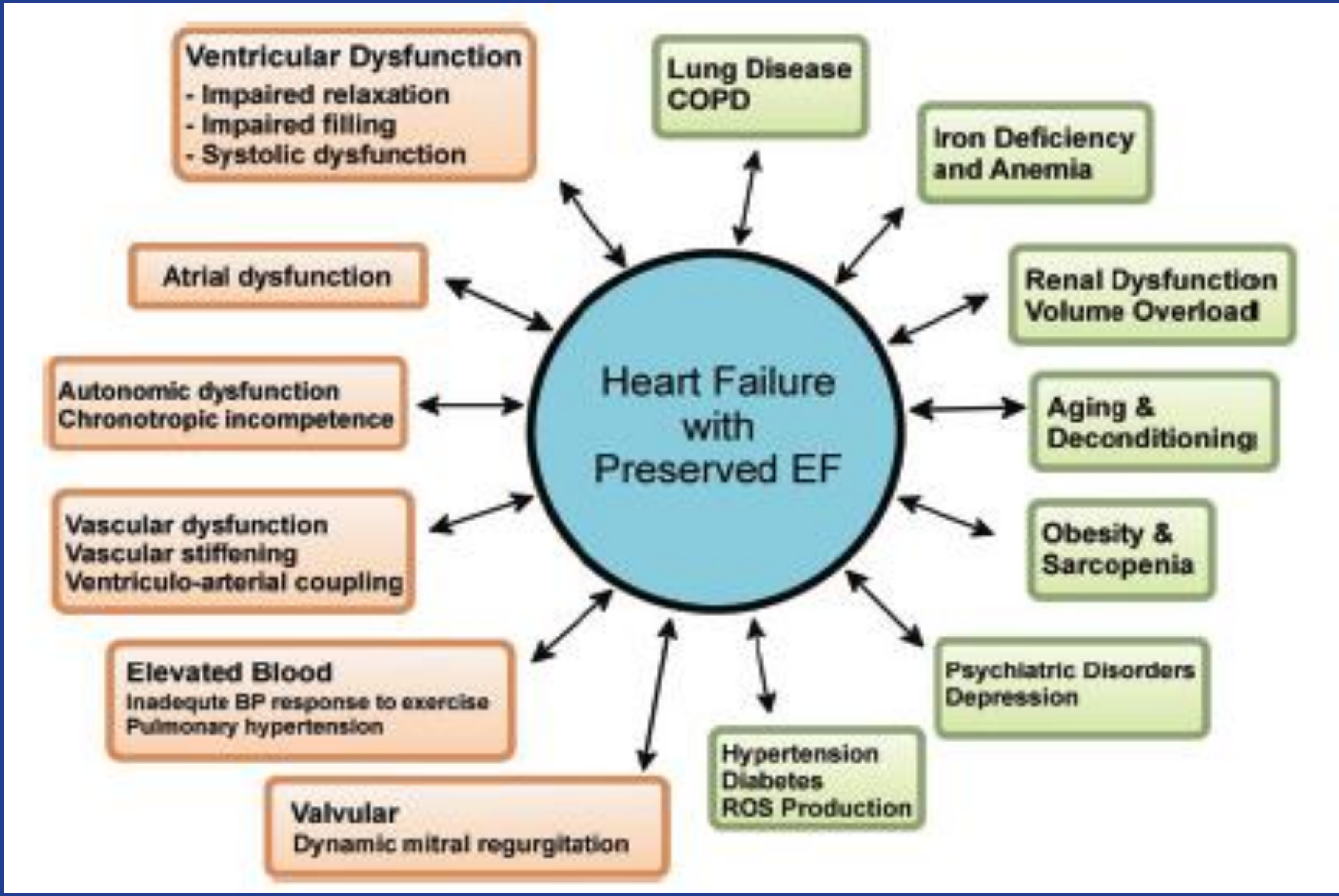


Abnormal exercise-induced vasodilation

Chronotropic incompetence

Extracardiac volume overload

Take-home messages (4)



HFpEF ("huffing-puffing" syndrome):
a multi-organ syndrome with intolerance to exercise

Take-home messages

The assessment of left ventricular (LV) diastolic function should be an integral part of a routine examination, particularly in patients presenting with dyspnea or heart failure.

ASE Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography, JASE 2009

LV diastolic dysfunction can be detected in many hypertensive patients without LV concentric geometry and that increased E/e' ratio is well correlated with MRI extent of myocardial fibrosis in the absence of evident LVH

Speckle-tracking echocardiography can offer functional markers of myocardial fibrosis, in hypertensive patients with normal EF

EACVI/ESH Consensus Paper on Non-invasive cardiovascular imaging for evaluating subclinical target organ damage in hypertensive patients, EHJ Cardiovasc Im 2017

Gemelli

Fondazione Policlinico Universitario A. Gemelli
Università Cattolica del Sacro Cuore

We must remember to treat the patient and not the disease or the echocardiogram

Grazie per l'attenzione

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Future role for CMR in HFpEF

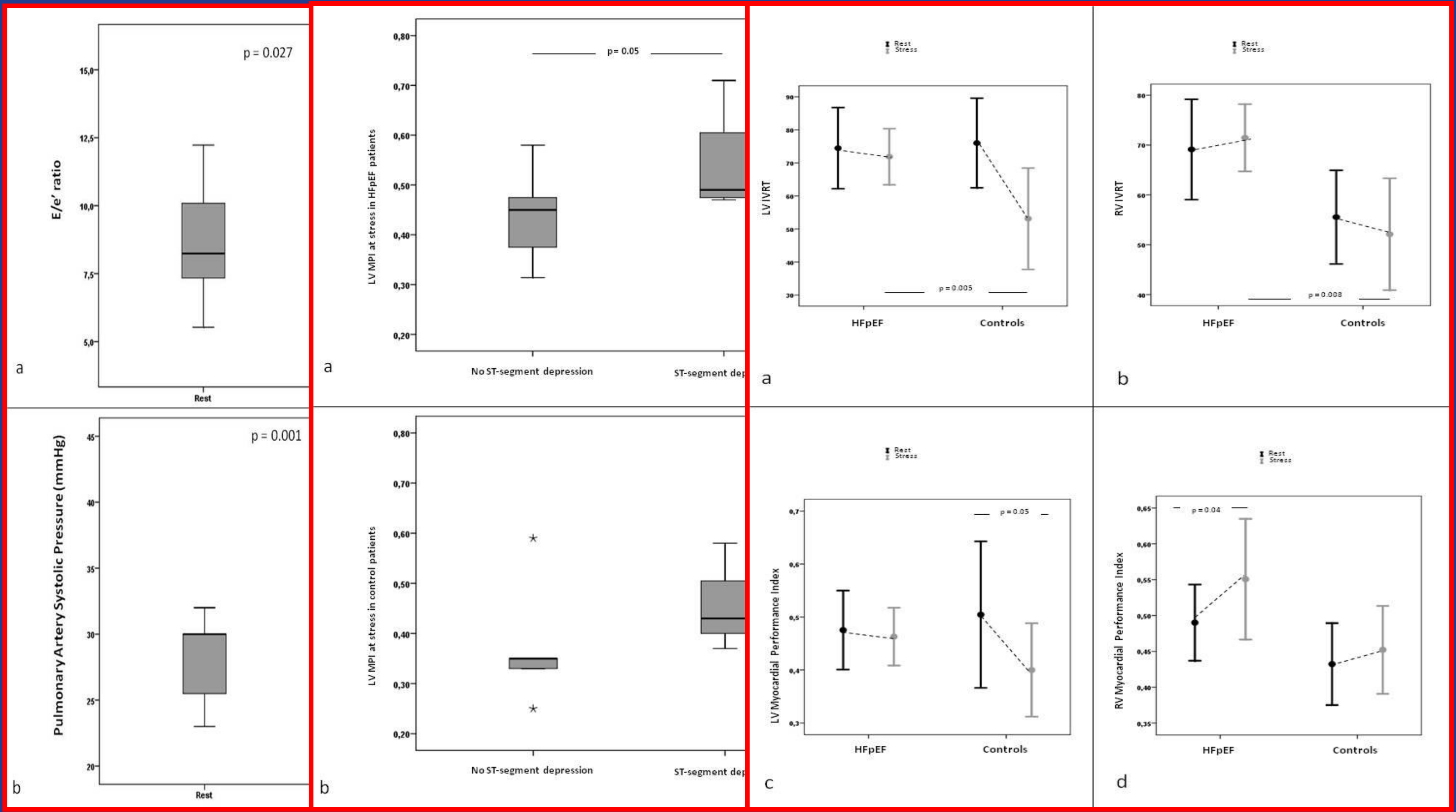
- Improved assessment of cardiac morphology
  - LVH
  - LA size
- Quantification of diffuse fibrosis
  - Possible role in diagnosis
  - Additional mechanistic and prognostic information
- Guiding treatment

⇒Identification of substrate for anti-fibrotic therapy

Courtesy of Taylor AJ, Department of Cardiovascular Medicine – Alfred Hospital, Melbourne, Australia

Dypiridamole stress echo in the early stage of HFpEF : results from MICRO-SCOPE study

15 pts with early stage HFpEF vs 10 hypertensive pts (controls)



Locorotondo G, Crea F, in submission

Prognostic value of dipyridamole stress echo in hypertensive patients with LVH.

82 patients (48 men and 34 women; average age 65+/-7.2 years)
LVH documented echocardiographically
Resting ST segment shift of 0.1 mV

↓

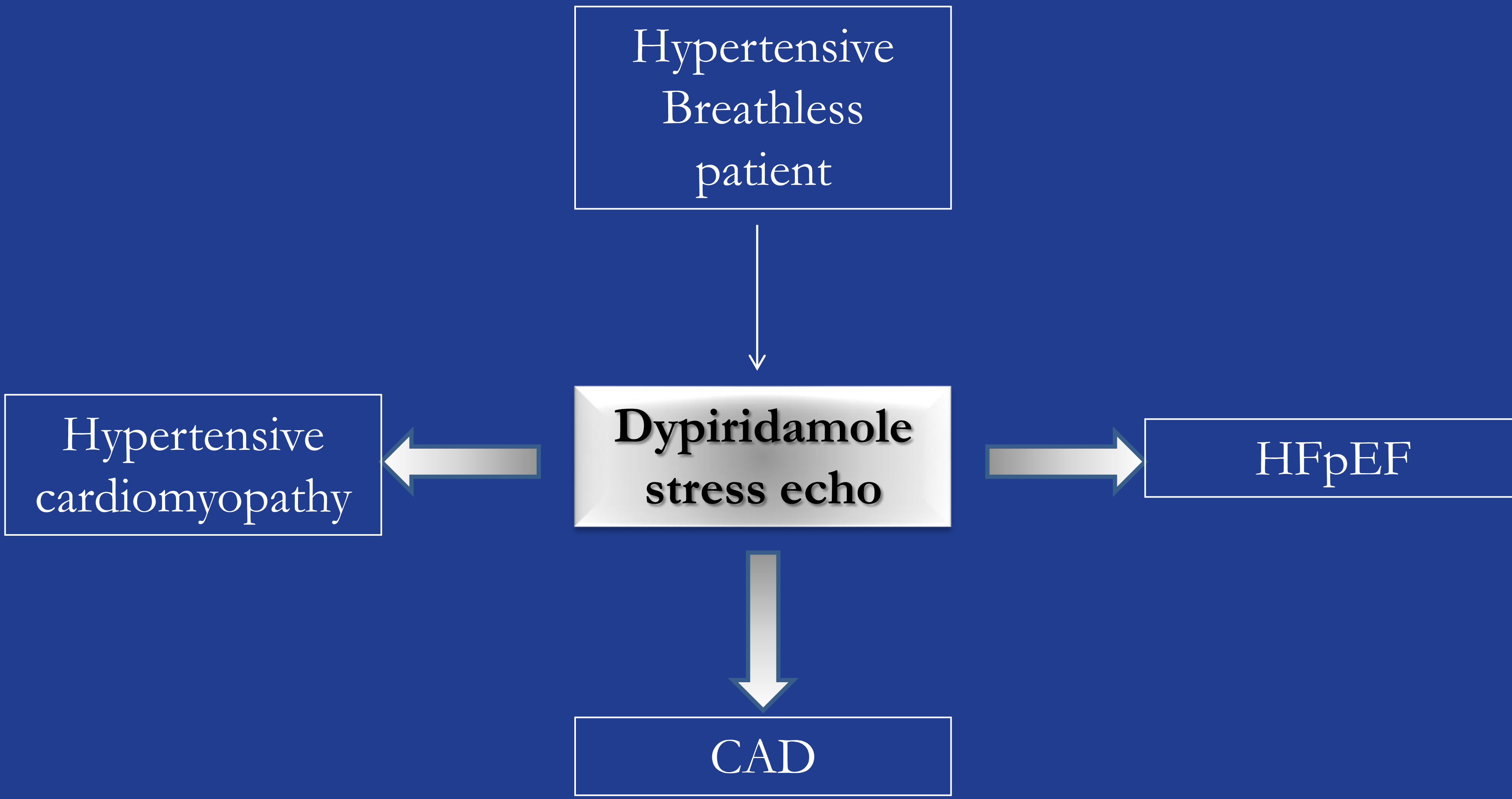
Dypiridamole stress echo

Positive		Negative
30 (36.5%) pts		52 (63.5%) pts
↓		↓
Cardiac events 16 (53%) pts		Cardiac events 3 (5%) pts
47%	2 year survival	95%

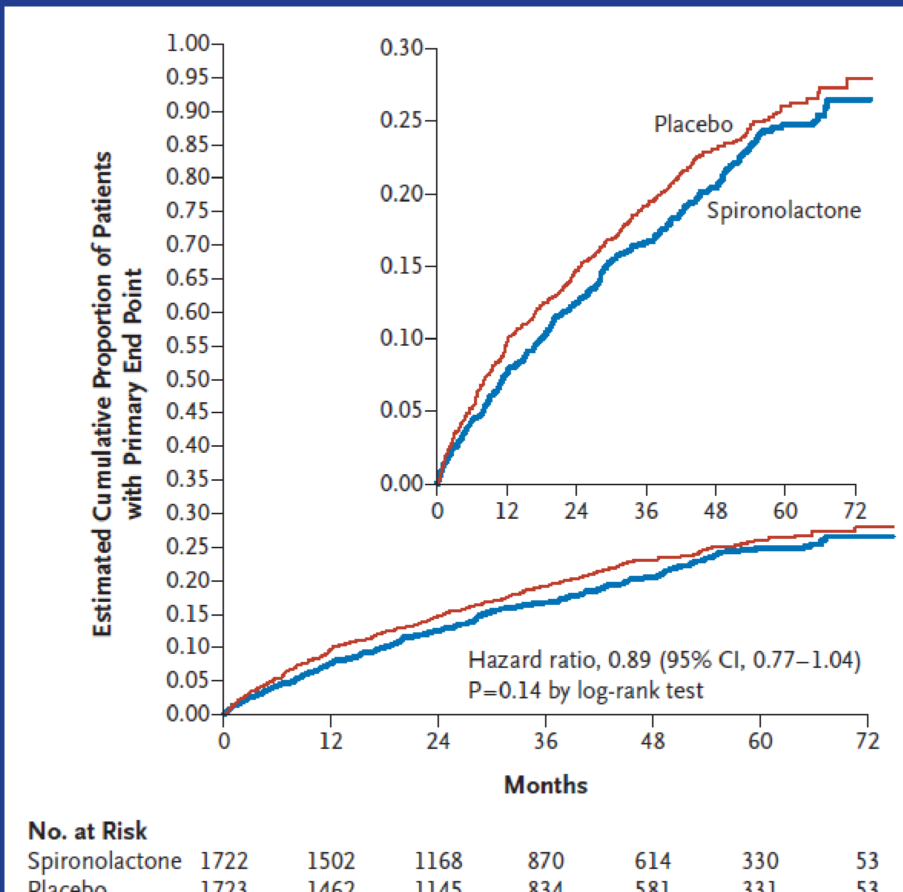
At multivariate analysis, positive response ($p < 0.001$), LVMi ($P=0.028$) and a family history of CAD ($P=0.037$) were independent predictors

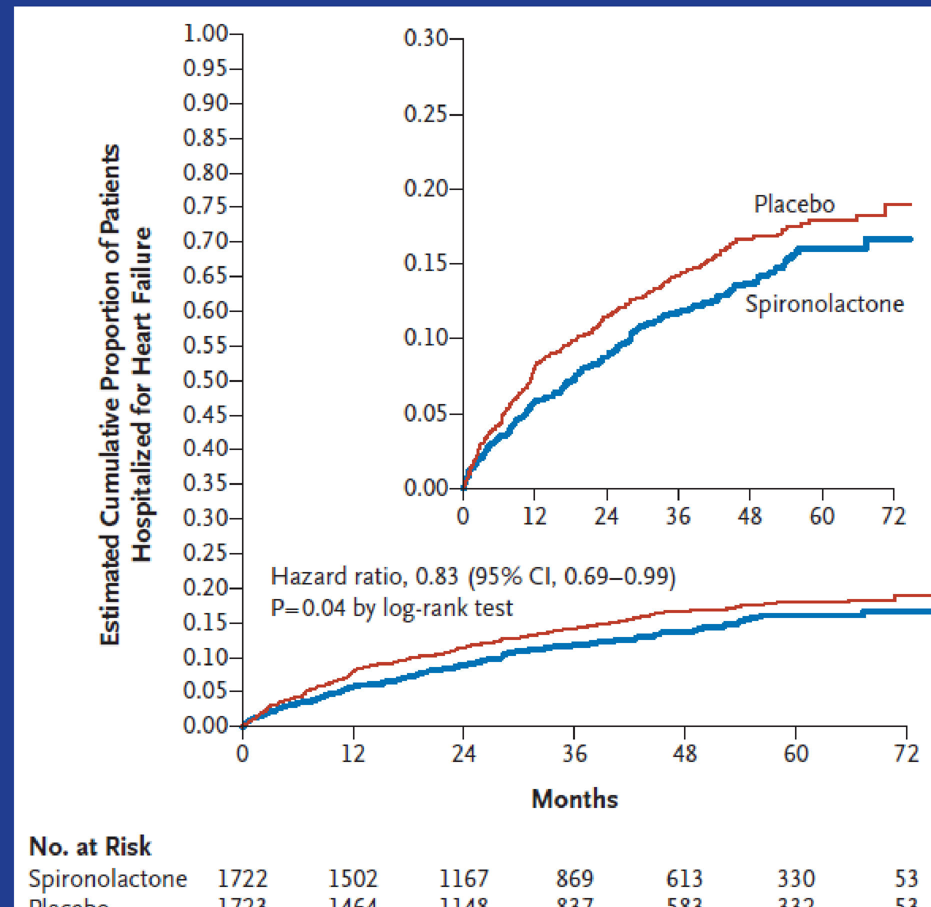
Mondillo S, Nami R, Can J Cardiol 2001

A new work-up hypothesis



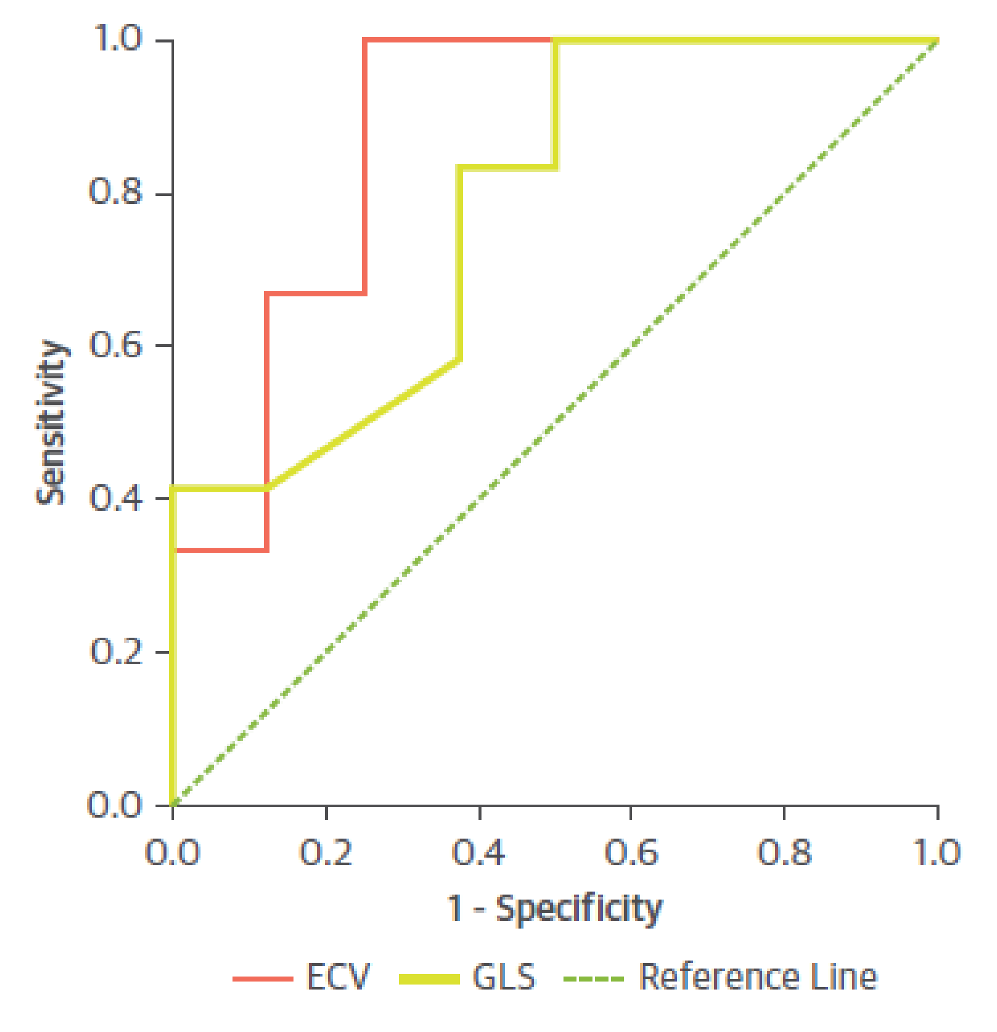
Spironolactone for HFpEF: TOPCAT trial





Pitt P, *NEJM* 2014

GLS and ECV correctly stratify between normal, hypertensive and HFpEF patients

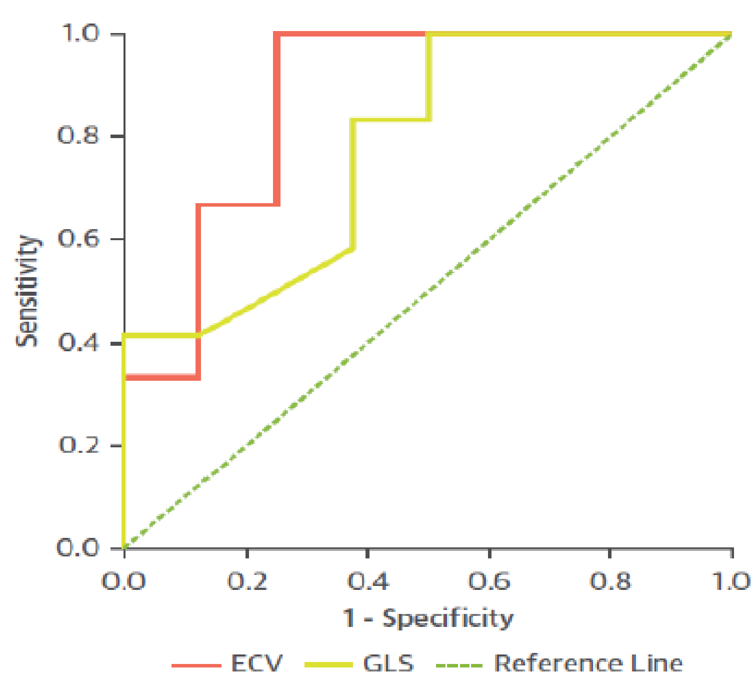


Modified from Mordi IF, J Am Coll Cardiol Img 2018

GLS and ECV are independent diagnostic markers of HFpEF

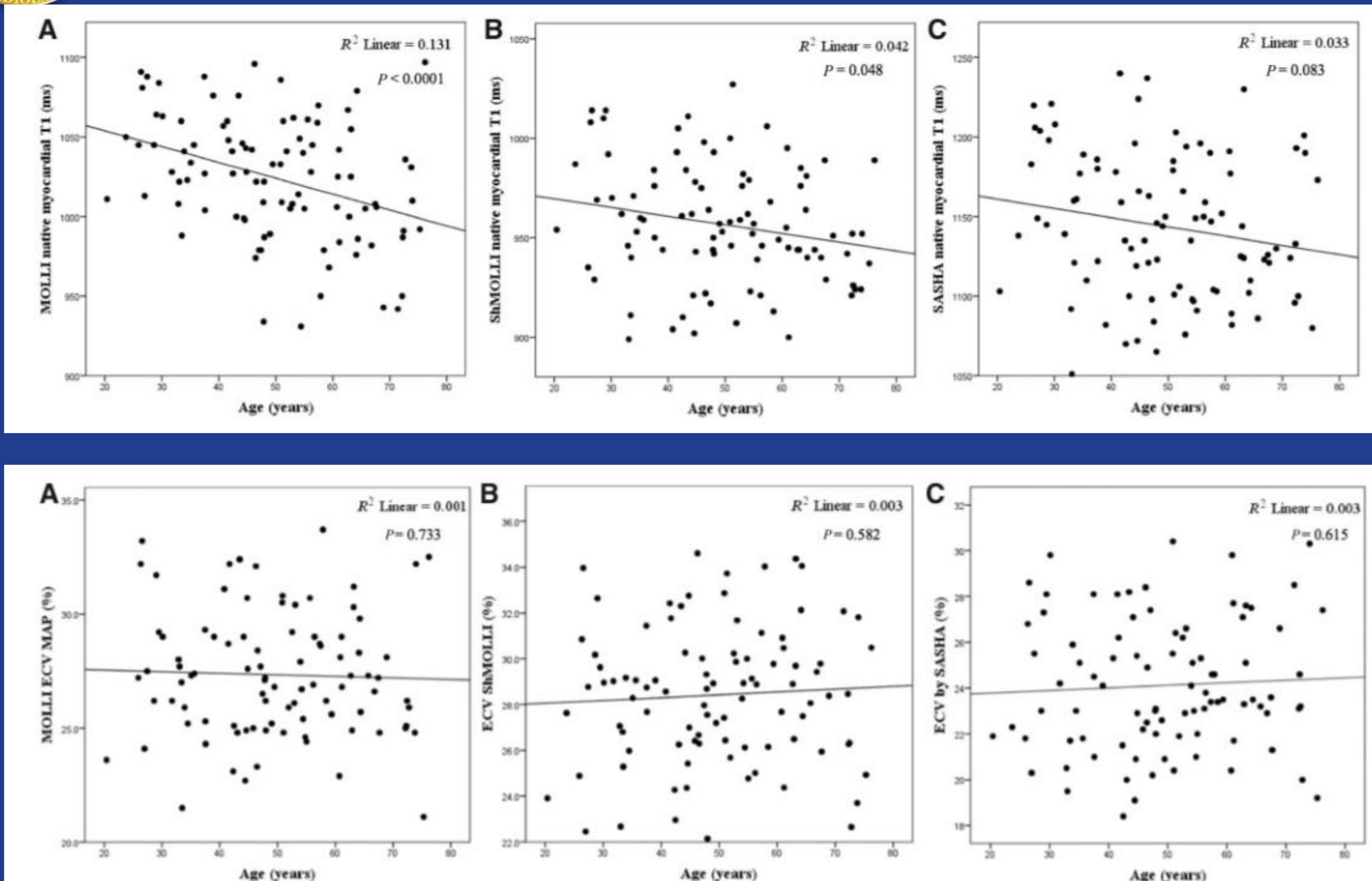
TABLE 3 CMR Data

	HFpEF Patients (n = 62)	Hypertensive Patients (n = 22)	Control Subjects (n = 28)	p Value
LVEF, %	66.7 ± 9.3	65.6 ± 6.7	64.3 ± 4.3	0.42
LVEDVi	67.8 ± 17.5	64.8 ± 11.7	60.6 ± 23.3	0.06
LVESVi	23.2 ± 12.1	17.5 ± 7.7	23.1 ± 11.9	0.82
LVMi	70.8 ± 20.2*	107.2 ± 23.1†	69.2 ± 23.2*	**<0.001**
cGCS, %	−15.10 ± 2.62	−16.23 ± 3.81	−18.50 ± 1.21†	**0.045**
Native T_1, ms	1218 ± 78	1185 ± 58	1194 ± 29	0.06
ECV, %	35.9 ± 5.0*	31.9 ± 5.2†	27.0 ± 4.3*†	**<0.001**



Mordi, JACC Cardiovasc Imaging. 2017

Myocardial native T1 and extracellular volume with healthy ageing and gender



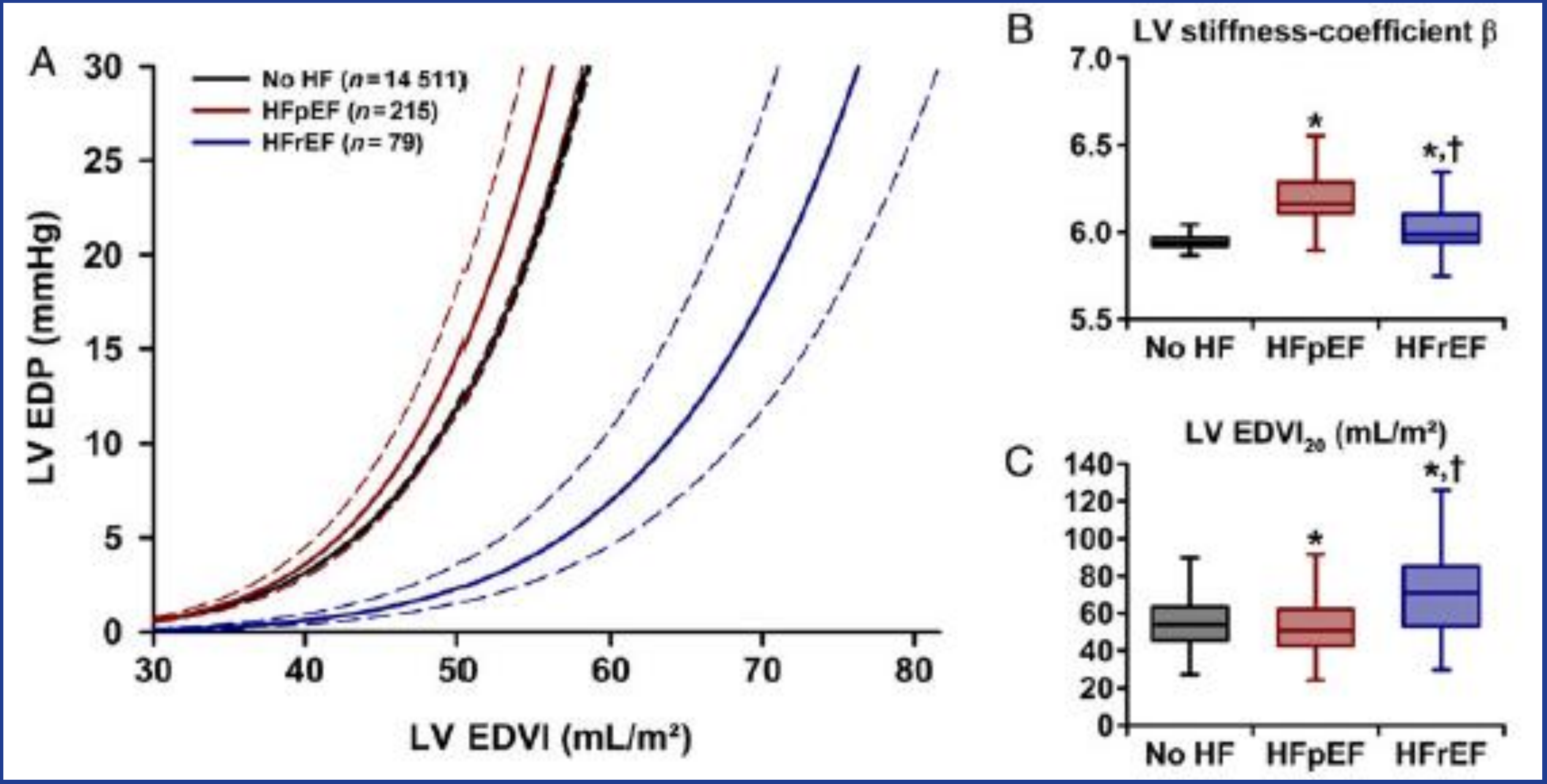
Rosmini S, EHJ Cardiovasc Imaging 2018

Determinants of E/E'

Impaired active relaxation

Increased LV stiffness

Increased LV filling pressure



Original Article

Reduced Myocardial Flow in Heart Failure Patients With Preserved Ejection Fraction

Kajenny Srivaratharajah, MD; Thais Coutinho, MD; Robert deKemp, PhD; Peter Liu, MD; Haissam Haddad, MD; Ellamae Stadnick, MD; Ross A. Davies, MD; Sharon Chih, MD; Girish Dwivedi, MD; Ann Guo, MSc; George A. Wells, MD; Jordan Bernick, MSc; Robert Beanlands, MD*; Lisa M. Mielniczuk, MD*

Echocardiographic Parameters	HFpEF (n=42)	Hypertensive Control (n=46)	Normotensive Control (n=27)	*P*-value
LV septal thickness [mm]	10.6±2.0	9.8±2.1	9.6±2.0	0.118 * 0.150 †
LV posterior wall thickness [mm]	10.2±2.5	9.8±2.0	9.2±1.8	0.176 * 0.593 †
PCWP [mmHg]	20.5±3.7	18.5±2.3	17.8±2.1	0.001 * 0.005 †
Tissue Doppler septal E' velocity [m/s]	0.06±0.02	0.07±0.02	0.08±0.02	<0.001 * <0.001 †
Tissue Doppler lateral E' velocity [m/s]	0.07±0.02	0.09±0.02	0.11±0.03	<0.001 * <0.001 †
Medial E/e' ratio	14.7±5.8	11.5±3.1	10.2±3.1	<0.001 * 0.003 †

Circ Heart Failure 2016

Clinical Investigation

Reduced Myocardial Flow Reserve Is Associated With Diastolic Dysfunction and Decreased Left Atrial Strain in Patients With Normal Ejection Fraction and Epicardial Perfusion

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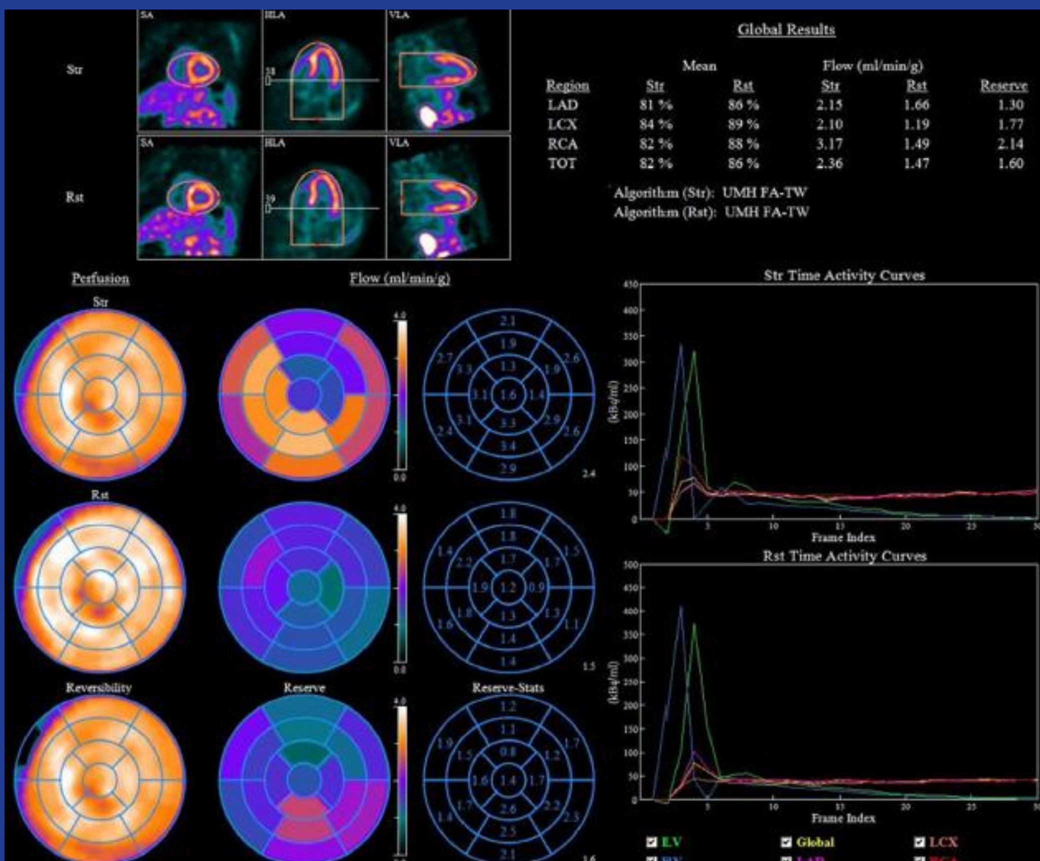
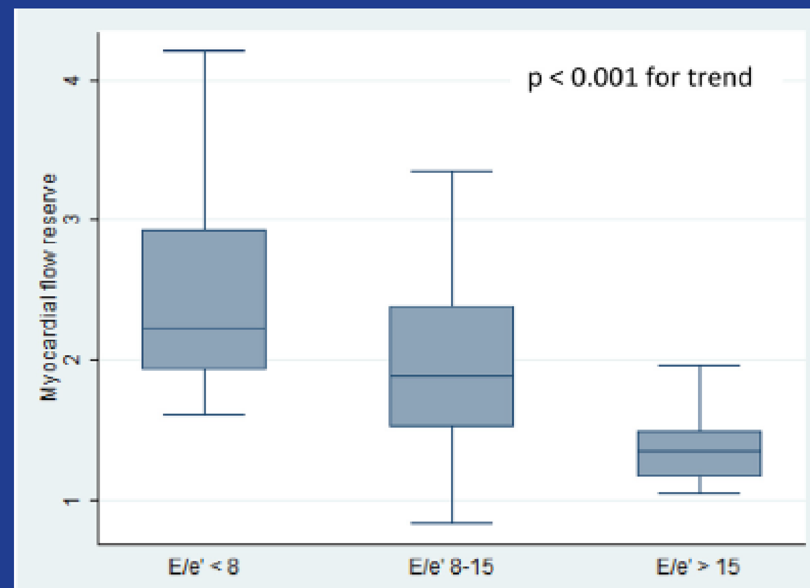
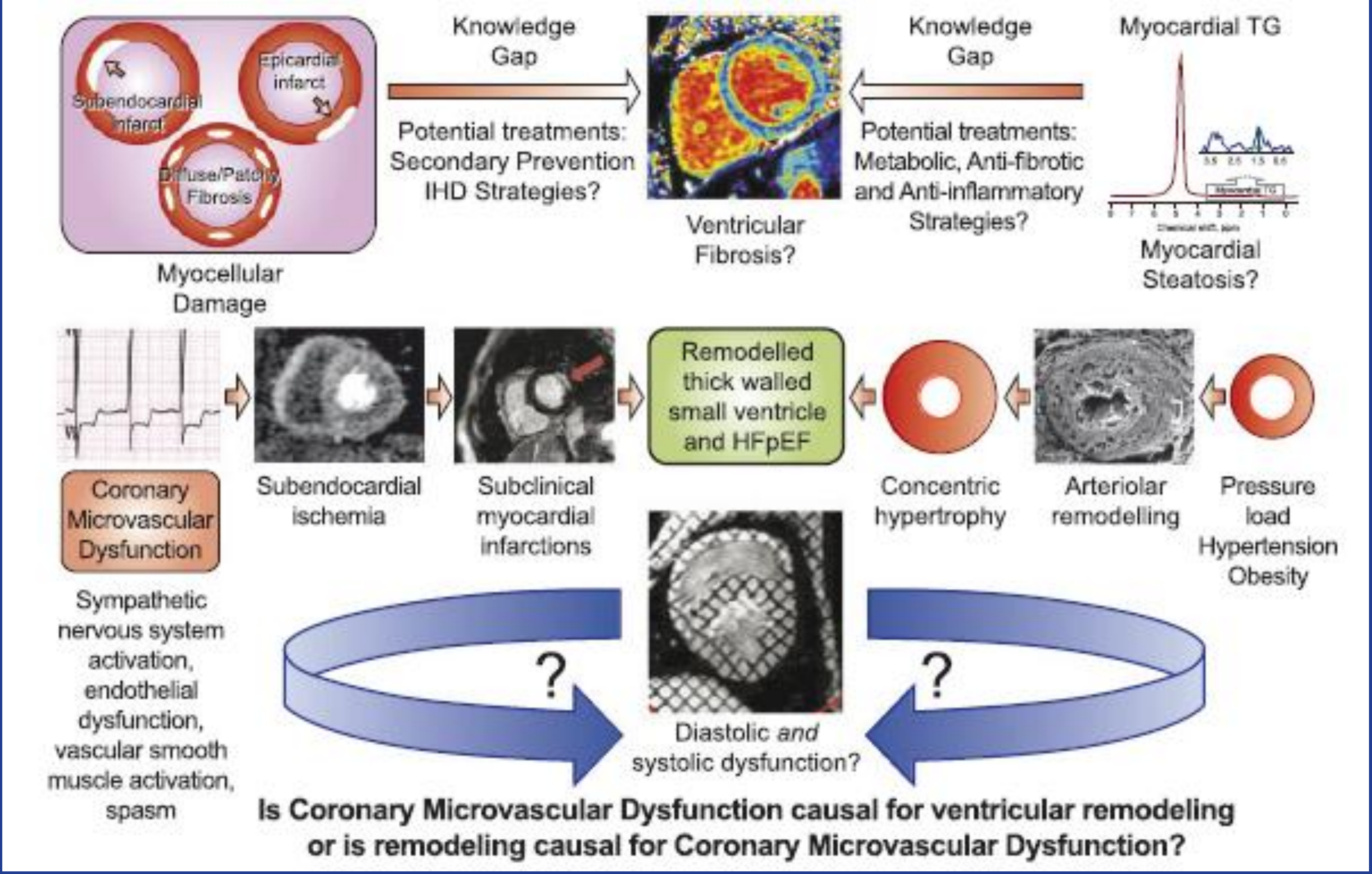
Ann Arbor and Detroit, Michigan; and Boston, Massachusetts





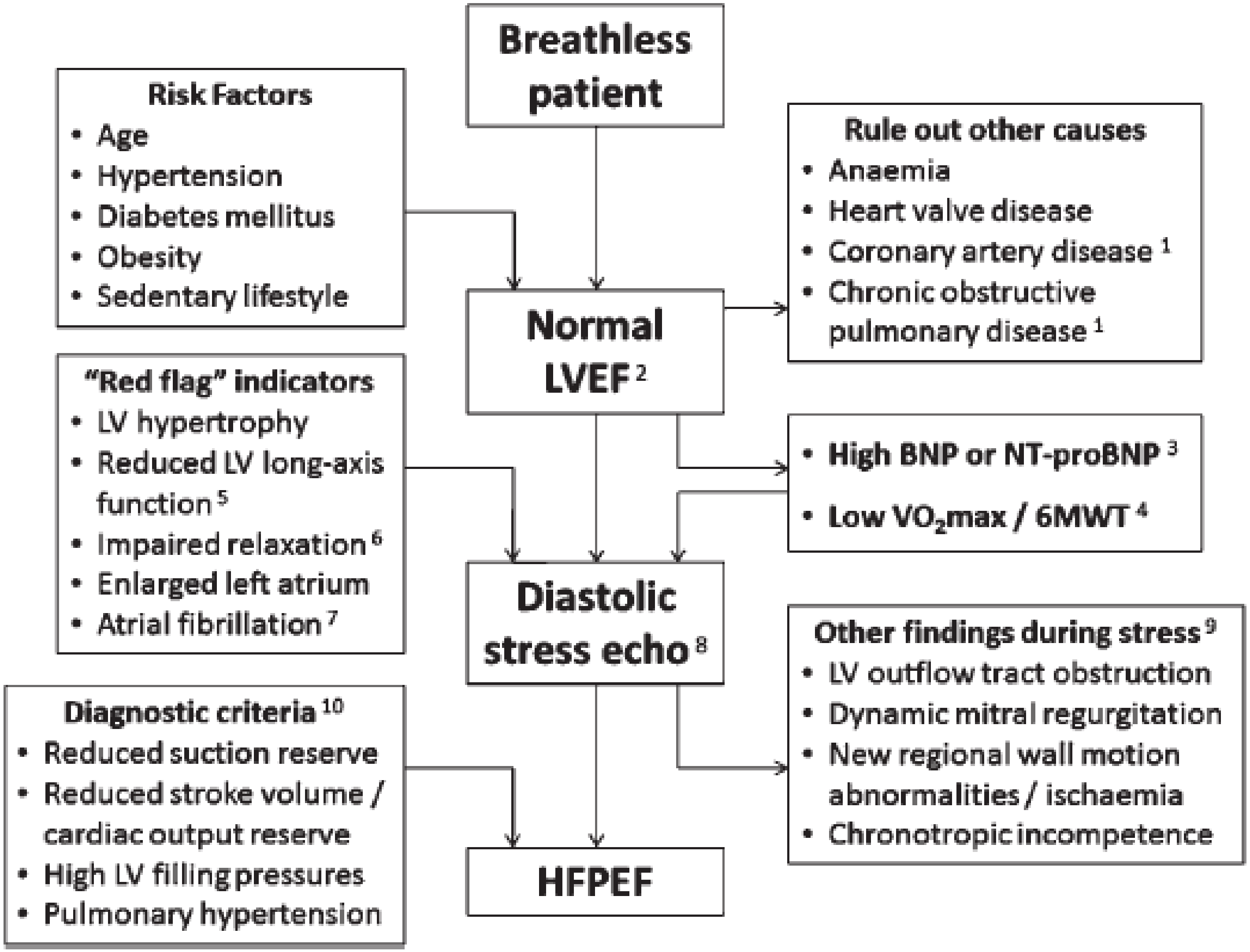
J Cardiac Failure 2017

The chicken or the egg?



Nelson MD, Eur Heart J 2018

Take-home messages (2)



Take-home messages (5)

echoresearch and practice | D Modin *et al.* | Echo and heart failure | 5:2 | **R65**–R79

REVIEW

Echo and heart failure: when do people need an echo, and when do they need natriuretic peptides?

Daniel Modin MB, Ditte Madsen

Department of Cardiology, Herlev & Gento

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JACC: CARDIOVASCULAR IMAGING VOL. 11, NO. 4, 2018

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Comprehensive Echocardiographic and Cardiac Magnetic Resonance Evaluation Differentiates Among Heart Failure With Preserved Ejection Fraction Patients, Hypertensive Patients, and Healthy Control Subjects

Ify R. Mordi, MD,[a] Satnam Singh, MBBS,[b] Amelia Rudd, HND,[b] Janaki Srinivasan, RCDS,[b] Michael Frenneaux, PhD,[b] Nikolaos Tzemos, MD,[c] Dana K. Dawson, DM, DPhil[b]