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CARDIAC RESYNCHRONIZATION THERAPY BY MULTIPOINT PACING IMPROVES THE ACUTE RESPONSE OF LEFT VENTRICULAR MECHANICS AND FLUID DYNAMICS: A THREE-DIMENSIONAL AND PARTICLE IMAGE VELOCIMETRY ECHOCARDIOGRAPHIC STUDY

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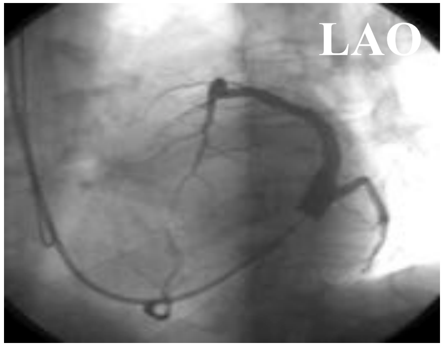
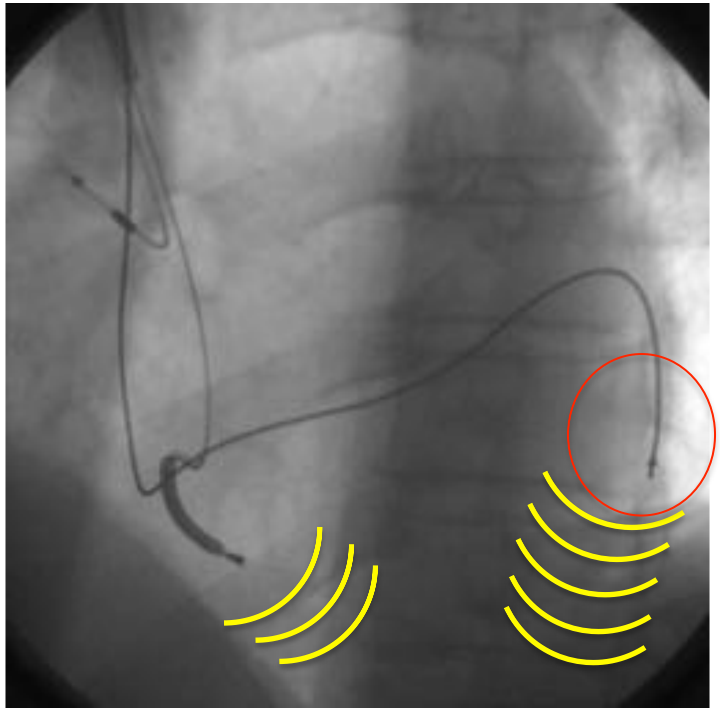
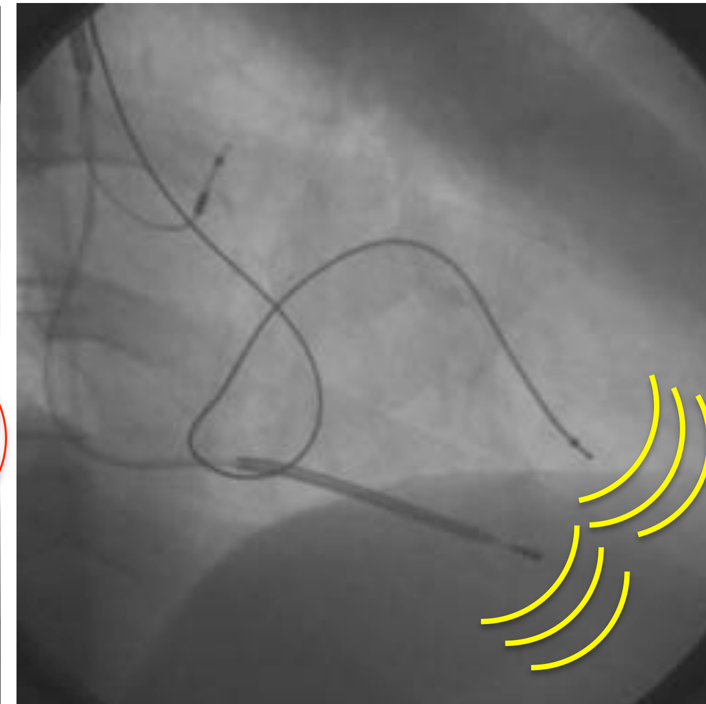
Disclosures: none

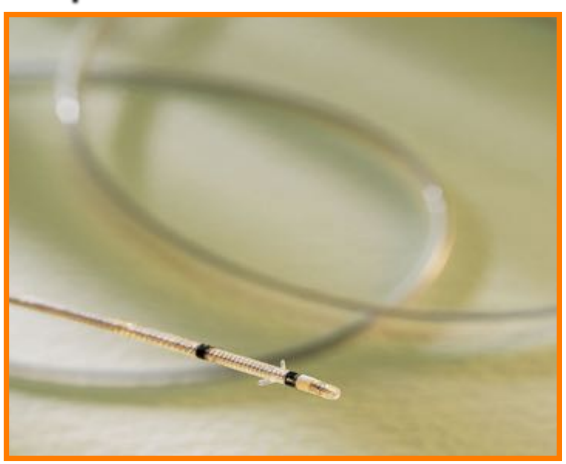
CONVENTIONAL Cardiac Resinchronization Therapy



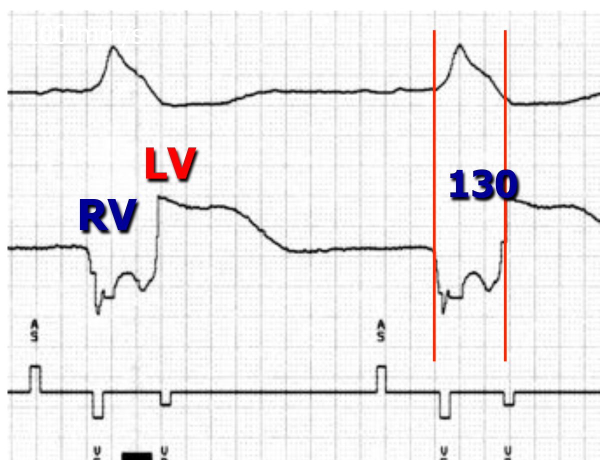


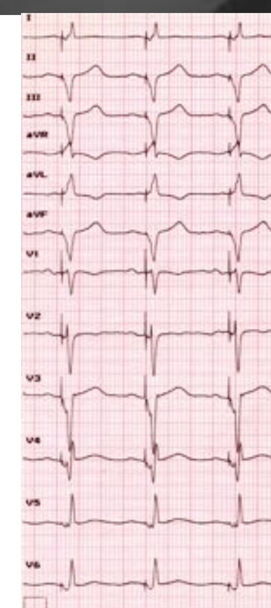


Bipolar LV Lead

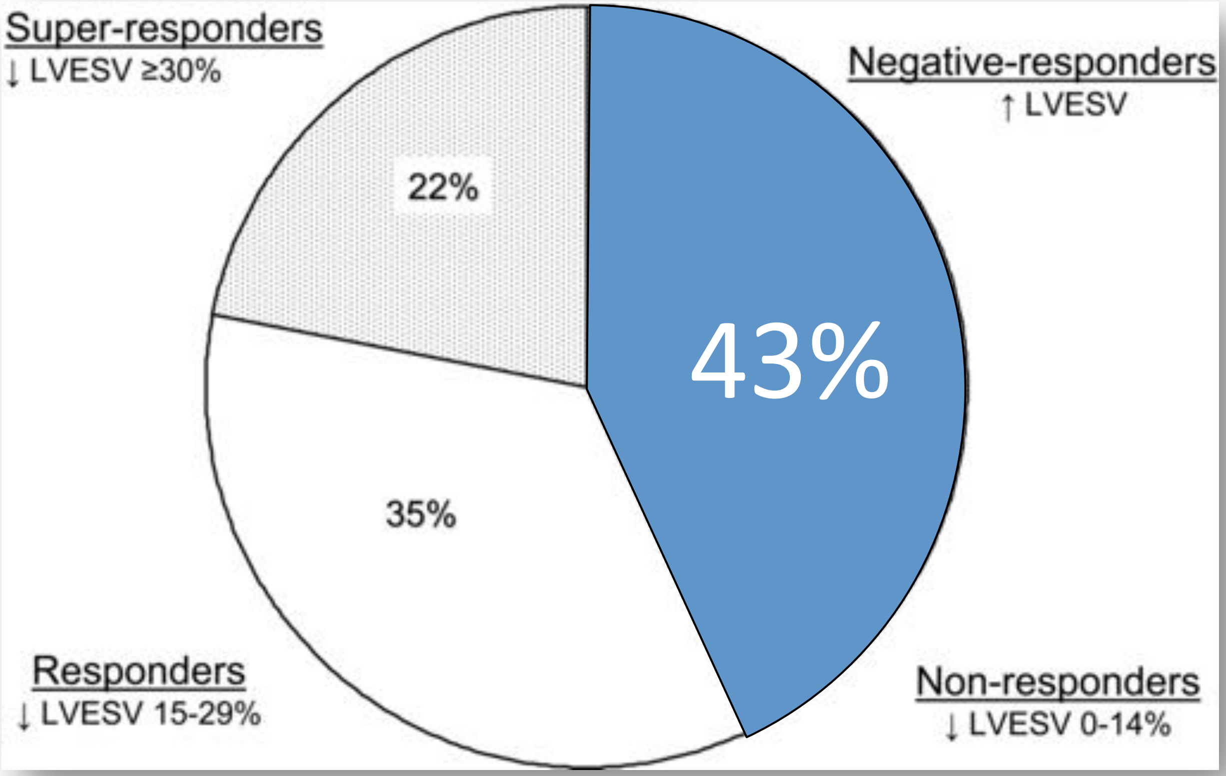


Electrical activations





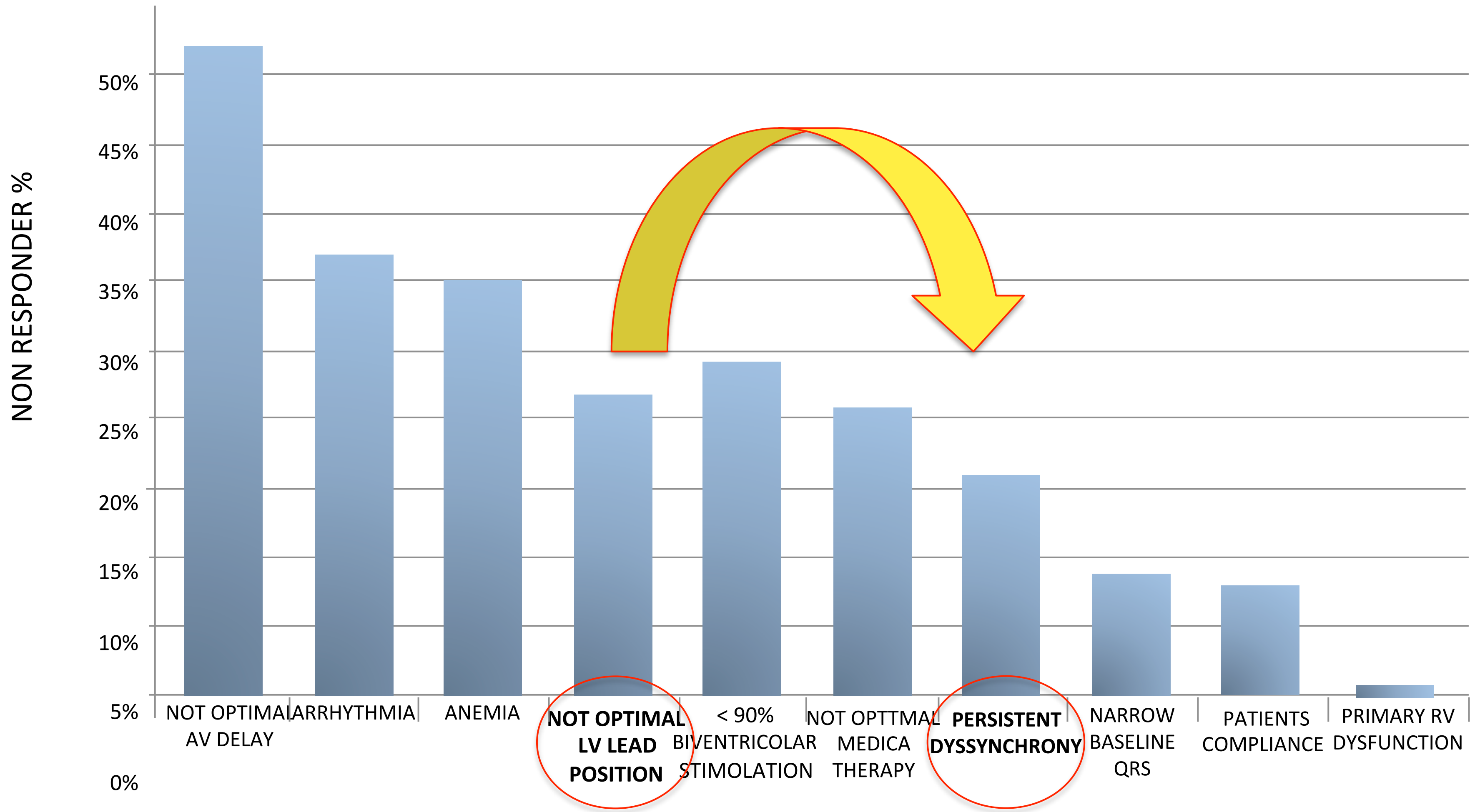
Non Responders to Cardiac Resinchronization Therapy
The Magnitude of the Problem



43% CRT patients are classified as **non-responder** o **negative-responder** referred to LVESV after 6 months (N=302)

Ypenburg et al. Long-Term Prognosis After Cardiac Resynchronization Therapy Is Related to the Extent of Left Ventricular Reverse Remodeling at Midterm Follow-Up. JACC 2009

Predictors of CRT failure



[1] Grimm W. *Intern J Cardiol* 2008; 125: 154-60

[2] Fung JW, Chan JY, Kum LC. *Int J Cardiol* 2007;115: 214-9

[3] Bogaard MD, Doevendans PA. *Europace* 2010;12: 1262-1269

[4] Cleland JG, Daubert JC. *N Engl J Med* 2005;352: 1539-49

[5] Leon AR, Abraham WTJC. *J Am CollCardiol*2005;46: 2298-304

[6] Wasserman K, Sun XG, Hansen JE. *American College of chest physicians* 2007; 132: 250-261

A review of multisite pacing to achieve cardiac resynchronization therapy

Christopher Aldo Rinaldi[1*], Haran Burri[2], Bernard Thibault[3], Antonio Curnis[4], Archana Rao[5], Daniel Gras[6], Johannes Sperzel[7], Jagmeet P. Singh[8], Mauro Biffi[9], Pierre Bordachar[10], and Christophe Leclercq[11]

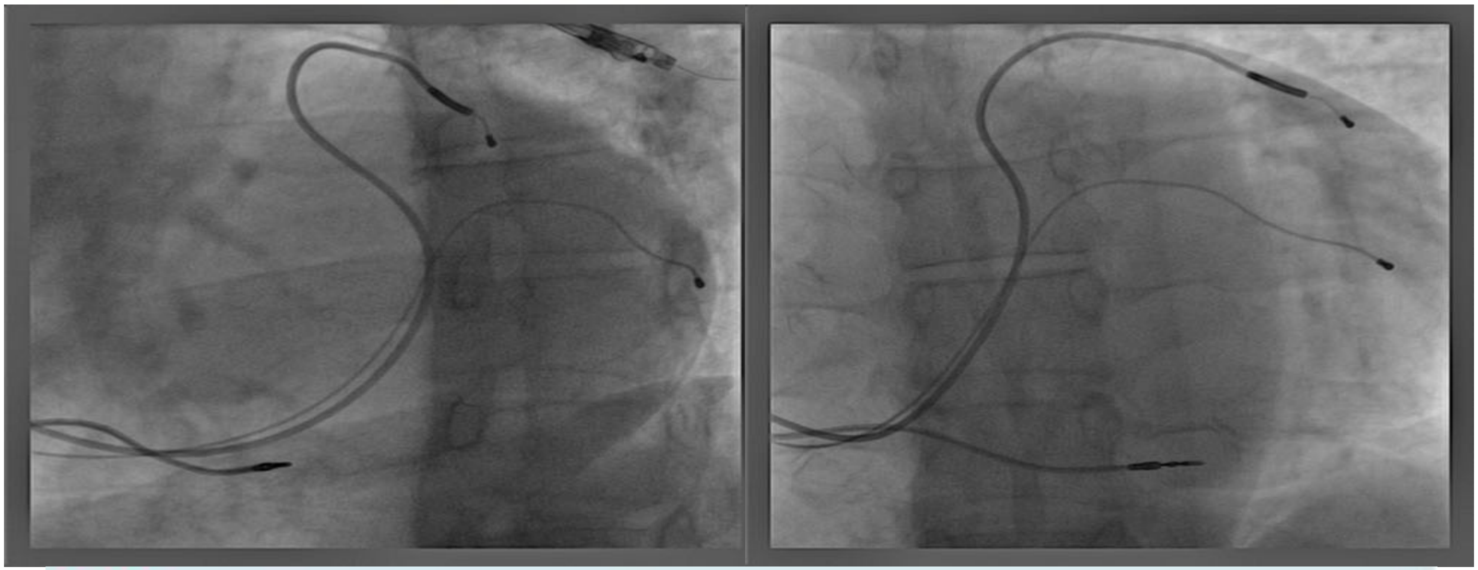


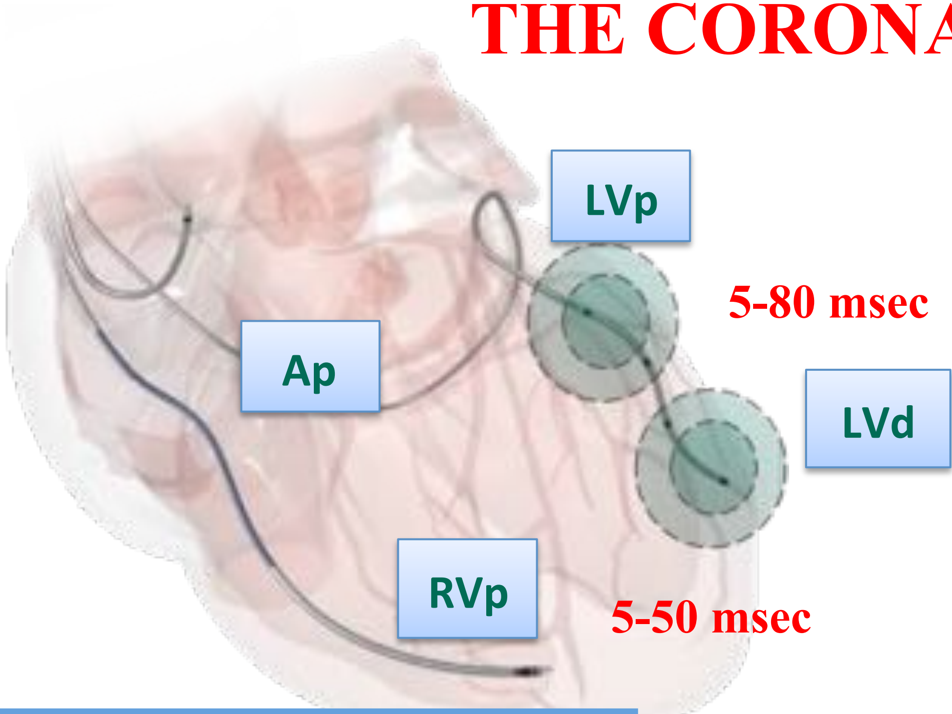
Table 1 Studies of MPS delivered by a quadripolar

Author, year	Number of patients	Study type	Findings
Thibault *et al.* (2013)	19 (21)	Acute comparative study Measurement: invasive haemodynamic evaluation (dP/dt)	72% of patients, MPP improved acute systolic function vs. conventional CRT. Pacing most distal and proximal electrodes most commonly yielded greatest $LVdP/dt_{max}$
Rinaldi *et al.* (2013)	41(52)	Comparative study after implant Measurement: echocardiographic dyssynchrony (TDI)	64% of patients MPP resulted in significant reduction in dyssynchrony vs. conventional CRT
Pappone *et al.* (2013)	44	Randomized comparative study at the time of implant Measurement: invasive haemodynamic evaluation (pressure–volume loops)	Main finding: CRT with MPP can significantly improve acute LV haemodynamic parameters assessed with PV loop measurements as compared with conventional CRT

2015

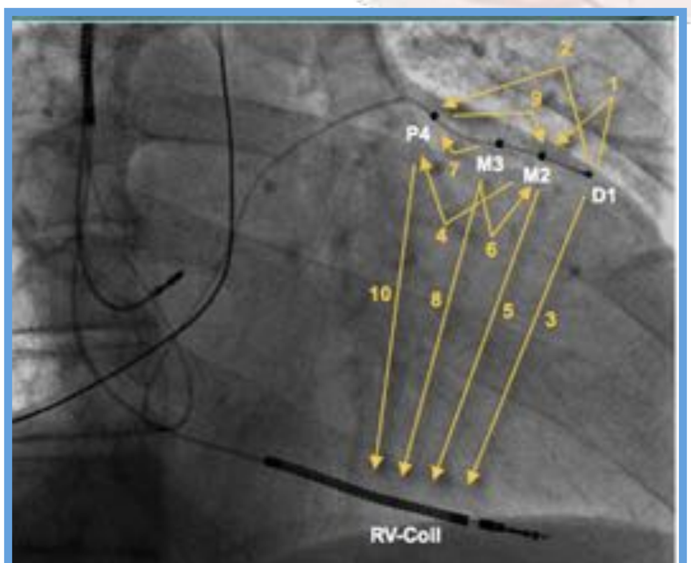
European Society of Cardiology
Europace
doi:10.1093/europace/euu197

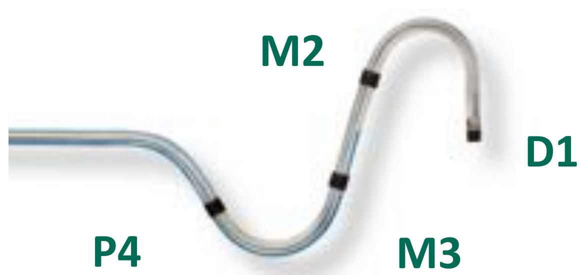
MULTIPOINT PACING IN A SINGLE BRANCH OF THE CORONARY SINUS



10 VectSelect Quartet™ Vectors

Vector	Cathode to Anode
1	D1 → M2
2	D1 → P4
3	D1 → RV Coil
4	M2 → P4
5	M2 → RV Coil
6	M3 → M2
7	M3 → P4
8	M3 → RV Coil
9	P4 → M2
10	P4 → RV Coil



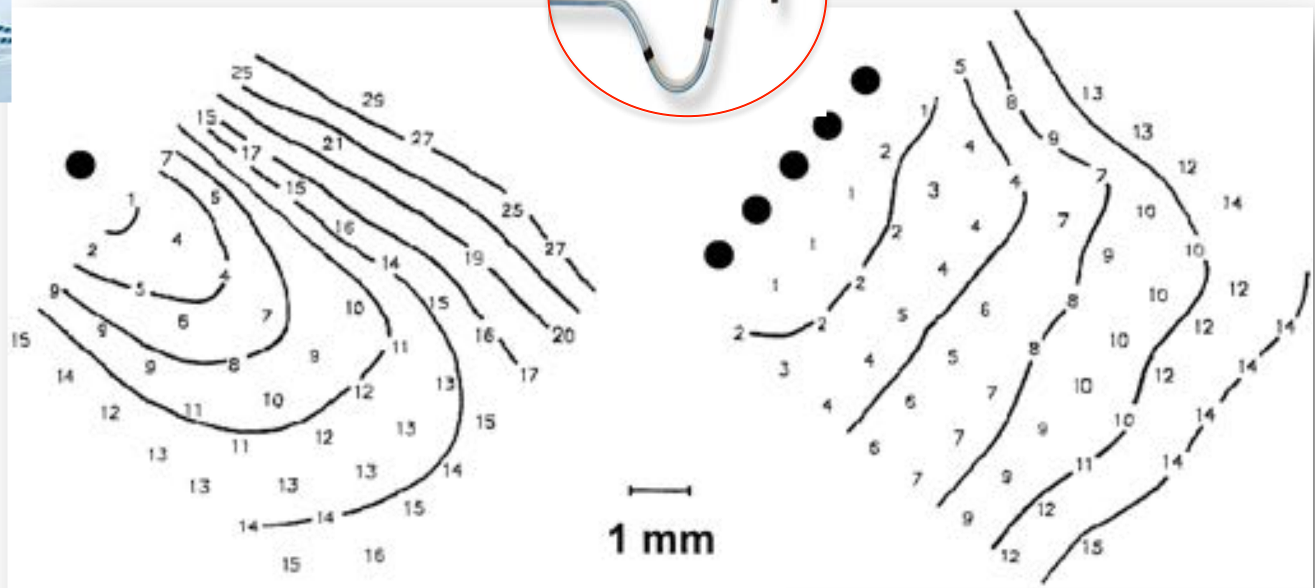


Forleo et al , Left ventricular pacing with a new quadripolar transvenous lead for CRT: Early results of a prospective comparison with conventional implant outcomes, Heart Rhythm 2011

Why use a MPP lead ?

SINGLE SITE PACING

MPP



CONVEX
NON-UNIFORM
SLOWER
WAVEFRONT

FLAT
UNIFORM
FASTER
WAVEFRONT

Fast VG, Klèber A. Role of wavefront curvature in propagation of cardiac impulse. Cardiovascular Research 1997

MULTIPOINT PACING IMPROVES ACUTE HEMODYNAMIC RESPONSE TO CRT

volume; RV = right ventricular; SW = stroke work.

Pappone C et al. Multipoint left ventricular pacing improves acute hemodynamic response assessed with pressure-volume loops incardiac resynchronization therapy patients. Heart Rhythm. 2014;11:394-401;

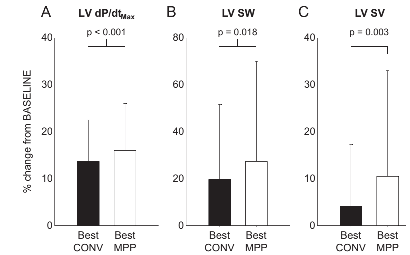
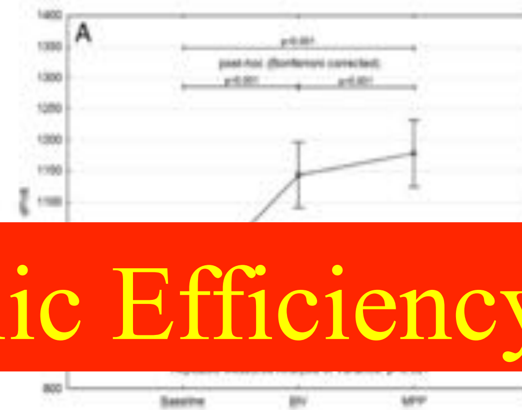


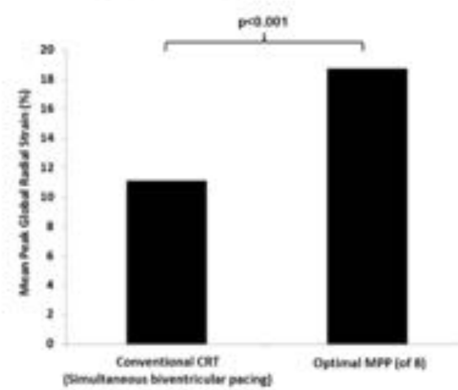
Figure 2 Improvement in acute hemodynamic parameters with MPP. Biventricular pacing with MPP result
(B) LV SW, (C) LV SV, and (D) LV EF as compared with CONV. CONV = conventional cardiac resynchro
EF = ejection fraction; LV = left ventricular; MPP = MultiPoint Pacing; SV = stroke volume; SW = stro

Zanon F et al. Multipoint pacing by a left ventricular quadripolar lead improves the acute hemodynamic response to CRT compared with conventional biventricular pacing at any site. Heart Rhythm. 2015;12:975-81;



Evaluated mostly Left Systolic Efficiency

Rinaldi CA et al. Improvement in acute contractility and hemodynamics with multipoint pacing via a left ventricular quadripolar pacing lead. J Interv Card Electrophysiol. 2014;40:75-80.

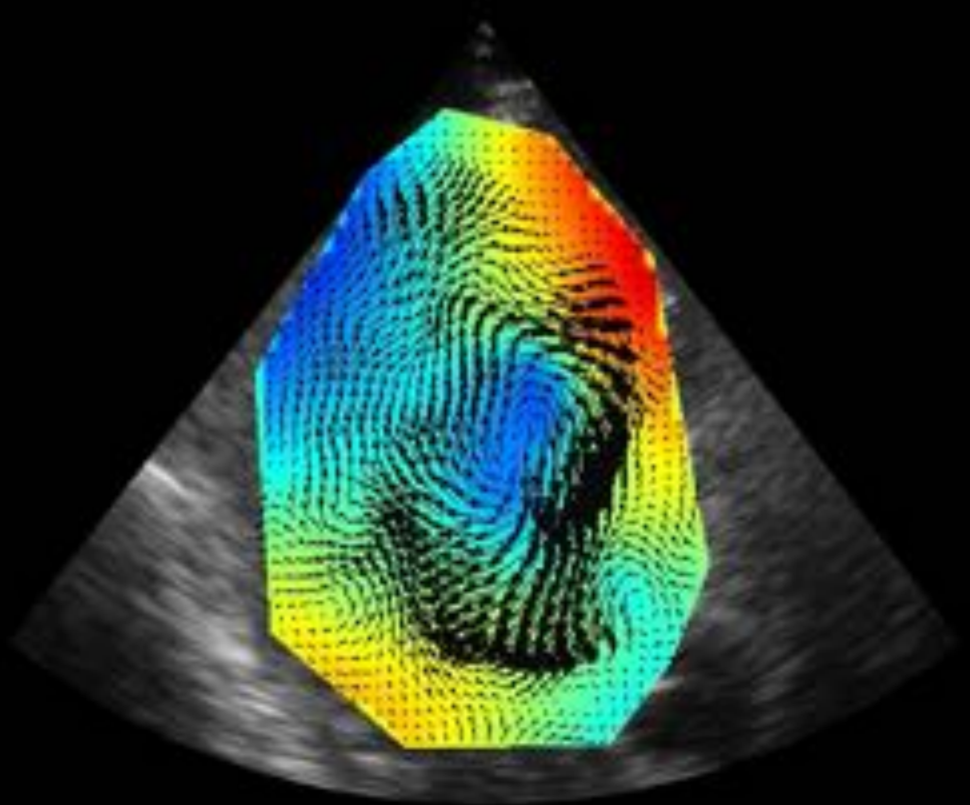


Fluid-dynamics

Fluid dynamics is a discipline of fluid mechanics that deals with fluid flow, the natural science of fluid in motion

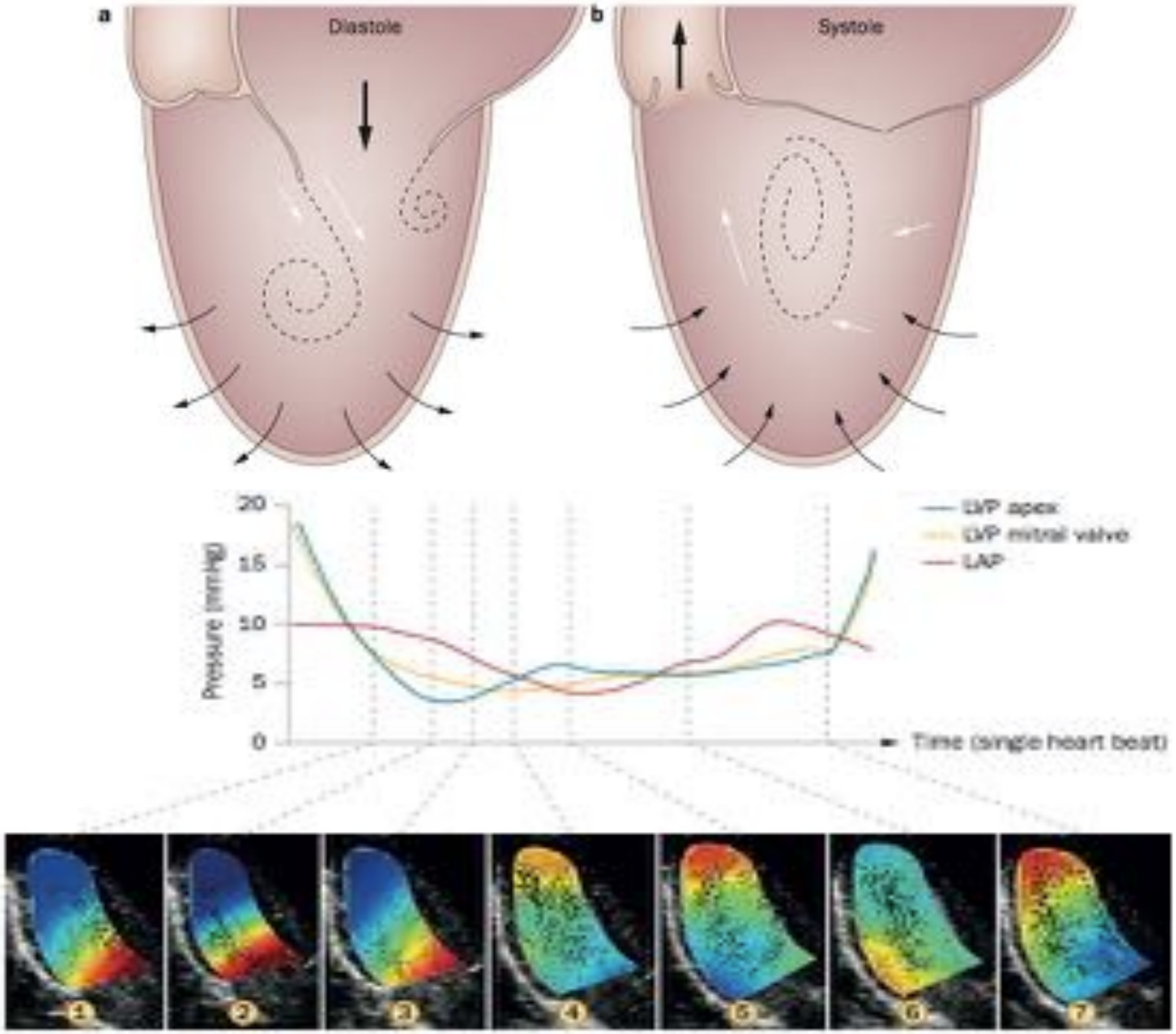
Intraventricular blood motion is characterized by the formation of *vortices*, which are fundamental performers in fluid dynamics with a marked, intrinsic instability that gives rise to rapid accelerations, deviations, and sharp fluctuations of pressure and shear stress.

Echo-PIV
(Echocardiographic particle image velocimetry)

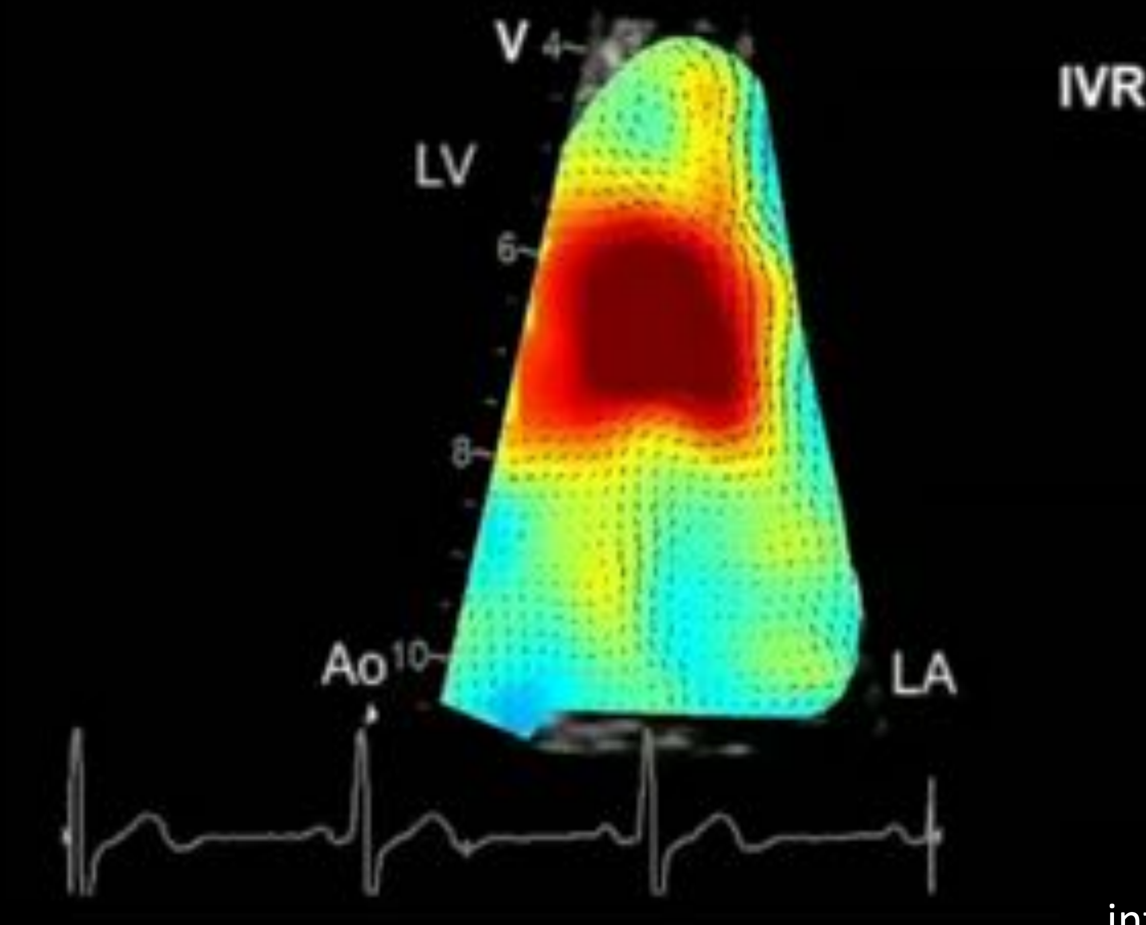


Allows blood flow dynamics visualization and characterization of diastolic ***Vortex*** formation that may play a key role in filling efficiency

Blood flow in healthy left ventricle



Healthy Left Ventricle



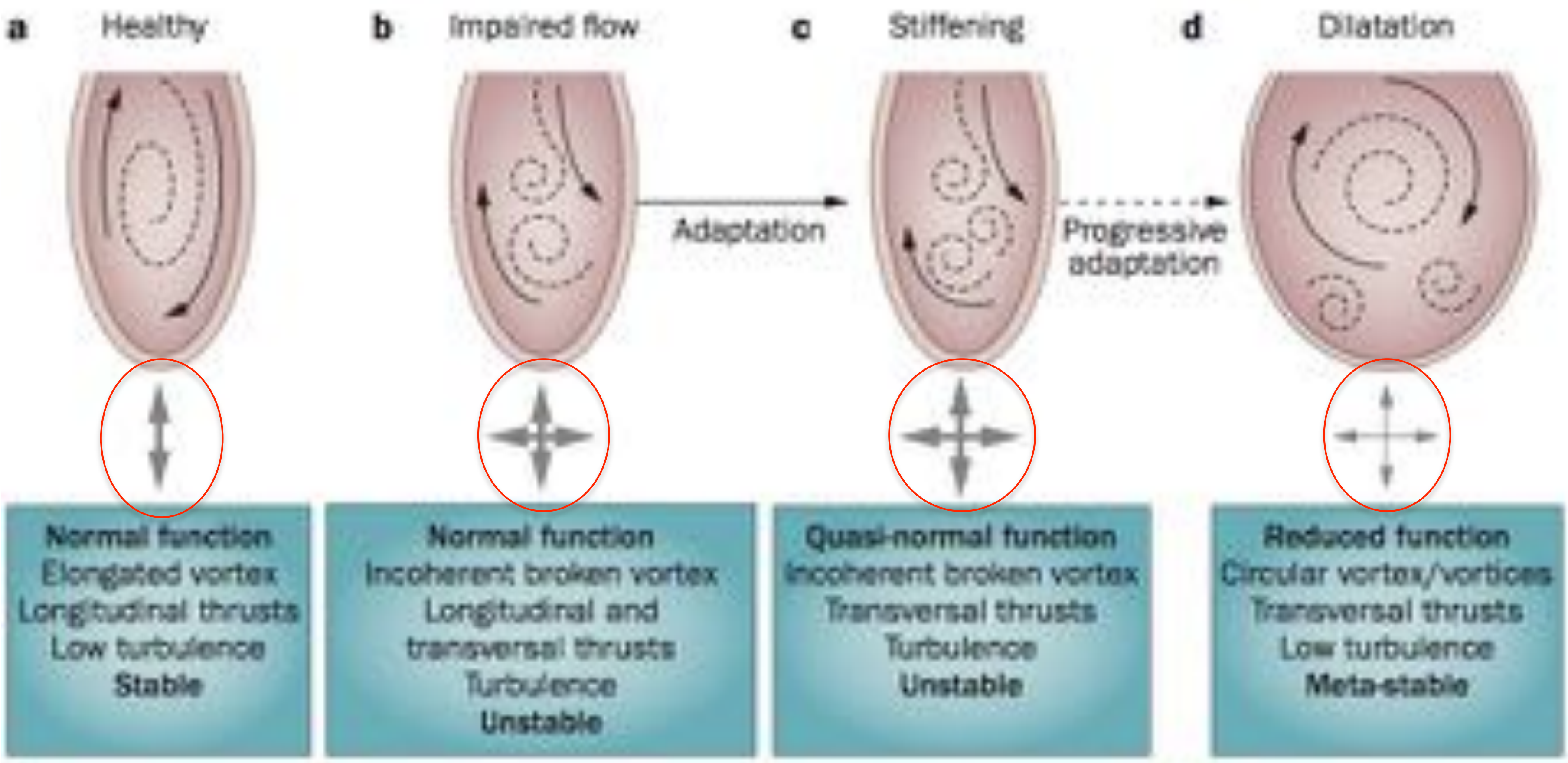
Momentum thrust distribution

apex

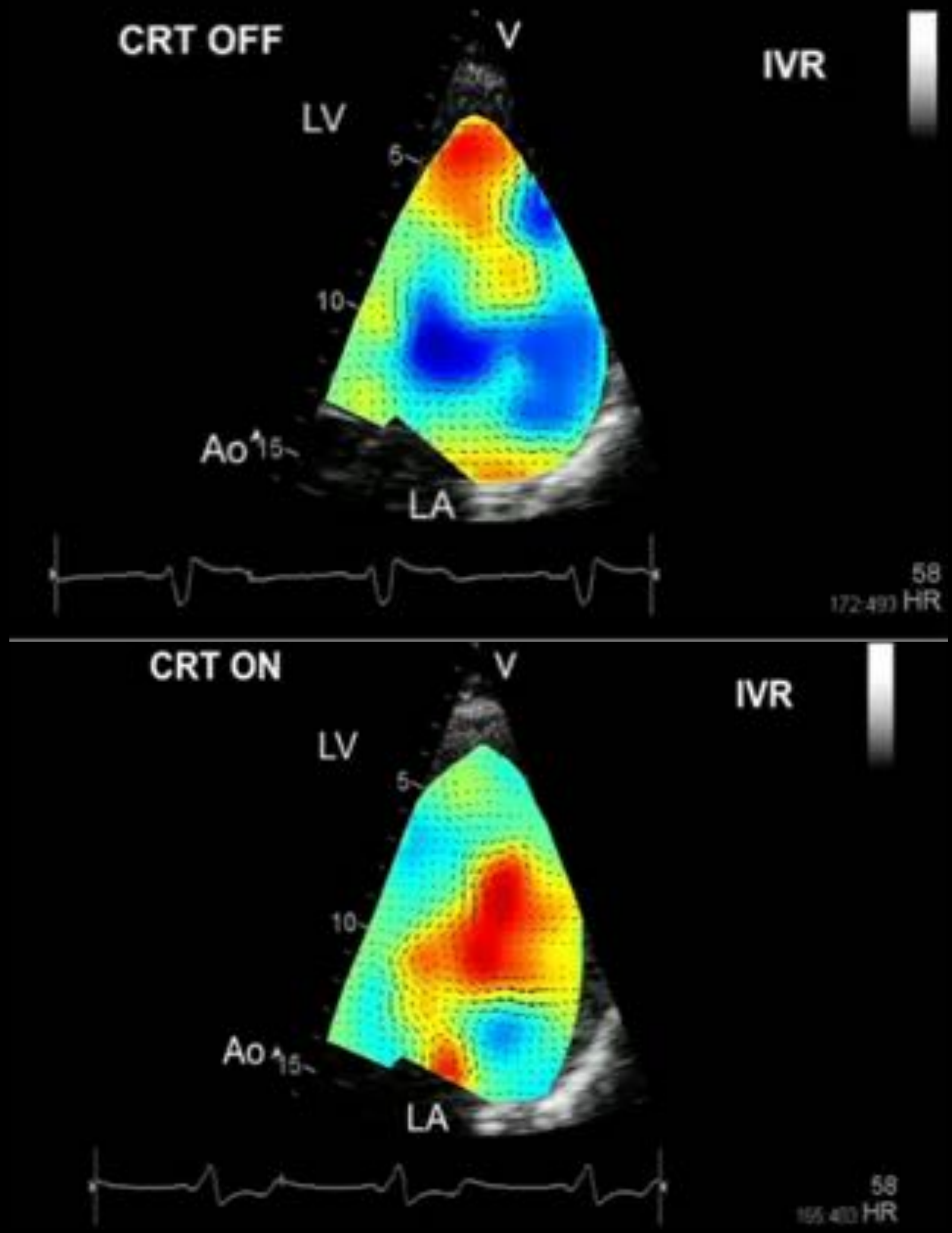
base

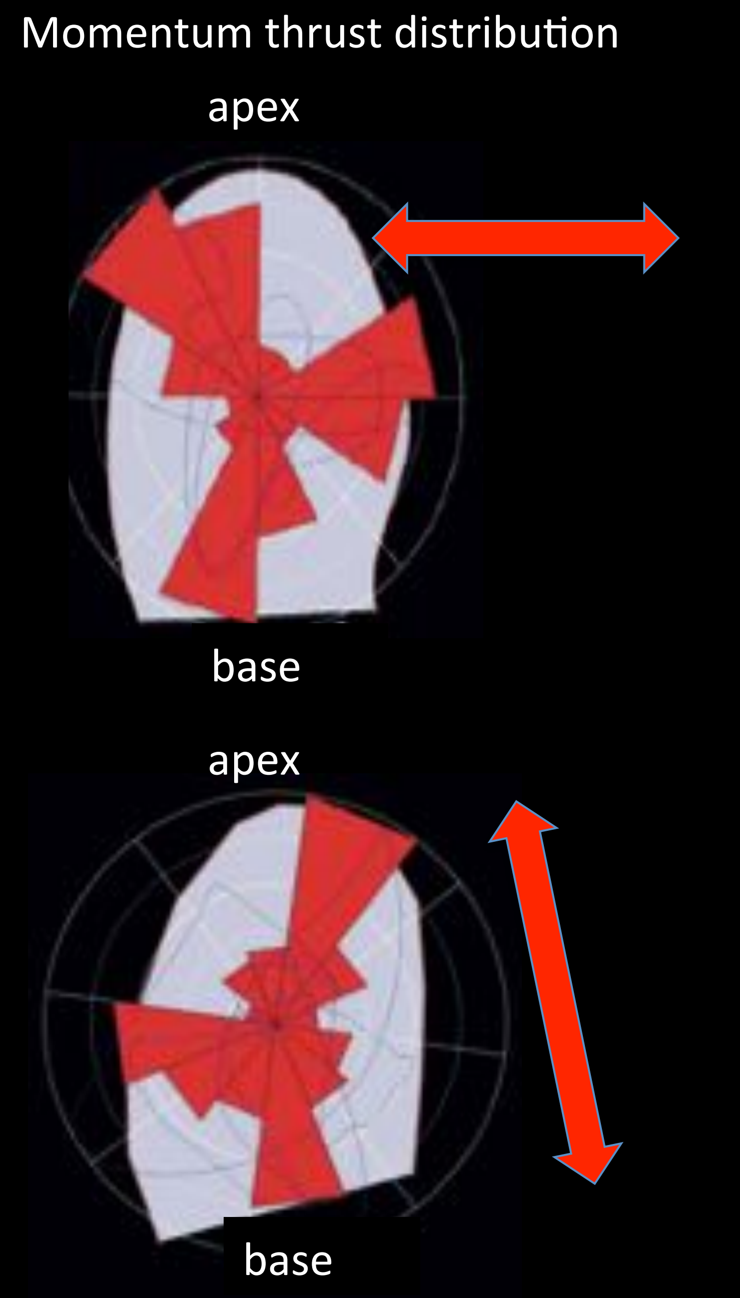
Longitudinal alignment of the
intraventricular hemodynamic forces

Rimodellamento ventricolare



Heart Failure Patient





Aim of the study

The aim of our study was to characterize the effect of MPP compared to conventional CRT (single site LV pacing) on

(i) LV mechanics assessed by ***3D-Echocardiography (3DE)***
(ii) fluid dynamics assessed by ***Echocardiographic Particle Image Velocimetry (Echo-PIV)***

Methods

Study Population

The study population included ***9 consecutive patients*** underwent CRT-D with a quadripolar LV lead (***Quartet, 1458Q, St Jude Medical, Inc., Sylmar, CA***) according to the current ESC guidelines.

Study Protocol

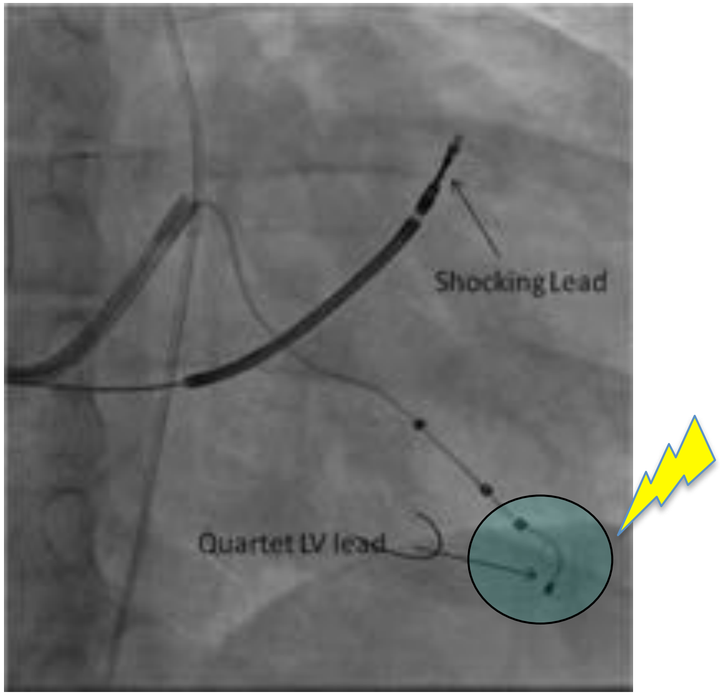
Patients with AF were excluded;
Six months after CRT-D implant we compared baseline (CRT-OFF), conventional-CRT and MPP;

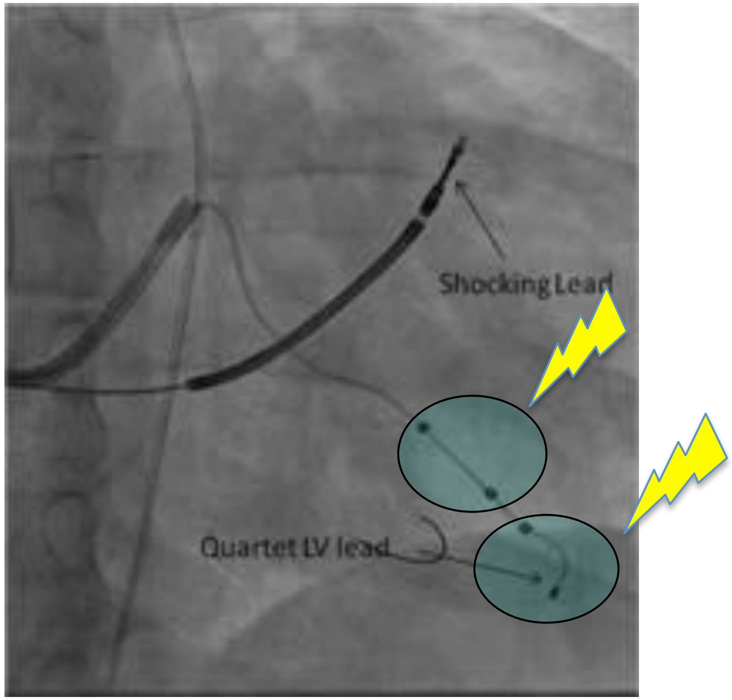
For each pacing configuration

- ✓ ***12-lead-ECG width;***
- ✓ ***2D/3D-Echocardiography***;
- ✓ ***Echocardiographic particle image velocimetry (Echo-PIV).***

Evaluation of pacing configurations was performed blinded and in a random order.

Pacing Protocol at Implant





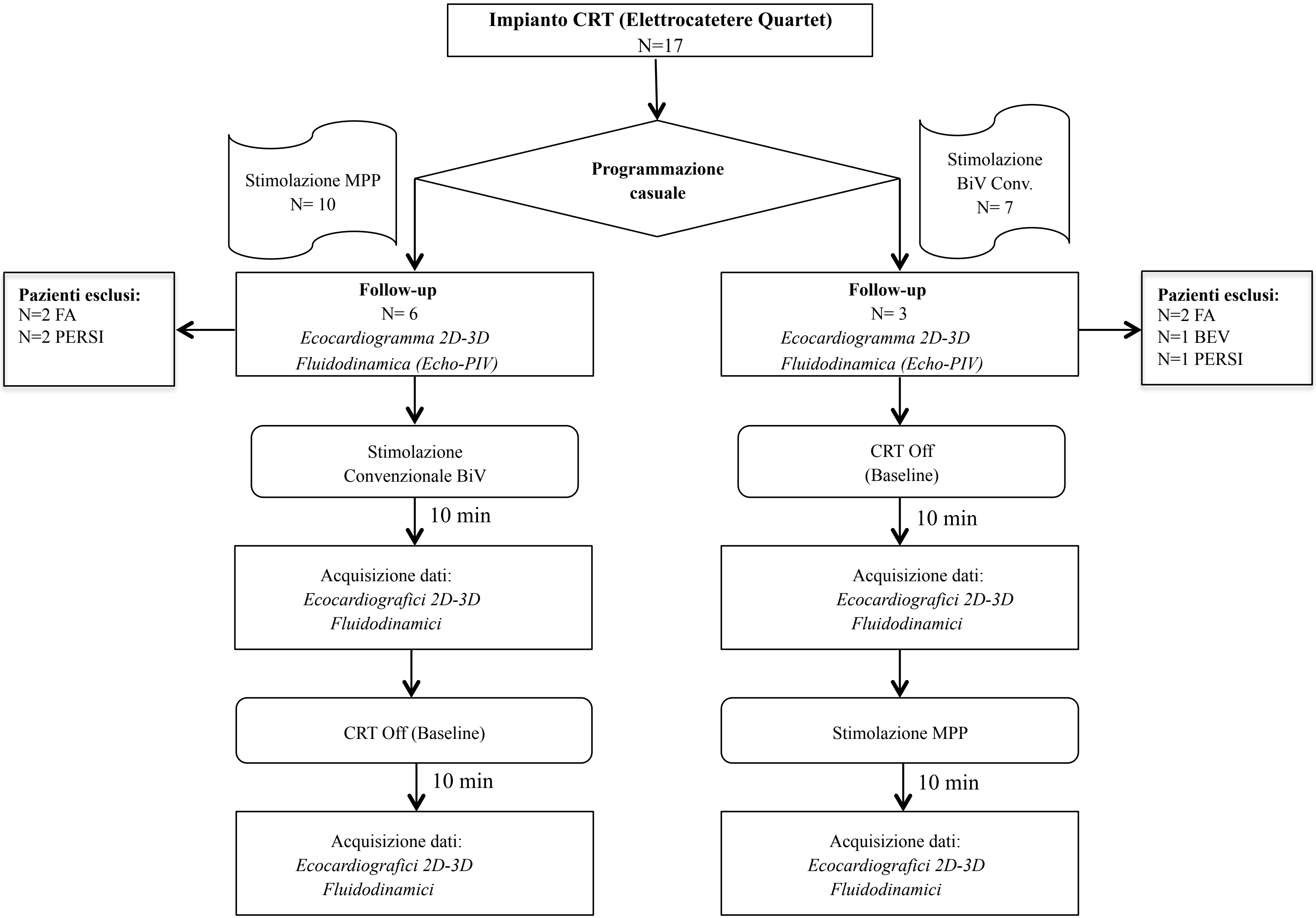
Conventional CRT (1 LV point)

Conv-CRT, was delivered using each of the four LV electrodes in extended bipolar configuration.
We chose the vector with the longest left ventricular electric delay as measured from RV sensing (by Toolkit).
Fixed AV 120ms; VV = 0 delay

MPP (2 LV points)

MPP was selected to pace first from a site of late electrical activation (LV1) and second from a site of early activation (LV2) as measured from RV sensing (by Toolkit) used as cathode and an adjacent electrodes as anode in order to capture as larger area of the LV as possible.
Fixed AV 120ms; VV delays were provided by QuickOpt with a fixed delay of 5 ms between LV pacing sites.

Protocollo di Studio

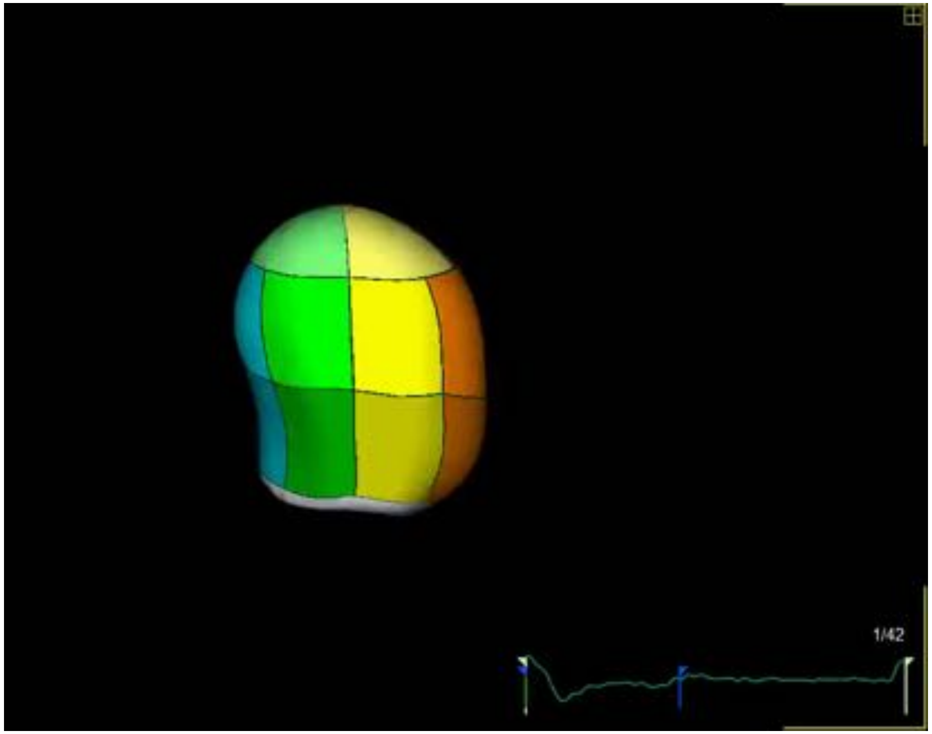


3D Echocardiographics Assessment

Ecocardiography *Vivid E9 (G.E. Vingmed, Horten Norway)*

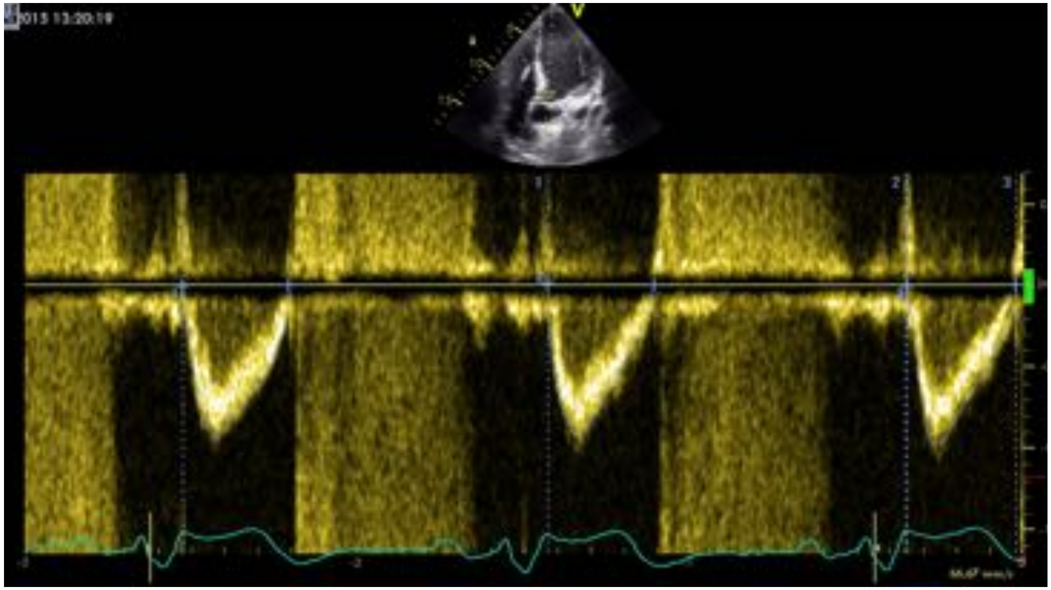
LV Volumes

- *End-Diastolic Volume (EDV)*
- *End-Systolic Volume (ESV)*



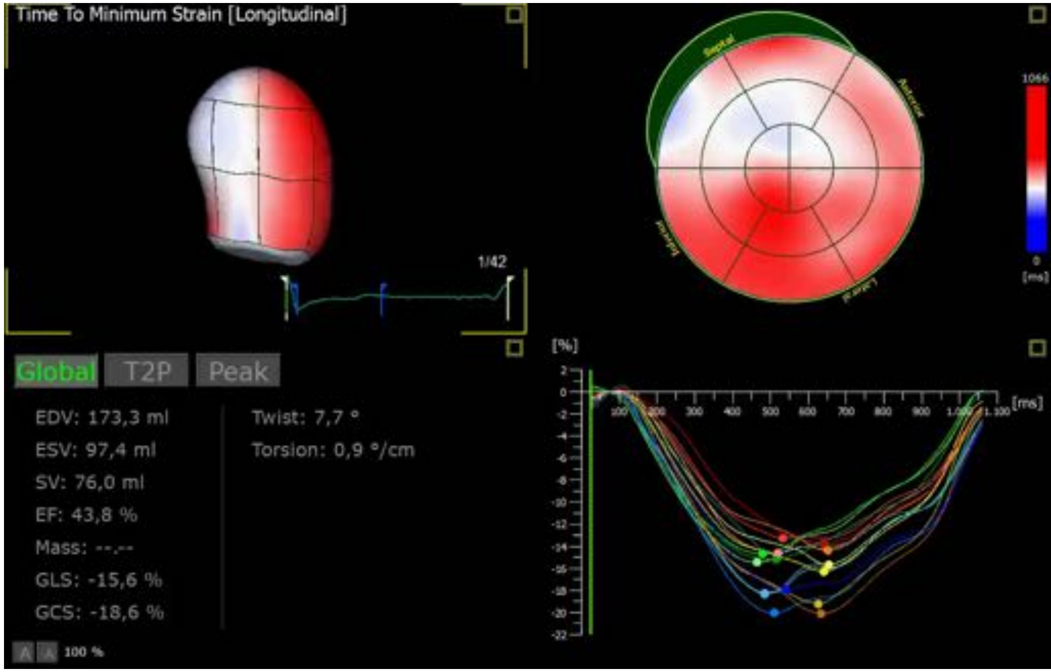
Hemodynamics

- *LVEF*
- *LVOT Vmax*
- *LVOT VTI*
- *LVCO (cardiac output)*
- *LVCI (cardiac index)*

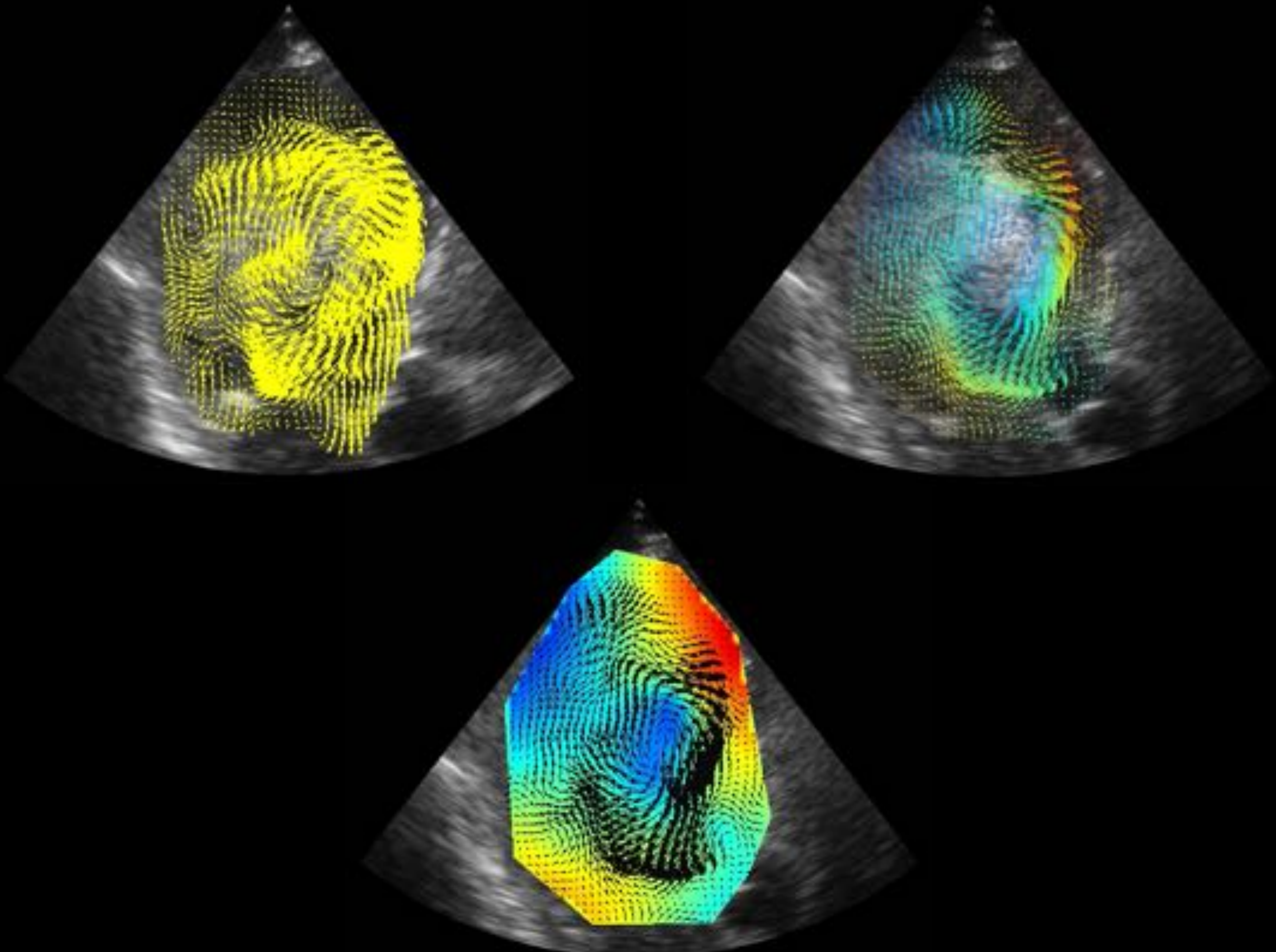


Mechanical Dyssynchrony

- *GLS (global longitudinal strain)*
- *GCS (global circunferential strain)*
- *SDI (systolic dyssynchrony index)*

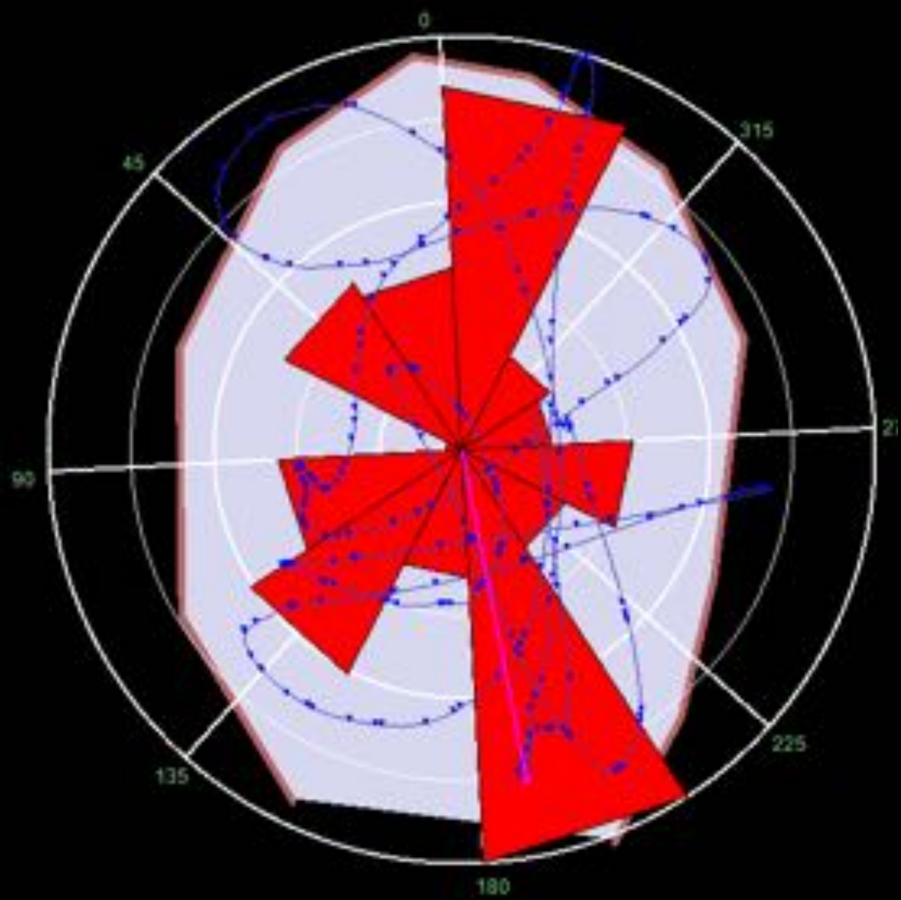


Echo-PIV
(Echocardiographic particle image velocimetry)



Momentum thrust distribution of the intraventricular hemodynamic forces

apex

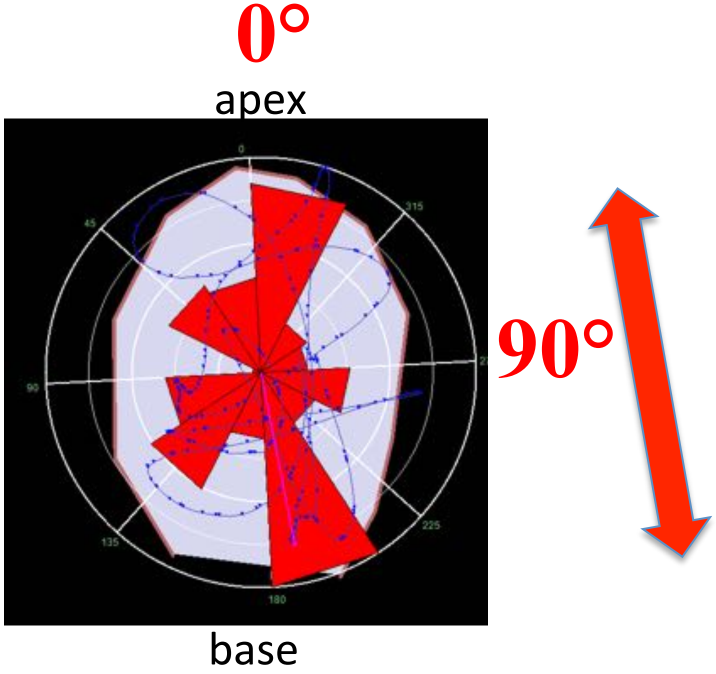


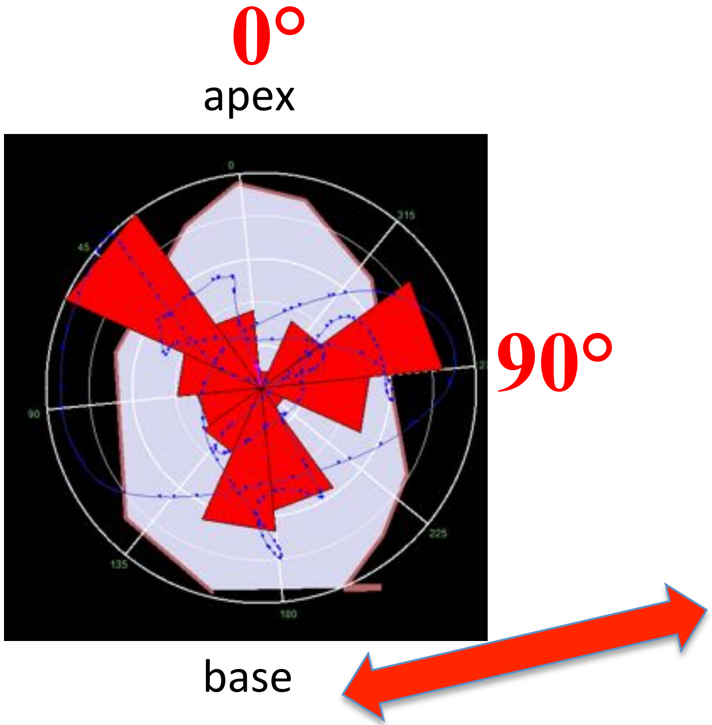
base

Fluid dynamics assessment

- *Vortex area*
- *Vortex intensity*
- *Vortex length*
- *Vortex depth*
- *Energy dissipation*
- *Vorticity fluctuation*
- *Kinetic energy fluctuation*
- *Shear stress fluctuation*
- ***Flow Force Angle***
- *Flow Force Dispersion Angle*

It indicates the dominant orientation of the *haemodynamic forces*.
This parameter ranges from 0°, when Flow Force Angle is predominantly *longitudinal*, along the base–apex direction, up to 90° when it becomes *transversal*.





Results: *baseline clinical characteristics*

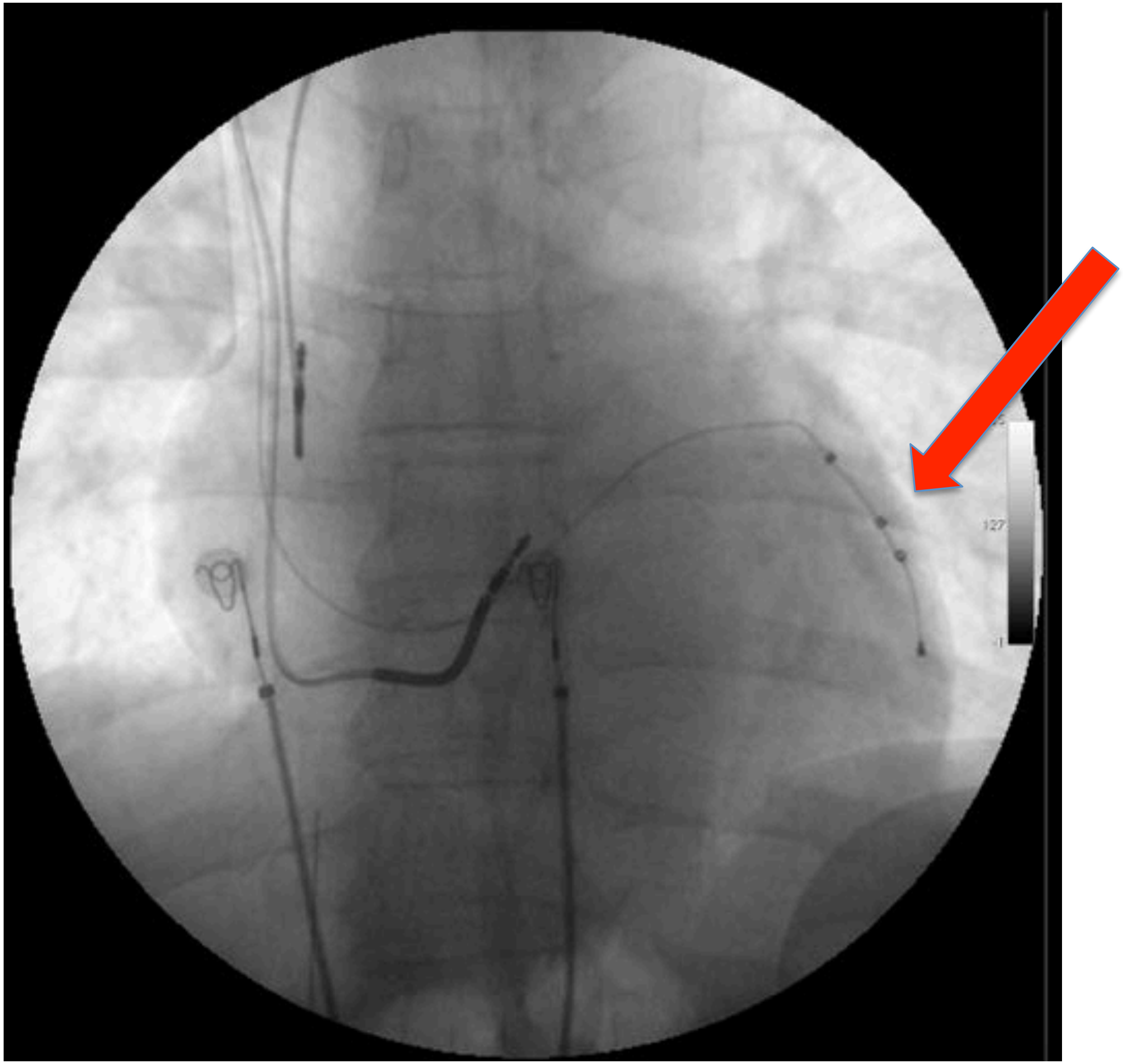
	Study population n = 9
Age, year	65 (57-75)
Sex, male	6 (67)
BSA, m^2	1.77 (1.76-1.8)
Hypertension	7 (78)
Diabetes	2 (22)
Dyslipidaemia	5 (55)
Renal failure	3 (33)
NYHA functional class	2 (2-3)
Ischaemic aetiology	2 (22)
Previous MI	1 (11)
Previous PTCA + STENT	1 (11)
QRS width, ms *	160 (155-160)
First degree AV block	2 (22)
Pharmacological therapy	
ACE-I	7 (78)
Spironolactone	8 (88)
Betablockers	9 (100)
Diuretics	8 (88)
Statins	5 (55)
Antiplatelets	4 (44)
Anticoagulants	2 (22)

**LBBB morphology according to Strauss*

Results: *basal 2D ecocardiographic characteristics*

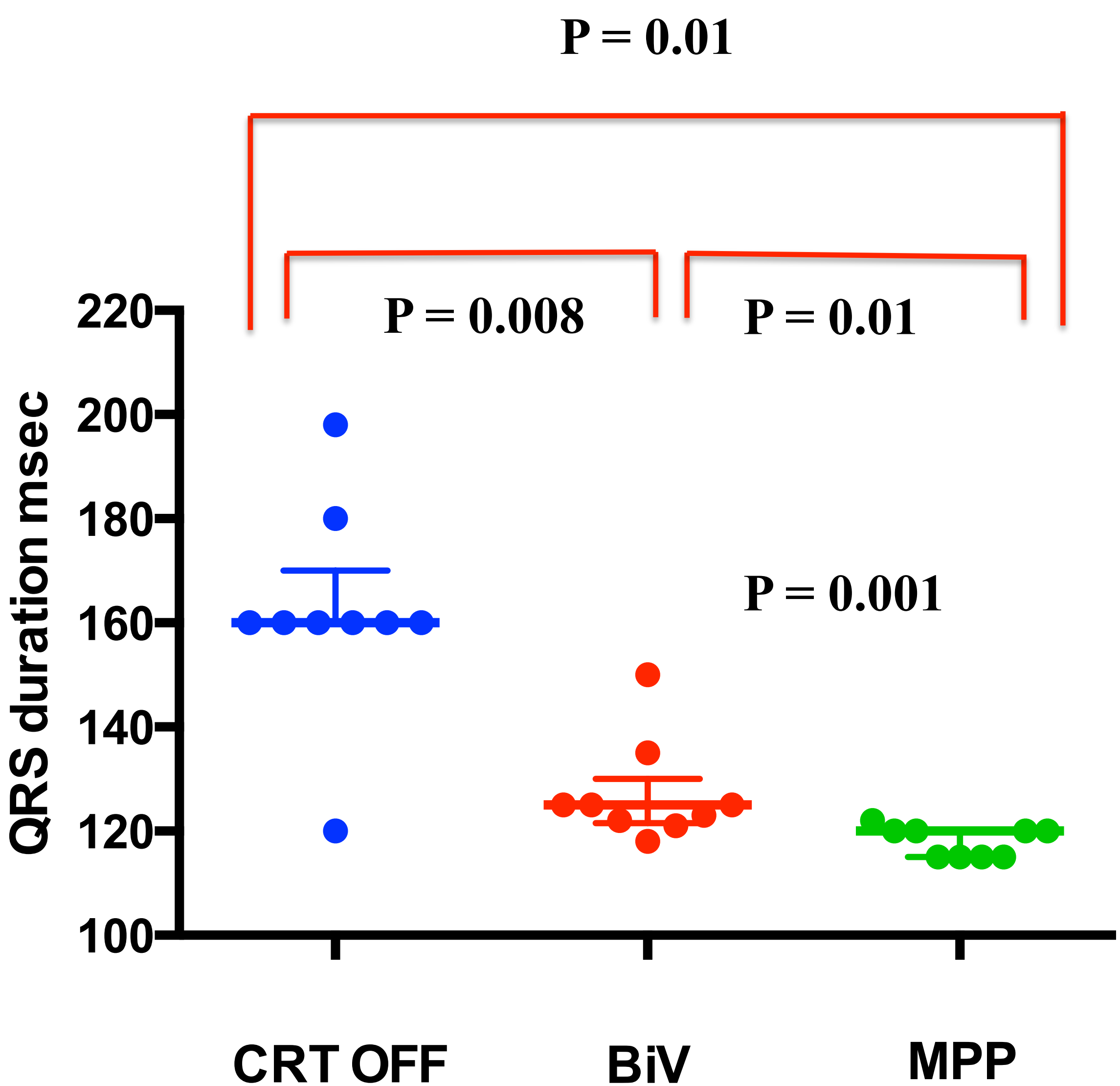
	Study population n = 9
EDV, ml/m^2	123 (117-169)
ESV, ml/m^2	108 (86-125)
LVEF, %	27 (23-28)
DTD, mm	71 (65-74)
MI almost moderate	7 (78)
PAPS, mmHg	35 (26-44)

Results: *implant procedure*

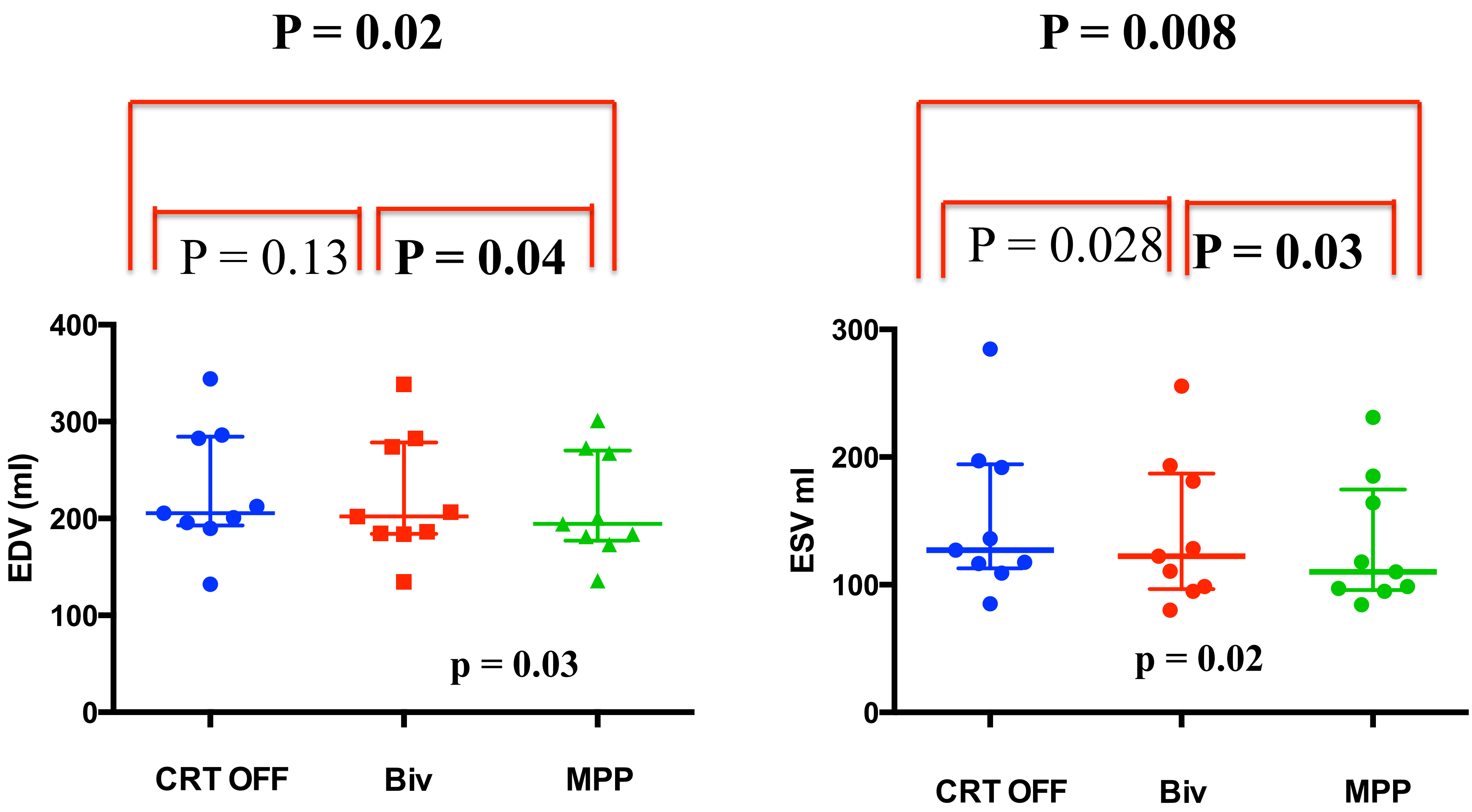


7 (78%) patients were CRT RESPONDER

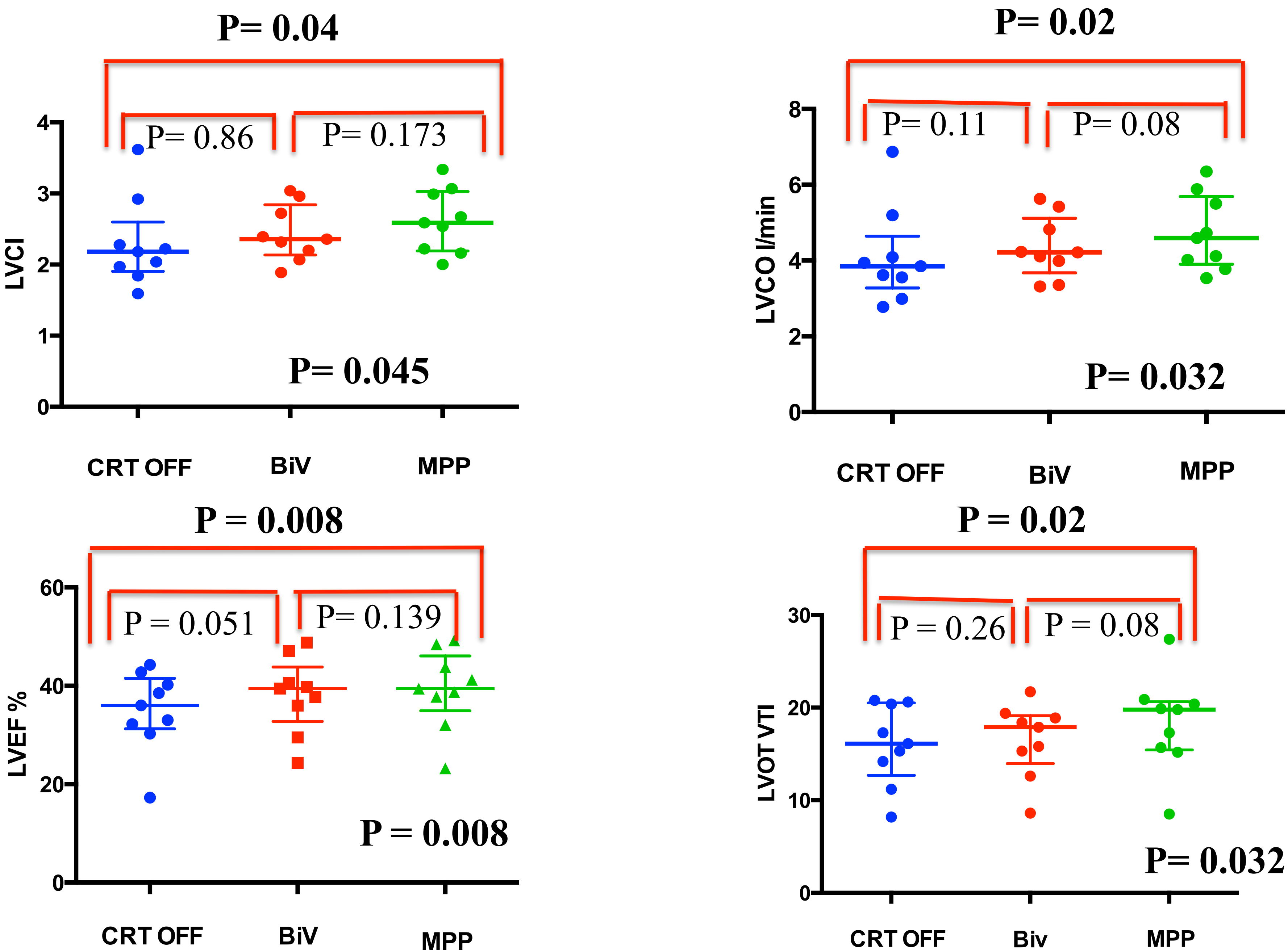
Results: *QRS width*



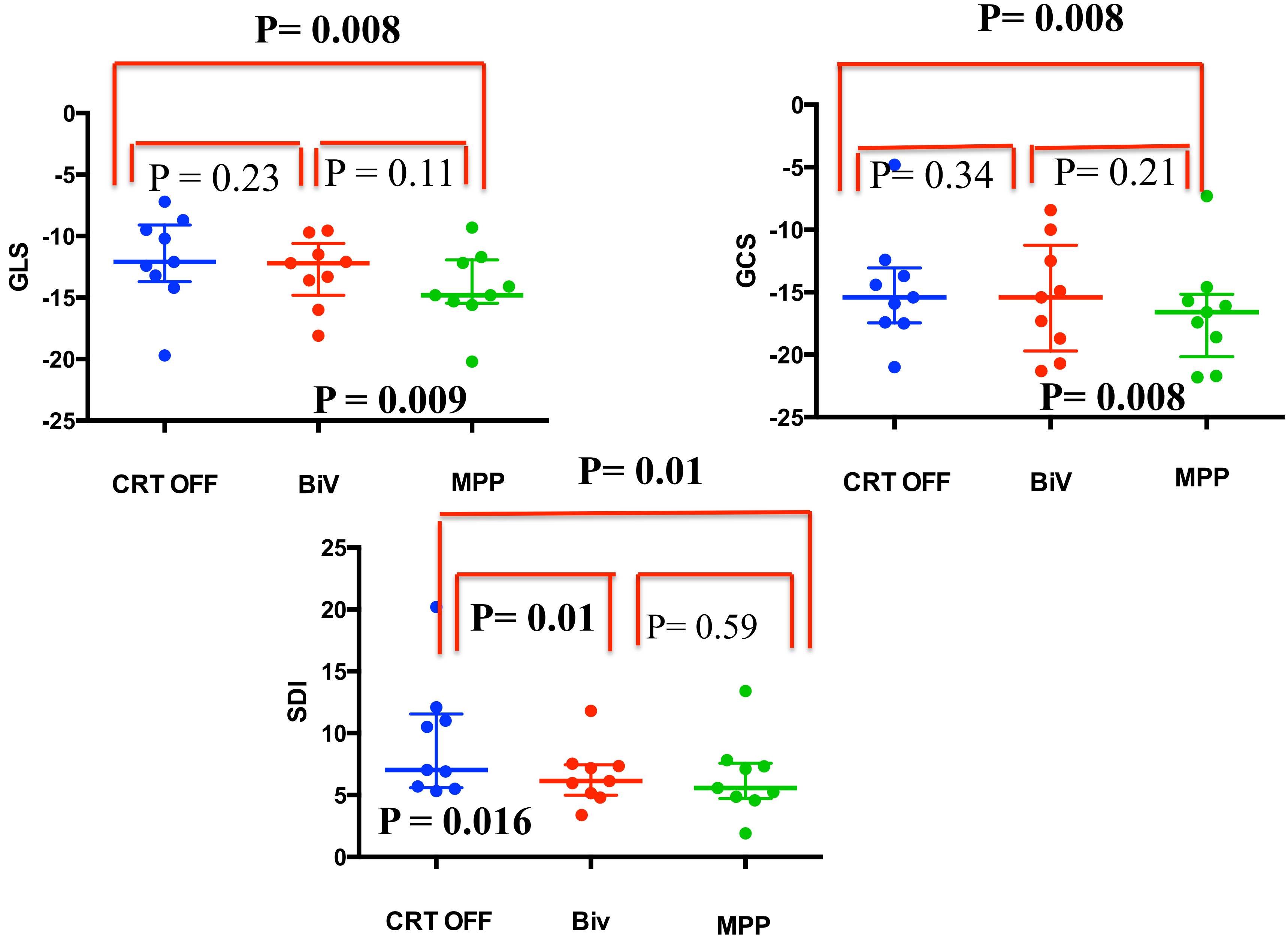
Results: *Volumetric 3D-Echo parameters*



Results: *3D Echo Systolic Parameters*

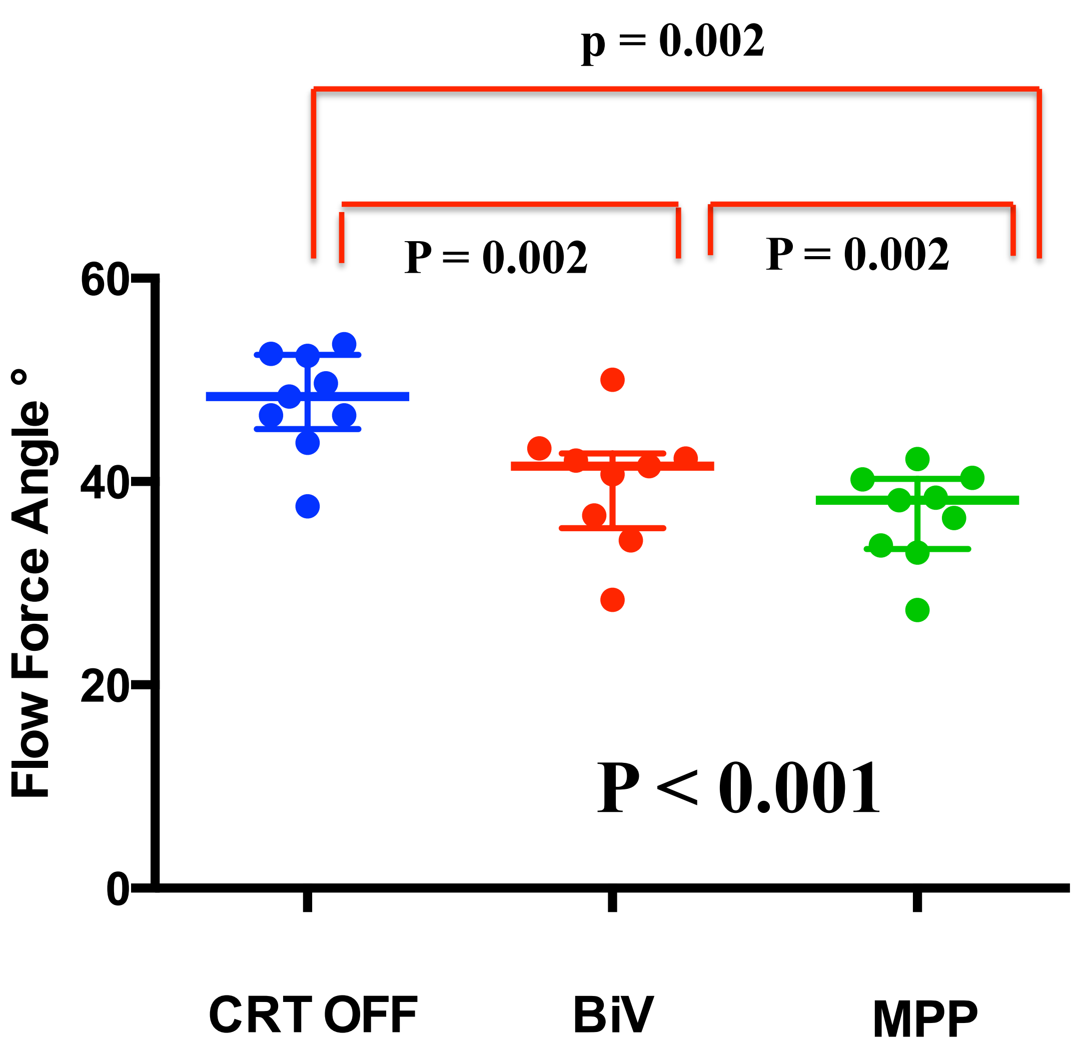


Results: *Dyssincrony parameters*



Results:

Fluid dynamics assessment
Flow Force Angle by Echo-PIV

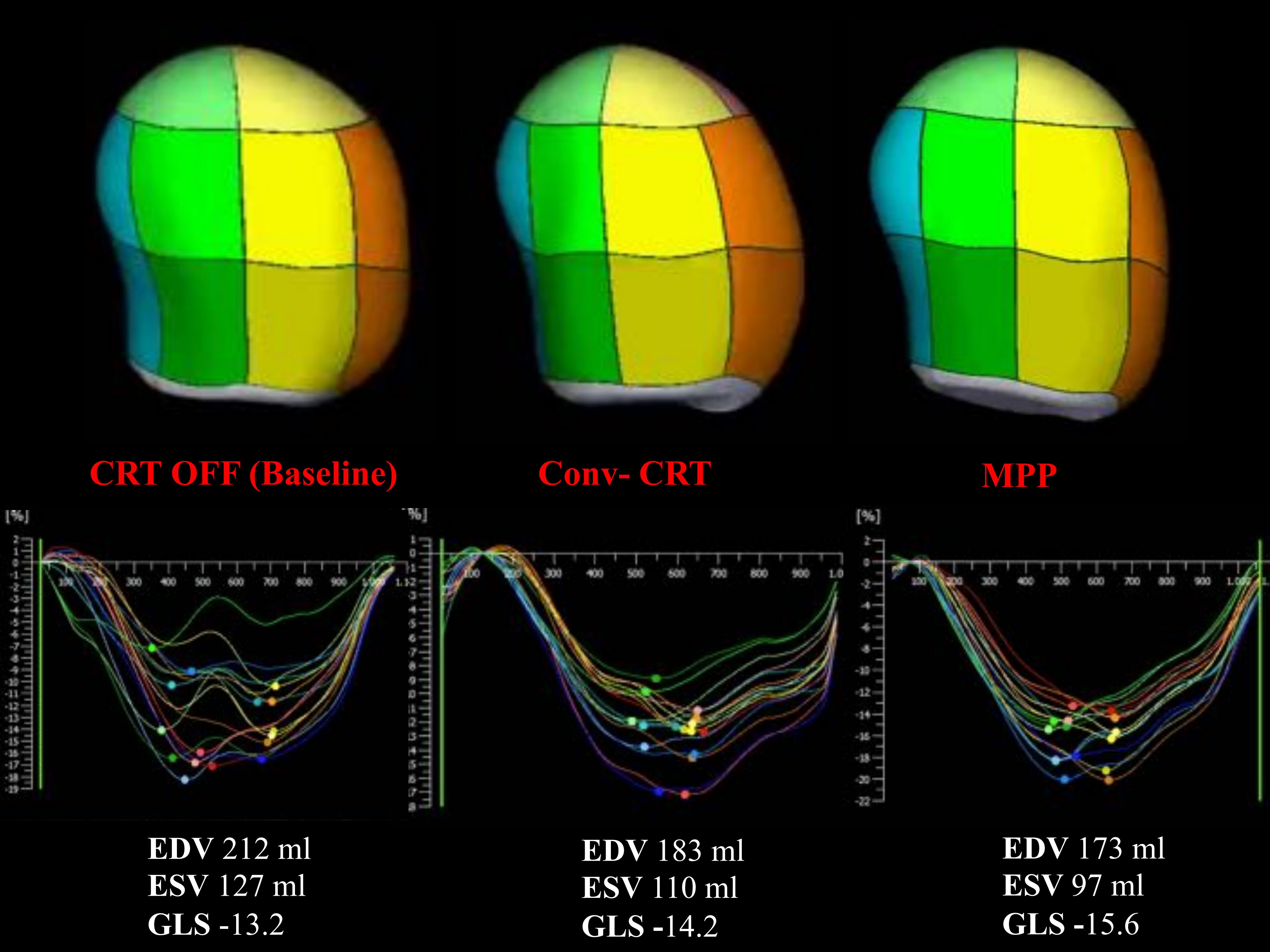


Case Report

- ✓ Female, 79 years old
- ✓ NYHA 3
- ✓ Primitive dilatated cardiomyopathy
- ✓ QRS width at baseline 160 ms
- ✓ LVEF at the baseline 27%
- ✓ Optimize pharmacological therapy

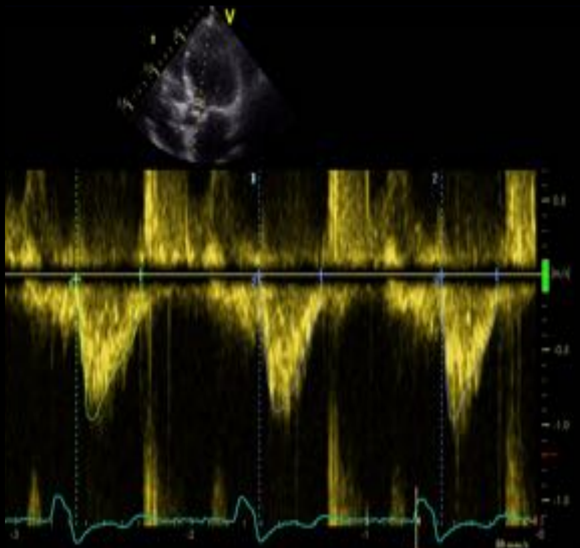
- ✓ She was implanted with CRT-D in primary prevention

- ✓ After 6 months she underwent our study protocol



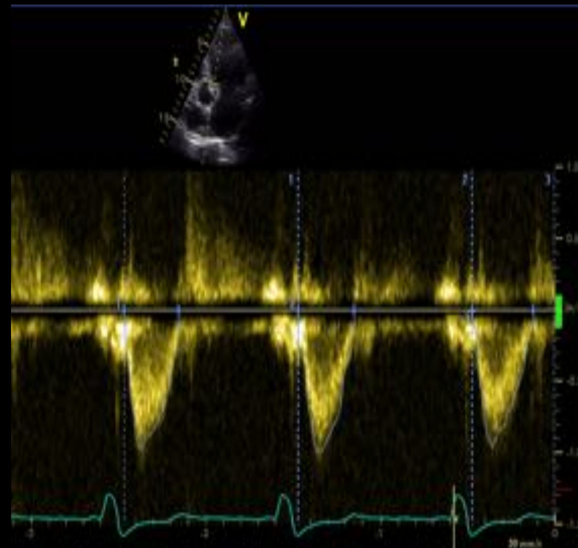
CRT OFF (Baseline)
Conv- CRT
MPP
[%]
EDV 212 ml
ESV 127 ml
GLS -13.2
EDV 183 ml
ESV 110 ml
GLS -14.2
EDV 173 ml
ESV 97 ml
GLS -15.6

CRT OFF



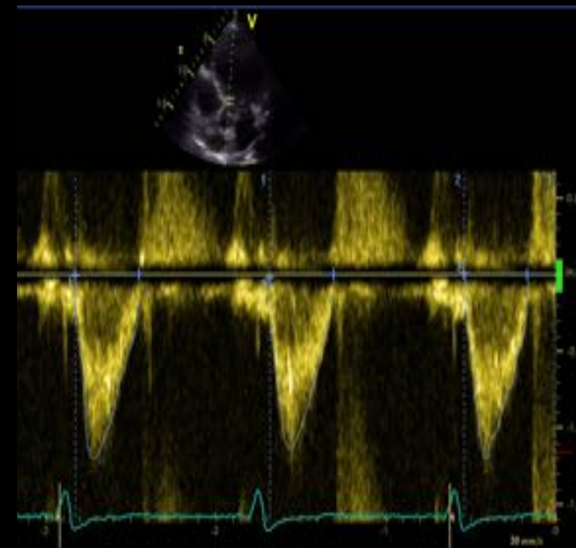
Doppler Measurements		
Aortic		
LVOT Diam	2.0 cm	Av
LVOT Trace		
LVOT Vmax	0.89 m/s	Av
LVOT Vmean	0.67 m/s	Av
LVOT maxPG	3.14 mmHg	Av
LVOT meanPG	1.62 mmHg	Av
LVOT Env. Ti	367 ms	Av
LVOT VTI	20.8 cm	Av
HR	58 BPM	Av
LVSV Dopp	68 ml	
LVCO Dopp	3.93 l/min	

BiV conv

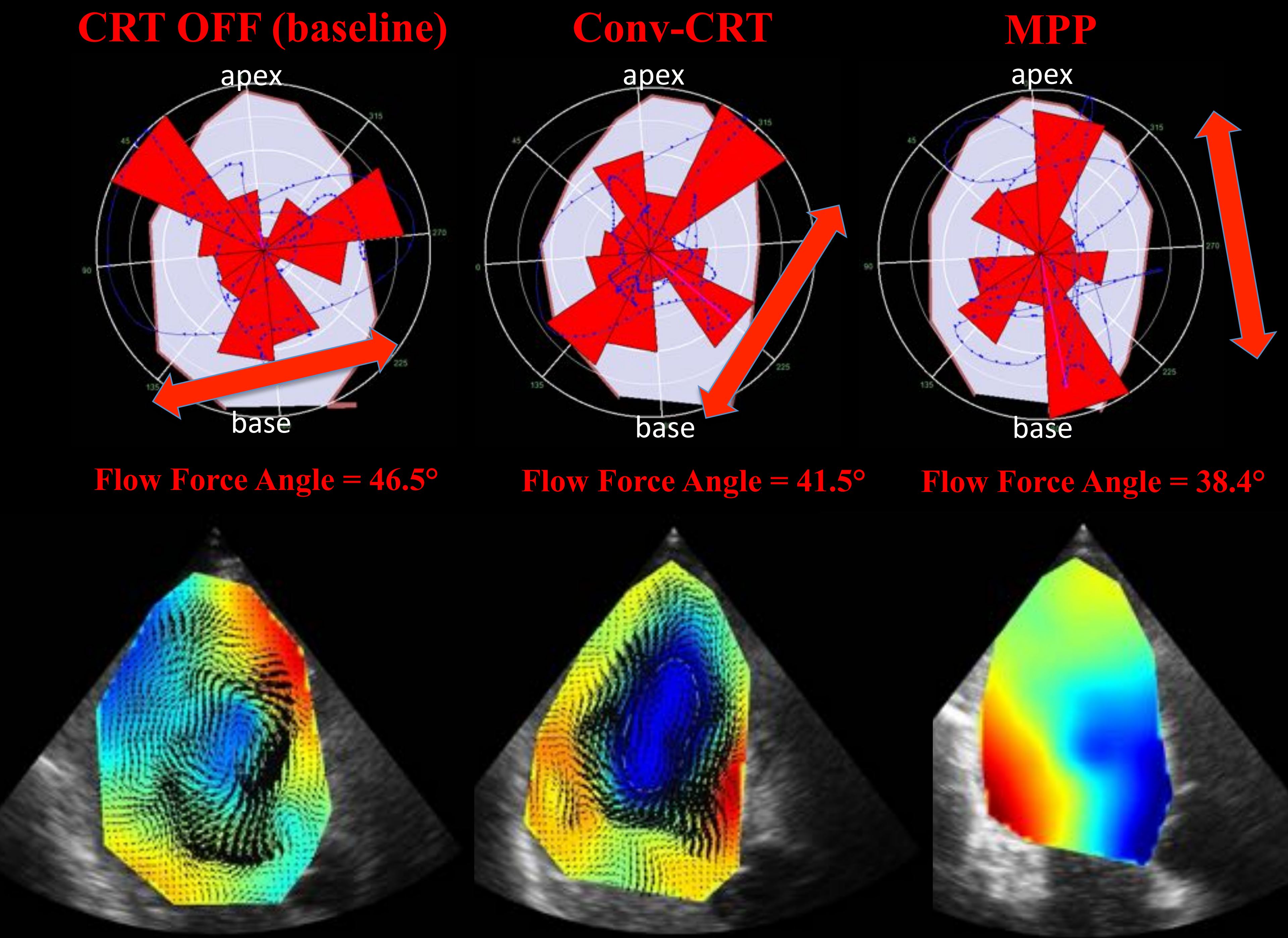


Doppler Measurements		
Aortic		
LVOT Diam	2.0 cm	Av
LVOT Trace		
LVOT Vmax	1.11 m/s	Av
LVOT Vmean	0.68 m/s	Av
LVOT maxPG	4.93 mmHg	Av
LVOT meanPG	2.27 mmHg	Av
LVOT Env. Ti	318 ms	Av
LVOT VTI	21.7 cm	Av
HR	60 BPM	Av
LVSV Dopp	71 ml	
LVSI Dopp	39.91 ml/m2	
LVCO Dopp	4.23 l/min	

MPP



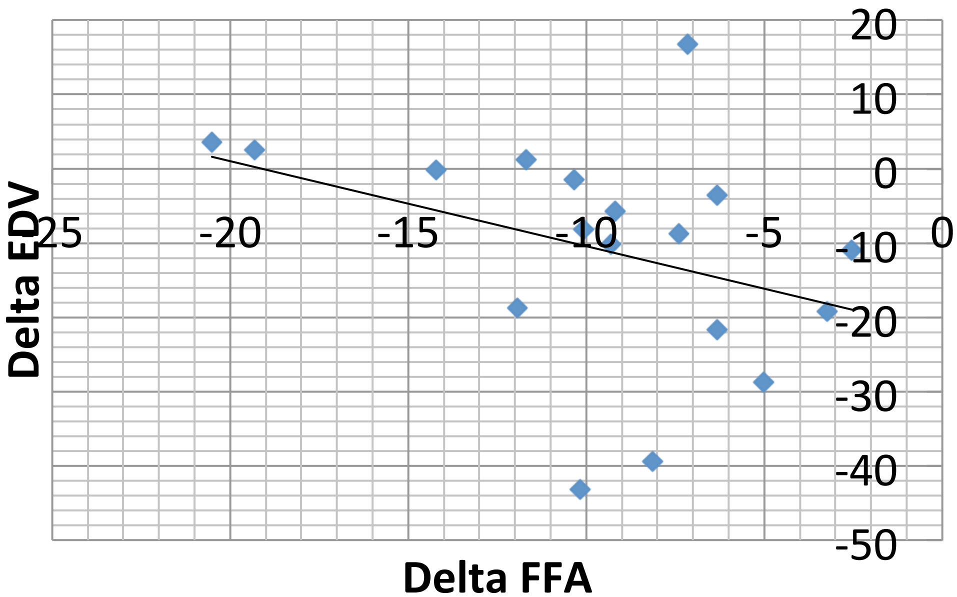
Doppler Measurements		
Aortic		
LVOT Diam	2.0 cm	Av
LVOT Trace		
LVOT Vmax	1.12 m/s	Av
LVOT Vmean	0.70 m/s	Av
LVOT maxPG	4.98 mmHg	Av
LVOT meanPG	2.38 mmHg	Av
LVOT Env. Ti	390 ms	Av
LVOT VTI	27.4 cm	Av
HR	53 BPM	Av
LVSV Dopp	88 ml	
LVCO Dopp	4.60 l/min	



CRT OFF (baseline)
Conv-CRT
MPP
apex
base
apex
base
apex
base
Flow Force Angle = 46.5°
Flow Force Angle = 41.5°
Flow Force Angle = 38.4°

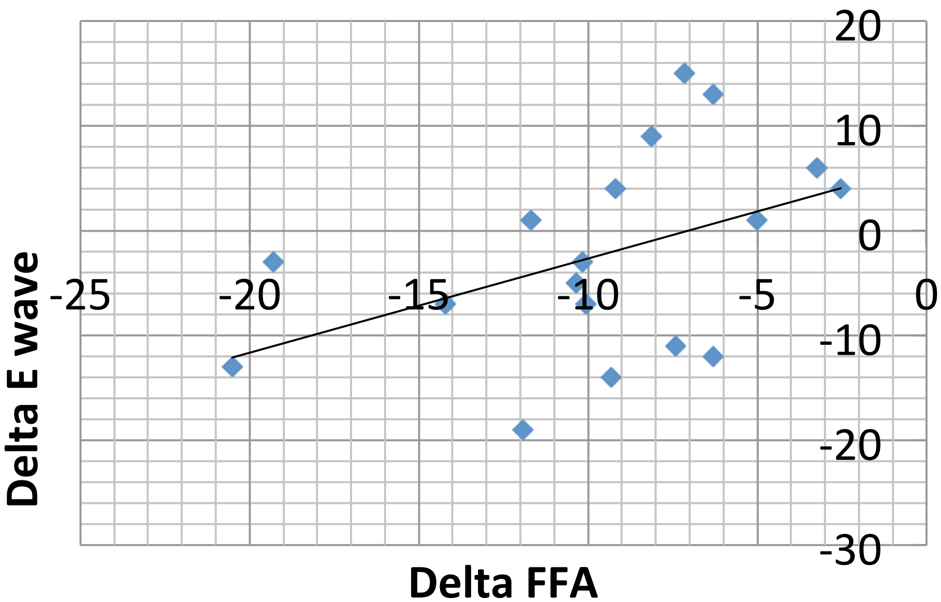
Correlations:

VOLUMETRIC REDUCTION



Spearman coeff = -0,60
P = 0.02

EARLY DIASTOLIC FILLING



Spearman coeff = 0,58
P = 0.03

This correlation resulted to be mainly ascribed to a ***significant correlation*** between ***Flow Force Angle at*** **MPP**, ***volumetric reductions and improvement of diastolic filling***.

Conclusions

- ✓ Our preliminary findings demonstrated that MPP resulted in a significant improvement in acute response of LV mechnanics and fluid dynamics by 3D Echo and Echo-PIV compared conventional CRT;
- ✓ MPP resulted in lower Flow Force Angle indicating a predominantly longitudinal orientation with a base–apex direction of the LV haemodynamic forces compared baseline and conventional CRT;
- ✓ This suggests that the electric changes provided by CRT are more effective when they reflect into haemodynamic modifications that improve the longitudinal orientation of flow forces;
- ✓ The emerging *Echo-PIV* technique may be useful for elucidating the favorable effects of CRT on diastolic filling and it could be used for optimizing the biventricular pacing setting;
- ✓ This is a preliminary study on a limited number of patients that should be confirmed or refined in larger prospective studies.


Thank you…

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Changes in electrical activation modify the orientation of left ventricular flow momentum: novel observations using echocardiographic particle image velocimetry

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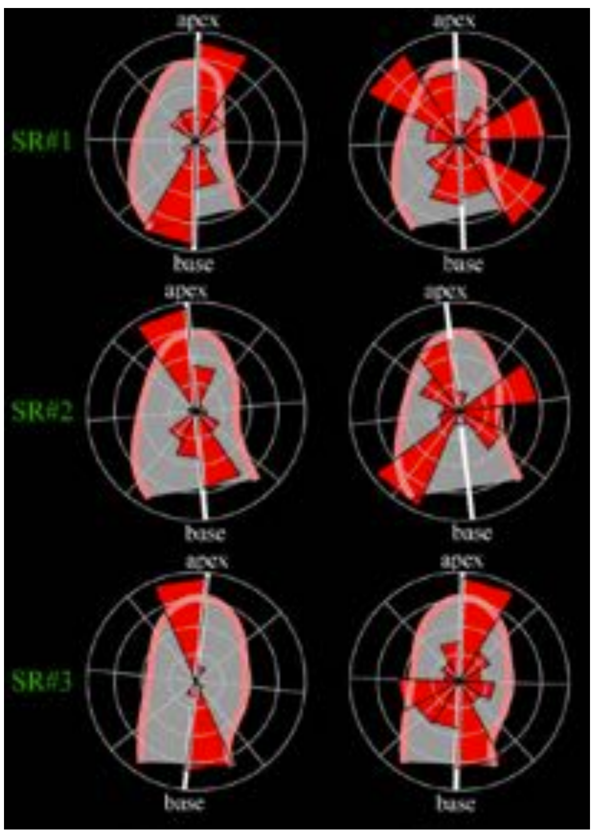
CRT-ON CRT-OFF



CRT-ON CRT-OFF