La fluidodinamica valutata con mezzi di contrasto ecografici

ECOCARDIOGRAFIA 2015 – XVII CONGRESSO NAZIONALE
SIEC Napoli, 16-18 aprile 2015

Prof Luciano Agati

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Sapienza Università di Roma

NEWS on Contrast Ultrasound 2015

- **World Imaging Agents Market to Exceed US$14 Billion by 2015, According to New Report by Global Industry Analysts, Inc.**

- This is mainly due to the wide availability of existing equipment in key markets including Europe and the US and increasing focus on diagnostic examinations that facilitate early identification of the disease and its treatment.

Contrast Ultrasound in Cardiology

- In the USA in 2010, there was 28 millions of echocardiographic studies and 1 million were with contrast (3.5%)
- In EU it is more difficult to get precise data. Estimation is 250.000 contrast procedures out of 20 millions (1.5%) echocardiographic studies.
- In the UK we have most precise data:

  - Stress echo procedures: 40.876

  - Contrast proc: 28.279 (69%)

Contrast echocardiography. Main problems

- No reimbursement of contrast echo in several EU countries
- No approval for myocardial perfusion
- Need for "top level" echo instruments and dedicated software
- Need for learning curve
- Operator/ Acoustic window dependent

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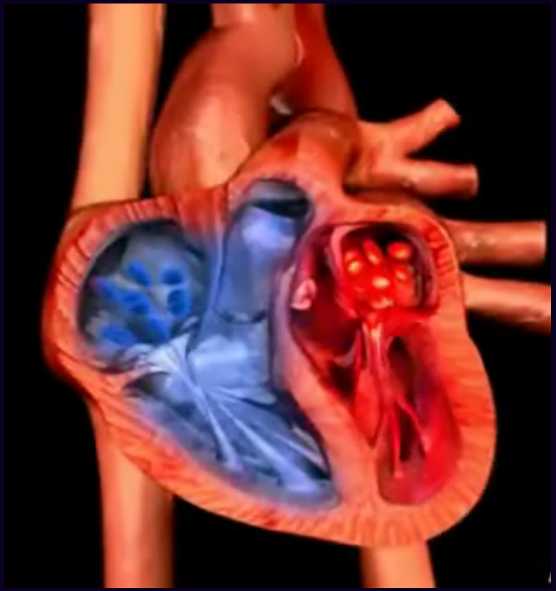


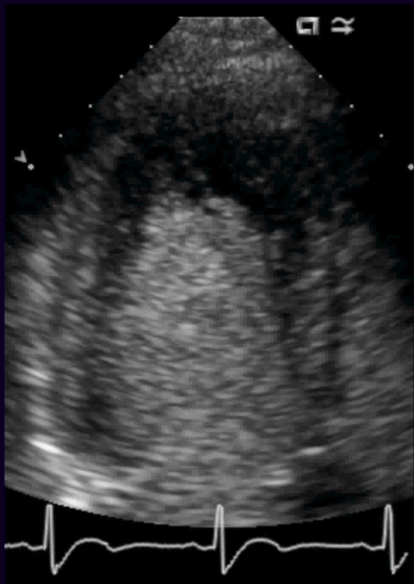
I.V. flow assessment

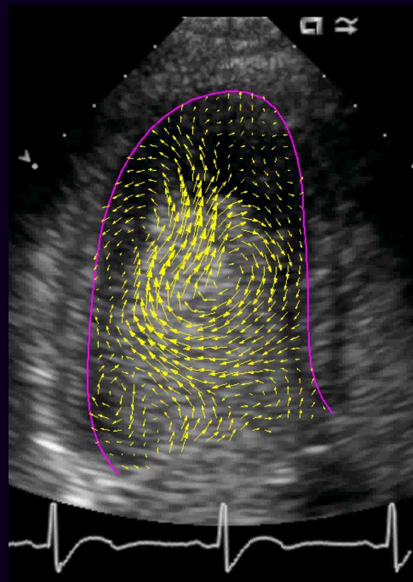
Luciano Agati, MD
Gianni Tonti, MD
Gianni Pedrizzetti, PhD

- Dept of Cardiology, Sapienza University of Rome, Italy
- Dept of Engineering. University of Trieste, Italy
- AMID, Italy

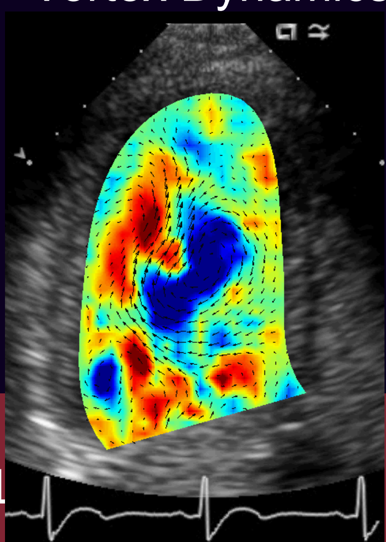
Vorticity & Energy Parameters

Parameter	Value
Vortex Area	0.360
Vortex Intensity	-0.392
Vortex Depth	0.473
Vortex Length	0.726
Energy Dissipation	0.633
Vorticity Fluctuation	0.838
Kinetic Energy Fluctuation	1.735
Shear Stress Fluctuation	0.185
Dominant Force Strength	12.397
CCW from Apex	-15.454

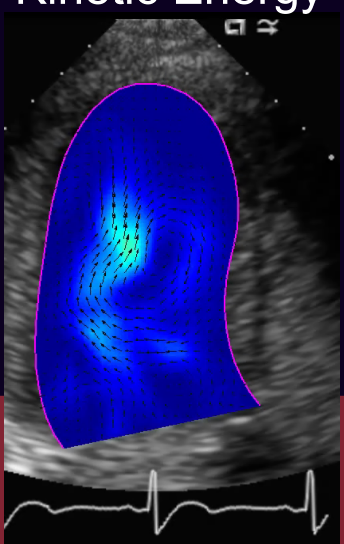




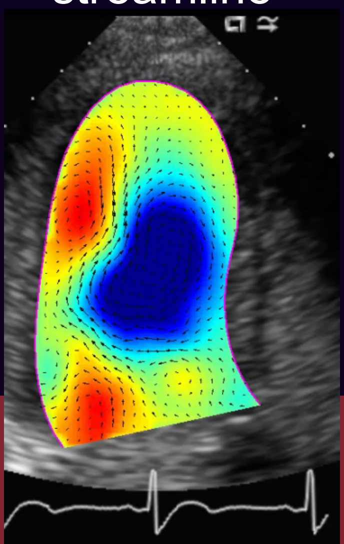
Vortex Dynamics



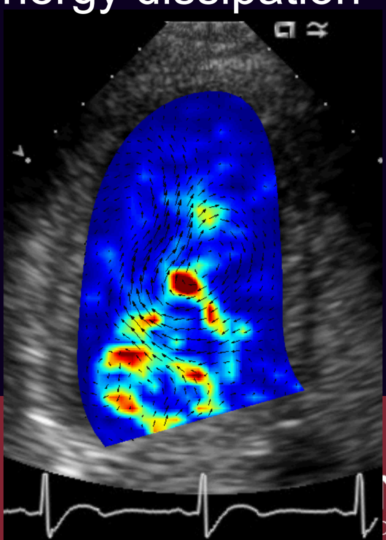
Kinetic Energy



Stream function streamline



Energy dissipation



3D Echo flow

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In vivo analysis of intraventricular fluid dynamics in healthy hearts

S. Cimino[a], G. Pedrizzetti[b], G. Tonti[c], E. Canali[a], V. Petronilli[a], L. De Luca[a], C. Iacoboni[a], L. Agati[a,*]

[a] Department of Cardiovascular Science, "Sapienza" University, Roma, Italy
[b] DICAr, University of Trieste, Italy
[c] SS. Annunziata Hospital, Sulmona, AQ, Italy

Table 2
Vortex and energetic dimensionless parameters.

Parameter	Mean ± st. dev	CI
Vortex area	0.29 ± 0.1	0.12–0.46
Vortex circulation	− 0.33 ± 0.28	− 0.56–0.17
Vortex length	0.62 ± 0.12	0.4–0.75
Vortex depth	0.36 ± 0.12	0.18–0.6
Energy dissipation	0.37 ± 0.13	0.2–0.58
Vorticity fluctuation	0.74 ± 0.12	0.61–0.93
Kinetic energy fluctuation	1.38 ± 0.3	0.9–1.7
Shear stress fluctuation	0.17 ± 0.3	− 0.3–0.64

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Quantitative analysis of intraventricular blood flow dynamics by echocardiographic particle image velocimetry in patients with acute myocardial infarction at different stages of left ventricular dysfunction

L. Agati[1]*, S. Cimino[1], G. Tonti[2], F. Cicogna[1], V. Petronilli[1], L. De Luca[1], C. Iacoboni[1], and G. Pedrizzetti[3]

Methods

Echo - PIV

Characterization and Quantification of Vortex Flow in the Human Left Ventricle by Contrast Echocardiography Using Vector Particle Image Velocimetry

Geu-Ru Hong, MD, PHD,*† Gianni Pedrizzetti, PHD,‡ Giovanni Tonti, MD,§ Peng Li, MD, PHD,* Zhao Wei, MD, PHD,* Jin Kyung Kim, MD, PHD,|| Abinav Baweja,|| Shizhen Liu, MD, PHD,* Namsik Chung, MD, PHD,¶ Helene Houle, RDCS,# Jagat Narula, MD, PHD, FACC,|| Mani A. Vannan, MBBS, FACC*

JACC Card Imag 2008

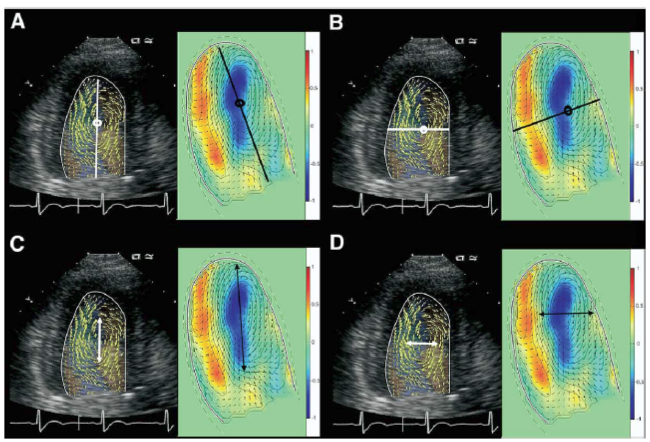
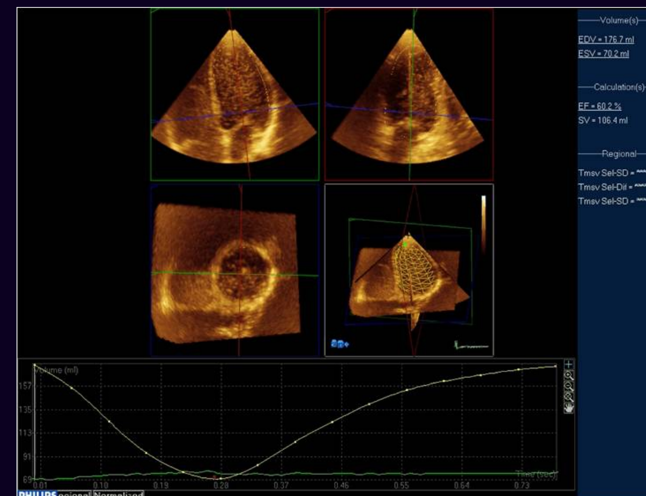
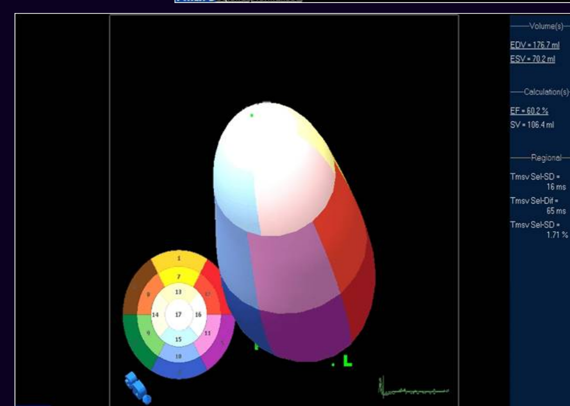


Figure 2. Description of How to Measure Quantitative Average Vortex Parameters That Represent Vortex Location and Shape

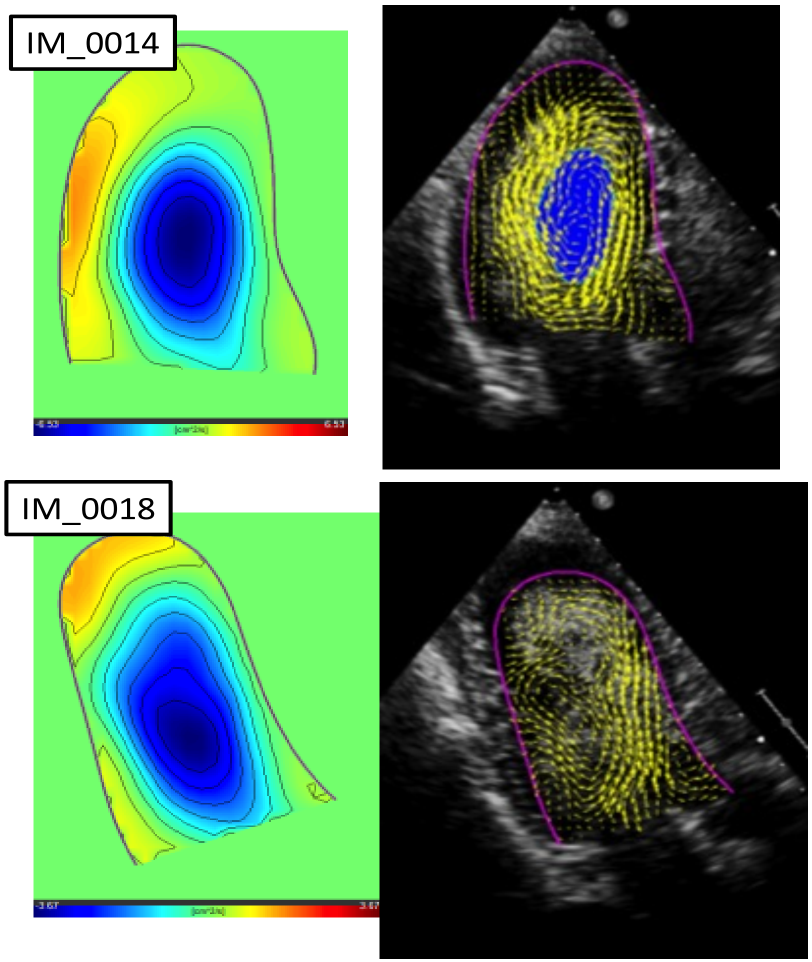
Vortex depth represents vertical position of center of vortex relative to left ventricular long axis (**A, white line**), and vortex transverse position represents transverse position relative to posteroseptal axis (**B, white line**). Vortex length was measured by longitudinal length of vortex relative to left ventricular length (**C, white arrow**), and vortex width was measured by horizontal length of vortex relative to left ventricular length (**D, white arrow**). A vortex sphericity index was calculated by vortex length and vortex width.

3D - Echo





Non invasive assessment of LV flow dynamics and mechanical function; a new approach for the global evaluation of LV efficiency



Parameter	IM_0014	IM_0018
Vortex Area	0,3413	0,4957
Vortex Intensity	-0,4838	-0,5527
Vortex Depth	0,3628	0,3803
Vortex Length	0,6699	0,7730
Energy Dissipation	0,1728	0,2221
Vorticity Fluctuation	0,6558	0,8557
Kinetic Energy Fluctuation	0,7085	0,8523
Shear Stress Fluctuation	0,0711	0,2641
Dominant Force Strength	3,2003	3,8587
CCW from Apex	14,8585	-102,1636

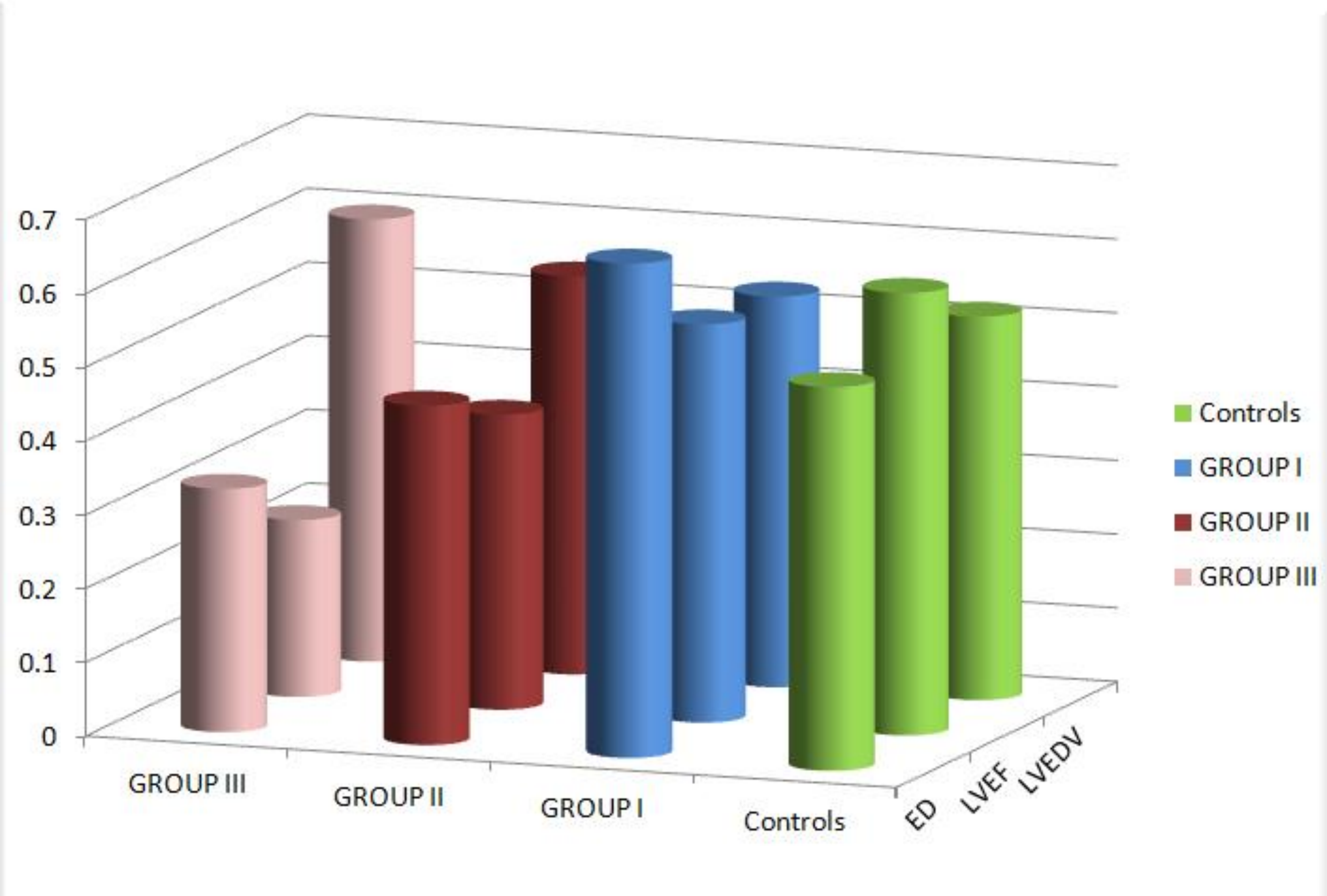
Study population n = 41

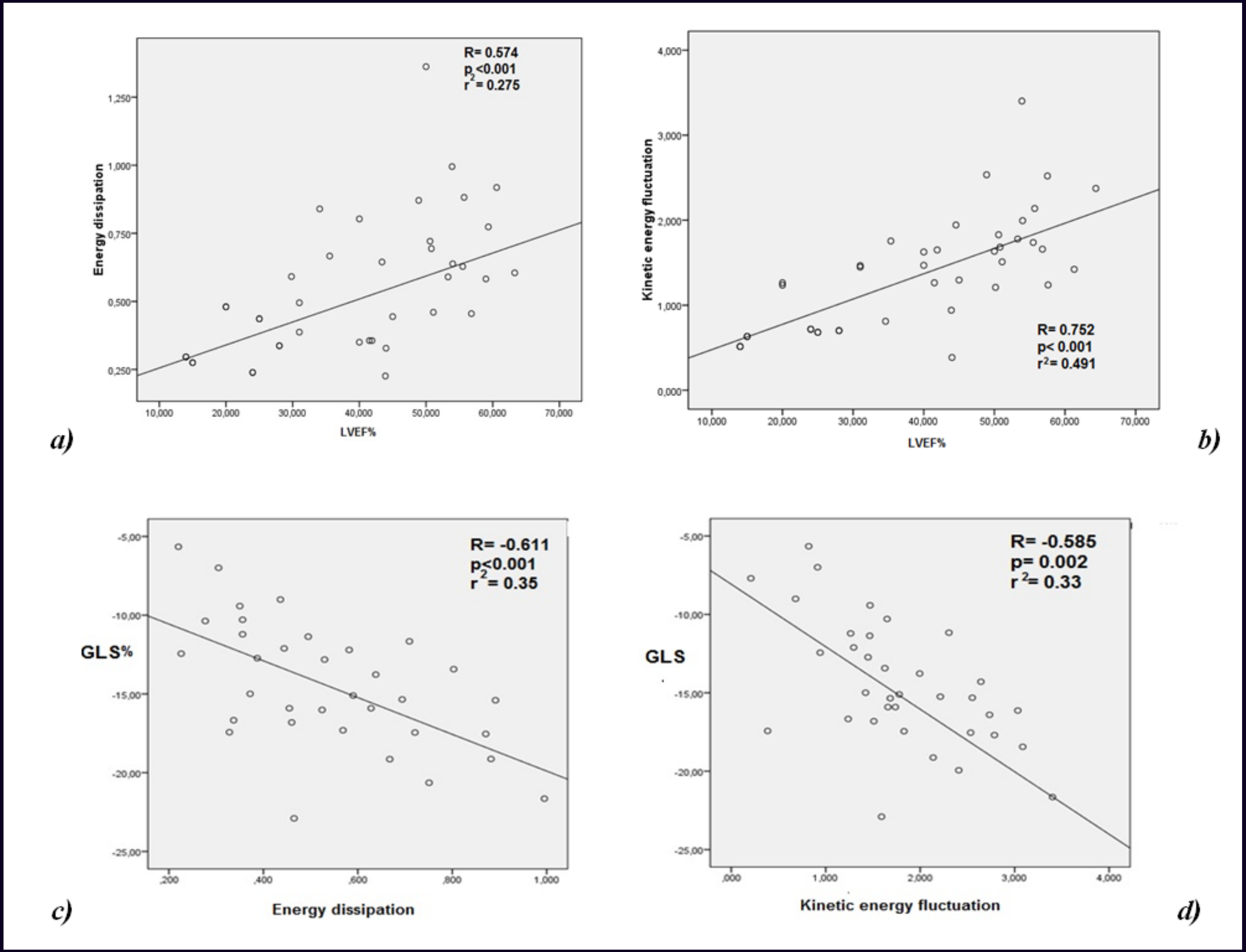
- Group I, LVEF >50%, (n= 14)
- Group II, LVEF 50-30%, (n=10)
- Group III, LVEF <30%, (n=10)
- Healthy controls (n=10)

Echo Data

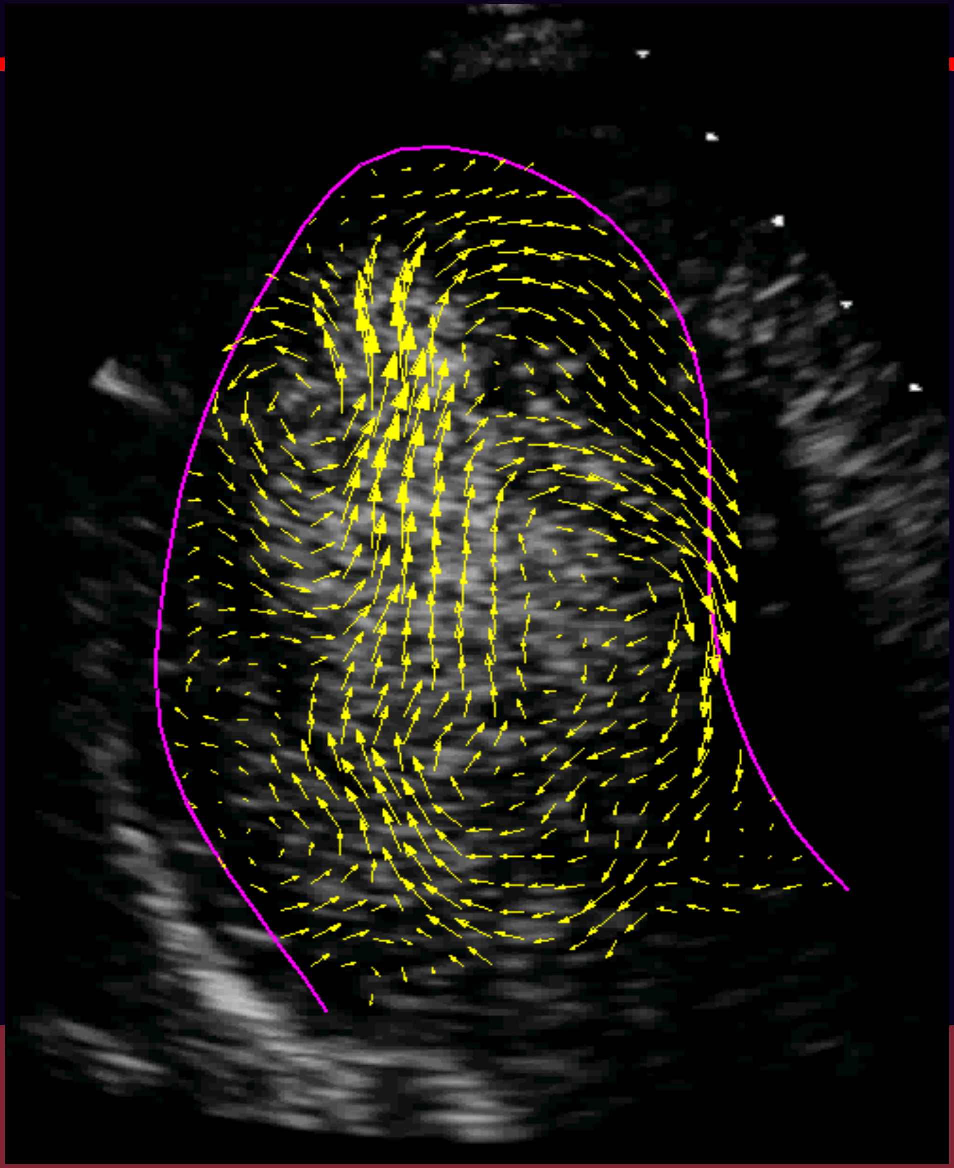
	Group I (n= 14)	Group II (n=10)	Group III (n= 10)	P value
LVEF, %	54.6±3.2	40.72±5.7	24.3±5.1	<0.001
GLS	-16±5.3	-13±6.7	-8±4.2	<0.001
LVEDV/i, ml/m²	53±15	54±26	60±12	0.045
LVESV/i, ml/m²	24±7.7	30±18	46±9.2	0.032
GWMSI	1.7±0.6	2.2±0.9	3.3±1.8	0.008

	Controls (n=10)	Group I (n= 14)	Group II (n=10)	Group III (n= 10)	P value
Vortex Area	0.34±0.08	0.35±0.07	0.35±0.09	0.33±0.09	0.42
Vortex Length	0.77±.5	0.7±0.1	0.68±0.14	0.64±0.09	0.38
Vortex Depth	0.4±0.1	0.37±0.1	0.45±0.11	0.46±0.054	0.25
Vortex Intensity	-0.44±0.1	-0.43±0.2	-0.43±0.23	-0.37±0.26	0.58
Energy Dissipation*	0.52±0.22	0.67±0.29	0.46±0.21	0.33±0.09	0.008
Vortex Fluctuation**	0.80±0.03	0.83±0.06	0.75±0.16	0.60±0.07	0.024
Kinetic Energy Fluctuation***	1.55±0.23	1.83±0.54	1.40±0.54	0.74±0.22	0.004


0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
GROUP III
GROUP II
GROUP I
Controls
ED
LVEF
LVEDV
Controls
GROUP I
GROUP II
GROUP III


R= 0.574
p<0.001
r²= 0.275
Energy dissipation
LVEF%
a)
R= 0.752
p< 0.001
r²= 0.491
Kinetic energy fluctuation
LVEF%
b)
R= -0.611
p<0.001
r²= 0.35
GLS%
Energy dissipation
c)
R= -0.585
p= 0.002
r²= 0.33
GLS
Kinetic energy fluctuation
d)

LVEF 45%, Energy Diss. = 0.88



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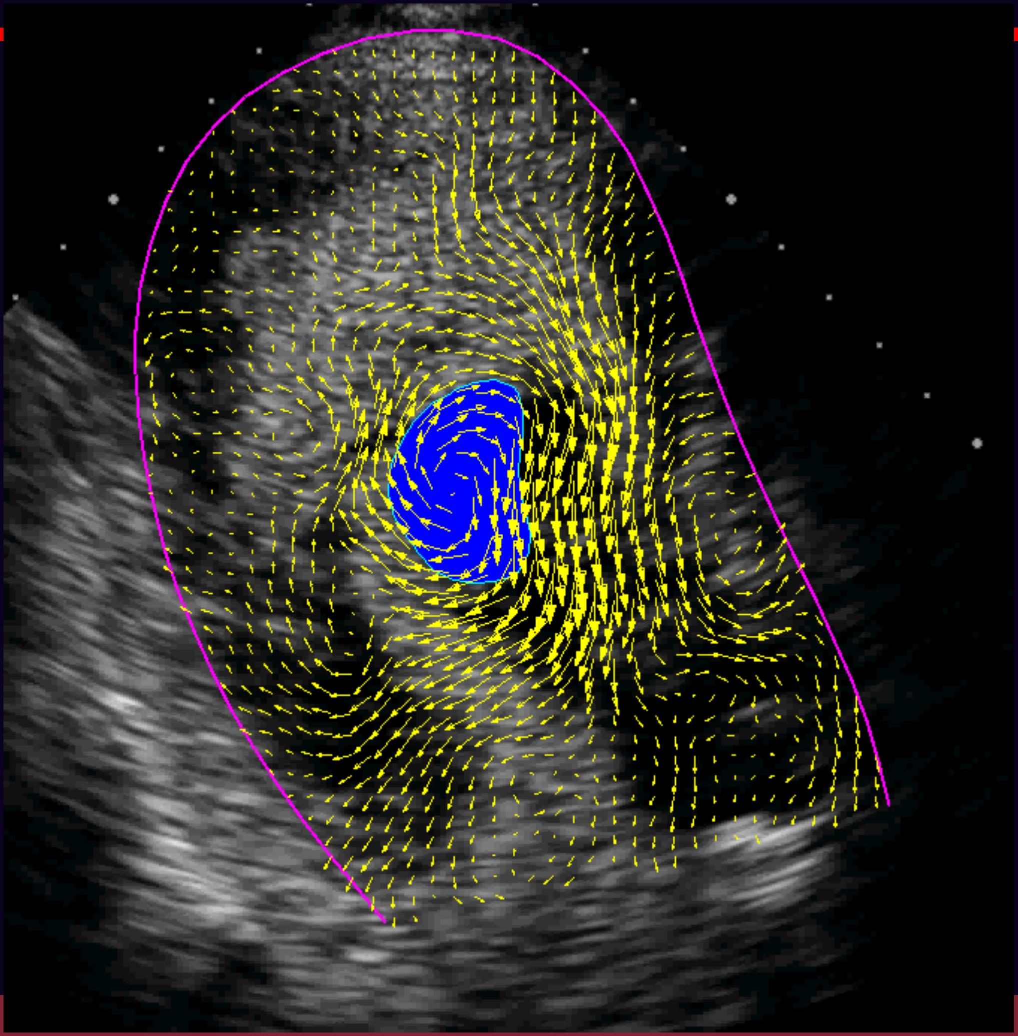
LVEF= 25% , Energy Diss. = 0.27

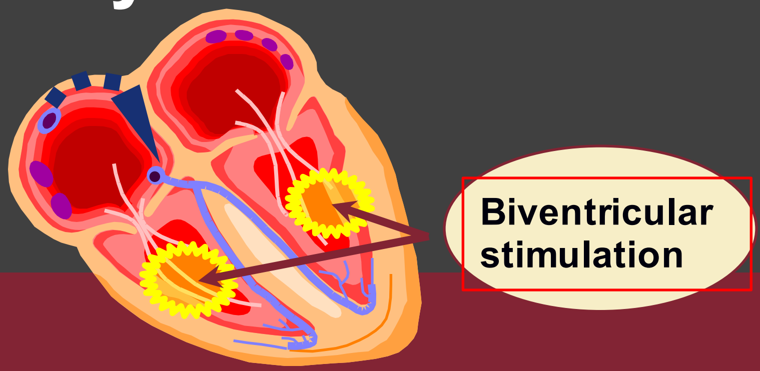


Conclusions

- Patients with preserved LV function exhibit a significant increase in energy dissipation suggesting the presence of a new fluid-tissue dynamical balance as compensatory mechanisms for maintaining an adequate LVEF.
- In the presence of a significant LV dysfunction, energy dissipation is markedly reduced as a consequence of a low flow kinetic energy.
- Serial monitoring of energy dissipation changes overtime allows quantitative information on LV pump efficiency.

- The role of these parameters in the development and maintenance of LV remodeling has to be clarified

Significant increase of flow kinetic energy in non responders patients to Cardiac Resynchronization Therapy



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Luciano Agati, MD

Guidelines Indication to CRT

Scientific Society	HFSA	ACCF/AHA/HRS	ESC/EHRA
CLASS I: Treatment should be performed (ACCF/AHA/HS) or is recommended (ESC/EHRA) *Level of Evidence A*	NYHA II – III LVEF≤35% Sinus rhythm QRS≥150ms Not due to RBBB	NYHA III and ambulatory NYHA IV LVEF≤35% Sinus rhythm QRS≥150ms LBBB	NYHA II, III, and ambulatory NYHA IV LVEF≤35% Sinus rhythm QRS≥150ms LBBB
CLASS I: Treatment should be performed (ACCF/AHA/HS) or is recommended (ESC/HFA) *Level of Evidence B*		NYHA II LVEF≤35% Sinus rhythm QRS≥150ms LBBB	NYHA II, III, and ambulatory NYHA IV LVEF≤35% Sinus rhythm QRS 120 - 150 ms LBBB
			NYHA III, and ambulatory NYHA IV LVEF≤35% Upgrade from IPG or ICD High percentage of ventricular pacing
CLASS IIa: Treatment is reasonable to be performed (ACC/AHA/HRS) or should be considered (ESC/HFA)		NYHA III and ambulatory NYHA IV LVEF≤35% Sinus rhythm QRS≥150ms Non-LBBB morphology	

Unsolved issues:

- Electrical dyssynchrony not necessary means mechanical dyssysnchrony
- ~ 30% CRT "non-responders" (clinical and echo parameters)

...."no single echocardiographic measure of dyssynchrony may be recommended to improve patient selection for CRT beyond current guidelines...."

European Heart Journal
doi:10.1093/eurheartj/eht150
ESC GUIDELINES

2013 ESC Guidelines on cardiac pacing and cardiac resynchronization therapy

The Task Force on cardiac pacing and resynchronization therapy of the European Society of Cardiology (ESC). Developed in collaboration with the European Heart Rhythm Association (EHRA).

Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION
American Heart Association

Results of the Predictors of Response to CRT (PROSPECT) Trial

Eugene S. Chung, Angel R. Leon, Luigi Tavazzi, Jing-Ping Sun, Petros Nihoyannopoulos, John Merlino, William T. Abraham, Stefano Ghio, Christophe Leclercq, Jeroen J. Bax, Cheuk-Man Yu, John Gorcsan III, Martin St John Sutton, Johan De Sutter and Jaime Murillo

Aim of the study

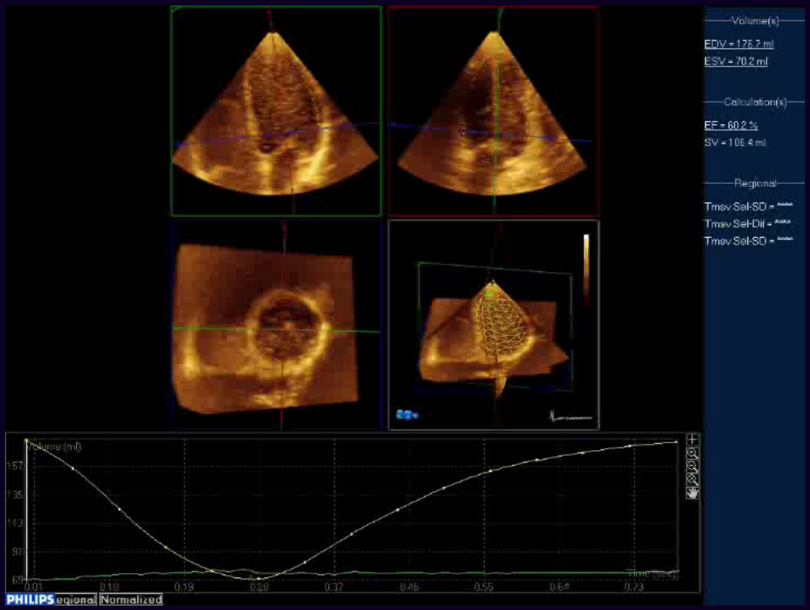
- To assess iv flow patterns in patients undergoing CRT

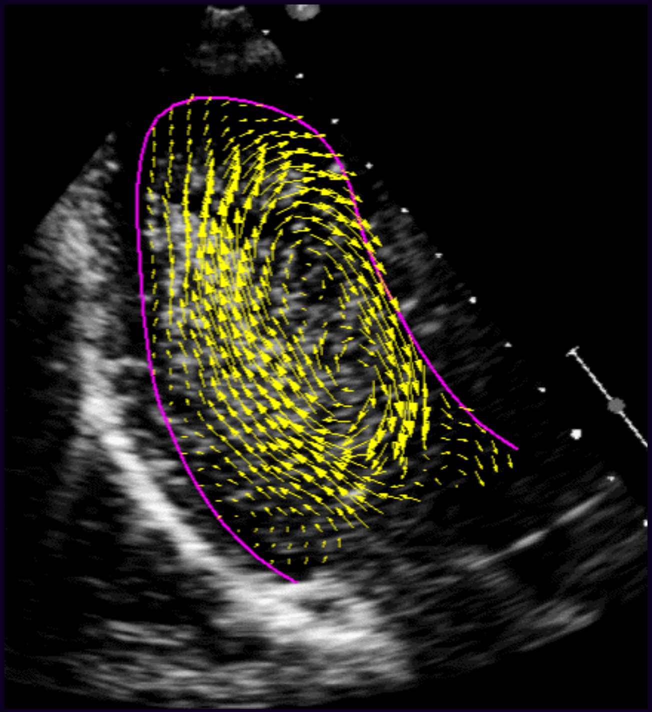
- To assess the correlation between reverse remodeling and iv flow dynamics in the attempt to find new non invasive predictive indexes of CRT responders

Study population

- 30 consecutive patients undergoing CRT following current guidelines.

Study design





- Echo 2D and 3D at baseline and after 6 months (GLS- SDI)
- Echo-PIV - at baseline and after 6 months (PMK ON and OFF)

CRITERIA TO DEFINE RESPONDERS

- Increase LVEF (> 20%)
- NYHA class improvement
- LV end-systolic volume reduction

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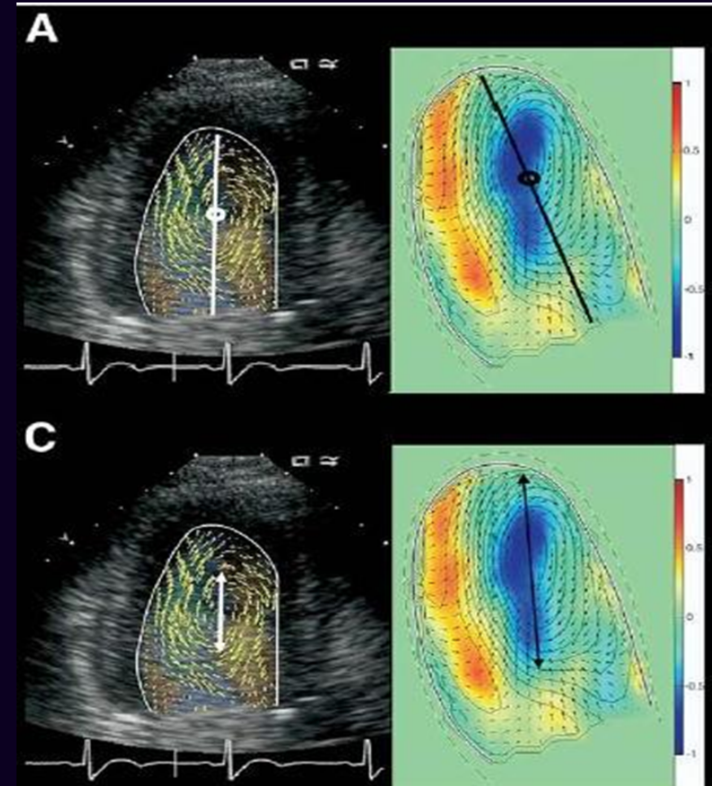
Echo-PIV

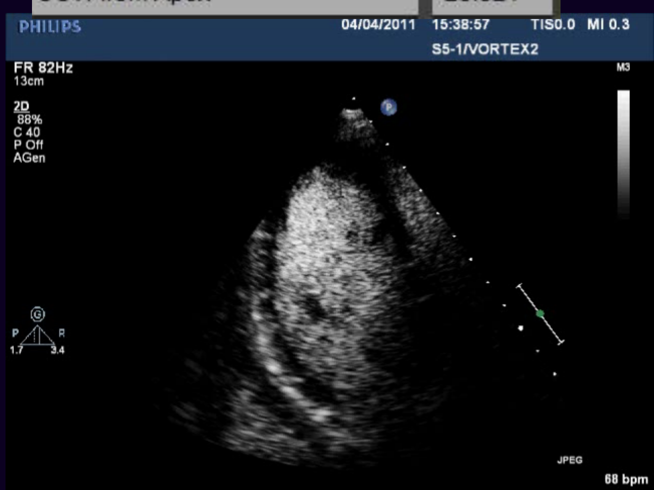
Software Hyper Flow 6.0.0.3.

Parameter	Value
Vortex Area	0.409
Vortex Intensity	-0.561
Vortex Depth	0.336
Vortex Length	0.712
Energy Dissipation	0.280
Vorticity Fluctuation	0.836
Kinetic Energy Fluctuation	1.549
Shear Stress Fluctuation	0.115
Dominant Force Strength	12.768
CCW from Apex	-23.821

Geometrical Parameters

Energetics





SonoVue
Sulphur Hexafluoride

European Heart Journal - Cardiovascular Imaging Advance Access published June 6, 2014

European Society of Cardiology

European Heart Journal – Cardiovascular Imaging
doi:10.1093/ehjci/jeu106

Quantitative analysis of intraventricular blood flow dynamics by echocardiographic particle image velocimetry in patients with acute myocardial infarction at different stages of left ventricular dysfunction

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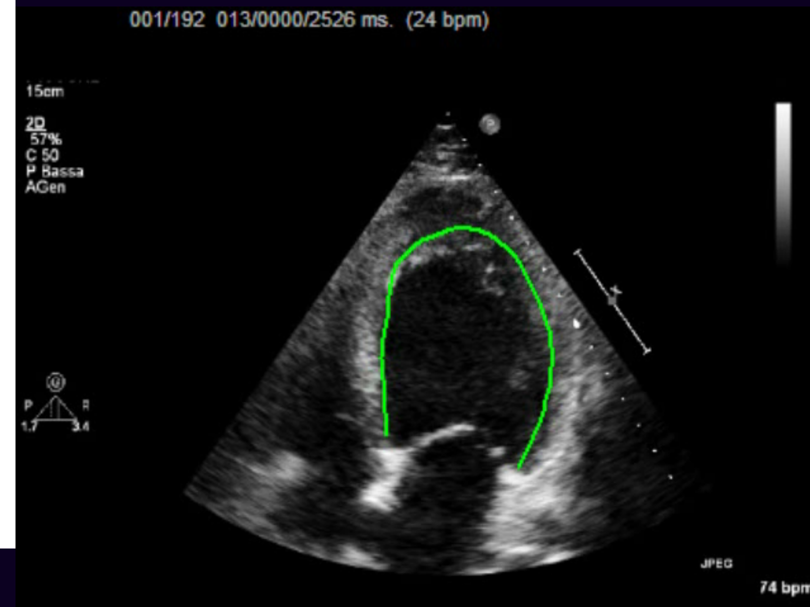
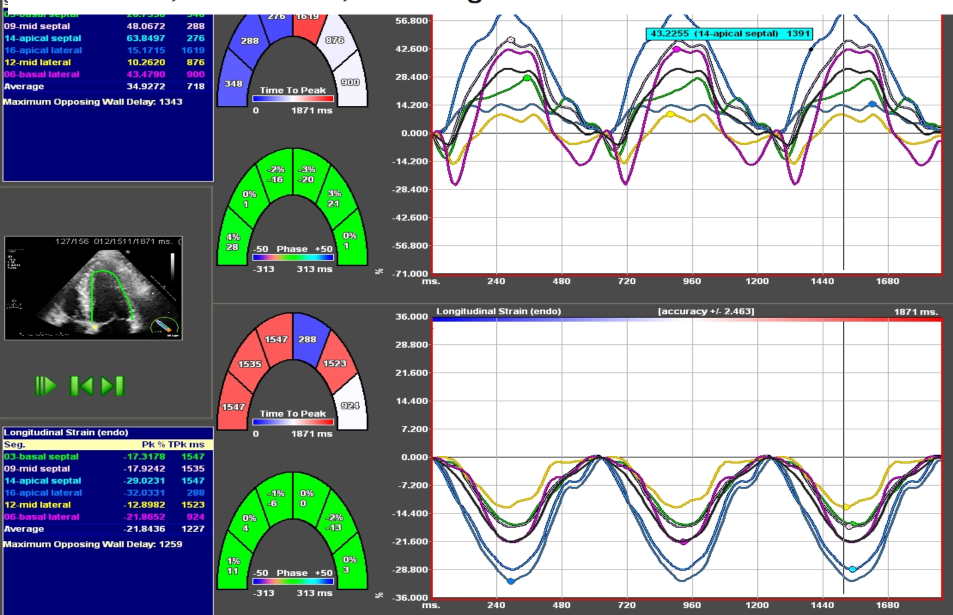
Speckle Tracking Echocardiography

European Heart Journal – Cardiovascular Imaging
doi:10.1093/ehjci/jes295

Global and regional longitudinal strain assessed by two-dimensional speckle tracking echocardiography identifies early myocardial dysfunction and transmural extent of myocardial scar in patients with acute ST elevation myocardial infarction and relatively preserved LV function

S. Cimino[1], E. Canali[1], V. Petronilli[1], F. Cicogna[1], L. De Luca[1], M. Francone[2], G. Sardella[1], C. Iacoboni[1], and L. Agati[1]*





-- **Longitudinal Strain**
-- Strain rate
-- Velocity
-- Displacement
-- Torsion

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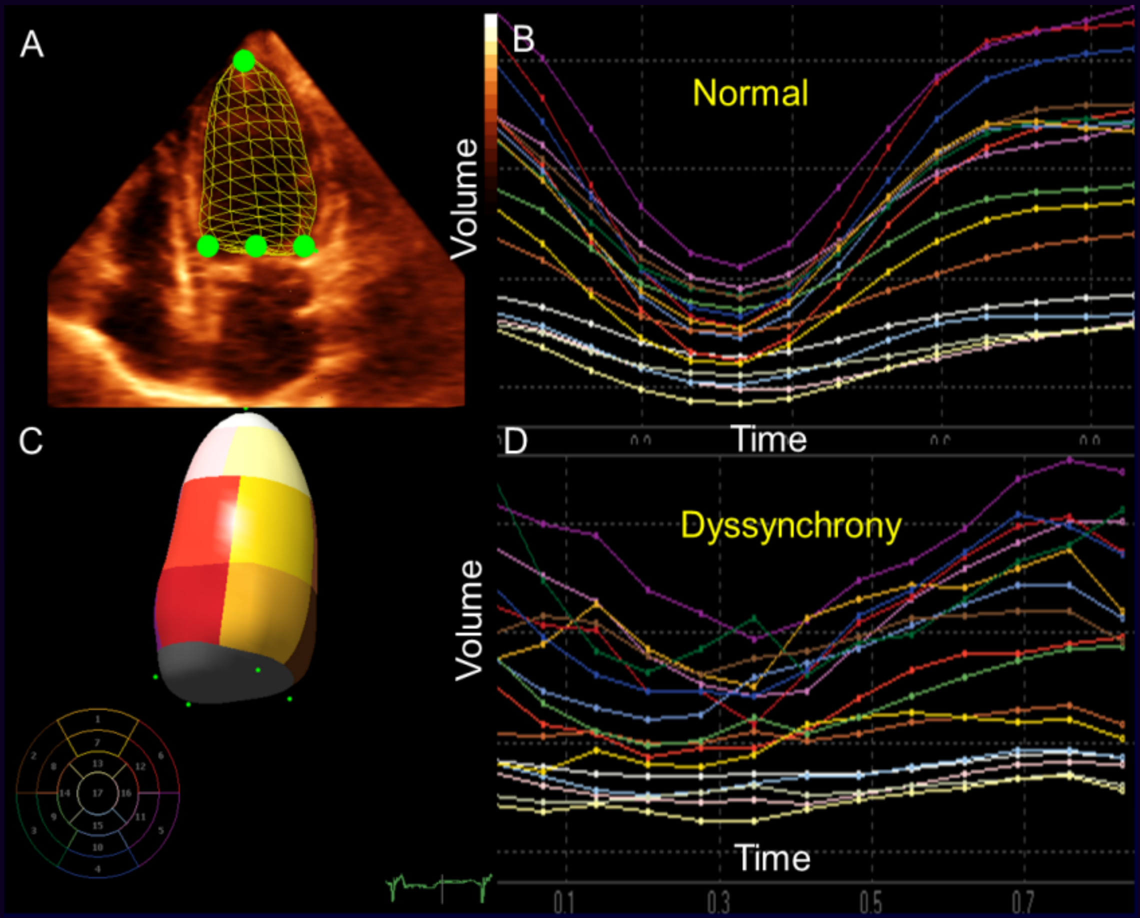
ECO 3D/4D and CRT



SYSTOLIC DYSSYNERGY INDEX (SDI):

Time necessary to reach minimum volume for each segment

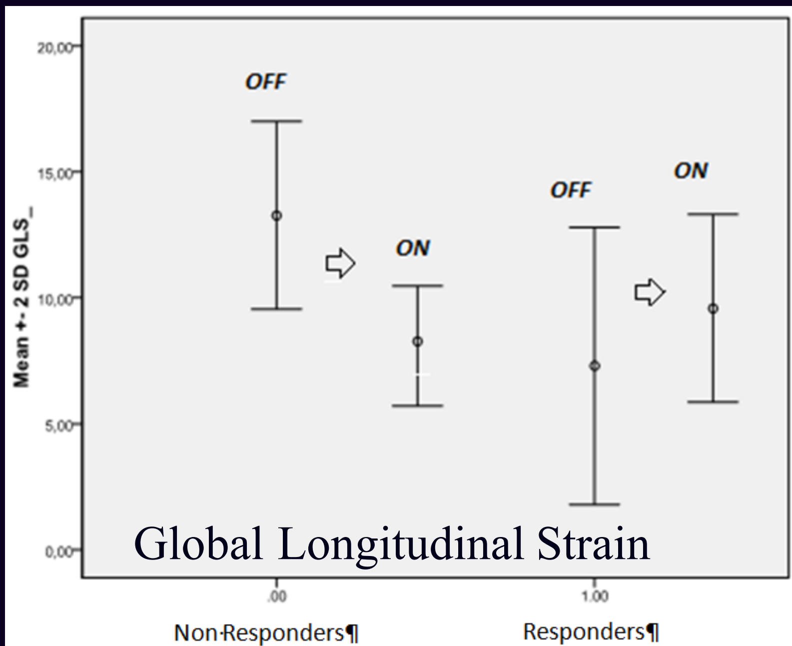
SDI <3.5±1.8% Normal

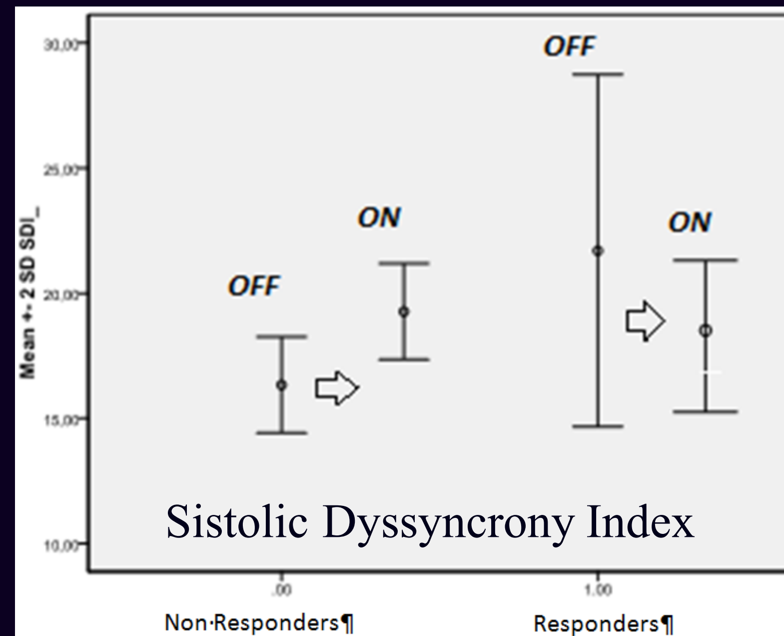
SDI >15±1% Severe LV dysfunction

BASELINE – Before CRT

Parameter	Responders (N=16)	Non responders (N=14)	p
Energy dissipation	0.578±0.08	0.54 ±0.001	NS
Vortex area	0.23 ±0.02	0.19 ±0.05	NS
Vortex intensity	0.35 ±0.01	0.13 ±0.36	NS
Vortex depth	0.36 ±0.01	0.49 ±0.03	<0.001
Vortex length	0.58 ±0.04	0.49 ±0.05	0.002
VortIcity fluctuation	0.81 ±0.001	0.82 ±0.06	NS
Kinetic Energy fluctuation	1.24 ±1.14	1.36 ±0.32	NS
LVEF (%)	17.5 ±2.6	25 ± 7.3	0.014
LVED vol (ml)	223 ±11.2	159 ±28	NS
LVES vol (ml)	188 ±28	121 ±29	NS
GLS (%) pre	-7.39 ± 3.55	-13.58 ± 2.1	0.001
SDI (%) pre	22.1 ± 4.5	16.5±0.7	0.048
NYHA III-IV (%) pre	80% (8)	100% (10)	NS
Age (yrs)	65±9	69±10	NS
Male%	60% (6)	50% (5)	NS

6-Months Follow-up: GLS and SDI
PMK ON vs PMK OFF



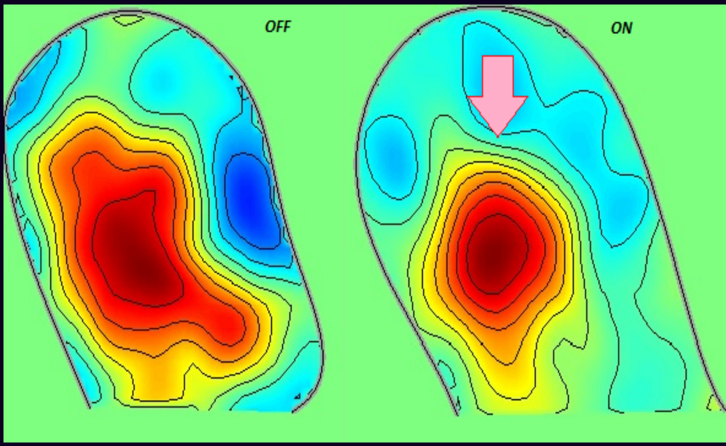


Parametro	Pmk off	Pmk on	P	
GLS (%)	-7.39±3.55	-9.77±4.4	0.038	**Responders**
SDI (%)	22.1±4.5	15.5±3.7	0.02	
GLS (%)	13.58±2.1	7.55±3.3	0.005	**Non Responders**
SDI (%)	16.5±0.7	19±1.4	NS	

6-Months Follow-up: Flow Parameters

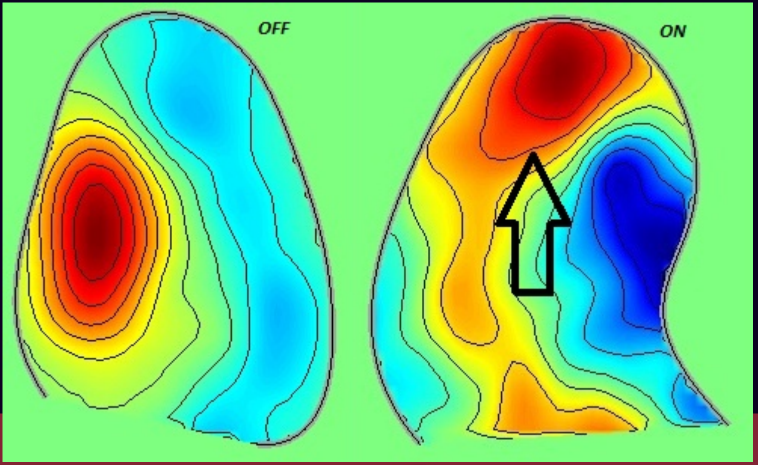
Responders

Parametro	Pmk off	Pmk on	p
Energy dissipation	0.578±0.08	0.523±0.09	NS
Vortex area	0.23±0.02	0.19±0.01	0.02
Vortex intensity	0.35±0.01	0.37±0.003	0.002
Vortex depht	0.36±0.01	0.34±0.07	NS
Vortex lenght	0.58±0.04	0.5±0.04	0.043
Vorticity fluctuation	0.81±0.001	0.74±0.09	NS
Kinetic Energy fluctuation	1.24±1.14	1.07±0.34	0.039



Non Responders

Parametro	Pmk off	Pmk on	P
Energy dissipation	0.54±0.001	0.766±0.32	0.004
Vortex area	0.19±0.05	0.21±0.05	NS
Vortex intensity	0.13±0.36	0.08±0.03	NS
Vortex depht	0.49±0.03	0.56±0.19	NS
Vortex lenght	0.49±0.04	0.59±0.18	NS
Vorticity fluctuation	0.82±0.05	0.87±0.05	<0.001
Kinetic Energy fluctuation	1.36±0.32	1.6±0.5	0.002



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Before and After CRT

Conclusions

- CRT in Responder significantly reduces energy dyssipation and increases flow uniformity.

- CRT in non-Responder further increase dyssynchronicity and iv flow turbulence likely responsible for adverse LV remodeling

- Fluid dynamics analysis before and after CRT may be useful to early identify non-Responders

- Prospective multicenter studies are needed to verify the additional value of fluid dynamics analysis in this setting

CRT optimization with quadripolar LV pacing leads through the novel Vortex® echocardiographic algorhythm

The Vortex-CRT study

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