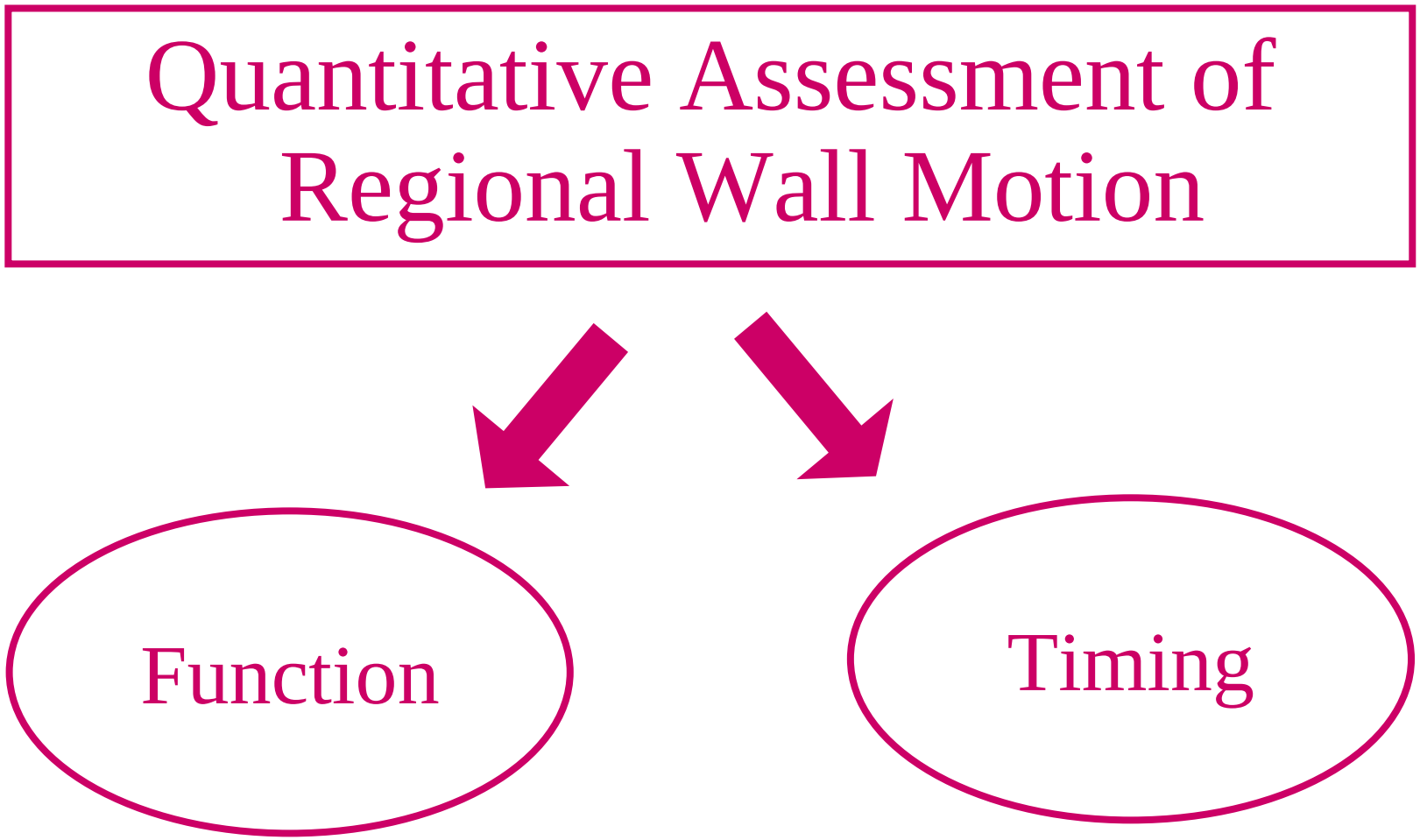
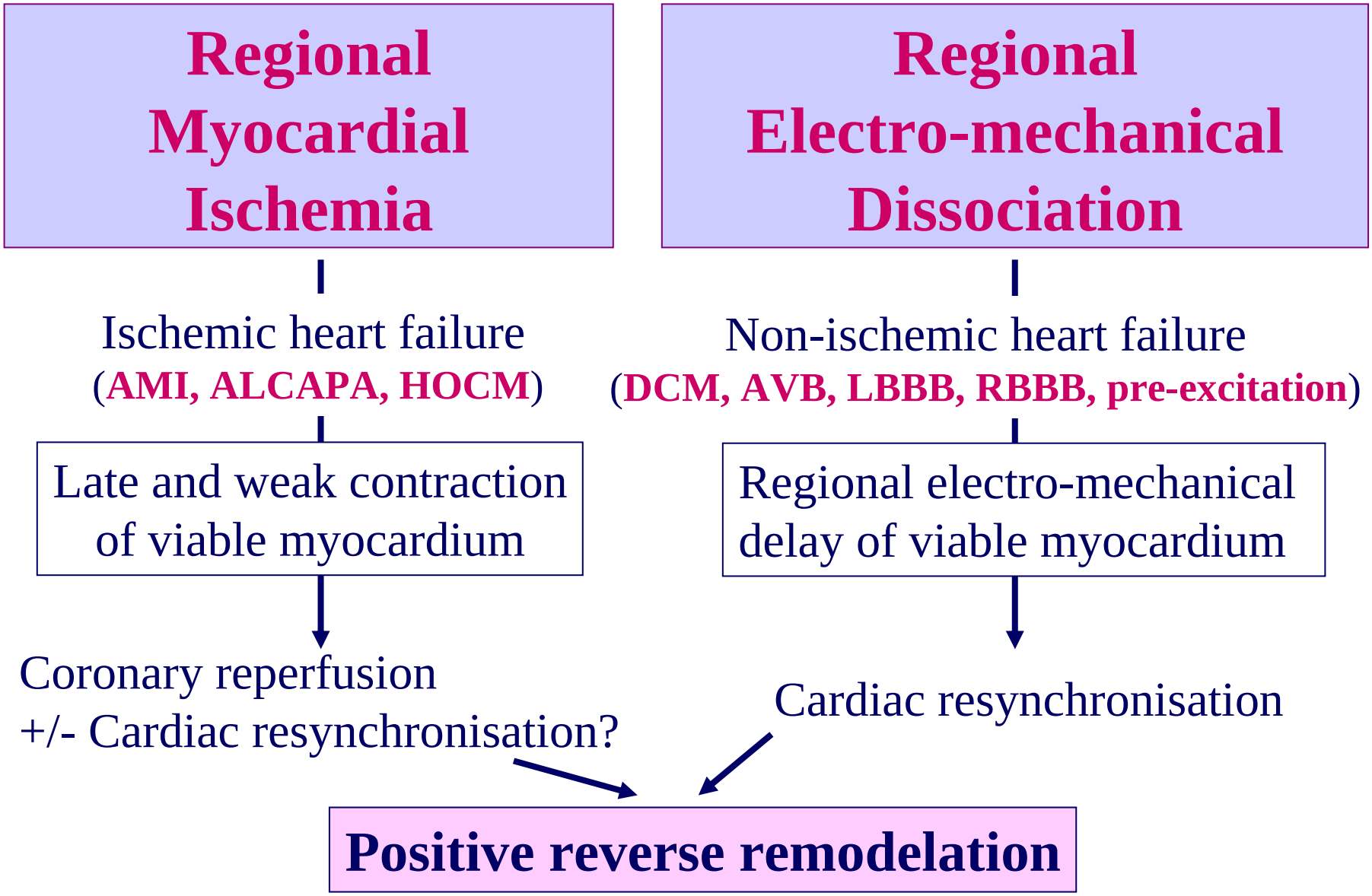
Myocardial Deformation Imaging: Clinical application in CRT in CHD

Jan Marek
Great Ormond Street Hospital
London

Myocardial Deformation Imaging: Clinical applications



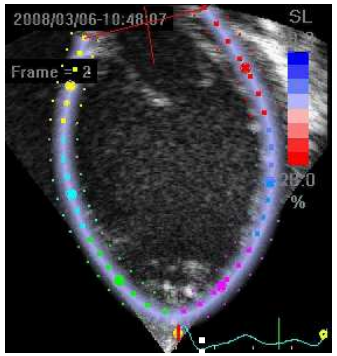
Myocardial wall motion abnormality

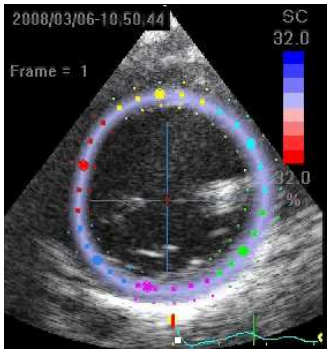


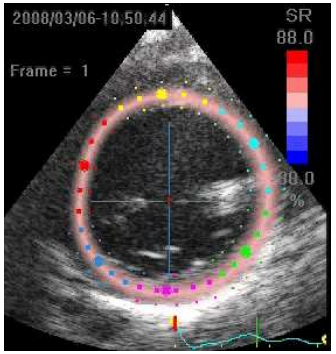
Mechanical dyssynchrony due to myocardial ischemia in viable myocardium

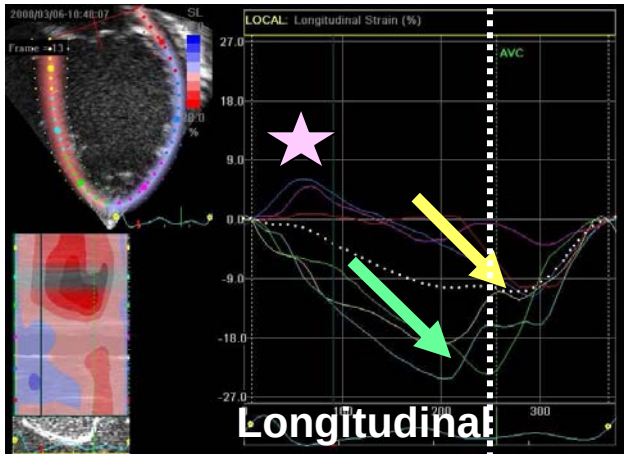
T.M., 3 months: **ALCAPA**, MR, LV ischemia
Severe heart failure
Deep Q: I.-III., aVF, V3-6
Operation: LCA reimplantation, MV annuloplasty

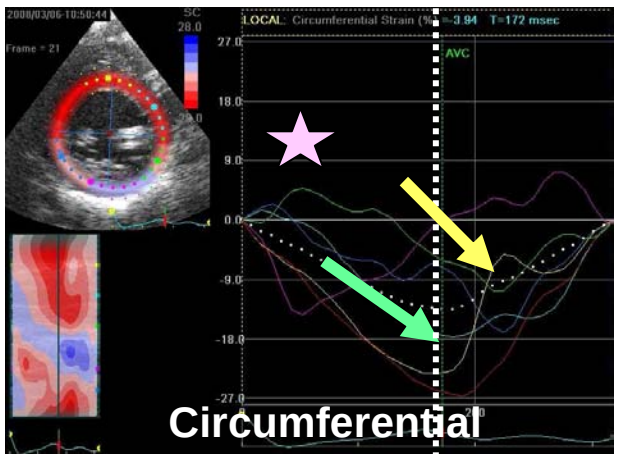
PREOPERATIVE

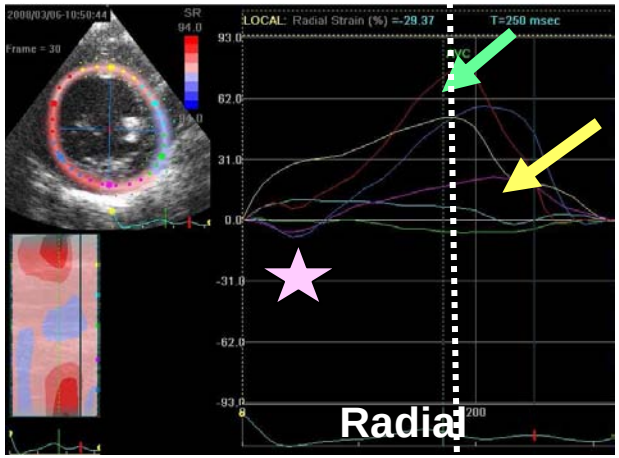




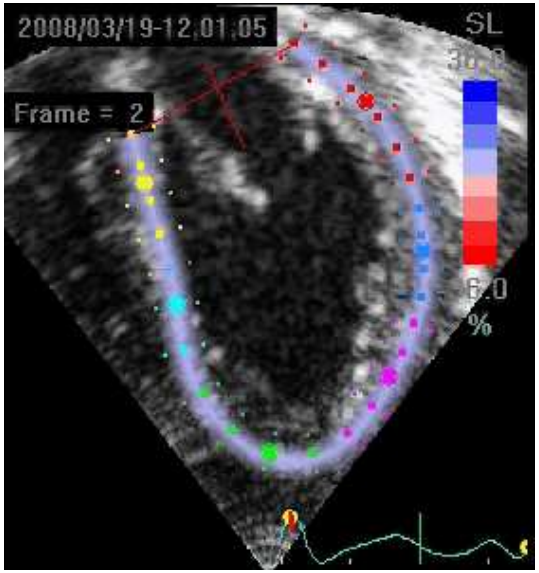


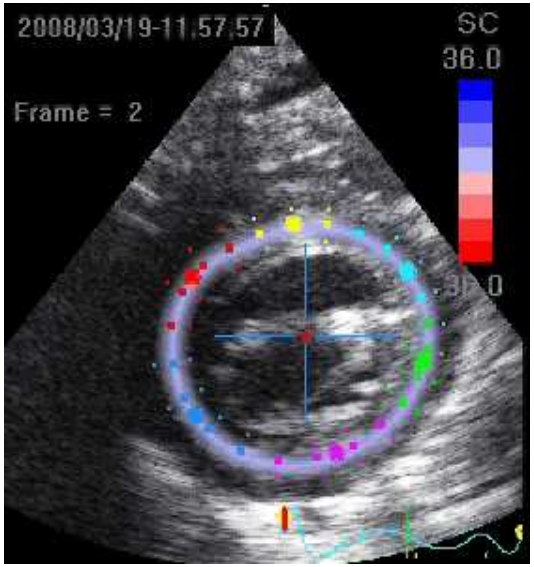


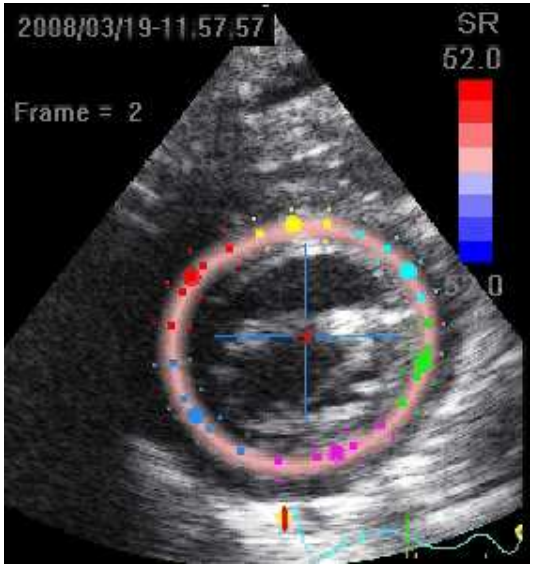


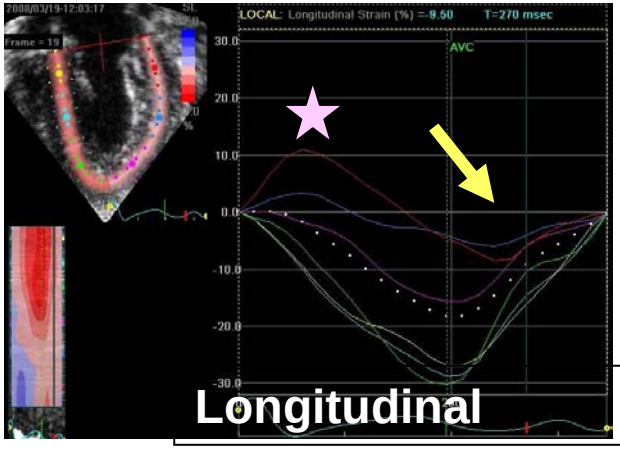


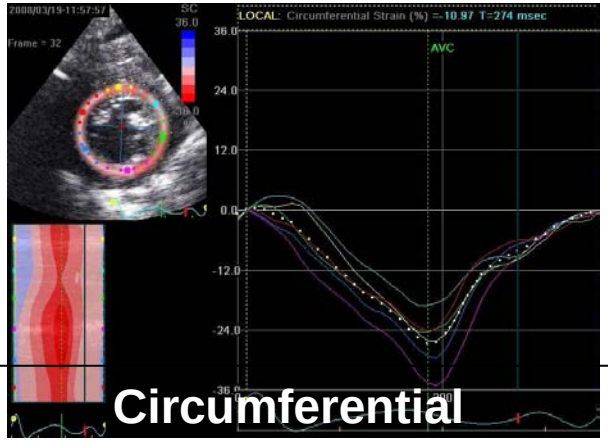
POSTOPERATIVE (10 days postop.)

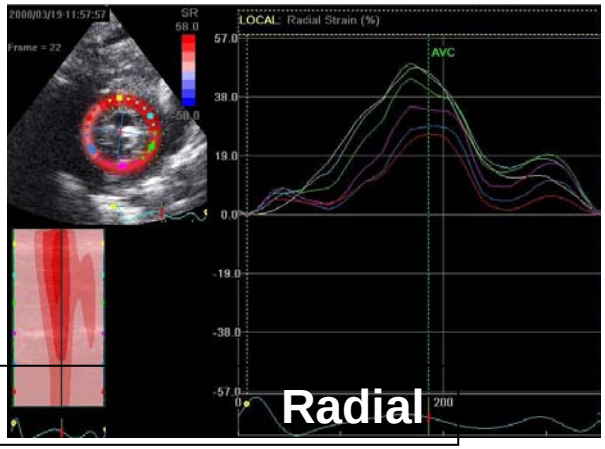






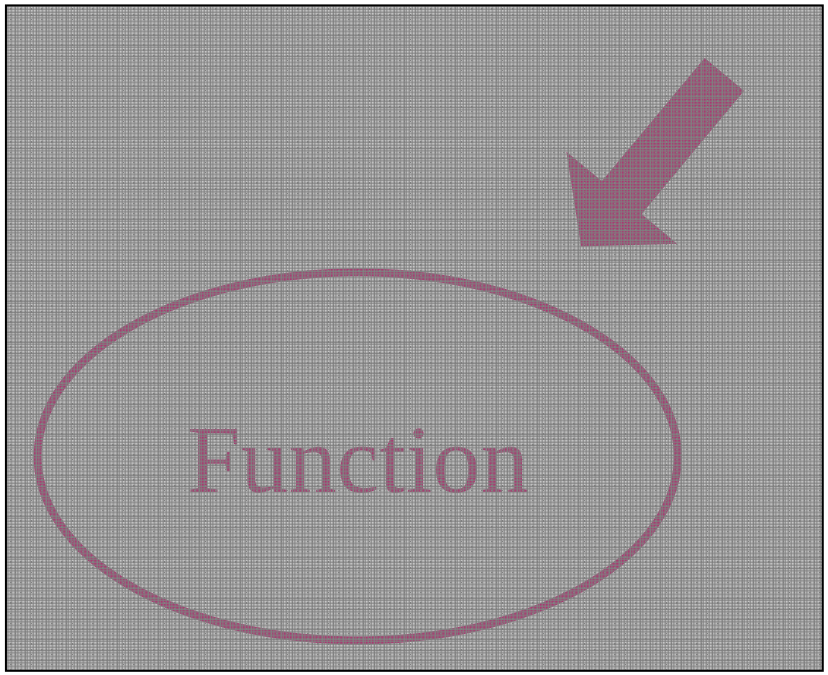






Myocardial Deformation Imaging: Clinical applications

Quantitative Assessment of Regional Wall Motion



Timing

Principles of Dyssynchrony

= Despite the same energy used, LV is unable to maintain cardiac output due to **reduced ejection volume caused by delayed mechanical activation of some myocardial segments**

- Occurs predominantly if QRS is long (ischemia, LBBB/RBBB) and/or LV filling is short (AVB I)

- A delay in regional wall contraction exist if contraction continues after closure of aortic valve (post-systolic contraction)

- Increased preload for lately contracting segments may increase SV but this event occurs when AoV is already closed

Leclerq C JACC 2002

Physiological Principles of CRT

Optimisation of atrioventricular synchrony

- Prolongation of ventricular filling period (atrial kick)
- Abolition of pre- / postsystolic AV regurgitation

Restoration of inter-/intraventricular synchrony

- Counteracts to ventricular contractile discoordination
- Abolition of paradoxical myocardial stretch
- Improvement in relaxation
- Decrease in myocardial oxygen consumption
- Decrease in sympathetic activity

Leclerq C JACC 2002

Traditional criteria for CRT in adults

- Symptomatic heart failure (NYHA III-IV)
- Optimal medical treatment
- Poor systolic function: EF < 35%

  (Simpson`s rule on 2D echo)
- Ventricular dyssynchrony demonstrated

  by QRS > 130msec

CRT performed using traditional criteria results in a favourable response in ~ 60 -70% of candidates

The Effect of Cardiac Resynchronization on Morbidity and Mortality in Heart Failure

813 patients NYHA III-IV enrolled

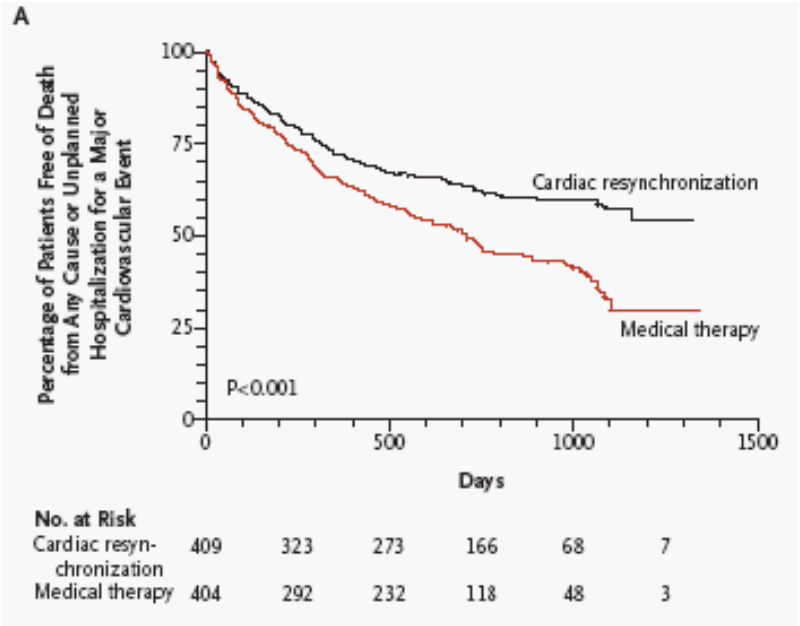
EF<35%, QRS>120msec

Randomised by pharmacological

and pharmacological + CRT

Primary endpoint - time to death

or major event (hospitalisation)



Outcome	Medical Therapy Alone (N=404)	Medical Therapy plus Cardiac Resynchronization (N=409)	Hazard Ratio (95% CI)	P Value
	no. of patients (%)			
Primary outcome				
Death or unplanned hospitalization for a cardiovascular event	224 (55)	159 (39)	0.63 (0.51 to 0.77)	<0.001
Unplanned hospitalization for a cardiovascular event†	184 (46)	125 (31)	0.61 (0.49 to 0.77)	<0.001

Cleland JGF, NEJM 2005

Echocardiographic Dyssynchrony Assessment

INTERVENTRICULAR DYSSYNCHRONY

- Pre-ejection RV / LV time dispersion (PDE, 40msec)

CRT: no ECHO criteria to predict responders

Complex 3D setting!

INTRAVENTICULAR DYSSYNCHRONY

- LV filling time (PDE, 40% R-R)
- Septal-to-free wall delay (M-mode, 130msec)
- Pulsed TDI: time-to-peak (TtP)
- CCTDI: Regional Strain / Strain rate (TtP 40-50msec)
- 2D: Strain / Strain rate (TtP 40-60msec)
- RT-3DE: Tissue Synchronicity Imaging (40-60msec, Index of Dysynchrony)

PROSPECT study

METHODS: "**PR**edict**O**r**S** of res**P**ons**E** to **C**ardiac resynchronisation **T**herapy (PROSPECT)," a prospective, multicentric, non-randomised study, aims to identify echocardiographic measures of dyssynchrony and evaluate their ability to predict response to CRT.

~ 300 patients (75 centres in the US, Asia, Europe), 6 months clinical follow up
Prospectively and individually tested a **variety of conventional echocardiographic** and **tissue Doppler imaging** parameters against measures of clinical response.

The primary endpoint: response criteria for improvement in the heart failure, Clinical Composite Score and left ventricular reverse remodelling

FAILURE!

Yu CM, Am Heart J 2005

Cheung ES, Circulation 2008

Agreement between GE and Philips:

- **Pulsed Doppler TDI** - velocities reasonable

- **Colour Coded TDI** - velocities differed substantially (lower for Philips vs. GE)

Koopman LP, JASE 2010, 23:929-37

- **2D Speckle Tracking**
  - Systolic Strain rate was lower compared with Coloured Doppler derived values
  - Longitudinal and Circumferential Strain comparable among different ultrasound machines
  - Radial Strain and SR significantly different

Koopman LP, JASE 2010, 23:919-28

CRT in children & young adults

- **Good evidence of response to CRT in**:

RV pacing induced CMP (CCAVB), broad QRS (LBBB, RBBB)

Dubin AM. JACC 2005
Janousek J, Am J Cardiol 2001
Dubin AM. Circulation 2003
Zimmerman FJ. Ann Thorac Surg 2003
Bacha EA. Ann Thorac Surg 2005
Janousek et al., HeartRhythm 2006
Gebauer RA, EHJ 2009

- **Uncertain long term benefit from CRT in:**

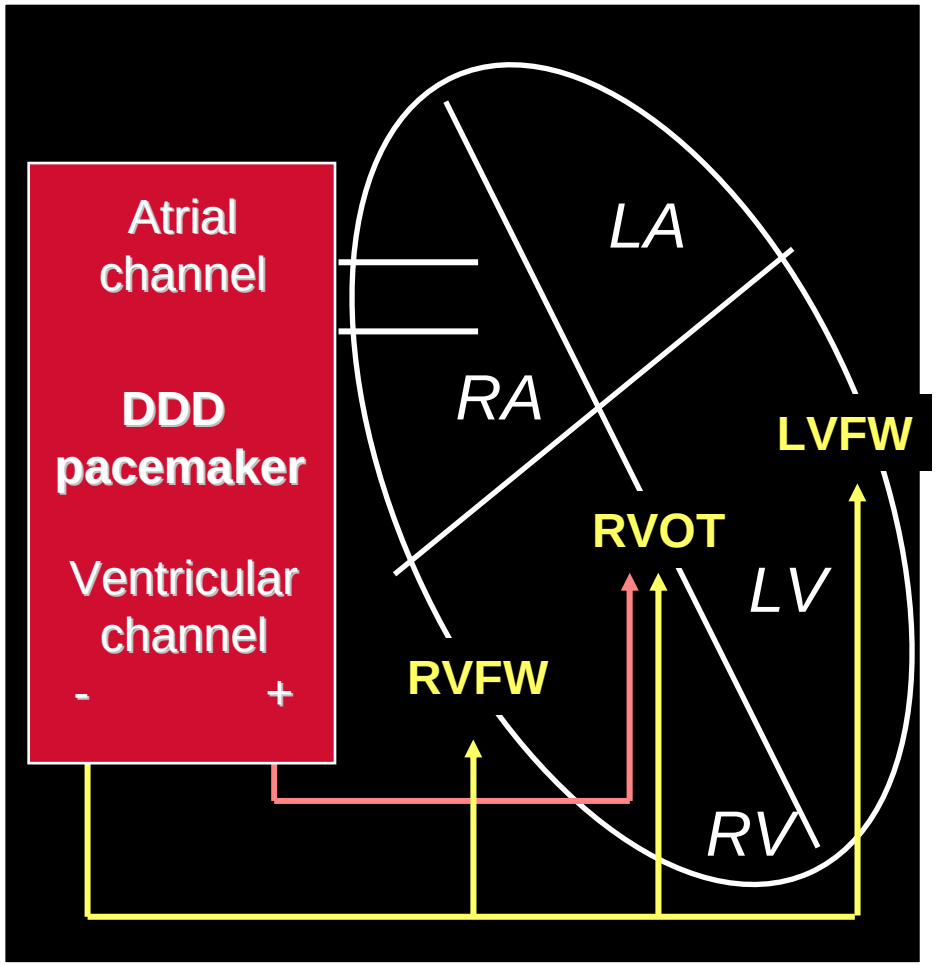
DCM with narrow QRS, single ventricle morphology

Dubin AM. JACC 2005
Bacha EA. Ann Thorac Surg 2005

- **Responders difficult to identify echocardiographically**

Dubin AM et al. JACC 2005

Acute effects of temporary CRT in CHD



- RV desynchronization
  - Right bundle branch block
- LV desynchronization
  - RV pacing induced
- Postop. single ventricle
  - Without electrical asynchrony

⇧ *Systolic / mean pressure*

⇧ *Pulse pressure*

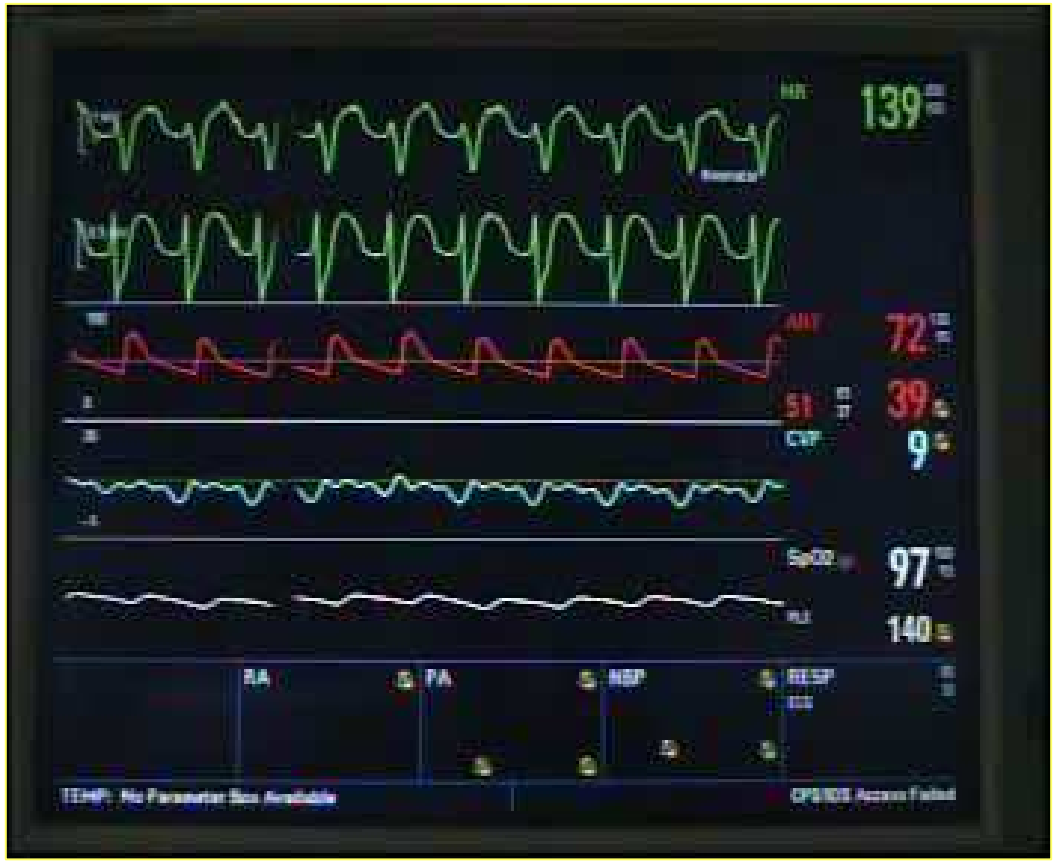
⇧ *Cardiac output*

⇧ *RV +dP/dt*

⇩ *Index of asynchrony*

Janousek J et al. PACE 2000, Janousek J et al. Am J Cardiol 2001
Dubin AM et al. Circulation 2003, Zimmerman FJ et al. Ann Thorac Surg 2003
Bacha EA et al. Ann Thorac Surg 2005

Temporary resynchronization pacing



Postop. TOF, RV failure
1℃AV block, RBBB

Perioperative resynchronisation

N=20, median age 20.4mo (3.4mo-14y)

Mixed type of CHD, CRT in 13 pts. (AVB I. in 10 pts, AVB III. in 3 pts)

Inclusion criteria:

1. need for inotropic support
2. AV/IV dyssynchrony

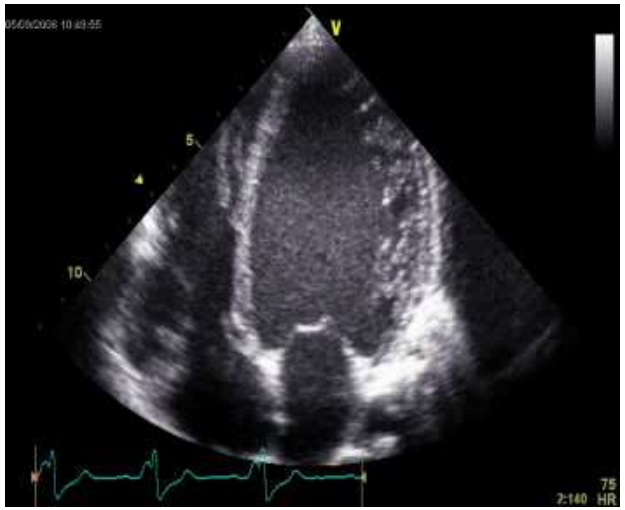
Epicardial pacing leads: atrial, RVOT, RV and LV free wall

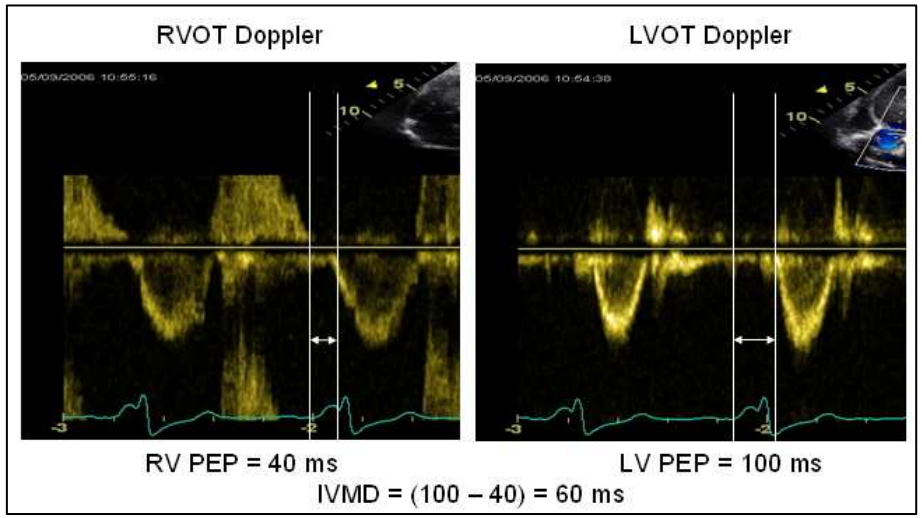
- Increase in arterial pressure $p < 0.001$ for all
(systolic 10.2 ± 5%, mean 8.6 ± 5.4%, pulse 15.2 ± 8.5%)
$p < 0.001$ for all
- Shortened QRS duration ($r=0.62$, $p<0.05$)

Janousek J, Am J Cardiol 2001

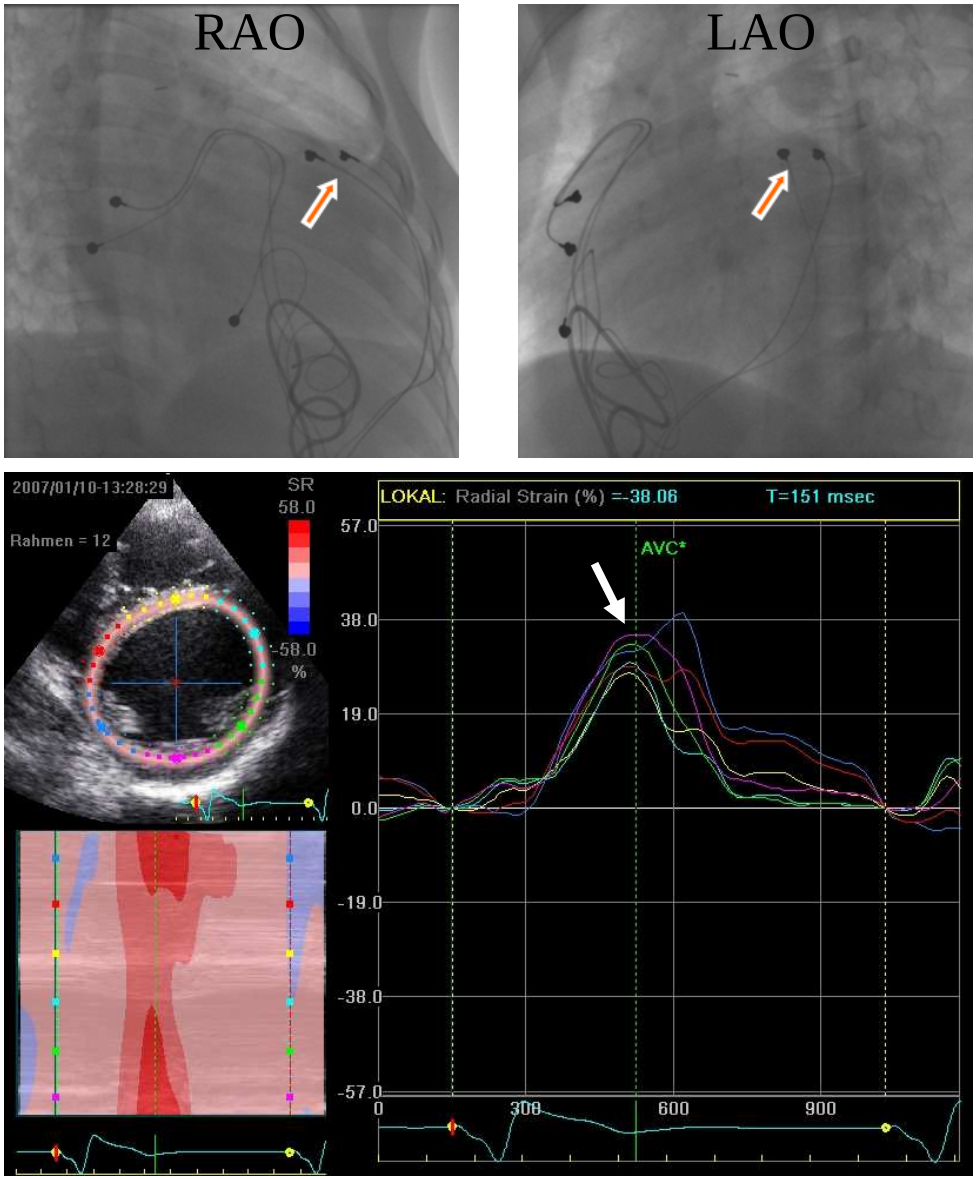
Regional Electro-mechanical Dissociation

6 years old, repair of ToF at 6 mo of age, surgical 3rd° AV block, RV epicardial DDD pacing, no important surg. residua, LV failure





Upgrade to biventricular pacing



Dyssynchronous left ventricular failure in infancy secondary to right sided pre-excitation

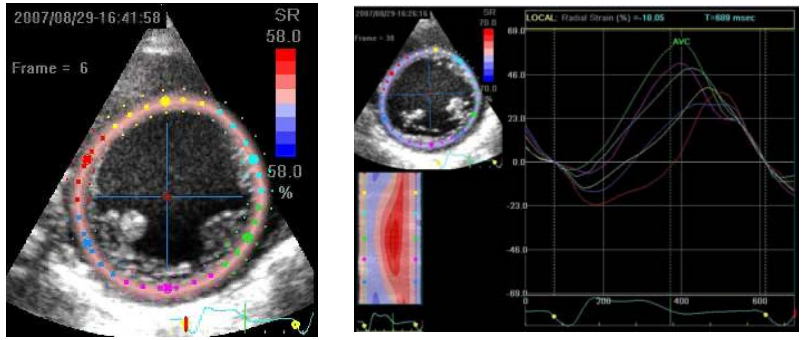
•R.N., severe LV failure + LBBB & preexitation at 9 month, initially considered for HTx

•Dual chamber left AV epicardial pacing at 9 month

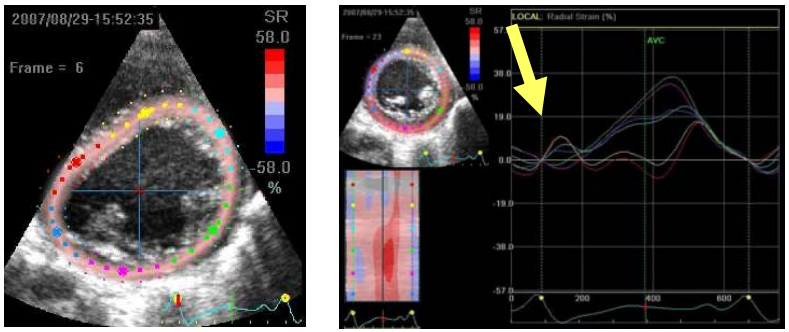
•Marked clinical and echocardiographic improvement

•At 5 years, echocardiography off pacing still demonstrated severe left ventricular dyssynchrony

Paced



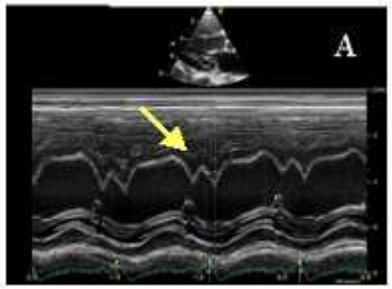
Off pacig

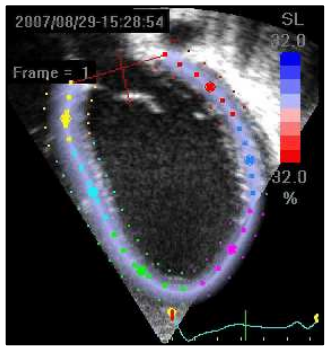


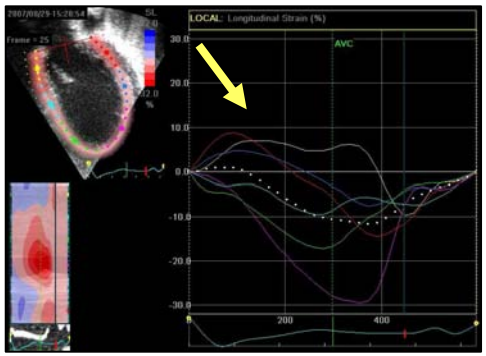
Regional Electro-mechanical Dissociation due to Preexitation

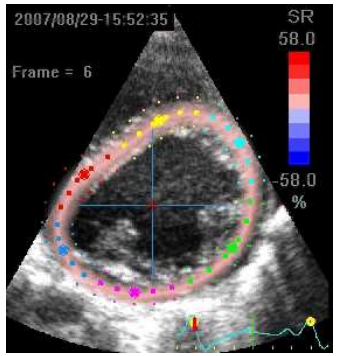
Ilina M, Ped Cardiol 2010

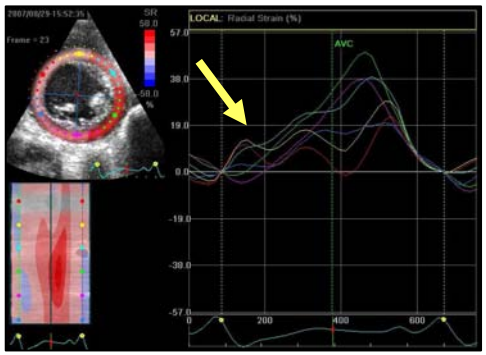
Non-paced pre-ablation



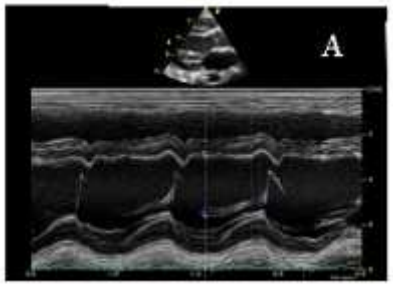


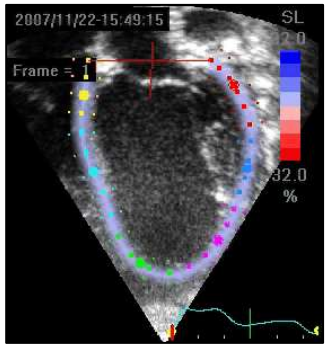


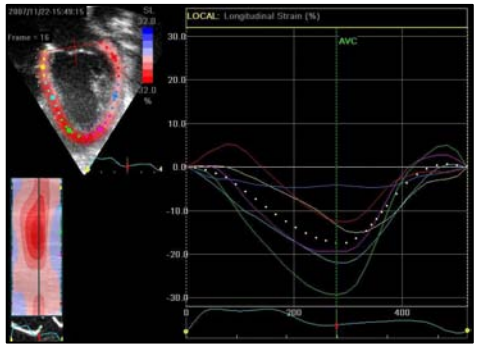


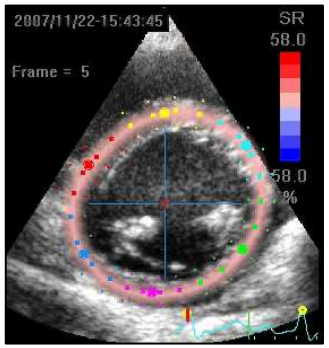


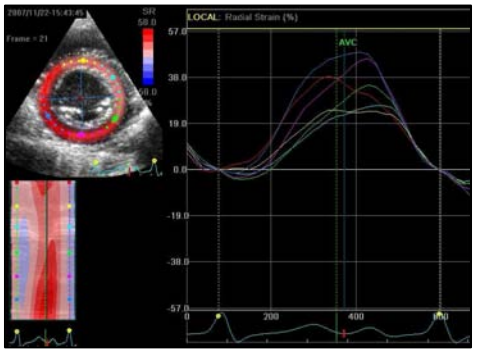
Non-paced post-ablation











- Successful radiofrequency ablation with loss of pre-excitation
- Markedly improved left ventricular synchrony

Regional Electro-mechanical Dyssynchrony

CRT as a bridge to recovery

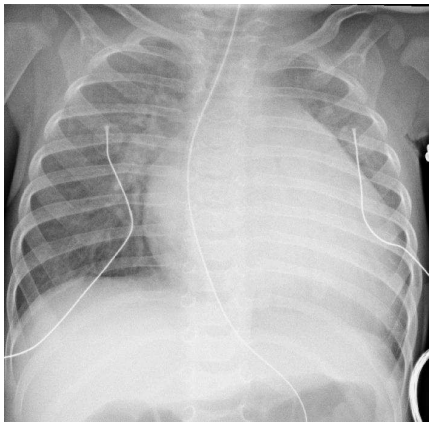
- Male infant presented 8/12, ECMO referral

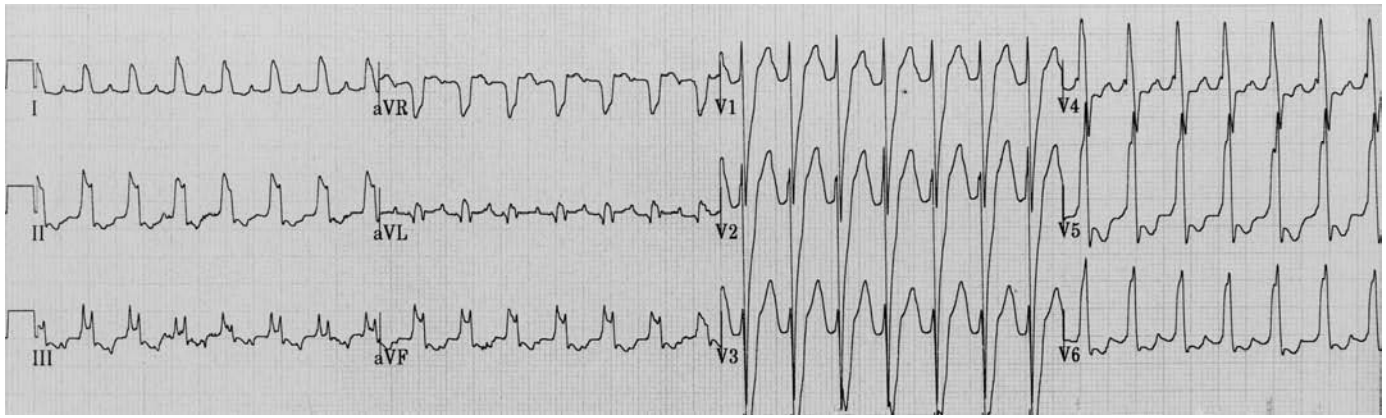
  2 week Hx of increasing SOB, coughing and sweating, weight loss: 2-9th centile to the 0.4th centile, no infection

  Heart failure

- Chest x-ray: Cardiomegaly

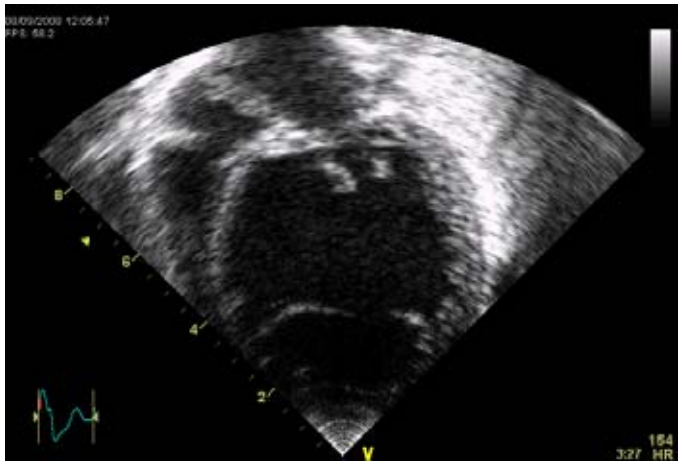
- ECG: Intermittent LBBB in the inferior leads and peaked T-waves in leads V1-V3

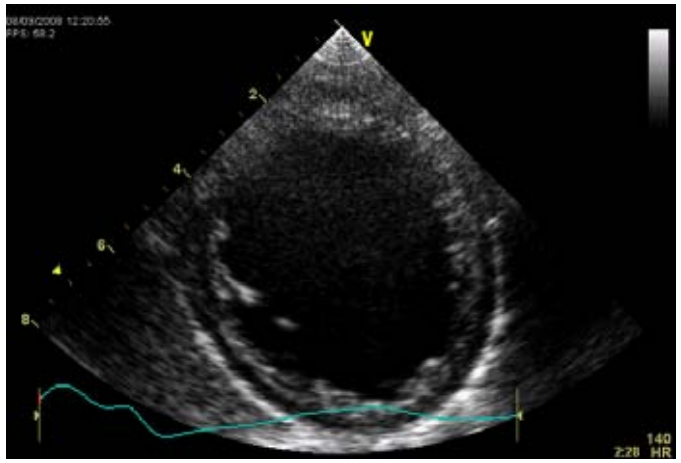


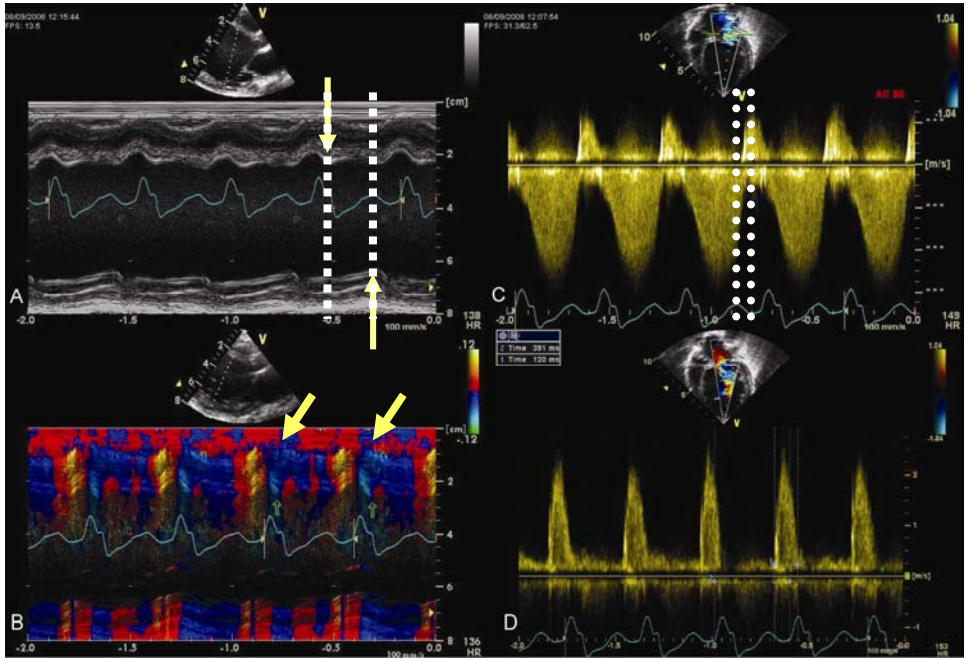


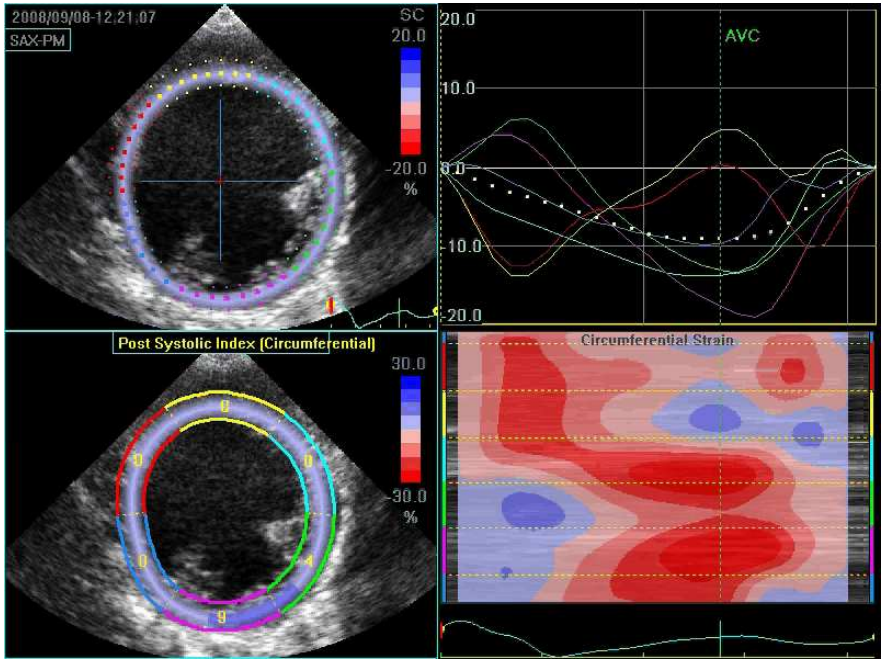
Dragulescu A, JASE 2010

CRT as a bridge to recovery

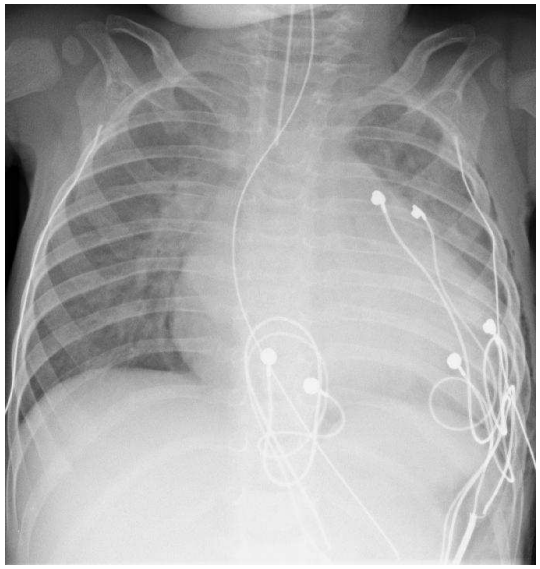






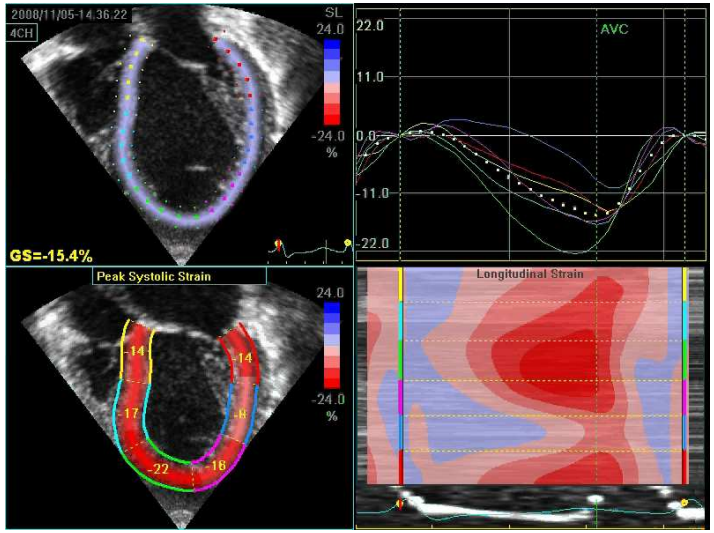


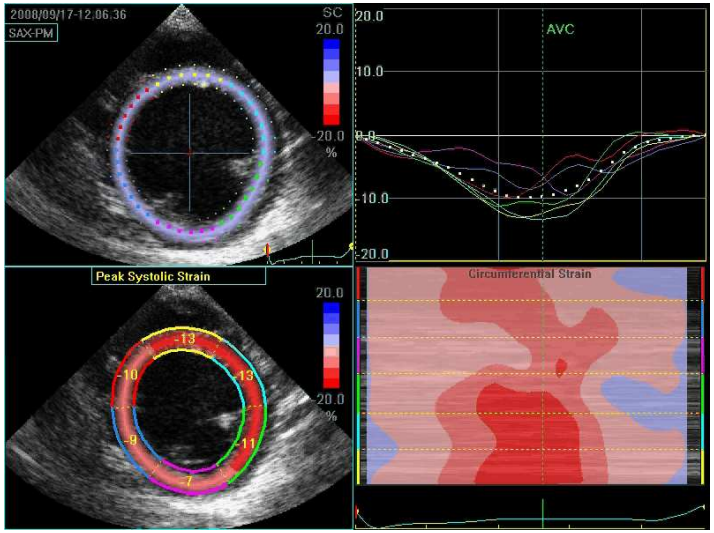
CRT as a bridge to recovery



A-V + V-V delay optimisation

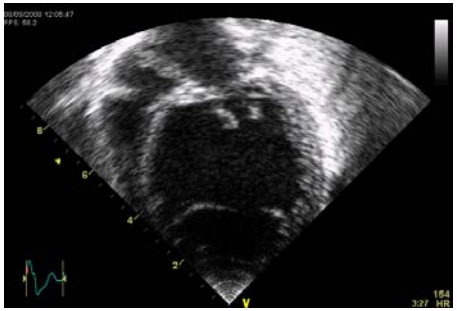
3 days after BiV implantation

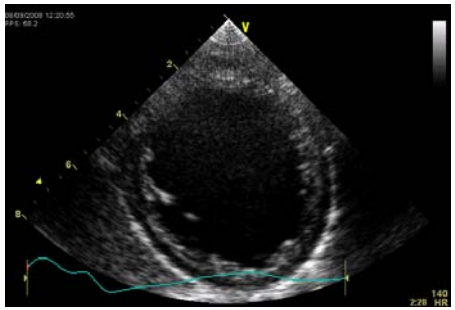




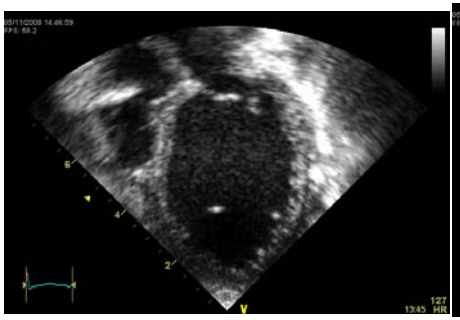
CRT as a bridge to recovery

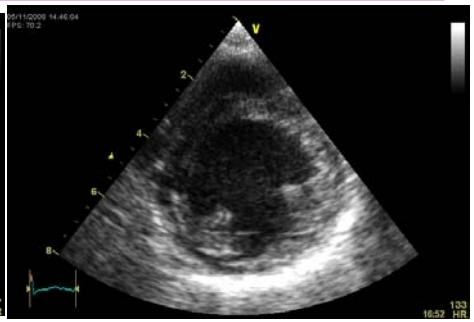
Before BiV implantation

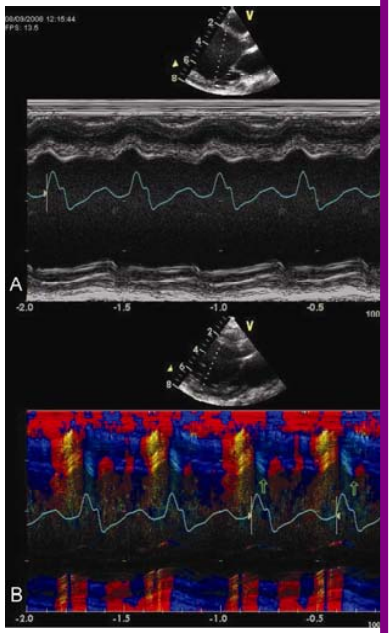


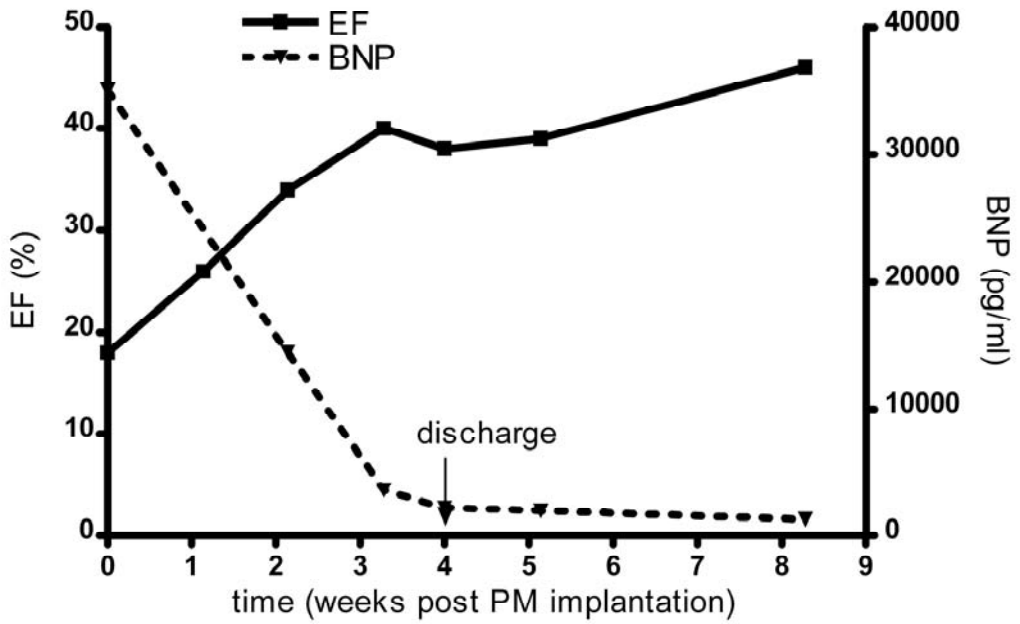


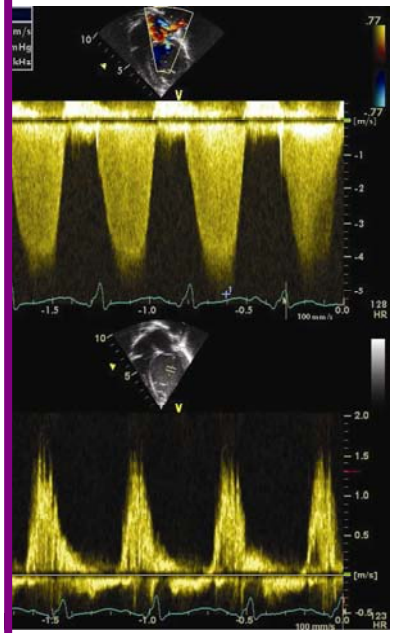
3 months after BiV implantation











Summary

Cont`d →

- **Myocardial deformation imaging (MDI)** has became **important diagnostic tool** to assess regional myocardial function and dyssynchrony

- **MDI is valuable** in assessing RWMA in paediatric patients as both **mechanical** and **electro-mechanical dyssynchrony** affecting mainly **viable myocardium**

Cont`d

Summary

- There is **no single echo MDI dyssynchrony parameter** which can be advised for selection of candidates for CRT

  All parameters have technical or theoretical limitations

- **Speckle tracking** (SC) relatively easy to use, not angle dependent and reproducible, however its predictive value is not known yet
- Accurate interpretation of ECHO findings requires **experience** and **learning curve is rather long**
- **Randomised trials** (in children) **are missing**