Programming and Follow-up of CRT

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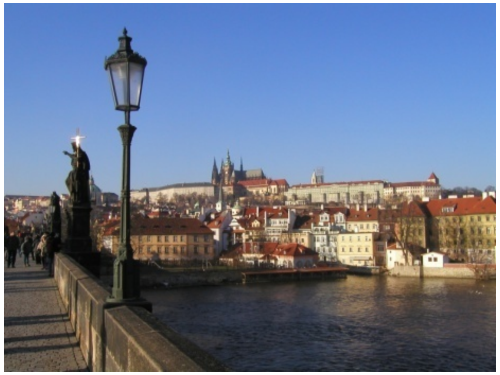


Kardiocentrum

No relationships to disclose

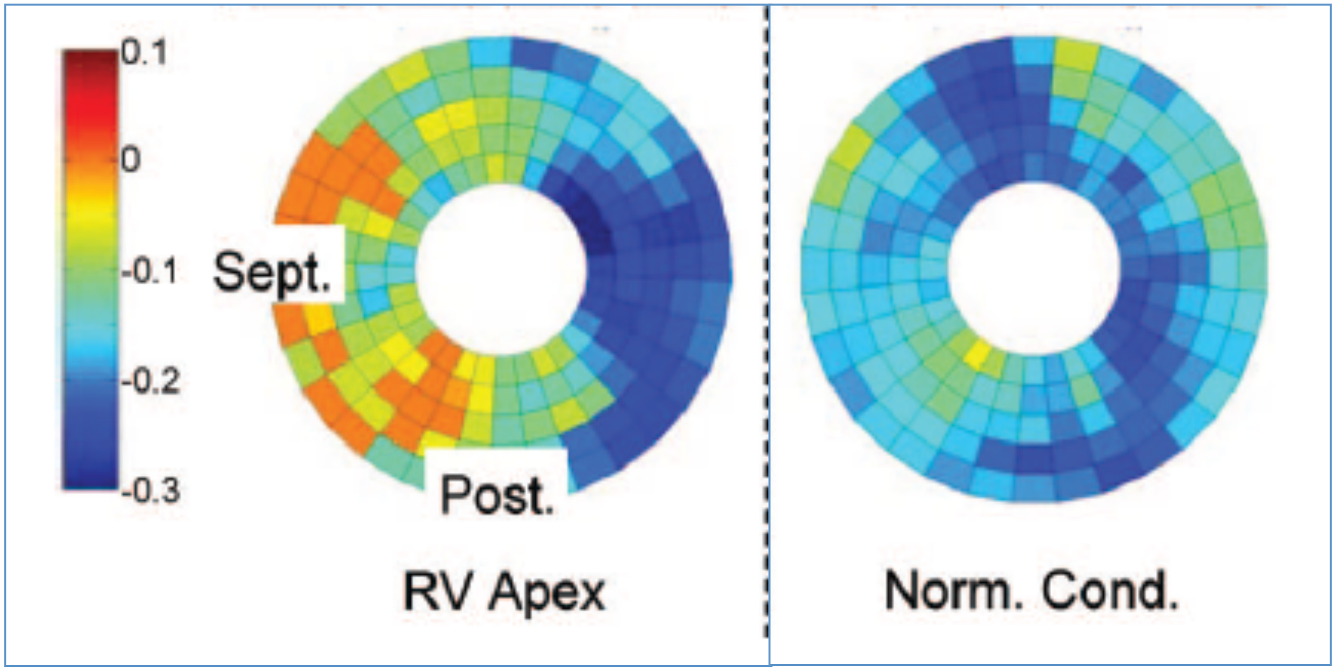
Left Ventricular Septal and Left Ventricular Apical Pacing Chronically Maintain Cardiac Contractile Coordination, Pump Function and Efficiency

Robert W. Mills, Richard N. Cornelussen, Lawrence J. Mulligan, Marc Strik, Leonard M. Rademakers, Nicholas D. Skadsberg, Arne van Hunnik, Marion Kuiper, Anniek Lampert, Tammo Delhaas and Frits W. Prinzen

Circ Arrhythm Electrophysiol 2009;2;571-579; originally published online August 25,

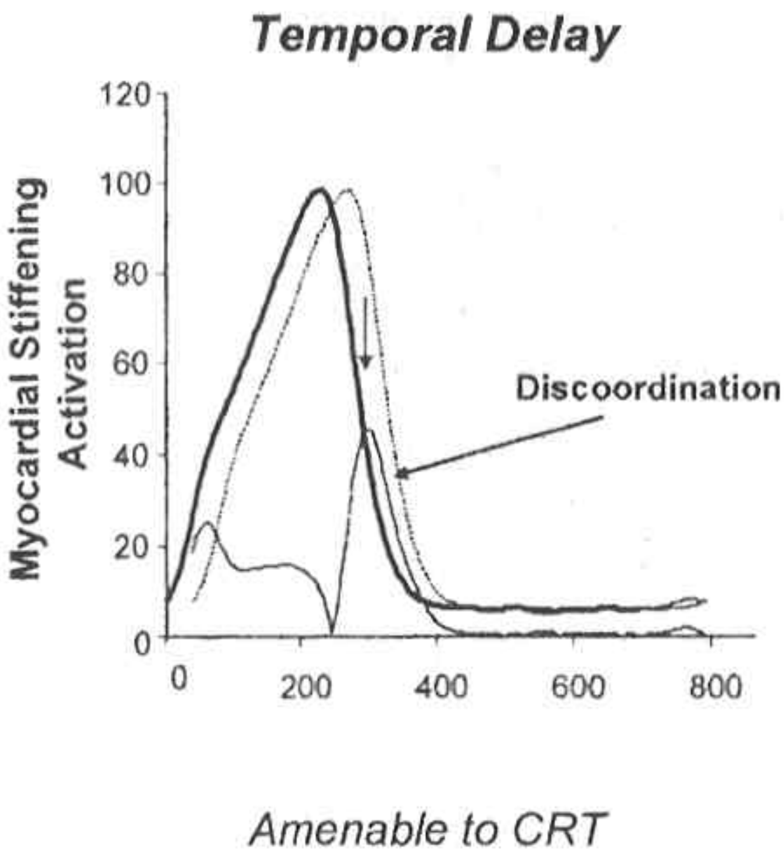
Dyssynchronous heart failure is a problem of contraction efficiency and energy loss

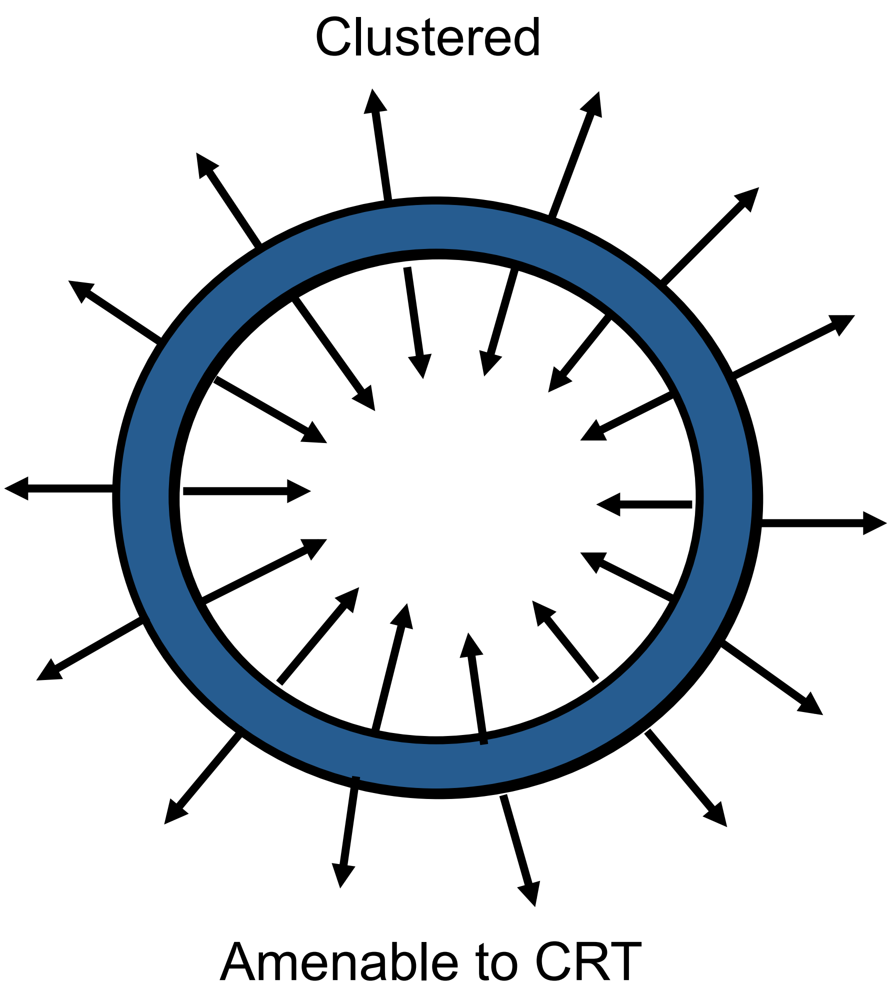
LV regional circumferential strain: ε_{cc} min-max during ejection



CRT should maximally improve the myocardial energetic bilance

Clustered dyssynchrony due to temporal activation delay

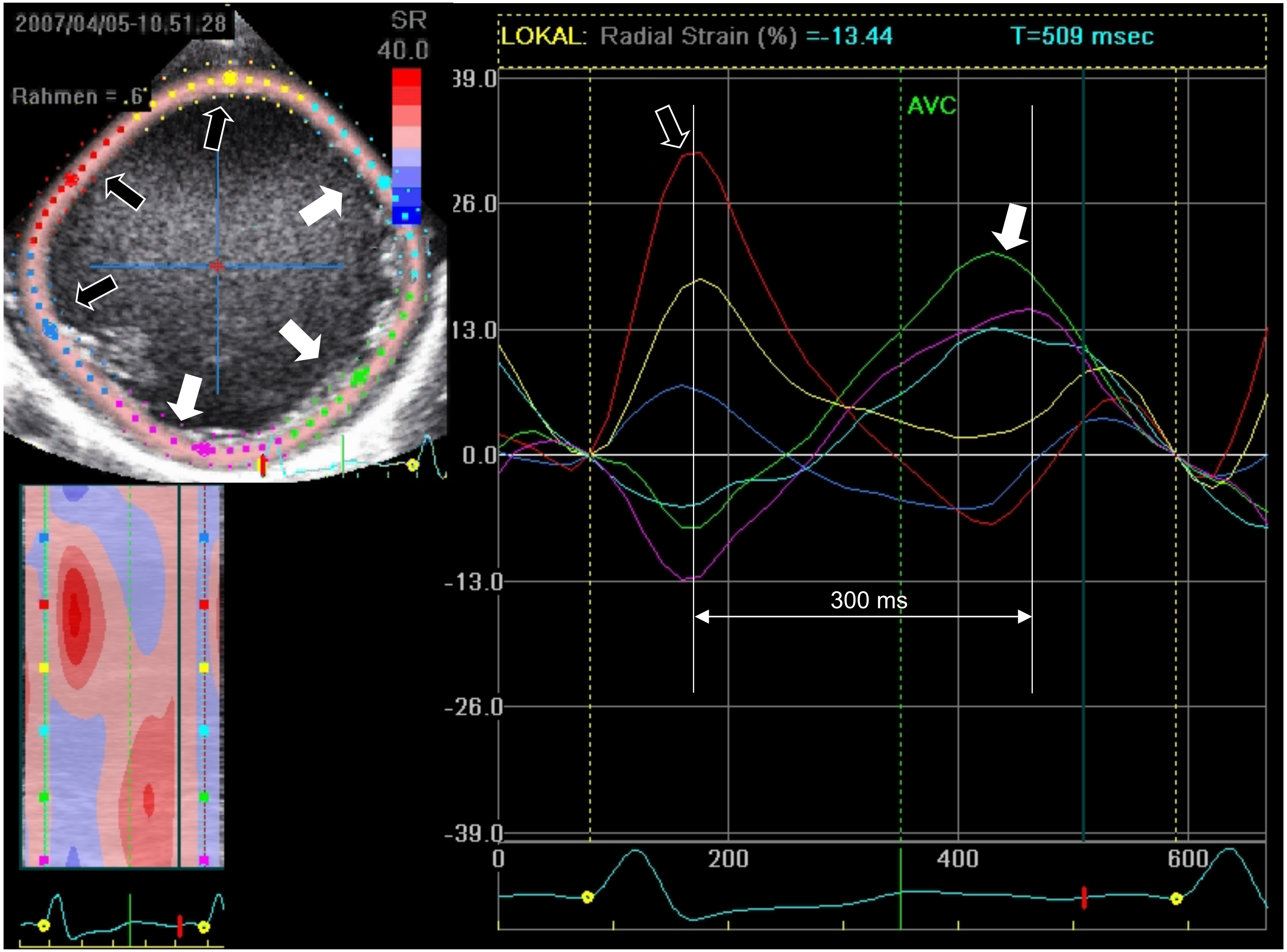




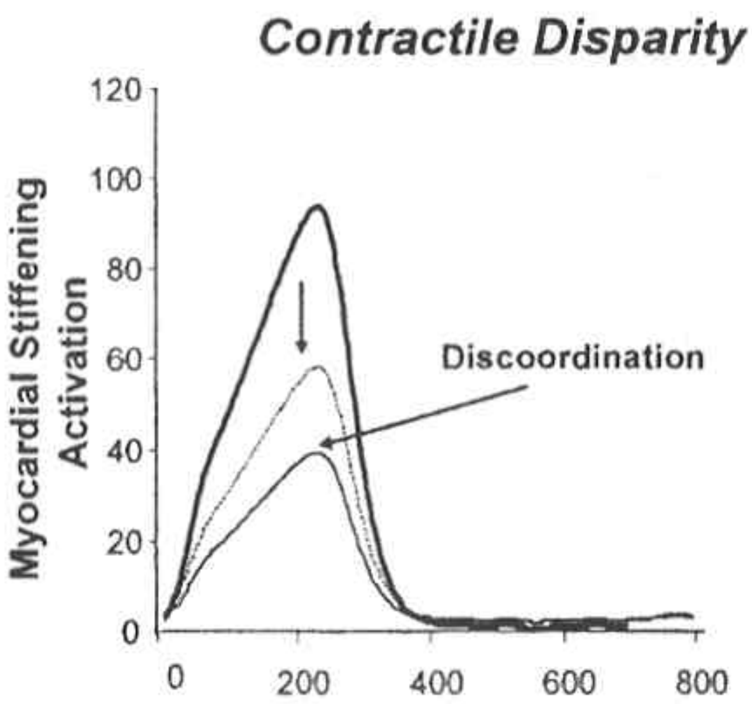
Kass DA, JACC 2008

Helm RH et al.,Circulation 2005

Dyssynchrony amenable to CRT

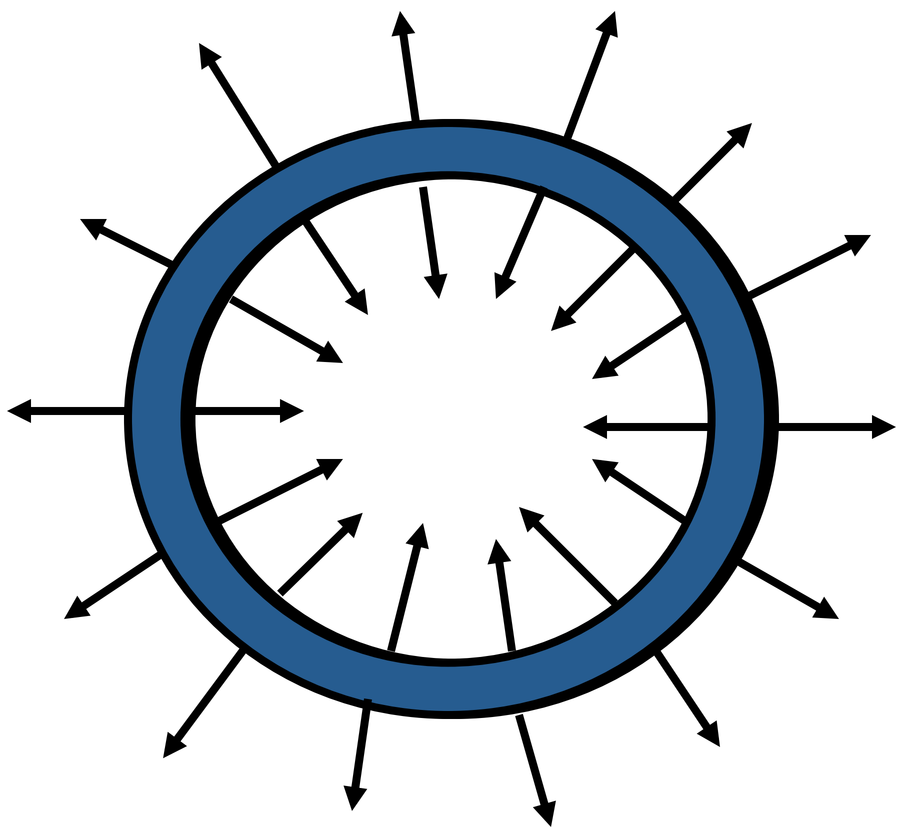


Dispersed dyssynchrony due to contractile disparity



Probably not amenable to CRT

Dispersed

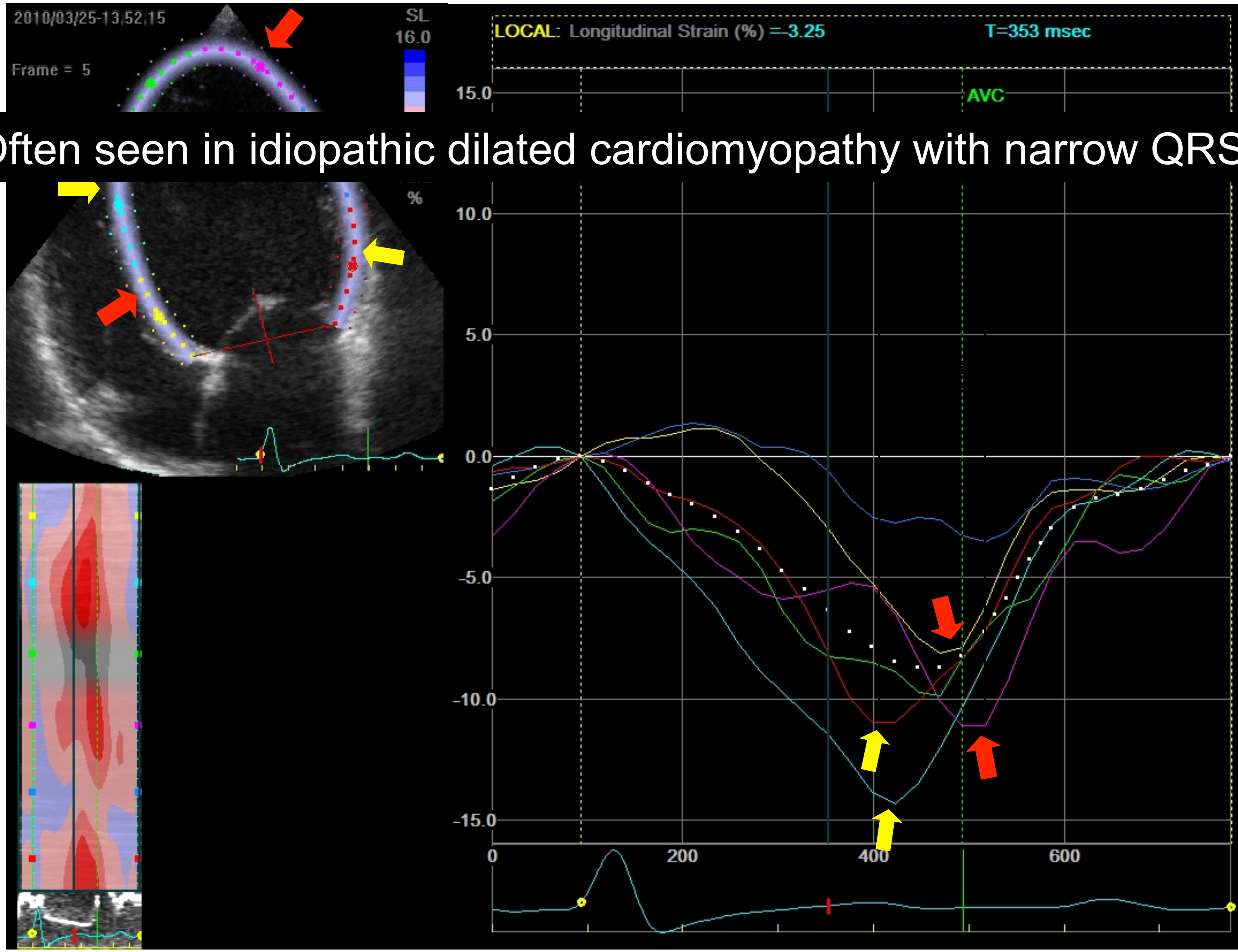


Not amenable to CRT

Kass DA, JACC 2008

Helm RH et al.,Circulation 2005

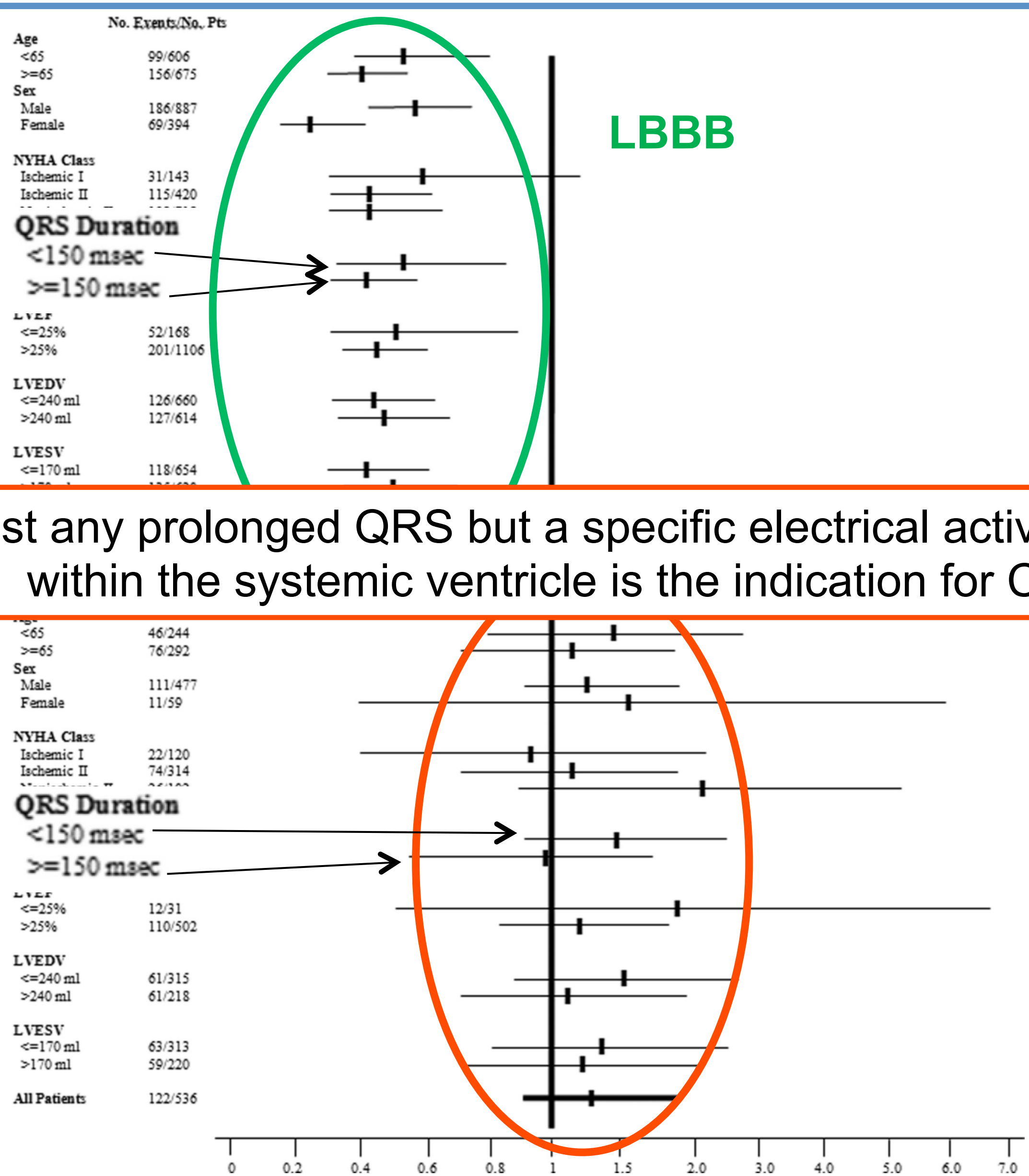
Dispersed segmental dyssynchrony due to contractile disparity



Often seen in idiopathic dilated cardiomyopathy with narrow QRS

Effectiveness of CRT by QRS Morphology

Risk of heart failure event or death after CRT



Not just any prolonged QRS but a specific electrical activation delay within the systemic ventricle is the indication for CRT!

Zareba W et al. MADIT-CRT trial. Circulation 2011

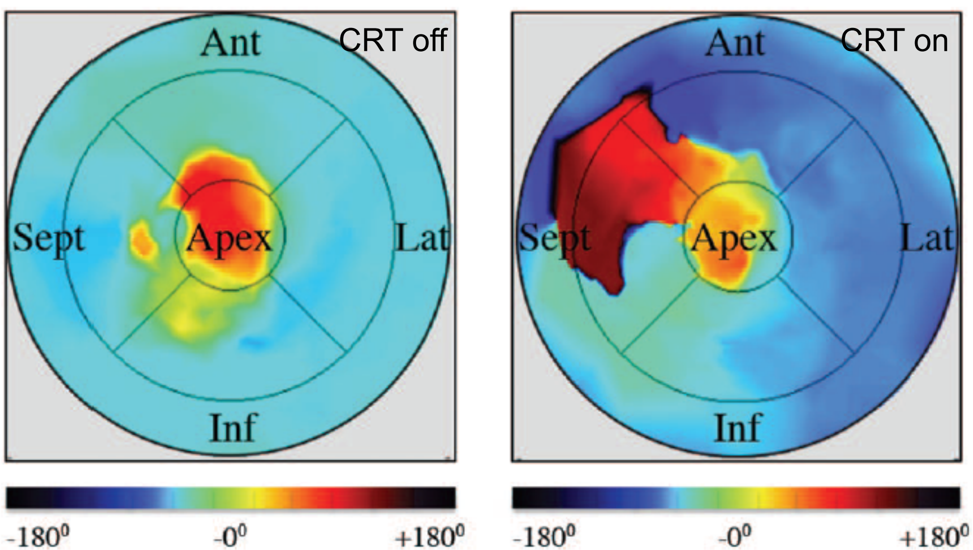
Cardiac Resynchronization Therapy in Patients With Heart Failure and a QRS Complex <120 Milliseconds

The Evaluation of Resynchronization Therapy for Heart Failure (LESSER-EARTH) Trial

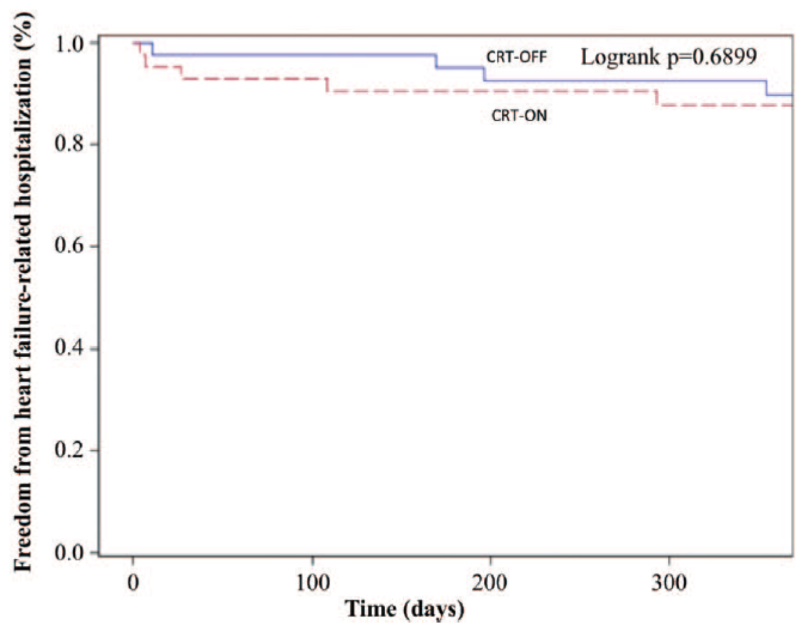
Circulation. 2013; 127:873-881

Bernard Thibault, MD; François Harel, MD, PhD; Anique Ducharme, MD, MSc; Michel White, MD; Kenneth A. Ellenbogen, MD; Nancy Frasure-Smith, PhD; Denis Roy, MD; François Philippon, MD; Paul Dorian, MD; Mario Talajic, MD; Marc Dubuc, MD; Peter G. Guerra, MD; Laurent Macle, MD; Léna Rivard, MD; Jason Andrade, MD; Paul Khairy, MD, PhD; for the LESSER-EARTH Investigators

Polar map of left ventricular contraction



Time to first hospitalization for heart failure



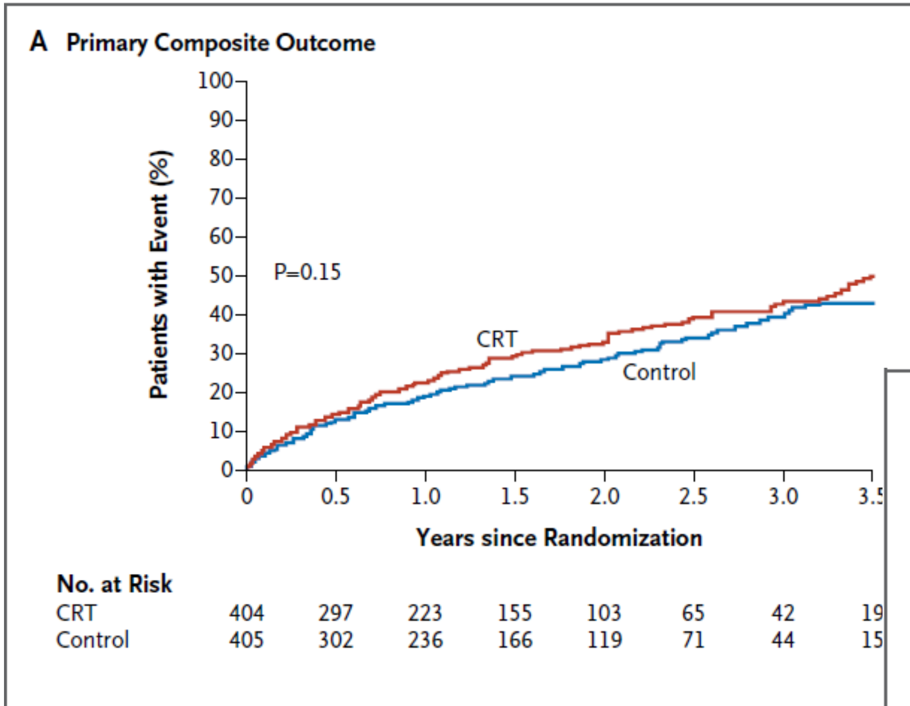
Cardiac-Resynchronization Therapy in Heart Failure with a Narrow QRS Complex

Echo-CRT study

NEJM 2013

Frank Ruschitzka, M.D., William T. Abraham, M.D., Jagmeet P. Singh, M.D., Ph.D.,

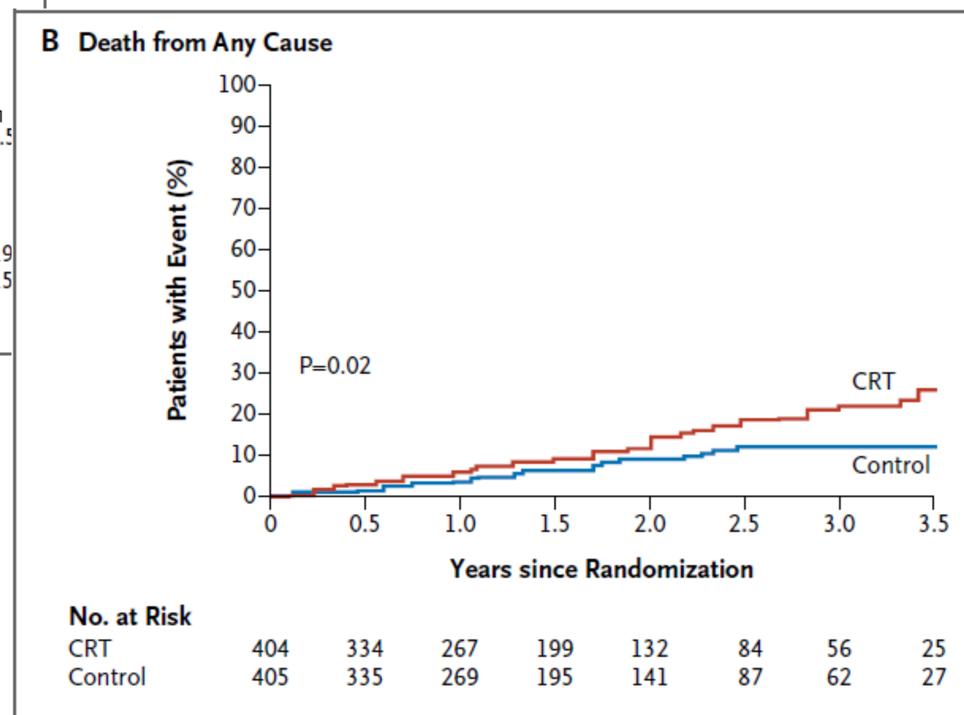
Death from any cause or hospitalization for heart failure



Conventional indication criteria met

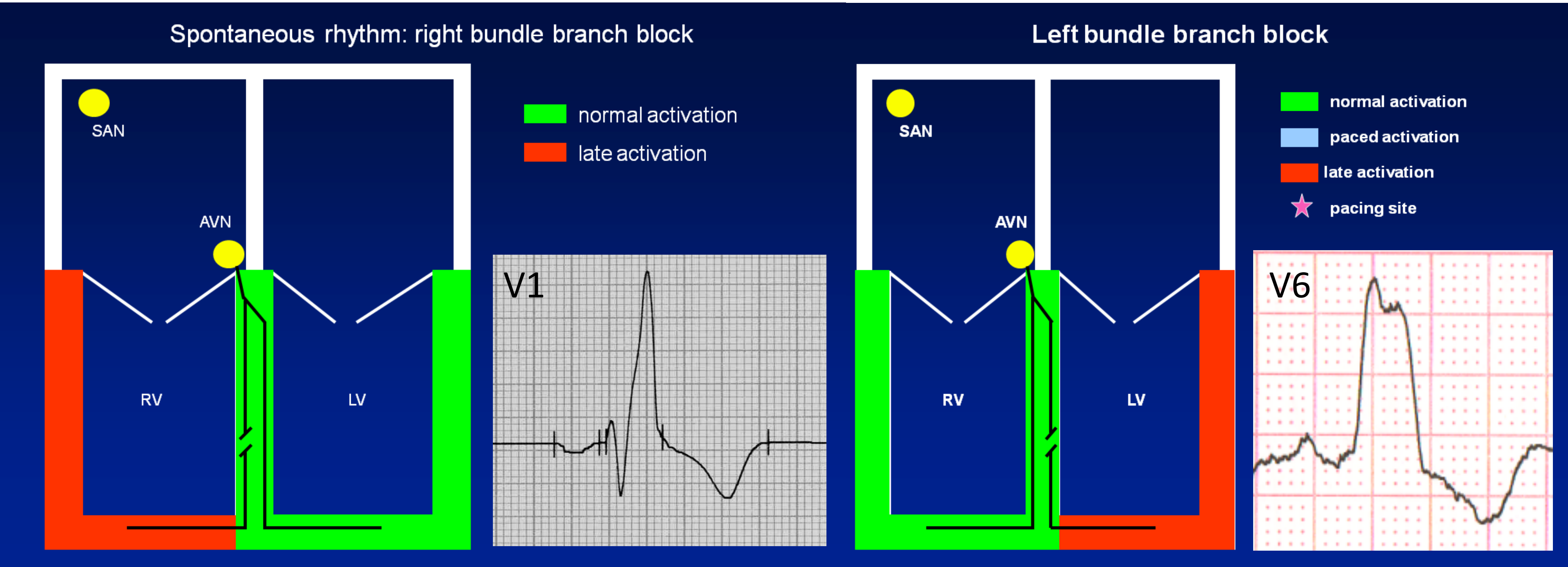
- NYHA III-IV
- QRS<130 ms
- Echo signs of dyssynchrony

Death from any cause

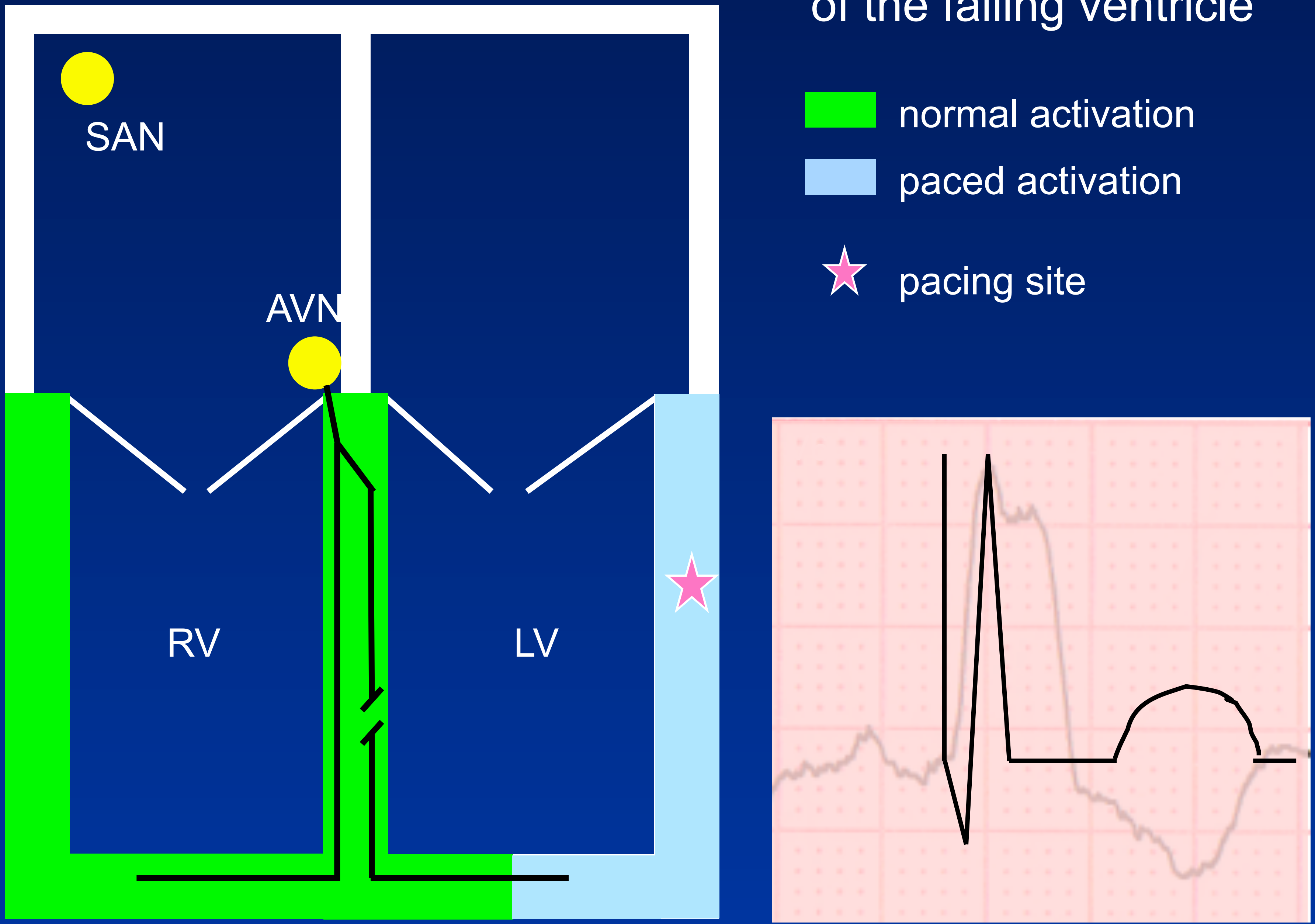


Look at ECG first!

- CRT is based on correction of an electrical activation delay within the failing ventricle
- Prove its presence!



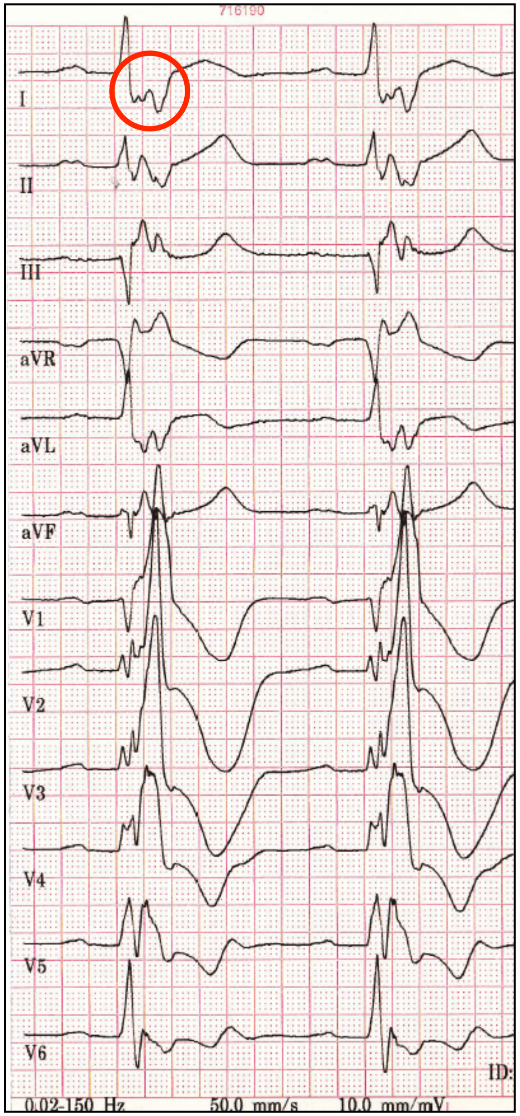
Electrical preexcitation of the electrically late activated segments of the failing ventricle



ECG changes

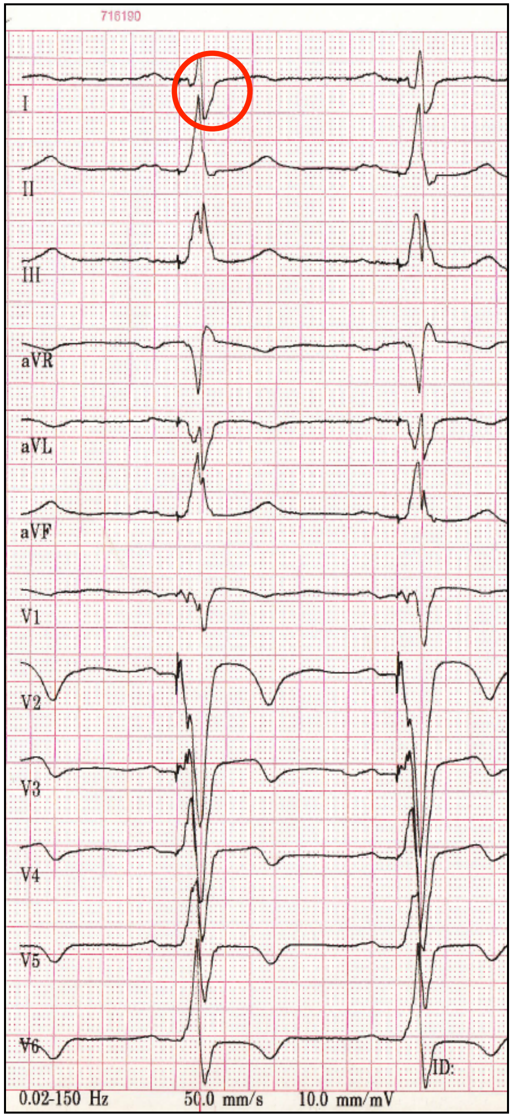
Before CRT

RBBB, QRS 200 ms

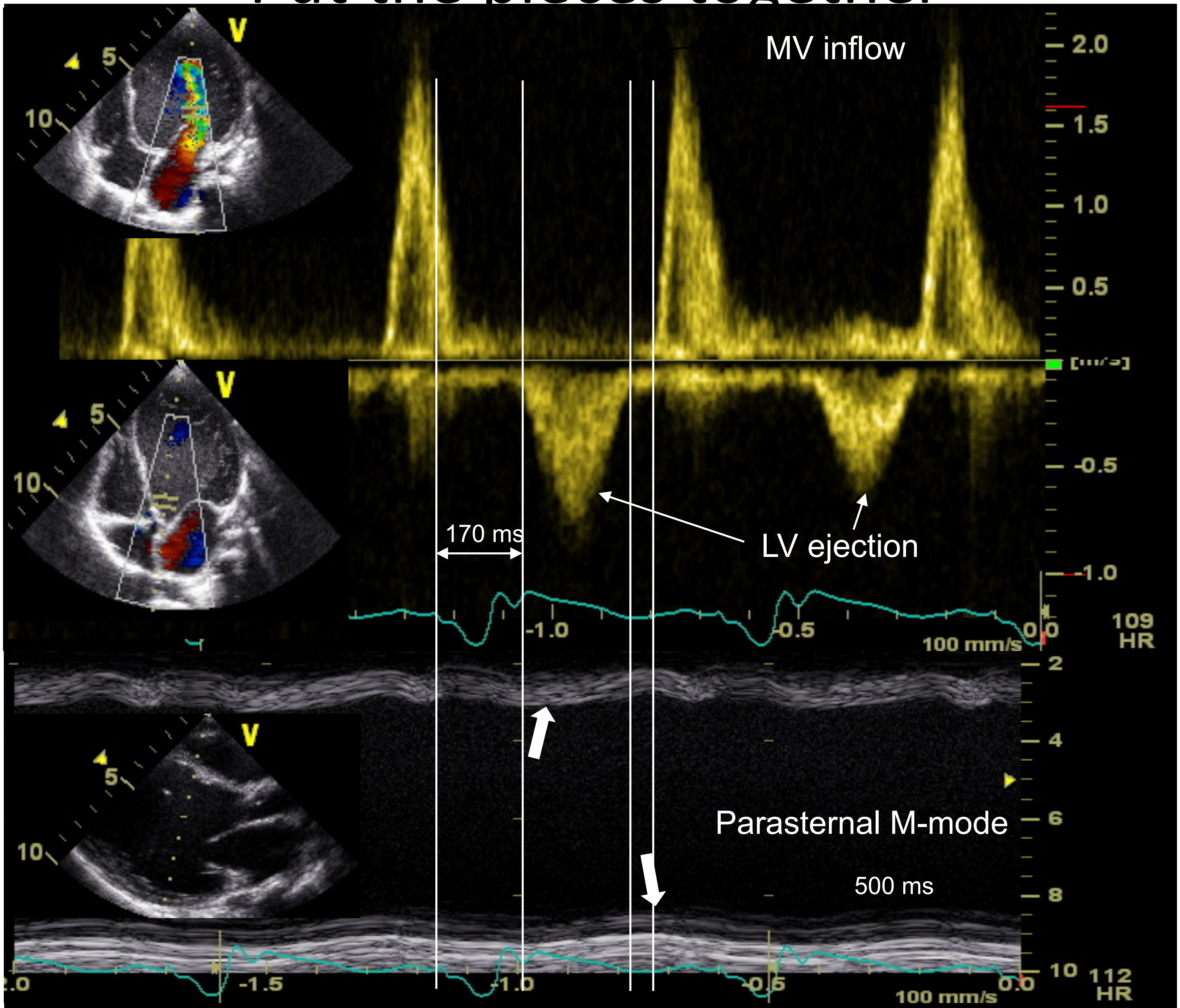


After CRT

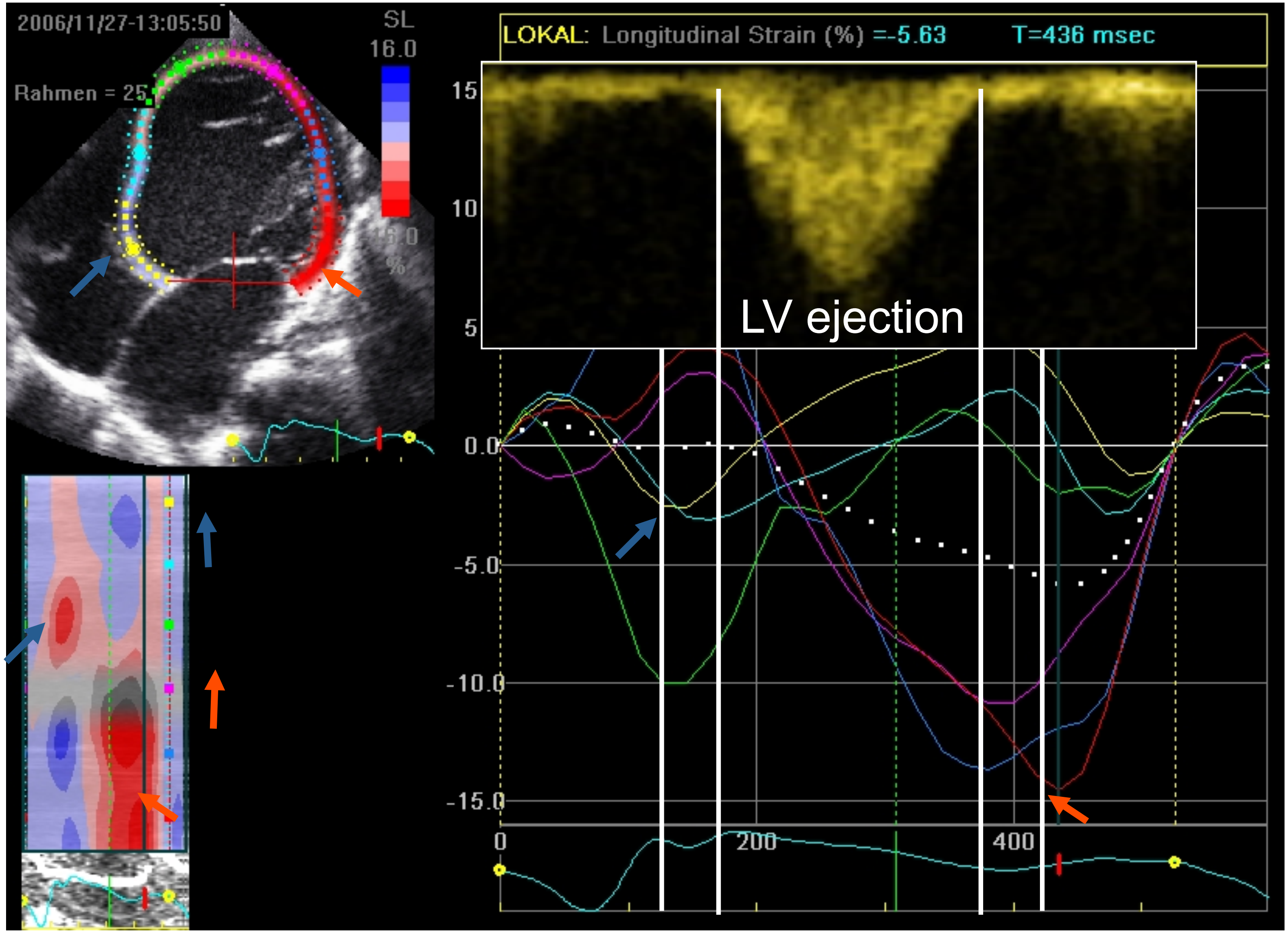
QRS 140 ms



Put the pieces together

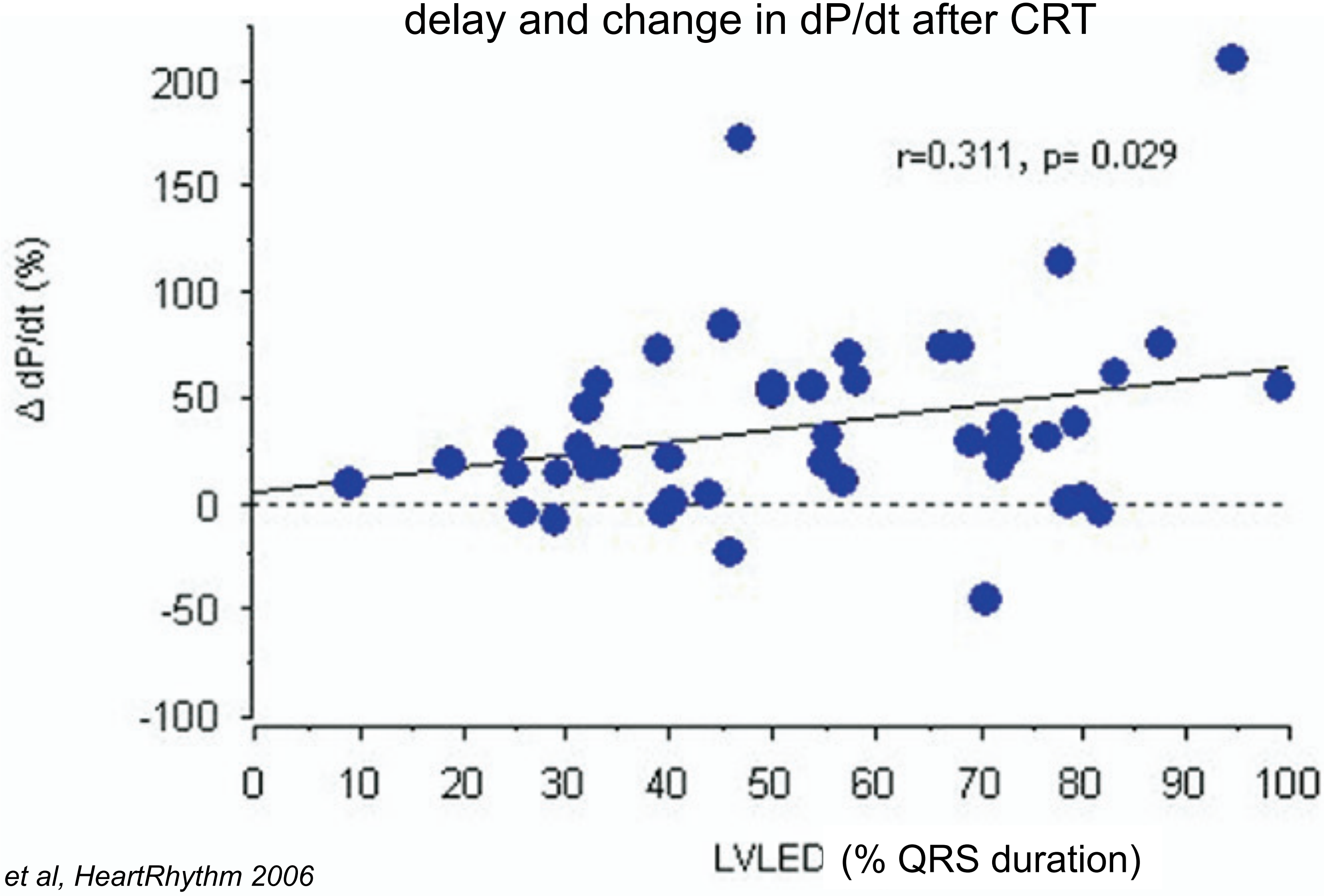


Put the pieces together



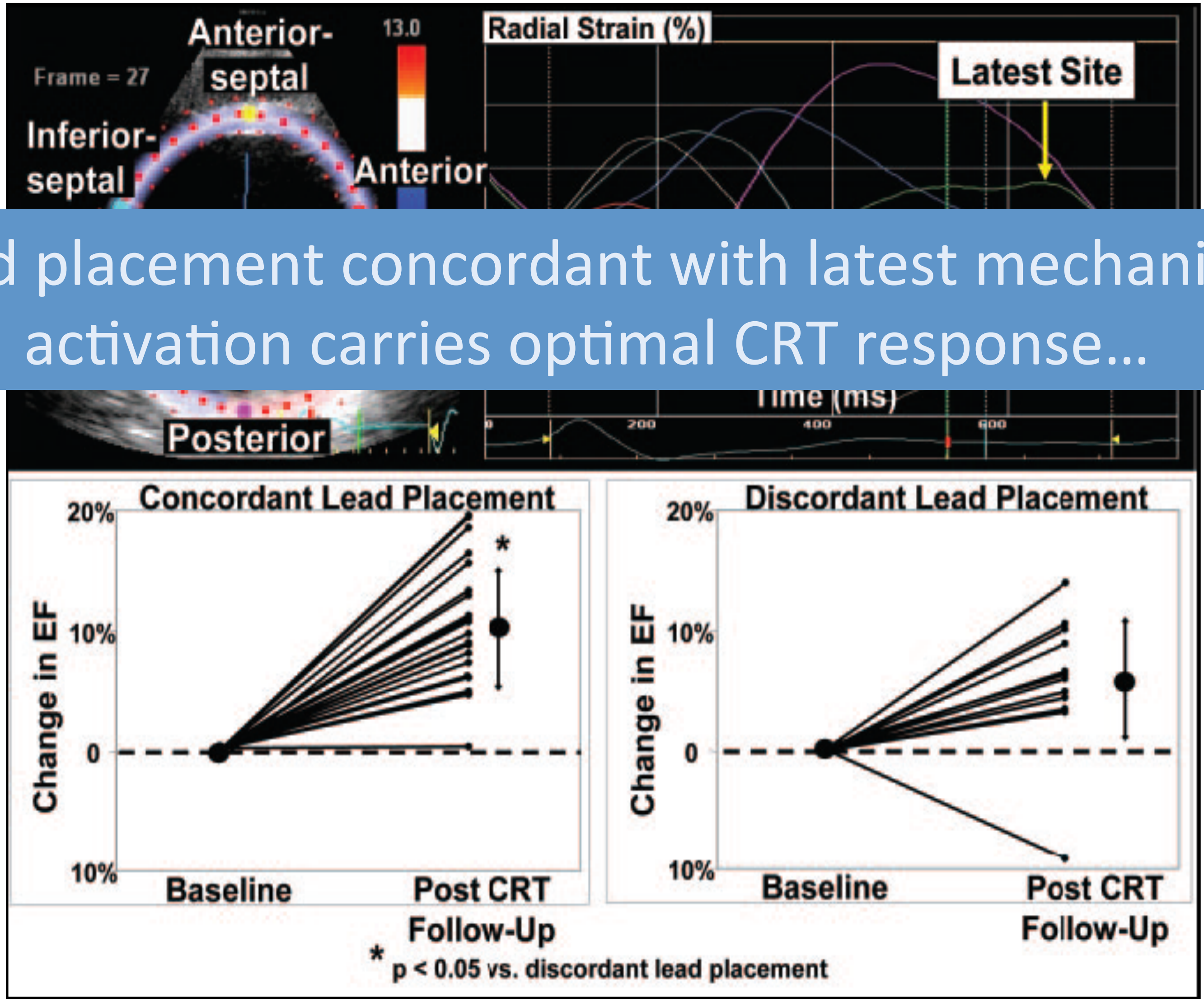
Electrical activation time predictive of CRT effect

Correlation between the extent of LV lead electrical delay and change in dP/dt after CRT



Singh JP et al, HeartRhythm 2006

Mechanical activation time predictive of CRT effect



Lead placement concordant with latest mechanical activation carries optimal CRT response…

Suffoletto MS, Circulation 2006

Testing of CRT effect prior to implantation

- May play a role in difficult to reach substrates
  - Systemic RV, functionally single ventricle

Table 2. Acute Hemodynamics Effects of CRT (in systemic RV)

Parameter	CRT Off Mean (SD)	CRT On Mean (SD)	% Change	p Value
QRS interval (ms)	161 (21)	116 (22)	−28.0	0.002†
Interventricular mechanical delay (ms)	median 60	median 50	−16.7	0.047‡
Dyssynchrony index (ms)	138 (59)	64 (21)	−53.6	0.042†
RV filling time (% RR)	45.1 (6.5)	50.0 (6.1)	10.9	0.002†
Tei index	median 0.65	median 0.60	−7.7	0.008‡
RV +dP/dt (mm Hg/s)	630 (142)	919 (211)	45.9	0.007†
Aortic VTI (cm)	17.2 (6.2)	18.4 (6.8)	7.0	0.028†
RV EF (%)*	41.5 (8.1)	45.5 (6.4)	9.6	0.04†

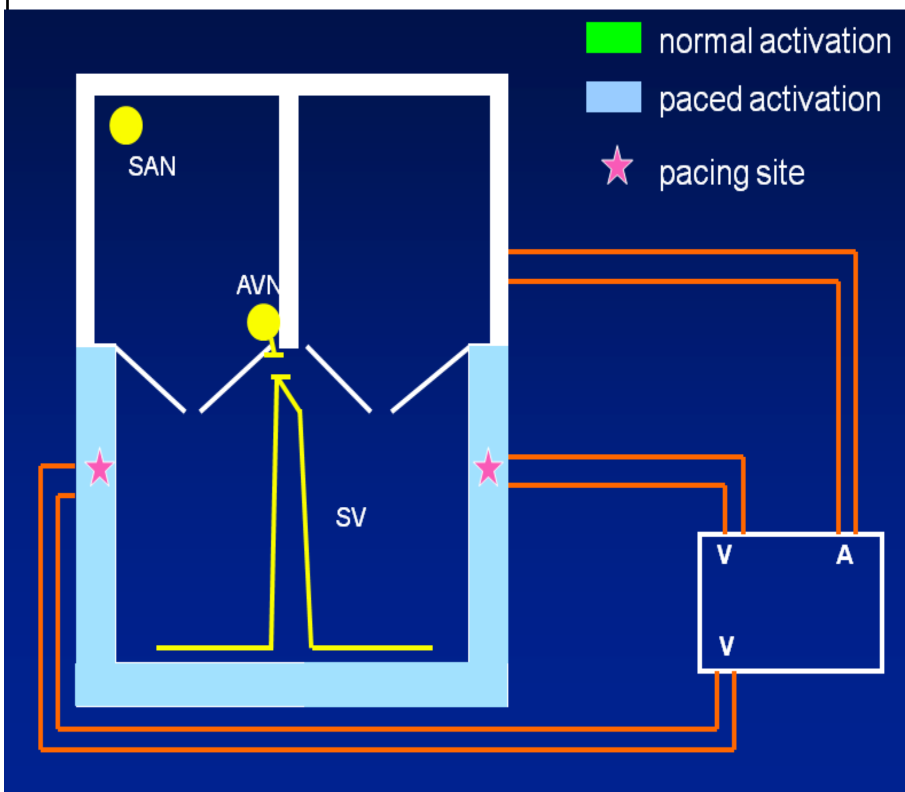
*Measured at a median of 3.8 months after initiation of CRT; †paired *t* test; ‡Wilcoxon signed rank test.
CRT = cardiac resynchronization therapy; EF = ejection fraction; RR = RR interval; RV = right ventricular; SD = standard deviation; VTI = velocity-time integral.

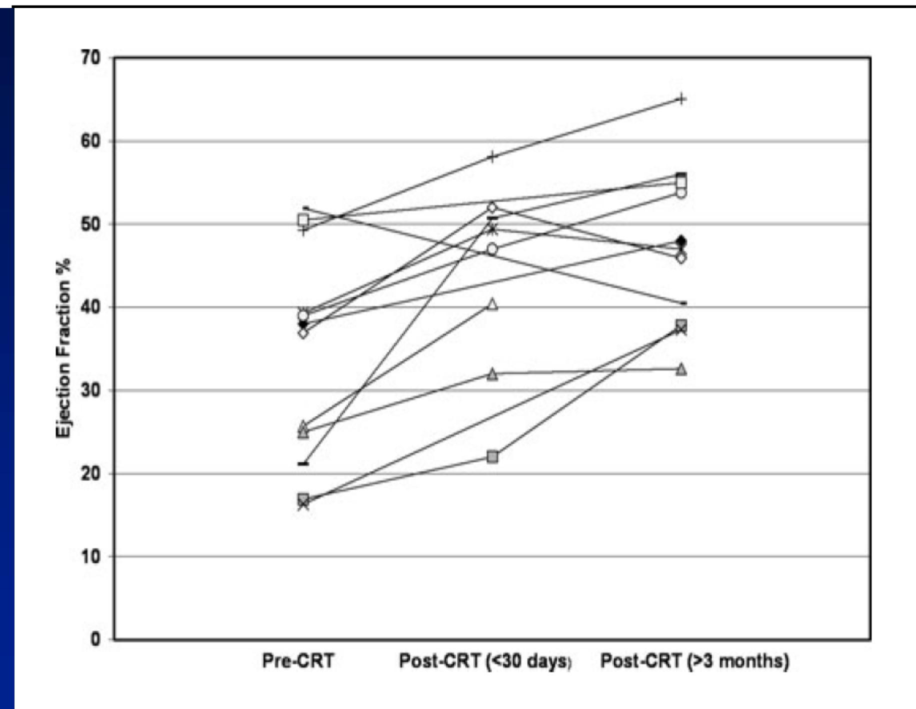
Janousek J et al. JACC 2004

Resynchronizing the single ventricle

The complete AV block patient

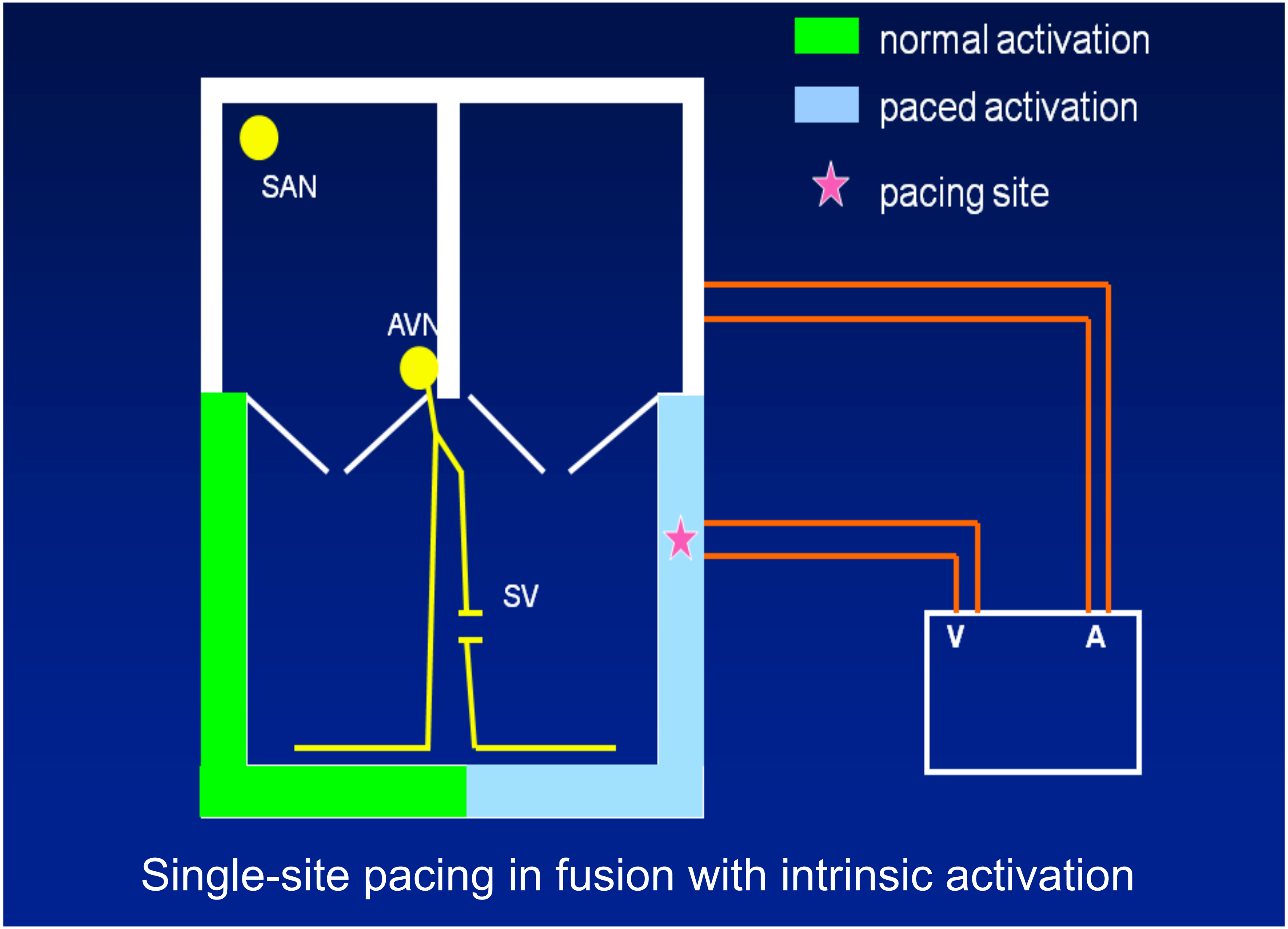
Our approach to this group has evolved our time, but a high importance was placed on obtaining maximal distance between



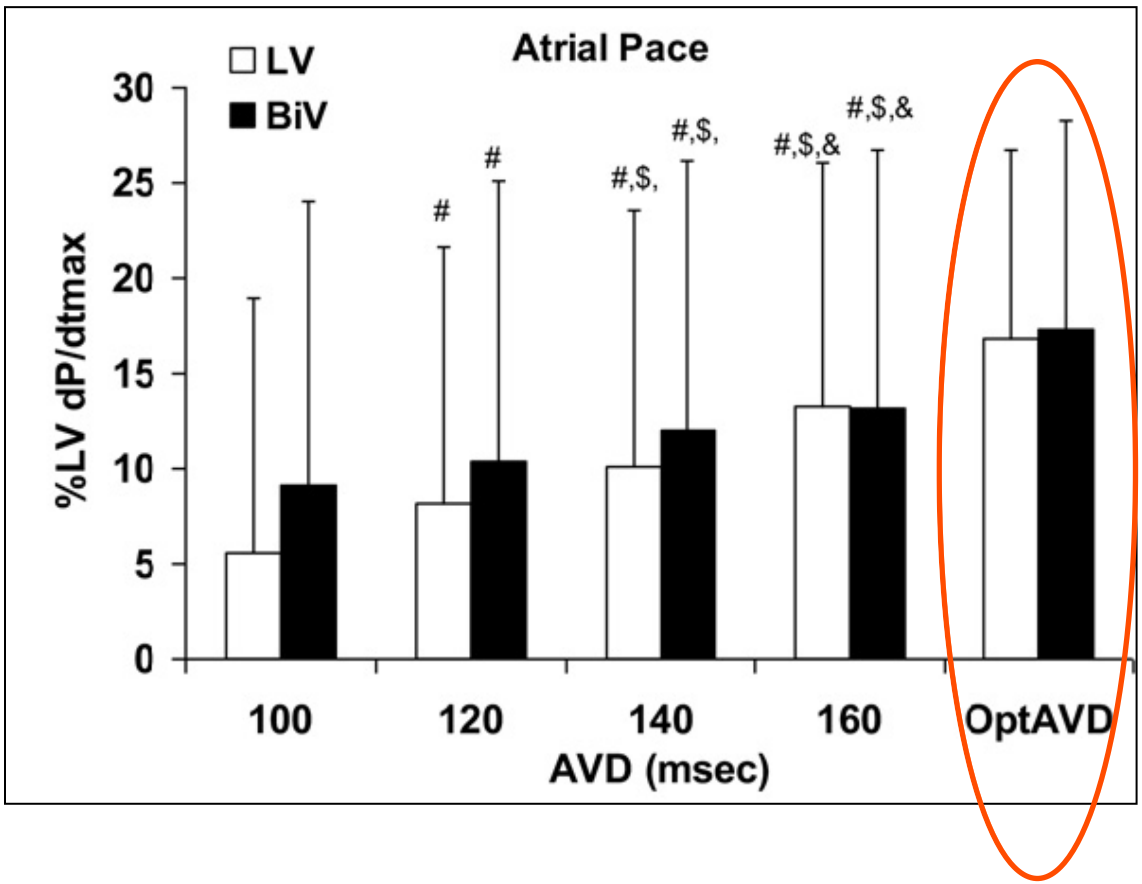


Cecchin F et al. JCE 2009;20:58-65

Resynchronizing the single ventricle
The bundle branch block patient



LV vs BiV pacing in adult idiopathic/ ischemic heart disease



Contractile function maximized if:

- optimal fusion between septal wall activation (intrinsic conduction) and free wall activation (pacing)

Post-procedural optimization

- Achieve >98 % of CRT pacing[1]
  - Propper AV-delay, PVARP and UTR settings
- AV and VV delay optimization
  - Current evidence does not support AV and VV optimization routinely
  - Little benefit over a fixed 100–120 ms AV delay in adults
  - May play a role in non-responders [2]
  - No clear difference between automatic ECG algorithms and echocardiographic methods[3,4]
  - Pediatric data?

[1]*Hayes DL et al. HeartRhythm 2011*
[2]*Brignole M et al. EHJ 2013*
[3]*Abraham WT et al., Am Heart J 2012*
[4]*Martin DO et al., HeartRhythm 2012*

A Pilot Study Assessing ECG versus ECHO Ventriculoventricular Optimization in Pediatric Resynchronization Patients

JCE 2016

RAJESH PUNN, M.D., DEBRA HANISCH, C.P.N.P., KARA S. MOTONAGA, M.D., DAVID N. ROSENTHAL, M.D., SCOTT R. CERESNAK, M.D., and ANNE M. DUBIN, M.D.

- Prospective, pediatric, single-center cross-over trial comparing ECHO and ECG optimization (N=19)
- Optimal synchronization
  - ECG = shortest QRSD
  - ECHO = lowest dyssynchrony index by tissue Doppler
- Endpoints
  - ejection fraction, velocimetry-derived cardiac index, quality of life, ECHO-derived stroke distance, M-mode dyssynchrony, study cost, time
- Conclusion
  - ECHO optimization not superior to ECG
  - ECG optimization required less time and cost

Cardiac Resynchronization Therapy for Pediatric Patients With Heart Failure and Congenital Heart Disease

A Reappraisal of Results

Kara S. Motonaga, MD; Anne M. Dubin, MD

(*Circulation*. 2014;129:1879-1891.)

Table 1. Single-Center Retrospective Studies of Permanent CRT in Pediatric and CHD-Related HF

	Janousek et al,[37] 2004	Strieper et al,[38] 2004	Moak et al,[39] 2006	Khairy et al,[40] 2006	Jauvert et al,[41] 2009	Cecchin et al,[42] 2009	Perera et al,[43] 2013
Total patients, n	8	7	6	13	7	60	67
Age (range), y	Median, 12.5 (6.9–29.2)	Mean, 11 (2.3–28)	Mean, 11.3 (0.5–23.7)	Mean, 7.8 (0.8–15.5)	Mean, 24.6 (15–50)	Median, 15 (0.4–47)	Unknown
Follow-up duration	Median, 17.4 mo	Median, 19 mo	Median, 10 mo	Mean, 16.5 mo	Mean, 19.4 mo	Median, 0.7 y	Mean, 2.75 y
CHD population, n (%)	8 (100)	7 (100)	3 (50)	10 (76.9)	7 (100)	46 (76.7)	50 (74.6)
Systemic RV	8 (100)	1 (14.3)	…	4 (30.8)	7 (100)	7 (11.7)	…
Systemic LV	…	6 (85.7)	3 (50)	6 (46.2)	…	26 (43.3)	…
Single ventricle	…	…	…	…	…	13 (21.7)	…

Patients

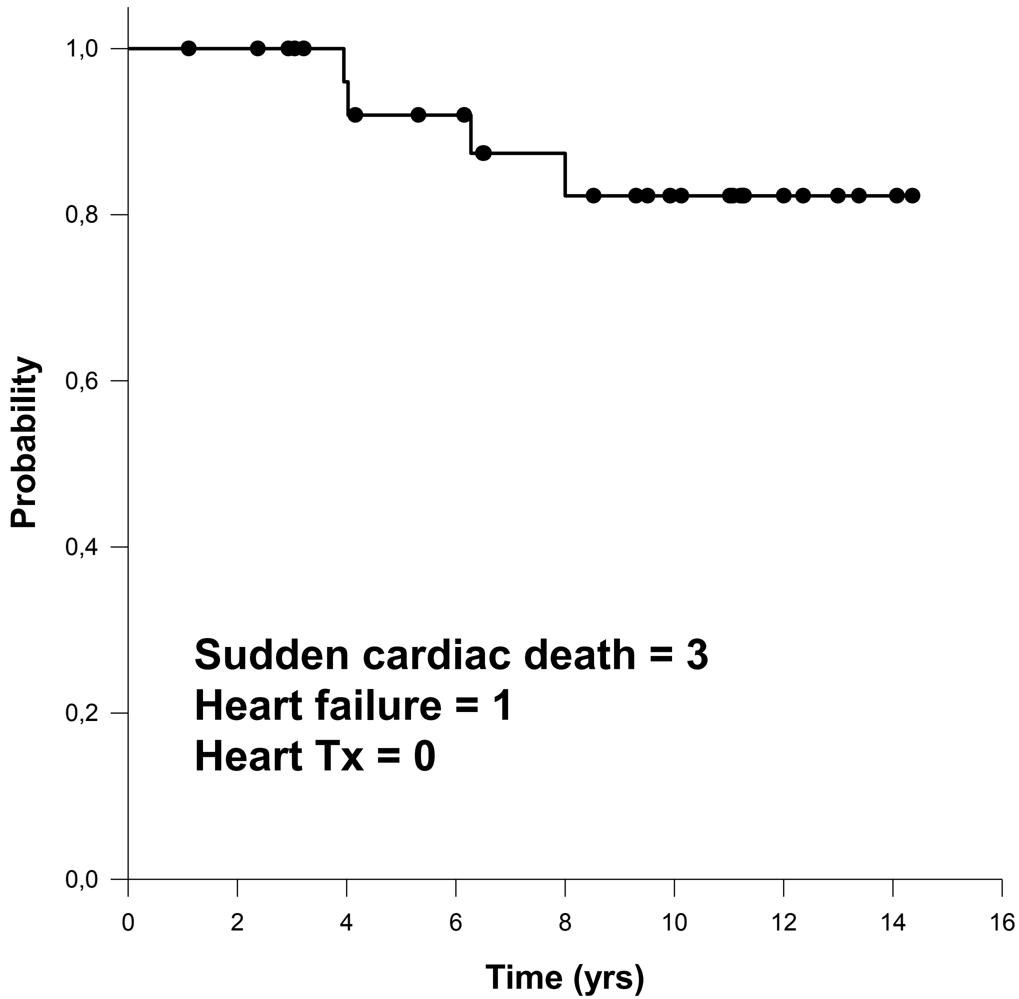
- Children´s Heart Centre, 30 consecutive pts
  - structural CHD (N=28), congenital AV block (N=2)
  - systemic ventricle: left (N=12), right/single (N=18)
- CRT implantation (2002 – 2014)
  - primary = 11, upgrade from conventional pacing = 19
  - transvenous = 3, thoracotomy = 19, mixed = 8
  - additional cardiac surgery = 13/30
- Age at CRT-P implantation: median 12.9 (IQR 6.5-18.2) yrs
- Follow up: median 9.0 (IQR 4.5-11.4) years on CRT
  - Ventricular function
  - Exercise capacity
  - NT-proBNP

Methods

- CRT response definition
  - increase in systemic ventricular
    - EF (Simpson biplane, systemic LV) or
    - fractional area of change (FAC, systemic RV/SV) by >10 points and
  - ≤ NYHA class at the end of FUP
- Actuarial survival probability
  - 5 and 10 years after CRT implantation

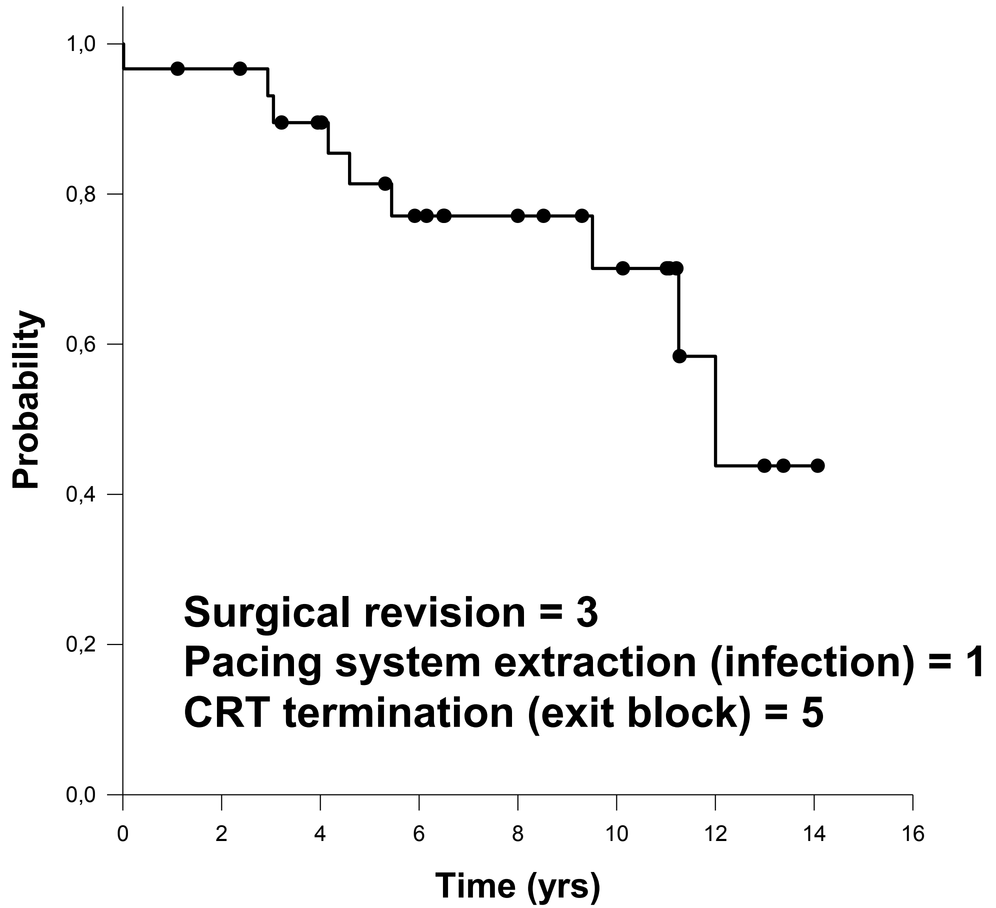
Results (I)

Freedom from cardiovascular death or heart failure hospitalization



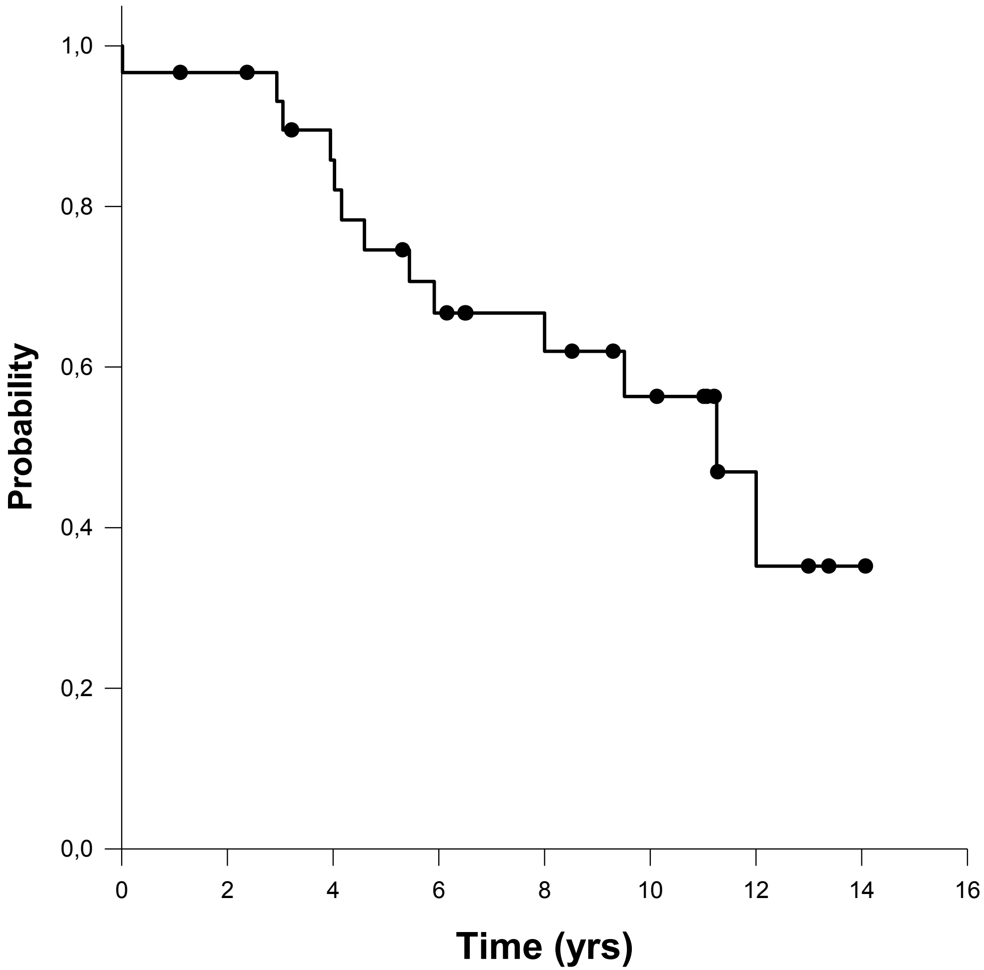
Results (II)

Freedom from CRT complications leading to surgical system revision (elective generator replacement excluded) or therapy termination

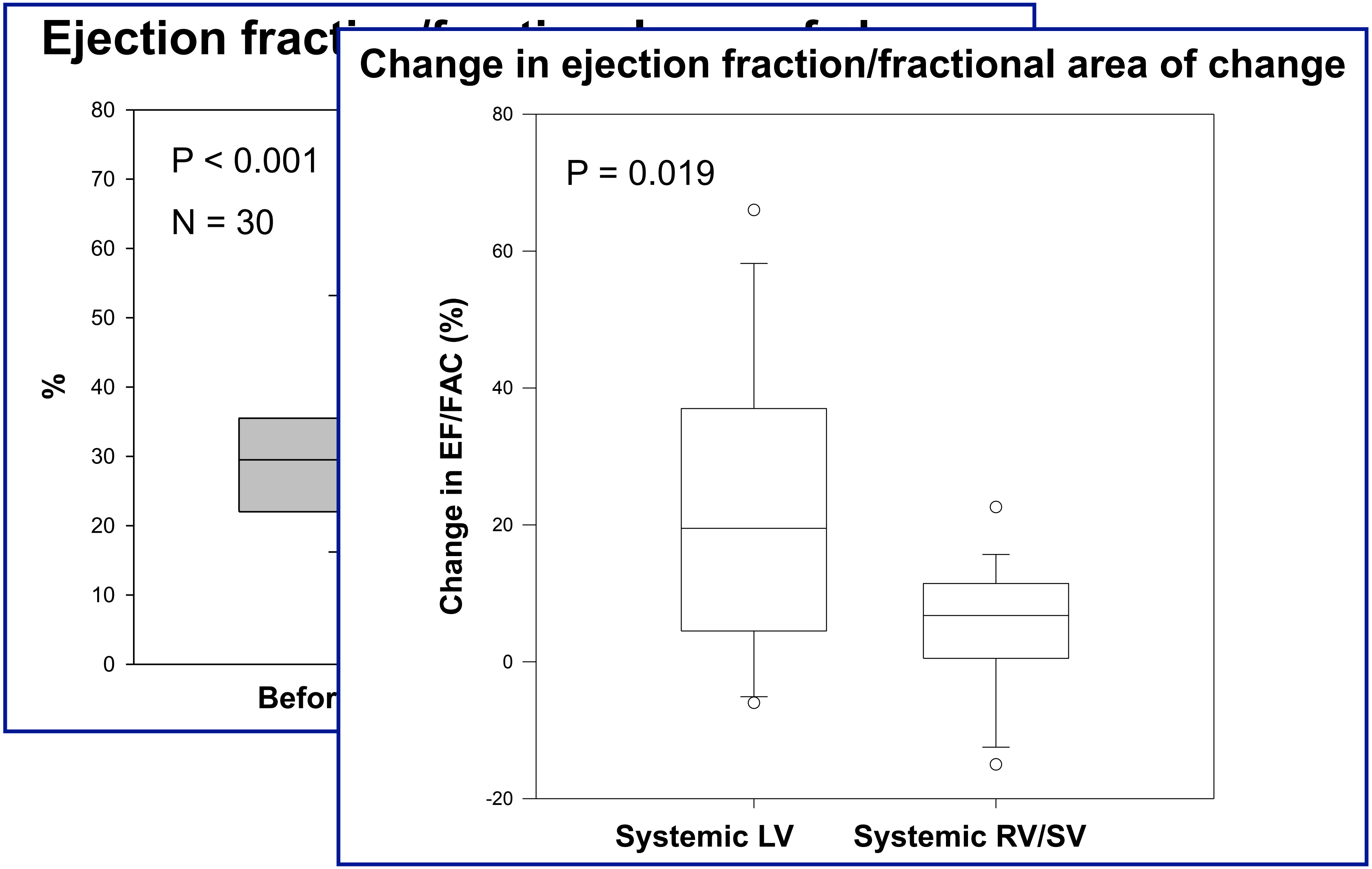


Results (III)

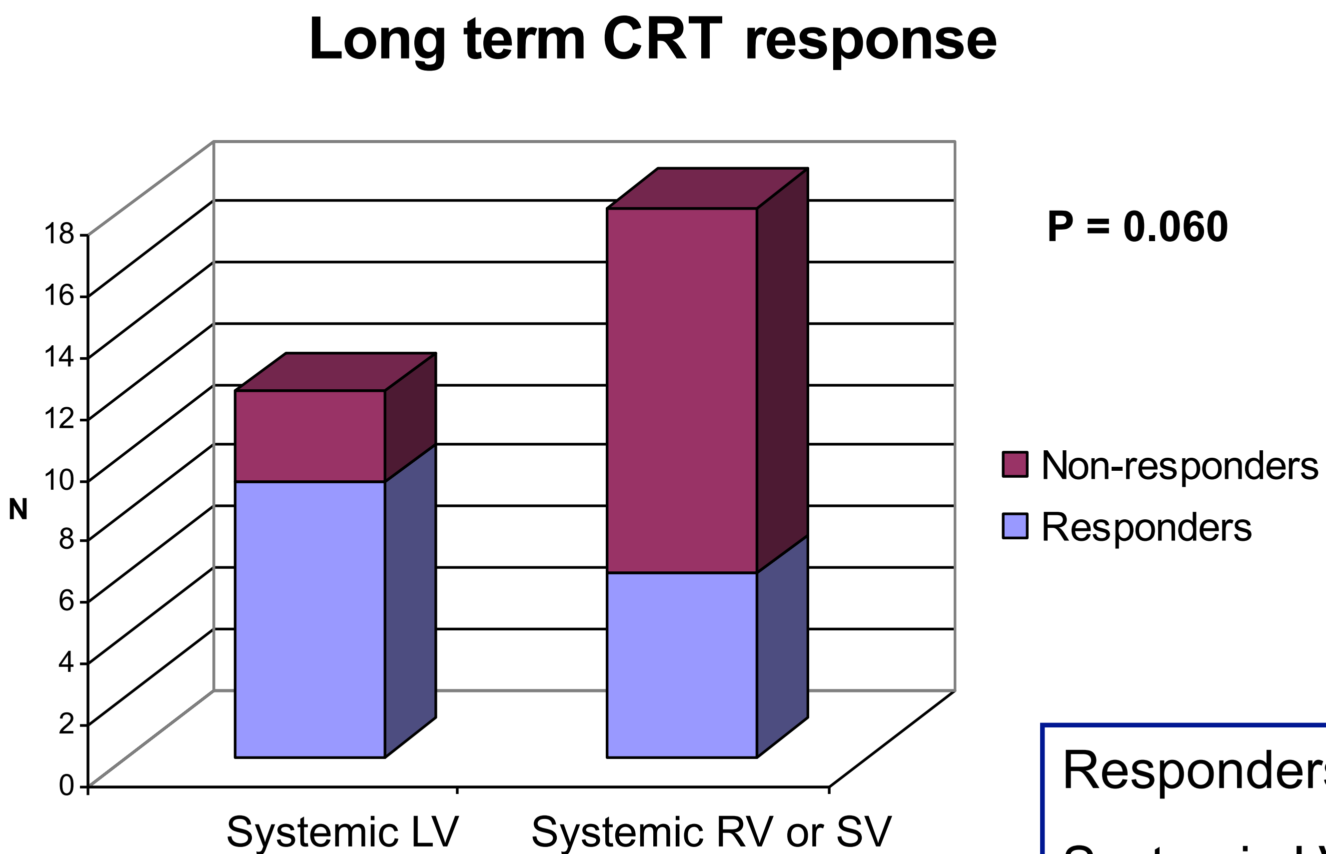
Overall probability of an uneventful therapy continuation



Results (IV)


Ejection fract
80
70
60
50
40
30
20
10
0
%
P < 0.001
N = 30
Befor
Change in ejection fraction/fractional area of change
80
60
40
20
0
-20
Change in EF/FAC (%)
P = 0.019
Systemic LV
Systemic RV/SV

Results (VI)



Responders (15/30 = 50 %):

Systemic LV = 9/12

Systemic RV or SV = 6/18

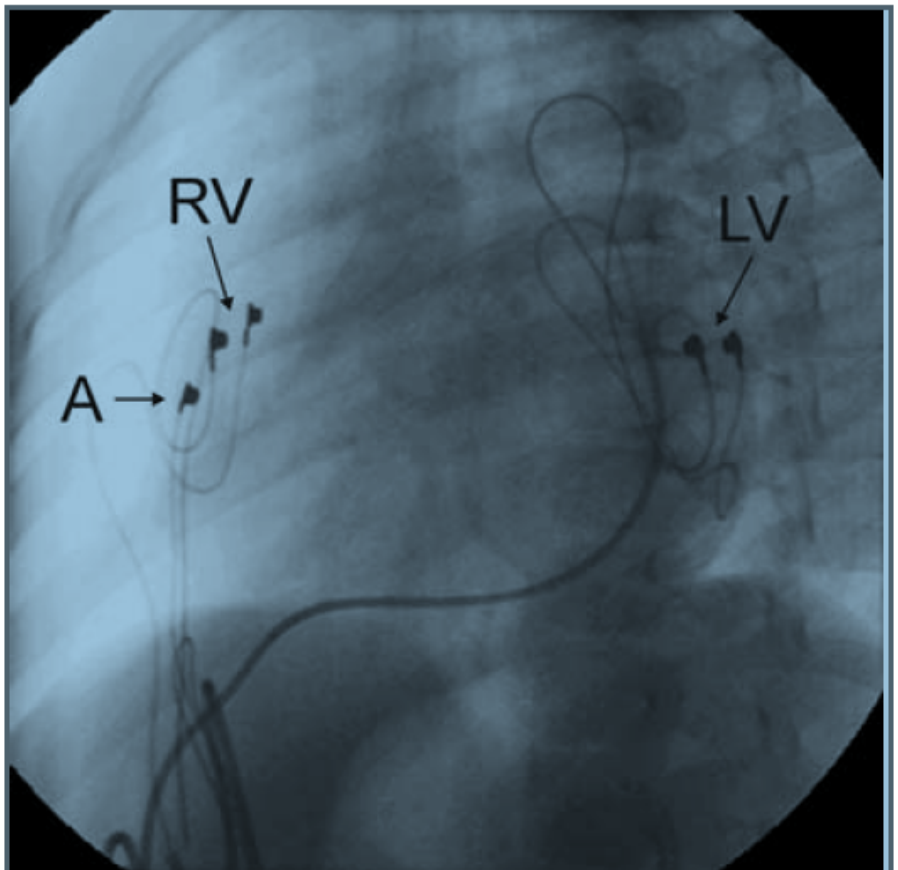
Cases

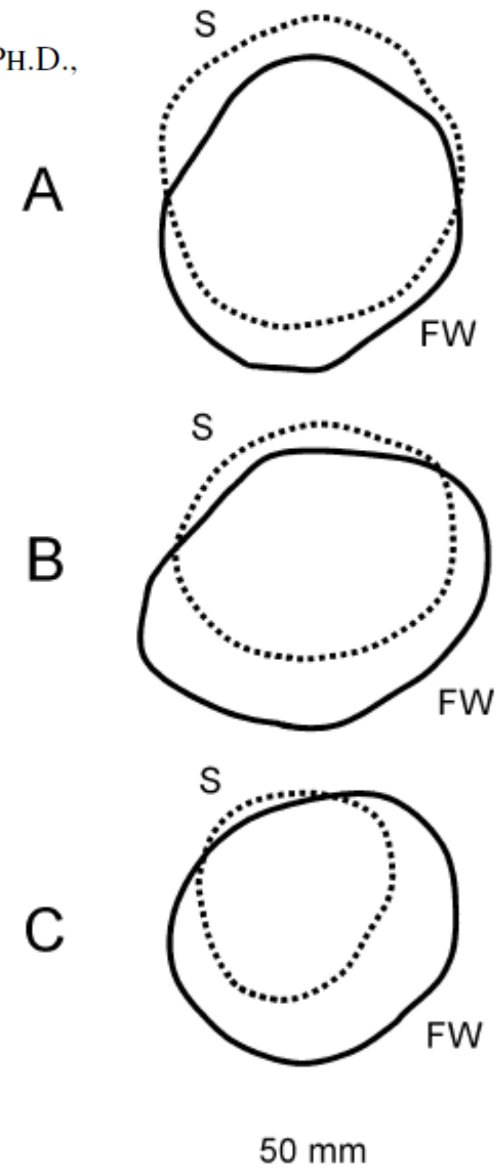
A patient-tailored approach

- To adapt to the variety of structural and functional conditions in congenital heart disease

Dilated Cardiomyopathy Associated with Dual-Chamber Pacing in Infants: Improvement Through Either Left Ventricular Cardiac Resynchronization or Programming the Pacemaker Off Allowing Intrinsic Normal Conduction JCE 2004

JAN JANOUŠEK, M.D., VIKTOR TOMEK, M.D., VÁCLAV CHALOUPECKÝ, M.D., PH.D., and ROMAN ANTONÍN GEBAUER, M.D.



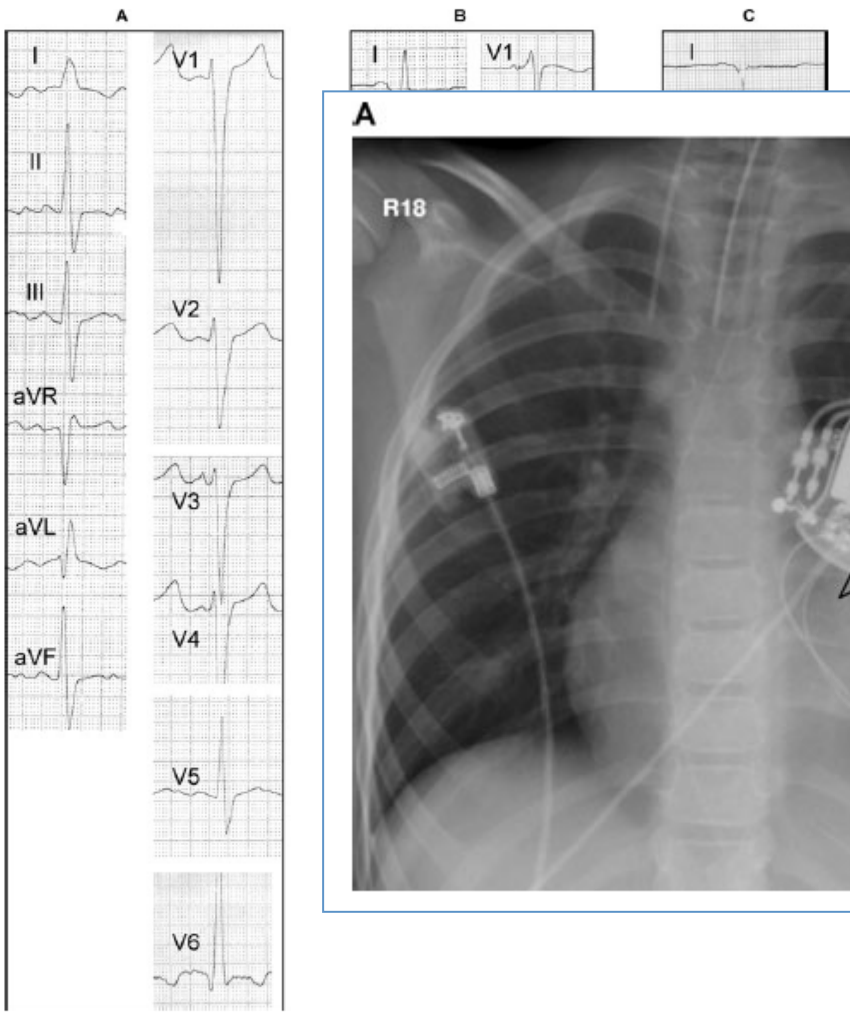


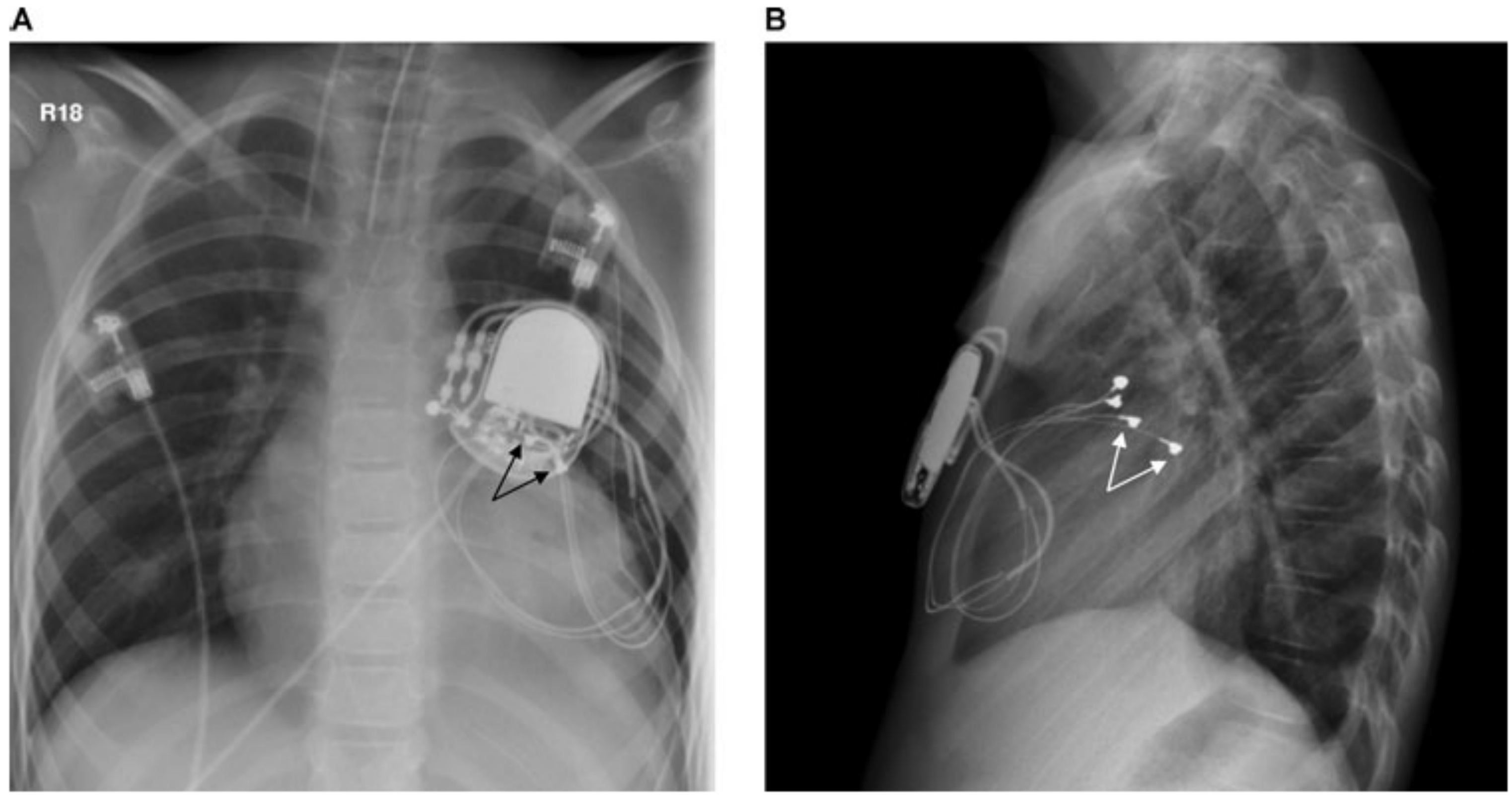
Cardiac Resynchronization in a Child with Dilated Cardiomyopathy and Borderline QRS Duration: Speckle Tracking Guided Lead Placement

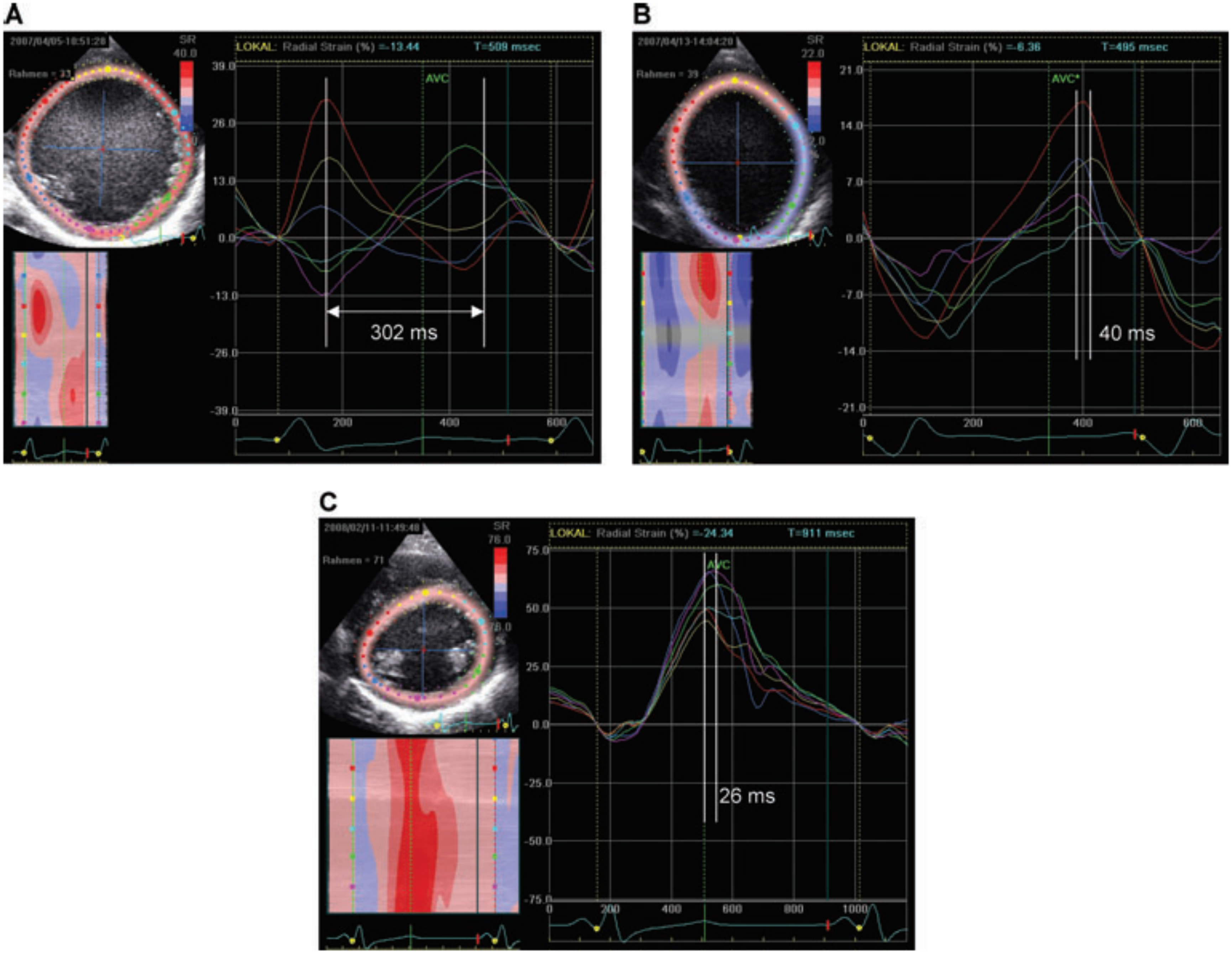
MARIA B. GONZALEZ Y. GONZALEZ, M.D.,* JOANA SCHWEIGEL, M.D.,* MARTIN KOSTELKA, M.D.,† and JAN JANOUŠEK, M.D., PH.D.*

From the *Department of Pediatric Cardiology, and †Department of Cardiac Surgery, University of Leipzig, Heart Center, Leipzig, Germany

PACE 2009







A
LOKAL: Radial Strain (%) =-13.44
T=509 msec
AVC
302 ms
B
LOKAL: Radial Strain (%) =-6.36
T=495 msec
AVC*
40 ms
C
LOKAL: Radial Strain (%) =-24.34
T=911 msec
AVC
26 ms

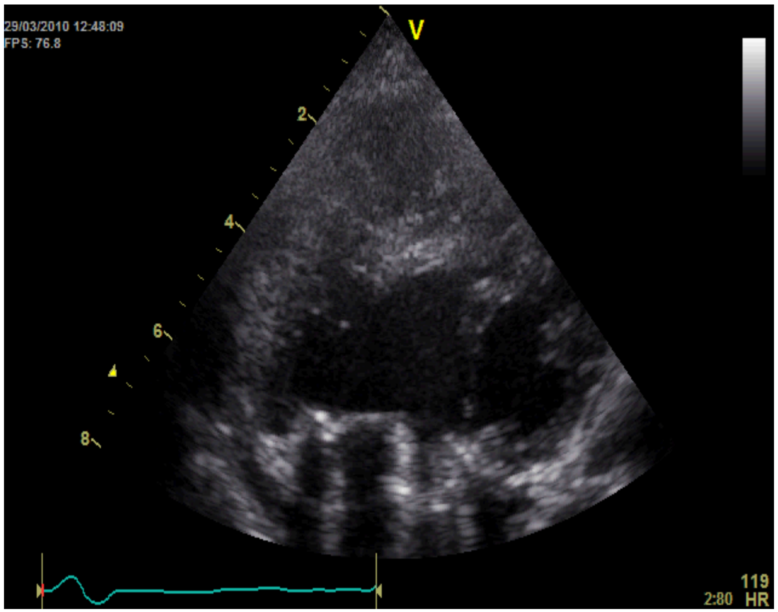
Right ventricular resynchronization in a child with hypoplastic left heart syndrome

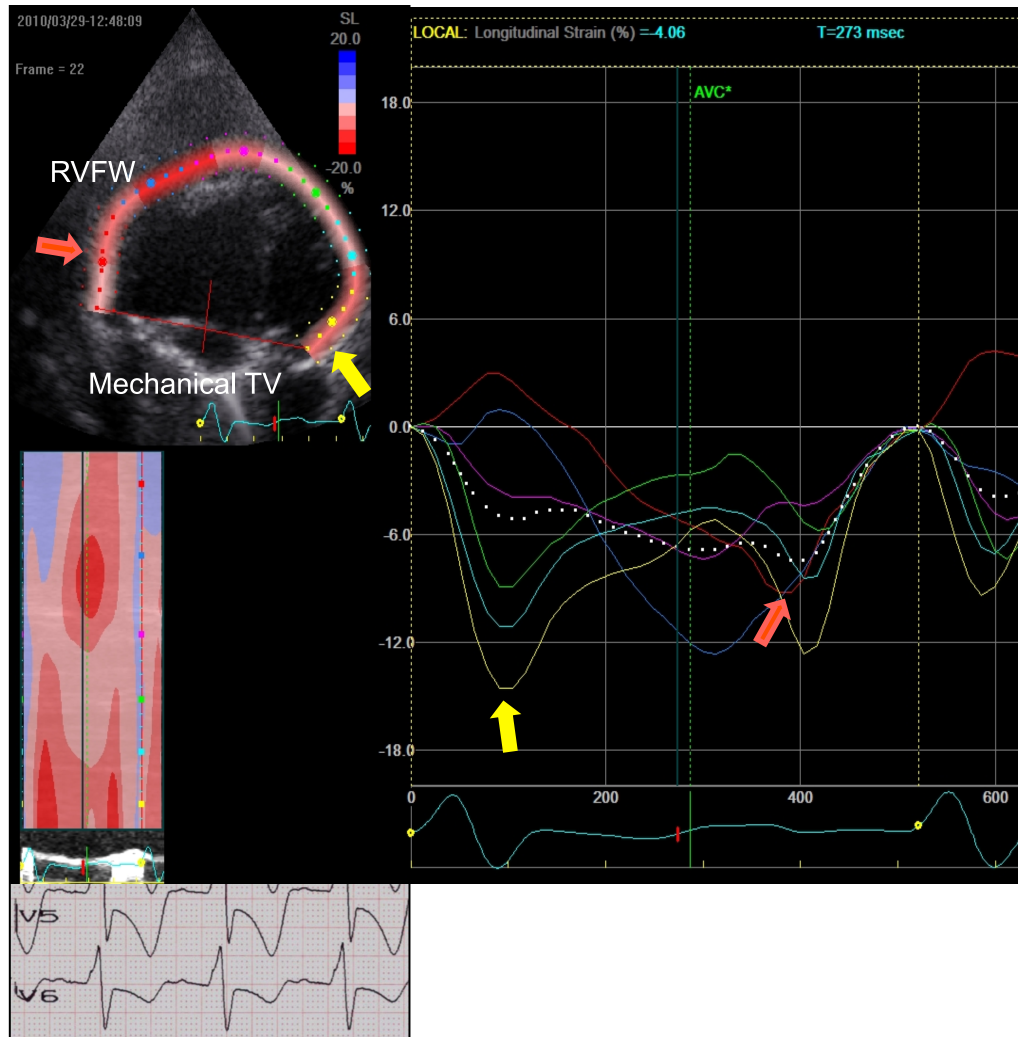
Heart Rhythm 2014;11:2303–2305)

Ondřej Materna, MD, Peter Kubuš, MD, Jan Janoušek, MD, PhD

From the Children's Heart Centre, Motol University Hospital, Prague, Czech Republic.

Pre-procedural mechanical activation mapping



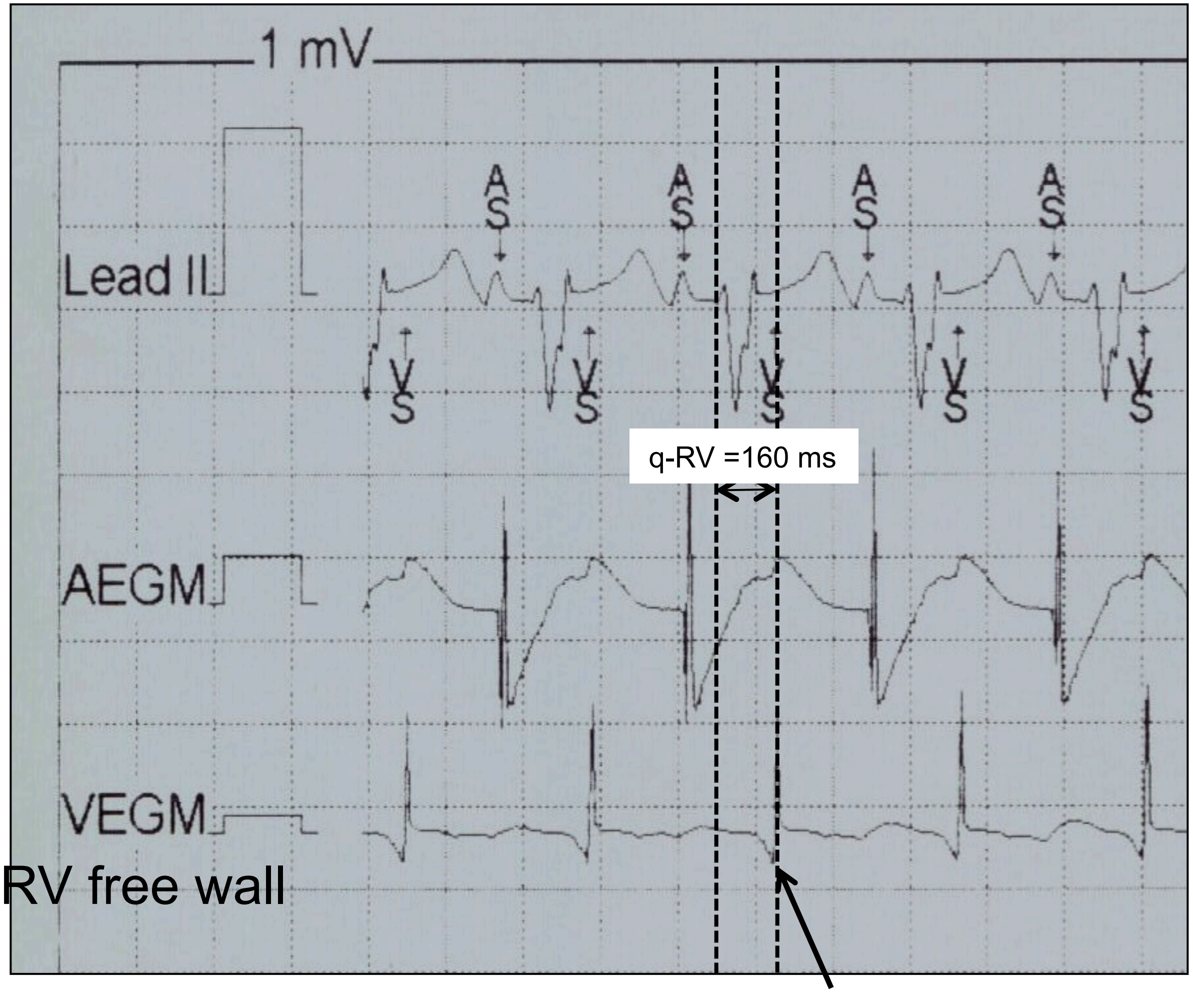


HLHS, st.p. BCPA and TV replacement

Failing dyssynchronous RV due to RBBB

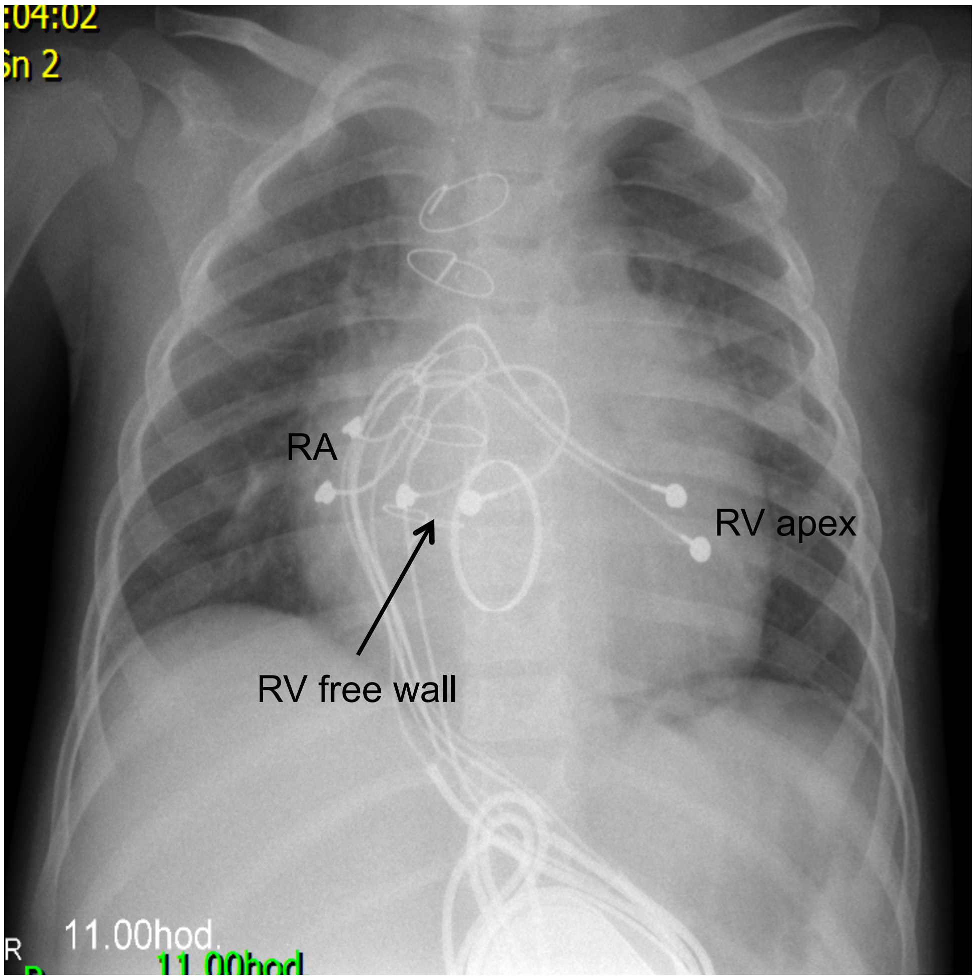
Peri-procedural electrical activation mapping

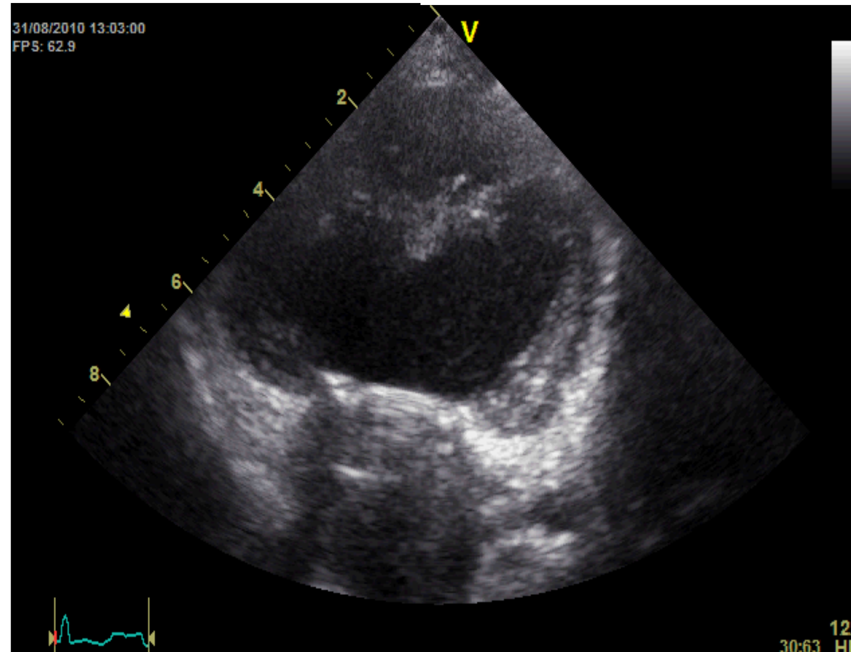
Search for latest local electrical activation during baseline rhythm

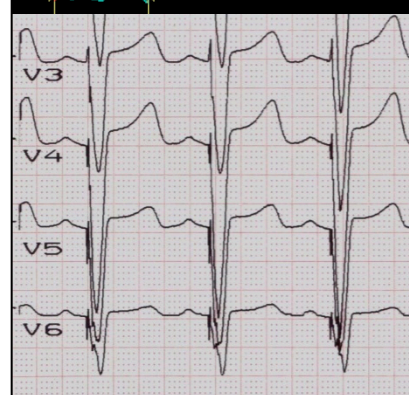


Late activation at the right ventricular free wall

Lead placement according activation mapping



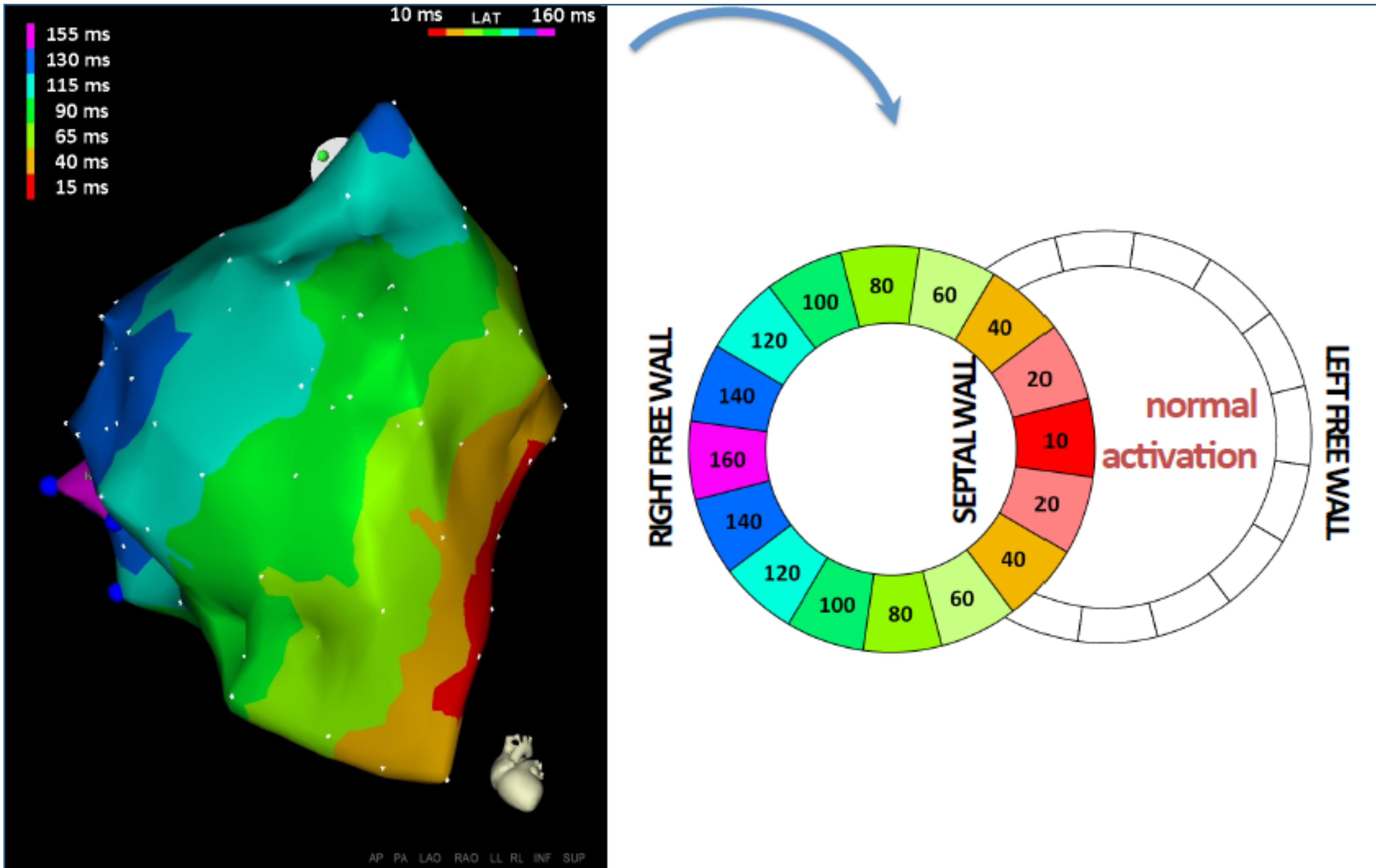




Resynchronizing the pulmonary RV?

RBBB is by far the most frequent dyssychrony pattern in CHD!

- PVR
- e



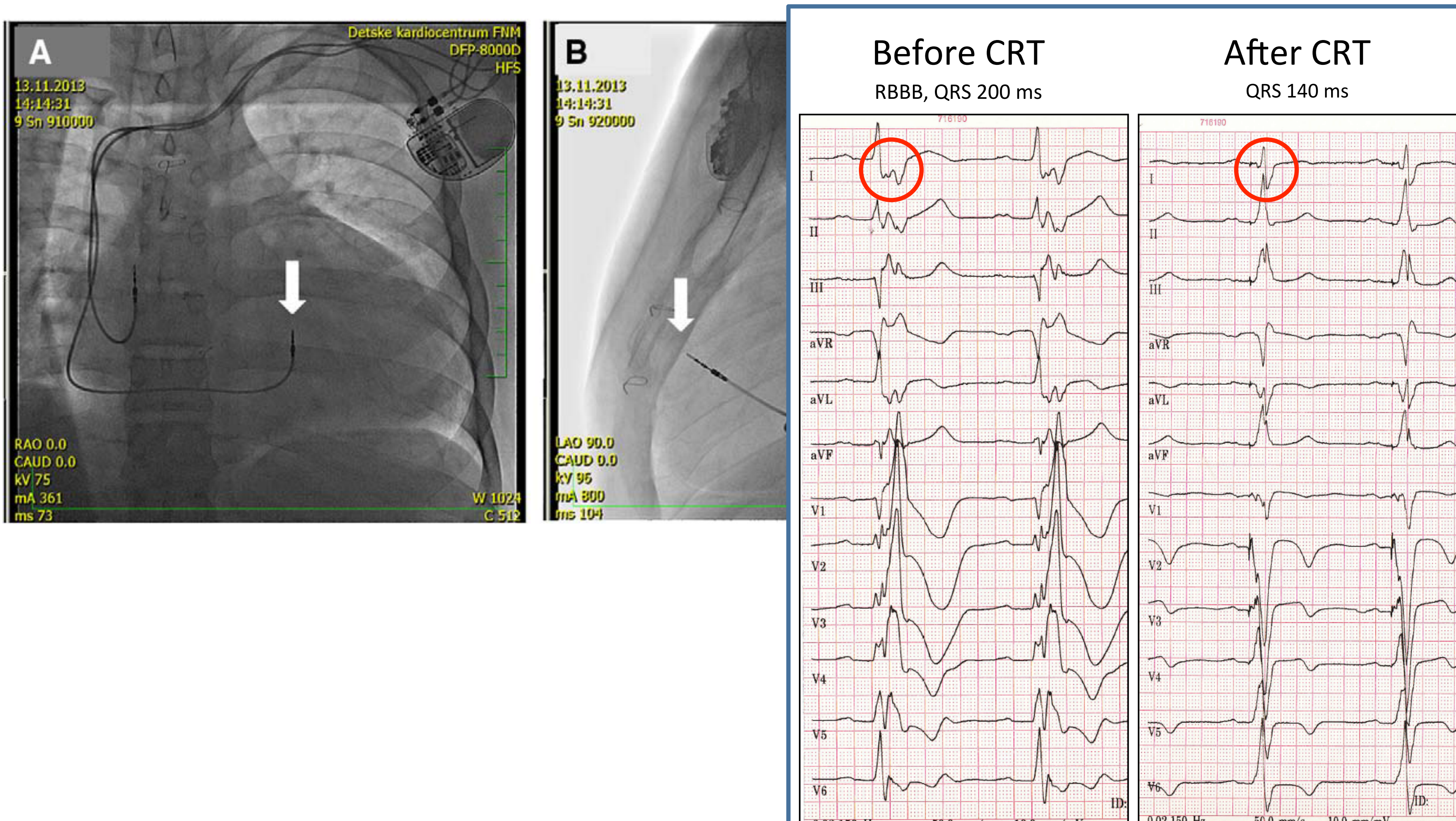
r 2008

Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

American Heart Association

Successful Permanent Resynchronization for Failing Right Ventricle After Repair of Tetralogy of Fallot

Peter Kubus, Ondrej Materna, Petr Tax, Viktor Tomek and Jan Janousek



Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

American Heart Association®

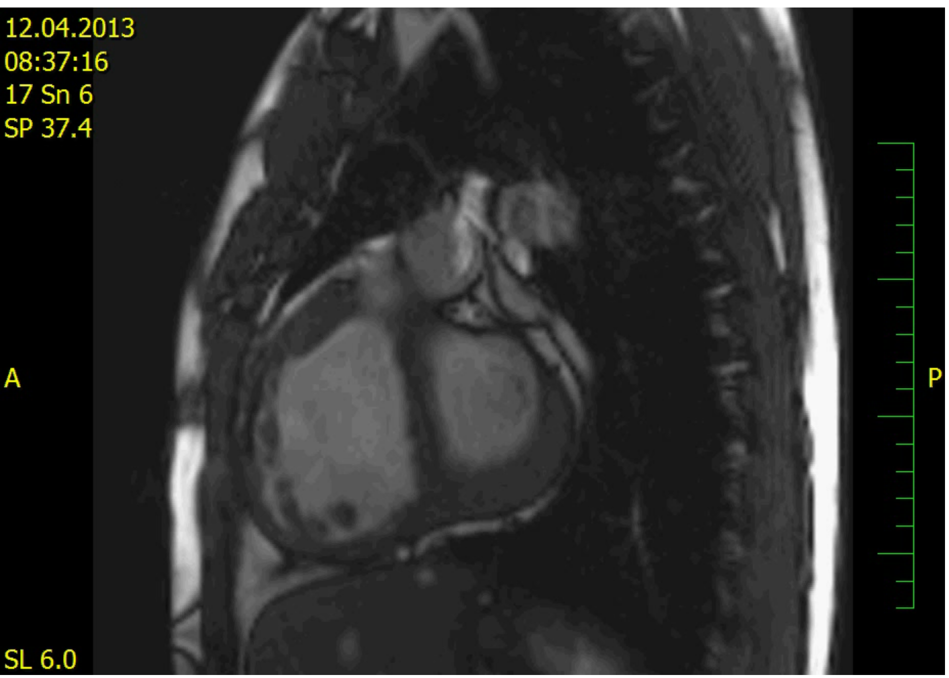
Circulation. 2014;130:e186-e190

Successful Permanent Resynchronization for Failing Right Ventricle After Repair of Tetralogy of Fallot

Peter Kubus, Ondrej Materna, Petr Tax, Viktor Tomek and Jan Janousek

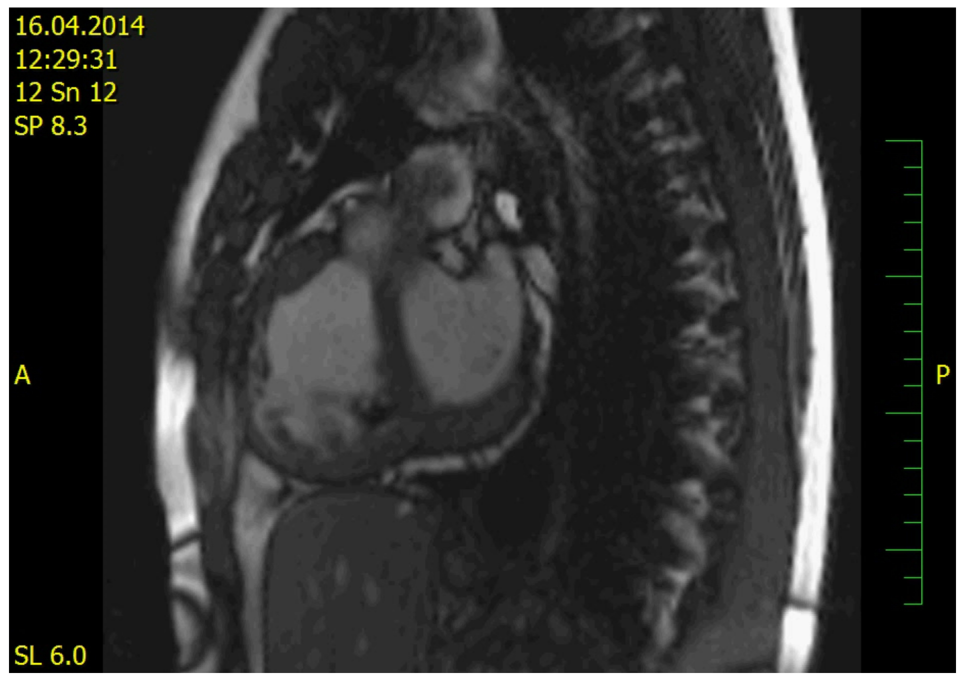
Before

- RV: EDV/ESV 212/172 ml/m2, EF 19 %
- LV: EDV/ESV 80/46 ml/m2, EF 41 %



6 months after

- RV: EDV/ESV 141/87 ml/m2, EF 38 %
- LV: EDV/ESV 63/28 ml/m2, EF 56 %



Exercise stress testing - $V0_2$ max: 21,0 (before) ➡ 30,4 ml/kg/min. (6 mos of CRT)

NYHA II ➡ I