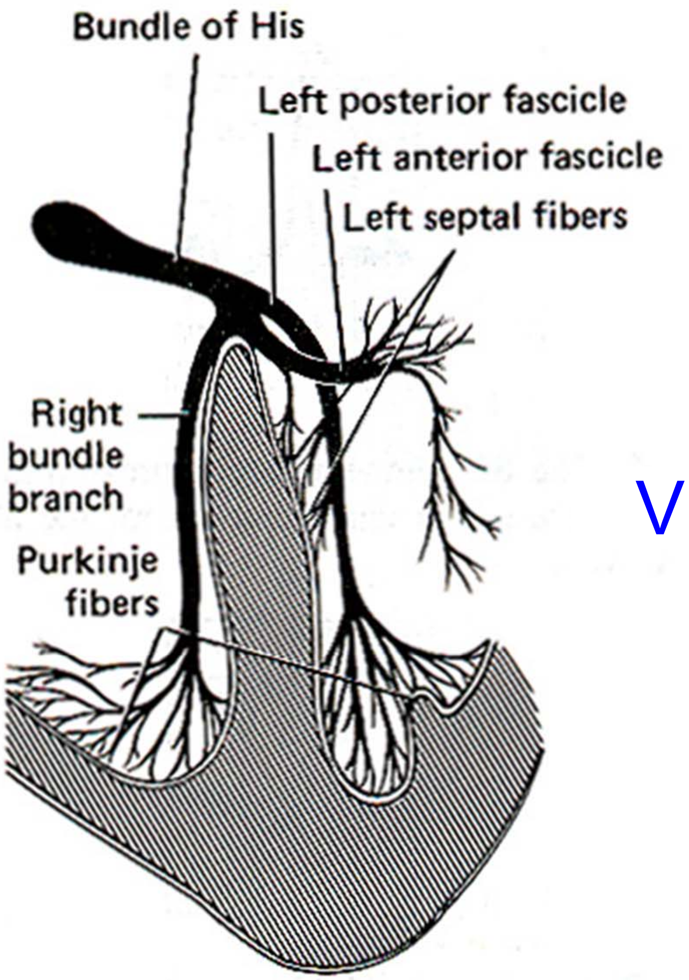
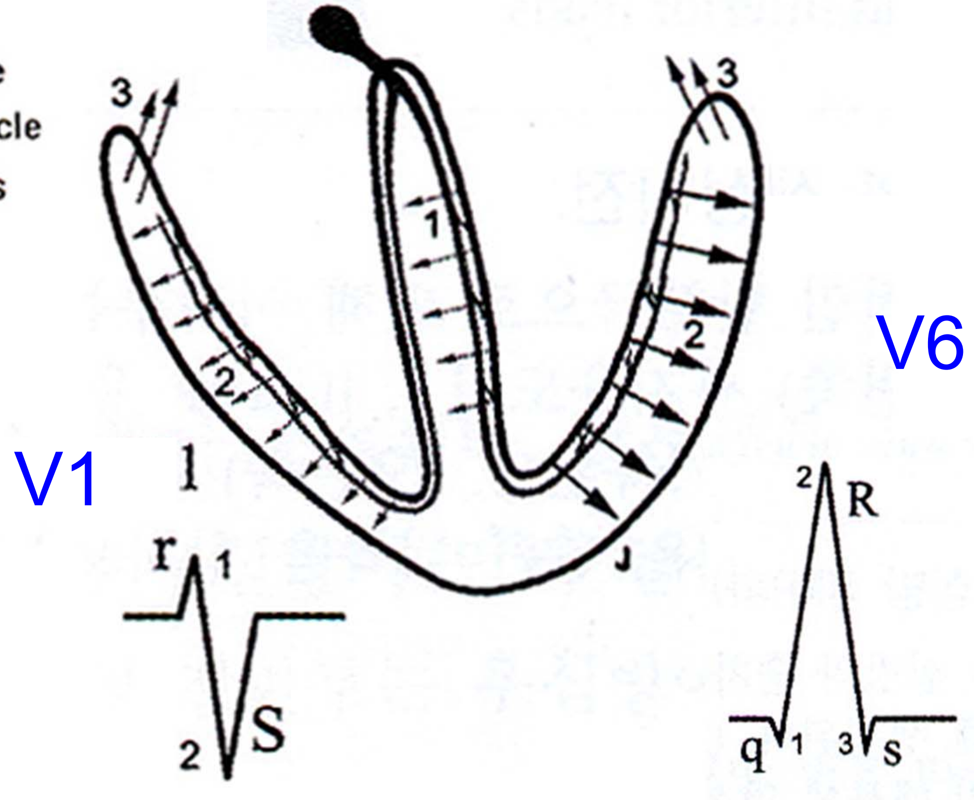
Management of conduction disturbances in CHD-Resynchronization

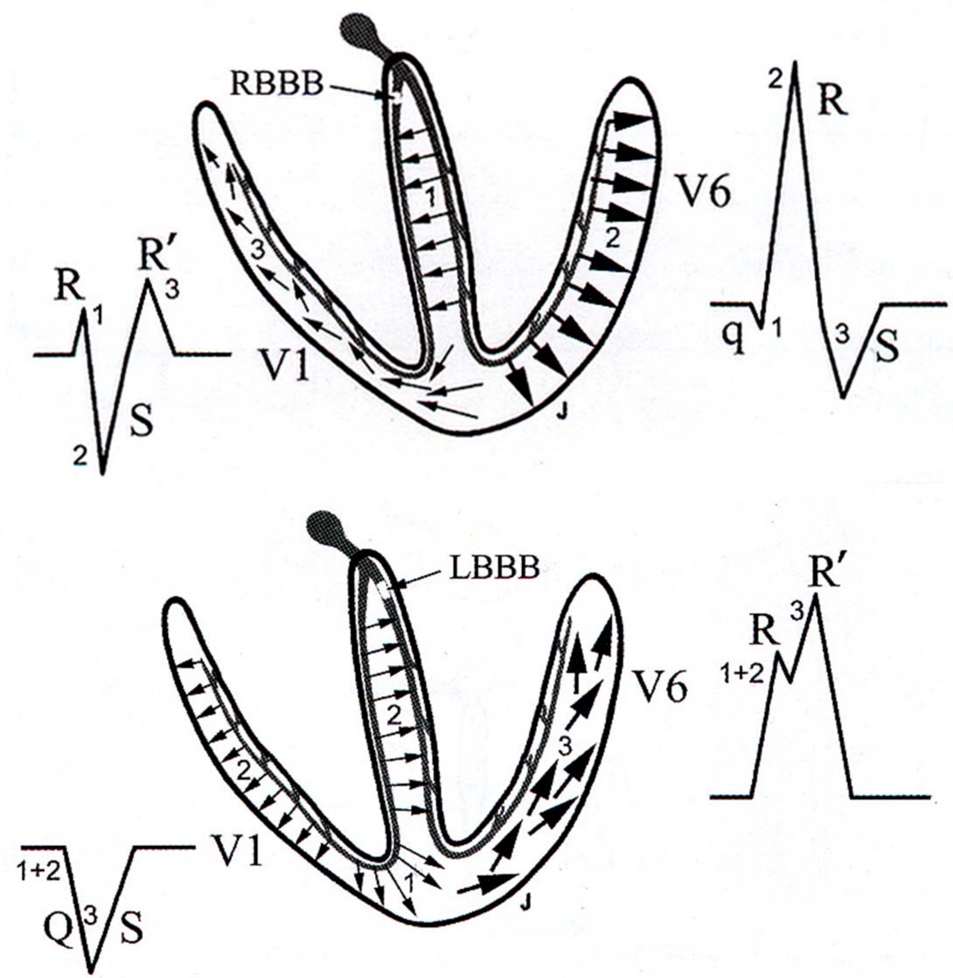
동아의대 이영석

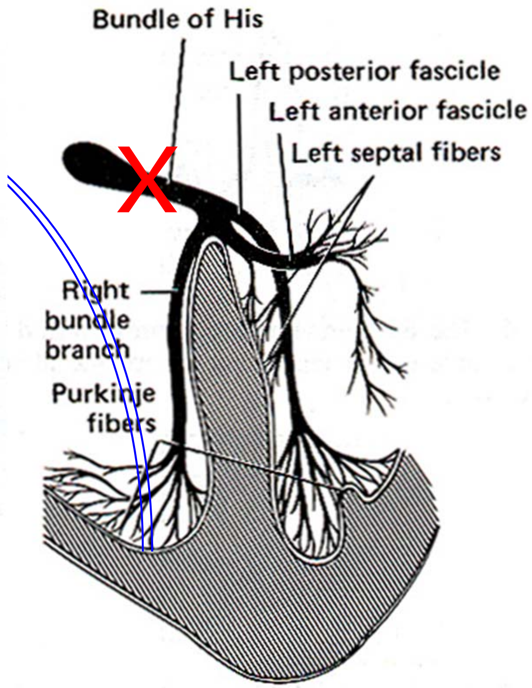
Normal conduction





Conduction disturbances





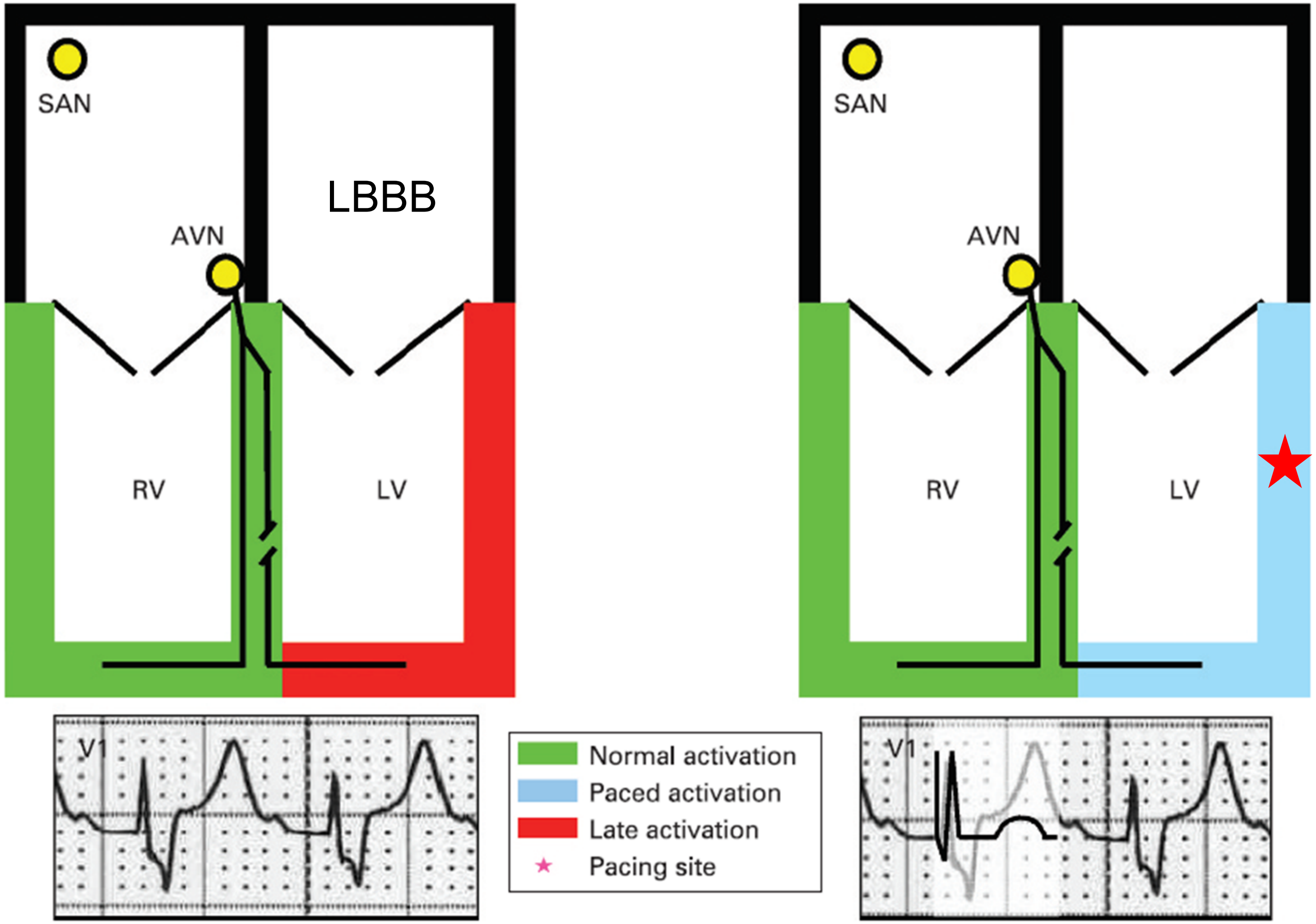
Dyssynchronization

- Dyssynchronous ventricular contraction

→ Late contracting segments are stretched by the early contracting regions and perform a higher local myocardial work (wasted because late contraction appears after semilunar valve closure and end of the ventricular ejection phase)

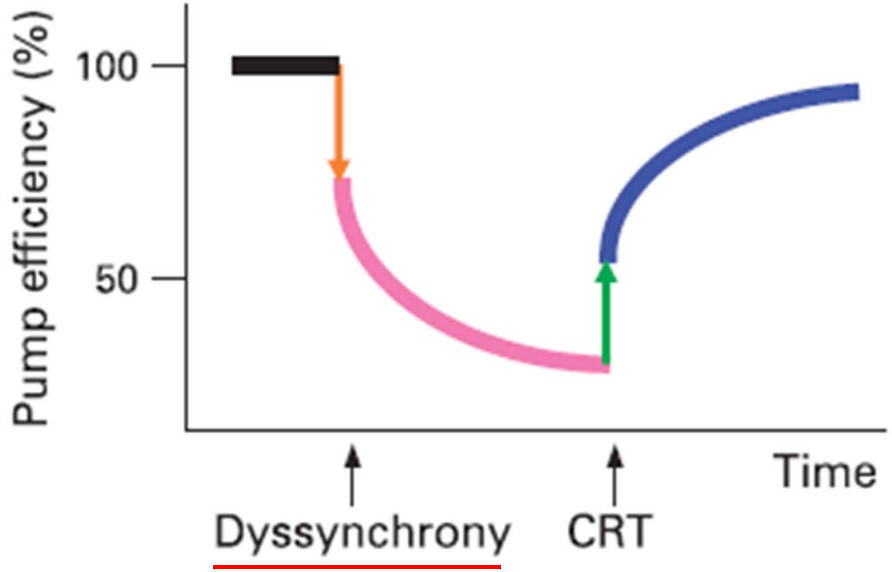
→ Inefficient ventricular contraction and pathologic remodelling results

Simple scheme of cardiac resynchronization therapy



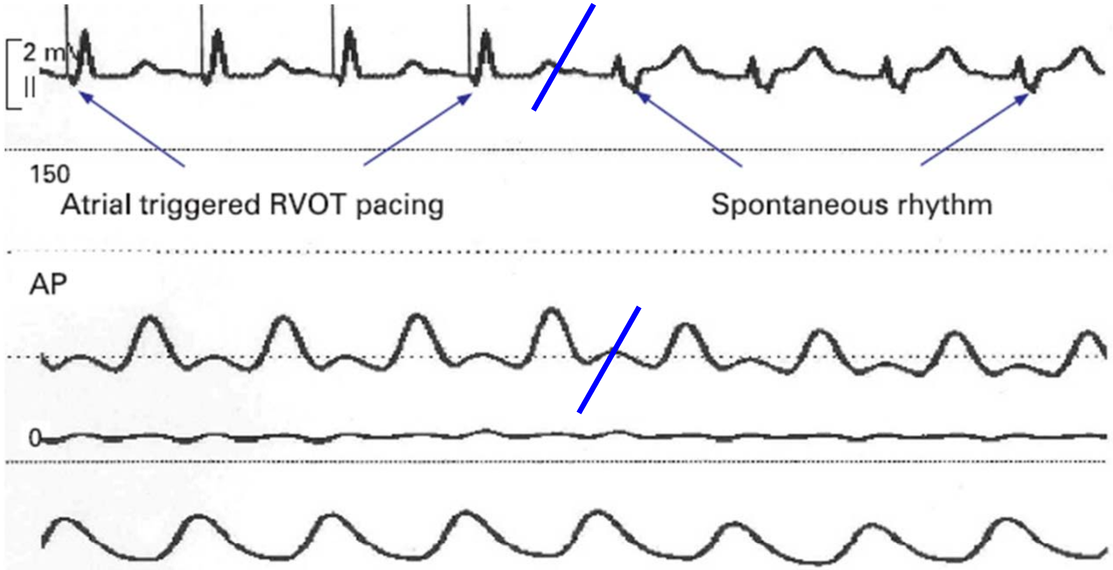
Heart 2009;95

Pathophysiology

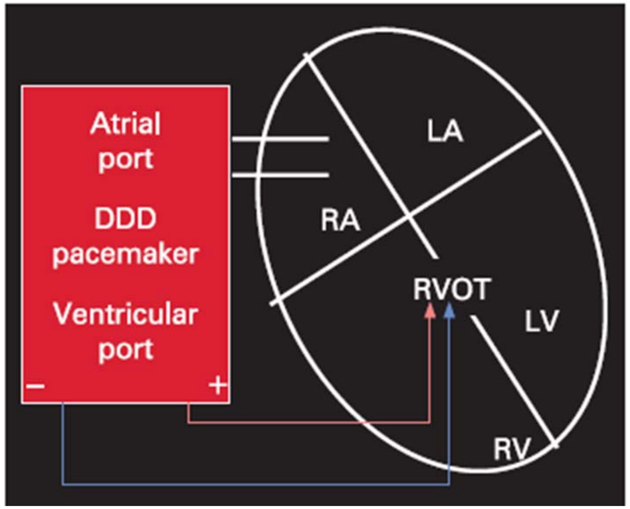


- Restoration of normal conduction
  → increase contractile efficiency

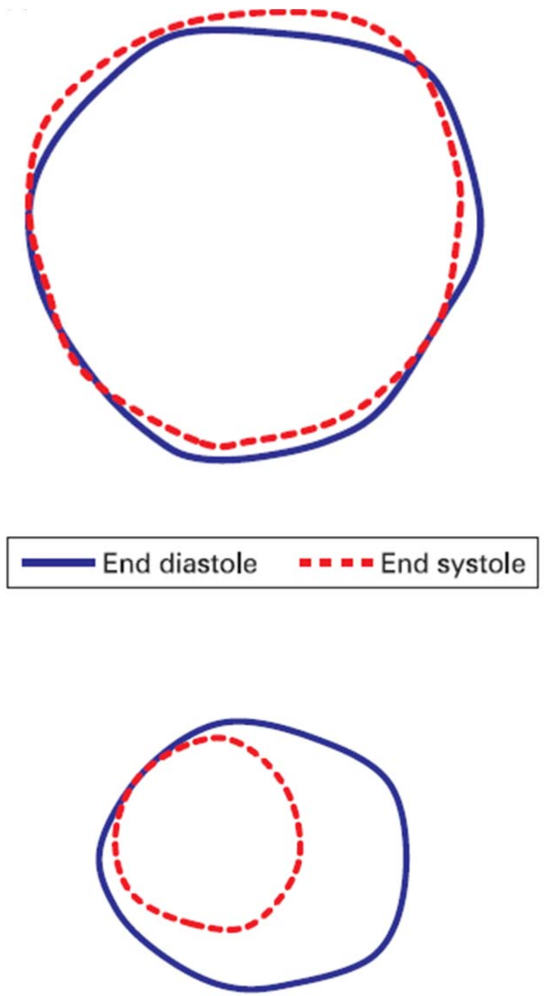
Heart 2009;95



RBBB



Before CRT



After CRT

Heart 2009;95

Cardiac Resynchronization Therapy

- Effective for adults with heart failure and ventricular dyssynchrony
- Improves - Symptom of heart failure
  NYHA functional class
  exercise tolerance
  hemodynamics
  quality of life
  mortality

Cardiac Resynchronization Therapy

- Treatment guidelines (Level A)[1,2]

  NYHA Ⅲ~Ⅳ with medical Tx & sinus rhythm

  QRS duration ≥ 120ms

  LVEF ≤ 35%

1. Task Force for the Diagnosis and Treatment of Chronic Heart Failure of the European Society of Cardiology. Guidelines for the Diagnosis and treatment of chronic heart failure: *Eur Heart J 2005;26.*
2. American College of Cardiology, American Heart Association. ACC/AHA 2005 guideline update for the diagnosis and management of chronic heart failure in the adult *J Am Coll Cardiol 2005;46.*

CRT in children

- Limited data

  A few case reports

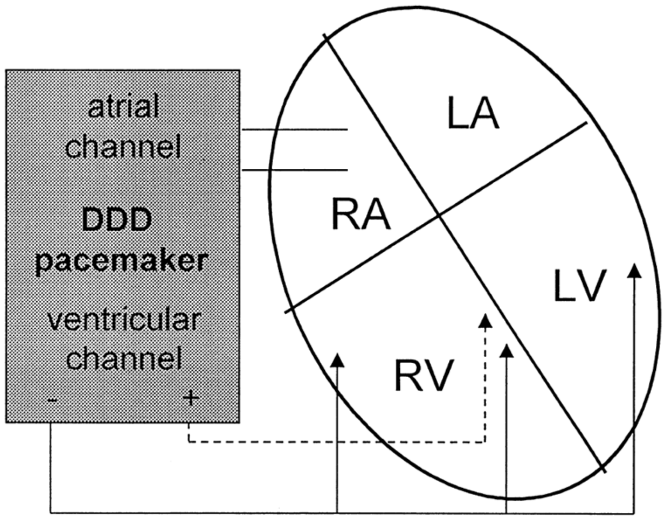
  Few large multicenter study

  No prospective randomized control study

- Intrinsic conduction delay after surgery - CAVB
- Ventricular dyssynchrony induced by conventional pacemaker therapy – RV pacing

Resynchronization Pacing Is a Useful Adjunct to the Management of Acute Heart Failure After Surgery for Congenital Heart Defects

20 children (aged 3.4mo to 14.0yrs), post op 36hrs (median)



AV resynchronization 13/20(1°AVB10, CAB3)

- atrial synchronous univent pacing 10
- atriouniventricular sequential pacing 3
- AV delay – optimized to achieve highest increase in syst and mean pressure

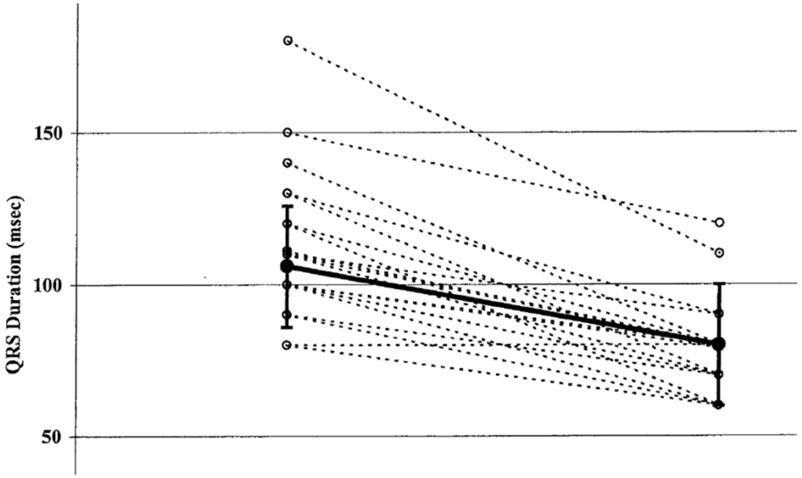
IV resynchronization 14/20

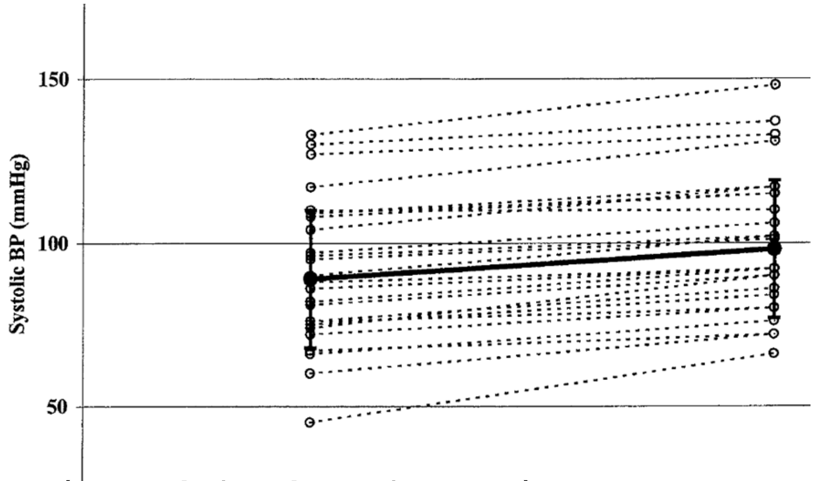
- 7RBBB - Rt lat vent , RVOT
- 7AV resynchro (LBBB) - multisite pacing
- max decrease in QRS duration

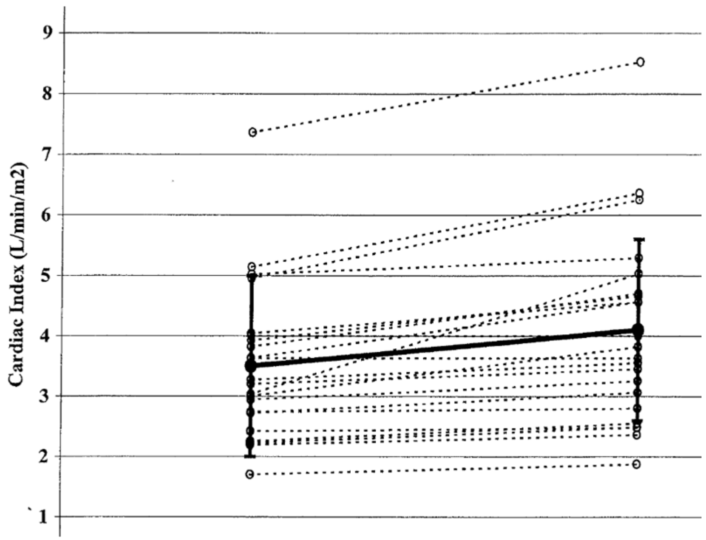
→ QRS duration↓, blood pressure↑, cardiac index ↑

Janousek et al. Am J Cardiol 2001;88

Acute Hemodynamic Benefit of Multisite Ventricular Pacing After Congenital Heart Surgery







29 pts (aged 1 wk ~ 17 yrs)
single ventricle 14(midant RV free wall, lat RV, distal RVOT)
two ventricle 15

Zimmerman et al..Ann Thorac Surg 2003;75

26 single-ventricle pts
(mean 28 mo; 7 days ~ 11 years)

Bacha et al. Ann Thorac Surg 2004;78

Impact of Conventional Versus Biventricular Pacing on Hemodynamics and Tissue Doppler Imaging Indexes of Resynchronization Postoperatively in Children With Congenital Heart Disease

19 children (median 5.5 mo)

Pacing Mode	QRS (ms)	p Value Compared With CDOO	Systolic Blood Pressure (mm Hg)	p Value Compared With CDOO	Cardiac Index (l/min/m^2)	p Value Compared With CDOO
AOO	96 ± 18	0.025	84 ± 18	NS	3.5 ± 1.2	NS
CDOO	105 ± 15		82 ± 14		3.7 ± 1.4	
BDOO	94 ± 13	0.025	83 ± 12	NS	4.7 ± 2.8	0.0032

TDI-derived strain rate

Pacing Mode	RV-IVT (ms)	LV-IVT (ms)	ΔIVT (ms)	p Value Compared With CDOO	RV-PSC (ms)	LV-PSC (ms)	ΔPSC (ms)	p Value Compared With CDOO
AOO	56 ± 17	60 ± 16	4 ± 8	0.0005	147 ± 39	143 ± 33	4 ± 24	<0.0001
CDOO	69 ± 28	100 ± 32	31 ± 26		147 ± 23	200 ± 34	53 ± 36	
BDOO	61 ± 32	73 ± 31	12 ± 16	0.0005	152 ± 28	158 ± 26	7 ± 18	<0.0001

AOO;atrial pacing
CDOO;conventional AV pacing
BDOO;biventricular pacing

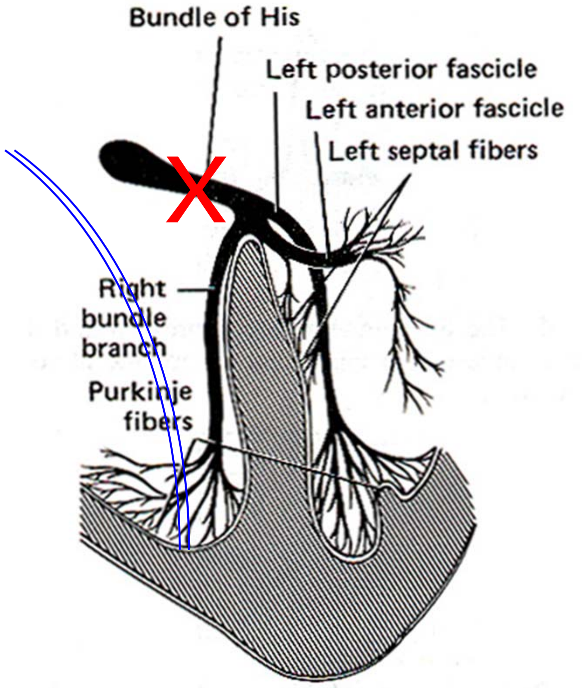
IVT;isovolumic tensing
PSC;peak systolic contraction

Pham et al. J Am Coll Cardiol 2005;45

Prerequisites of successful use of temporary CRT

- Identification of the failing dyssynchronous ventricle
- Placement of temporary ventricular pacing wires close to segments with late contraction
- Appropriate external pulse generator programming and hemodynamic optimization of the AV delay
- Use temporary CRT in the operating room if there are problems with weaning from cardiopulmonary bypass (cooperation between surgeon, EP)

RV pacing



Traditional RV apex pacing

easily accessible

allows a stable position

low pacing thresholds

→ differs from normal activation

→ asynchronous RV, LV contraction and relaxation

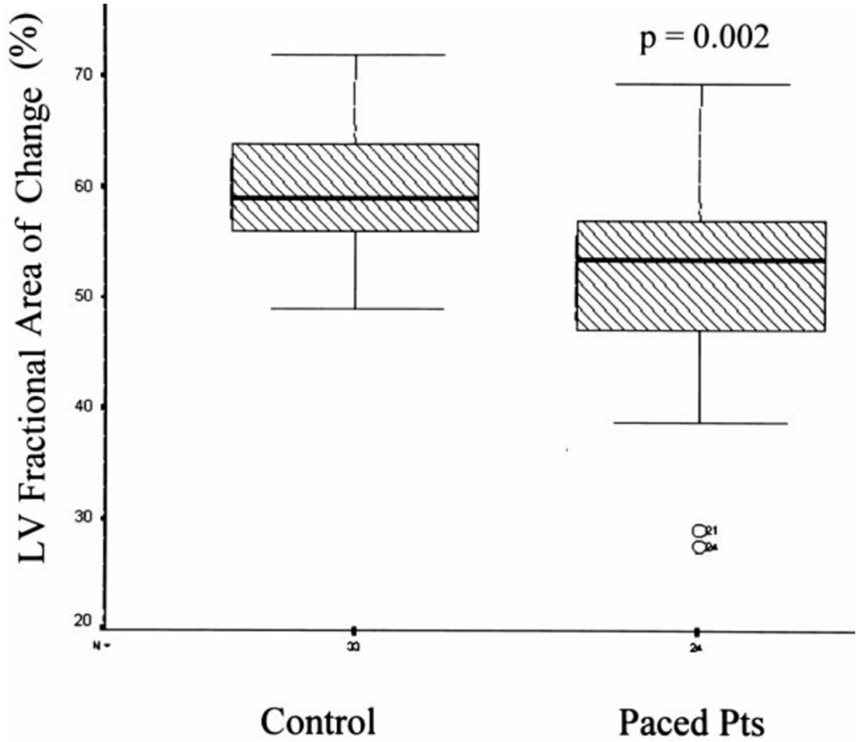
activation of apical IV septum

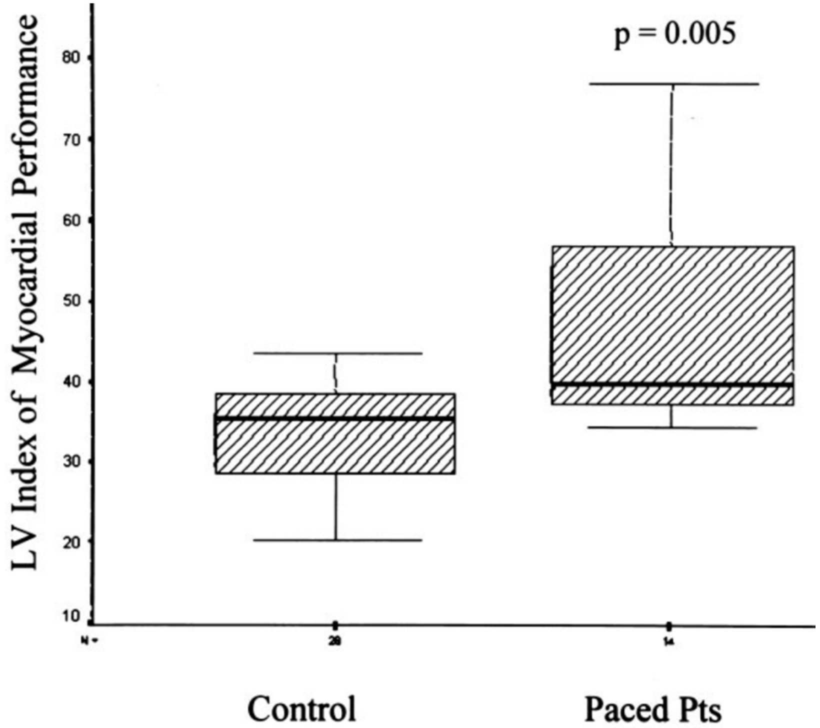
basal septum-lat LV wall

→ long-term RV apical pacing can result in LV failure

Left Ventricular Dysfunction After Long-Term Right Ventricular Apical Pacing in the Young

24 RV apex pacing (mean f/u 9.5 years) pts Vs 33 controls





MPI↑ = combined sys/dia vent function

Tantengco et al. J Am Coll Cardiol 2001;37

Detrimental Ventricular Remodeling in Patients With Congenital Complete Heart Block and Chronic Right Ventricular Apical Pacing

23 CAVB Vs 30 controls, f/u 10±3yrs

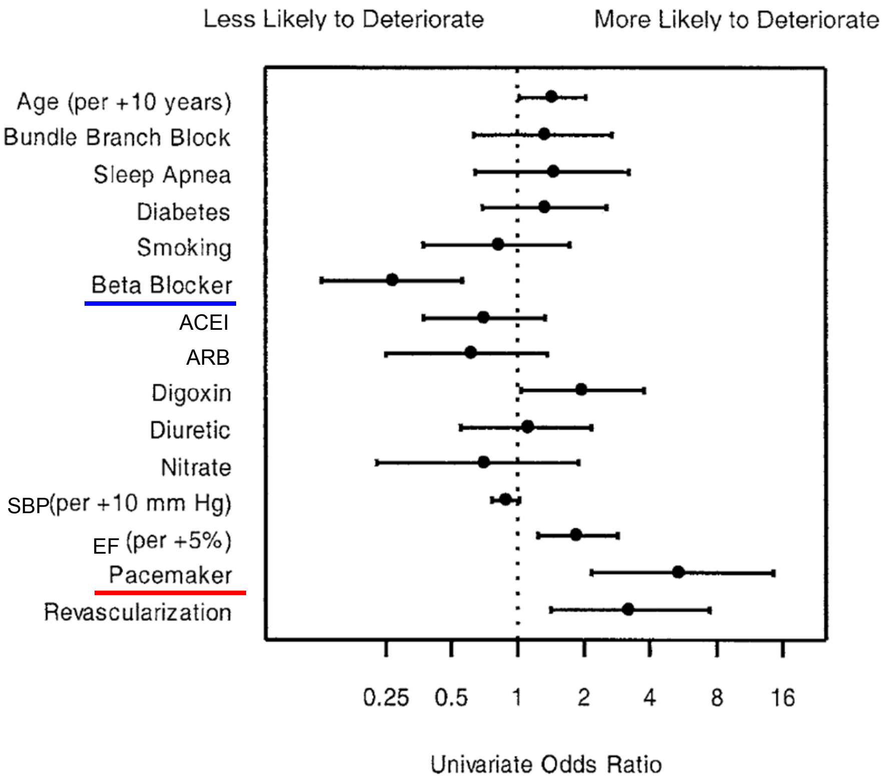
	Long-Term RV Pacing	Controls
Cardiac output, L/min	3.8±0.6*	4.9±0.8
Mean LV EDD, mm	55±7*	46±6
Pathological LV EDD, %	52†	0
Ratio posterior/septal wall	1.3±0.2†	1±0.1
Ratio mitral regurgitation/left atrium	16±8*	5±2
LV filling time, ms	415±39*	477±51
Interventricular dyssynchrony, ms	55±18†	18±11
Intra-LV delay, ms	59±18†	19±9
Septal/posterior wall delay, ms	84±26†	18±9
DLC, %(delayed longitudinal contraction)	39±15†	10±7
Exercise, W	123±24†	185±39

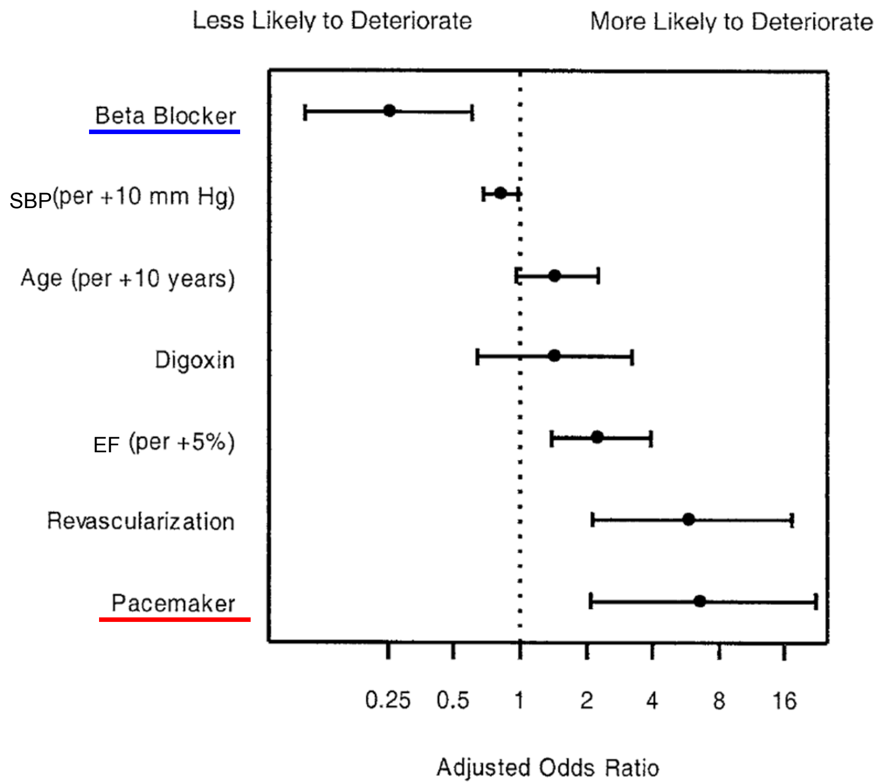
→ deleterious LV remodeling, LV dilatation
LV asymmetrical hypertrophy , low exercise capacity

Thambo et al. Circulation 2004;110

Effect of Chronic Right Ventricular Apical Pacing on Left Ventricular Function

1128pts, SPECT LVEF 25~40% initial Vs 18mo later
148 EF increase Vs 59 EF decrease

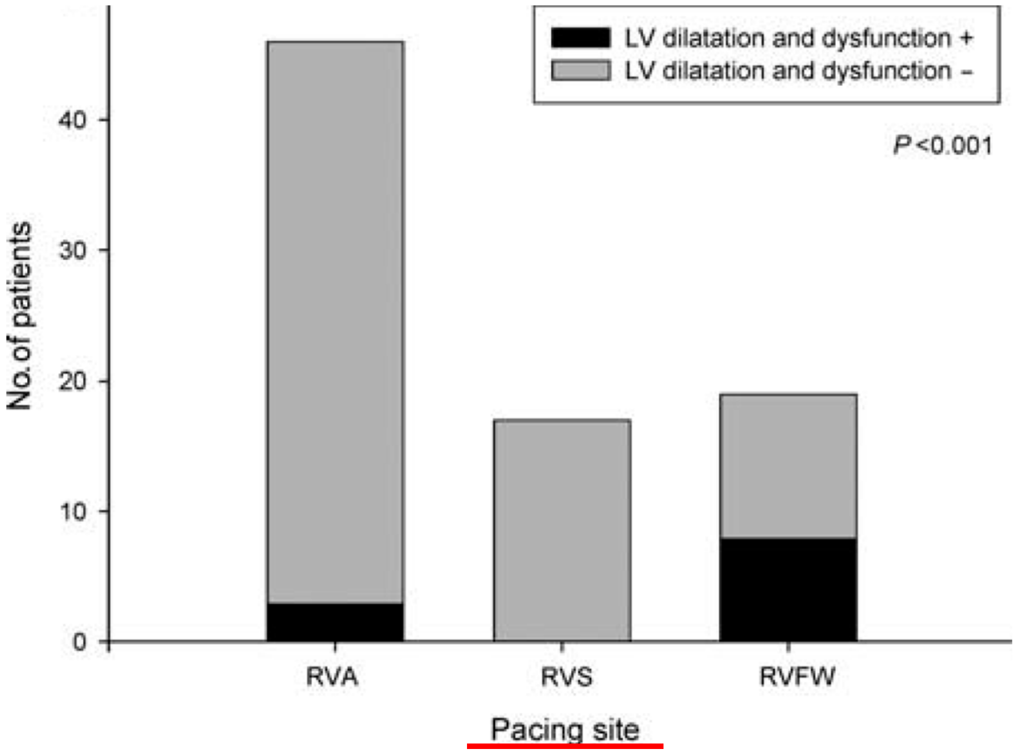




O'Keefe et al. Am J Cardiol 2005;95

Predictors of left ventricular remodelling and failure in right ventricular pacing in the young

82 AVB, RVP mean 7.4yrs, 13% LV dilatation & dysfunction



- LV function – decreased
  FS 39→32
- RVFW-high risk of dysfunction
- RVA-not a significant risk factor
- RVS-protective

Gebauer et al. Eur Heart J 2009;30

Dilated Cardiomyopathy Following Right Ventricular Pacing for AV Block in Young Patients: Resolution After Upgrading to Biventricular Pacing Systems

DCMP, RVP 7.6±2.4 yrs

Patient Number	Age at First PM Implant Years/Gender/Race	Age at CRT Upgrade (Years)	Length of Pacing Pre-CRT (Years)	Length of Follow-Up Post CRT (Months)	Cardiac Disease	Electrical Diagnosis
1	NB/M/C	0.5	0.5	1	None	CCHB
2	3/M/AA	5	2	28	TOF	SCHB
3	0.2/F/H	6	5.7	5	None	CCHB
4	3/M/C	15.5	12.5	13	None	CCHB
5	5.5/M/C	17	11	27	None	2° AVB and VT
6	2/F/H	23.7	14.5	7	TOF	SCHB

	Ejection Fraction (%)			Septal to LVFW Contraction Delay Time (msec)	
Patient Number	Pre < 1 month	1 month Post	Most Recent (months)	Pre-CRT	Post-CRT
1	44	53	—	170	90
2	50	60	61 (20)	140	80
3	30	53	59 (3)	340	40
4	20	34	60 (13)	300	110
5	12	52	66 (15)	350	70
6	47	48	59 (4)	320	60

	LVIDd cm (Z-score)			LVIDs cm (Z-score)		
Patient Number	Pre < 1 month	1 month Post	Most Recent	Pre < 1 month	1 month Post	Most Recent
1	3.2 (3.1)	2.5 (0.5)	—	3.1 (7.0)	1.9 (1.9)	—
2	3.7 (1.1)	3.3 (−0.6)	3.3 (−1.4)	2.7 (2.6)	2.0 (−0.5)	2.0 (−1.0)
3	4.5 (3.4)	4.3 (2.6)	4.1 (1.7)	3.8 (6.9)	2.9 (3.1)	2.9 (2.7)
4	7.2 (NA)	6.5 (2.6)	4.7 (−1.5)	6.2 (NA)	4.5 (2.8)	3.1 (−0.7)
5	7.7 (6.4)	5.9 (2.4)	5.4 (0.95)	7.1 (10.0)	4.3 (3.1)	3.4 (0.6)
6	6.4 (5.1)	6.0 (4.0)	5.5 (2.3)	5.2 (8.0)	4.1 (4.2)	3.9 (3.5)

Moak et al. J Cardiovasc Electrophysiol 2006;17

Preserved cardiac synchrony and function with single-site left ventricular epicardial pacing during mid-term follow-up in paediatric patients

25pts with epicardial RVP(10) and epicardial LVP(15) Vs control(15)

7.9±2.9yrs 4.3±2.6yrs

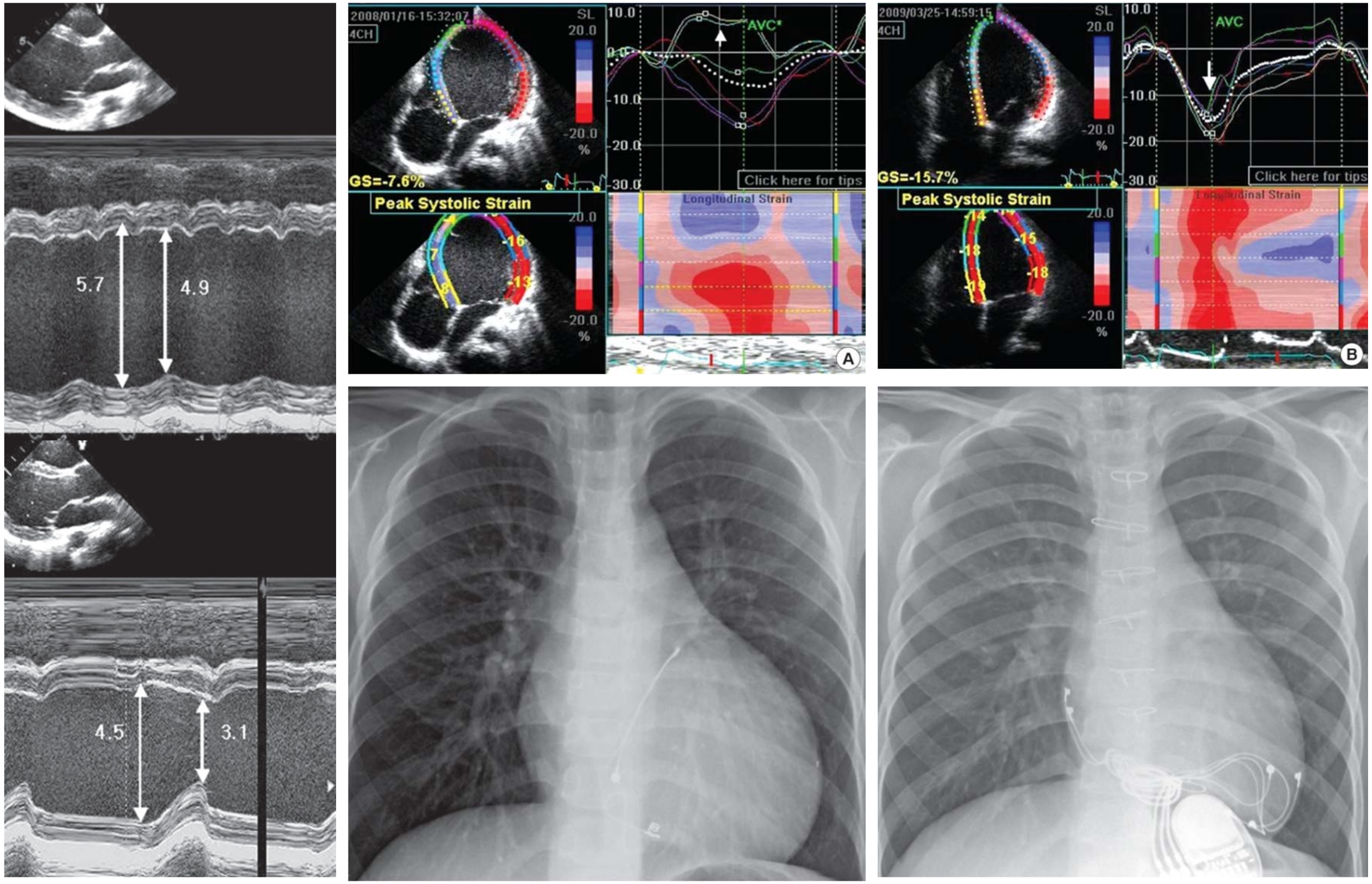
	RV pacing (n = 10)	LV pacing (n = 15)	Control group (n = 15)	P-value*	P-value**
Interventricular mechanical delay (ms)	62 ± 15	17 ± 10	11 ± 9	<0.0001	NS
Septal-to-posterior wall motion delay (ms)	294 ± 84	59 ± 23	57 ± 26	<0.0001	NS
Septal-to-lateral wall delay, by TDI (ms)	59 ± 12	40 ± 19	47 ± 25	0.009	NS
LV mechanical delay, 2D strain (ms)					
Mitral valve level	159 ± 44	72 ± 31	74 ± 44	<0.0001	NS
Papillary muscle level	127 ± 25	64 ± 23	54 ± 28	<0.0001	NS
SD of LV mechanical delay, 2D strain (ms)	63 ± 17	35 ± 9	35 ± 14	0.0001	NS
RV mechanical delay, 2D strain (ms)	62 ± 33	57 ± 23	46 ± 13	NS	NS
Timing of systolic velocity peaks, by TDI					
Left lateral wall (ms)	250 ± 31	157 ± 36	118 ± 29	<0.0001	0.007
Septum (ms)	208 ± 35	192 ± 41	167 ± 37	NS	0.04
RV (ms)	197 ± 42	210 ± 43	189 ± 26	NS	NS
LV ejection fraction (%)	45 ± 6	60 ± 6	59 ± 4	<0.0001	NS
LV end-systolic volume index (mL)	33 ± 11	22 ± 5	21 ± 5	0.003	NS
Aortic velocity–time integral (cm)	21 ± 2	26 ± 4	27 ± 3	0.004	NS
LV Tei index	0.63 ± 0.11	0.38 ± 0.07	0.34 ± 0.04	<0.0001	NS

→ RVP may cause dyssynchronous LV contraction and systolic dysfunction
LVP has no detectable harmful effects on LV function

Tomaske et al. Eropace 2009;136

Cardiac Resynchronization Therapy for Left Ventricular Dysfunction Induced by Chronic Right Ventricular Pacing in a Child

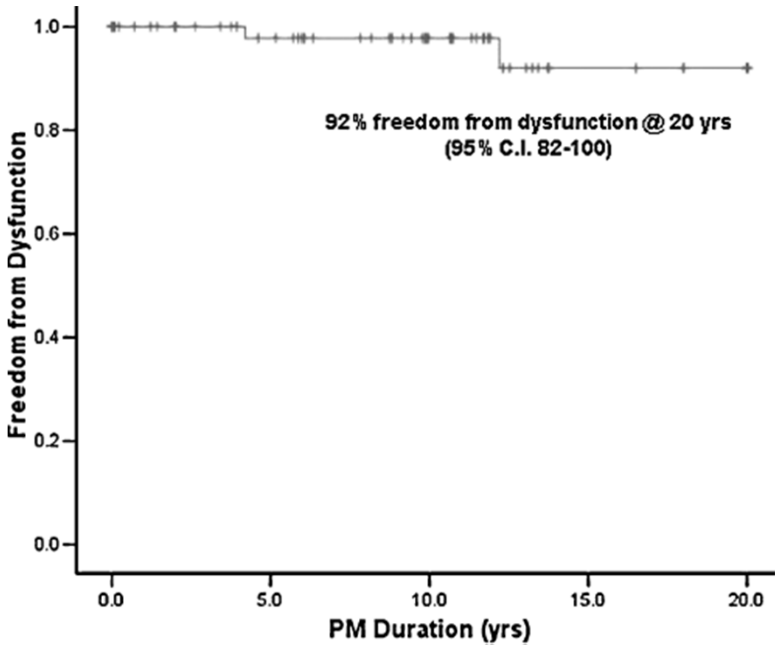
9yrs old RVP for CAVB



Kim et al. J Korean Med Sci 2010;25

Ventricular Function and Long-Term Pacing in Children with Congenital Complete Atrioventricular Block

63 pts RVP mean f/u 9.9yrs
6% LV dysfunction 15yrs after RVP



	Mean Left Ventricular Ejection Fraction (%)		P-Value
Gender	Male 50.3 ±12.1	Female 54.3 ± 7.0	0.23
Anti-Ro/La	Positive 51.8 ± 12.9	Negative 53.9 ± 7.6	0.62
Pacing mode	DDD 54.6 ± 9.5	VVI 50.3 ± 10.3	0.26
Pacing location	Apex 49.5 ± 11.6	Septum 58.9 ± 5.2	0.04

→ fast, very safe, excellent lead performance
RVP should still be considered an acceptable first-line therapy

Kim et al. J Cardiovasc Electrophysiol. 2007;18

Resynchronization Therapy in Pediatric and Congenital Heart Disease Patients

US retrospective multicenter study

Too well to benefit?

103 pts (median 12.8yrs, f/u 4mo)

Type of Disease	n	Age (yrs)	EF Improvement (EF units)	QRS Shortening (ms)
Congenital heart disease	73	12.2 (0.5–55.4)	11.9 ± 12.9%	39.1 ± 31.9
Cardiomyopathy	16	15.8 (0.3–19.6)	12.3 ± 13.6%	31.9 ± 37.9
Heart block	14	12.5 (0.3–24.3)	16.1 ± 12.9%	36.8 ± 13.0
p Value		NS	NS	NS

	Responders (n = 78)	Non-Responders (n = 11)	p Value
Age (yrs)	11.9 (0.4–55.4)	14.8 (3.1–18.4)	NS
Baseline EF (%)	24.3 ± 11.0	32.0 ± 14.2	0.04
Baseline QRS (ms)	166.5 ± 33.2	172.9 ± 21.3	NS
Change in QRS (ms)	36.8 ± 24.7	33.4 ± 18.3	NS
% with CHD	71%	73%	NS
Baseline NYHA functional class 3/4	38%	31%	NS

Heart failure medication↓, 18 heart Txpl – 3 delisted

Dubin et al. J Am Coll Cardiol 2005;46

Cardiac resynchronization therapy in congenital and pediatric heart disease: a retrospective European multicenter study

- 74 pts. Age median 16.9yrs, f/u median 8.1 mo

  QRS duration ↓

  Z-score of the systemic ventricular EDD↓

  systemic AV valve regurgitation ↓

  Shortening fraction of the systemic ventricle ↑

  NYHA class ↓

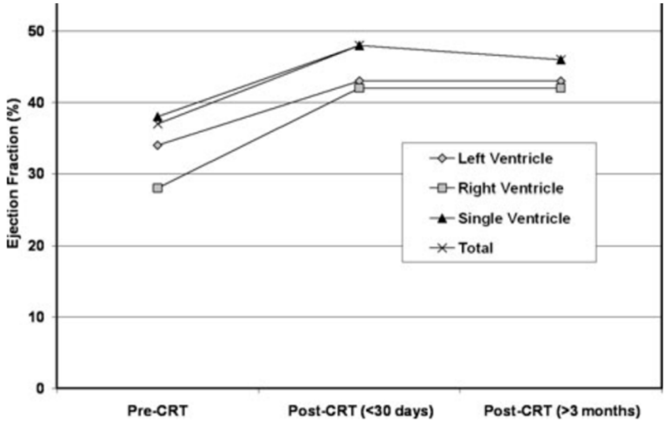
  delisted from HTx candidates (3/8)

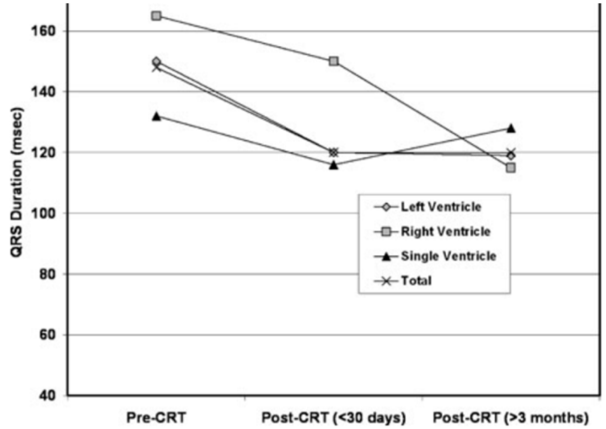
  Non responder – 9 (12.2%)

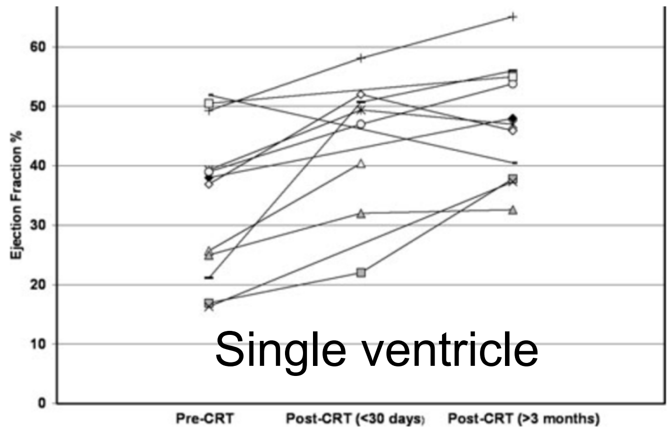
Janousek et al. Cardiol Young 2006;16

Cardiac Resynchronization Therapy (and Multisite Pacing) in Pediatrics and Congenital Heart Disease: Five Years Experience in a Single Institution

60 pts (46CHD, 14DCMP) median f/u 0.7yrs







Single ventricle

Cechin et al. J Cardiovasc Electrophysiol. 2009;20

Does Biventricular Pacing Improve Hemodynamics in Children Undergoing Routine Congenital Heart Surgery?

25 pts, prospective study

	Baseline 1	RV pacing*	Baseline 2	BiV pacing*	Baseline 3
Atrial rate (bpm)	140 (107–165)	150 (115–167)	140 (107–165)	150 (115–167)	140 (107–165)
Ventricular rate (bpm)	140 (107–165)	150 (115–167)	140 (107–165)	150 (115–167)	140 (107–165)
PR interval (ms)	100 (80–180)	80 (40–120)	100 (80–180)	80 (40–120)	100 (60–160)
QRS duration (ms)	80 (60–140)	100 (60–160)	80 (60–120)	80 (80–100)	80 (60–100)

	Baseline 1	RV pacing*	Baseline 2	BiV pacing*	Baseline 3
Blood pressure (mm Hg) Systolic	88 (66–120)	85 (51–120)	85 (54–111)	87 (52–109)	87 (59–111)
Diastolic	50 (37–68)	50 (29–64)	48 (33–56)	46 (30–62)	47 (33–71)
Mean	63 (43–89)	62 (38–86)	61 (40–76)	62 (34–76)	62 (43–89)
CVP (mm Hg)	13 (7–18)	11 (6–17)	12 (7–18)	11 (5–19)	11 (6–19)
SVI (ml/m^2)	23.7 (6.3–58.0)	24.3 (7.4–49.5)	25.0 (8.2–56.0)	21.7 (6.5–52.3)	25.0 (8.4–52.9)
CI (L/min/m^2)	3.39 (1.28–9.56)	3.23 (1.14–7.36)	3.26 (1.15–6.83)	3.42 (1.03–8.40)	3.28 (1.14–7.45)
Mixed venous sat. (%)	63.0 (36–81)	57.5 (31–75)	54.5 (32–76)	55.0 (33–75)	54.0 (33–74)

	Baseline 1	RV pacing*	Baseline 2	BiV pacing*	Baseline 3
Time to peak PW (ms)	220 (150–285)	257.5 (150–331)	225 (160–294)	237.5 (150–330)	224 (153–300)
Time to peak IVS (ms)	220 (143–458)	255 (208–460)	225 (190–485)	240 (160–434)	220 (200–433)
ΔPW–IVS	−30 (−199 to 80)	−10 (−230 to 170)	0 (−200 to 60)	0 (−157 to 90)	0 (−190 to 70)

→ BVP did not improve C/O when compared to intrinsic sinus rhythm or RVP

Jeewa et al. Pediatr Cardiol 2010;31

Cardiac resynchronisation therapy in paediatric and congenital heart disease: differential effects in various anatomical and functional substrates

109pts,f/u 7.5mo

Working Group for Cardiac Dysrhythmias and Electrophysiology of the Association for European Paediatric Cardiology

109 pts, age median 16.9yrs, f/u median 7.5 mo

non-responders - 16.1%

Predictors of non-response

primary cardiomyopathy

higher NYHA class

greater systemic ventricular end diastolic dimension

Janousek et al. Heart 2009;95

Issues

- Measures of ventricular dyssynchrony

  QRS duration, M-mode, pulsed Doppler

  real time 3D echo, TDI, strain rate image

- Implant method

  transvenous, epicardial

  pacing site, optimizing lead placement - sweet spot?

- Optimization method

  AV delays, RV Vs LV delays

Summary(1)

- Although prospective and randomized trials are still lacking, large retrospective series demonstrate that CRT is effective in young patients.
- CRT is a promising option for the treatment of heart failure and evidence of ventricular dyssynchrony in children
- All pacemaker patients require serial echocardiographic evaluation for detection of unfavorable remodelling.
- Heart transplant candidates should specifically be screened for mechanical dyssynchrony as a CRT correctable cause of heart failure.

Summary(2)

- RVP is acceptable and CRT can be a good therapeutic modality - pacing induced DCM.
- Further work is necessary to delineate, in complex and heterogenous group of patients, who will benefit and who will not.
- Detailed, prospective studies evaluating ventricular dysfunction, dyssynchrony and use of CRT is needed.