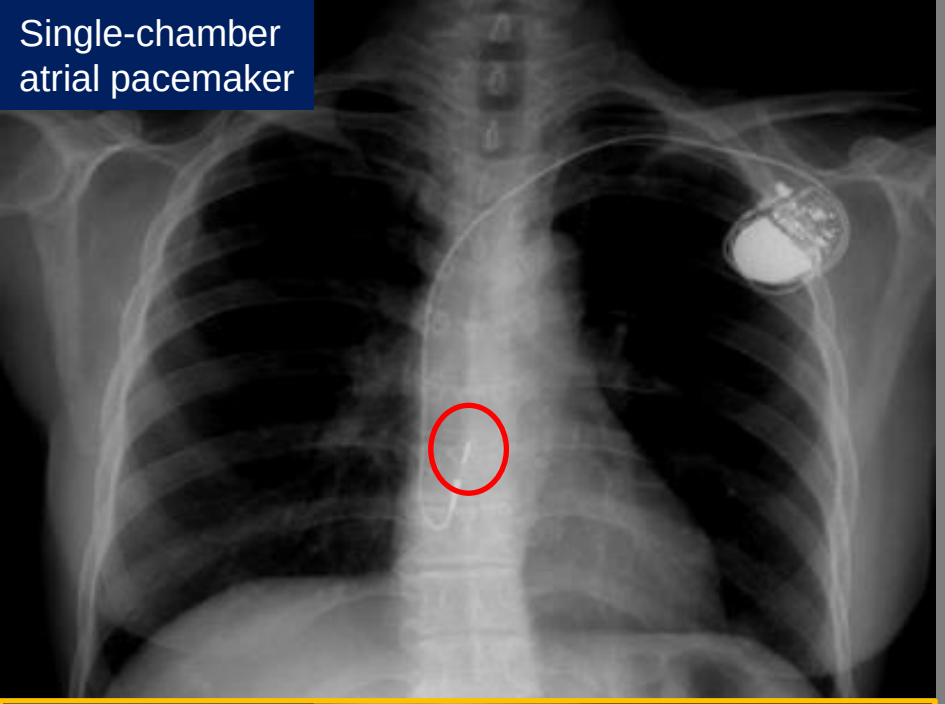
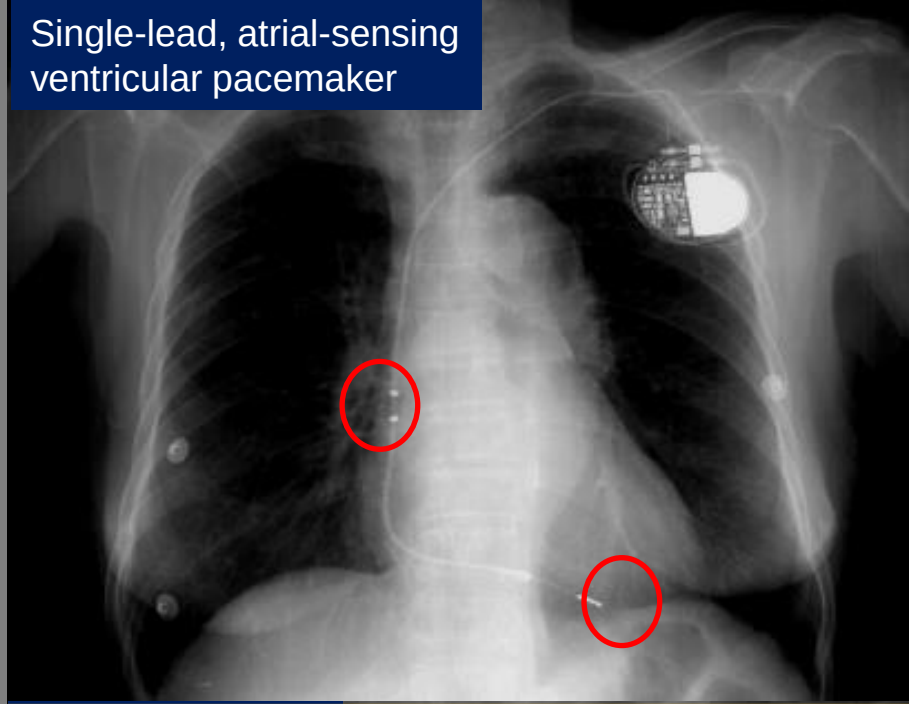
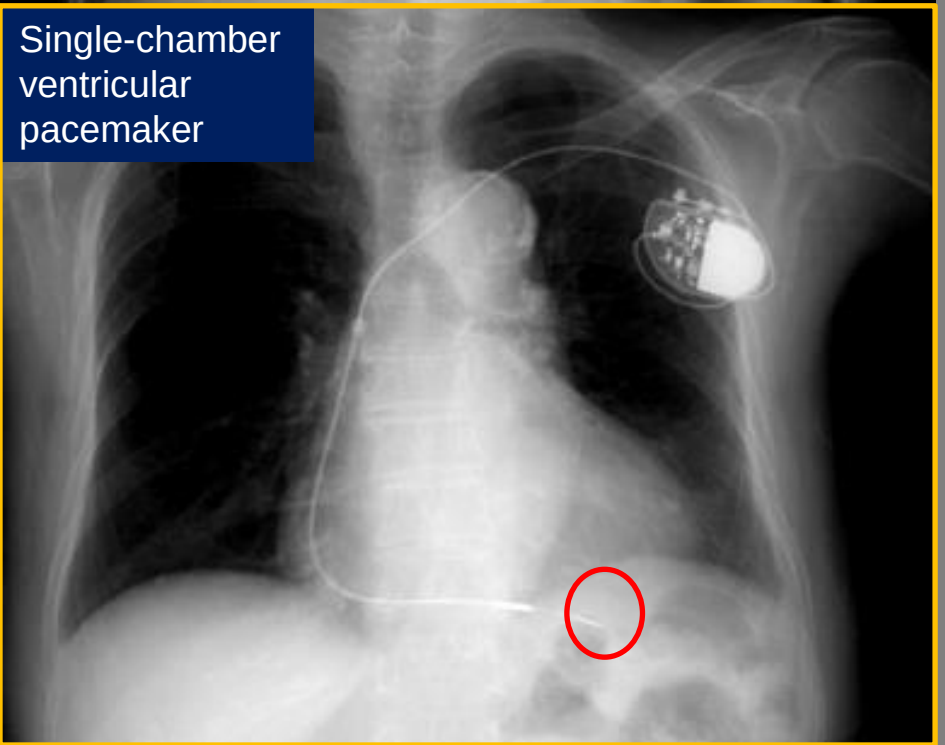
Single Chamber Ppm vs Dual Chamber Ppm in Children

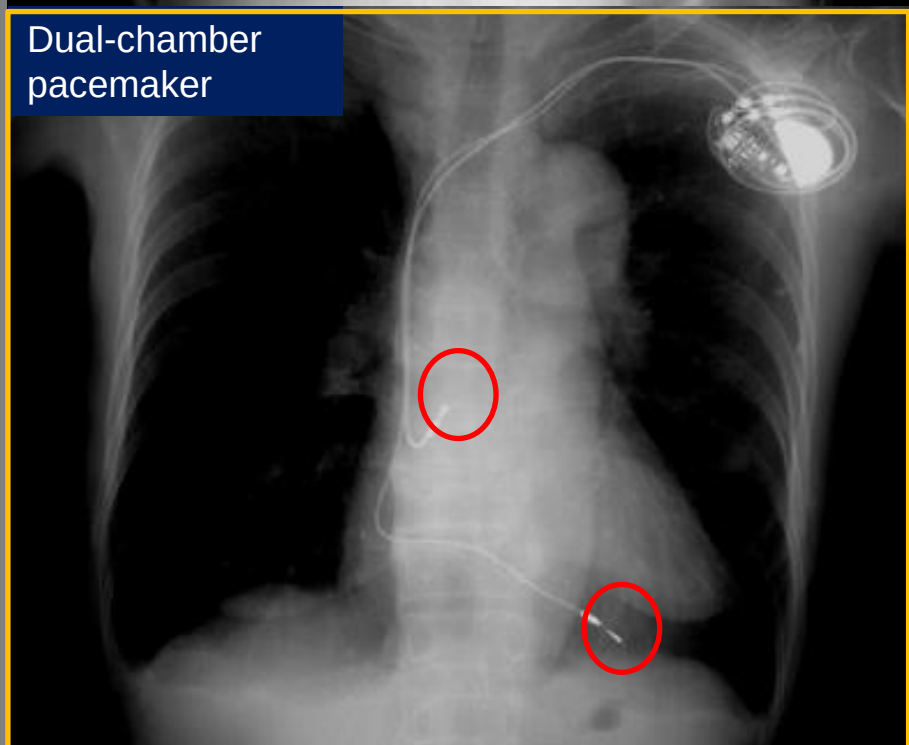
부산대학교병원

조민정


Single-chamber
atrial pacemaker


Single-lead, atrial-sensing
ventricular pacemaker


Single-chamber
ventricular
pacemaker


Dual-chamber
pacemaker

DDD pacing might be superior to VVI pacing in adults

Outcome of RCTs of Dual-chamber vs. Ventricular pacing

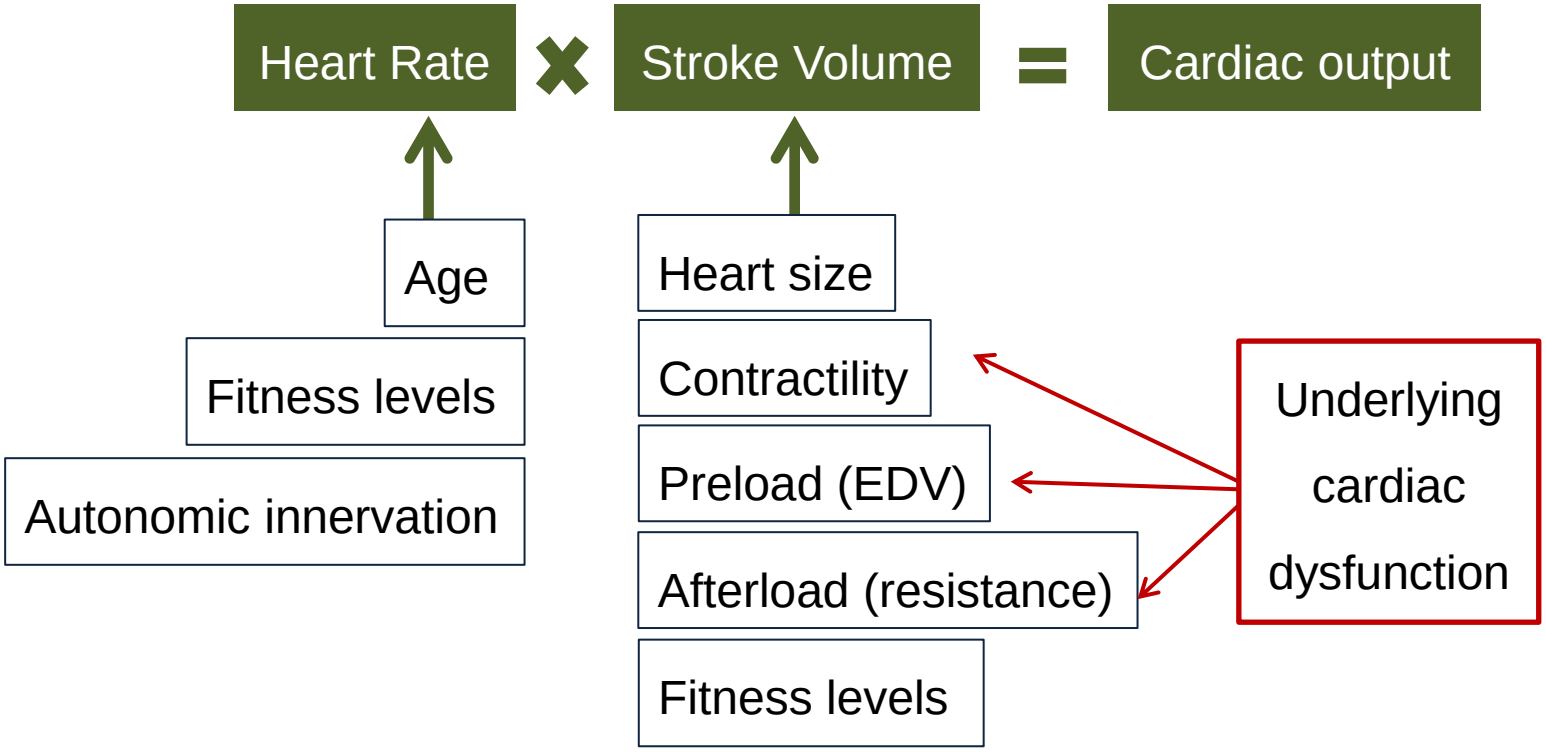
	Dual-chamber	Single-chamber VVI	Notes
All-cause deaths	No difference		
Stroke, embolism	**Benefit**		Benefit higher in SSS
Atrial fibrillation	**Benefit**		Benefit higher in SSS
HF hospitalization	No difference		
Exercise capacity	**Benefit**		Not significant compared to VVIR
Pacemaker syndrome	**Benefit**		
Functional status	No difference		
Quality of life	Variable		
Complications		**Benefit**	

2013 ESC Guidelines on cardiac pacing and cardiac resynchronization therapy, Europace (2013) 15, 1070–1118

Do Children Need Dual Chamber as the Initial Pacing Mode?

	Adult	Children
Cardiac function and CV physiology	• Usually dysfunctional LV	• Frequently normal LV function, • Some differences in CV physiology (vs. adult)
Cardiac anatomy	• Usually normal	• Frequently CHD patient
Body size	• No limitation	• Smaller body and vessel size
Basal HR	• Lower	• Higher
pacing period	• Shorter (about 75.5 yr at implantation)	• Nearly lifelong pacing

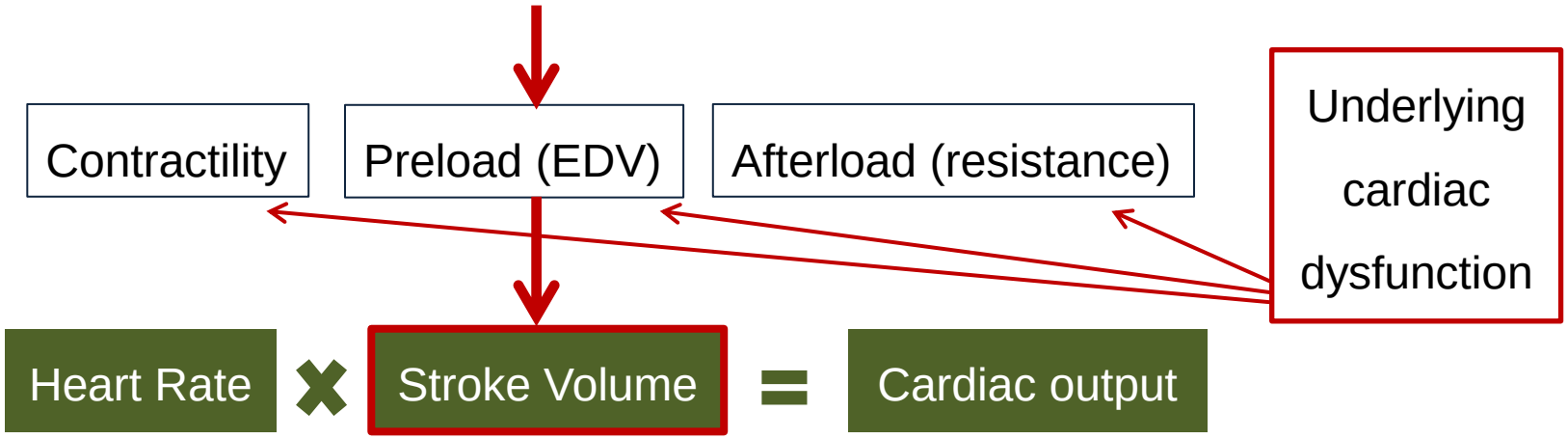
CV physiology



- Atrial function contribute 10% to 30% to left ventricular stroke volume in adults with dual-chamber PMs
- AV sequential pacing is especially important in compromised myocardial function

AV Dyssynchrony in Adult

- Atrial contraction against closed AV valves
- Ventricular filling ↓, Atrial & Venous pr. ↑



- **Pacemaker syndrome –**

  dyspnea, headache, fatigue, syncope, exercise intolerance

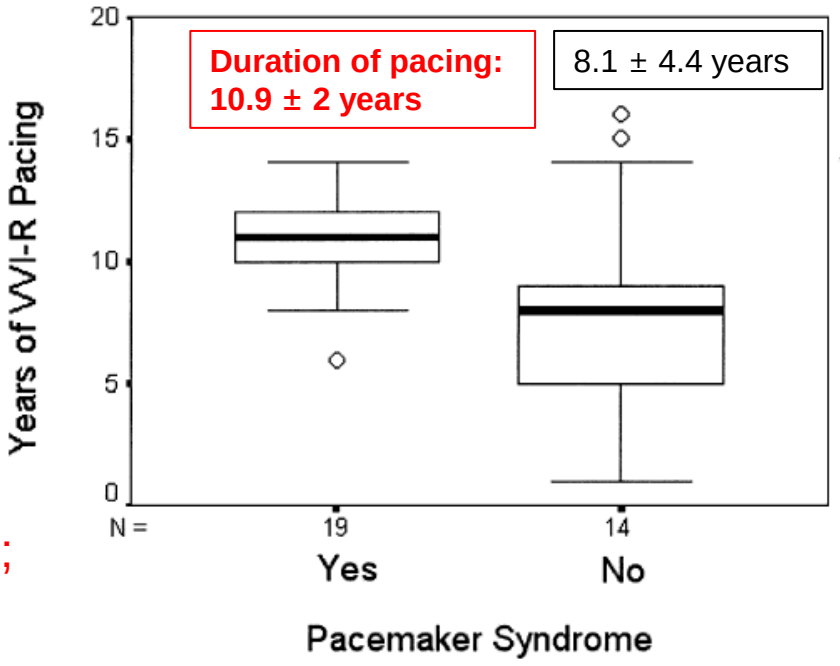
- **Development of Afib**

Pacemaker Syndrome in Children with Normal LV Fx: VVIR Predisposes to Develop?

- Pacemaker syndrome : 15% to 75% in older adult patients
- Pacemaker syndrome do not typically appear during the first decade after institution of pacing in the young.

(PACE 2004; 27:600–605)

- 33 pt. (older than 5 y.o)
- congenital CAVB c/s CHD; postop. CAVB
- 100% VVIR pacing
- 19 of 33 pt. with pacemaker sd.
- Mean age at onset of pacemaker sd.; 22 ± 10 years



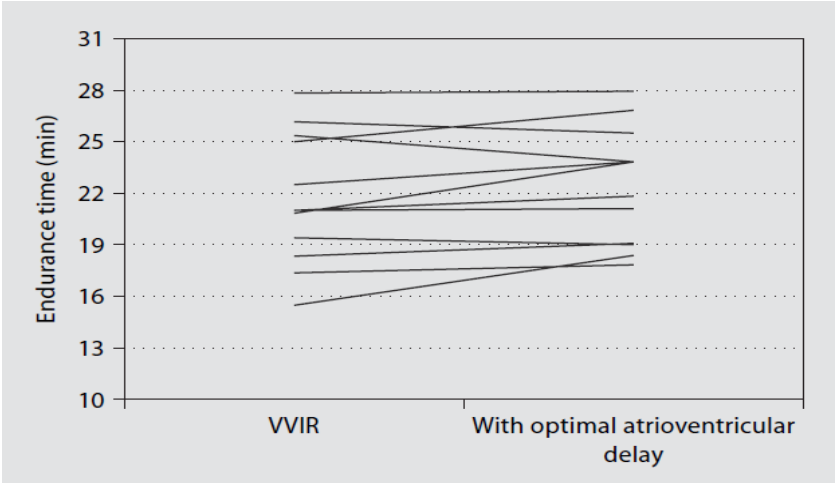
Exercise Capacity in Children with normal LV Fx: Does Pacing Mode Make a huge Difference?

- 12 children with VDD/DDD pacemaker
- VDD/DDD during 100, 125, 150, 200 ms AV delays and VVIR pacing
- Cardiac index: VDD/DDD > VVIR

Pacing mode	Cardiac index (l/min/m^2)	p
VVIR	5.25 ± 2.39 (2.77 ± 12.27)	<0.05*
With 100 ms atrioventricular delay	6.70 ± 3.06 (3.73 ± 15.01)	NS
With 125 ms atrioventricular delay	6.49 ± 2.51 (4.02 ± 12.84)	NS
With 150 ms atrioventricular delay	6.15 ± 2.35 (3.86 ± 12.50)	NS
With 200 ms atrioventricular delay	6.37 ± 2.69 (3.69 ± 12.88)	NS

- Exercise endurance time:

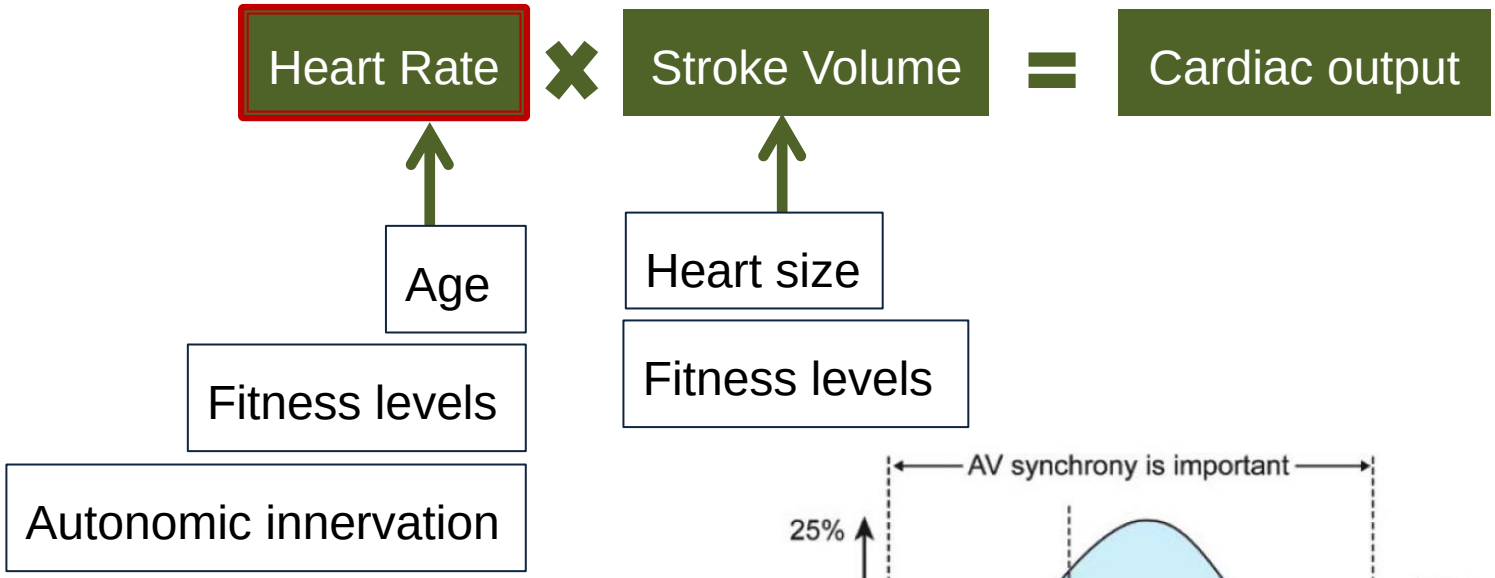
  no difference



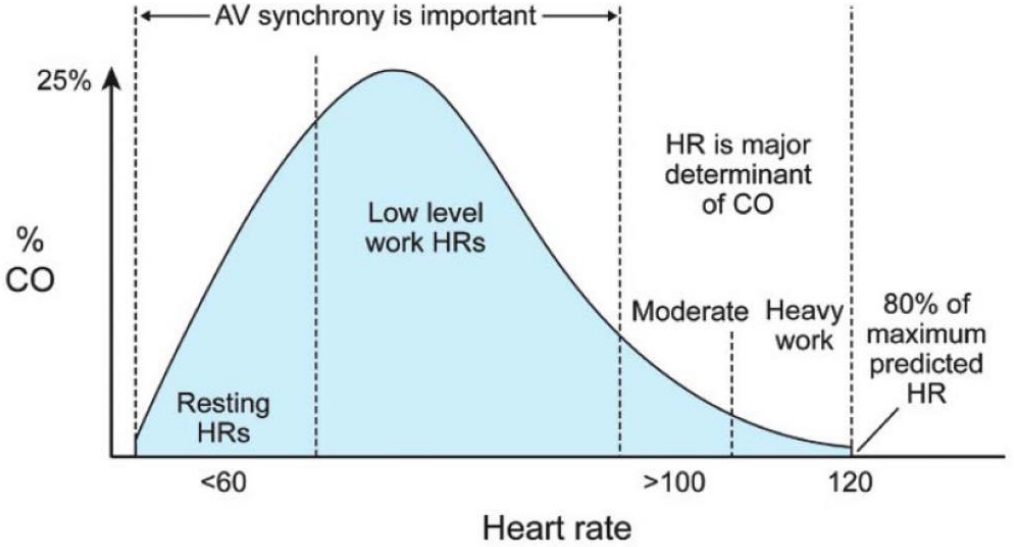
Cardiology 2007;107:185–189

Maintenance of cardiac output in children with normal LV function

Heart rate response is the most important contribution



- Especially during exercise



Dual Chamber Ppm vs Single Chamber Ppm in Children

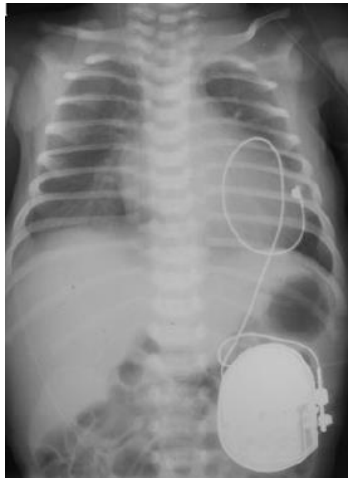
- DDD may be deferred until an older age in pediatric patients with normal LV Fx as clinical symptoms of PS arise.
- Regarding exercise capacity and tolerability, VVIR pacing is an acceptable alternative to the DDD

	Dual-chamber	Single- chamber VVI
• Pacemaker syndrome	• No difference in normal LV function	
• Exercise capacity	• No difference in normal LV function	

Body Size issue

VVI

Smaller generator

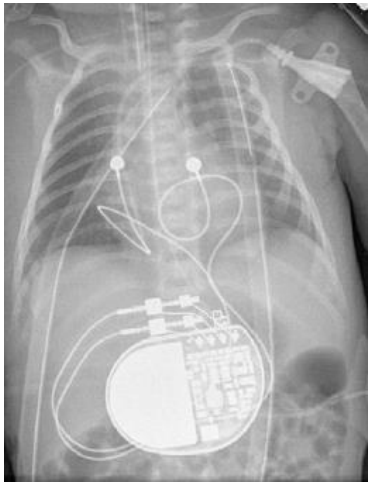


One lead required

- Epicardial - simple limited lower sternotomy

DDD

Larger generator



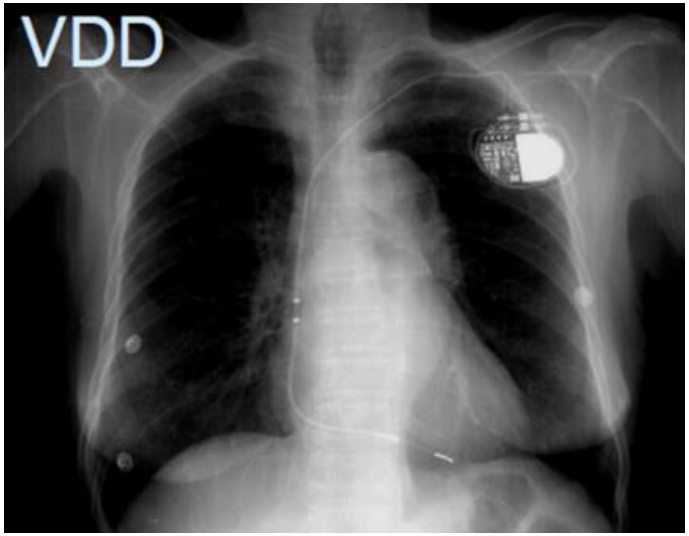
Two lead required

- Epicardial- median sternotomy or a left lateral thoracotomy
- Endocardial- the veins may be too small to accommodate two leads easily

Body Size issue

A single pass VDD lead?

- With growth, easy of atrial sensing lost
- Only large diameter leads are available



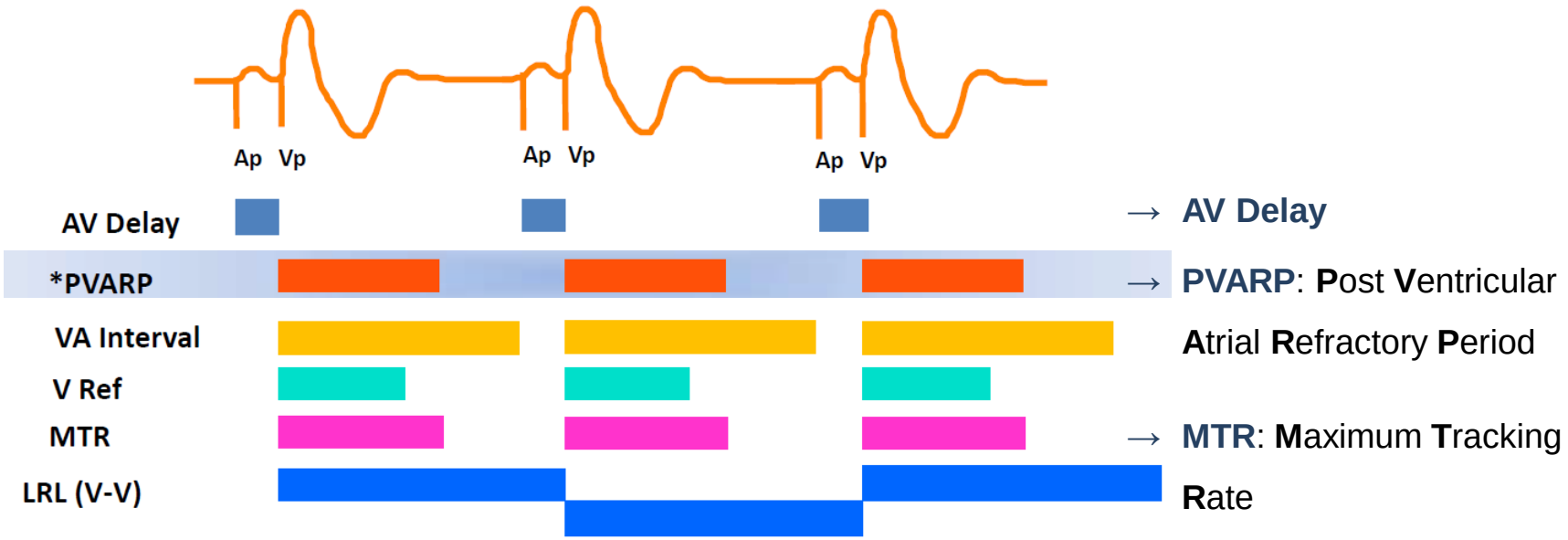
Pacemaker functions for Dual Chamber pacemaker

Single chamber

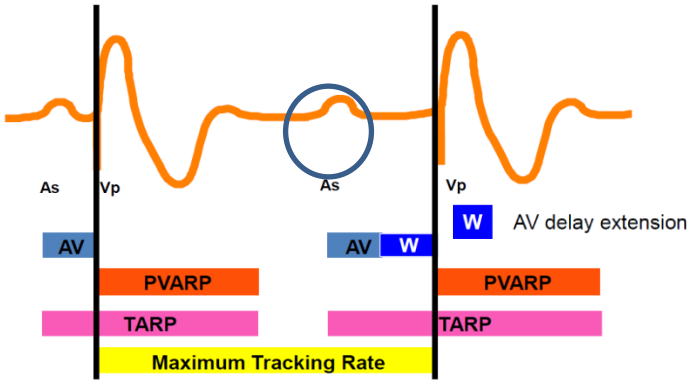
- pacing mode
- lower rate
- pulse width and amplitude
- Sensitivity
- refractory period

+

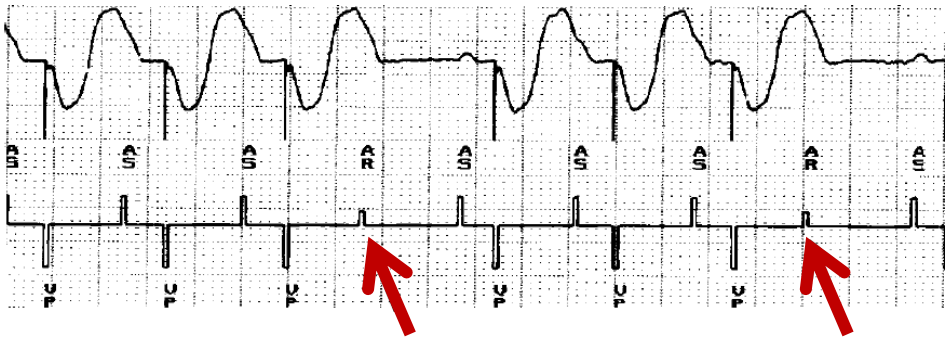
- maximum tracking rate (MTR)
- AV delay
- Post-ventricular atrial refractory period
- mode-switching algorithms for atrial arrhythmia…etc..

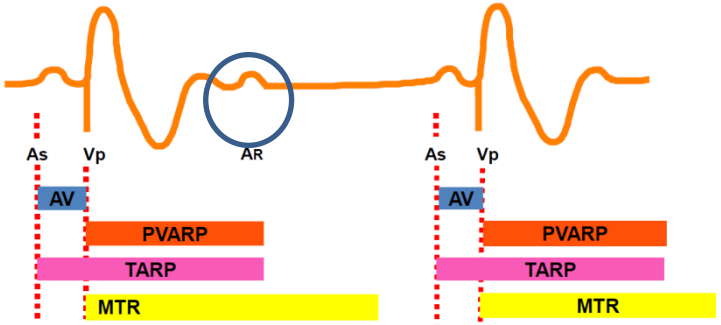


“Upper Rate Behavior”

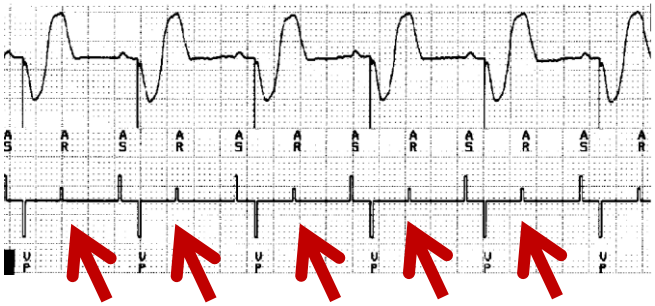


Pacemaker Wenckebach



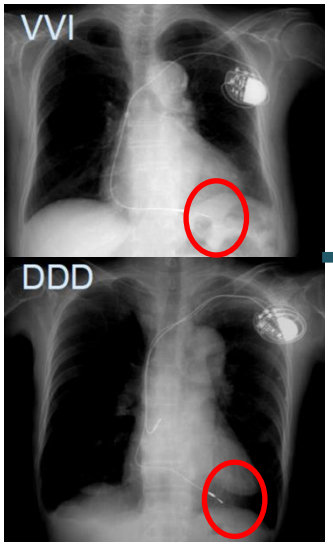


2:1 Block

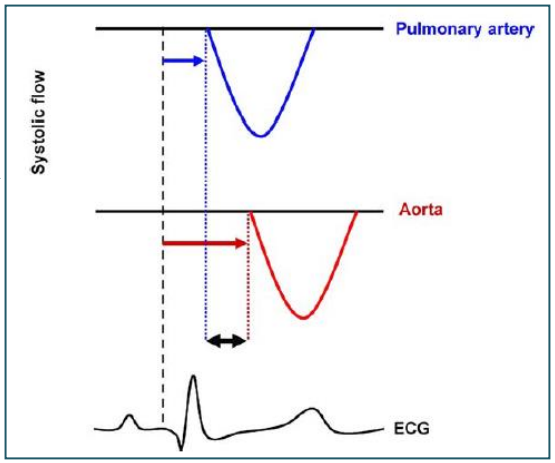


- Exercise heart rates in children may exceed maximum track rate of DDD → Sudden drop of HR

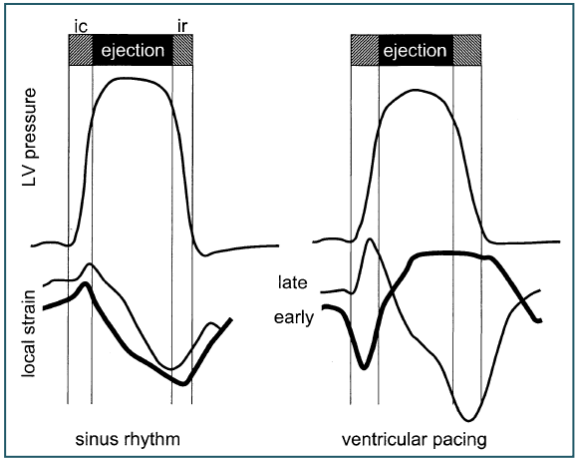
Effect of chronic RV apical pacing



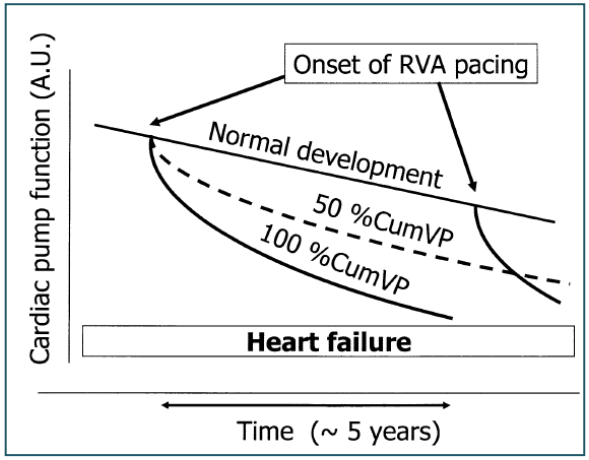
Dyssynchronous contraction



Adverse hemodynamics
: Ejection time ↓, IVCT ↑, IVRT ↑



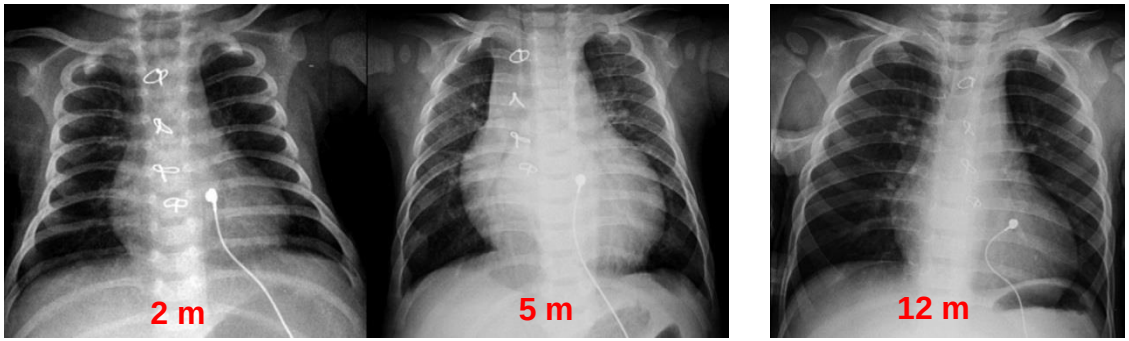
Pacing induced heart disease

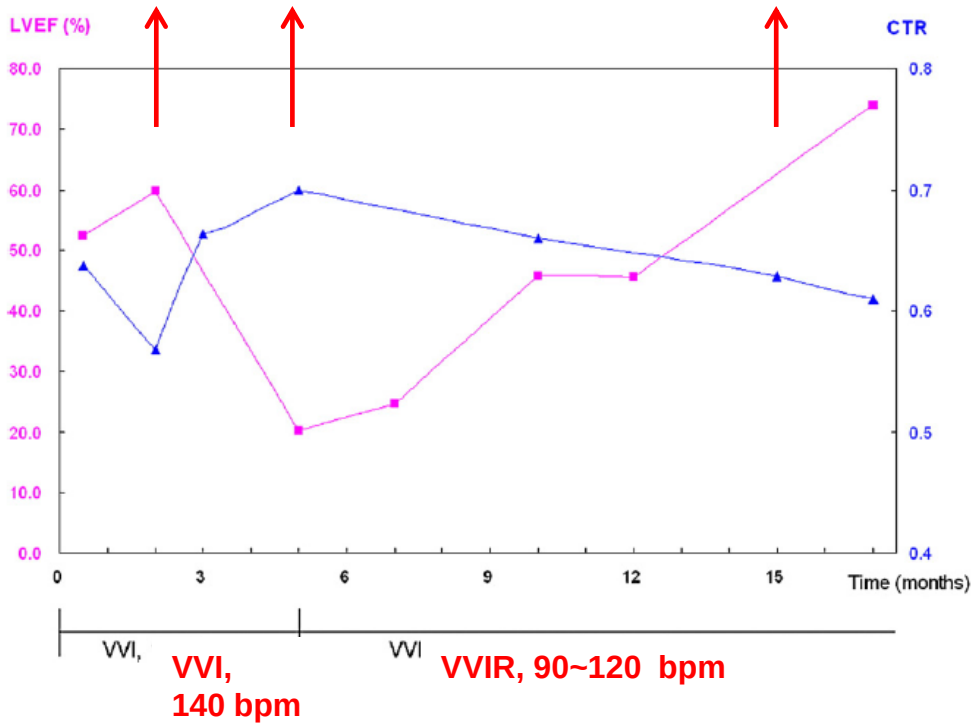


J Am Coll Cardiol 2006;47:282– 8

Pacing induced Heart Failure

- newborn with Congenital CAVB, VVI pacemaker





International Journal of Cardiology 131 (2008) e38–e40

Pacing-induced Heart Failure

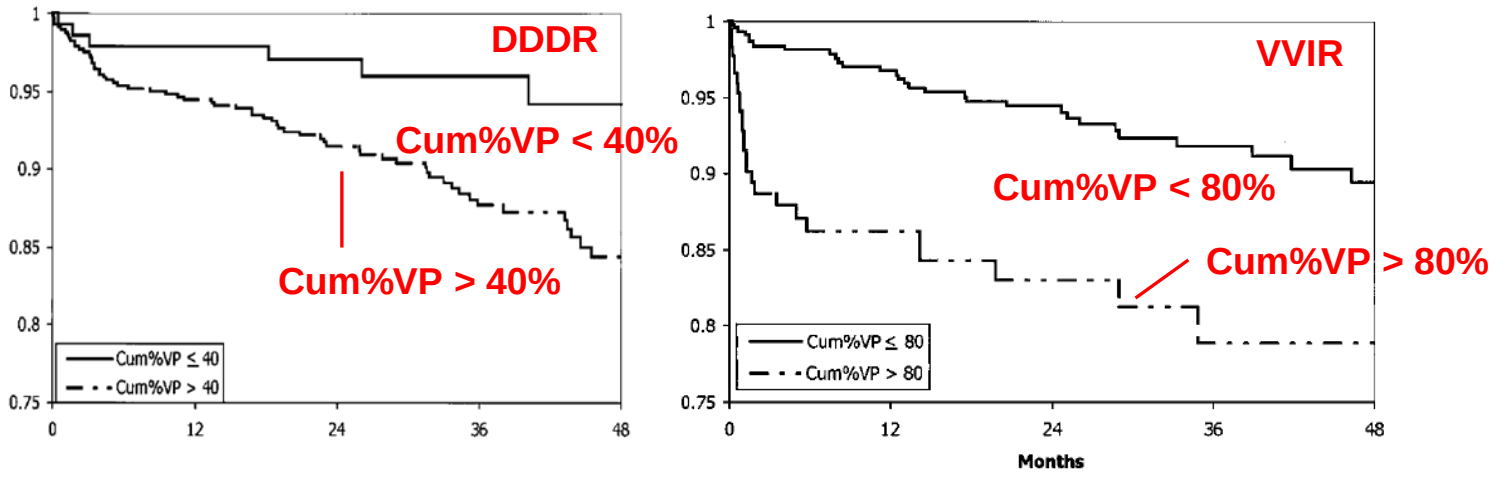
- Dyssynchronized contraction caused by RV pacing

  → factor in the development of heart failure

- Matter of the "frequency" of dyssynchrony

  = the amount of V-pacing

Free from 1st HF hospitalization



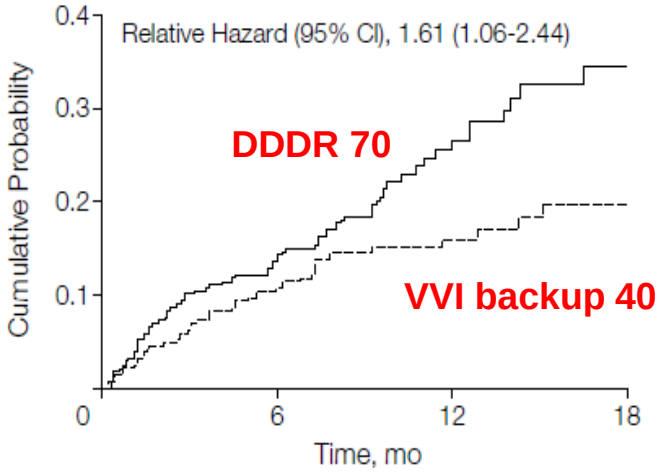
Circulation. 2003;107:2932-2937.

Pacing induced Heart Failure

JAMA 2002;288:3115-23

- Adults with ICD
  - DDDR at 70 bpm (n=250) vs.
  - Ventricular backup pacing at 40 bpm (n=256)

Death or 1st Hospitalization for new or worsened CHF



No. at Risk				
DDDR	250	159	76	21
VVI	256	158	90	25

- Sinus-based chronotropy → the amount of V-pacing↑ → HF risk ↑
- In children: a higher heart rate with DDD than VVIR pacing

  → risk of HF ↑

Dual Chamber Ppm vs Single Chamber Ppm in Children

	Dual-chamber	Single- chamber VVI
• Body size / technical issue	• #2 lead; larger generator	• Benefit
• Higher heart rate related complication	• may cause symptomatic 2:1 AV block	• Benefit
• Prevention of chronic pacing induced heart failure	• may increase the amount of V-pacing	• Benefit

Approximate risk estimates for arrhythmias in CHD

Complexity of CHD	Type of CHD	Prevalence (in CHD population)	Atrial Arrhythmia			Ventricular Arrhythmia	Other Pacing Needs		
			AT	AF	Other		SND	AV block	Dyssynchrony, heart failure
Simple	Patent ductus arteriosus	6-8%							
	Pulmonary stenosis	6-8%							
	Ventricular septal defect	30-32%							
	Secundum atrial septal defect	8-10%							
Moderate	Aortic coarctation	5-7%							
	Anomalous pulmonary venous return	0.5-2.5%							
	Atrioventricular septal defect	3-5%							
	Aortic stenosis	3-5%							
	Ebstein anomaly	0.5-1.5%							
	Tetralogy of Fallot	8-10%							
	Primum atrial septal defect	2-3%							
Severe	Truncus arteriosus	1.5-2%							
	Pulmonary atresia	2-2.5%							
	Double outlet right ventricle	1.5-2%							
	D-transposition of the great arteries	6-7%							
	L-transposition of the great arteries	1-2%							
	Hypoplastic left heart syndrome	3-4%							
	Other (heterotaxy, other single ventricles)	7-10%							

PACES/HRS Expert Consensus Statement, 2014

Considerations in Single ventricle morphology and Fontan palliation

- 15% ~ 45%, up to 60% of Fontan - Sinus node dysfunction.
- Prone to the development of AV block.
- Fibrosis, scarring and multiple suture lines causes atrial flutter and IART in up to 50%.
- Limited cardiac reserve and function decreases with increased heart rate

J Am Coll Cardiol, 46:1937-1942.

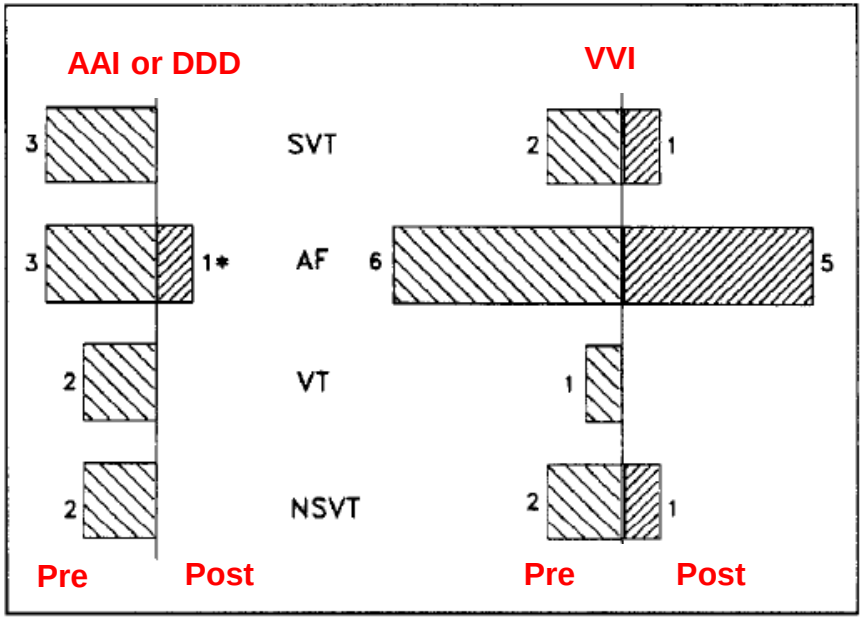
Circulation 1998;98(Suppl):II-352-9.

Am J Cardiol 1996;77:887-9.

Prevention of tachyarrhythmia in postop. CHD

- Favors physiologic pacing

- 21 pacemaker pt with CHD.
- FU for tachyarrhythmia > 12mo. before and after pacemaker
- Recurrence of tachycardia:
  - 1 of 10 with AAI or DDD (1 DDD; pacemaker-mediated tachycardia)
  - 7 of 11 with VVI



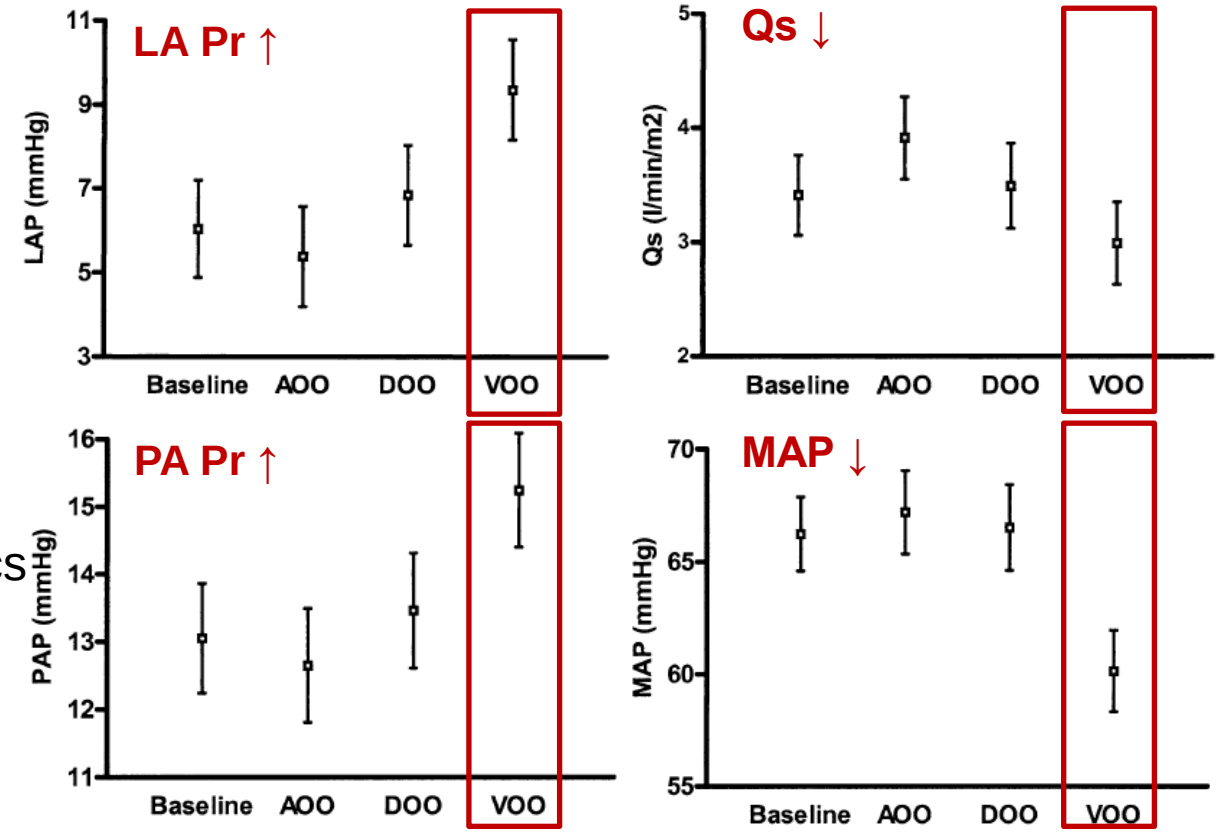
Am J Cardiol 1990;65:488-493

AV synchrony is vital in patients with Fontan physiology

- Acute adverse hemodynamic effects of asynchronous ventricular pacing in Fontan

- Cross-over trial
- 21 pt
- 2 to 18 years
- in the ICU after a Fontan op.

- VOO: Significantly worse hemodynamics than DOO and AOO



J Am Coll Cardiol 2005;46:1937– 42

DDD pacing for the Failing AP Fontan Hemodynamics

- DDD improves single ventricle hemodynamics and can help decompensated Fontan patients.

- 9 Failing AP Fontan
- Follow-up: 3.3±1.0 years

- Clinical status: Improved in all
- Arrhythmia (3) : subsided in all
- PLE (2) : 1 temporary; 1 complete resolution
- HF sx (2) : NYHA IV→II
- Pleural effusion (1) : disappear

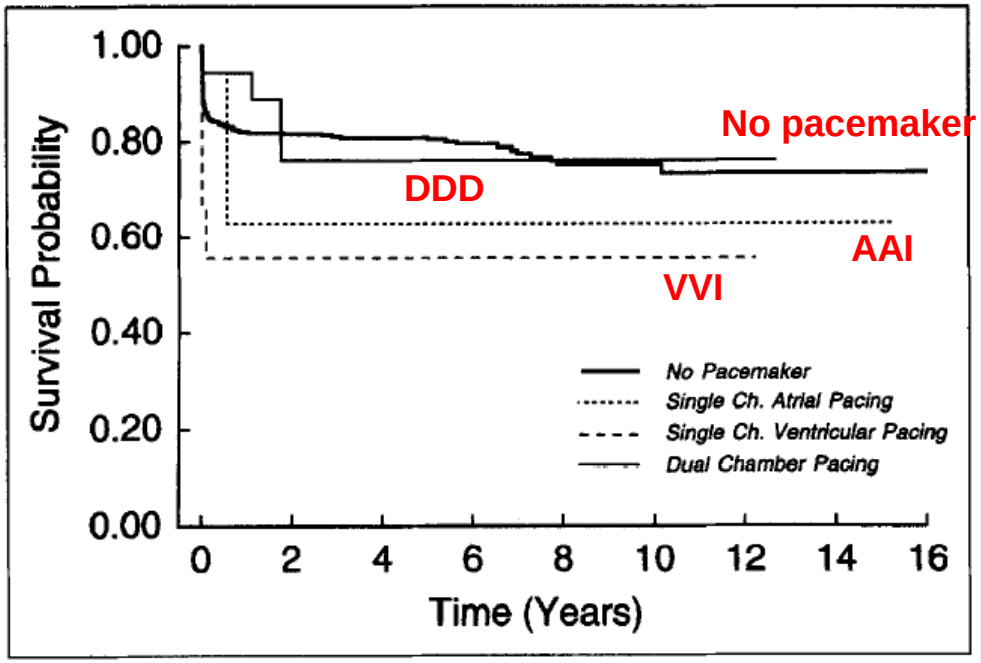
Ann Thorac Surg 2005;80:1440–4

Diagnosis	Symptoms Pre-Implant	Symptoms Post-Implant
CCTGA	IART, sotalol	No arrhythmia
TA	Ex intolerance IV	Ex intolerance II
DILV,TGA	PLE	Relief 4 months
TA	Ex intolerance IV	Ex intolerance II
TA	SND, Afib, amiodarone	No arrhythmia
TA	IART, sotalol	No arrhythmia
DORV-TGA, MA	PLE, digitalis, Bradycardia	No PLE
Criss-cross, small RV	IART, sotalol	No arrhythmia
TA	CHF, effusions	No effusions

Long-term outcome of Physiologic pacing in Fontan

- The establishment of AV synchrony with dual-chamber pacing may improve long-term survival in Fontan.

- 500 Fontan op
- 46 pacemaker (9.2%)
- 9 VVI; 19 DDD; 18 AAI
- Preop. Hemodynamics: no difference



- No correlation btw. Functional class and pacing mode.
- VVI (4 of 9) vs. DDD (15 of 19) survival (p=0.07)
- AAI (16 of 18) vs. DDD vs. no pacemaker survival (NS)

Am. J. Cardiol. 77, 887–889 (1996).

Dual Chamber Ppm vs Single Chamber Ppm in Children

	Dual-chamber	Single- chamber VVI
CHD issue: • Risk of atrial arrhythmia ↑ • Concomitant SND + AVB • Coexisting ventricular dyssynchrony, heart failure	• Benefit – especially for Fontan patients	

Conclusions and Recommendations

	Dual-chamber	Single- chamber VVI
• Body size / technical issue	• #2 lead; larger generator	• Benefit
• Higher heart rate related complication	• may cause symptomatic 2:1 AV block	• Benefit
• Prevention of chronic pacing induced heart failure	• may increase the amount of V-pacing	• Benefit
• Pacemaker syndrome	• No difference in normal LV function	
• Exercise capacity	• No difference in normal LV function	
CHD issue: • Risk of atrial arrhythmia ↑ • Concomitant SND + AVB • Coexisting ventricular dyssynchrony, heart failure	• Benefit – especially for Fontan patients	