Prevention and Management of Long Term Pacing Related Complications

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Frequency and type of pacemaker primary implantations

Indications for pacemaker implantation

Petr K et al. Europace (2012) 14, 509–514
### Difference Indication for PPM btw adults & children

<table>
<thead>
<tr>
<th>Adults</th>
<th>Children</th>
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</table>
| • Bradycardia, LV dysfunction, dyssynchrony due to partially diseased conduction systems often combined with degenerative diseases and infarctions of the myocardium | • Bradycardia due to complete AV conduction block usually a/w healthy myocardium  
• Structural normal heart
  • Congenital AV block
    • Maternal SLE  
  • Acquired AV block
    • Infectious diseases
    • Progressive AV-conduction tissue fibrosis  
• Congenital heart disease
  • A/w structural ds itself  
  • Surgical or percutaneous procedures |
Children and pacemakers
- Long term results-

- Battery & lead longevity
  - More frequent pacemaker generator or lead changes
  - For the child undergoing an initial implantation at age 1 year, a minimum of nine electrode changes and 17 generator changes (at 100% pacing) can be expected during its lifetime.
  - Generator half-life
    - 5yr (for children < 4 years of age at implantation)
    - 7yr (for children > 4 years of age at implantation)
  - Lead failure: more in children
    - Lead fracture, insulation break, displacement, and abnormalities in sensing or pacing
    - Stretching due to somatic growth, compression of epicardial leads caused by the small space between ribs, direct impact forces during daily activities
Children and pacemakers
- Long term results-

- Redundant loop of pacing lead d/t growth allowance
  - Too short – lead fracture
  - Too long – cardiac strangulation

- Systemic ventricular dysfunction
Ventricular pacing for Pt. with CAVB

- Ventricular pacing is indicated to increase heart rate, rather than to ‘resynchronize’ electrical activation.

- **Benefits**
  - Restoration of HR
  - Unpredictable risk of SCD as well as LV failure a/w untreated complete heart block is cured

- Ventricular pacing induces an abnormal electrical activation pattern, which may cause mechanical dyssynchrony, associated with impairment of pump function, LV remodeling, and increased risk of heart failure.
Pathophysiology of ventricular pacing

- Electrical asynchrony, as induced by ventricular pacing, results in a **dyssynchronous contraction pattern**.
  - Early systolic shortening of the early-activated myocytes results in stretch of late-activated myocytes.
  - When myocytes in remote regions are subsequently activated and start to contract, they contract even more powerfully due to the early systolic pre-stretching.
Pacing induced Cardiomyopathy

- Significant LV systolic dysfunction attributable to the effects of RV pacing
  - LV EF <45 %
  - Absence of other known causes of cardiomyopathy
  - RV pacing creates a constellation of adverse electromechanical changes including dyssynchronous left ventricular (LV) contraction and impaired hemodynamics that have deleterious effects on ventricular structure and function.
Pathophysiology of ventricular pacing

- Electrical activation of the LV is fast and synchronous during normal activation.
- During ventricular pacing, the region in the proximity of the pacing site is early-activated, whereas myocardium remote from the pacing site is late-activated.
- In LV apical pacing, electrical activation is circumferentially synchronous.

Heart Fail Rev (2011) 16:305–314
Pacing strategies to avoid PiCMP

- Programmed algorithms to minimize unnecessary ventricular pacing and promote intrinsic activity in paced patients
- Adequate ventricular pacing site
  - RV apex & free wall
  - Alternative- site RV pacing
  - Biventricular pacing
  - Single- site LV pacing
Strategies to Minimize Right Ventricular Pacing

- AAI: Where clinically indicated—young patient with normal AV conduction
- VVI backup 40–50 beats per minute
  - Patients with ICD without bradycardia
  - Patients with syncope 2° to transient AV block (eg, setting of bifascicular block where infrequent pacing expected)

Limited use for high-grade atrioventricular block

- AV hysteresis (Biotronik)
- AS search hysteresis (Boston Scientific)
- Search AV+ (Medtronic)
- Ventricular Intrinsic Preference (St Jude Medical)

Pacing Mode Switch from AAI to DDD
- AAISafeR, AAISafeR2 (Sorin Group)
- Managed Ventricular Pacing (Medtronic)
- Reverse Mode Switch/RhythmIQ (Boston Scientific)
Conventional pacing sites
- RV apex and free wall

- RV apex and free wall are easily accessible
- Mimic LBBB
- Paradoxical septal motion during early systolic phase
- RV pacing is well tolerated in most children

Anne M. Gillis Circ Arrhythm Electrophysiol. 2014;7:968-977
Radu Vatasescu. et al.

Evolution of left ventricular function in paediatric patients with permanent right ventricular pacing for isolated congenital heart block: a medium term follow-up

*Europace* (2007) 9, 228–232

- 45 children with RVA pacing for ICHB
- 58.69±45.23 months

Overall LV SF did not change significantly
Roman AG. et al.

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

*European Heart Journal (2009) 30, 1097–1104*

- 82 pediatric patients
- Non-surgical (n = 41) or surgical (n= 41) complete atroventricular block
- 100% RV paced, mean F/U = 7.4 years

### Table 3 Changes in left ventricular size and function

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Preimp (n = 77)</th>
<th>Postimp (n = 62)</th>
<th>Last (n = 82)</th>
<th>P-value (overall)</th>
<th>P-value (preimp vs. postimp)</th>
<th>P-value (postimp vs. last)</th>
<th>P-value (preimp vs. postimp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVEDD (z-score)</td>
<td>Median (range)</td>
<td>+0.9 (-6.3 to +8.5)</td>
<td>+0.3 (-4.0 to +6.9)</td>
<td>+0.9 (-3.4 to +11.3)</td>
<td>0.017</td>
<td>NS</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>LV SF (%)</td>
<td>Median (range)</td>
<td>39 (24–62)</td>
<td>37 (15–58)</td>
<td>32 (8–49)</td>
<td>&lt;0.001</td>
<td>NS</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Left ventricular dilatation and dysfunction a</td>
<td>n (%)</td>
<td>1 (1.3)</td>
<td>1 (1.6)</td>
<td>11 (13.4)</td>
<td>0.001</td>
<td>0.574</td>
<td>0.026</td>
</tr>
</tbody>
</table>

Last, last follow-up; LVEDD, left ventricular end-diastolic diameter; LV SF, left ventricular shortening fraction; Preimp, pre-implantation; Postimp, post-implantation.

aLVEDD > +2z, SF < 26%.
Roman AG. et al.

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


- Epicardial RV free wall pacing (OR $\frac{1}{4} 14.3, 95\%$ CI = 2.3–78.2, P < 0.001) as the only significant predictor of the development of late LV dilatation and dysfunction
Alternative-site RV pacing

- His-bundle pacing
  - Normal physiological sequence of activation
  - In children
    - Challenging procedure and seems not very applicable in children
    - Post-surgical AVB/ Congenital AVB
      - His bundle may be involved in the pathological interruption of the conduction system
- RV outflow tract
  - The inferior part of septal side of RVOT
Biventricular pacing

- Biventricular pacing is mainly applied in adult heart failure patients with normal cardiac anatomy, suffering from LV dysfunction in association with LV dyssynchrony due to intrinsic LBBB.
- Based on the rationale that the sequence of activation in RV pacing similar to the activation pattern in LBBB, application of biventricular pacing has been extended to heart failure patients with RV-pacing-associated dyssynchrony.
- Data from large randomized adult CRT trials cannot simply be translated to children with cardiac failure.

  - Mixed etiology (normal cardiac anatomy with LV HF + UVH + systemic RV + RV failure)
Dubin et al.
Resynchronization Therapy in Pediatric and Congenital Heart Disease Patients- An International Multi-Center Study
JACC Vol. 46, No. 12, 2005

- 103 patients from 22 institutions
- Age at time of implantation: 12.8 yrs (3 m - 55.4 yr)
- F/U duration: 4 mon (22 day ~ 1 yr)
- 73 CHD, 16 CMP, 14 CAVB

**Upgrade of pacemaker to CRT**
- 46 patients
- Significant improvement in EF with CRT therapy
  => 14.5 ± 11.4 EF units (p < 0.05).
John G. et al.

Cardiac resynchronization therapy in pacemaker-dependent patients with left ventricular dysfunction

*Europace* (2013) 15, 1609–1614

- 50 patients with unavoidable RV pacing, LVSD, and mild or no symptoms of heart failure
- At the time of pulse generator replacement
- Randomized 1 : 1 to either standard RV-PGR (comparator) or CRT
# 2013 ESC guideline

Recommendations for cardiac resynchronization therapy directly or upgrade from a conventional pacing system in patients with heart failure and formal indication for cardiac pacing therapy.

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Class</th>
<th>Level of evidence</th>
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<tr>
<td>1. Upgrade of conventional PM or ICD. CRT is indicated in HF patients with LVEF &lt;35% and a demand for high percentage of ventricular pacing who persist in the NYHA functional class III or IV even with optimized medical treatment</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>2. CRT in a direct way. CRT should be considered in patients with HF, depressed LVEF and a demand for high percentage of ventricular pacing under risk of worsening of HF symptoms</td>
<td>IIa</td>
<td>B</td>
</tr>
</tbody>
</table>

Eur Heart J. 2013;34(29):2281
Single-site LV pacing

- Comparable to that of upgrade to biventricular pacing, in children with LV dysfunction after chronic RV pacing, functional improvement and reverse remodeling are reported for LV single-site pacing.
Janoušek. et al.
Permanent Cardiac Pacing in Children: Choosing the Optimal Pacing Site - A Multicenter Study
*Circulation.* 2013;127:613-623

- 178 children (<18 yrs), 21 center
- AV block, normal heart
- Median age – 11.2 yr (6.3-15.0)

![Graph showing change in LV SF][1]

![Box plot of pacing site comparison][2]

**Legend:**
- EF < 55%
- EF ≥ 55%
- P = 0.001
- P compared to pre-implantation:
  - RVOT: 0.004
  - RVLat: <0.001
  - RVA: <0.001
  - RVS: <0.001
  - LVA: NS
  - LVLat: NS
  - LV: NS
  - P overall = 0.002
Recommendations for optimal pacing in children

- **Ventricular pacing should be minimized** in patients with (partially) preserved AV conduction & intact His-Purkinje system, such as sick sinus syndrome.

- Surgically induced AV block
  - Regularly check-up for re-established AV conduction

- In children with CAVB & normal heart
  - Use of single LV apex and LV free wall sites

- **Regular echocardiographic checkup** is warranted
  - Esp. in children with RV pacing
  - BV pacing / single site LV pacing should be considered as soon as echocardiography reveals signs of ventricular dilatation or dysfunction
Optimal pacing site in children with Normal heart

Pediatric EP: Pediatric Bradyarrhythmia and Device Therapy
Optimal pacing site in children with Structural HD

Pediatric EP: Pediatric Bradyarrhythmia and Device Therapy
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