His bundle pacing
Theory and Implantation

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CONFLICTS OF INTERESTS

Honoraria and Travel Subsidy from Medtronic
<table>
<thead>
<tr>
<th>Year</th>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958</td>
<td>5800</td>
<td>First External Pacemaker</td>
</tr>
<tr>
<td>1960</td>
<td>Chardack - Greatbatch</td>
<td>First Implantable Pacemaker</td>
</tr>
<tr>
<td>1970</td>
<td>5858</td>
<td>Pediatric Asynchronous Pulse Generator</td>
</tr>
<tr>
<td>1979</td>
<td>Byrel</td>
<td>Dual chamber rate response</td>
</tr>
<tr>
<td>1986</td>
<td>Activitrax</td>
<td>Rate response</td>
</tr>
<tr>
<td>1989</td>
<td>Synergist</td>
<td>Dual chamber rate response</td>
</tr>
<tr>
<td>1990</td>
<td>MicroMinix</td>
<td>Radically smaller size</td>
</tr>
<tr>
<td>1991</td>
<td>Elite</td>
<td>Rate response via activity &amp; minute ventilation</td>
</tr>
<tr>
<td>1995</td>
<td>Thera™</td>
<td>1st Micro-processor-based, Mode switching</td>
</tr>
<tr>
<td>1998</td>
<td>Kappa™</td>
<td>Rate response via activity &amp; minute ventilation</td>
</tr>
<tr>
<td>2004</td>
<td>EnPulse</td>
<td>Full automaticity</td>
</tr>
<tr>
<td>2006</td>
<td>Adapta™</td>
<td>MVP™, Full automaticity</td>
</tr>
<tr>
<td>2011</td>
<td>EnRhythmMRI™</td>
<td>1st MRI-Conditional</td>
</tr>
<tr>
<td>2013</td>
<td>Advisa MRI™</td>
<td>2nd MRI-Conditional</td>
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</tbody>
</table>
Thank to Peter Spector and Dan Lusgarten
Damaging Activation is Harmful

Death or First Hospitalization for New or Worsened CHF

Relative Hazard (95% CI), 1.61 (1.06-2.44)

Dual Chamber Rate-Responsive Pacing 70bpm

Ventricular Backup Pacing 40bpm

P = 0.03
Damaging Activation is Harmful

Death or First Hospitalization for New or Worsened CHF

Relative Hazard (95% CI), 1.61 (1.06-2.44)

Time (Months)

Cumulative Probability

DAVID (The Dual Chamber and VVI ICD Trial)  Wilkoff et al., AMA 2002; 288(24):3115-3123
Improving Ventricular Activation is Good

LBBB vs BiV Pacing

RV vs BiV Pacing


Thank to Peter Spector and Dan Lusgarten
Avoiding Pacing

Managed Ventricular Pacing
MVP

Ventricular Intrinsic Preference
VIP

RHYTHMIQ
How about avoiding RV pacing?

Control Group – ICD only

- Long PR interval
- Normal PR interval

P < 0.001

How about avoiding RV pacing?

Selective His Bundle Pacing

Thank to Peter Spector and Dan Lusgarten
Intrinsic

Selective His Pacing
Primary Outcome
(Death, Heart Failure Hospitalization, or Upgrade to Biventricular Pacing)

- p = 0.02
- HR = 0.71

RV pacing

His pacing

All patients

Follow Up in Years

Event-Free Rate
Intrinsic Rhythm LBBB
Intrinsic Rhythm LBBB

Selective His Pacing with LBBB reversal
Reversing Bundle Branch Block

Longitudinal Dissociation in the His Bundle

Bundle Branch Block due to Asynchronous Conduction within the His Bundle in Man

Onkar S. Narula, M.D.
Bundle Branch Block Reversal

Longitudinal Dissociation
- no conduction disease
Usefulness of His Bundle Pacing to Achieve Electrical Resynchronization in Patients With Complete Left Bundle Branch Block and the Relation Between Native QRS Axis, Duration, and Normalization

Alexandra E. Teng, MD\textsuperscript{a}, Daniel L. Lustgarten, MD, PhD\textsuperscript{b}, Pugazhendhi Vijayaraman, MD\textsuperscript{c}, Roderick Tung, MD\textsuperscript{d}, Kalyanam Shivkumar, MD, PhD\textsuperscript{a}, Galen S. Wagner, MD\textsuperscript{c}, and Olujimi A. Ajijola, MD, PhD\textsuperscript{d,\textasteriskcentered}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure}
\caption{Absolute Change in QRS Duration}
\end{figure}

\begin{align*}
\text{QRS Duration (ms)} & \\
\text{Mean QRS: 160ms \pm 16ms} & \quad \text{Mean QRS: 115ms \pm 36ms} \\
\text{pre-procedure QRS} & \quad \text{post-procedure QRS}
\end{align*}
When to use His pacing?
When to use His pacing?

Figure 2: Potential of His Bundle Pacing

<table>
<thead>
<tr>
<th>A</th>
<th>Initial cardiac activation (Narrow or broad QRS)</th>
<th>B</th>
<th>Current pacing solutions (Never narrow QRS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow QRS</td>
<td><img src="image1" alt="Waveform" /></td>
<td>RVP</td>
<td><img src="image2" alt="Waveform" /></td>
</tr>
<tr>
<td>Activation prolonged</td>
<td><img src="image3" alt="Waveform" /></td>
<td>BVP</td>
<td><img src="image4" alt="Waveform" /></td>
</tr>
<tr>
<td>LBBB</td>
<td><img src="image5" alt="Waveform" /></td>
<td>BVP</td>
<td><img src="image6" alt="Waveform" /></td>
</tr>
<tr>
<td>Activation moderately improved</td>
<td><img src="image7" alt="Waveform" /></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Narrow QRS long PR interval</td>
<td><img src="image8" alt="Waveform" /></td>
<td>Activation prolonged</td>
<td><img src="image9" alt="Waveform" /></td>
</tr>
</tbody>
</table>
When to use His pacing?

Figure 2: Potential of His Bundle Pacing

His bundle pacing across three classes of indications: (A) narrow QRS, (B) left bundle branch block (LBBB), and (C) long PR interval and narrow QRS. Right ventricular apical pacing (RVP) and biventricular pacing (BVP) do not completely restore narrow QRS. His bundle pacing fully maintains or restores narrow QRS and ventricular synchrony with atrioventricular delay optimisation.
Performing His bundle pacing
Understanding His electrophysiology

His Bundle Anatomical variations

Type 1 patients 50% (thin layer of myocardial fibres only covering the his bundle)
Understanding His electrophysiology

His Bundle Anatomical variations

**Type 1 patients 50%** (thin layer of myocardial fibres only covering the his bundle)

**Type 2 patients 30%** (his bundle lies within the muscular interventricular septum) i.e not as close to lead implant site
Understanding His electrophysiology

His Bundle Anatomical variations

Type 1 patients 50% (thin layer of myocardial fibres only covering the his bundle)

Type 2 patients 30% (his bundle lies within the muscular interventricular septum) i.e not as close to lead implant site

Type 3 patients 20% (naked his bundle)
His lead electrophysiological positions and responses

**Nomenclature:**

*Selective HBP*

*Non-Selective HBP*
His lead electrophysiological positions and responses

Nomenclature:

**Selective HBP**

*Ventricular activation occurring solely over the His Purkinje system*

**Non-Selective HBP**
Selective His Bundle Pacing

Thank to Peter Spector and Dan Lusgarten
His lead electrophysiological positions and responses

Nomenclature:

Selective HBP

Ventricular activation occurring solely over the His Purkinjee system

Non-Selective HBP

Fusion between local ventricular capture in the basal anteroseptal RV and His bundle capture
Non-selective capture

Thank to Peter Spector and Dan Lusgarten
Selective Vs Non-Selective His Bundle pacing

Type 1 patients (thin layer of myocardial fibres only covering the his bundle)

Type 2 patients (his bundle lies within the muscular interventricular septum)

Type 3 patients (naked his bundle)
Selective Vs Non-Selective His Bundle pacing

Type 1 patients (thin layer of myocardial fibres only covering the his bundle) minimal ventricular fusion and selective capture is common (high voltage probable Non-Selective capture)

Type 2 patients (his bundle lies within the muscular interventricular septum)

Type 3 patients (naked his bundle)
Selective Vs Non-Selective His Bundle pacing

Type 1 patients (thin layer of myocardial fibres only covering the his bundle) minimal ventricular fusion and selective capture is common (high voltage probable Non-Selective capture)

Type 2 patients (his bundle lies within the muscular interventricular septum) selective his capture is almost impossible but may get non-selective with high voltages

Type 3 patients (naked his bundle)
Selective Vs Non-Selective His Bundle pacing

Type 1 patients (thin layer of myocardial fibres only covering the his bundle) minimal ventricular fusion and selective capture is common (high voltage probable Non-Selective capture)

Type 2 patients (his bundle lies within the muscular interventricular septum) selective his capture is almost impossible but may get non-selective with high voltages

Type 3 patients (naked his bundle) significant his bundle injury currents can be observed with Selective capture and very low capture thresholds (<0.5) can be achieved, rare to get non-selective
His lead electrophysiological positions and responses

*His Bundle pacing: Selective Capture*
His lead electrophysiological positions and responses

*His Bundle pacing: Higher Output*
His lead electrophysiological positions and responses

*His Bundle pacing: Membranous Septum*
Performing His bundle pacing
Use the PSA

- Use atrial channel for His bundle mapping
- Use gain settings of 0.05 mV @ 50mm/s sweep speed
- Printing on paper may show His signal better
EP system displays both signal and 12 lead ECG
Medtronic SelectSecure 3830 lead

- 4.1 French Lead
- Fixed screw helix
- No Lumen (therefore requires a delivery sheath)
- 69cm
- IS-1 connectivity
Medtronic C315 delivery catheter

- Fixed Primary and Secondary curves
- Proximal curve directs lead to tricuspid annulus
- Secondary curve directs the lead toward the septum
- Fits through a 7 French sheath
Advance the delivery system to the His region
How to perform His bundle pacing

Position the Lead

Once the delivery sheath is in position use the pacing lead to locate the His electrogram
His bundle mapping
Don’t Map in Bipolar

Red clip to pocket

Black clip to lead

Sheath

Lead

Unipolar

Bipolar
Use the sheath to provide good lead support

~5 clockwise turns

Should feel resistance when turning lead
Repositioning lead

• Counterclockwise rotation to free the lead

• Remove the lead from sheath and ensure helix is clean
Intrinsic
Intrinsic 2 Volts
Non-Selective HBP

Selective HBP-LBBB correction

AV node

I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6

Intrinsic
2 Volts
1.5 Volts
1 Volts
His Bundle Pacing

Maintains Activation
His Bundle Pacing

Maintains Activation
His Bundle Pacing

Maintains Activation
Improves Activation
His Bundle Pacing

Maintains Activation

Improves Activation

Lead Contained in RA
His Bundle Pacing
His Bundle Pacing
His Bundle Pacing
His Bundle Pacing

Maintains Activation

Improves Activation

Lead Contained in RA

AV synchrony without worsening activation
Questions
Selective

Base

AP

RV

LAD

Apex

PA

LV

LAD

Intrinsic

Base

RV

LAD

Apex

LV

LAD

Keene et al. ESC Heart Failure (2018) DOI: 10.1002/ehf2.12315
B Reversal due to distal pacing lead

Proximal site of left bundle branch block

Proximal left bundle branch block bypassed by pacing lead positioned distal to site of block
B Reversal due to distal pacing lead

Proximal site of left bundle branch block

Proximal left bundle branch block bypassed by pacing lead positioned distal to site of block

C Reversal due to remote electrical activation

Distal site of left bundle branch block

Distal left bundle branch block overcome by electrical remote activation. Consider: higher outputs, source-sink or virtual electrode theories.
B Reversal due to distal pacing lead

Proximal site of left bundle branch block

Proximal left bundle branch block bypassed by pacing lead positioned distal to site of block

C Reversal due to remote electrical activation

Distal site of left bundle branch block

Distal left bundle branch block overcome by electrical remote activation. Consider: higher outputs, source-sink or virtual electrode theories

D Reversal due to close proximity to high septal branch

Left bundle branch block

Left bundle branch block overcome by pacing lead in close proximity to high septal branch, with initial retrograde activation back up branch before facilitating antegrade conduction beyond block
His lead electrophysiological positions and responses

What to measure?

When his signal found

1) His – V (HV) time
His lead electrophysiological positions and responses

What to measure?

When his signal found

1) His – V (HV) time
His lead electrophysiological positions and responses

What to measure?

When his signal found

1) His – V (HV) time
2) QRS Duration
His lead electrophysiological positions and responses

What to measure?

When his signal found

1) His – V (HV) time
2) QRS Duration
3) His to end QRS

50ms
92ms
142ms
His lead electrophysiological positions and responses

What to measure?

When pacing
His lead electrophysiological positions and responses

**What to measure?**

**When pacing**

1) *Stim to V time and comment is it isoelectric and does it differ from intrinsic HV time*
His lead electrophysiological positions and responses

**What to measure?**

When pacing

1) **Stim to V time and comment** is it isoelectric and does it differ from intrinsic HV time

2) **QRS duration and comment** on morphology change
His lead electrophysiological positions and responses

What to measure?

When pacing

1) Stim to V time and comment is it isoelectric and does it differ from intrinsic HV time

2) QRS duration and comment on morphology change

3) Stim to end of QRS time and does it differ from H to terminal QRS time
His lead electrophysiological positions and responses

Selective His Bundle pacing

1. Isoelectric interval between stimulus and QRS onset

![Electrophysiological tracings showing His bundle pacing and responses.](image)
His lead electrophysiological positions and responses

Selective His Bundle pacing

1. Isoelectric interval between stimulus and QRS onset
Selective His Bundle pacing

1. **interval between stimulus and QRS onset**
2. **HV interval** = stimulus – V interval or a shorter stimulus – V interval if QRS narrowing occurs in BBB
His lead electrophysiological positions and responses

Selective His Bundle pacing

1. interval between stimulus and QRS onset
2. HV interval = stimulus – V interval OR a shorter stimulus – V interval if QRS narrowing occurs in BBB
His lead electrophysiological positions and responses

Selective His Bundle pacing

1. Isoelectric interval between stimulus and QRS onset

2. HV interval = stimulus – V interval or a shorter stimulus – V interval if QRS narrowing occurs in BBB

3. QRS identical to native morphology or narrower QRS (if intrinsic BBB) with concordance of the T wave complexes
His lead electrophysiological positions and responses

Selective His Bundle pacing

1. **Isoelectric interval** between stimulus and QRS onset

2. **HV interval = stimulus – V interval** or a shorter stimulus – V interval if QRS narrowing occurs in BBB

3. **QRS identical to native morphology or narrower QRS** (if intrinsic BBB) with concordance of the T wave complexes

4. **Discrete local ventricular electrogram** on HBP lead
His lead electrophysiological positions and responses

Selective His Bundle pacing

1. Isoelectric interval between stimulus and QRS onset
2. HV interval = stimulus – V interval or a shorter stimulus – V interval if QRS narrowing occurs in BBB
3. QRS identical to native morphology or narrower QRS (if intrinsic BBB) with concordance of the T wave complexes
4. Discrete local ventricular electrogram on HBP lead
5. Widening of the QRS at higher outputs as local myocardium is captured (2/3 of cases)
His lead electrophysiological positions and responses

Non-Selective His Bundle pacing

1. Interval from stimulus to end of the QRS = His to end of QRS during native conduction
His lead electrophysiological positions and responses

Non-Selective His Bundle pacing

1. Interval from stimulus to end of the QRS = His to end of QRS during native conduction
His lead electrophysiological positions and responses

Non-Selective His Bundle pacing

1. Interval from stimulus to end of the QRS = His to end of QRS during native conduction
2. Shorter stim to end QRS interval in normalisation of BBB.
His lead electrophysiological positions and responses

Non-Selective His Bundle pacing

1. Interval from stimulus to end of the QRS = His to end of QRS during native conduction

2. Shorter stim to end QRS interval in normalisation of BBB.

3. Pseudo delta wave after stimulus reflecting basal anteroseptal ventricular capture
His lead electrophysiological positions and responses

Non-Selective His Bundle pacing

1. Interval from stimulus to end of the QRS = His to end of QRS during native conduction
2. Shorter stim to end QRS interval in normalisation of BBB.
3. Pseudo delta wave after stimulus reflecting basal anteroseptal ventricular capture
4. Electrical axis of the paced QRS must be concordant with the electrical axis of the native QRS
His lead electrophysiological positions and responses

Non-Selective His Bundle pacing

1. Interval from stimulus to end of the QRS = His to end of QRS during native conduction
2. Shorter stim to end QRS interval in normalisation of BBB.
3. Pseudo delta wave after stimulus reflecting basal anteroseptal ventricular capture
4. Electrical axis of the paced QRS must be concordant with the electrical axis of the native QRS
5. More likely narrowing of QRS with high output
Perfection is the enemy of good
Perfection is the enemy of good

Intrinsic

Pacing 1
Perfection is the enemy of good
Perfection is the enemy of good

1) Accept
2) Different pacing configuration
3) Unscrew and change position

Intrinsic

Pacing 1

3.8V at 1ms
Perfection is the enemy of good

1) Accept
2) Different pacing configuration
3) Unscrew and change position
4) Second lead approach
Perfection is the enemy of good

1) Accept
2) Different pacing configuration
3) Unscrew and change position
4) Second lead approach

1.2V at 1ms
Perfection is the enemy of good
Performing His bundle pacing