His bundle pacing as a treatment for patients with heart failure

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Conflict of interest

• Medtronic: research support, speaker fees, proctor
• Boston Scientific: consultant fees, advisory board
• Abbot: speaker, consultancy fees, advisory board
• Patent for a hemodynamic optimization method
Pacing therapy for heart failure
Biventricular pacing

Mortality reduced by 10% with BVP

Mortality still high despite BVP

Only applies to wide QRS
What is dominant mechanism of action of BVP?

- 1. Ventricular Resynchronisation
- 2. Improved atrioventricular timing
- 3. Other
What is mechanism of action of BVP?

What is mechanism of action of BVP?

Intrinsic Rhythm  
His Pacing  
LBBB preserved  
Biventricular Pacing

Electrocardiogram tracings showing different cardiac rhythms and pacing modes.
Comparison of acute haemodynamic improvement With AV optimisation only and biventricular pacing
Comparison of acute haemodynamic improvement With AV optimisation only and biventricular pacing
Improving AV timing appears to be an important mechanism through which BVP delivers its effect.
CAN PACING THERAPY FOR HEART FAILURE BE EXTENDED TO NON-LBBB PTS?
PR prolongation is not benign

MADIT study
ICD arm
non LBBB pts
BVP reduces events when PR is prolonged
PR prolongation and Heart Failure

Long PR interval and heart failure
Missed Potential of Conventional Biventricular Pacing

LBBB
QRS > 120ms
not LBBB
Narrow
QRS
Unwanted lengthening of activation
Shortening obtained with conventional BVP

Hemodynamic effect of His Bundle Pacing to allow shortening of AV delay

- Intrinsic conduction
- His pacing

<table>
<thead>
<tr>
<th>Rhythm</th>
<th>Duration</th>
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<tbody>
<tr>
<td>Intrinsic</td>
<td>40ms</td>
</tr>
<tr>
<td>Intrinsic</td>
<td>80ms</td>
</tr>
<tr>
<td>Intrinsic</td>
<td>120ms</td>
</tr>
<tr>
<td>Intrinsic</td>
<td>160ms</td>
</tr>
<tr>
<td>Intrinsic</td>
<td>200ms</td>
</tr>
</tbody>
</table>

[Image of ECG and ultrasound]
Acute Haemodynamic study: His pacing in patients with HF and long PR interval

~ 60% the effect size of BVP when delivered to patients with LBBB

JACC: Clinical Electrophysiology, Volume 1, Issue 6, 2015, 582–591
AV optimisation delivered with direct His bundle pacing, in patients with heart failure, long PR without left bundle branch block: randomised multi-centre clinical outcome study.

The His Optimised Pacing Evaluated for Heart Failure Trial

**AV delay optimisation delivered with His bundle pacing**

Long PR interval, narrow QRS/RBBB and LV impairment

Improve objective exercise capacity?
Trial Flow Diagram

0 months

- Pre-Screening
- Eligibility and Patient Informed Consent
- Device Implantation

Recovery Period Post Device Implant
(non-His VVI 30bpm back-up pacing and ICD functions as indicated)

2 months

- Post Implant Visit 1 at Coordinating Centre
  - Baseline assessment of study endpoints: Cardio-Pulmonary Exercise Test, ECHO, BNP & QOL
  - AV delay Hemodynamic Optimization performed
  - RANDOMISATION
    - AV Optimized His Pacing
    - No His Pacing
      (AV Optimized His pacing and ICD functions as indicated)

8 months

- Post Implant Visit 2 at Coordinating Centre
  - Repeat assessment of study endpoints: Cardio-Pulmonary Exercise Test, ECHO, BNP & QOL
  - AV delay Hemodynamic Optimization performed
  - CROSSOVER
    - AV Optimized His Pacing
    - No His Pacing
      (non-His VVI 30bpm back-up pacing and ICD functions as indicated)

14 months

- Post Implant Visit 3 at Coordinating Centre
  - Final Assessment of study endpoints: Cardio-Pulmonary Exercise Test, ECHO, BNP & QOL
  - STUDY END & UNBLINDING FOR INDIVIDUAL PATIENT

*Post study device programming as per consensus opinion between study team, referring clinician and patient*
His bundle pacing in RBBB

Permanent His Bundle Pacing for Cardiac Resynchronization Therapy in Patients with Heart Failure and Right Bundle Branch Block

First Author’s Surname: Sharma

Short Title: His Bundle Pacing for Cardiac Resynchronization in RBBB.

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Rush University Medical Center, Chicago, IL*; Chinese University of Hong Kong, Hong Kong#; Imperial College, London, UK§; Virginia Commonwealth University Health System, Richmond, VA^; Geisinger Heart Institute, Wilkes-Barre, PA§|
Figure 8  Baseline RBBB

1.0 V @ 1 ms

1.2 V @ 1 ms

Baseline RBBB

Intra-Hisian RBBB

Selective-HBP

Selective RB pacing

HBP lead

RV

His bundle

Right bundle

LAF

LPF

aVR

aVL

aVF

V1

V2

V3

V4

V5

V6
Figure 4

A. ECG Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Overall (N=37)</th>
<th>RV Paced group (N=8)</th>
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<tbody>
<tr>
<td>Baseline QRSd (ms)</td>
<td>160</td>
<td>198</td>
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<tr>
<td>HBP QRSd (ms)</td>
<td>127</td>
<td>141</td>
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B. LV Function

<table>
<thead>
<tr>
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<th>Overall</th>
<th>Baseline LVEF ≤ 35%</th>
<th>Baseline LVEF 35-50%</th>
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<tr>
<td>P</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.009</td>
</tr>
<tr>
<td>P</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.009</td>
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<tr>
<td>P</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.009</td>
</tr>
<tr>
<td>Overall</td>
<td>31</td>
<td>26</td>
<td>41</td>
</tr>
<tr>
<td>Baseline LVEF ≤ 35%</td>
<td>39</td>
<td>34</td>
<td>49</td>
</tr>
<tr>
<td>Baseline LVEF 35-50%</td>
<td>41</td>
<td>49</td>
<td>39</td>
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C. Response to HBP

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>RBBB Recruited with HBP</th>
<th>RBBB narrowed with fusion</th>
<th>Baseline QRSd 120-150ms</th>
<th>Baseline QRSd &gt;150ms</th>
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<tbody>
<tr>
<td>Clinical response (%)</td>
<td>76</td>
<td>73</td>
<td>79</td>
<td>79</td>
<td>71</td>
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<tr>
<td>Echocardiographic response (%)</td>
<td>69</td>
<td>79</td>
<td>86</td>
<td>69</td>
<td>70</td>
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<tr>
<td>Super responders (%)</td>
<td>19</td>
<td>14</td>
<td>14</td>
<td>31</td>
<td>0</td>
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</table>
CAN PACING THERAPY FOR HEART FAILURE BE MADE MORE EFFECTIVE IN LBBB?
What is mechanism of action of BVP?

His pacing in LBBB

Intrinsic Rhythm

His Pacing
Mechanism of QRS shortening

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

Onkar S. Narula, M.D.

Dissociation

Pacing CL = 680

Left Bundle Branch Block

Restored Native Conduction
Permanent His-bundle pacing for cardiac resynchronization therapy: Initial feasibility study in lieu of left ventricular lead

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**BACKGROUND** Permanent His-bundle pacing (HBP) has the potential to physiologically normalize wide QRS duration in patients with bundle branch block and cardiomyopathy.

**OBJECTIVE** The purpose of this study was to assess the feasibility of incorporating a His-bundle lead for cardiac resynchronization therapy (CRT) in lieu of a coronary sinus lead.

**METHODS** Patients with an indication for CRT (n = 21) underwent attempted implantation of an HBP placed into the left ventricular (LV) lead port. Intracardiac intervals, QRS duration, New York Heart Association functional class, ejection fraction (EF), echocardiography, and lead characteristics were measured at baseline and at follow-up.

**RESULTS** Of the 21 patients in whom implantation was attempted, HBP was successfully implanted in 16 (age 62 ± 18 years, 4 females, EF 25 ± 8). A significant reduction in mean QRS was observed, with narrowing from 180 ± 23 ms to 129 ± 13 ms (P < .0001). During the follow-up period, median New York Heart Association functional class improved from III to II (P < .001), and mean LV left ventricular internal dimension in diastole (LVIDd) was from 27% ± 10% to 41% ± 13% (P < .001) and from 5.4 ± to 4.5 ± 0.3 cm (P < .001), respectively. At median 11 follow-up, no dislodgments were observed, and only one lost nonselective capture that resolved with increased pacing.

**CONCLUSION** Permanent HBP is feasible for patients with indication for CRT using the LV port in lieu of a coronary sinus. In this initial experience, narrowing of QRS duration was in 76% of patients with bundle branch block, and improvement in clinical and echocardiographic measures were observed with HBP. Future prospective comparative studies with CRT are justifiable.

**KEYWORDS** Cardiac resynchronization; His bundle; Pacing; branch block; Heart failure

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Permanent His-bundle pacing as an alternative to biventricular pacing for cardiac resynchronization therapy: A multicenter experience

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From the ∗Division of Cardiology, Rush University Medical Center, Chicago, Illinois, †Krannert Institute Cardiology, Indiana University, Indianapolis, Indiana. ‡Division of Cardiology, University of South Florida College of Medicine, Tampa, Florida.§Division of Cardiology, Virginia Commonwealth University Health System, Richmond, Virginia, and ¶Division of Cardiology, Geisinger Heart Institute, Wilkes-Barre, Pennsylvania.

BACKGROUND Cardiac resynchronization therapy (CRT) using biventricular pacing (BVP) is effective in patients with heart failure, bundle branch block (BBB), or right ventricular pacing. Permanent His-bundle pacing (HBP) has been reported as an alternative option for CRT.

OBJECTIVE The purpose of this study was to assess the feasibility and outcomes of HBP in CRT eligible or failed patients.

METHODS HBP was attempted as a rescue strategy in patients with failed left ventricular lead or nonresponse to BVP (group I), or as a primary strategy in patients with AV block, BBB, or high ventricular pacing burden as an alternative to BVP (group II) in patients with indications for CRT. Implant characteristics, New York Heart Association functional class, and echocardiographic data were assessed in follow-up.

RESULTS HBP was successful in 95 of 106 patients (90%); 30 in group I and 65 in group II. Mean age was 71 ± 12 years and 30% were female, with BBB in 45%, paced rhythm in 39%, and AV block in 18%. His capture and BBB correction threshold and 2.0 ± 1.2 V at 1 ms, respectively. During 16 months, both groups demonstrated similar QRS duration (157 ± 33 ms to 117 ± 18 ms) and left ventricular ejection fraction from 30% (P = .0001), and improvement in New York Heart Association class from 2.8 ± 0.5 to 1.8 ± 0.6. Lead-related complications occurred in 7 patients.

CONCLUSION Permanent HBP is a promising option in CRT patients. HBP may be considered as a rescue strategy or a primary alternative to CRT.

KEYWORDS Biventricular pacing; Bundle resynchronization therapy; His-bundle pacemaker

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| Procedural Outcomes |  
|---------------------|---|
| Total number of successful cases (n, %) | 95 (90%)  
| Type of device (n, %) |  
| CRT-D | 58 (61%)  
| CRT-P | 14 (15%)  
| DC-ICD | 5 (5%)  
| DC-PPM | 18 (19%)  
| S-HBP (n, %) | 47 (50%)  
| S-HBP in BBB (n, %) | 19/44 (43%)  

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Baseline</th>
<th>Follow-up</th>
<th>P-value</th>
</tr>
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<tbody>
<tr>
<td>R-wave amplitude (mV) (mean ± SD)</td>
<td>4 ± 3.4</td>
<td>5.4 ± 4.9</td>
<td>0.03</td>
</tr>
<tr>
<td>Impedance (ohms) (mean ± SD)</td>
<td>483 ± 153</td>
<td>413 ± 109</td>
<td>0.0001</td>
</tr>
<tr>
<td>His capture threshold (V @ 1ms) (mean ± SD)</td>
<td>1.4 ± 0.9</td>
<td>1.72 ± 1.4</td>
<td>0.17</td>
</tr>
<tr>
<td>BBB recruitment threshold</td>
<td>2 ± 1.2</td>
<td>2.2 ± 1.7</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Complications:

<table>
<thead>
<tr>
<th>Complication</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumothorax</td>
<td>0</td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td>0</td>
</tr>
<tr>
<td>Increase in capture threshold (n, %)</td>
<td>7/95 (7.4%)</td>
</tr>
<tr>
<td>Loss of BBB recruitment (n, %)</td>
<td>3/44 (7%)</td>
</tr>
<tr>
<td>Device infection</td>
<td>1</td>
</tr>
</tbody>
</table>

BB: bundle branch block; CRT-D: cardiac resynchronization defibrillator; CRT-P: cardiac resynchronization pacemaker; ICD: defibrillator; PPM: pacemaker; LBBB: left bundle branch block; HBP: His Bundle Pacing; S-HBP: sele...
His pacing in LBBB

A: Intrinsic, Unpaced QRS (LBBB)
B: His Bundle Pacing LBBB Reversal
C: Biphasic Pacing
Comparison of left ventricular activation time

Reduction in LVAT−95 (ms)

BVP     HBP

Difference in LVAT−95 (ms)

HBP − BVP

Type
○ Non-Ischaemic
□ Previous MI

JACC in press
Comparison of acute haemodynamic response

Increase in SBP over AAI (mmHg)

BVP

HBP

Difference in SBP Response (mmHg)

HBP−BVP

Non-Ischaemic

Previous MI

JACC in press
Comparison of electrical and haemodynamic responses

JACC in press
Summary

- Shortening AV delay appears to be an important mechanism through which BVP delivers its beneficial effect.
- AV optimized His bundle pacing improves acute hemodynamic function in patients with a long PR interval and heart failure without LBBB.
- When applied to LBBB, His Resynchronization therapy can deliver more effective ventricular resynchronization and greater improvements in acute hemodynamic function compared with BVP.
How does BVP deliver it beneficial effect?

![Missed Potential of Conventional Biventricular Pacing](image1)

- **Missed Potential**: Conventional biventricular pacing.
- **Unwanted lengthening of activation**: Shows the missed potential.
- **Shortening obtained with conventional BVP**: Indicates the improvement.

**Graph**:

- **X-axis**: Total Activation Time (ms) with categories: Narrow QRS, QRS > 120ms not LBBB, LBBB.

**Bar Chart**:

- **AV opt LBBB**: Improvement in SBP relative to intrinsic conduction (MMHG).
- **BiV**: Bar chart showing the improvement compared to AV opt LBBB.