LEADLESS PACING TECHNOLOGIES
DISCLOSURES

• None
HISTORY

EVOLUTION OF PACEMAKER TECHNOLOGY

1958
Weight: 73.4g
Size: 35cc

1981
Weight: 55g
Size: 25cc

1995
Weight: 14g
Size: 6cc

2009
Weight: 23g
Size: 12.8cc

2013
Weight: 2g
Size: 1cc

1970

2013
Relatively high incidence of complications

- Acute up to 10-15%
- Chronic ~10%
- Most related to lead or pocket

Figure 1: Kaplan-Meier curve with survival free from any pacemaker complication during a mean follow-up of 5.8 years.

Incidence and predictors of short- and long-term complications in pacemaker therapy: The FOLLOWPACE study

(Heart Rhythm 2012;9:728–735)
• Complications:
  • Pocket Hematoma
  • Infection
  • Pneumothorax
  • Perforation
  • Cardiac tamponade
  • Dislodgement
  • Lead failure
PATIENT CASE

• 78 year old woman with DM and COPD
• H/o breast CA with bilateral mastectomy with mild lymphedema
• Chronic AF with slow VR and syncope
• Needs chronic ventricular pacing
• Single chamber PPM..
• TV-PPM vs LL-PPM?
LEADLESS PPM

**ADVANTAGES**
- Lower risk for infection
- No need for UE vascular access
- No pocket
- No lead

**DISADVANTAGES**
- VVI pacing only (at this point)
- Challenging retrievability
- Additional device when EOL
- Large sheath for placement
PATIENT SELECTION

Poor UE venous access
H/o or high risk for infection
Hemodialysis
High risk for complications
Prior lead fractures
Severe comorbidities
Pulmonary disease
(pneumothorax)
Difficult anatomy
Congenital heart disease
MICRA (MEDTRONIC)

- Volume 0.8 cc (l=26mm)
- 23 Fr inner introducer, 27 Fr outer sheath
- RF communication
- **Passive** fixation tines (nitinol)
- Extraction with conventional material (several successful cases)
- Battery: 10-12 years
- MRI compatible
MICRA DELIVERY SYSTEM

Micra delivery system

23 F

27 F

Introducer and dilator

Guide wire

Needle

http://www.cardiostim.com/?IdNode=958&Zoom=0b3432ba3d00a5e85ce68df41f643ccf&Lang=GB
- Prospective, multicenter, historical comparison study
- Successfully implanted in 719/715 (99.2%)
- **Primary safety endpoint**: Freedom of system- or procedure related major complications: 96% (p<0.001).
- **Primary efficacy endpoint**: Low stable pacing thresholds at 6 months: 98% (p<0.001).
- 28 major complications; no dislodgements (p=0.001).

**Absence of major complications**

**Graphs and tables**

- Threshold
- Amplitude
- Impedance
Micra Delivery Catheter
Micra Pacing Capsule
Radiopaque Marker Band
Radiopaque Marker Band
Micra Introducer
27 Fr
Micra™ Transcatheter

PACING SYSTEM

Not currently available for clinical use
CXR post Micra
REDUCTION IN TVP COMPLICATIONS

Randomized data needed

8.0%

4.0%

TVP

MICRA

HR: 0.52 (95% CI: 0.35–0.77)
P-value: 0.001

Number at Risk

Reference 2667 2260 1965 1698 1537 1319 1212
Micra 726 684 671 658 643 432 251

Reynolds-nejm-A Leadless Intracardiac Transcatheter pacing system
Reddy- HRS 2016 – Late breaking clinical trials session
WHAT TO DO AFTER END OF LIFE

- Retrieval is safe (up to 3 years)
- New tools need to be developed

Micra: Postmortum at 12 months

NANOSTIM
# Retrievability Overview:

Success approx. 90%

(Longest in situ: 3 years) No complications

## Table 1: Overview of Retrieval Data of Leadless Pacemaker Therapy

<table>
<thead>
<tr>
<th>Study Type</th>
<th>Leadless Pacemaker</th>
<th>Year of Publication</th>
<th>First Author</th>
<th>Number</th>
<th>Time LP in situ (mean)</th>
<th>Extraction Success Rate</th>
<th>Reason Unsuccessful Extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-clinical</td>
<td>Nanostim</td>
<td>2014</td>
<td>Koruth</td>
<td>10</td>
<td>160 days</td>
<td>100%</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td>2.3 years</td>
<td>100%</td>
<td>N/A</td>
</tr>
<tr>
<td>Clinical</td>
<td>Micra TPS</td>
<td>2014</td>
<td>Bonner</td>
<td>4</td>
<td>28 months</td>
<td>75% (3)</td>
<td>Complete encapsulation of device</td>
</tr>
<tr>
<td></td>
<td>Nanostim</td>
<td>2016</td>
<td>Jung</td>
<td>1</td>
<td>506 days</td>
<td>100%</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Nanostim</td>
<td>2016</td>
<td>Reddy</td>
<td>5</td>
<td>&lt;6 weeks</td>
<td>100%</td>
<td>The docking feature could not be reached.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11</td>
<td>&gt;6 weeks</td>
<td>91% (10)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nanostim</td>
<td>2017</td>
<td>Lakkireddy</td>
<td>73</td>
<td>1.7 years</td>
<td>90.4% (66)</td>
<td>The docking button could not be reached. In one case, the docking button detached.</td>
</tr>
<tr>
<td></td>
<td>Micra TPS</td>
<td>2017</td>
<td>Tjong and Reddy</td>
<td>10</td>
<td>229 and 259 days*</td>
<td>80% (8)</td>
<td>Unable to be removed due to fluoroscopy malfunction</td>
</tr>
<tr>
<td></td>
<td>Micra TPS</td>
<td>2016</td>
<td>Karmi</td>
<td>1</td>
<td>3 weeks</td>
<td>100%</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Micra TPS</td>
<td>2016</td>
<td>Giocondo</td>
<td>1</td>
<td>228 days</td>
<td>0%</td>
<td>Unknown</td>
</tr>
<tr>
<td></td>
<td>Micra TPS</td>
<td>2016</td>
<td>Koay</td>
<td>1</td>
<td>1 month</td>
<td>100%</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Micra TPS</td>
<td>2016</td>
<td>Gerdes</td>
<td>1</td>
<td>Intraprocedural</td>
<td>100%</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*LP = leadless pacemaker; N/A = not applicable; TPS = transcatheter pacing system.

*In unsuccessful attempt cases used source: Micra Transcatheter Pacing System, 2016.**

**Heart Rhythm Society, 2016.**

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FUTURE CONCEPTS

• AV synchronous pacing (Medtronic)
• ATP in SICD (Boston Scientific)
• DDD (Nanostim)
• CRT ?
1) AV SYNCHRONY

MARVEL Study

- Micra Atrial TRacking Using A Ventricular AccELerometer
- Feasibility study presented at Heart Rhythm 5/2018
- 64 patients at 12 centers in 9 countries.
- *Built in accelerometer* to monitor and detect *atrial contractions*, even though the device is implanted in the ventricle.
- AV synchrony was measured using continuous device telemetry and an electrocardiogram via a Holter monitor.
MARVEL ALGORITHM:

- **4 distinct segments** of cardiac activity were seen in the accelerometer signal:
  1. Isovolumetric contraction and MV/TV closure (A1)
  2. Aortic/pulmonic valve closure (A2)
  3. Passive ventricular filling (A3)
  4. Atrial contraction (A4)

- A3 and A4 were associated with MV flow E- and A-wave measurements.

- Based on these signals, an AV synchronous algorithm was developed to provide a **VDD pacing mode**.

- Blanking windows were manually set to reject detection of signals of ventricular origin (A1, A2).
• If atrial contraction was detected (A₄), an atrial marker (AS) was output via telemetry, and a programmable AV interval was initiated.

• The algorithm incorporated a rate smoothing feature designed to maintain AVS during intermittent A₄ undersensing.

• If an atrial contraction (A₄) was not detected, a ventricular pace was delivered at a programmable rate smoothed interval.
MARVEL RESULTS:

- **AV beats in synchrony:**
  - **87%** among all patients
  - **80%** in high-degree AV block patients
  - **94.5%** in patients with predominantly intact AV conduction
2) ATP AND BRADY PACING WITH SICD
**BSCI LEADLESS PPM**

**Key Properties**

<table>
<thead>
<tr>
<th>Details</th>
</tr>
</thead>
</table>
| **Size** | <1 cc  
          31.9 mm length x 6.0 mm diameter |
| **Active Fixation** | 4 Nitinol Talons (tines) |
| **Electrode** | • Iridium Oxide coated  
                 • Steroid eluting |
| **Pacemaker Functionality** | • Modes: VVIR, VVI, VOO, Off  
                              • Rate response (accelerometer based)  
                              • Conductive communication  
                              • Battery Longevity Est. 10 yrs @ 100% pacing |
| **ATP** | Provide ATP when commanded by paired S-ICD |

*Not for official use yet.*  
EMPOWER Trial 2019

Retrieval catheter available, MRI compatible
4th Generation S-ICD System

2nd generation

Upgradable

3rd generation

*Caution: Investigational devices. Limited by Federal law to investigational use only. Not available for sale.
VALUE OF A MODULAR CRM SYSTEM

TV-ICD

Documented need for Pacing or ATP

mCRM™ System

Potential need for Pacing or ATP

S-ICD

No need for Pacing or ATP

EMBLEM™ S-ICD
EMPOWER™ Modular Pacing System™
1. Leadless pacemaker designed to sense and treat bradycardia \textit{independently} from the S-ICD

2. ATP schemes will be built into the leadless pacemaker, but can be \textit{activated only by the S-ICD or the programmer}

3. S-ICD will continue to sense tachycardia, following which it is designed to \textit{command ATP} in the leadless pacemaker prior to a shock
FIRST IN VIVO ATP FROM A LEADLESS PACEMAKER (SHEEP)

An episode of simulated VT (LV Pacing) followed by manually triggered S-ICD ATP command resulting in successful ATP-delivery by the LLP (10 beats, at 81% of coupling interval)

Human trials: MODULAR trial 2019

1. Tjong et al, AMC Heart Center, JACC Letters, http://dx.doi.org/10.1016/j.jacc.2016.02.039
CONCLUSION

• Leadless devices have fewer long-term complications
• Durable performance
• Do not fulfill all pacing requirements at this point but VDD and ATP available soon..
• For now: Niche but may become standard of care some day....