Pacing Lead Implant Testing
Objectives

Upon completion of this presentation, the participant should be able to:

Name the two primary surgical options for implanting pacing leads

Describe three significant PSA measurements that should be taken during lead implantation

Explain how lead measurements are used to determine device parameters in conjunction with specific patient needs
Implant Equipment and Room Set-Up

The EP lab/surgical suite equipment consists of:
Fluoroscopic imaging
Patient hemodynamic monitors (EKG, blood pressure, pulse oximeter)
External defibrillator- external pacemaker
Sterile table and instruments
Draping
Sterile Table

- Pacemaker tray
- Surgical instruments
- Drapes
- Cautery equipment
- Sterile basins
Pre-implant Preparation

ECG and blood pressure monitoring equipment is attached to the patient

Gentle restraints may be applied

Skin is shaved and prepped

Surgical area is cordoned off with sterile towels

Patient’s entire body is draped
Administration of Local Anesthetic

The skin is numbed with Xylocaine.
A sedative is usually given prior to the procedure to help relieve anxiety.
Permanent Pacemaker Insertion

**Introducer Kit**

- Peel-Away Introducer
- Needle w/ 12cc Syringe
- Guide Wire
- Introducer sheath
- Guide wire
- Needle with syringe
Venous Access Sites

- Internal Jugular
- External Jugular
- Subclavian Cephalic (Subclavian Bifurcation)
Venous Access: Surgical Methods

Subclavian or Cephalic Cutdown

- The cephalic vein travels from the arm, through the deltopectoral groove, and joins the subclavian vein.
Venous Access: “Subclavian Stick”

Percutaneous Subclavian Approach
Implant Measurements

Sensing Threshold
Pacing Impedance
Stimulation Threshold

Slew Rate
Retrograde Conduction Time
Diaphragmatic / Phrenic Nerve Stimulation

Note: Implant measurements via the PSA are documented in the Guidant implant form(s) and patient file. Confirm with your region.
## Target Values with Pacing System Analyzer (PSA)

<table>
<thead>
<tr>
<th>Sensing Threshold</th>
<th>Acute</th>
<th>Chronic</th>
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</thead>
<tbody>
<tr>
<td>Atrial</td>
<td>&gt; 1 mV</td>
<td>&gt; 1 mV</td>
</tr>
<tr>
<td>Ventricular</td>
<td>&gt; 10 mV</td>
<td>&gt; 10 mV</td>
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### Impedance

- 300 – 1500 ohms*

* Different tip electrode and/or lead design characteristics may result in lead impedances normally falling outside this range and/or being consistently at one end of the range, i.e., high-impedance leads

- DSP/ENDURANCE EZ = 300 – 1000 ohms
- ENDURANCE RX/RELIANCE = 500 – 1500 ohms
- Shocking Electrode (Dual coil) = 20 – 80 ohms

### Stimulation Threshold

#### Voltage (at 0.5 ms)

<table>
<thead>
<tr>
<th></th>
<th>Atrial</th>
<th>Ventricular</th>
<th>ENDOTAK</th>
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<tbody>
<tr>
<td>Atrial</td>
<td>&lt; 1.0 V</td>
<td>&lt; 1.0 V</td>
<td>&lt; 1.0 V</td>
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<tr>
<td>Ventricular</td>
<td>&lt; 1.0 V</td>
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<tr>
<td><strong>ENDOTAK</strong></td>
<td>&lt; 1.0 V</td>
<td>&lt; 1.0 V</td>
<td>&lt; 1.5 V</td>
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#### Current (at 0.5 ms)

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<th>Ventricular</th>
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<tbody>
<tr>
<td>Atrial</td>
<td>&lt; 1.5 mA</td>
<td>&lt; 1.5 mA</td>
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<tr>
<td>Ventricular</td>
<td>&lt; 1.5 mA</td>
<td>&lt; 6 mA</td>
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### Slew Rate

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<tr>
<td>Atrial</td>
<td>≥ 0.3 V/sec (mV/ms)</td>
<td>≥ 0.3 V/sec</td>
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<tr>
<td>Ventricular</td>
<td>≥ 1.0 V/sec</td>
<td>≥ 0.5 V/sec</td>
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### Retrograde Conduction Time (RCT) “VDD/DDD”

100 – 400 ms (stable value if present)
Implant Measurements

*Sensing Threshold (P & R-Wave Amplitudes)*

The minimum intrinsic electrical signal (P-wave and/or R-wave), expressed in millivolts (mV), required for consistent sensing by a pacemaker’s sensing amplifier(s)

“Intrinsic measurement” No pacing during test

Reference: Guidant PGs measure “baseline-to-peak” and the Biotronik PSA measures “peak-to-peak”
**Implant Measurements**

**Sensing Threshold**

**Purpose:**
- To assure that intrinsic signal is of adequate amplitude to be detected by the pulse generator and inhibit pacing
- To assure proper lead placement
- To assure pacing system integrity
  - Lead integrity
  - Lead-to-tissue interface

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Implant Measurements

**Sensing Threshold (P & R Wave Amplitudes)**

Proper sensing depends on:

- Signal amplitude (mV)
- Frequency (Hz)
- Slew rate (V/sec)

The PG Bandpass Filter attenuates signals which are not typical of P and R-wave frequency, so they will not be sensed. Conversely, it amplifies signals which are of an appropriate frequency, to increase the likelihood of sensing.
Implant Measurements

Sensing Threshold (P & R Wave Amplitudes)

Figure A: an electrogram taken at time of implantation with a marked ST elevation due to localized myocardial damage

Figure B: an electrogram taken approximately 3 months after implantation with no S-T elevation and a somewhat lower amplitude
Implant Measurements

Programming Guidelines for Sensitivity

Acute

- Typically at nominal sensitivity setting or lower
- Minimum: At least twice as sensitive as the measured intrinsic signal amplitude
- Setting at ½ or less than the mV measurement of the signal (i.e., 5 mV R-wave requires setting of 2.5 mV or less, 2 mV P-wave requires setting of 1 mV or less)

Chronic (6 weeks to 3 months post implant)

- At least twice as sensitive as the measured intrinsic signal amplitude
Implant Measurements

**Impedance**

Total opposition to flow of electrical current through the lead conductor(s), electrodes, electrode/myocardial tissue interface and body fluids/tissues

Requires delivery of pacing pulse

Measured in ohms (Ω)

May also be known as “Resistance”
Implant Measurements

**Impedance**

- **Purpose:**
  - To verify lead integrity
    - Insulation compromised = lowered impedance
    - Conductor compromised = higher impedance
  - To verify stable lead-to-tissue interface
    - Stable interface = stable impedance
    - Unstable interface = fluctuating impedance

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Implant Measurements

*Stimulation Threshold*

The minimum amount of electrical stimulation that consistently produces cardiac depolarization (captures)

Also called Pacing Threshold or Capture Threshold

Typically measured as voltage (V) at a given pulse width (usually 0.5 ms)

- May also be measured as current (10^{-3} or mA)

Threshold value is the minimum voltage that regains consistent capture after losing capture when decrementing the voltage
Implant Measurements

**Stimulation Threshold**

**Purpose:**
- To assure adequate safety margin between the stimulation threshold and the programmed output of the pulse generator
- To assure proper lead placement
- To assure pacing system integrity
  - Lead integrity
  - Lead-to-tissue interface

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Implant Measurements

Stimulation Threshold: Acute to Chronic Transition

• Presence of electrode next to endocardial surface causes an inflammatory reaction which heals within the first few months, leaving behind a small fibrotic capsule around the electrode

Figure A: Acute threshold at implant
Figure B: Peak threshold approx. 1-4 weeks post implant
Figure C: Stable chronic threshold approx. 6-12 weeks post implant
Implant Measurements

**Stimulation Threshold**

Affected by:

- Lead maturation
- Lead technology
- Lead placement
- Medications
- Electrolyte imbalance

![Diagram of Stimulation Threshold](image)

- **Peak**
- **Acute Phase**: 1-6 weeks
- **Chronic Phase**: 6-12 weeks
- **Voltage Threshold**
- **Steroid**
- **Non-Steroid**
Implant Measurements

Programming Guidelines for Pacing Outputs

Acute
- Typically at nominal amplitude (voltage) and pulse width settings or higher
- Minimum amplitude: 2x stimulation threshold

Chronic
- 2x stimulation threshold or 3x pulse width threshold
- Ventricular channel may be programmed higher in pacemaker dependent patients
**Implant Measurements**

**Slew Rate**

The maximal change in amplitude (voltage) in the electrogram over time

Intrinsic measurement

“Slope of the signal”

Measured in volts per second (V/sec) or millivolts per milliseconds (mV/ms)
**Implant Measurements**

**Slew Rate**

**Purpose:**
- To help ensure appropriate sensing
- Generally the higher the slew rate, the higher the frequency content of the signal and the more likely it is to be sensed

May be used as an adjunct measurement if signal amplitude is borderline acceptable or unacceptable

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Implant Measurements

**Slew Rate**

Slew rate, or the length of time for an R-wave to reach peak amplitude, has an effect on sensing because of its frequency and amplitude characteristics. When the slew rate is low ($V < .5 \text{ V/sec.}$, $A < .3\text{V/sec.}$), the frequency is also low, and therefore a larger amplitude is needed before an R-wave can be sensed. Signals with low slew rates can potentially result in undersensing.

Leads designed to minimize fibrotic capsule thickness can overcome sensing difficulties resulting from low slew rates.
Implant Measurements

**Retrograde Conduction Time**

Period of time it takes an electrical impulse originating in the ventricles to travel through the conduction system to the atria where it causes atrial depolarization (retrograde P-wave)

Ventriculoatrial (VA) conduction may result if AV synchrony is dissociated by any event, i.e., PVC
Retrograde conduction may result in Pacemaker-Mediated Tachycardia (PMT) or “Endless-loop Tachycardia” in an atrial-tracking pacing mode...if retrograde P-wave is sensed by the atrial sensing circuit, it begins an AV delay.

PMT is ventricular pacing at the Maximum Tracking Rate (MTR).

Testing may be deferred until post-implant follow-up using EGMs and/or event markers from device and programmer.
Implant Measurements

**Retrograde Conduction Time (VA conduction)**

**Purpose:**
- To prevent retrograde-induced pacemaker mediated tachycardia by optimally programming Post-Ventricular Atrial Refractory Period (PVARP)

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Implant Measurements

**Programming Recommendations**

Program PVARP at least 25 ms longer than measured retrograde conduction time. Retrograde conduction times may vary with rate (100 – 400 ms).

Program on other special features designed to prevent/terminate PMT, i.e. PVARP After PVC, PMT Termination feature, etc.

Program other parameters to help ensure AV synchrony maintained, i.e. appropriate AV Delay

67% of patients with sinus node dysfunction and 14% of patients with fixed complete heart block have retrograde conduction
Implant Measurements

Diaphragmatic/Phrenic Nerve Stimulation

Test by providing temporary high output (10 V) pacing through each implanted lead to assess for phrenic nerve stimulation with atrial lead and diaphragmatic stimulation with ventricular lead.

May observe (“hiccoughing”) or pectoral muscle stimulation (“pocket twitching”) from pacer output

If nerve/muscle stimulation observed:
- Determine minimum output it occurs
- May need to reposition lead(s)
### Implant Measurements

**Diaphragmatic/Phrenic Nerve Stimulation**

#### Purpose:
- To prevent nerve or muscle stimulation from pacer output

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Device Implanted

Evaluation of pacing lead measurements are repeated and final device programming is done prior to patient leaving the O.R.

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ZOOM Design Philosophy
• Make it easy
• Save the clinician time
• Deliver a quality ECG
# Implant Measurements

## Sample Implant Data Form

### Purpose:
- To document measurements taken during the procedure

<table>
<thead>
<tr>
<th>Patient Name:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacemaker Model:</td>
<td>S/N:</td>
</tr>
<tr>
<td>Ventricular Lead:</td>
<td>S/N:</td>
</tr>
<tr>
<td>Atrial Lead:</td>
<td>S/N:</td>
</tr>
</tbody>
</table>

**Atrial Lead**
- Lead Impedance: 
- Threshold: 
- P-Waves: 
- Check @ 10V: 
- Slew Rate: 
- Retrograde Conduction Test: 

**Ventricular Lead**
- Lead Impedance: 
- Threshold: 
- R-Waves: 
- Check @ 10 V: 

### Programmed Parameters:
- Mode: 
- Lower Rate Limit: 
- MTR/MSR 
- AV Delay 
- Other parameters: 
- GUIDANT Representative: 

<table>
<thead>
<tr>
<th>Mode</th>
<th>A</th>
<th>V</th>
</tr>
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<tbody>
<tr>
<td>Lower Rate Limit</td>
<td>Amplitude</td>
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</tr>
<tr>
<td>MTR/MSR</td>
<td>Pulse Width</td>
<td></td>
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<tr>
<td>AV Delay</td>
<td>Sensitivity</td>
<td></td>
</tr>
</tbody>
</table>

GUIDANT Representative: ____________________
Final Steps

Complete Guidant implant forms and return to Guidant Medical Records
Ensure lead measurements and final device programming information is documented in patient chart according to hospital-specific protocol
Summary

Name the two primary surgical options for implanting pacing leads: Subclavian Stick and Cephalic Cutdown

Describe the three significant PSA measurements that should be taken during lead implantation: Sensing Threshold, Impedance, Stimulation Threshold; (Others: Slew Rate, Retrograde Conduction, and Diaphragmatic/Phrenic Nerve Stimulation)

Explain how lead measurements are used to determine device parameters in conjunction with patient needs: Amplitude, Sensitivity, PVARP, etc.
Target Values with Pacing System Analyzer (PSA)

References

• AICD System Guide (PRIZM) Guidant 2000
• Physician’s Manual (ENDURANCE) Guidant 1998
• Physician’s Manual (RELIANCE) Guidant 2000