Implanted Cardiac Devices: Pacemaker and Defibrillator Facts

Michael Hartman, CRNA, DNP, MSN, BSN, BA
Cardiac Electrophysiology
Cardiac Myocyte Action Potential

- **K^+**, Cl^− (out)
- **I_{to1,2}** (transient outward)
- **Ca^{2+}** (in), **K^+** (out)
- **I_{Ca-L}** (Ca long)
- **I_{KS}** (K slow delayed rect.)
- **K^+** (out)
- **I_{KS}** (K slow delayed rect.)
- **I_{Kf}** (K rapid delayed rect.)
- **I_{K1}** (inward rect.)

- **Na^+** (in)
- **I_{Na}** (rapid)

-52 mV

-96 mV

200 ms
Intrinsic Conduction
Automaticity-cardiac cells ability to spontaneously depolarize and initiate impulse
Depolarization-cardiac cells go to a+ intracellular and – extracellular charges from influx of Na and Ca
Repolarization –return to resting
Permanent Pacemaker

SIEMENS-ELEMA
1958
Methods of Pacing

Transcutaneous
External Pacing (R2 Pads with Defibrillators)

Epicardial
Temporary lead placement in the epicardium and utilized with open heart surgery

Transvenous
Temporary lead placed within a vein (femoral, subclavian, or internal jugular veins)

Permanent
Surgical placement with fluoroscopy of the lead(s) within a vein and connected to a generator with implantation under the skin
Pacemaker

- **Diagnostic Testing**

*Sensing*: assesses ability of device to identify intrinsic cardiac activity within the atria and/or ventricles

*Impedance*: assesses integrity of lead

*Threshold*: determines the minimal amount of energy required to potentiate depolarization of the atria or ventricle
Permanent Pacemakers

Existence as of 2007:

PPM - 3 Million

ICD’s - 300,000
Implantable Cardioverter Defibrillator (ICD)

Founded in 1980
Implantable Cardioverter Defibrillator (ICD)
Pacemaker Leads
Pacemaker Lead Types

- **Uni-polar**
  - Primarily utilized with pacers
  - Creates large pacer spike on EKG
  - Very sensitive to EMI

- **Bi-polar**
  - Common with pacers
  - Less operating watts
  - More resistant to EMI
ICD Lead

- Conductor to anode crimp joint is a reliable connection
- Tip seal designed to facilitate reinsertion
- Solid tip housing protects internal mechanisms from damage
- Tensi-Lock™ cable design secures the tip assembly and provides greater lead strength
ICD Lead Types

- Bipolar
- Single-coil
- Dual-coil
  * Active and Passive Fixation
  * Multiple lengths and diameter
  * Flexible “Floppy”
Pacemaker Indications

**Rhythm**
- Bradycardia
  - (Symptomatic)
- Brady/Tachy Syndrome
- Tachycardia

**Conduction**
- Complete AV Block
- Second Degree AV Block
- Intraventricular Conduction Defects
Pacemaker Indications

Anatomical
Hypertrophic Cardiomyopathy
Dilated Cardiomyopathy
**Leads to heart failure and require Bi-ventricular pacing or cardiac resynchronization therapy (CRT)s
Pacemaker

- **Types:**
  - *Single Chamber-* one lead implanted within the appropriate chamber atrial or ventricular
  - *Dual Chamber-* two leads implanted with one in the right atrium and one in the right ventricle
  - *Bi-ventricular-* right atrial and ventricular leads with a lead passed through the coronary sinus to pace the left ventricle (Goal is to resynchronize the heart chambers thus optimizing cardiac output)
### Pacemaker (PPM)

- North American Society of Pacing and Electrophysiology (NASPE) and British Pacing and Electrophysiology Group (BPEG)

#### Programming Codes:

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamber(s) Paced</td>
<td>Chamber(s) Sensed</td>
<td>Response to Sensing</td>
<td>Rate Modulation</td>
<td>Multisite Pacing</td>
<td></td>
</tr>
<tr>
<td>O=</td>
<td>None</td>
<td>O=</td>
<td>None</td>
<td>O=</td>
<td>None</td>
</tr>
<tr>
<td>A=Atrium</td>
<td>A=Atrium</td>
<td>T=Triggered</td>
<td>R=Rate Modulation</td>
<td>A=Atrium</td>
<td></td>
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<tr>
<td>V=Ventricle</td>
<td>V=Ventricle</td>
<td>I=Inhibited</td>
<td></td>
<td>V=Ventricle</td>
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<tr>
<td>D=Dual (A+V)</td>
<td>D=Dual (A+V)</td>
<td>D=Dual (T+I)</td>
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<td>D=Dual (A+V)</td>
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Implantable Cardioverter Defibrillator (ICD)

- North American Society of Pacing and Electrophysiology (NASPE) and British Pacing and Electrophysiology Group (BPEG)
- **Programming Codes:**

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<tr>
<td>Shock Chamber</td>
<td>Antitachycardia Pacing Chamber</td>
<td>Tachycardia</td>
<td>Antibradycardia Pacing Chamber</td>
</tr>
<tr>
<td>O = None</td>
<td>O = None</td>
<td>E = Electrogram</td>
<td>O = None</td>
</tr>
<tr>
<td>A = Atrium</td>
<td>A = Atrium</td>
<td>H = Hemodynamic</td>
<td>A = Atrium</td>
</tr>
<tr>
<td>V = Ventricle</td>
<td>V = Ventricle</td>
<td></td>
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American College of Cardiology (ACC) and American Heart Association (AHA)

Classifications (I-III) for ICD Therapy
Implantable Cardioverter Defibrillator (ICD) Indications:

Class I:

1. Cardiac arrest due to ventricular fibrillation (VF) or ventricular tachycardia (VT) not due to a transient or reversible cause.

2. Spontaneous sustained VT in association with structural heart disease.

3. Syncope of undetermined origin with clinically relevant, hemodynamically significant sustained VT or VF induced at electrophysiologic study when drug therapy is ineffective, not tolerated, or not preferred.

4. Nonsustained VT in patients with coronary artery disease, prior myocardial infarction (MI), left ventricular (LV) dysfunction, and inducible VF or sustained VT at electrophysiologic study that is not suppressible by a Class I antiarrhythmic agent.

5. Spontaneous sustained VT in patients who do not have structural heart disease that is not amenable to other treatments.
Implantable Cardioverter Defibrillator (ICD) Indications:

Class IIa

- Patients with LV ejection fraction of 30% or less, at least 1 month post-MI and 3 months post coronary artery revascularization surgery.
**Implantable Cardioverter Defibrillator (ICD) Indications:**

**Class IIb:**

- 1. Cardiac arrest presumed to be due to VF when electrophysiologic testing is precluded by other medical conditions.
- 2. Severe symptoms (eg, syncope) attributable to sustained ventricular tachyarrhythmias in patients awaiting cardiac transplantation.
- 3. Familial or inherited conditions with a high risk for life threatening ventricular tachyarrhythmias, such as long QT syndrome or hypertrophic cardiomyopathy.
- 4. Nonsustained VT with coronary artery disease, prior MI, LV dysfunction, and inducible sustained VT or VF at electrophysiologic Study.
- 5. Recurrent syncope of undetermined etiology in the presence of ventricular dysfunction and inducible ventricular arrhythmias at electrophysiologic study when other causes of syncope have been excluded.
- 6. Syncope of unexplained etiology or family history of unexplained sudden cardiac death in association with typical or atypical right bundle-branch block and ST-segment elevations (Brugada syndrome).
- 7. Syncope in patients with advanced structural heart disease in which thorough invasive and noninvasive investigation has failed to define a cause.
Implantable Cardioverter Defibrillator (ICD) Indications:

Class III:

1. Syncope of undetermined cause in a patient without inducible ventricular tachyarrhythmias and without structural heart disease.
2. Incessant VT or VF.
3. VT or VF resulting from arrhythmias amenable to surgical or catheter ablation; for example, atrial arrhythmias associated with the Wolff-Parkinson-White syndrome, right ventricular outflow tract VT, idiopathic LV tachycardia, or fascicular VT.
4. Ventricular tachyarrhythmias due to a transient or reversible disorder (eg, acute MI, electrolyte imbalance, drugs, or trauma) when correction of the disorder is considered feasible and likely to substantially reduce the risk of recurrent arrhythmia.
5. Significant psychiatric illnesses that may be aggravated by device implantation or may preclude systematic follow-up.
6. Terminal illnesses with projected life expectancy of 6 months or less.
7. Patients with coronary artery disease, LV dysfunction, and prolonged QRS duration in the absence of spontaneous or inducible sustained or nonsustained VT who are undergoing coronary bypass surgery.
8. NYHA Class 4 drug-refractory congestive heart failure in patients who are not candidates for cardiac transplantation.
Explanations:

1. Literature - published conflicting information
2. Literature – current advances and care practices
   (New Anesthesia Machines - Battery and MH preparation)

Information Confusion

“It’s a pacemaker for your heart. Plus, you can download apps for your liver, kidneys, lungs, and pancreas!”
Anesthesia Practice
Preoperative

- Anesthesia Evaluation for PPM and ICD:
  - Chest x-ray
  - Serum K+, H&H, and coagulation
  - Device Card
  - Device Type
  - Device Last Interrogation
  - Determine use of EMI (Cautery)

**Prevention:**
- Delays
- Cancellation
- Sentinel Complications
Best practices are to have the device evaluated or contact company representative for specific care instructions.

Questions:

PPM - Is the patient dependent?
ICD- Is it magnet resistant?
Preoperative

Medtronic and Biotronik with magnet on and off will disable shock therapy with ICD – indicating no need to contact representative unless the surgery is within 6-inches of the device.

Exceptions:
If PPM/ICD is within the sterile field (i.e. Rotator cuff repair or carotid endarectomy) than device representative needs to program the device into asynchronous mode/no shock therapy

If patient positioning (i.e. prone) not optimal to maintain magnet than device representative should program device to asynchronous mode/ no shock therapy
# Preoperative ICD Guide

<table>
<thead>
<tr>
<th>Pacer Dependent</th>
<th>Cautery with 6”</th>
<th>Prone Positioning</th>
<th>Device in Sterile Field</th>
<th>MRI</th>
<th>Lithotripsy (ESWL)</th>
<th>Boston Scientific / Guidant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reprogramming pre and post-operatively</td>
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<td>Reprogramming pre and post-operatively</td>
<td>Contraindicated</td>
<td>Reprogramming pre, intra, and post-operatively</td>
<td>Call representative to determine magnet response</td>
</tr>
</tbody>
</table>
Implantable Device Companies:

- Medtronic
- Guidant/Boston Scientific
- Biotronik
- St. Jude / Pacesetter
Intraoperative

- Heart Rate and rhythm monitoring
- Place magnet on pacer if EMI is interfering or if patient is pacer dependent
- Remove magnet from ICD to activate detection and therapy settings for a patient displaying an aberrant arrhythmia
- External defibrillation equipment readily available (i.e. defibrillator, zoll pacer, transvenous pacing catheter, transesophageal pacing)
- Minimize use of SA and AV node sensitive medications such as Precedex and opiates with known underlying rhythm of SSS or asystole
Postoperative

- **Pacer and ICD:**
  - Monitor heart rate and rhythm
  - Contact device representative
  - Follow care guidelines of the facility
  - Available external pacing and defibrillator devices
Magnet-Activated Switch

- Pacemakers

Designed to evaluate generator life
Pacing threshold safety factors
## Magnet-Activated Switch

### Medtronic (PPM)
- Paced at a heart rate of 85 indicates generator OK
- Paced at a heart rate below 65 indicates that generator requires replacement

### St. Jude Medical (PPM)
- Paced at a heart rate of 98 indicates generator OK
- Paced at a heart rate below 87 indicates that generator requires replacement
**Magnet Response**

- ICD
- *Medtronic:*

**Anesthesia Provider’s Awareness:**
Magnet remains secured over device
Nonprogrammable for magnet resistance
Audible confirmation only if patient alert or care alert is activated (30 seconds of constant tone) **NOTE:** if sustained constant or pulsing tone audible- stop and contact device representative

*Disables tachyarrhythmia detection and therapy from EMI*

Remove magnet to reactivate detection and therapy settings for tachyarrhythmia

Have device evaluate postoperatively by representative
Magnet Response

- ICD
- *Guidant and Boston Scientific:*

**Anesthesia Provider’s Awareness:**
Magnet remains secured over device
Programmable for magnet resistance
Audible confirmation – synchronous tones with heart beat to continuous after 30 seconds

**NOTE:** Tones present prior to magnet placement or no tones auscultated with magnet placement requires device interrogation from company representative
Disables Tachyarrhythmia detection and therapy from EMI
Remove magnet greater than 2’ to reactivate detection and therapy settings for tachyarrhythmia
Have device evaluate postoperatively by representative since electrical reset can occur
Magnet Response

- ICD
- *St. Jude Medical:*

**Anesthesia Provider’s Awareness:**
Magnet remains secured over device

**Note:** Magnet positioning must be secured over the top or bottom edge of the device in order to achieve magnet reversion

Programmable for magnet resistance

No Audible

Disables Tachyarrhythmia detection and therapy from EMI

Remove magnet to reactivate detection and therapy settings for tachyarrhythmia

Have device evaluate postoperatively by representative
Magnet Placement

*Magnet placement is important since poorly positioned may not produce the desired effect.*

Magnets placed directly on top of the Medtronic, Boston Scientific, and Biotronik ICD’s.

*Exception: St. Jude ICD’s, magnet is placed off-centre with the curve of the magnet over the bottom or top end of the ICD*
Awareness:
1. Difficult to differentiate a PPM from an ICD on an EKG
2. Underlying rhythm
3. Magnet on ICD does not convert pacer function to asynchronous mode (VOO)
4. ICD’s translate electromagnetic interference (EMI) differently
5. Chest x-ray to identify lead type and Bi-Ventricular left ventricle lead location in relation to the coronary sinus especially with central line placement
6. Reprogramming to VOO requires an increased heart rate than intrinsic rate in order to ensure tissue perfusion and deter under sensing and over sensing from EMI (cautery)
Anesthesia Practice

- Development of Practice Guidelines:
  Surgeon notifying the scheduling department indicates devices existence
  Magnets available on all anesthesia carts
  Access to an alternative pacing or defibrillator source
  No EMI within six inches of the device
  Utilize Bipolar EMI or harmonic scalpel
  Minimize EMI Joules
  Grounding Pad away from device but as close to the surgical field to minimize aberrant current absorption by device
  Utilize burst EMI with unipolar with five second pauses to minimize inhibition of the device
  Device in reprogrammed preoperatively it should be evaluate postoperatively by a device representative
Case Study # 1

- Colonoscopy
- 78yr old with prior history of colon polyps with ICD
- Company representative present to inform that the device was a magnet resistant device and required reprogramming prior to start of case

As of 2007: **45,000** Magnet Resistant Devices Exist
Case Study #2

- Colonoscopy
- 70 yr old with prior history of colon polyps and ICD
- ICD representative present and informed that available for reprogramming if cautery is to be utilized.
Discussion of Case Reports

- Need for Anesthesia departments to develop pacer and ICD clinical practice guidelines
- Need for Anesthesia providers to be aware of such variances in order to optimize care
  - Question company representatives
  - Educate fellow practitioners and students of anesthesia
  - Ensure safe surgical experience for the patient through vigilance
The variations of models, magnet responses, and evolution of new technology requires anesthesia providers to heighten their awareness and vigilance to pre, intra, and postoperative care measures of PPM and ICD patients in order to optimize surgical outcomes.

If uncertain contact the devices representative and inquire about care measures, device settings, and patient details (i.e. magnet resistant or pacer dependent)
Disclosure

- Prepared without any financial incentives or obligations from any PPM and ICD device manufactures or any company in relation to interventional cardiac therapy.

Questions or Comments...