Pacemakers & Implantable Cardiac Defibrillators

The Basics for Bedside Nursing

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Objectives:

- Identify the operational characteristics of implantable Pacemaker, ICD, and CRT systems
- Demonstrate an understanding of how the presence of implantable devices impact patient care
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A Quick Review
The Electrical System of the Heart

- Sinoatrial (SA) Node
- Anterior Internodal Tract
- Middle Internodal Tract
- Posterior Internodal Tract
- Atrioventricular (AV) Node
- Bachmann's Bundle
- Left Bundle Branch
- Conduction Pathways
- Right Bundle Branch
Common Conduction Abnormalities

- Bradycardia
  - To slow
- Tachycardia
  - To fast
- Dys-synchrony
  - Unequal contraction

http://www.emedu.org/ecg/lbba.htm
Conduction Abnormalities Cause

- Syncope or pre-syncope
- Dizziness
- Congestive heart failure
- Mental confusion
- Palpitations
- Shortness of breath
- Exercise intolerance
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What’s the Same & What’s Different?
Implantable Devices Treat

- Conduction System Abnormalities
  - Bradycardia
  - Tachycardia
  - Dys-synchrony
**Pacemakers**

- Support the heart rate
  - make a heart beat
- Sense
  - see a native heart beat
- Provide physiologic heart rates
- Provide diagnostic information

**ICDs**

- Everything a Pacemaker does plus.....
- Treat life threatening arrhythmias
  - Pacing
  - Shock
What exactly is Cardiac Re-synchronization?
Ventricular Dyssynchrony

- Delayed electrical conduction results in late contraction of the left ventricle
Re-synchronization

- **Goal**
  - Simultaneous stimulation of both ventricles
  - Synchronized contraction
Benefits of a CRT Device

- Functions the same as a Pacemaker / ICD does plus...
- Optimization of hemodynamic performance
  - Improve contraction pattern
  - Reduce paradoxical septal motion
  - Improve LV regional wall motion
  - Improve Left Ventricular Ejection Fraction
- Symptom improvement
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Components
Power Source

- Housed inside the device or “can”
  - Battery
  - Circuitry
- Hermetically sealed
  - Elective replacement means a brand new can
Leads

- Attach to the “can”
  - Deliver energy to the heart
  - See or sense native heart beats
- Epicardial
- Transvenous
Transvenous lead insertion sites

- Internal/external jugular veins
  - Used when access is limited

- Subclavian/Cephalic veins
  - Most common for implantable devices

- Brachial/Femoral veins
  - Usually for temporary wires
How many wires?

- Single
- Dual
- Cardiac Re-Synchronization
  - CRT
A Closer Look.....
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Terminology

- Asynchronous
- DDD
- VVI
- High Energy Shock
- Stimulation
- Lower Rate Limit
- Detect Rate
- Capture
- Sensing
- Anti-Tachycardia Pacing
- Threshold
- Magnet Operation
- Magnet Operation
### NBG code: Language of devices

<table>
<thead>
<tr>
<th>1st Letter</th>
<th>2nd Letter</th>
<th>3rd Letter</th>
<th>4th Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamber(s) Paced</td>
<td>Chamber(s) Sensed</td>
<td>Response to Sensing</td>
<td>Rate Response</td>
</tr>
<tr>
<td>A = atrium</td>
<td>A = atrium</td>
<td>I = inhibit (Demand mode)</td>
<td>R = Rate Response</td>
</tr>
<tr>
<td>V = ventricle</td>
<td>V = ventricle</td>
<td>T = triggered</td>
<td></td>
</tr>
<tr>
<td>D = dual (both atrium and ventricle)</td>
<td>D = dual</td>
<td>D = dual</td>
<td></td>
</tr>
<tr>
<td>O = none</td>
<td>O = none</td>
<td>O = none (Asynch)</td>
<td></td>
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- **Chamber paced**
- **Chamber sensed**
- **Action or response to a sensed event**
- **Rate Response on**
VVI

- 1\textsuperscript{st} “V” = Chamber Paced (Ventricle)
- 2\textsuperscript{nd} “V” = Chamber Sensed (Ventricle)
- 3\textsuperscript{rd} “I” = Inhibit
AAI

- 1\textsuperscript{st} “A” = Chamber Paced (Atrium)
- 2\textsuperscript{nd} “A” = Chamber Sensed (Atrium)
- 3\textsuperscript{rd} “I” = Inhibit
DDD: The “four faces” of DDD pacing

- 1st “D” = Chamber Paced (Atrium & Ventricle)
- 2nd “D” = Chamber Sensed (Atrium & Ventricle)
- 3rd “D” = Inhibit & Trigger
Lower Rate Limit

- The lowest rate the pacemaker will pace the heart in the absence of intrinsic or native events
  - DDD
  - LRL 50 ppm
Detect Rate

- The rate that determines when a device will initiate therapy
  - Can be Ventricular or Atrial therapy
Stimulation

- Consists of a given amount of energy
  - Voltage

- Delivered over a given period of time
  - Pulse Width
Capture

- Depolarization of cardiac tissue in response to stimulation or the output pulse.
  - Wide QRS complexes
  - Usually LBBB
Variations on Capture

- Intrinsic Beat
- Paced Beat
- Fusion Beat
- Pseudo Fusion Beat
Stimulation Threshold

- The minimum output pulse needed to consistently capture cardiac tissue
  - Determined through manual or automatic testing
  - Output pulse is incrementally decreased until capture is lost
- Energy safety margin is 2-3 times the threshold.
Stimulation Threshold Influences

- Changes in electrolyte balance within the body
  - Dialysis
  - Severe acid/base imbalances
- Drug and/or dosage changes
  - Class IC agents
    - Pacing thresholds
      - Flecainide, Encainide & Propafenone
      - Class I agents may also increase defibrillation thresholds
- Changes at the tissue/lead interface
  - Ischemia
  - Scar tissue
Sensing

- The ability of the device to “see” native or intrinsic heart beats
  - Measured in millivolts

![Graph showing heart beats with voltage levels of 5 mV, 2.5 mV, and 1.25 mV.]
Sensitivity setting

- Inverse relationship between the sensitivity and the programmed value
  - 2mV setting is more sensitive than a 5mV setting
Anti-tachycardia

- Pacing therapy used to treat tachy-arrhythmias
  - Ventricular tachycardia
  - Atrial tachycardia / flutter
High Energy Shock

- Programmed shock to terminate tachyarrhythmia
  - Ventricular Fibrillation
  - Fast Ventricular Tachycardia
Asynchronous

- Not in synchrony
- Magnet Operation (in pacemakers)
  - Suspends sensing “closes the **pacemakers** eyes”
  - Forced pacing at a pre-determined rate
Magnet Operation & ICD’s

- Detection suspended “closes the eyes of the ICD portion”
- Device cannot see
  - Ventricular Tachycardia
  - Ventricular Fibrillation
- Pacemaker portion of the ICD will function as programmed.
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Patient Management
Evaluating ECG’s
Patient Management.....

- 53 year old male
  - Woke up feeling dizzy
  - Called the device clinic

- History
  - Pulmonary Hypertension
  - Complete Heart Block

- Advised to go to the ER
Presenting EKG
Cause for concern?

- Symptoms?
- What do you see?
  - Pacing spikes without corresponding QRS.
Cause for Concern?

- Symptoms?
- What do you see?
  - Pacing spikes where they don’t belong
- When does it happen?
  - Look for a pattern
Cause for Concern?

- Symptoms?
- What do you see?
  - Pacing spikes where they don’t belong
- Measure the spikes
  - Spike to spike (1000 msec / 60ppm)
- Ventricular undersensing
Cause for Concern?

- Symptoms?
- What do you see?
  - Missing pacing spikes
  - If pacing occurs at all.....it is “tardy”.....pauses
- Ventricular Oversensing

![Graph showing pacing intervals and ventricular oversensing](image-url)
Cause for Concern?

- Symptomatic?
- What do you see?
  - Pwaves without QRS’s
  - Note change from ApVs to ApVp
**Managed Ventricular Pacing (MVP)**

**AAI(R) Mode**
Atrial based pacing allowing intrinsic AV conduction

**Ventricular Backup**
Ventricular pacing only as needed in the presence of transient loss of conduction

**DDD(R) Switch**
Ventricular support if loss of A-V conduction is persistent
Managed Ventricular Pacing (MVP)

- Functionally AAIR
  - Apace, Asense, Inhibit, Rate Response
- Note the PR interval
  - Normal is 120-200msec (.12-.20 seconds)
  - 400msec (.4sec)
- There must be a ventricular event between every two atrial events.
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Patient Management

Medical Testing & Emergencies
Cardiac Arrest

- Treat the patient
  - Initiate CPR
  - Defibrillate
    - Paddle Position: 13cm / 5in from the device
    - Apex / Posterior position
- Evaluate the device once the patient is stable
- If the patient has an Implantable defibrillator
  - The device will attempt to treat the arrhythmia
  - You may feel a slight “shock” if touching the patient
  - Evaluate the patient and treat accordingly.
Electromagnetic Interference (EMI)

- Electromagnetic energy signals from an outside source
- EMI signals in the 10-60hz frequency range
  - Overlaps the cardiac signal range
- May interfere with implantable devices
  - Device sees the interference as native heart beats & doesn’t pace enough or paces with irregularity.
  - Transient mode change
    - Noise reversion
    - Electrical (power-on) reset
- Loss of function
  - Nearing end of service
Electromagnetic Interference (EMI)

- What does EMI look like?
  - Repetitive signal that overloads the sensing circuit
Electromagnetic Interference (EMI)

- Real life example
External Sources of EMI

- Rapid advancement of technology creates unanticipated sources of EMI
- Prevention: Keep technology at least 12 inches from the implantable device
  - Moving away from the signal returns the device to normal function
  - Consult with cardiologist
  - Call device manufacturer
    - Patient services
Hospital Sources of EMI

- Recommendation: Consult with Cardiologist prior to initiation of therapy for risk assessment / device reprogramming.
  - Extracorporeal Shock Wave Lithotripsy
  - Electroconvulsive Shock Therapy (ECT)
  - Radiofrequency Ablation
  - TENS unit
  - TURP
Hospital Sources of EMI

- Electrocautery
  - Most Common Hospital Source
  - Bipolar preferred
  - Grounding plate > 15cm from device
  - 1 sec bursts every 10 seconds recommended
  - Reprogramming / magnet application for dependent patients.
Hospital Sources of EMI

- Therapeutic Radiation risks
  - Device malfunction
  - Device failure
- Precautions
  - Cumulative dose < 500 rads
  - Shielding
  - Device repositioning
Magnetic Resonance Imaging

- **Facts about MRI**
  - Standard of care for diagnosis & treatment of many comorbidities
    - Stroke
    - Various types of Cancer
    - Orthopedic conditions
  - 86% of pacemaker patient are older than 65 with comorbidities that may require an MRI
    - As a rule, pacemaker patients have had limited to no access to this diagnostic tool.
Magnetic Resonance Imaging

- MRI Risks
  - High Pacing rates during testing
    - Runaway Pacemaker
  - Delivery of RF energy down the leads to heart tissue
  - Historically contra-indicated & only performed in extreme circumstances under the supervision of the physician.
- Recent changes
  - MRI conditional Pacemakers
Magnetic Resonance Imaging

- Identify system compatibility with MRI
- Patient ID card will identify MRI conditional system
Magnetic Resonance Imaging

- X-ray
  - Ensures against unknown additional leads
  - Identifies radiopaque symbol

1. Location of the device radiopaque symbol
2. Device radiopaque MRI symbol
3. Lead radiopaque MRI symbol
Magnetic Resonance Imaging

- Reprogramming guidelines
  - Obtain order from Cardiologist
  - Schedule with device clinic personnel or company representative
    - Reprogramming prior to scan
    - Testing and reprogramming post scan

- Patient Monitoring guidelines
  - Visual & voice communication
  - Continuous monitoring of oximetry or ECG
    - NOTE: oximetry is monitored during sequences which make ECG unreadable
  - External defibrillator accessible to control area staff.
MRI 101

Static Field

Gradient Field

RF
Magnetic Resonance Imaging

- Scan guidelines
  - Horizontal cylindrical bore magnet system
  - 1.5 Tesla
  - Normal operating mode
  - Maximum gradient slew rate performance per axis of $\leq 200$ Teslas/meter/second (T/m/s)
  - Whole body averaged SAR $\leq 2\text{dW/kg}$, head averaged SAR $\leq 3.2\text{W/kg}$. 
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Technology
Remote Monitoring

- Transtelephonic
  - Rhythm strip transmitted via the telephone
    - Presenting
    - Magnet
    - Non-magnet
  - Clinician initiated
Remote Monitoring

- Website based monitoring

1. The Remote Monitor collects device data via interrogation

2. Data sent from the Monitor to a secure server via a standard telephone line

3. Clinicians review the patient’s device data using the secure website
Remote Monitoring

- Hospital leverage of website based monitoring
  - Data can be exported to the facilities EHR
  - Patient’s device clinic receives transmission data for those patients currently enrolled in their remote monitoring network.

- Allied Health professional uses monitor to interrogate implanted device.
- Transmission confirmation faxed to facility
- Transmission reviewed remotely by Monitoring Center or local clinician
- Findings discussed with facility staff and/or device follow-up clinicians
- Facility receives faxed copies of reports for their records
Leveraging Technology

- Improves workflow
- Decreases patient wait times
- Provides diagnostic information to clinician in less than half the time of traditional workflow methods.
  - From an average of 80 minutes to 15 minutes.
- Improves quality of care
  - Rapid access to diagnostic data
  - More tools to better manage the patient’s arrhythmia status
Questions?

