Pacemakers and beyond: The why, how, and what of caring for pediatric pacemakers

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# Learning Objectives

<table>
<thead>
<tr>
<th>Define</th>
<th>Define the purpose of pacemakers.</th>
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<tbody>
<tr>
<td>Describe</td>
<td>Describe how pacemakers support patients with rhythm disturbance.</td>
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<tr>
<td>Analyze</td>
<td>Analyze nursing interventions to support the patient with a permanent or temporary pacemaker.</td>
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</table>
What’s our why?

Non-Hispanic black and Hispanic children with specific phenotypes of CHDs have poorer survival rates in early childhood than NH white children.

How did we get here?

1700s
Experiments on frogs - electrophysiology

1899
Early meta-analysis application of electrical impulse to the human heart

1951
First tabletop pacemaker to treat heart block

1958
1st implantable pacemaker (Senning and Elmquist)

1962
First pediatric pacemaker: 14 yr old with myocarditis

1979
Dual chamber pacemaker

What is your primary goal as a nurse?

Deliver oxygen to tissues.

That’s literally it.

How do we measure oxygenation to tissues?

**Cardiac Output**

\[ CO = \text{Volume of blood pumped by each ventricle in 1 minute.} \]

\[ CO = \text{HR (beat/min)} \times \text{SV (volume)} \]

**SV is affected by:**
- Preload (volume/stretch)
- Afterload (resistance)
- Contractility (squeeze)
Why would we use a pacemaker?

\[ \text{CO} = \text{HR} \times \text{SV} \]

**SV is affected by:**
- Preload (volume/stretch)
- Afterload (resistance)
- Contractility (squeeze)

1. Increase heart rate
2. Optimize contractility

- Symptomatic bradycardia
- Atrioventricular block
- Tachyarrhythmias
Quick Review on Contractility

It’s all about coordination = AV Synchrony
How does the pacemaker achieve improved contractility?

- The pacemaker delivers an electrical stimulus to the myocardium.
- Ideally, this will propagate a series of action potentials that depolarize the atria, ventricles (or both).
Pacemaker Implants

Seattle Children’s Data

- 2019: 15 implants
- 2020: 20 implants

*Most common indication: Heart Block


Cardiac rhythm devices in the pediatric population: utilization and complications.
Czosek RJ, Meganathan K, Anderson JB, Kililans TK, Marino BS, Heaton PC

 Courtesy: Theresa Vu
Pediatric Considerations

• **Increasing rate of long-term survival** from complex surgical interventions.

• **Technical challenges** may complicate device placement with small or atypical venous and cardiac anatomy.

• **No RCT clinical studies** evaluating cardiac pacing in pediatrics, consensus-based medicine.

Most common use of pediatric pacemakers:

1) Symptomatic sinus bradycardia related to sinus node dysfunction, associated with poor cardiac output or to prevent episodes of recurrent atrial tachycardias.

2) “Advanced second- or third-degree AV block, either congenital or postsurgical, when associated with low cardiac output, ventricular dysfunction, complex ventricular ectopy, syncope or potential of recovery is minimal, especially after cardiac surgery.”
Post operative Arrhythmias

- Cardiac surgery bypass may cause myocardial “stunning” reducing heart function.
- Inflammation or interference from operative instruments
- Surgery: electrolytes disturbances, acidosis, hypotension, and hypoxia which are arrhythmogenic
- **Other risk factors for early post-op rhythm disturbances:**
  - Younger age
  - Longer bypass and cross-clamp times
  - Repair of septal defects
How does it work? Potential implant sites.

Locations of pacing devices

- Transcutaneous
- Transvenous
- Epicardial
- Permanent/Implanted
Common diagnostic questions to determine need for pacing

<table>
<thead>
<tr>
<th>Question</th>
<th>Color</th>
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<tbody>
<tr>
<td>What is the patient’s average heart rate?</td>
<td>Blue</td>
</tr>
<tr>
<td>What is the patient’s lowest heart rate?</td>
<td>Blue</td>
</tr>
<tr>
<td>Are there long pauses between one impulse and next?</td>
<td>Green</td>
</tr>
<tr>
<td>Is the rhythm coming from the atria (where is should) or the junction/ventricles?</td>
<td>Green</td>
</tr>
<tr>
<td>Are there any extra beats coming from the bottom chamber?</td>
<td>Green</td>
</tr>
<tr>
<td>What is the patient’s perfusion status?</td>
<td>Green</td>
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How does it work?
Pacemaker modes

• **Synchronous (Demand):** Pacemaker will cause a stimulus when no intrinsic activity is sensed.

• **Asynchronous (Fixed):** In fixed mode the stimulus is provided at a preset rate and the pacer fires at that rate regardless of what the patients heart is doing.
Two Types

- Single Chamber
- Dual Chamber
How does it work? Functions of the Pacemaker

“Sense” (Monitor)

• Sense intrinsic cardiac rhythm
• Provide diagnostic information stored by the pacemaker

Pace

• Stimulate depolarization of the myocardium
Why would we use a pacemaker?

$$\text{CO} = \text{HR} \times \text{SV}$$

- Increase heart rate
- Optimize contractility
- Restore AV Synchrony
How does a pacemaker achieve optimal cardiac output?

Settings: overview

- **Rate**: the number of impulses per minute sent from pulse generator
- **Output**: The amount of energy that the pulse generator sends to the heart. Measured in milliamps. mA: milliamps (low 0.5 - 20 high)
- **Sensitivity**: Minimum voltage required to be detected as a P wave or R wave, measured in mV.
- **AV Interval**: Amount of time between the atrial spike (stimulus) and the ventricular spike in AV Sequential pacing (only in DDD)
Capture

Depolarization of atria or ventricles in response to a pacing stimulus
Sensitivity

- Ability of device to detect intrinsic cardiac activity
- Goal to detect appropriate intrinsic activity and filter out unwanted data.
- Measured in mV = 0.5-20

The higher the set mV, the less sensitive the pacer.
Sensitivity: When it goes wrong

**Undersensing**
- Low sensitivity set.
- **Problem**: Potential stimulus on T wave

**Oversensing**
- High sensitivity set.
- **Problem**: Pacer might not fire, as it thinks everything is electrical activity (e.g. hiccups, outside electrical interference, IV pumps)
<table>
<thead>
<tr>
<th>(I) Chamber Paced</th>
<th>(II) Chamber Sensed</th>
<th>(III) Mode of Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>A= Atrium</td>
<td>A= Atrium</td>
<td>I= Inhibited</td>
</tr>
<tr>
<td>V= Ventricle</td>
<td>V= Ventricle</td>
<td>T= Triggered</td>
</tr>
<tr>
<td>D= Atrium &amp; Ventricle</td>
<td>D= Atrium and Ventricle</td>
<td>D= Inhibited and Triggered</td>
</tr>
<tr>
<td>O= None</td>
<td>O= None</td>
<td></td>
</tr>
</tbody>
</table>

**NBG Codes**

(N) North American Society of Pacing and Electrophysiology
(B) British Pacing and Electrophysiology Group
(G) Generic pacemaker code.
Atrial Pacing (AAI)

Used in patients with Sinus Node dysfunction and intact AV node function.

Common Uses:
- Symptomatic sinus bradycardia: Pacemaker offer a higher heart rate to increase cardiac output (better perfusion)
- Sick Sinus Syndrome
- Junctional Rhythms (JET)

Considerations:
- Pacing spike precedes the p wave.
- Morphology of p wave dependent of lead placement but may appear normal.
Ventricular Pacing (VVI)

Common Uses:
- AV Block
- A Fib

Considerations:
- Delivers stimulus to ventricles causing ventricular depolarization
- Ventricular pacing spike is followed by a widened QRS (slower conduction through ventricles)
- No atrial kick if patient has no intrinsic P waves. Potential loss of AV synchrony.
- Thrombus risk if no atrial contraction (atrial clot)
**A-V Sequential: Dual Pacing (DDD)**

**Common uses:**
- Symptomatic bradycardia
- AV Block

**Considerations:**
- Stimulates the atria then the ventricles in sequence
- Can optimize atrial kick to improve cardiac output and perfusion.
- Can program AV delay (correlates with PR interval) in milliseconds to align with intrinsic AV conduction. *Increasing AV interval prolongs fill time.*
Pulse check time......
What percentage of cardiac output is contributed by atrial kick?
What can you do to support your patients?

• Monitor rhythm analysis
• Optimize electrolytes
• Focused cardiac assessment
• Check connections and batteries
• Patient Teaching
• Monitor for complications:
  • Device-related complications (e.g. issues with a generator, lead, or electrode) 7.2% 11.5% 26.7%
  • Patient-related complications (e.g. pneumothorax, hematoma, infection) 11.2% 5.9% 19.4%

Source: Adapted from Czosek et al. (2012) (1).
Can I do CPR my patient with a pacemaker?

- Yes! Remember cardiac output is essential.
- Try to avoid pulse generator with placement of hands during compressions.
What about defibrillation?

Yes! But...avoid placing pads over the pulse generator if possible and interrogate device after.
Case Study: Maya

Admitted to your care post-implantable pacemaker for complete AV block.
What are your nursing interventions?

What are nursing considerations for managing this patient?
A. With any clinical change: **ASSESS**
B. Perform a full assessment (focused cardiac and neuro assessment)
C. Rhythm analysis: capture, sensing, AV synchrony
   • Failure to sense
   • Failure to capture

What are interventions for optimizing contractility and perfusion?
A. Replace electrolytes
B. Avoid hypoglycemia
C. Maintain normothermia
D. Reduce oxygen consumption
E. Reduce arrhythmogenic medications when possible
It’s time to send Maya home....

What will you tell Maya and her care takers?

• Develop a trusting relationship with patient and family to reduce fear, anxiety, and feelings of loss of control.
• Develop an education plan that meets the patients learning needs and level of health literacy.
• Limitations on activity: avoid excessive bending, stretching, lifting heavy, strenuous exercise, or contact sports until medically cleared.
• Protect the surgical incision by keeping it clean and dry.
• Teach patient and family to check pulse every day for 1 month, then every week, and alert provider with variations set by provider.
• Instruct patient to wear a medication alert bracelet, avoid electromagnetic fields, and avoid or use protection with radiation exposure.
• Avoid shoulder straps over generator site.
• Overcommunicate any changes to provider team (lethargy, syncopal episodes)

No change is small!
“The heart is the source of all movement, as the heart links the soul with the organs of life.” – Aristotle
Questions?
References


