A Primer on Cardiac Devices

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October 2019
Objectives:

• Overview of the indications for pacemaker, ICD and CRT implant

• Review programming basics and key differences in the programming options between different types of devices
Quick review of intrinsic conduction

- Sinus node
- AV node

Diagram showing heart nodes and conduction pathways:
- His bundle
- RBB
- LBB
When is a pacemaker indicated?

1) Problem with FORMATION of electrical impulse

2) Problem with CONDUCTION of electrical impulse
Sinus node dysfunction (aka Sick Sinus Syndrome)

- Generally age-dependent and secondary to progressive fibrosis of sinus nodal tissue and surrounding myocardium

- Can result in abnormalities of sinus node and atrial impulse formation and propagation

- May present as various bradycardias or pause-related syndromes

1) Problem with *FORMATION* of electrical impulse
Sinus node dysfunction (aka Sick Sinus Syndrome)

- Symptomatic sinus bradycardia (< 50 bpm)
- Chronotropic incompetence
- Sinus pause (>3 sec) / Sinus node arrest
- Tachy-brady syndrome (degenerative fibrosis also responsible for development of atrial tachyarrhythmias coexisting with sinus node disease)

“In sinus node dysfunction, there is no established minimum heart rate or pause duration where permanent pacing is recommended. Establishing temporal correlation between symptoms and bradycardia is important when determining whether permanent pacing is needed.” – 2018 ACC/AHA/HRS Guideline on the Evaluation and Management of Patients with Bradycardia and Cardiac Conduction Delay
Sinus Pause

Duration: 6.8 secs (9 bpm)

6.8 sec pause
Chronotropic Incompetence: heart rate is inadequate to meet metabolic demand

- 4 min 30 sec into stress test, 5% grade on treadmill; HR 74 bpm
- 7 min 30 sec into stress test, 10% grade on treadmill; HR 74 bpm
Tachy-brady syndrome — degenerative fibrosis is etiology for development of atrial arrhythmias which can coexist with SND and the combination is called “tachy-brady syndrome.”

atrial tachyarrhythmias + SND = tachy-brady syndrome
2) Problem with \textit{CONDUCTION} of electrical impulse

\textbf{Heart block:}

- $2^{nd}$ degree AV block
- $3^{rd}$ degree AV block
Second degree Mobitz type 1 AV block (Wenckebach)

• **NOT** an indication for permanent pacemaker UNLESS there is clear correlation between symptoms and observed conduction issue
2nd degree AV - Mobitz type 2 and 3rd degree AV block

• Permanent pacing is recommended * (regardless of symptoms) BECAUSE the patient is at risk from sudden complete AV block resulting in syncope and subsequent harm

• Determination of level of block may be important (infranodal, intra- or infra-Hisian)...
  ▪ AV block at the AV node is associated with slower progression, a faster/reliable junctional escape mechanism
  ▪ AV block within or below the His bundle may progress rapidly and unexpectedly, has slower/less predictable ventricular escape

* Prior to consideration for permanent pacing, rule out reversible causes of AV block (ie, Lyme carditis, drug toxicity, etc.)
<table>
<thead>
<tr>
<th>Category</th>
<th>Causes</th>
</tr>
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<tbody>
<tr>
<td>Congenital/genetic</td>
<td>Congenital AV block (associated with maternal systemic lupus erythematosus)</td>
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<td></td>
<td>Congenital heart defects (e.g., L-TGA)</td>
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<td>Genetic (e.g., SCNSA mutations)</td>
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<td>Infectious</td>
<td>Lyme carditis</td>
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<td>Bacterial endocarditis with paravalvular abscess</td>
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<td>Acute rheumatic fever</td>
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<td>Chagas disease</td>
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<td>Toxoplasmosis</td>
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<td>Inflammatory/infiltrative</td>
<td>Myocarditis</td>
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<td>Amyloidosis</td>
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<td>Cardiac sarcoidosis</td>
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<td></td>
<td>Rheumatologic disease: Systemic sclerosis, SLE, RA, reactive arthritis (Reiter’s syndrome)</td>
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<td></td>
<td>Other cardiomyopathy-idiopathic, valvular</td>
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<tr>
<td>Ischemic</td>
<td>Acute MI</td>
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<td>Coronary Ischemia without infarction—unstable angina, variant angina</td>
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<td>Chronic ischemic cardiomyopathy</td>
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<td>Degenerative</td>
<td>Lev’s and Lenegre’s diseases</td>
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<td>Vagotonic-related</td>
<td>Sleep, obstructive sleep apnea</td>
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<td></td>
<td>High-level athletic conditioning</td>
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<td></td>
<td>Neurocardiogenic</td>
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<tr>
<td>Metabolic/endocrine</td>
<td>Acid-base disorders</td>
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<td></td>
<td>Poisoning/overdose (e.g., mercury, cyanide, carbon monoxide, mad honey)</td>
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<td>Thyroid disease (both hypothyroidism and hyperthyroidism)</td>
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<td>Adrenal disease (e.g., pheochromocytoma, hypoadrenal)</td>
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<tr>
<td>Other diseases</td>
<td>Neuromuscular diseases (e.g., myotonic dystrophy, Kearns-Sayre syndrome, Erb’s dystrophy)</td>
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<td>Lymphoma</td>
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<tr>
<td>Iatrogenic</td>
<td>Medication related</td>
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<tr>
<td></td>
<td>Beta blockers, verapamil, diltiazem, digoxin</td>
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<td></td>
<td>Antiarrhythmic drugs</td>
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<tr>
<td></td>
<td>Neutrons/ectopics</td>
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<tr>
<td></td>
<td>Catheter ablation</td>
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<td></td>
<td>Cardiac surgery, especially valve surgery</td>
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<td>TAVR, alcohol septal ablation</td>
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FUN FACT...

• 2:1 AV block is not an indication for permanent pacing UNLESS clearly symptomatic...and is NOT necessarily evidence of higher degree AV block

• **2:1 AV block cannot be classified as Mobitz type 1 or Mobitz type 2** because observation of PR interval constancy versus lengthening is precluded by every other P wave being non-conducted

• Again, determination of level of block is important *(infranodal, intra- or infra-Hisian)*
Case #1

• Don is an 82 yo gentleman with HTN. He comes to clinic complaining of low energy / fatigue.
• Physical exam is unremarkable apart from bradycardia with HR 42 bpm.

• What next?
• Order an ECG
• Review HTN medications – Is he on a beta blocker or calcium channel blocker?
• Consider lab work-up (ie, TSH)
• Consider ambulatory rhythm monitoring (ie, 24-48 hr Holter monitor or Event monitor)
• Consider echocardiogram
Scenario #1
Results of work-up:
- ECG shows sinus rhythm with Mobitz type 1 2nd degree AV block
- Med review shows that he is taking metoprolol succinate 50 mg for blood pressure
- Stop metoprolol succinate and use another agent for HTN
- likely no need to proceed with labs or other diagnostics at this time unless symptoms and bradycardia persist
Scenario #2
Results of work-up:
- ECG shows sinus rhythm with complete heart block
- Med review shows that he is taking lisinopril for HTN
- TSH ordered, 3.89
- Refer to cardiology – urgent (pacemaker implant is indicated)
Scenario #3

Results of work-up:
- ECG shows sinus bradycardia with 1st degree AV block
- Med review shows that he is taking lisinopril for HTN
- TSH ordered, 4.5
- Holter monitor ordered, shows average heart rate of 57 bpm over 48 hrs with max heart rate 72 bpm, min heart 33 bpm
- Is pacemaker indicated?
Pacemaker Function

• Pacemakers can have 1, 2 or 3 leads…OR, NO leads (Micra, transcatheter pacing system from Medtronic)

In general…

• If there is a problem with impulse formation, the atrial lead will send an electrical impulse

• If there is a problem with impulse conduction, the ventricular lead will send an electrical impulse
Pacemakers can

- Pace
- Sense
- Inhibit or trigger
- Provide rate response

[Diagram showing pacemaker components]
• **AAI** – paces in the atrium, senses in the atrium (inhibits)

• **VVI** – paces in the ventricle, senses in the ventricle (inhibits)

• **DDD** – paces in both chambers, senses in both chambers (both triggers and inhibits)

**Pacemaker dependent**: no intrinsic underlying rhythm / only escape rhythm
Inhibit and Trigger??

Sinus node works → atrial lead “inhibited”
AV conduction is not intact → ventricular lead “triggered”
DDD EXAMPLES
THE FOUR FACES OF DDD

1. Atrial and ventricular pacing

2. Atrial pacing, ventricular sensing
3. Atrial sensing, ventricular pacing

An AS (P-wave) inhibits lower rate timer and triggers an AV delay timer (SAV)
- SAV expires without being inhibited by a VS, resulting in a VP

4. Atrial and ventricular sensing

An AS (P-wave) inhibits lower rate timer and triggers an AV delay timer (SAV)
- Before the SAV can expire, it is inhibited by a VS (R-wave)
Programming basics:
- Lower rate limit: 50 - 70 bpm
- Upper rate limit: 120 - 140 bpm
- Magnet rate: manufacturer dependent
- Magnet response: “DOO” or “VOO”
- Rate response: can be programmed ON
  • can be programmed to be more or less aggressive
  • Different sensors per device manufacturer
Quick note on the Micra...

- VVIR
- Implanted directly in the right ventricle
- MR conditional

Dimensions:
- 6.7 mm
- 25.9 mm
ICD’s
(implantable cardioverter defibrillator)

Indications:

- **Primary prevention:**
  - familial or inherited conditions with high risk for life-threatening ventricular tachycardia (ie, long QT syndrome, HCM)
  - ischemic / non-ischemic cardiomyopathy with LVEF <35%

- **Secondary prevention:**
  - documented cardiac arrest due to ventricular fibrillation (VF)*
  - documented sustained ventricular tachycardia (VT), either spontaneous or induced *

*and not due to transient or reversible cause
Case #2

- Gary is a 63 yo who was found down and unresponsive at work. EMS was called and when they arrived, he was found to be in VF.
- He was defibrillated successfully en route to hospital.
- He underwent an angiogram which showed no significant atherosclerotic disease.
- Is an ICD indicated?  YES
Case #3

- Gary is a 63 yo who was found down and unresponsive at work. EMS was called and when they arrived, he was found to be in VF.
- He was defibrillated successfully en route to hospital.
- He underwent an angiogram which showed 99% occlusion of RCA which was successfully treated with stent.
- Is an ICD indicated? **NO**
Case #4

• Suzy is a pleasant 58 yo woman with history of atrial fibrillation treated with dofetilide. She suffered a syncopal episode and was admitted for observation after runs of NSVT were seen on tele in the ED.
• Overnight, she developed ventricular tachycardia and required cardioversion.
• Ventricular tachycardia was attributed to low magnesium (1.4 upon admission) and treatment with dofetilide.

• Is an ICD indicated? NO
ICD functionality

- ICD’s have the ability to pace the heart (have all the same functionality of a simple pacemaker) but, most importantly, they provide “tachy therapies”
  - Detect ventricular tachyarrhythmias (V-Tach, V-Fib)
  - Provide anti-tachycardia pacing (ATP)
  - Defibrillate sustained malignant arrhythmias which do not terminate with ATP
Treated Ventricular Rhythm - ATP

VT Rate approx 207 BPM
Can you tell the difference between these two images?
Cardiac Resynchronization Therapy

• prolonged interventricular conduction (ie, LBBB) frequently seen in LV systolic dysfunction (+ clinical HF)
• 1/3 of patients with advanced HF will have wide QRS
• Prolonged interventricular delay -> reduced ventricular systolic function + functional mitral regurgitation + ventricular dilatation
• QRS prolongation can lead to “dyssynchrony”
Cardiac Resynchronization Therapy (CRT)

- Biventricular pacing / CRT -> modified ventricular electromechanical delay -> improved LVSF, improved functional MR, induce favorable remodeling
- IMPROVED function
- ~ 30% decrease in hospitalizations
- 24 – 36% mortality rate benefit
• **Class I indication:**
  – LVEF ≤ 35%
  – LBBB with QRS duration ≥ 150 ms
  – NYHA II – IV symptoms on GDMT

• **Class II a:**
  – LVEF ≤ 35%, LBBB with QRS 120 – 149 ms, NYHA II – IV on GDMT
  – LVEF ≤ 35%, non-LBBB pattern with QRS ≥ 150 ms, NYHA III – IV on GDMT
  – a-fib, LVEF ≤ 35% on GDMT if ventricular pacing or other CRT criteria AND will require near 100% ventricular pacing
References


• Medtronic Core Curriculum – Pacing Therapy, ICD Therapy and Cardiac Resynchronization Therapy; [www.medtronicacademy.com/core-curriculum](http://www.medtronicacademy.com/core-curriculum).