Conflict of Interest

- I do not receive any support from manufactures of pacemakers or CRMDs

Goals

- How pacemakers sense and how electrical capture works
  - Define capture thresholds and its importance in the OR
  - What are sensing thresholds
  - How sensing threshold affect pacemaker behavior
- Basics of pacemaker timing cycles
  - How these intervals affect other settings like “backup” rates (LRL)
  - Electrophysiologists second only to the military for acronym use so brace yourselves
- Manage basic pacemaker settings for optimal hemodynamics during surgery
  - Make the pacemaker do what you want
Goals

- Try to move beyond magnets and asynchronous modes
  - VOO is not always the right mode for the patient
  - Magnet response is programmable
  - Magnet mode/Intervals may not be optimal for surgery
- Demonstrate to you that these functions are relevant in your practice
- Understanding how a pacemaker functions helps you to optimize pacing for surgery
  - What is optimal for home may not be for surgery

Capture Threshold

- Probably the parameter with which most are familiar
- Energy required to consistently stimulate the myocardium to contract when it is not refractory
- Affected by:
  - The lead site and maturation
  - The milieu of the tissue,
    - electrolytes balance, acidemia, ischemia
  - Medications
- Capture thresholds are dynamic

Capture Threshold

- 68 y/o male with a CRMD placed for bradycardia after Maze procedure presents for elective cardioversion for atrial fibrillation
  - EKG shows ventricular pacing at 70 (lower rate limit) with atrial fibrillation
  - Pt sedated, pads positioned perpendicular to pacing system axis
  - Cardioversion successful; no a-fib…..
    - Heart rate is a little low
Successful Cardioversion?

Intermittent Loss of Ventricular Capture

Ensuring Capture

Pulse Width: Duration (msec)

Amplitude

Pacing Pulse

- Capture Energy = (voltage)^2 (pulse width) / Lead Impedance

- If there is significant potential for loss of capture (acidosis, electrolyte changes etc) consider increasing the pulse width and/or the amplitude

Management of CRMD for Surgery

- 72y male

- Biventricular pacemaker and ICD for CHF, low EF, SSS, and interventricular conduction delay

- Urgent case
  - MVA with multiple severe injuries including a mid-humerus fracture on the side of his CRMD
CRMD Management for Surgery

- Goals for all ICD for surgery
  - Disable the anti-tachycardia features
  - Disable rate response/adaptive features
  - Establish the need for pacing

Methods to disable anti-tachycardia therapies vary by manufacturer
- You will see a variety of methods during the workshop
In almost every circumstance changes to pacemaker or ICD settings is a two step process

- Get lots of chances to catch mistakes

Goals for the OR

- Goals for ICD/PM (CRMD)
  - Disable the ICD: Tachy mode OFF
  - Rate Response/Rate adaptive features—should be disabled for surgery
    - ie DDDR to DDD
    - Varies by manufacturer

- ICD is off
- Need to disable the sensor for rate adaptive features
ICD is off
Rate adaptive features off
DDD rate of 60
- Pacer dependant?
- Do we need to do anything to the pacing features?

Underlying Rhythm….such as it is

Historical Use…..
How to Proceed

- Patient is pacemaker dependant
  - Paced essentially 100%
  - Hemodynamically unstable underlying rhythm
  - What mode would be safest?
    - Nonsensing mode: DOO
      - Ensures patient is paced despite ESU "noise"
      - Little likelihood of competing with underlying rhythm (since there is not much of one)

- Small problem…it isn’t an option

Asynchrony Gone Awry

- Increasingly frequent issue of asynchronous modes being not available for permanent programming

Now What

- Available modes are programmable
  - Understand how a pacemaker senses allows us to “work-around” not having an asynchronous mode
  - Intrinsic activity has to reach a pre-specified threshold to be sensed by the pacemaker
  - If we adjust the threshold high enough, the pacemaker becomes essentially nonsensing
Sensing

Note that as the mV level increases, the pacemaker becomes LESS sensitive and fewer signals will be sensed.
Sensing

<table>
<thead>
<tr>
<th>Programmed sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0 mV</td>
</tr>
<tr>
<td>2.0 mV</td>
</tr>
<tr>
<td>1.0 mV</td>
</tr>
</tbody>
</table>

Note that as the mV level increases, the pacemaker becomes LESS sensitive and fewer signals will be sensed.

Almost DOOne

- Sensitivity is set to maximum value for both the atrium and ventricular leads (detecting the least amount of activity)
- Have "virtual" DOO at 60; but pacemaker mode is set to DDD

Noise Mode

- ESU noise filtering has been much improved
- With modern devices rarely will the pacemaker be inhibited with ESU
  - Unless ESU is very close to generator
- Noise mode
  - Detection of high frequency electrical signal and the device will mode switch - typically to asynchronous (DOO, VOO)
  - Can lead to irregular pacing
Is Virtual DOO at 60 ideal?

- Prolonged multi-service surgical effort
- Needs constant fluid resuscitation
  - Paced at 60; MAP borderline
- Wouldn’t a higher heart rate be more physiologic?
  - We can increase the rate to 90
  - Small problem…..

Uncooperative Pacing Rates

- In sensing modes the allowable LRL is conditional upon other parameters
  - This programmer will change other parameters to allow your desired rate; others will not
How Pacemakers See the World

- Series of programmable intervals (msec) between sensed or paced events
- A sensed or paced event resets the current timer and/or starts a new timer for the next interval
- These intervals include:
  - AA, VV, and AV intervals
  - Refractory intervals (no response to sensing)
- These intervals, primarily in DDD mode, can conflict, limiting maximum pacing rates

Nonsensing Modes

VOO or AOO
- Impulses are delivered at intervals determined by the lower rate limit (LRL) – “backup” rate
- Paced events will occur every 60,000/LRL msec

DOO
- Same as VOO and AOO, except….
- Ventricular impulses follow after the set AV delay (programmable)

Single Chamber Sensing Modes

AAI or VVI
- Intrinsic activity that exceeds the sensing threshold prior to the end of the AA or VV interval (EI) will reset the timer
  - Interval is 60,000/LRL msec
- Need to prevent inappropriate sensing of intrinsic (T wave) or pacing signals
- Add refractory period during which sensed activity will NOT reset the timer
VVI with VRP

If VRP is set too short, T wave sensing causes the timer to reset

Oversensing of T wave

DDD

- Two leads compound the problems
- Sensing in both chambers creates the chance of:
  - Crosstalk: Pacing of the other chamber is sensed as native activity in the sensing chamber
  - Far field sensing: native activity in other chamber is sensed as native activity in the sensing chamber
- Need multiple refractory periods (and completely nonsensing blanking periods) to prevent inappropriate sensing
Acronym Word Salad; Brace Yourself

- AVI: Atrioventricular interval
- VAI or AEI: ventricular-atrial interval or atrial escape interval
- ARP/VRP: atrial or ventricular refractory period
  - Nonsensing periods
- PVARP: post-ventricular atrial refractory period
  - Prevent atrial sensing of ventricular signals
- TARP: total atrial refractory period
  - AVI + PVARP

- LRL: lower rate limit
  - VV interval, AA interval, EI Escape Interval
- URL and MTR: Upper Rate Limit or Maximum Tracking Rate
  - Maximum possible paced ventricular rate due to atrial sensing
- Upper Sensor Rate: Highest rate allowed in response to biomechanical sensor (Rate Responsiveness)

Everyone Lost Yet?

- How does this affect the allowable heart rate???
- In patients with relatively long total atrial refractory period (TARP) the atrial alert period becomes very short as the LRL increases
**Everyone Lost Yet?**

- With a very short atrial alert period, it is impossible for the pacemaker to track an atrial rate faster than the LRL
  - Conflicts with the MTR
  - To increase the LRL, we would need to decrease the paced AV delay or PVARP
  - OR select a nonsensing mode if available

- What is most important: Be aware these intervals exist and that dual chamber devices are doing many things to maintain AV synchrony

**What if the pacer is too fast?**

- We generally worry about a pacemaker not pacing when we want it to
  - However......
- 32y female undergoing an LVOT myomectomy for hypertrophic cardiomyopathy
- Coming off CPB, patient has 3rd degree AV block with a ventricular rate of 32
  - Goals of temporary pacing?
    - Maintain AV synchrony
    - Maintain relatively low rate
Too Much of a Good Thing

- Temporary atrial and ventricular epicardial pacing leads placed
- DDD mode, rate 70, ventricular capture at 5 mA
  - Patient rate is now 130: As,Vp
  - Echo: SAM with severe mitral regurgitation
- Pacing well above our LRL

Maximum Tracking Rate

- Maximum Tracking Rate (or URL)
  - Maximum rate that the ventricle will be paced in response to native atrial activity (above LRL)
  - Goal is to maintain AV synchrony without producing high ventricular rates (a fib/flutter)
- MTR changed from 130 to 80
  - SAM and MR gone

Conclusion

- Hopefully this, as part of this workshop, has helped you to understand
  - How pacemakers sense electrical activity
  - What factors affect electrical capture
  - How timing cycles affect pacemaker function
  - Managing pacemaker functions to optimize hemodynamics in the operating room