Is This *#@!* Thing Working?
Pacemaker (and ICD) ECG and Telemetry Pitfalls

Wayne O. Adkisson, MD
adki0004@umn.edu
Disclosures

• I currently receive research support from Medtronic, Inc.

• I have been compensated by Medtronic, Inc for participating in Adverse Events Adjudication Committees (AEAC). There is a conflict of interest plan in place, administered by the University of Minnesota.
Objectives

• At the end of the presentation participants should be able to discuss
  1. How rhythm devices may fail
  2. How normal device function may mimic device failure
  3. When to worry
How Is the Device Supposed to Work?

The earliest pacemakers of the era of modern medicine had only one function:

THEY PACED THE HEART.
How Is the Device Supposed to Work?

If your patient was attached to a pacemaker that paced at 60 bpm that’s all it did – pace at 60 bpm.
What’s the Only Thing That Can Go Wrong?

FAIL TO PACE

What could cause this type of early pacemaker to fail to pace the heart?

1. No output
2. Output insufficient to capture the heart
The next innovation was the ability to sense intrinsic cardiac events.

Why?
To avoid unnecessary pacing.
The next innovation was the ability to sense intrinsic cardiac events.
Pacemaker is programmed in a VVI mode

Do the starred pacemaker spikes represent a failure of sensing?

Absolutely.
The next step in pacing was AV synchrony, dual-chamber pacing.

• A DDD pacemaker should:
  1. Pace in both chambers
  2. Sense in both chambers
  3. Sensed events will both inhibit and trigger pacemaker output

• That gives us four possible combinations of events:
  1. AS-VS
  2. AP-VS
  3. AS-VP
  4. AP-VP
Four possible combinations of dual-chamber pacing:
One more thing:

What the heck is this?

Biventricular pacing
AV synchrony is wonderful but what happened here?
We already saw an example of under sensing in a VVI pacemaker:
This is an example of *over* sensing in a DDD pacemaker.

This is an example of “cross-talk”. The ventricular lead senses the output from the atrial lead (starred) and ‘assumes’ what it sensed was an intrinsic QRS and withheld pacing.
Ways a pacemaker can fail:

1. **FAILURE TO PACE**
   - Tried to pace but couldn’t – failure of output or of capture
   - Didn’t attempt to pace when it should have

2. **FAILURE TO SENSE**
   - *Oversensing* results in *Underpacing*
   - *Undersensing* results in *Overpacing*
Back to “cross talk”

What if every atrial output was sensed as a “ventricular sensed” beat in a pacemaker-dependent patient?

Asystole
And that’s bad
Back to “cross talk”

What if ever atrial output was sensed as a “ventricular sensed” beat in a pacemaker-dependent patient? Asystole. And that’s bad
Too many pacemaker spikes? Failure to sense?
Failure to sense?

No, this is an example of Ventricular Safety Pace, our first ‘mimic’.

How can I tell?
The shortened AV delay.
Are there too many pacing spikes?
i.e. Is there under sensing? Is this a malfunction?

No. This is an example of fusion and pseudo-fusion.
Pacemaker fusion and pseudo-fusion

When the pacemaker ‘sees’ the ventricular depolarization may be after you see it on the ECG.
Pacemaker fusion and pseudo-fusion

- Sinus QRS
- Fusion Beat
- Paced QRS
- OR

Pseudofusion
Pacemaker fusion and pseudo-fusion

[Diagram of ECG waveforms showing pacemaker fusion and pseudo-fusion]
Too many spikes?
Too many spikes?

Biventricular stimulus delivered relatively late to “resynchronize” intrinsic ventricular event.

Lloyd et al.  Pacing Features That Mimic Malfunction
Journal of Cardiovascular Electrophysiology  Vol. 20, No. 4, April 2009
Too many spikes?

Cardiac resynchronization therapy only works if both ventricles are paced 100% of the time. Therefore, if the patient has a cardiac resynchronization therapy (CRT) you may see pacemaker spikes that appear to suggest a failure of sensing during:

- Atrial fibrillation
- Premature ventricular beats

This is not a malfunction. It is done in an attempt to maintain a high degree of CRT.
Too many spikes?

CRT devices are designed to **maximize** RV-LV pacing.

That’s CRT devices. What about standard, non-BiV, pacing?

In standard pacing the opposite is true. In standard pacing the goal is to **minimize** RV pacing.

This can lead to situations where it appears the device is failing to pace.
Minimizing RV pacing

The most common method of reducing RV pacing is by using a technique called *hysteresis* – “deficiency” or “lagging behind”.

To a physicist hysteresis is - *a retardation of an effect when the forces acting upon a body are changed*.

For pacing systems hysteresis refers to – *gradually extending the programmed AV interval*. 
Too many spikes?
Too many spikes?

Programmed max AV delay
200ms

AV search hysteresis
Delay 270 (AV+30%)
With pseudofusion

Termination due to failure to sense RV after 8 beats

Lloyd et al.  Pacing Features That Mimic Malfunction
What would have happened if the patient had complete heart block?
Too many spikes?

A Closer Look
Product Education at a glance

A-V Search Hysteresis in Dual-Chamber Pacemakers
Too few spikes?
i.e. Over sensing or failure to pace?
Too few spikes? i.e. Over sensing or failure to pace?
Too few spikes?
i.e. Over sensing or failure to pace?
Too few spikes? i.e. Over sensing or failure to pace?

Switch from AAI(R) to Temporary DDD(R) Mode
Ventricular support if loss of A-V conduction is persistent.

2 out of 4 Most Recent A-A Intervals with No Conducted VS Event
Too few spikes? i.e. Over sensing or failure to pace?
Failure to pace?

Often devices will have an algorithm intended to conserve battery life by adjusting the energy output based on automated determinations of the capture threshold.
Failure to pace?

Often devices will have an algorithm intended to conserve battery life by adjusting the energy output based on automated determinations of the capture threshold.

Red ovals are showing VCM test pulse and backup pulse at 110 ms
How else can these devices confuse me?

The lower rate is supposed to be 60 bpm and the heart rate is slower than that.

Confirm that the rate that the ECG reports is correct.
Is it dark outside?
Is the patient asleep?
How else can these devices confuse me?

The lower rate is supposed to be 60 bpm and the heart rate is faster than that.

Confirm that the rate that the ECG reports is correct. Is the heart rate fast due to pacing? Is rate response programmed on? Is the patient having atrial fibrillation or frequent atrial ectopic beats?
How else can these devices confuse me?

The lower rate is supposed to be 60 bpm and the heart rate is faster than that. Is the patient having atrial fibrillation or frequent atrial ectopic beats?

Many devices have features that attempt to avoid pauses in the atrial rhythm in an attempt to minimize atrial fibrillation or ‘smooth’ out the ventricular rate either during AF or when AF terminates.
When NOT to worry?

• If the *pacing* rate varies from what the programmed rate is ‘supposed’ to be.
• Seeing occasional pacemaker spikes on top of, or inside, PVCs.
• Seeing occasional pacemaker spikes in the QRS during atrial fibrillation *if* the device is a CRT device.
• Even if there is true failure of sensing resulting in unneeded pacing that is rarely an emergency.
When NOT to worry?

• Even if there is true failure of sensing resulting in unneeded pacing that is rarely an emergency.

**EXCEPT WHEN IT RESULTS IN THIS:**
When NOT to worry?

• Failure of capture when it is:
  • Followed by pacing with a short AV interval
  • Occurs at fixed intervals – 1 min, 2 min, 4 min; every 12 hours; etc
When **TO** worry?

- The pause in ventricular pacing is more than twice the programmed lower rate. If the lower rate is 60 bpm, you shouldn’t see a failure of pacing that causes the *true (not computer reported)* heart rate to be less than 30 bpm.
The pause in ventricular pacing is more than twice the programmed lower rate. If the lower rate is 60 bpm, you shouldn’t see a failure of pacing that causes the true (not computer reported) heart rate to be less than 30 bpm.

The blue bars indicate the current lower interval. The red bars are twice the lower interval or half the lower rate. There is a V paced beat at less than half the lower rate and the AV interval on the paced beat is short.  

This is a case of DON’T worry.
When **TO** worry?

- ● = P wave
- ★★ = paced QRS complexes
- ★☆ = pacemaker spikes
- ↓ = ventricular escape beats
- ↓ = conducted beat

Is this Managed Ventricular Pacing? **NO!**
When **TO** worry?

Is this a type of automated threshold testing? **NO, again.**

Threshold testing includes a back-up pulse to ensure capture.
When **TO** worry?

Threshold testing includes a back-up pulse to ensure capture.
Conclusions - I

• Cardiac Implantable Electronic Devices (CIEDs) are complicated.
• If the patient is being paced the level of concern is immediately lower.
• Pacemaker output on time with or shortly after the QRS (or PVC) is usually normal.
• Pacemaker output during atrial fibrillation is usually normal if the device is one that provides cardiac resynchronization therapy.
• In general, abnormal sensing is less of a concern.
• A rare missing pacemaker output, esp if it occurs in a repeating pattern, is usually not a problem.
Conclusions II

• Ventricular output (‘spike’) without a QRS or evidence of back-up output is worrisome.

• If you aren’t sure, call someone.

St. Jude Medical Toll-free number: +1-800-722-3774

BIOTRONIK, Inc. Tel +1 800-547-0394

Medtronic, Inc Clinician Services & Technical Support (800) 328-0810

Boston Scientific Cardiac Rhythm Support (800) CARDIAC (1-800-227-3422)