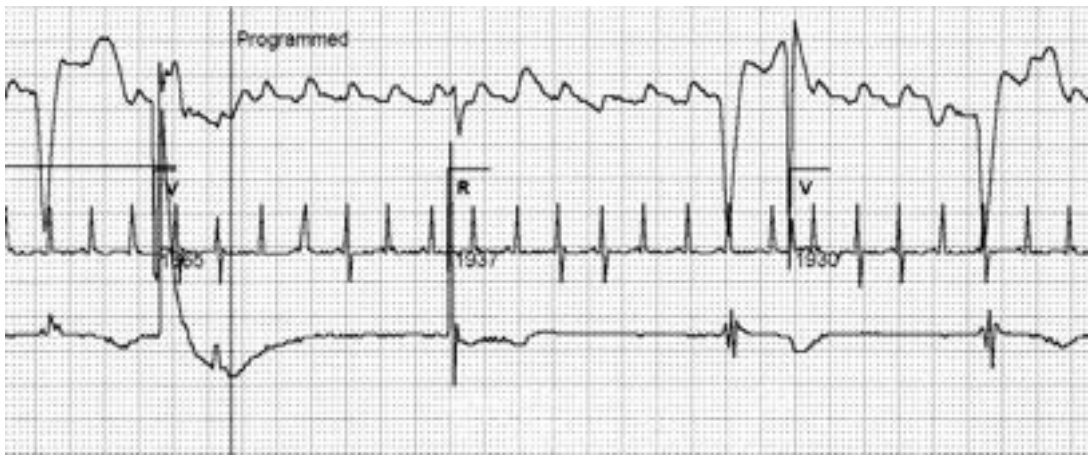
Paced ECG Interpretation: A Case-Based Approach

David Hayes, MD

BIOTRONIK

1



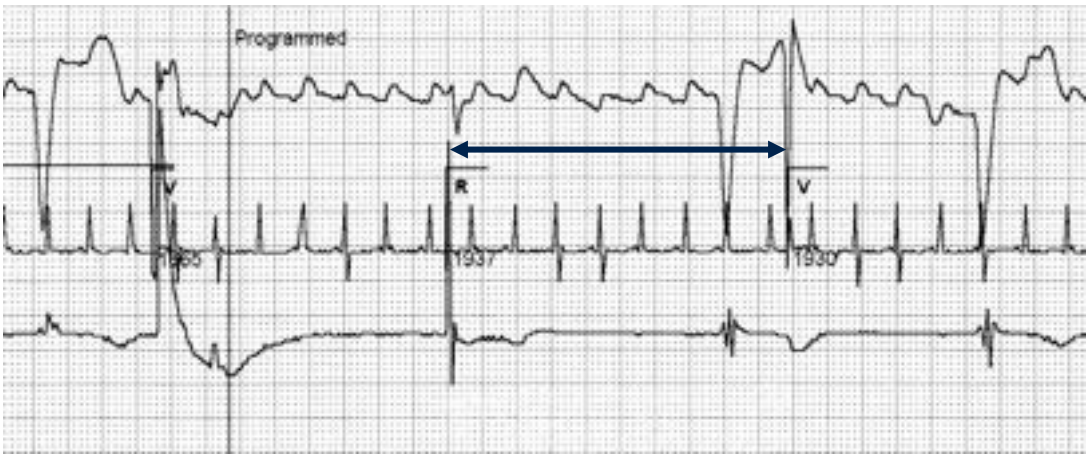
What would correct the observed abnormality:

1. Increase V pacing output
2. Make V more sensitive
3. Increase V pacing rate
4. Lengthen the AV interval

Pay attention to what the device tells you, but pay equal attention to what it "doesn't" tell you!

BIOTRONIK

2



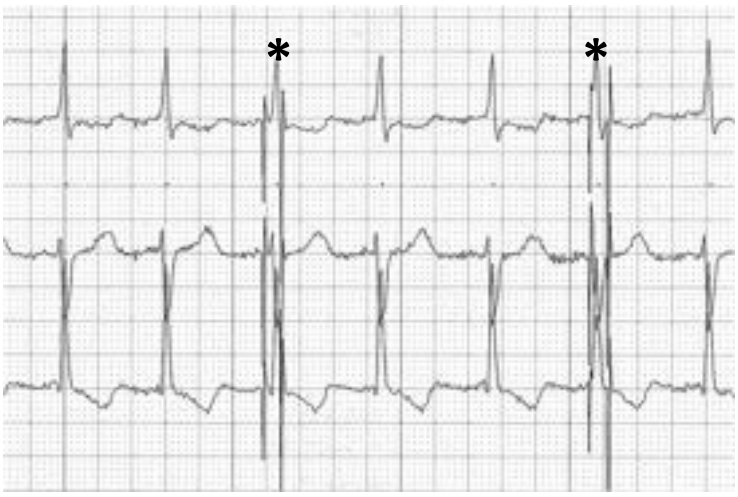
What would correct the observed abnormality:

1. Increase V pacing output
2. Make V more sensitive
3. Increase V pacing rate
4. Lengthen the AV interval

Pay attention to what the device tells you, but pay equal attention to what it "doesn't" tell you!

BIOTRONIK

3



The programmed P-AVI is 240 ms. Labeled QRS complex (*) occurs in:

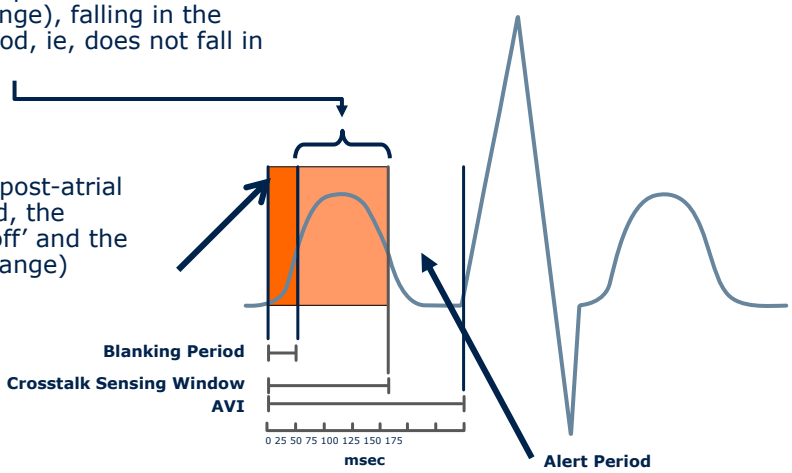
1. Crosstalk sensing window
2. Post-Atrial Ventricular blanking period
3. Alert window

BIOTRONIK

4

If the event occurs in the crosstalk sensing window is sensed, the V is paced after an abbreviated AVI (light orange), falling in the physiologic refractory period, ie, does not fall in the vulnerable period

If the event occurs in the post-atrial ventricular blanking period, the sensing circuit is turned 'off' and the event is not seen (dark orange)

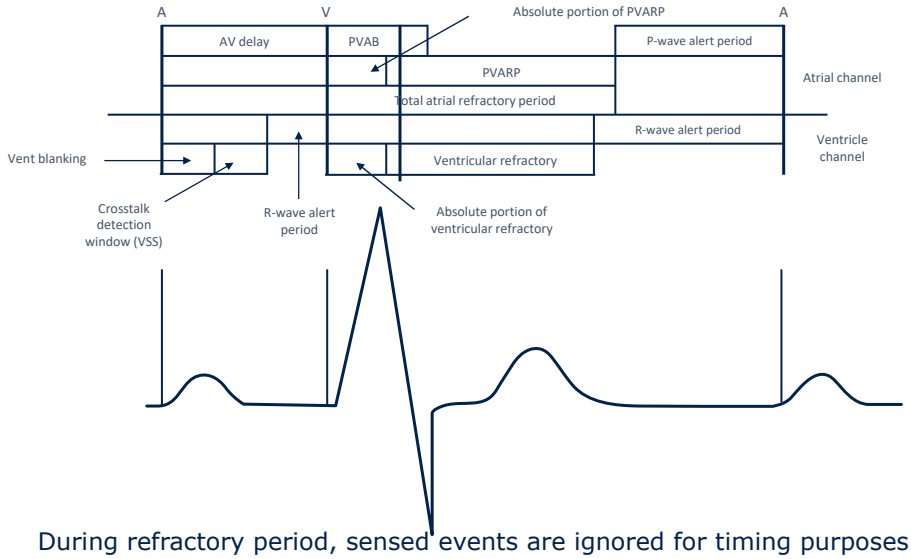


If sensing occurs during the 'alert' period, ventricular output is inhibited.

5

BIOTRONIK

5



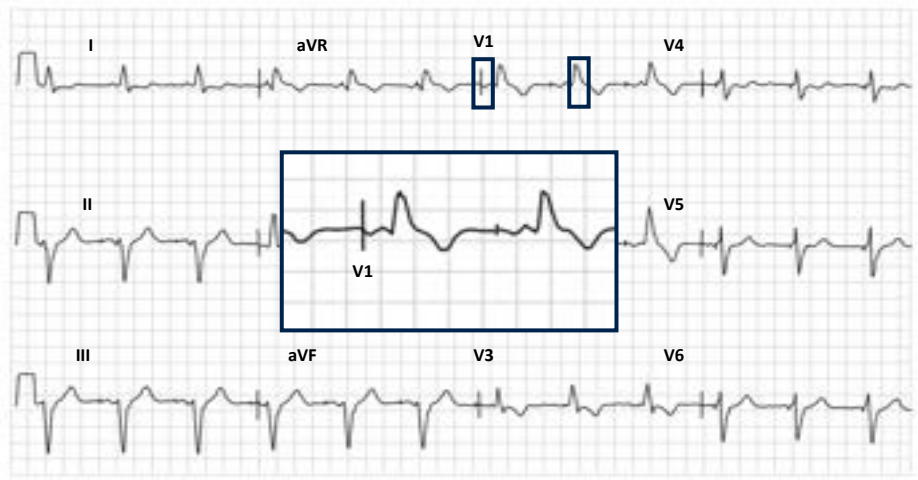
During refractory period, sensed events are ignored for timing purposes

During BP, sensing amplifier is turned off and sensing cannot take place

Pattern of refractory and BPs play a critical role in determining the beat-to-beat behavior of the pacemaker

BIOTRONIK

6



Inspect for patterns

ECG following dual-chamber pacemaker implant suggests?

BIOTRONIK

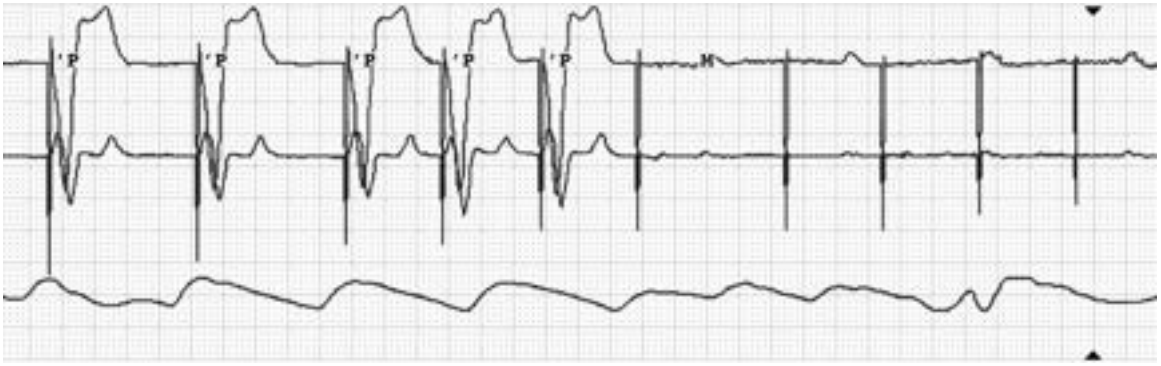
7

83-Year-Old Male with Increasing Dyspnea on Exertion

- History of coronary artery disease status post stent placement ×2
- Third-degree AV block, status post pacemaker placement 8 years earlier (Medtronic dual-chamber Kappa KDR 901, atrial lead 5568, ventricular lead 4076)
- Programmed DDDR, lower rate 60 bpm, upper rate 130 bpm

BIOTRONIK

8

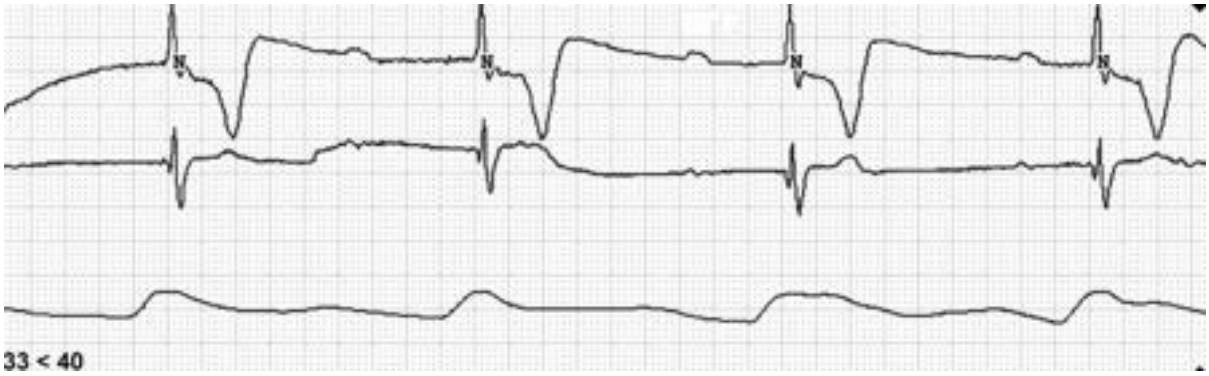


Prior to pacemaker interrogation, rhythm was ventricular pacing at 65 bpm. This tracing obtained when the programming wand is placed on the pacemaker. Tracing can be explained by:

1. Conductor coil completely fractured
2. ERI (Elective replacement indicator)
3. EOS (End of service)
4. Ventricular lead loose in header

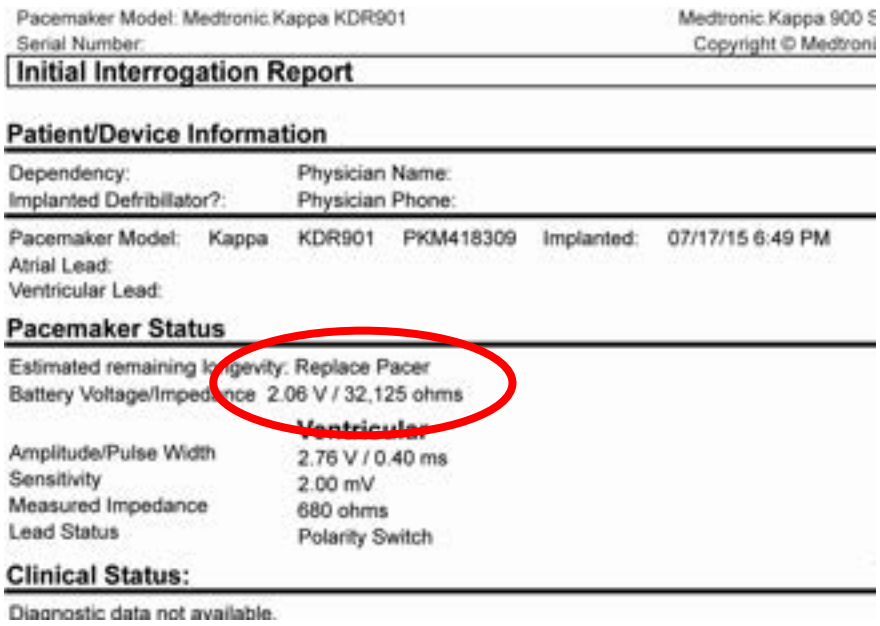
BIOTRONIK

9



BIOTRONIK

10



Pacemaker Model: Medtronic Kappa KDR901
Serial Number:
Medtronic Kappa 900 S
Copyright © Medtroni

Initial Interrogation Report

Patient/Device Information

Dependency:	Physician Name:
Implanted Defibrillator?:	Physician Phone:

Pacemaker Model: Kappa KDR901 PKM418309 Implanted: 07/17/15 6:49 PM
Atrial Lead:
Ventricular Lead:

Pacemaker Status

Estimated remaining longevity: Replace Pacer
Battery Voltage/Impedance: 2.06 V / 32,125 ohms

	Ventricular
Amplitude/Pulse Width	2.76 V / 0.40 ms
Sensitivity	2.00 mV
Measured Impedance	680 ohms
Lead Status	Polarity Switch

Clinical Status:

Diagnostic data not available.

BIOTRONIK

11

83-Year-Old Male with Increasing Dyspnea on Exertion

- Battery voltage of 2.06 is compatible with EOS (EOL), at which point no reliable pacing occurs and diagnostic information is unreliable. It is difficult for manufacturers to give a single specific voltage at which EOS occurs because of multiple variables that may be present
- For this old Medtronic device, the company states that a measured battery voltage of 2.2 is a reasonable value to consider for EOS, but some devices may reach EOS at a higher value, and some have been identified at <2.0 V before
- Battery impedance is often ignored. In this case, the battery impedance was 32,125 ohms. As a rule, if battery impedance is ≥ 10,000 ohms, there should be a heightened concern that battery is approaching EOS. If battery impedance is ≥ 20,000 ohms, there is a high likelihood the device is at or near EOS.

BIOTRONIK

12

Pacemaker Troubleshooting: A case-based approach

David Hayes, MD

BIOTRONIK

13

Goals:

1. Address one of the most commonly confusing concepts in brady pacing
2. How to approach an unknown – beat by beat
3. Moving from a 'generic' diagnosis to a specific etiology
4. To be specific with terminology

BIOTRONIK

14

Device Electrocardiography

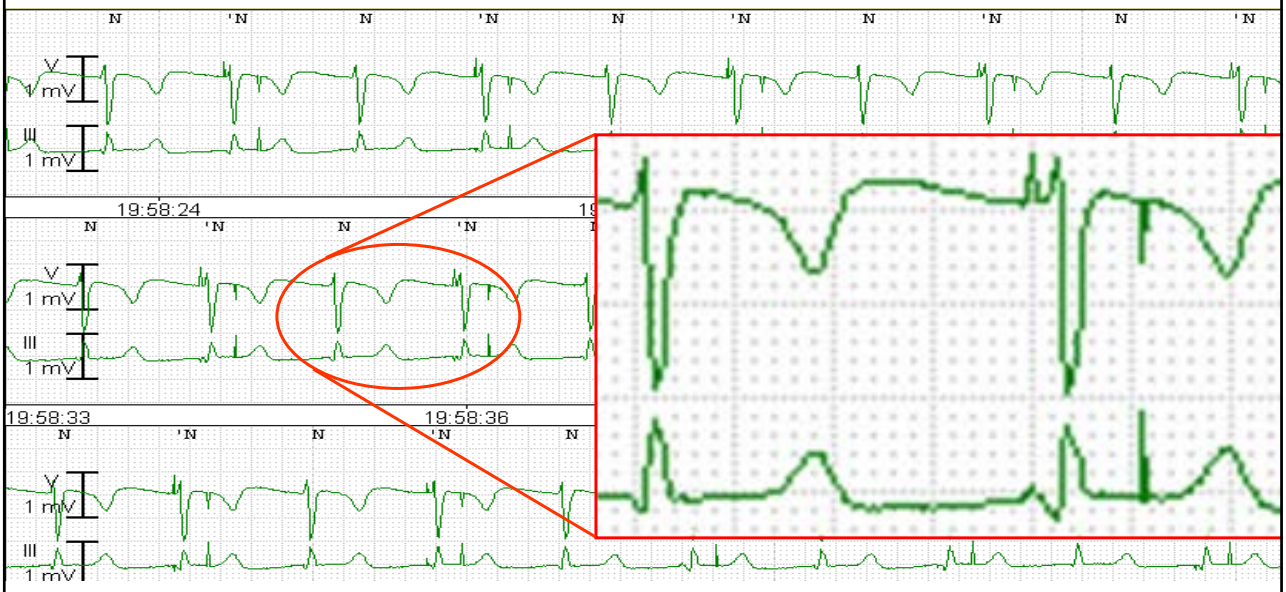
Need to know and understand differential diagnoses of each of the following:

- Failure to sense
- Failure to capture
- Failure to output/oversensing
- Rate variations
- Crosstalk / safety pacing

BIOTRONIK

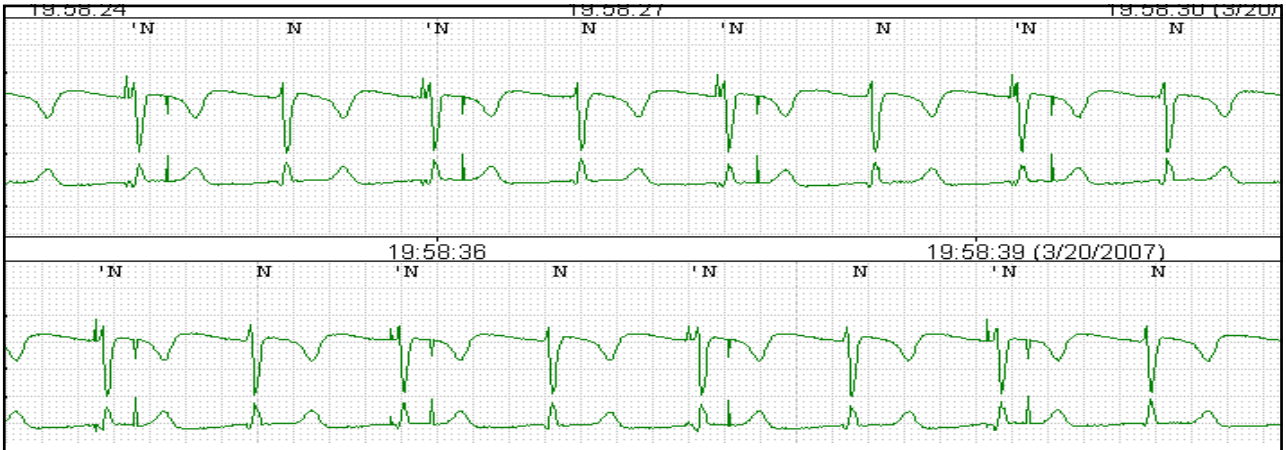
15

DDDR 60-140, AV delay 220 msec, V-A interval (AEI) @ LRL: 780 ms



BIOTRONIK

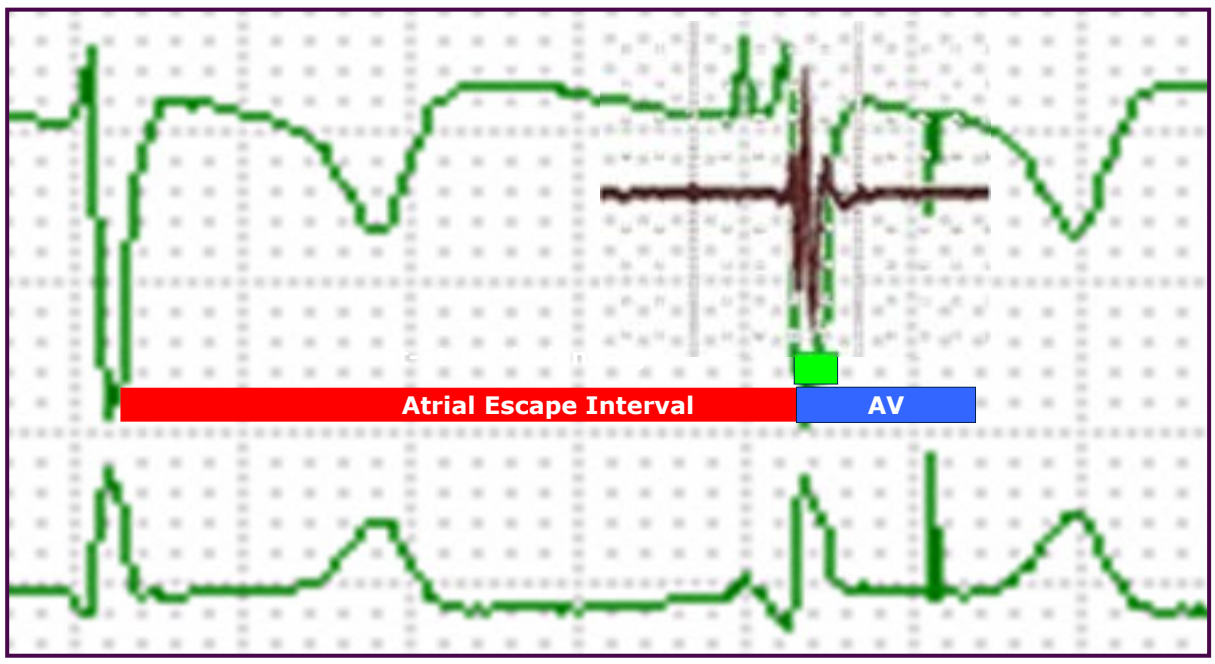
16



DDDR 60-140, AV interval 220 msec

When pacing activity is present, QRS occurs in:
1. Post-atrial Ventricular blanking period
2. Crosstalk sensing window
3. Alert period

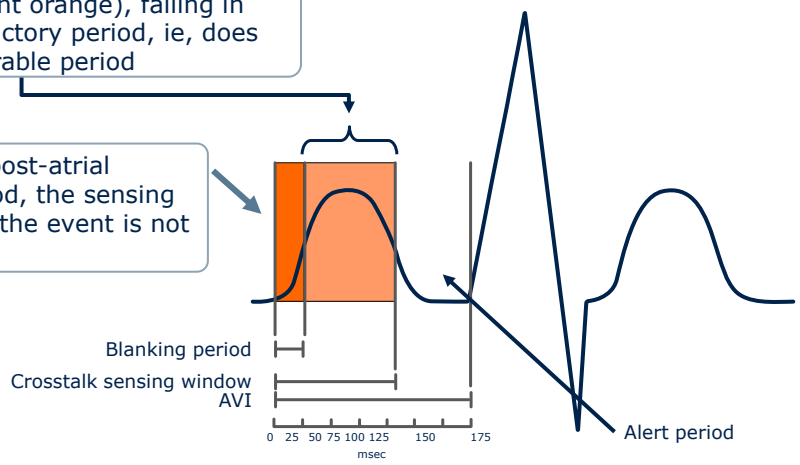
17



18

If the event occurs in the crosstalk sensing window is sensed, the V is paced after an abbreviated AVI (light orange), falling in the physiologic refractory period, ie, does not fall in the vulnerable period

If thevent occurs in the post-atrial ventricular blanking period, the sensing circuit is turned 'off' and the event is not seen (dark orange)



If sensing occurs during the 'alert' period, ventricular output is inhibited.

19

Crosstalk

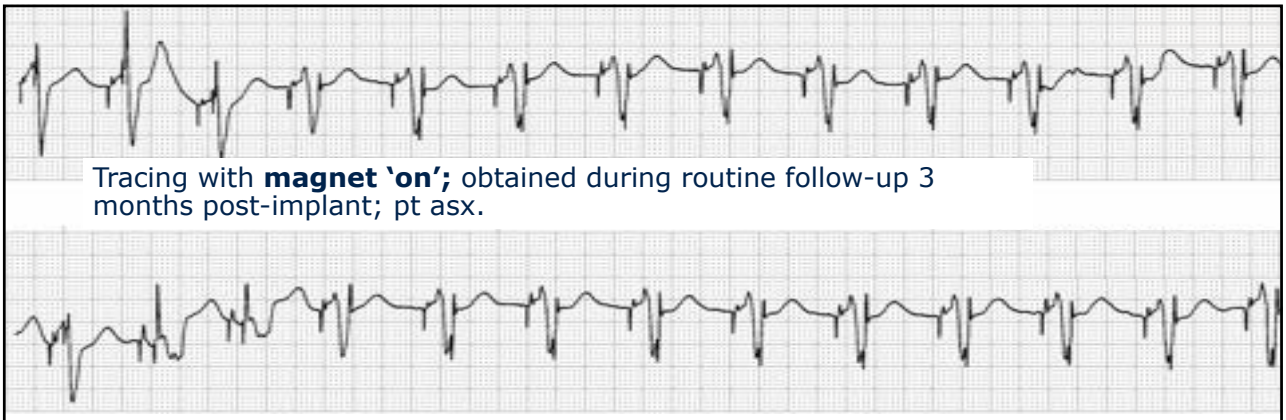
VSP doesn't eliminate crosstalk – it prevents asystole

- Unwanted detection in one channel of a signal from another channel
- Most common: afterpotential from atrial output sensed by V channel and resets VA interval
- AV crosstalk easier to avoid with bipolar sensing configuration, less sensitive to far-field signals

May be eliminated by:

- ↑ the blanking period (so that ventricular sensing resumes later)
- ↓ the atrial stimulus voltage or duration (if adequate safety margin can be maintained)
- Make ventricular channel less sensitive

20



Tracing with **magnet 'on';** obtained during routine follow-up 3 months post-implant; pt asx.

Without any interim procedures, the difference between post-implant tracing and 3 mo. magnet tracing could only be due to:

21 FEBRUARY 20, 2024 BIOTRONIK

21

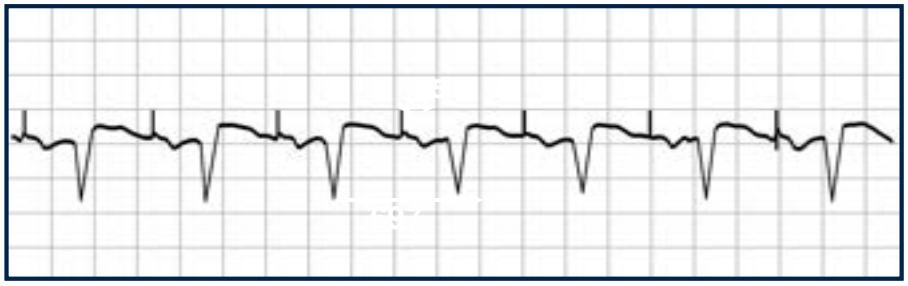
Onset of magnet tracing now shown. Without any prior history, this tracing would exclude:
1. Atrial lead dislodgement
2. Lead reversal in connector block – *transient evidence of normal fx*

22 FEBRUARY 20, 2024 BIOTRONIK

22

Pacemaker programmed to DDI 86 ppm; AVI = 165 ms; PVAB = 13 ms. Referred with ? of abnormal PM function

Note – all A activity is paced & all V activity is intrinsic



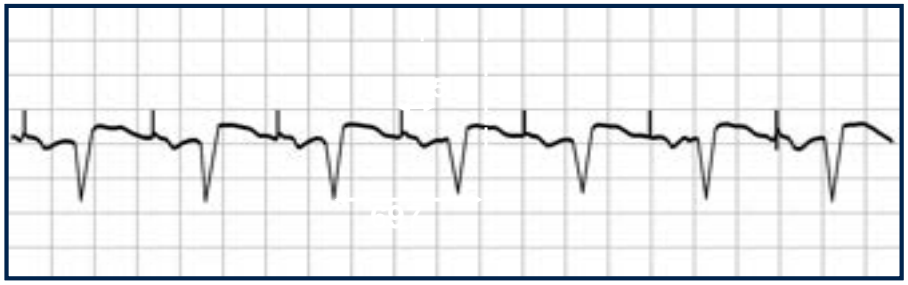
The most appropriate approach would be:

1. Lengthen PVARP
2. Lengthen PVAB
3. Lengthen AVI
4. Lower the upper rate limit

BIOTRONIK

23

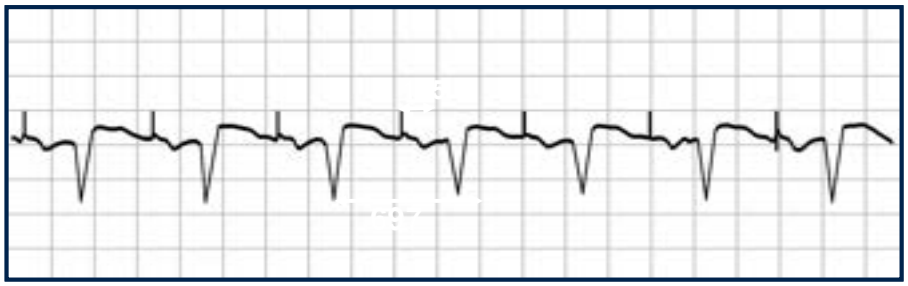
Determining the VA Interval



- VV = AV + VA
- VV - AV = VA
- Programmed VV = 86 ppm = 697 ms
- AV = 165 ms
- 697 - 165 = 532 ms (VA)

BIOTRONIK

24



- Measured RR = 575 ms = VV
- 575 - 532 (VA) = 43 ms (AV)
- Point of sensing after atrial output is 43 ms
- Blanking period of > 43 ms should avoid crosstalk

BIOTRONIK

25

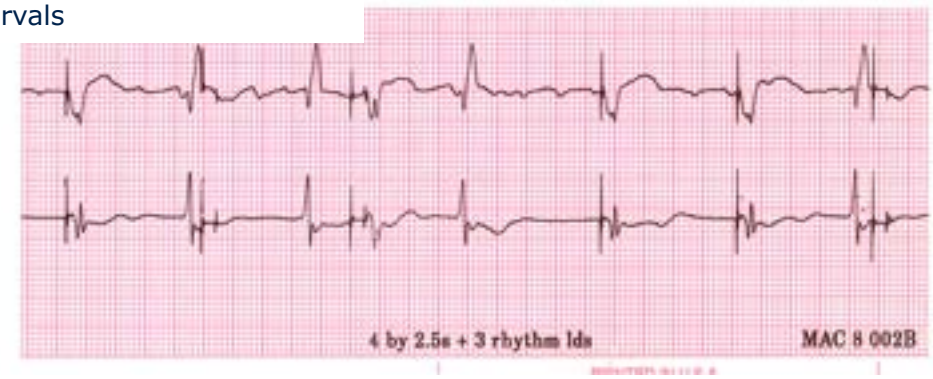
After lengthening the ventricular blanking period to > 43 ms the tracing is compatible with programming, i.e. rate 86 bpm, AVI 165 ms

BIOTRONIK

26

Based on your ECG diagnosis you would:

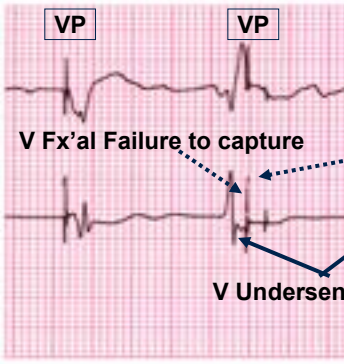
Always ask:
1. Single or dual
2. Underlying rhythm
3. Obvious pacing mode
4. Measurable intervals



BIOTRONIK

27

1. Make ventricular channel more



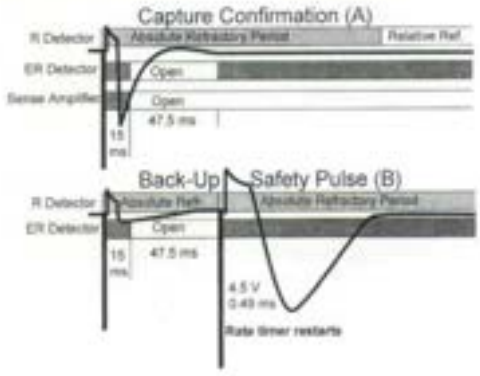
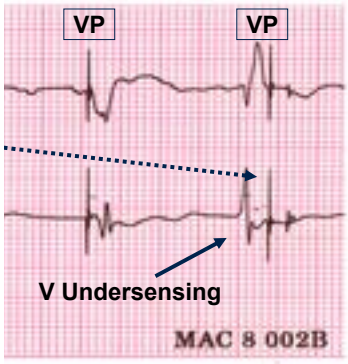


Figure 1. *A. Capture confirmation based on ER detection and B. Loss of capture results in a backup safety pulse (4.5 V/0.49 ms) emitted 62.5 ms after the normal pulse.*



BIOTRONIK

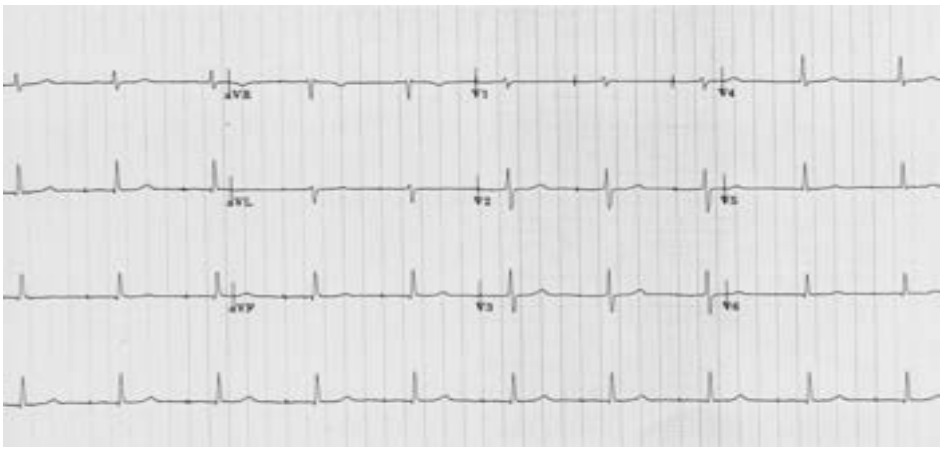
28

- The abnormality that must first be recognized is intermittent ventricular undersensing. However, the presence of 'Autocapture' with backup pulses results in a confusing tracing. Furthermore, functional failure to capture may make it even more confounding.
- The Autocapture backup pulse is delivered at approximately 80 ms after the initial output. The appearance is that of intermittent loss of capture followed by backup pulses that do capture as long as the myocardium is not refractory. The device times off of these backup pulses, resulting in irregular intervals between captured complexes.
- Once a diagnosis of intermittent ventricular undersensing is made, the only possible correct answer of those listed is to correct the fundamental problem by making the ventricular channel more sensitive.

BIOTRONIK

29

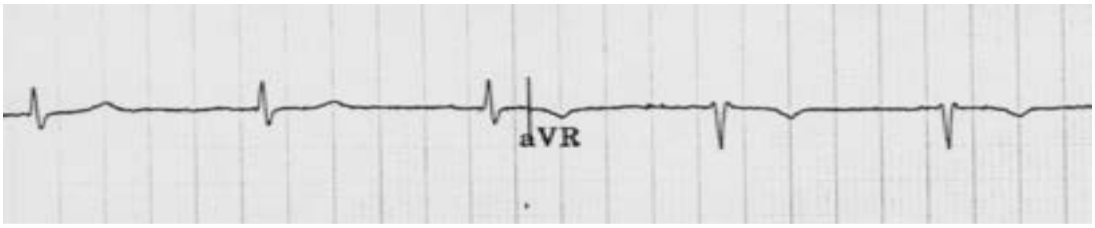
Routine visit 3 months post DDDR implant; programmed DDD mode AVI-P – 175 ms; AVI-S – 150 ms



BIOTRONIK

30

Routine visit 3 months post DDDR implant; programmed DDD mode AVI-P – 175 ms; AVI-S – 150 ms



Your initial observation leads you to which of the following general diagnostic categories?
1. Ventricular failure to capture
2. Ventricular failure to output
3. Ventricular true undersensing
4. Ventricular functional undersensing

BIOTRONIK

31

In the clinic with the patient, which of the following would help narrow your differential diagnosis?
1. Program to AAI
2. Magnet application
3. Disable rate-adaptive pacing
4. Lengthen the AVI

BIOTRONIK

32

Magnet Application

BIOTRONIK

33

Measured Data

Ventricular

• Pulse amplitude	4.1 V
• Pulse current	.2 mA
• Pulse energy	0
• Pulse charge	0
• Impedance	> 3000

Atrial

• Pulse amplitude	3.8V
• Pulse current	9.6 mA
• Pulse energy	12
• Pulse charge	4
• Impedance	398

BIOTRONIK

34

BIOTRONIK

35

Which of the following could explain the abnormality noted?

1. Exit block
2. Ventricular lead dislodgement
3. Loose set screw
4. Ventricular oversensing

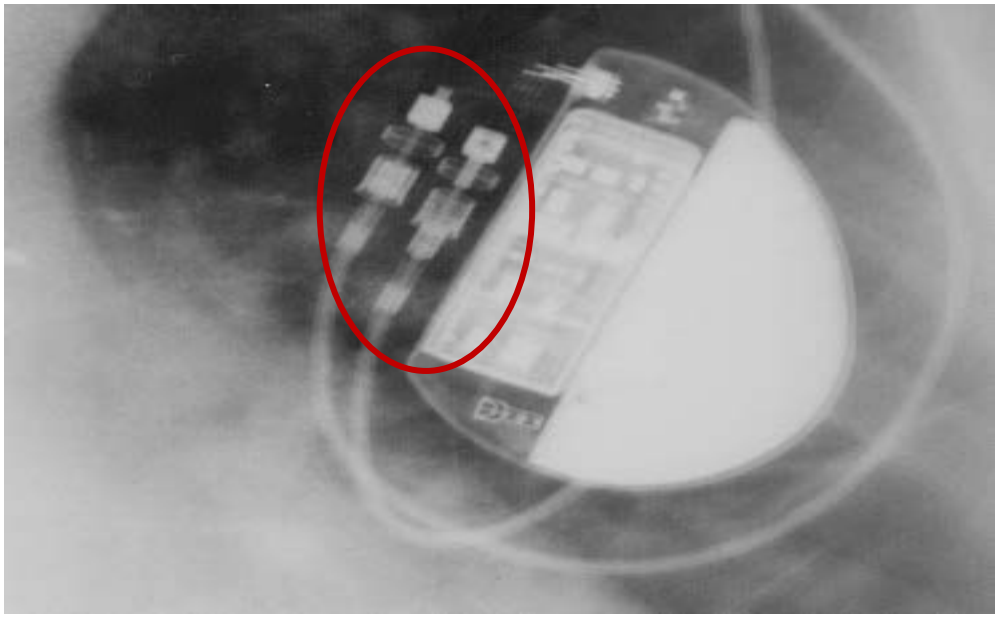
BIOTRONIK

36

1. Exit block – *would result in failure to capture NOT failure to output and artifacts would have been present with magnet*
2. Ventricular lead dislodgement - *would result in failure to capture NOT failure to output and artifacts would have been present with magnet*
3. **Loose set screw**
4. Ventricular oversensing – *Although this could present as failure to output or inhibition, it would be unlikely to be as regular as noted on the non-magnet tracing and magnet would have forced pacing artifacts*

BIOTRONIK

37



BIOTRONIK

38

Rhythm strip obtained the afternoon after the pacemaker implant. Patient asymptomatic. Generic diagnosis?

1. Failure to capture
2. Failure to output
3. Undersensing
4. Rate variation

BIOTRONIK

39

Failure to Output

- Oversensing
  - Crosstalk
  - EMI
- Battery failure
- Circuit failure
- Lead fracture
- Internal insulation failure
- Loose set-screw
- Incompatible lead/header
- Pseudomalfunction, i.e. device nuance

BIOTRONIK

40

If intervals are regular and baseline steady, less likely to be oversensing.

BIOTRONIK

41

Failure to Output

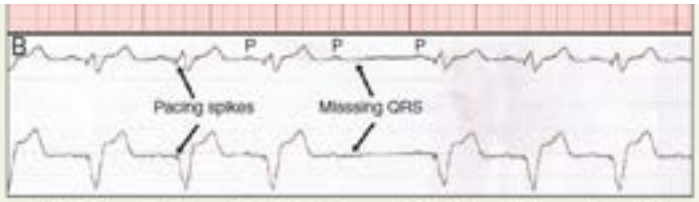
- ~~Oversensing~~
  - ~~Crosstalk~~
  - ~~EMI~~
- ~~Battery failure~~
- ~~Circuit failure~~
- ~~Lead fracture~~
- ~~Internal insulation failure~~
- ~~Loose set-screw~~
- ~~Incompatible lead/header~~
- Pseudomalfunction, i.e. device nuance

BIOTRONIK

42

Engineering explanation:

- An occasional 'dropped VP' is specific to DDDR and DDD modes during atrial tracking (AS–VP) and may occur intermittently on an hour and 30 s schedule.
- A false ventricular sense may occur due to residual electrical disturbance on the ventricular sense amplifier and may be created by turning on/off the diagnostic EGM amplifiers during reference EGM collection. The scheduled reference EGM collection is synchronized to sensing and pacing events so that the device's sense amplifiers are blanked. However, there is no ventricular blanking following an AS event, which makes this phenomenon possible. The collection of reference EGM is non-programmable and is always active in the device.



Mehra, et al. Europace e-Pub April 16, 2015

BIOTRONIK

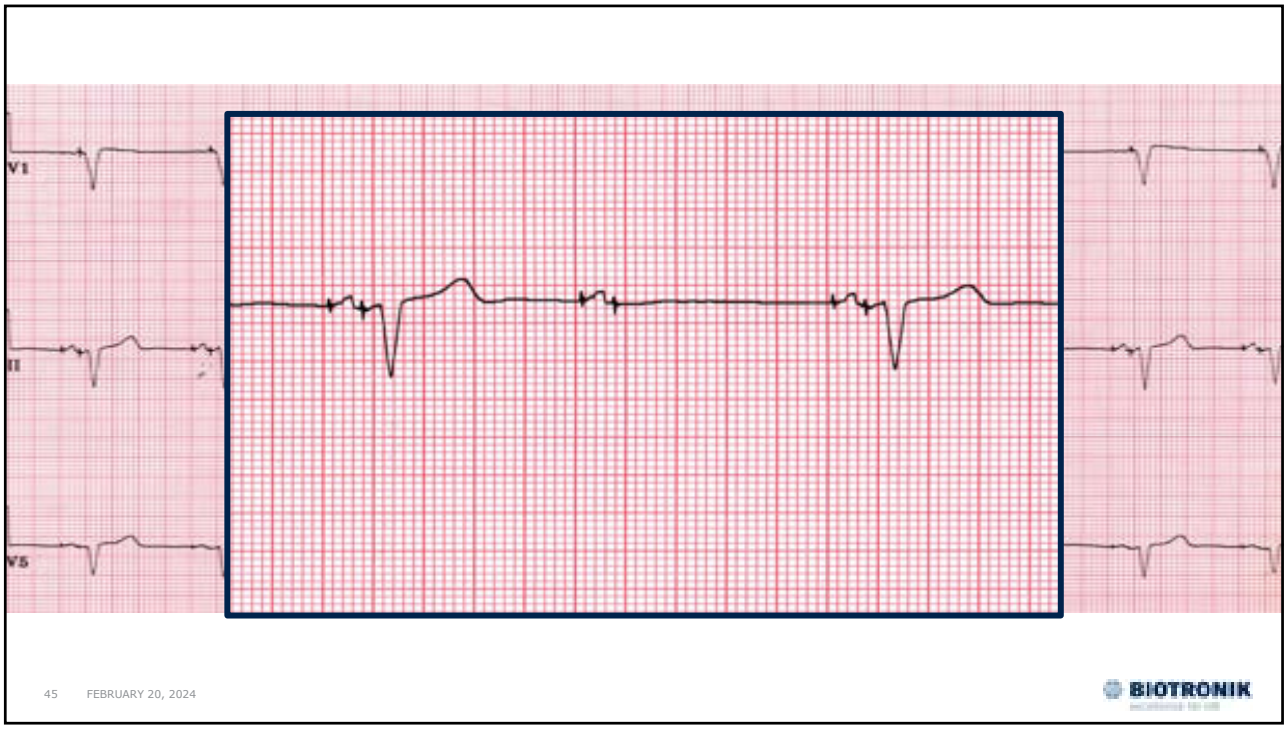
43

16 yo female with intermittent CHB

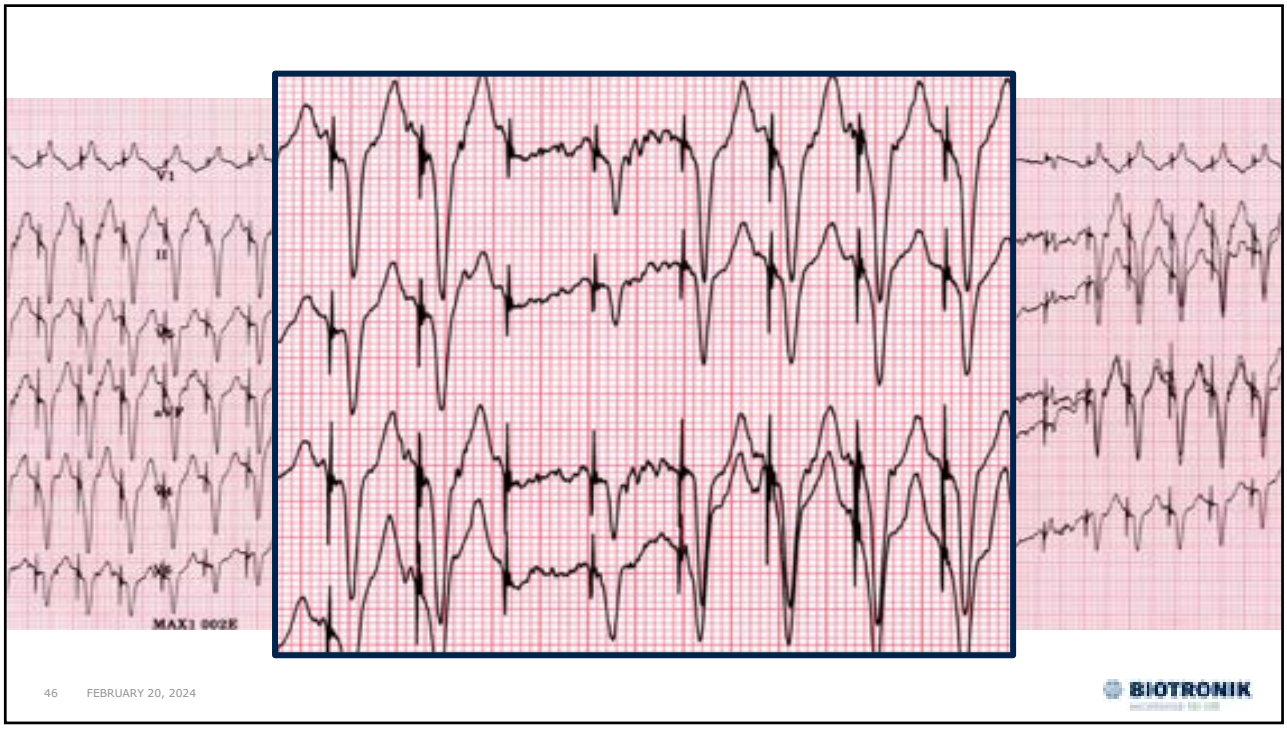
- Paced 2 years earlier for CHB
- Local basketball star--good chance of getting college scholarship to play
- Presents with intermittent exertional lightheadedness

BIOTRONIK

44


V1
II
V5
45 FEBRUARY 20, 2024
BIOTRONIK

45


V1
II
46 FEBRUARY 20, 2024
BIOTRONIK

46

47

You would:

1. Observe
2. Holter to determine frequency of abnormality
3. Replace ventricular lead

What advice would you give regarding activities?

48

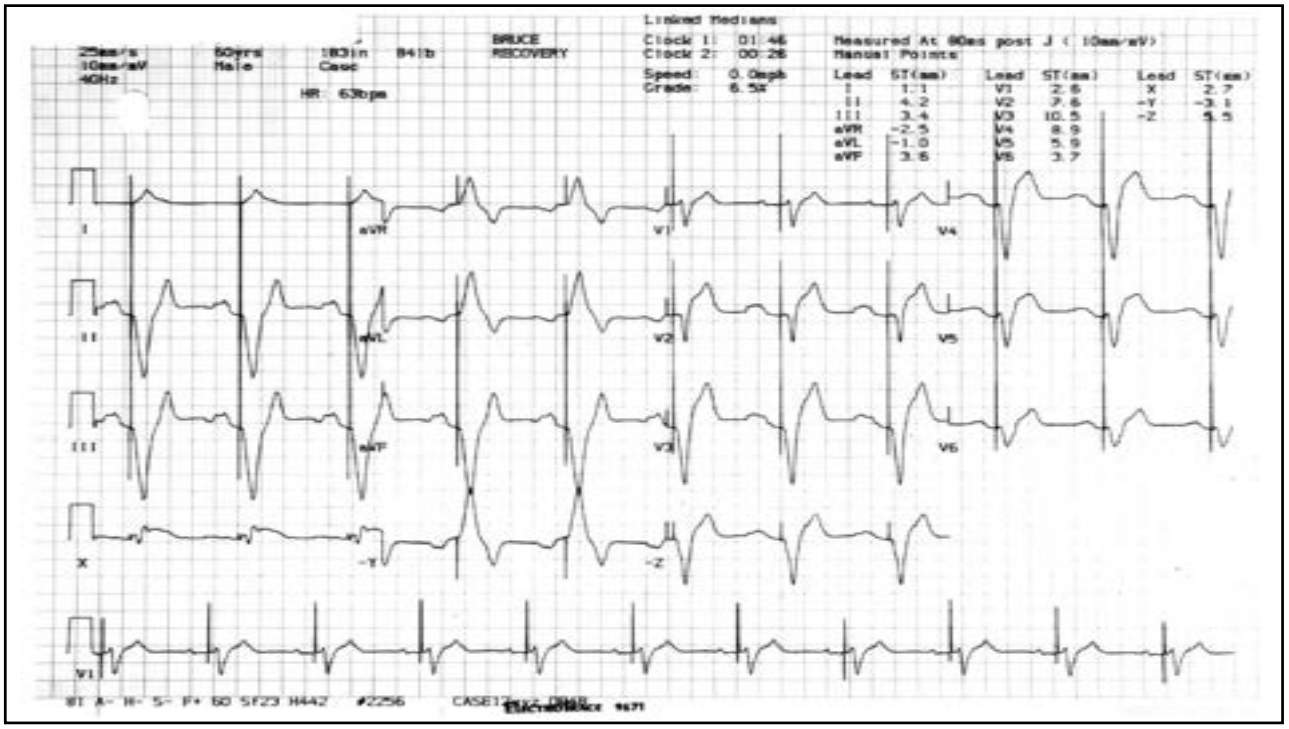
Sudden Fatigue During Exertion

You would perform:

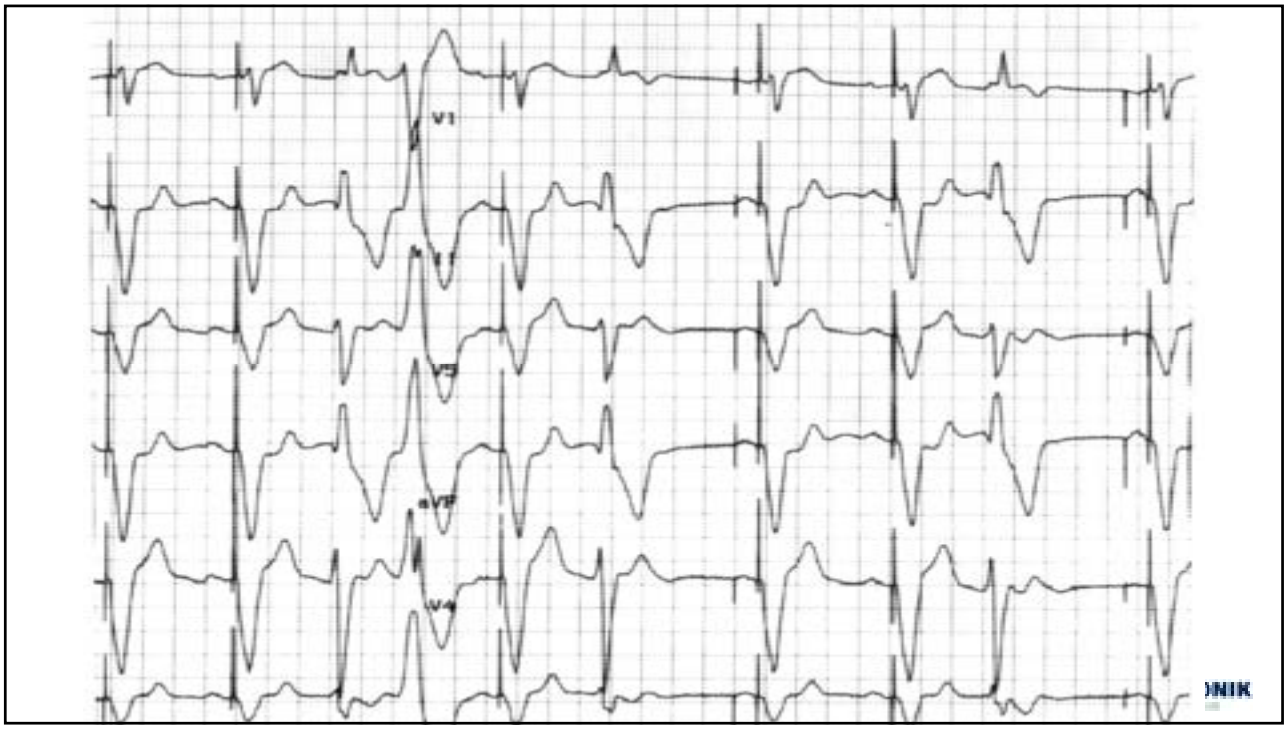
1. V-stim
2. Tilt-table testing
3. Exercise test
4. Coronary angiogram

BIOTRONIK

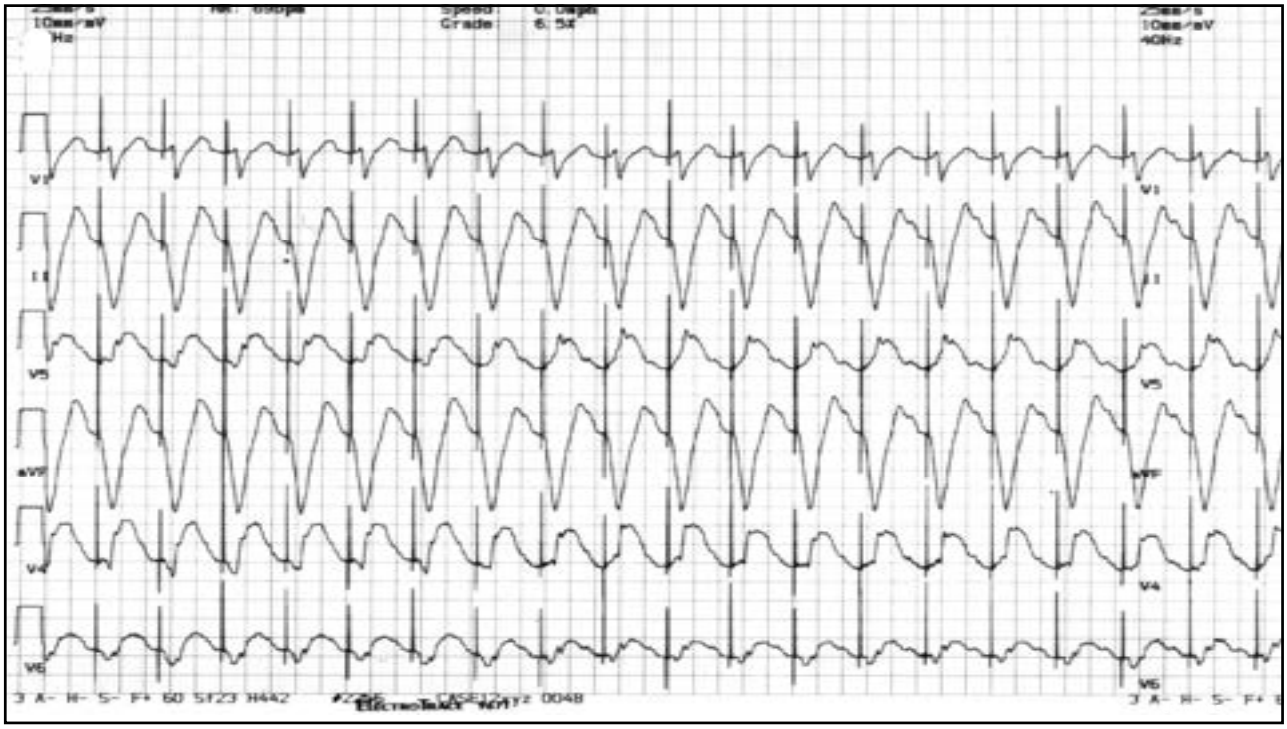
49



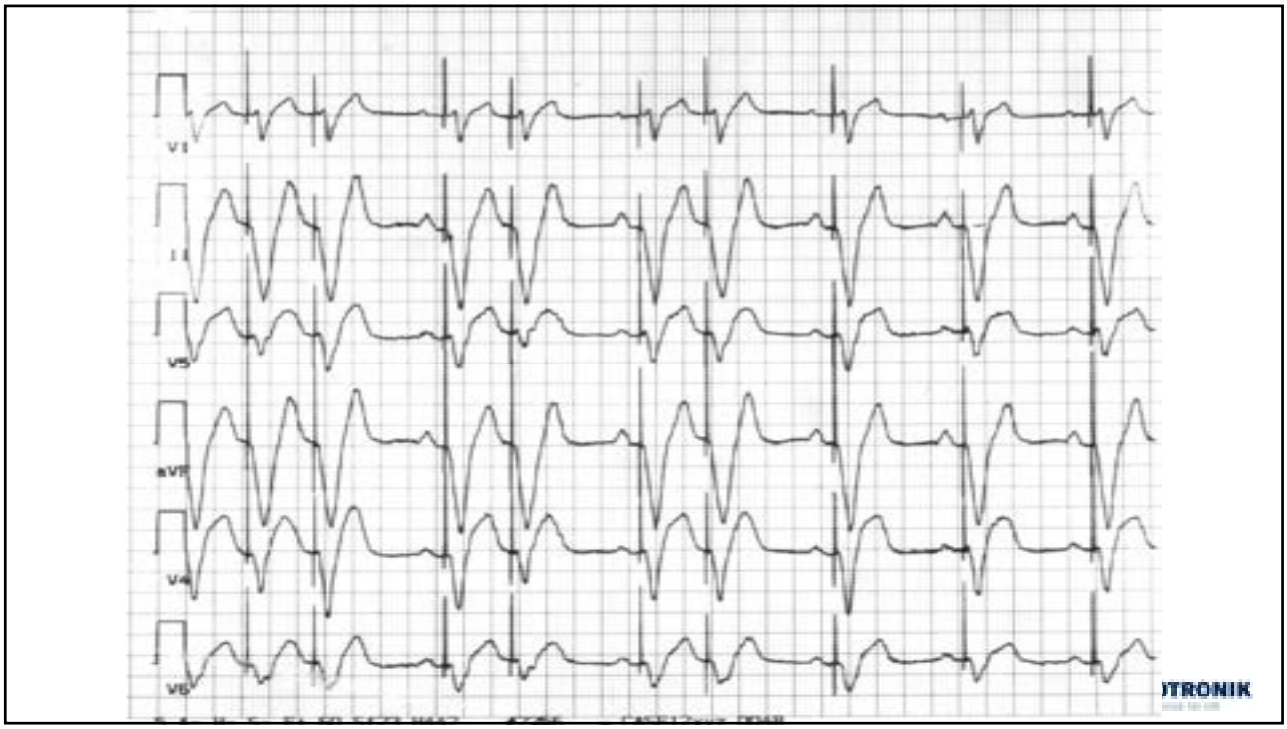
50



51



52



53

54

Approach to Paced ECG in Clinic or on Exam

- Carefully assess the clinical question
  - Determine important components
  - Ignore extraneous information
- Utilize all diagnostics available
- Assess tracing left to right and also horizontally
- Make 'generic' diagnosis
- Consider differential diagnosis for generic etiology

BIOTRONIK