ECG WORKBOOK
Dual Chamber Pacemaker ECG Interpretations
DUAL CHAMBER ECG WORKBOOK

How To Use This Book:

This dual chamber ECG workbook is divided into two parts. The first part displays the ECG with a notation of its programmed parameters. The second part again reproduces the ECG and presents an interpretation along with possible causes and suggested corrective procedures.

Note that in some cases there may be more than one plausible explanation for the ECG with the limited information presented. As you go through each rhythm think about the following:

[] what is the atrial rhythm?
[] what is the ventricular rhythm?
[] is there proper atrial and ventricular sensing?
[] is there proper atrial and ventricular capture?
[] what additional information would you need for a good differential diagnosis?
[] what additional testing would you want to perform on this patient?

For each of the rhythms give your interpretation, what you think are the possible causes and what corrective procedures if any you would perform.

ECG NOTATION

D D D / 60 / 150 / 125 / 225

- PVARP measured in milliseconds
  (Post Vent. Atrial Refrac. Period)
- Upper Rate measured in ppm
- A V interval measured in milliseconds
- Lower Rate measured in ppm
- Mode as programmed according to ICHD code
Dual Chamber Pacemaker
ECG Interpretations

ANSWER KEY
INTERMITTENT ATRIAL UNDERSENSING

This ECG demonstrates a fairly common problem you may encounter with a DDD pacemaker especially during the acute stage of lead maturation.

The ECG pattern shows intermittent atrial sensing, where every other P wave is detected. The first observable P wave is not sensed and is followed by an appropriately timed atrial pace pulse which captures. This is followed by a sensed R wave. Next is a sensed P wave and R wave. The pattern then repeats. Note that if the second intrinsic P wave was also not sensed there would have been an atrial pulse at the VA interval (750 ms) following the R wave.

**Possible Cause**
- marginal atrial signal
- lead maturation
- lead dislodgement
- insulation break

**Corrective Procedure**
- reprogram to more sensitive setting
- wait for lead to stabilize
- reposition lead
- consider lead replacement
LOSS OF VENTRICULAR SENSING

The pacer appears to be running asynchronously at the lower rate. There is no ventricular sensing. The third and sixth ventricular complexes represent pseudo-fusion beats. The fifth and last (partial) ventricular complexes show capture. Atrial sensing is difficult to assess without knowing the PVARP value, but the ECG demonstrates no detected P waves. Atrial capture appears intact with the last two complexes.

Possible Cause
- marginal R wave signal
- misprogrammed pacemaker
- lead insulation break
- poor lead position
- sensing component failure

Corrective Procedure
- increase ventricular sensitivity
- interrogate & verify ventricular sensitivity is not asynchronous
- consider lead replacement
- reposition lead
- replace pulse generator
INTERMITTENT LOSS OF ATRIAL SENSING

The first complex demonstrates safety pacing with the AV interval shortened to 110 ms. This was caused by the loss of atrial sensing. The next seven beats appear to demonstrate normal pacer function yet the marker channel shows intermittent failure to sense P waves.

When the sensed R-R interval is less than the pacer’s VA interval (V-V minus AV or 800 ms here), then assessment of proper atrial sensing is necessitated through the use of the marker channel or temporarily reprogramming the AV interval to be less than the intrinsic P-R.

The last two ventricular complexes demonstrate pseudo-fusion beats.

Possible Cause                                   Corrective Procedure

- marginal atrial signal                        - increase atrial sensitivity
- lead maturation                               - wait for electrode-tissue interface to stabilize – about 6-8 weeks
- lead dislodgement                             - reposition lead
- insulation break                              - consider lead replacement
VENTRICULAR OVERSENSING

Oversensing is evident when sense markers occur without corresponding depolarizations on the ECG. Possible causes for such oversensing may be: intermittent and incomplete fracture of the lead wire, sensing of EMI or myopotentials, or programming the sensitivity to a setting which is too responsive. Further testing should be done to isolate the cause.

### Possible Cause
- Insulation break
- Intermittent wire fracture
- Myopotential sensing (unipolar only)
- EMI sensing
- Programmed too sensitive

### Corrective Procedure
- Consider lead replacement
- Replace lead
- Decrease sensitivity; consider bipolar system
- Move away from source; reprogram to higher sensitivity value
- Decrease sensitivity
LOSS OF ATRIAL CAPTURE

This ECG demonstrates lower rate pacing with a DDD pacemaker. There are no sensed events. From this lead vector there is no sign of atrial capture. As part of the diagnosis a twelve lead ECG is recommended to fully assess atrial function. Some places utilize ultrasound, esophageal lead or an MCL lead to better check atrial function. Note that the spike variations are due to a digitizing recording unit. Also, some of the variations in the Vp spike to ventricular depolarization are due to artistic enhancement of the ECG and variations in the printing process as well as an observable phenomena of digital recorders.

Possible Cause
- output programmed too low
- exit block
- lead dislodgement
- drug effects
- insulation break

Corrective Procedure
- increase amplitude or pulse width
- increase output and check threshold non-invasively
- check x-ray and reposition if needed
- check therapy levels; balance pacemaker output and function with drug therapy
- test lead integrity; replace if needed
NO ATRIAL OUTPUT

The ECG appears to be VVI pacing. The marker channel shows that atrial pacing was supposed to occur but there is an absence of atrial artifacts on the ECG. However, at the second complex there is an atrial sensed event. Loose connections, wire fractures or component failure are the likely causes. The sensed atrial event tends to rule out complete continuous wire fractures or disconnected leads.

**Possible Cause**
- component failure
- wire fracture
- loose connection
- output programmed too low

**Corrective Procedure**
- test generator; replace if needed
  (invasive test needed)
- test lead for high impedance; replace if needed
- invasively test with hex driver and tighten if needed
- interrogate and program to appropriate values
LOSS OF VENTRICULAR CAPTURE

In complexes 2 and 5, there is complete loss of ventricular capture. Complexes 3, 6 and 8 demonstrate appropriate ventricular sensing. Atrial capture appears intact except for complex 5. Atrial sensing cannot be properly assessed from this strip.

Proper sensing usually indicates lead integrity and proper placement. Perform an auto-threshold test to verify an adequate safety margin. Programming pulse width and/or amplitude will usually correct the problem.

<table>
<thead>
<tr>
<th>Possible Cause</th>
<th>Corrective Procedure</th>
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<tbody>
<tr>
<td>output too low</td>
<td>reprogram amplitude and/or pulse width; check safety margin</td>
</tr>
<tr>
<td>exit block with lead maturation</td>
<td>reprogram output</td>
</tr>
<tr>
<td>drug effects</td>
<td>check dosages and influence on thresholds; find appropriate balance between pacing and drug therapy</td>
</tr>
<tr>
<td>insulation break</td>
<td>test lead integrity; check for low impedance</td>
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NORMAL OPERATION:
MAGNET APPLICATION

Application of magnet or the programming head to a Medtronic dual chamber
pacemaker programmed to the DDD mode produces the following:

1) Three pairs of coupled (A&V) pacing pulses at a rate of 93 ppm (DOO) and
an AV interval of 100 ms constitute the Threshold Margin Test (TMT).

2) On the last of the three sets of pulses the pulse widths for both A&V are
reduced by 25% of the programmed value. Check for appropriate capture.

3) Asynchronous pacing (DOO) at a rate of 85 ppm and the programmed AV
interval follows the TMT during normal battery life.

4) Battery depletion is indicated by either DOO 75 ppm or VOO 65 ppm pacing
during magnet application.

Check the technical manual for additional details.
INTERMITTENT ATRIAL SENSING

This ECG demonstrates intermittent loss of atrial sensing and ventricular pseudo-fusion pacing. This may not be a very uncommon problem with acute systems especially with tined leads. With maturation of the atrial lead, sensing will usually be regained. The diagnosis is complicated, without the use of a marker channel, because the R-R interval is less than the pacemaker's atrial escape interval or VA interval (V-V-AV ≥ 800 ms).

Shortening the AV interval to 100 ms for a short time will help to assess atrial sensing when no marker channel is available.

<table>
<thead>
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<th>Possible Cause</th>
<th>Corrective Procedure</th>
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<tr>
<td>ATRIAL SENSING</td>
<td></td>
</tr>
<tr>
<td>o lead maturation</td>
<td>o reprogram sensitivity; wait for lead stabilization</td>
</tr>
<tr>
<td>o insulation break</td>
<td>o check for low impedance on atrial lead and replace if needed</td>
</tr>
<tr>
<td>o lead dislodgement</td>
<td>o check x-ray; reposition if needed</td>
</tr>
<tr>
<td>o marginal atrial signal</td>
<td>o reprogram to increase sensitivity</td>
</tr>
<tr>
<td>PSEUDO-FUSION</td>
<td></td>
</tr>
<tr>
<td>o inappropriate output</td>
<td>o increase amplitude or pulse width;</td>
</tr>
<tr>
<td>o dislodged lead</td>
<td>check safety margins</td>
</tr>
<tr>
<td>o inappropriate timing</td>
<td>o check X-ray; reposition if needed</td>
</tr>
<tr>
<td></td>
<td>o shorten AV intervals and check for appropriate capture; reprogram as needed</td>
</tr>
</tbody>
</table>
NORMAL UPPER RATE PACING:
WENCKEBACH

A Medtronic dual chamber pacemaker will track sensed atrial activity, i.e., pace the ventricles (after a programmed A-V interval), on a 1:1 basis up to the programmed upper rate. However, as the atrial rate exceeds the programmed upper rate, the pacemaker begins a Wenckebach-like behavior. Successive A-V intervals are prolonged until a P wave occurs during the postventricular atrial refractory period, is not sensed, and fails to initiate an A-V interval. When this occurs, the pacemaker synchronizes its ventricular output to the next sensed P wave. (Note that the intervals between ventricular outputs are equal to the interval corresponding to the upper rate except for the interval in which the P wave occurs during the postventricular atrial refractory period. Thus the average ventricular pacing rate is reduced.) As the atrial rate increases even further, fewer P waves will be sensed because they too will fall into the postventricular atrial refractory period. Depending on the P-P coupling interval, the pacemaker may even go to 2:1, 3:1 sensing block.
PACEMAKER MEDITED TACHYCARDIA (PMT)

A Pacemaker Mediated Tachycardia (PMT) is a ventricular paced rhythm, synchronized to retrogradely conducted ventricular depolarizations, i.e., retrograde P waves. PMT can only occur when the pacemaker is programmed to an atrial synchronized pacing mode, e.g., DDD. Retrograde activity is sensed after ventricular pacing and causes the pacemaker to pace the patient at or near the programmed upper rate. This rhythm may self-terminate due to fatigue of the retrograde pathway or be terminated by some other means, e.g., automatic extension of the atrial refractory period (ARP), programmed parameters, magnet application, etc.
NORMAL OPERATION:
VENTRICULAR SAFETY PACING (VSP)

This ECG shows normal operation for a dual chamber pacemaker programmed to the DVI mode with the “Safety Pacing” feature programmed “ON.” The safety pacing events are characterized by a paced AV interval of 110 ms. In this example, the R wave is detected within 110 ms following the atrial output for complexes 1, 3, 5, 7, & 9 resulting in a triggered ventricular output 110 ms after the atrial output. This feature is designed to prevent crosstalk.

Check the technical manual for additional details.
NORMAL PACEMAKER OPERATION

While the ECG strip shows a mixture of paced and spontaneous ventricular events, the atrial rhythm is not all that clear on the ECG tracing.

However, the marker channel clarifies the situation completely. The patient is experiencing atrial tachycardia with a regular P-P interval (about 480 ms).

The “missing” P wave in the middle of the strip is absent because it occurred during the blanking interval of the atrial refractory period. As a result, the marker channel does not display an atrial sense marker where one might be expected.

The atrial marker channel displays all three types of markers, i.e., $A_P$, $A_S$ and $A_V$. Ventricular activity varies between paced and intrinsic sensed activity because of intermittent A-V block.

Atrial Refractory Period has been programmed to 325 ms. Careful observation will demonstrate that the P-P coupling interval is approximately 480 ms. The physician chose to program the Symbios pacemaker’s atrial refractory period to 325 ms to ensure that the ventricular rate would remain comfortably low during those times when the patient was subject to transient episodes of atrial tachycardia.