Pacemakers

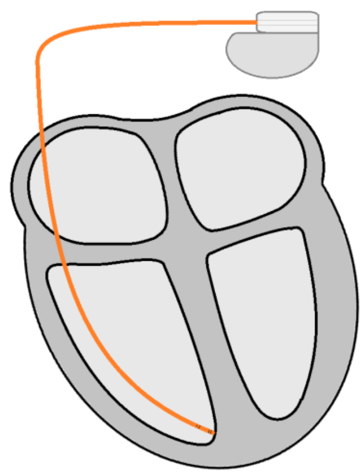
Pacemaker Overview

Implantable pacemakers help to regulate the electrical conduction system of the heart when it can no longer regulate itself. Pacemakers have the ability to sense the hearts intrinsic electrical activity, such as the atrial or ventricular rate, in order to determine if pacing is necessary. The pacemaker has preprogrammed algorithms customized to the specific needs of the patient. If the pacemaker determines that pacing is necessary it will initiate depolarization in the atria, ventricles, or both depending on the pacemaker's algorithms and configuration.

Pacemaker Lead Configurations

Pacemaker configurations will vary based on the needs of the patient. Possible lead configurations include single chamber, dual chamber, and bi-ventricular pacing. Single chamber ventricular pacing initiates an electrical impulse within the ventricles producing a pacing spike immediately before a wide QRS. Dual chamber pacing has leads positioned in both the right atrium and right ventricle and can initiate pacing in both chambers. Bi-ventricular pacemaker configurations can pace the left ventricle as well as the right.

Single Chamber Ventricular Pacemaker (VVI)

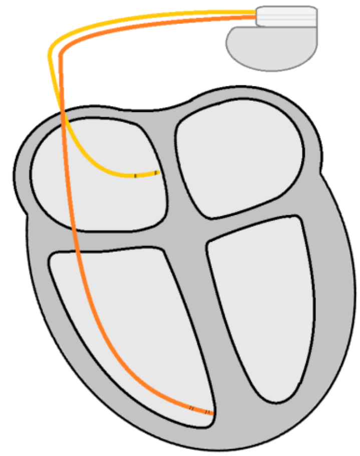


Characteristics:

- Lead placement: Right ventricle
- Sensing and pacing functions only in the ventricles
- Pacing spike before QRS on ECG tracing
- QRS is wide
- P waves may be present prior to the pacing spike or dissociated. Underlying atrial fibrillation may be present.

Example Strip: Ventricular Pacing (VVI)

Dual Chamber Pacing



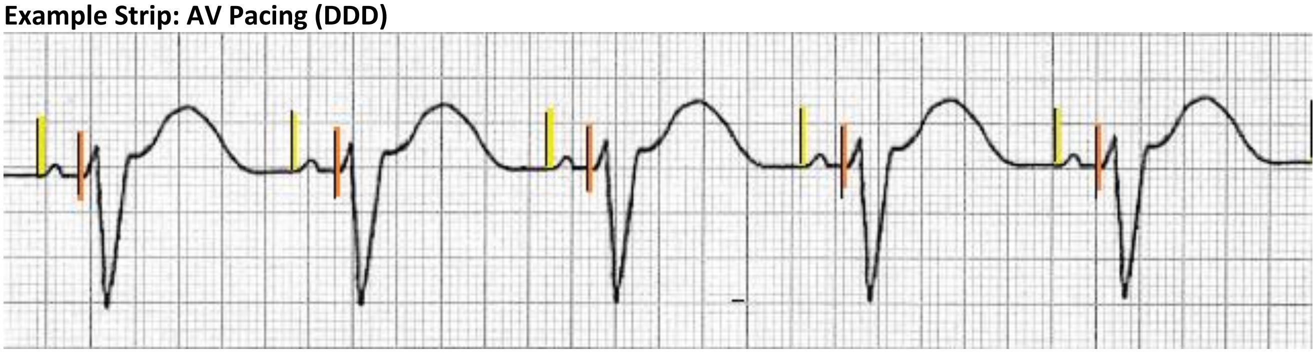
Characteristics:

- Lead placement: Right atrium and Right ventricle.
- Sensing and pacing functions in atria and ventricle.
- Pacing spike possible before the P wave, QRS, or both.
- QRS is relatively narrow for Atrial Pacing.
  QRS is wide for Ventricular or AV Pacing.

Example Strip: Atrial Pacing (AAI)

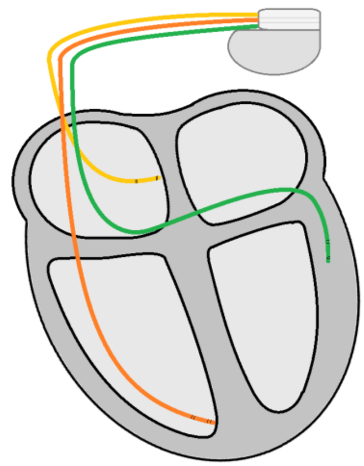
Example Strip: Ventricular Pacing (VVI)

Example Strip: AV Pacing (DDD)

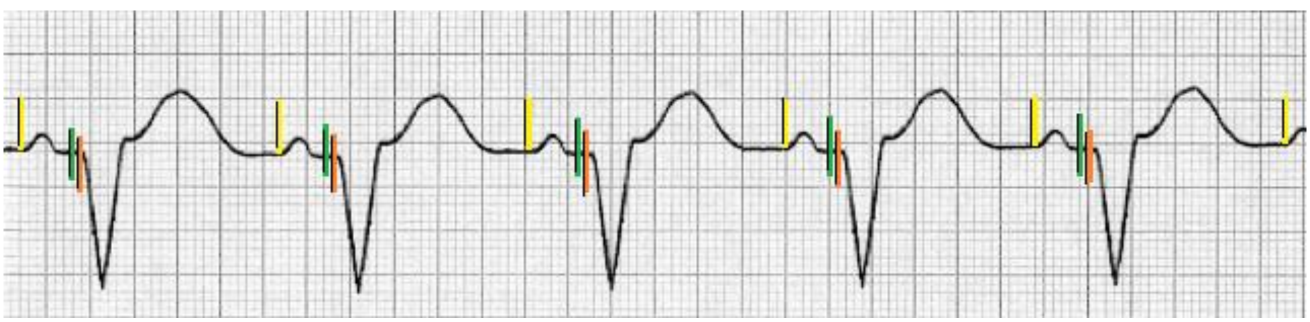


Atrial / Bi-Ventricular Pacing

Characteristics:



- Lead placement:
  - Right atrium
  - Right ventricle
  - Left ventricle
- Sensing and pacing functions in atria and ventricles
- Pacing spike before P wave and two before the QRS on ECG tracing
- QRS is wide

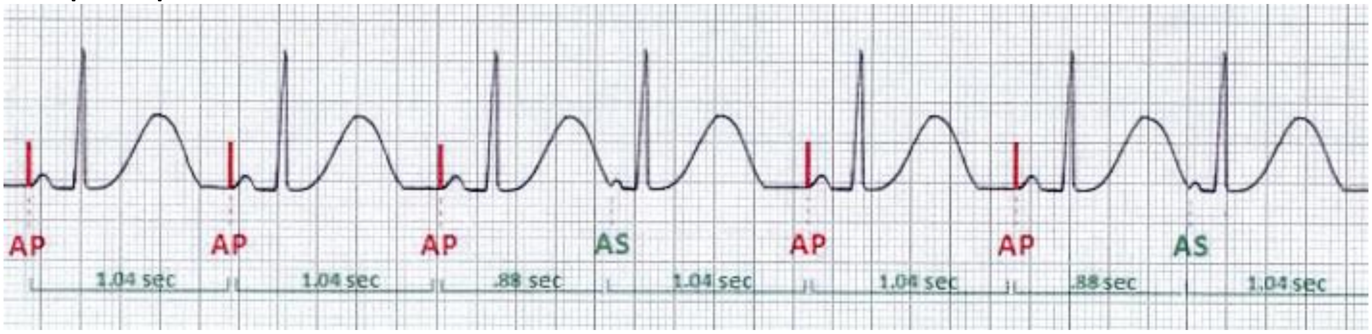


Pacemaker Modes

Pacemakers can be switched to different pacing modes depending on the type of pacemaker installed. The pacemaker mode is a 3-5 letter code which describes how the pacemaker is programmed to behave. The first letter indicates what chambers are being paced. The second letter indicates what chambers are being sensed by the pacemaker. The third letter indicates the response the pacemaker will have depending on what is being sensed. The fourth position indicates if rate modulation is active.

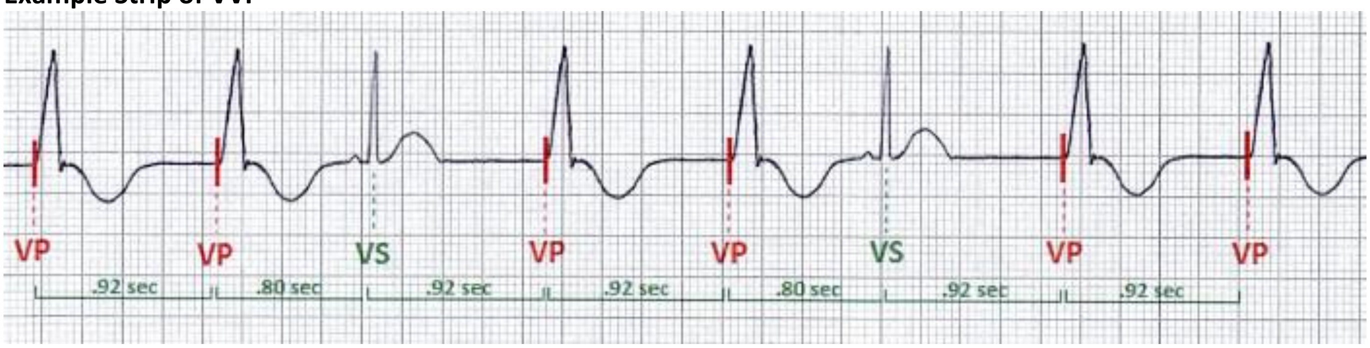
I	II	III	IV
Chamber Paced	**Chamber Sensed**	**Sensing Response**	**Rate Modulation**
A (Atria)	**A (Atria)**	**T (Triggered)**	**R (Rate Modulation)**
V (Ventricle)	**V (Ventricle)**	**I (Inhibited)**	**O (None)**
D (Dual)	**D (Dual)**	**D (Dual)**	
O (None)	**O (None)**	**O (None)**	

Example Strip of AAI



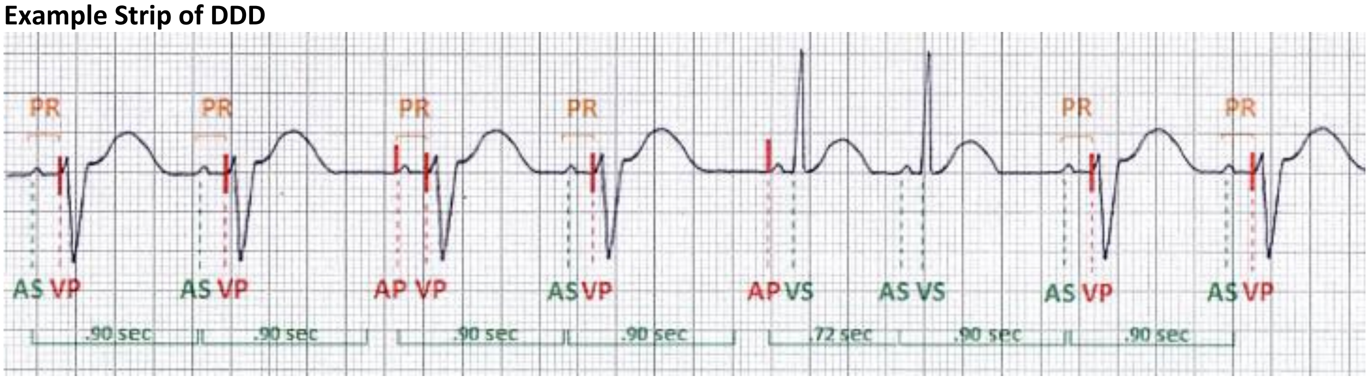
A = The pacemaker will only pace the atria.
A = The pacemaker is sensing the atrial rate to determine if pacing is necessary.
I = The pacemaker will inhibit pacing if it detects appropriate atrial activity.

Example Strip of VVI



V = The pacemaker will only pace the ventricles.
V = The pacemaker is only sensing the ventricular rate to determine if pacing is necessary.
I = The pacemaker will inhibit pacing if it detects appropriate ventricular activity.

Example Strip of DDD



D = The pacemaker can pace the atria as well as the ventricles.
D = The pacemaker is sensing the atrial and ventricular rates to determine if pacing is necessary.
D = The pacemaker will inhibit pacing in both the atria and ventricles if it detects appropriate atrial and ventricular activity but can trigger ventricular pacing if necessary.

<u>Cardioversion</u>

Implantable Cardioverter Defibrillator:

Patients at high risk for lethal arrhythmias may receive an **Implantable Cardioverter Defibrillator** (ICD). For example, Long QT syndrome cause the patients QT to be longer than normal increasing their risk for lethal arrhythmias like ventricular fibrillation and Torsades de Pointes. ICDs have the ability to detect lethal arrhythmias and can deliver an electric shock to the heart to reset its electrical conduction system.

Example Strip of ICD Shock

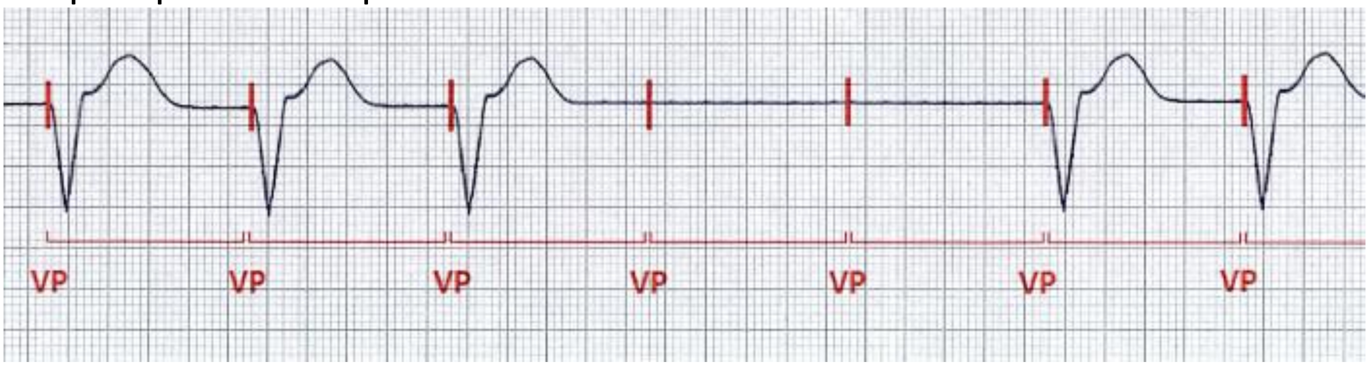
This real patient strip shows a patient initially in ventricular fibrillation until the ICD fires. The shock of the ICD resets the hearts electrical conduction system allowing the pacemaker to resume AV pacing seen in the second half of the strip.

Pacemaker Malfunction

Failure to capture:

Failure to capture means the pacemaker initiated an electrical impulse but there was no cardiac response. This can be identified on the ECG tracing as a pacing spike with no P wave or QRS as seen in the example strip below.

Example Strip of Failure to Capture

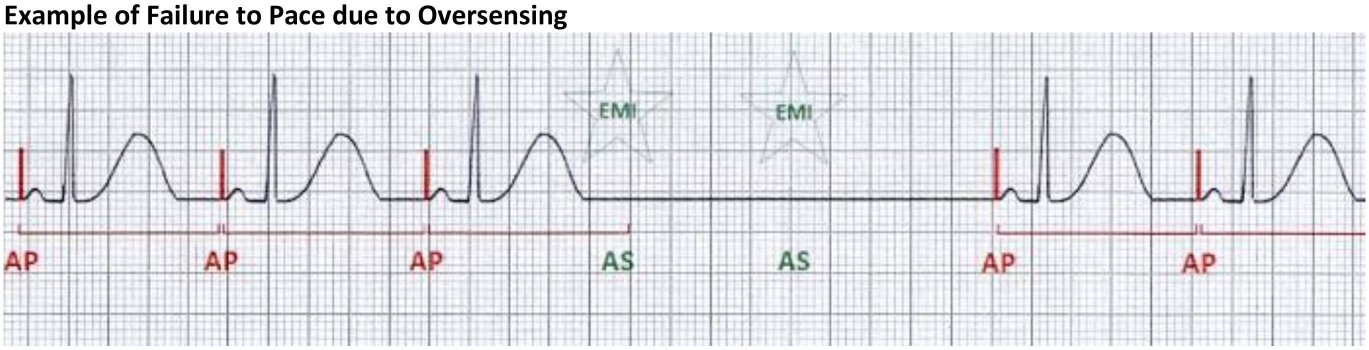


This strip shows ventricular pacing and capture for the first 3 beats. The 4th and 5th pacing spikes do not capture resulting in asystole.

Failure to Pace:

Failure to pace means the pacemaker failed to initiate pacing when expected. This can be identified on the ECG tracing by long pauses or unusually slow heart rates with no pacing spikes present. Oversensing is one potential cause for a pacemaker failing to pace. **Oversensing** is when the pacemaker senses external electrical impulses and mistakes them for intrinsic cardiac activity, causing it to inhibit pacing.

Example of Failure to Pace due to Oversensing

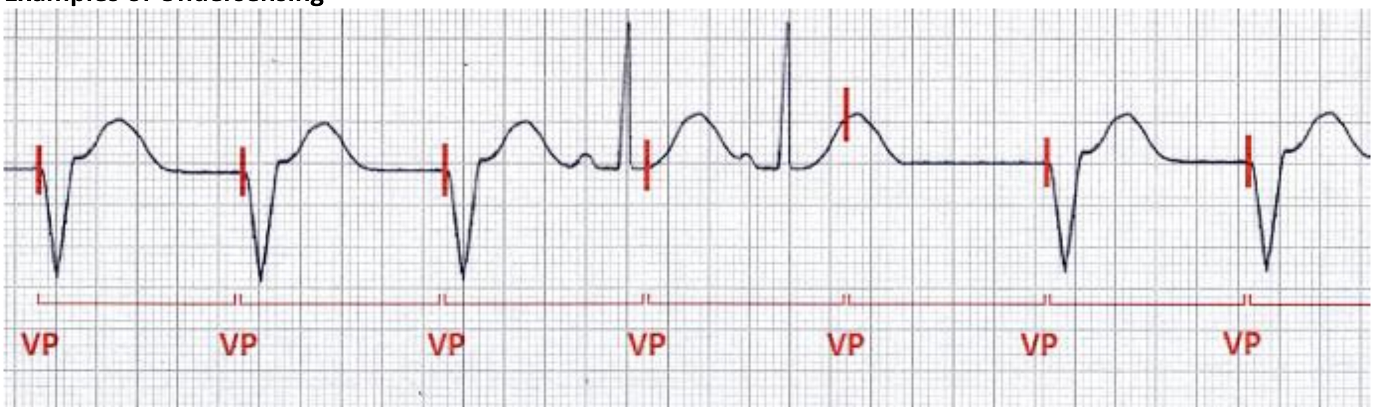


In this strip the pacemaker's atrial lead is sensing Electromagnetic Interference (EMI), which is misinterpreted as the hearts intrinsic activity. Since the pacemaker believes the heart is beating on its own it does not pace resulting in arrest.

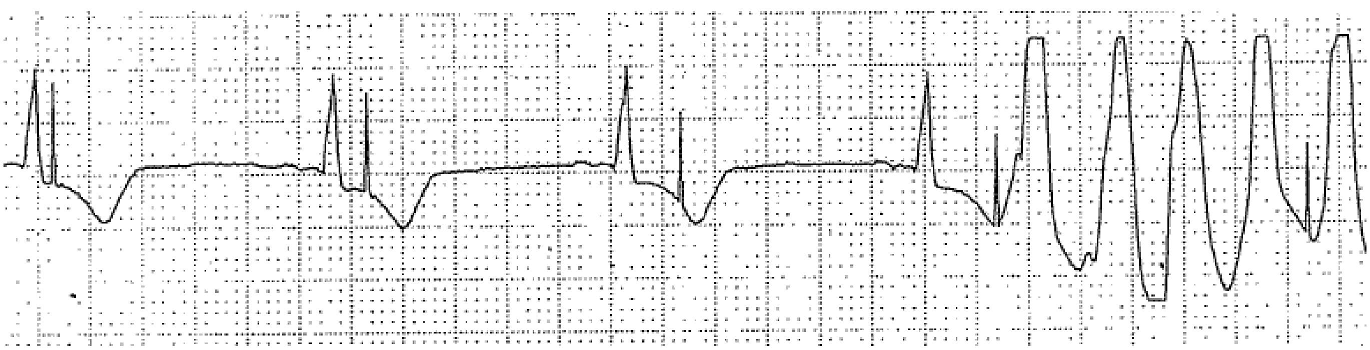
Undersensing

Undersensing is when the pacemaker fails to sense intrinsic cardiac activity. Because the pacemaker doesn't sense the heart is already beating it continues to pace.

Examples of Undersensing



The above strip shows ventricular pacing for the first 3 beats. The patient's intrinsic rhythm takes over for beats 4 and 5 but the pacemaker fails to sense the intrinsic activity. The pacemaker continues to pace through the patient's intrinsic rhythm and then resumes ventricular pacing for beats 6 and 7.



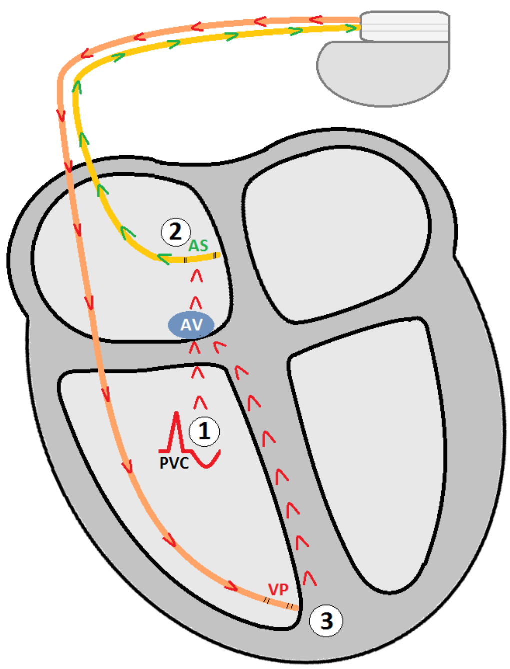
The above strip is a real patient strip showing the danger of a pacemaker undersensing. The pacemaker fails to sense the patient's intrinsic activity and paces through the T wave. When the pacemaker initiates ventricular pacing through the patients T wave it causes an onset of ventricular tachycardia.

Pacemaker Mediated Tachycardia:

Pacemaker Mediated Tachycardia (PMT) is a tachycardia which forms as a result of the pacemaker's ability to sense the atria and pace the ventricles. This may result from the onset of a rapid atrial arrhythmia like atrial flutter. **Automatic Mode Switching** (AMS) allows the pacemaker to sense the increased atrial rate and turn off atrial tracking so PMT does not result. PMT may also result from retrograde conduction from the ventricles to the atria when a dual chamber pacemaker is present. When PMT is present the pacing rate will always be at its upper rate limit, usually 120-130 bpm. PMT can be eliminated by placing a pacemaker magnet over the pacemaker.

Example of Pacemaker Mediated Tachycardia:

1. Step 1 shows a PVC depolarizing the ventricles prematurely and the depolarization travels up through the AV node depolarizing the atria.
2. Step 2 shows the atrial lead of the pacemaker sensing the atrial depolarization and perceiving it as an intrinsic atrial depolarization.
3. Step 3 shows the pacemaker responding to the sensed atrial depolarization by initiating ventricular pacing. This depolarizes the ventricles and travels up through the AV node which also depolarizes the atria. This is once again sensed by the atrial lead and the process starts all over again.



Example Strip of PMT

The PVC in this strip causes retrograde depolarization of the atria. This is sensed by the lead placed in the atria, which interprets it as an intrinsic event and prompts the ventricles to pace. The consecutive ventricular pacing events also cause retrograde depolarization of the atria and the cycle continues.

Rate Management Algorithms

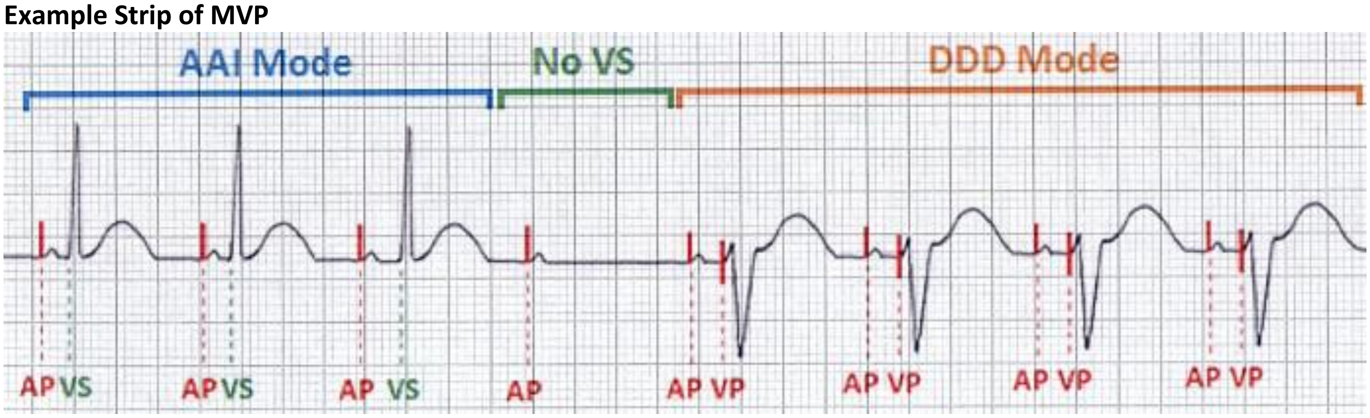
Rate hysteresis:

Rate hysteresis algorithms may lower the pacemaker's lower rate limit if intrinsic ventricular activity is sensed. This gives the heart the opportunity to pace on its own assuming it is providing sufficient cardiac output.

Managed Ventricular Pacing:

Medtronic's **Managed Ventricular Pacing** (MVP) is a sophisticated algorithm designed to reduce overpacing while also promoting AV synchrony. The pacemaker may switch between AAI(R) and DDD(R) depending if AV synchrony is sensed. For example, if the pacemaker is in AAI mode and it fails to sense an intrinsic ventricular response it may switch to temporary DDD pacing. The pacemaker will then periodically check for AV synchrony and if present may resume AAI pacing. When the pacemaker is checking for AV synchrony it will initiate an atrial pace and wait to see if there is an intrinsic ventricular response before resuming DDD pacing. This behavior is often mistaken for pacemaker malfunction however this is a normal function of MVP.

Example Strip of MVP



This strip shows the pacemaker in AAI mode pacing only in the atria. When there is no intrinsic ventricular response (No VS) then the pacemaker switches to DDD mode temporarily.

The algorithms pacemakers use and how they are programmed can vary widely. Each pacemaker manufacturer has different pacemakers with different algorithms and capabilities. Pacemaker manufacturers have their own programmers used to analyze their pacemakers. These programmers are used by the pacemaker reps to check the pacemaker's functionality. Patients should have a card with them indicating their pacemakers make and model.

Pacemaker manufacturer contact numbers:

Boston Sci-1-800-CARDIAC, Medtronic-1-800-MEDTRONIC, SJM 1-800-PACE-ICD

References

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