

# Pacemaker learning package

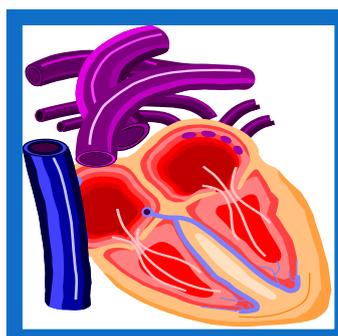


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## INDICATIONS

- Sinus bradycardia
- AV blocks
- Complete heart block
- Overriding tachy atrial and/or ventricular arrhythmia (AF, A Flutter & SVT), Re-entrant tachycardia's
- Prior to the implant of a permanent pacemaker
- Acute myocardial infarction complicated by heart block
- Temporary support of a patient after heart surgery



# ANATOMY

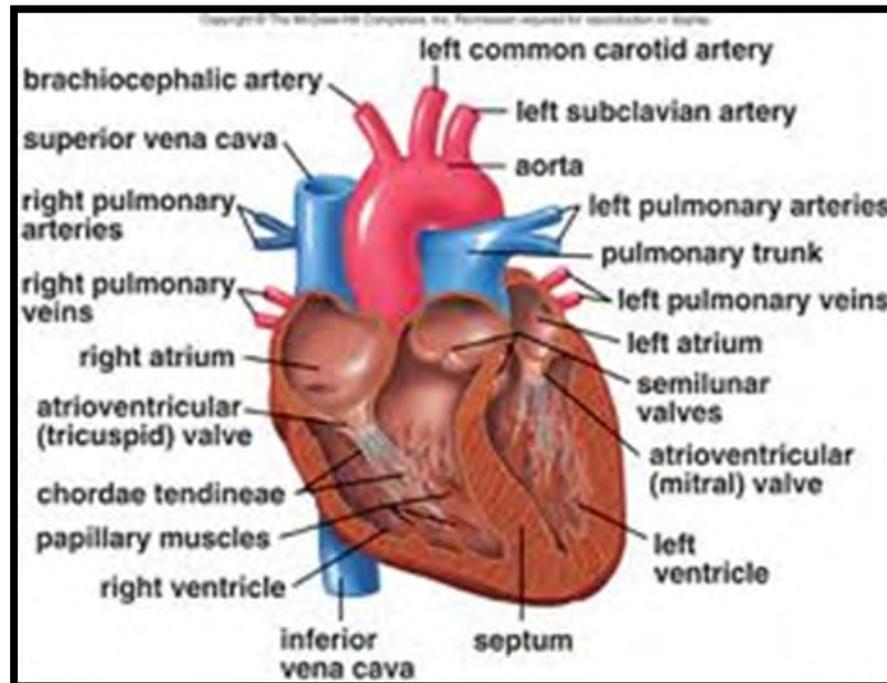


Figure 1: [www.nursing-lectures.com/2011/01/cardiovascular-system-introduction](http://www.nursing-lectures.com/2011/01/cardiovascular-system-introduction)

## The Heart

- the heart is a cone-shaped, muscular organ located between the lungs behind the sternum.
- The heart muscle forms the myocardium
- the inner lining of the myocardium is called Endocardium and the outer layer cells is called the Epicardium.
- The pericardium (visceral) is the outer membranous sac with lubricating fluid.
- The heart has four chambers: two upper, thin-walled atria, and two lower, thick-walled ventricles.
- The ventricles are the chambers that eject blood in to arteries.
- The functions of the atrium are to receive the incoming blood from the vein

- The septum is a wall dividing the right and left sides of the heart
- Coronary arteries are the vessels that supply blood to the heart muscle.

### **Cardiac Valves:**

Cardiac valves permit blood to flow in only one direction through the heart

- Atrioventricular Valves:
  - 1] Tricuspid valve: separates the Right atrium from the Right ventricle
  - 2] Bicuspid valve [Mitral valve]: lies between the Left atrium and Left ventricle.
- Semi lunar Valves:
  - 1] Pulmonic valve: is the valve between the Right ventricle and the pulmonary artery.
  - 2] Aortic valve: is the valve between the Left ventricle and the aorta.

### **The Heartbeat**

- Each heartbeat is called a cardiac cycle.
- When the heart beats occur, the two atria contract together, then the two ventricles contract; then the whole heart relaxes.
- Systole is the contraction of heart chambers; diastole is their relaxation.
- The heart sounds, lub-dup, are due to the closing of the atrioventricular valves, followed by the closing of the semi lunar valves.

### **Conduction System**

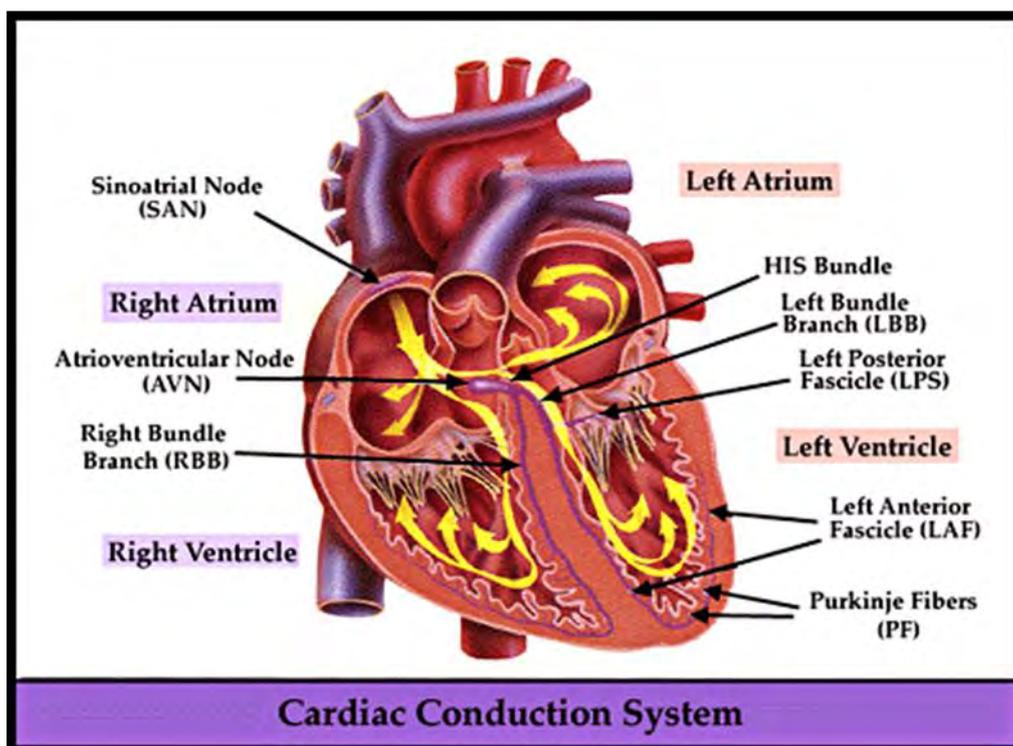
- The hearts cardiac conduction functions by emitting electrical currents that cause the myocardium to contract.
- The atria are the first to contract then the ventricle.
- There are two specialized cells in the heart that keep the synchronization of the atria and the ventricle:
  1. Nodal cells
  2. Purkinje cells

These cells have three characteristics that help to keep everything in time:

1. *Automaticity*: the ability to initiate an electrical impulse
2. *Excitability*: the ability to respond to an electrical impulse

3. *Conductivity*: the ability to transmit an electrical impulse from one cell to another.

- The electrical current is first initiated in the SA node, the heart's natural pacemaker, located at the top of the right atrium.
- The SA node is composed of nodal cells. In a normal resting adult heart, the SA node initiates firing at 60 to 100 impulses/minute, but the rate can change in response to the metabolic demands of the body. The impulses cause electrical stimulation and subsequent contraction of the atria.
- These signals then travel across the atrium to the atrioventricular node, located close to the septal leaflet of the tricuspid valve.
- The AV node is also made up of nodal cells. The AV node coordinates these incoming electrical impulses. After a slight delay (giving the atria time to contract and complete ventricular filling), it relays the impulse to the ventricles.
- The Purkinje cells then take over in the ventricle.
- The impulse in the ventricles is initially conducted through a bundle of specialized conducting tissue called the bundle of His, which then divides into the right bundle branch (conducting impulses to the right ventricle) and the left bundle branch (conducting impulses to the left ventricle).
- To transmit impulses to the left ventricle, the heart's largest chamber, the left bundle branch divides into the left anterior and left posterior bundle branches.
- Impulses travel through the bundle branches to reach the Purkinje fibers (the terminal point in the conduction system).
- The Purkinje cells rapidly conduct the impulses through the thick walls of the ventricles. At this point, the myocardial cells are stimulated, causing ventricular contraction. (1)

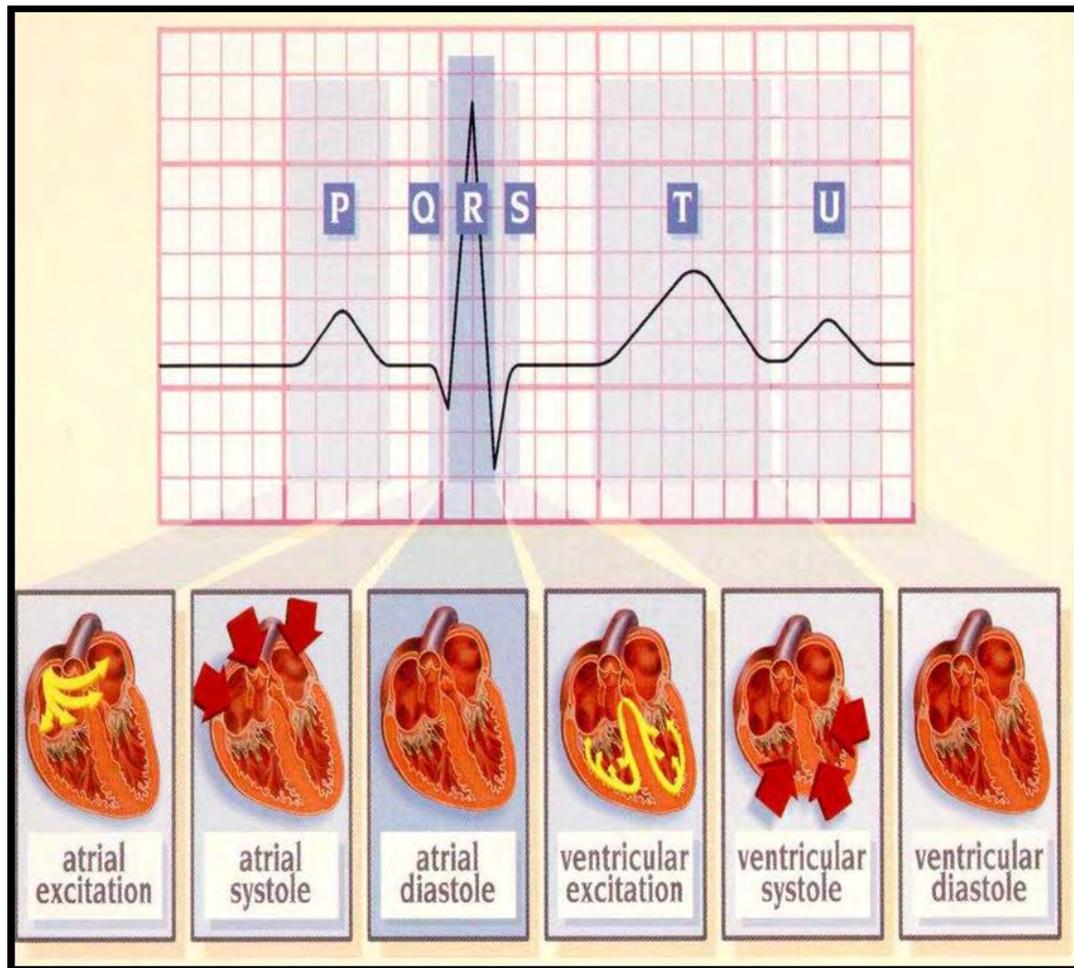


**Figure 2:** Cardiac conduction system. Marquette, K.H.

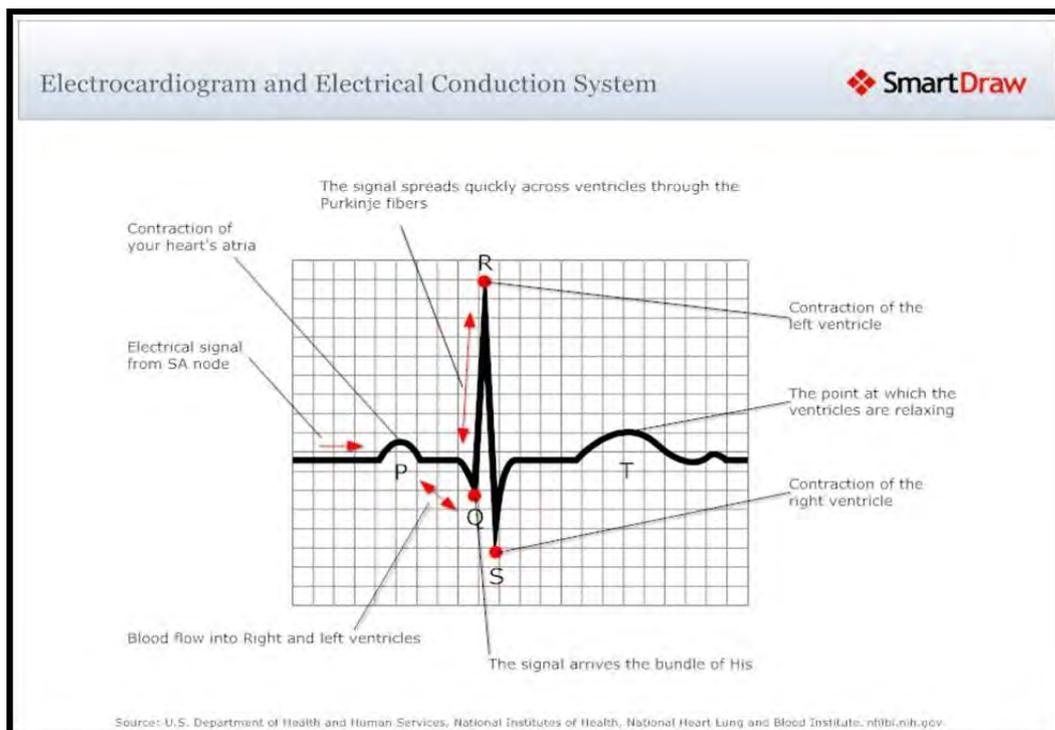
- Impulses can occur in various sites within the heart.
- Heart rate is determined by the Nodal and Purkinje cells with the fastest firing rate.
- Normally, the SA node has the highest inherent rate, 60 to 100 impulses/minute.
- The AV node has an inherent rate of 40 to 60 impulses/minute
- Ventricular pacemaker sites have the lowest inherent rate, of 30 to 40 impulses/minute.
- If the SA node malfunctions, the AV node generally takes over the heart's pacemaker function at its inherently lower rate.
- Should both the SA and the AV nodes fail in their pacemaker function, a pacemaker site in the ventricle will fire at its inherent bradycardic rate of 30 to 40 impulses/minute.

It is when one or both of these nodes fail that a temporary pacemaker may be needed.

Electrical activity of the heart is recorded on the ECG



**Figure 3:** Electrical representation and cardiac cycle. Marquette, K.H



## DEFINITIONS

There are numerous terms used in pacing. Some of these are listed below:

- **Action Potential:**

The action potential is brought on by a rapid change in membrane permeability to certain ions, with unique properties necessary for function of the electrical conduction system of the heart.

- **Automaticity:**

Is the ability of the cardiac muscles to depolarize spontaneously, i.e. without external electrical stimulation from the nervous system.

- **Ampere (AMP, A):**

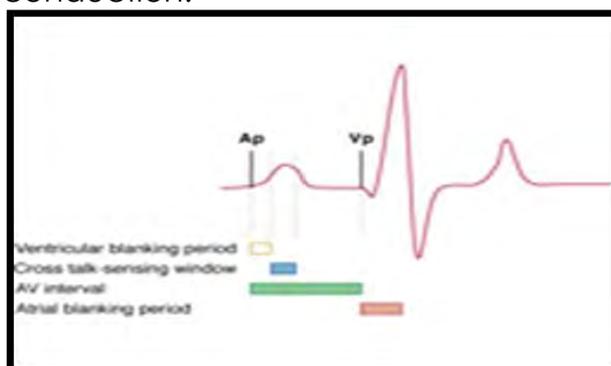
Is a measure of electrical current flowing past a point in a conductor when one volt of potential is applied across one ohm of resistance. In pacing, these currents are so small that they are expressed in thousandths of amperes (milliamperes, mA) or in millionths of amperes (microamperes,  $\mu$ A)

- **Amplitude:**

The maximum absolute value attained by an electrical waveform, voltage or current. The amplitudes of pacemaker output pulses are expressed in volts (the difference in electrical potential), or in milliamperes (the measure of the electrical current flow).

- **AV Interval / Atrioventricular Interval, AV Delay:**

In a dual chamber pacemaker mode the AV Interval is the period of time between an atrial event (sensed or paced) and a scheduled paced ventricular event. It is typically measured in milliseconds. The AV Interval can also be thought of as the pacemaker equivalent to the PR interval in normal conduction.



- **Asynchronous pacing:**

(a = not; syn = together; chrono = time) are those that are not together in time with the heart because they do not know what the heart is doing. Pacemakers such as AOO and VOO are asynchronous as they stimulate the heart at a fixed, preset rate independent of the electrical and/or mechanical activity of the heart.

- **Burst Pacing:**

Is a technique of rapid pacing which may be used to terminate a tachycardia by delivering a series of pacing pulses in which the delivery rate remains constant within each pacing attempt. This technique is used in both the atria and the ventricles to attempt to terminate organized arrhythmias.

- **Capture:**

Is initiation of depolarization of the atria and/or ventricles by an electrical stimulus delivered by an artificial pacemaker. Capture can be visualized on the monitor by a spike before every p wave (for atrial pacing) and a spike before every QRS (for ventricular pacing)



- **Demand Pacing:**

A pacing stimulus is delivered to the myocardium if the intrinsic rate falls below the set rate on the pacemaker.

- **Dual-Chamber Pacemaker:**

A pacemaker with two leads (one in the atrium and one in the ventricle) to allow pacing and/or sensing in both chambers of the heart to artificially restore the natural contraction sequence of the heart.

- **Epicardial Pacing:**

Is a type of temporary pacing where pacing wires are fixed directly to the myocardium (ventricular and often atrial) and are exposed through the skin on the chest wall, usually following cardiac surgery.

- **Fixed Rate Pacing:**

A pacing stimulus is delivered to the myocardium at a programmed fixed rate regardless of the underlying rate and rhythm. This is also known as asynchronous ventricular pacing.

- **Electromagnetic Interference (EMI):**

Radiated or conducted energy – either electrical or magnetic – which can interfere with the function of the pacemaker.

- **Fusion Beat:**

Is a spontaneous cardiac depolarisation which occurs coincidentally with a paced depolarisation. The paced and natural depolarisation waveforms collide or fuse, causing distortion of the surface ECG complex.

- **Intrinsic:**

Inherent; belonging to or originating from the heart itself, (e.g., an intrinsic beat refers to a naturally occurring heart beat).

- **Inhibited:**

Is any pacemaker which, after sensing a spontaneous depolarization, withholds its pacing stimulus. Examples are AAI, VVI

- **Millivolt:**

One one-thousandth of one volt. A unit of measure for low levels of voltage. Spontaneous, intrinsic P-waves and R-waves are measured in millivolts.

- **Millisecond:**

One one-thousandth of one second. Most pacemaker timing functions, e.g., pulse width and pacing intervals, are expressed in milliseconds.

- **No Output:**

Is the absence of energy delivery to the heart.

- **Output:**

The electrical stimulus or energy generated by a pulse generator and intended to trigger a depolarization in the chamber of the heart being paced.

**▪ Sensitivity:**

Is the pacemaker's ability to sense a patient's intrinsic rhythm or when *natural* depolarization is occurring

- *The sensitivity number represents the minimum size, in millivolts, of an electrical signal that will be detected by the pacemaker*
- The higher the sensitivity (number) the less likely the pacemaker will see the patients rhythm

**▪ Sensing Threshold:**

The minimum atrial or ventricular intra cardiac signal amplitude required to inhibit or trigger a demand pacemaker, expressed in millivolts.

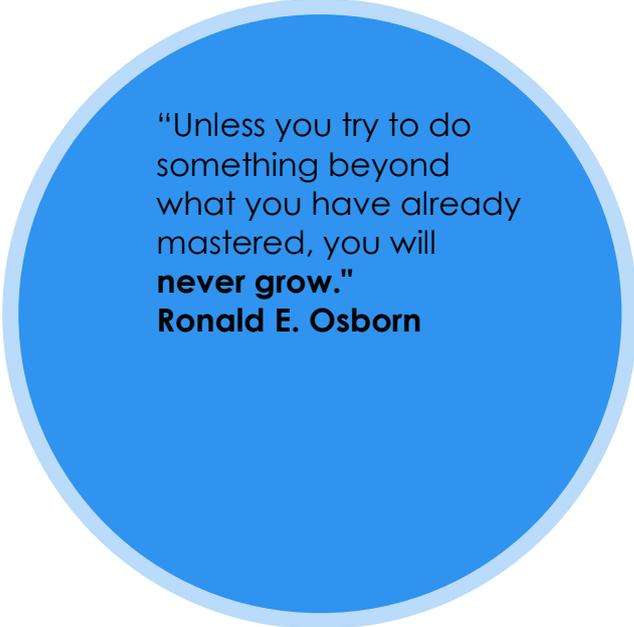
**▪ Stimulation or output Threshold:**

The minimum electrical stimulus needed to consistently elicit a cardiac depolarization. It can be expressed in terms of amplitude (volts, milliamps) and pulse width (milliseconds), or energy (microjoules).

**▪ Triggered:**

In pacemaker terms, a Triggered pacing mode is the opposite of inhibited. Upon detecting a spontaneous depolarization or other signal, a triggered mode will deliver an electrical stimulus to the heart.

**Medtronic Pacing Glossary. 2005**

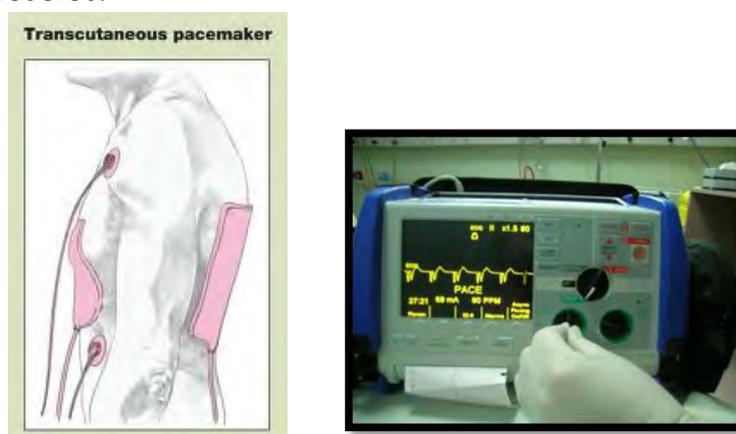


"Unless you try to do something beyond what you have already mastered, you will **never grow.**"  
**Ronald E. Osborn**

## TYPES OF PACING

### ■ TRANSCUTANEOUS PACING

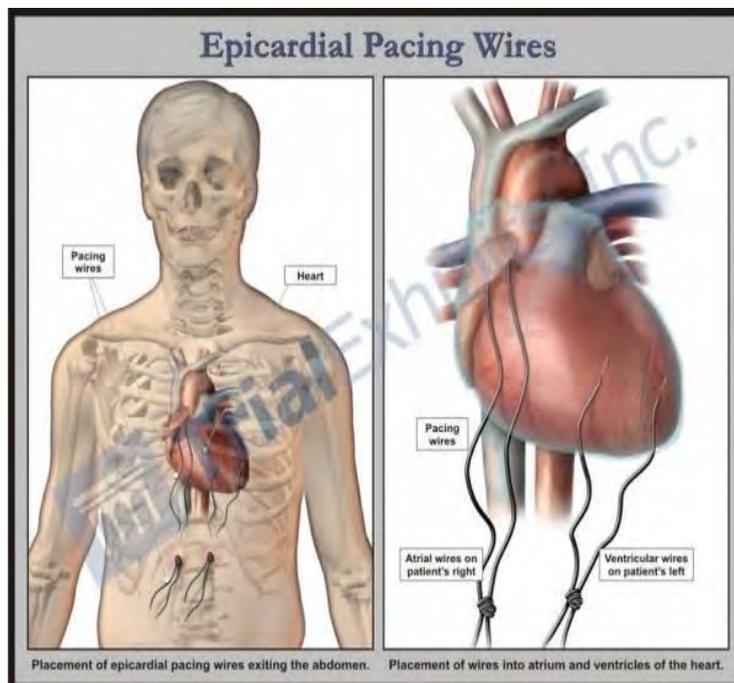
- Is only used in emergency situations due to the discomfort felt by the patient.
- The electrodes are incorporated into the pads and cover a large surface area over the skin. The pads are connected to an external pulse generator which delivers energy through the pads to the chest wall muscles.



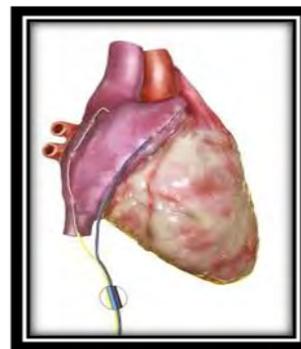
**Figure 4:** Pacing pad placement for transcutaneous pacing. Lippincott's Nursing centre.com 2011

- By continuously monitoring cardiac rate and rhythm and delivering pacing impulses through the skin and chest wall muscles as needed, transcutaneous pacing causes electrical depolarization and subsequent cardiac contraction to maintain cardiac output until the patient receives a transvenous pacemaker
- The pacing stimulus travels through chest wall, pectoralis and intercostals muscle, ribs pericardial fluid and fat before finally reaching the heart. Therefore a much higher energy level is needed to deliver the correct energy to the heart. One side effect of this is chest muscle contraction from the electrical stimulus. Therefore giving the patient some sedation for comfort is high priority
- Pacing or defibrillation pads must be in good contact with chest wall
- Once capture has been verified on monitor by a spike before every QRS, patient's haemodynamics must also be assessed ensuring electrical and mechanical capture.

- See Transcutaneous pacing guideline for detailed management information
- **EPICARDIAL PACING**
  - is used post cardiac surgery and involves pacing wires being sutured to surface of heart
  - the **atrial** pacing wires exit the patient's chest on the **right** side and the **ventricular** wires exit the chest on the **left** side
  - is a form of temporary pacing for bradycardia and override pacing in atrial fibrillation
  - These wires may only last a few days to a week.
  - If left for longer than a week the pacing thresholds may rise and there may not be adequate and reliable capture

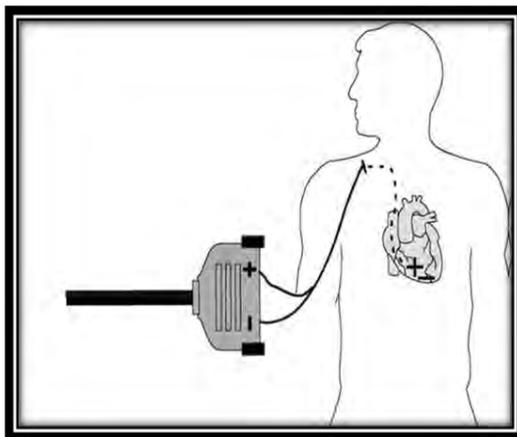


**Figure 5:** Placement of epicardial pacing wires:  
[www.legalmedicalexhibits.com](http://www.legalmedicalexhibits.com)

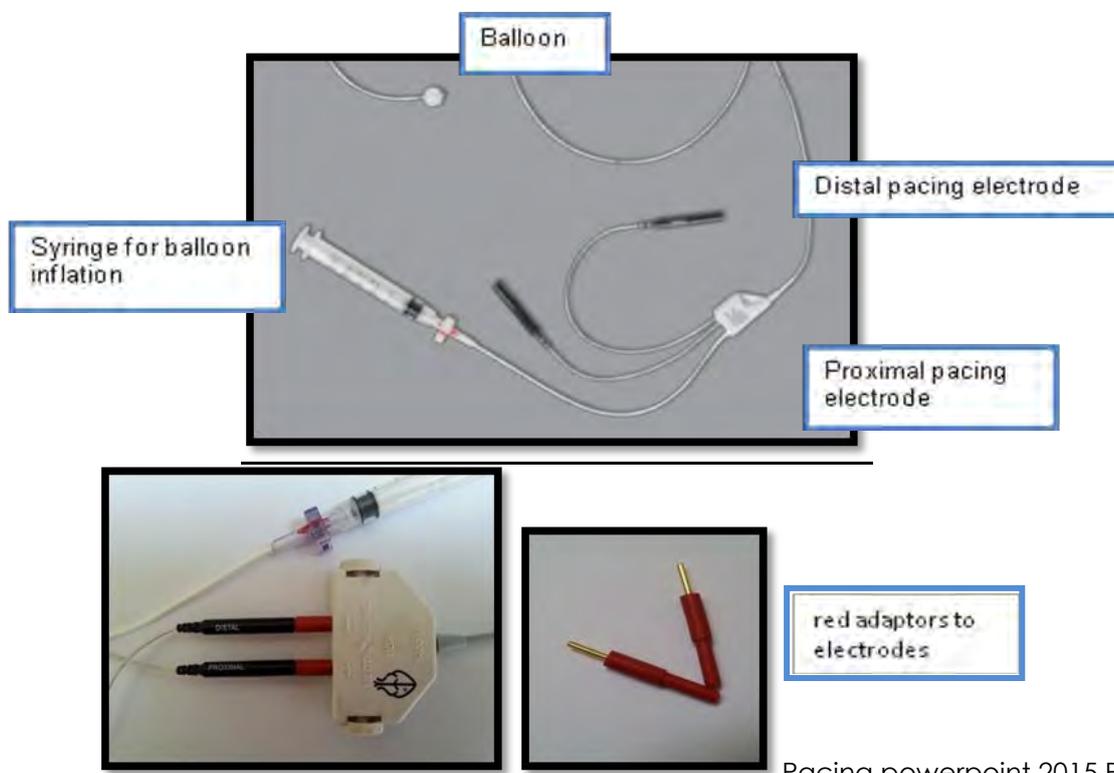


**▪ TRANSVENOUS PACING**

- Transvenous pacemakers are inserted into the venous system through a catheter site such as a specially designed pulmonary artery catheter, or sheath, and deliver the stimulus via electrodes that are in direct contact with the heart tissue itself.
- Generally the subclavian, femoral or internal jugular veins are used to access the right atrium or the right ventricle.



**Figure 6:** Transvenous pacing. Critical Care Nurse 2004



(CNE)

Pacing powerpoint 2015 P.Nekic

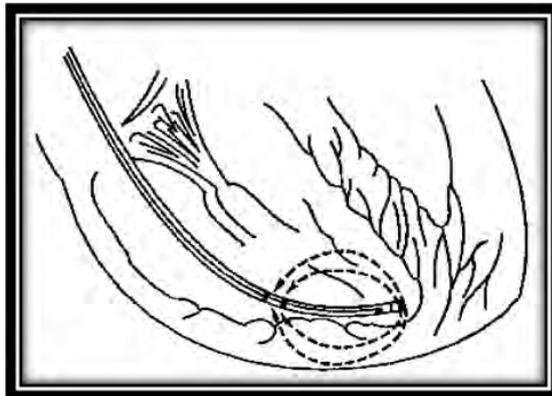
## TYPES OF PACEMAKER LEADS

With any electrical current the electrical impulse must flow between two poles (or electrodes) in order to stimulate the heart.

The pacing leads used can be either bipolar or unipolar

### Bipolar

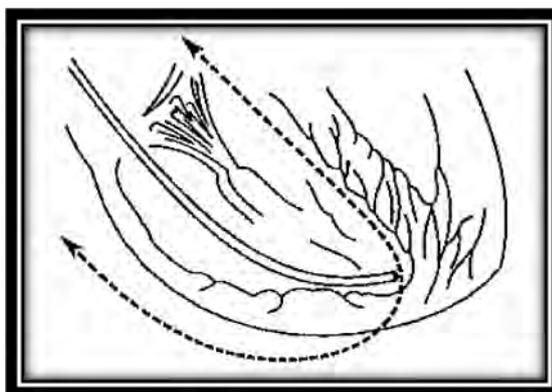
- There are two electrodes positive and negative
- involves a single wire with two conductors insulated from one another, which both run to the epicardial surface



**Figure 7:** Bipolar pacing. Single chamber temporary pacing ppt 2001

### Unipolar

- Only one electrode ( negative) is in contact with the heart
- The positive electrode is located somewhere else on the body

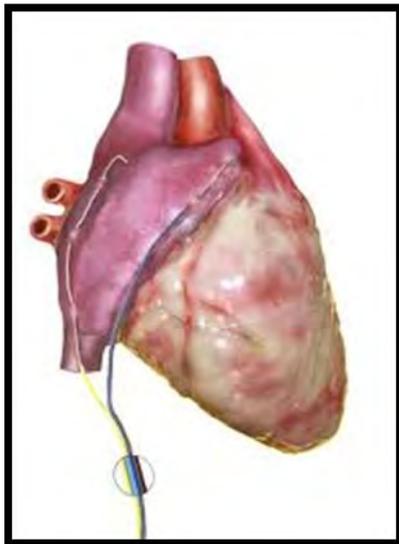


**Figure 8:** Unipolar pacing. Single chamber temporary pacing ppt 2001

In both systems the current flows from the negative terminal of the pacing box down the pacing lead to the negative electrode and into the heart. The current is then picked up by the positive electrode and goes back up the lead to the positive terminal of the pacing box.

### **Epicardial pacing leads:**

- Bipolar leads are usually used post op
- Bipolar epicardial leads have two separate insulated wires, one positive and negative
- These are sutured to the chamber of the heart that needs to be paced
- Both leads are in contact with the heart so either wire may be used as the negative or pacing electrode
- The remaining wire is used as the ground or positive electrode



**Figure 9** : Right atrial wire placement. [ctsnet.org](http://ctsnet.org) accessed 02/2012

# ANATOMY OF A PACEMAKER



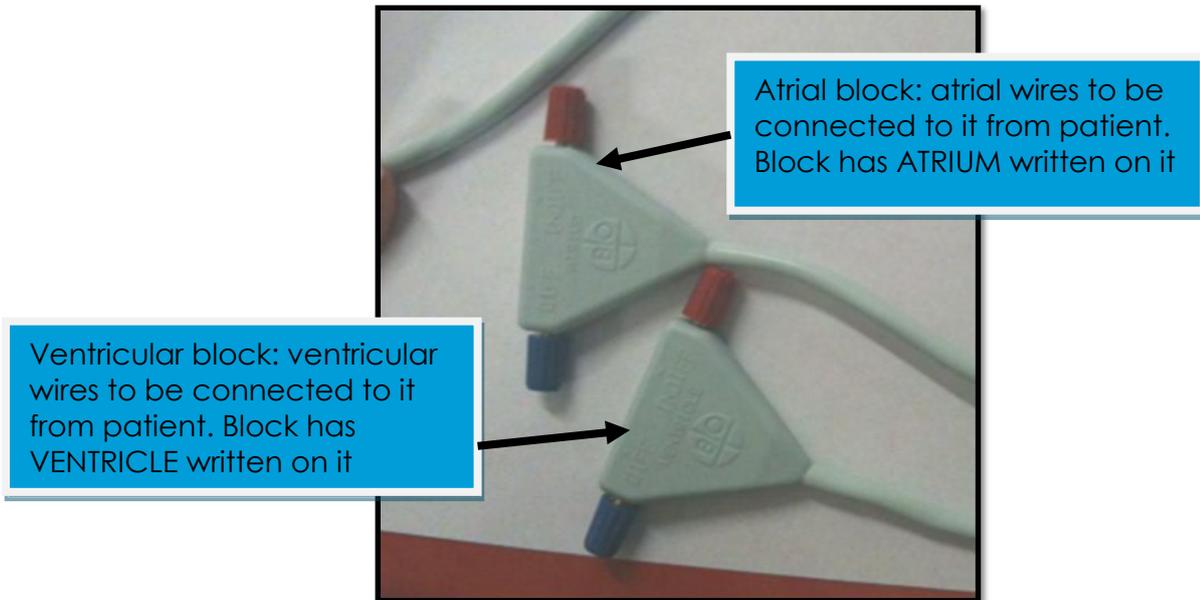
Figure10: Medtronic 5392 Pacemaker

The control panel displays the following settings:

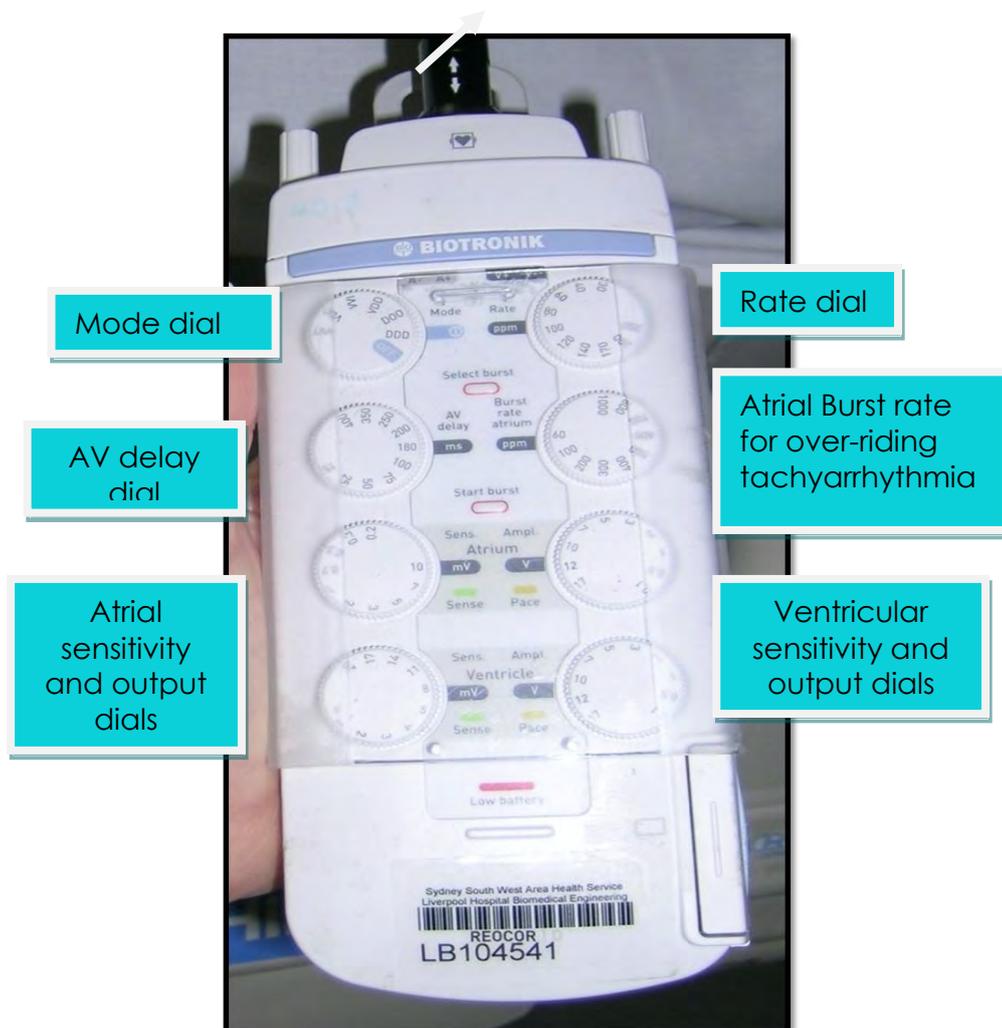
- A Sensitivity: 0.4 mV
- V Sensitivity: 0.8 mV
- A-V Interval: \*200 mS
- Upper Rate: 110 min<sup>-1</sup>
- PVARP: 300 mS
- A. Tracking: 0n
- Settings: Manual(\*)
- Rapid Atrial Pacing
- Mode Selection

Labels for the control panel components and functions:

- Enter key
- Selection key
- Dial to change settings
- Pause button to check underlying rhythm
- Rapid atrial pacing can be used to interrupt atrial tachycardia's
- A. Tracking: applicable in DDD only. If ON it paces ventricle in synchrony with intrinsic atrial depolarisations
- AV delay
- Upper rate limit sets maximum ventricular pacing rate allowed while tracking the ventricle
- PVARP: Post Ventricular Atrial Refractory Period Sets length of time after a ventricular event during which atrial sensing doesn't affect pacemaker timing
- Atrial and Ventricular sensitivity



**Figure 12:** Pacing leads for Biotronic EDP 30 and Biotronic Reacor



**Figure13:** Biotronic Reacor pacing box.

## How do pacemakers work?

- The pacemaker essentially does two things :
  - it senses the patient's own rhythm using a "sensing circuit",
  - It sends out electrical signals using an "output circuit".
- If the patient's intrinsic rhythm becomes too slow or goes away completely, the electronic pacemaker senses that, and starts sending out signals along the wires leading from the pacing box to the heart muscle.
- The signals, if they're "capturing" properly, provide a regular electrical stimulus, making the heart contract at a rate fast enough to maintain the patient's blood pressure.
- Pacemakers are not simply applied to the patient and turned on; we must tell the pacemaker how to pace the heart.
- The goal of pacing the heart is to maximize cardiac output. There are two determinants of cardiac output; stroke volume and heart rate.
- Pacemakers use the sensing and output circuits and then determine the heart rate by timing and intervals

### How do pacemakers determine heart rate?

Before being able to understand pacemaker codes, it is necessary to have an understanding of pacemaker timing.

### **INTERVALS AND TIMING**

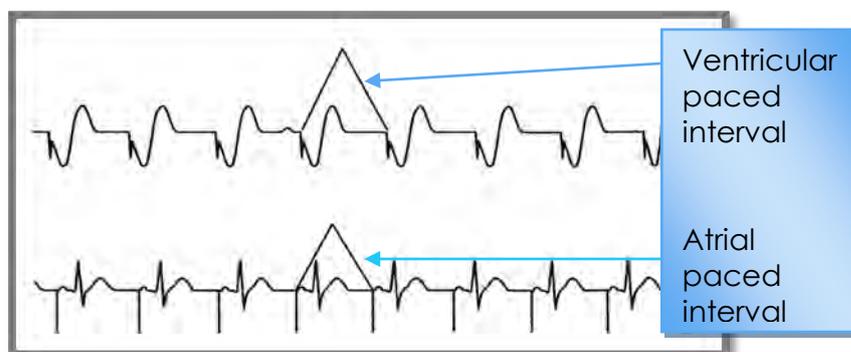
Cardiac devices calculate everything in terms of intervals, from one event to the next. The pacemaker does not keep track of how many beats the heart has in a minute, it simply determines how long it has been since the last beat has occurred.

It does this by transforming the programmed minimum heart rate into a **time interval** by dividing the programmed heart rate into 60,000 (the number of milliseconds in one minute)

The result is the number of milliseconds that the pacemaker waits before deciding to deliver a stimulus. (6)

For Example:

- pacing heart rate set at 60
- pacemaker waits  $60,000/60$  or 1000ms after the last beat before it delivers the next stimulus
- if the heart has an intrinsic beat before 1000ms then pacemaker resets the lower rate timer and starts again at zero



**Figure 14:** Paced intervals: Single chamber temporary pacing ppt 2001

### **INTERVAL DEFINITIONS**

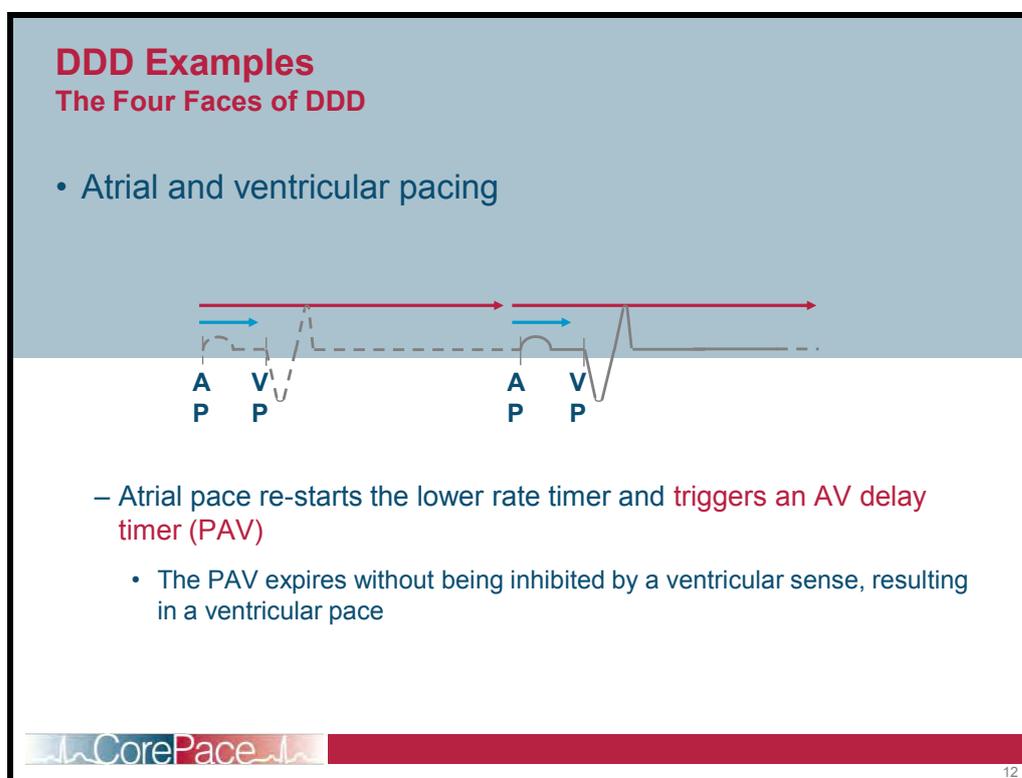
- Lower Rate interval( V-V)
  - Lowest rate the pacemaker will pace the atrium in the absence of intrinsic atrial activity
- AV Intervals
  - Initiated by a paced atrial event
- V-A Interval
  - A pace-maker timing scheme that is based on the interval between a ventricular event and the subsequent atrial event (the VA Interval). This is in contrast to an atrial escape interval in which the interval between subsequent atrial events is fixed. (NOTE: This may make a difference when a patient has some intrinsic AV conduction. Since a sensed ventricular beat

comes earlier than a paced one, and the pacemaker bases its lower rate on the atrial escape interval, the pacemaker rate from beat-to-beat could be slightly faster than the programmed rate.

- **Atrial escaped interval**

- The interval from a paced or sensed ventricular event to the next scheduled paced atrial event.

**Figure 15:** Intervals and timing in DDD mode. Core Pace Module 6. Single and Dual Pacemaker timing ppt presentation 2003



On this slide, we see AV sequential or dual chamber pacing. Both the atrium and the ventricles are being paced, first the atrium and then the ventricle.

Looking at the 2 complexes shown:

The pacemaker begins by pacing in the atrium. 2 timers are started:

- The lower rate timer
- The AV Interval timer

- The AV Interval timer expires WITHOUT BEING INHIBITED by a ventricular sense – so the pacemaker paces in the ventricle.
- The lower rate timer continues.
- If it expires without being inhibited by an atrial event (as shown above), the pacemaker paces in the atrium, and the cycle begins again.

## **IN SUMMARY**

Intervals and timing can be a hard concept to understand, but fortunately the pacemaker calculates all these intervals for us. It is important to know how pacing works using its sensing, output and timing mechanisms as it helps with troubleshooting.

For example: looking at the above slide and DDD mode

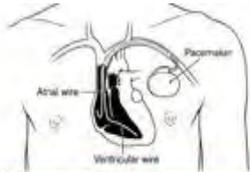
- *Why does the pacemaker's AV interval timer expire without being inhibited?*
  - Perhaps the patient has a heart block
  - Perhaps the patient has delayed AV conduction — the patient's PR interval is longer than the PAV programmed into the pacemaker
- *Why does the pacemaker's atrial escape interval expire?*
  - The patient's sinus rate is less than the pacemaker's programmed rate (i.e. sinus bradycardia)

## MODES OF PACING

Over the years pacemakers have developed from the very early devices which merely delivered a timed impulse at set amplitude in a single chamber, and paid no attention to the patient's intrinsic rhythm.

Now even temporary pacemakers are relatively sophisticated devices which can deliver a range of therapeutic options from the basic fixed rate asynchronous, to dual chamber demand pacing.

In order to be able to easily communicate to others the potential capabilities and actual programming of pacemakers, it was necessary to develop a code, which is shown here, generally called the NBG code. Generally the first three codes are utilised.



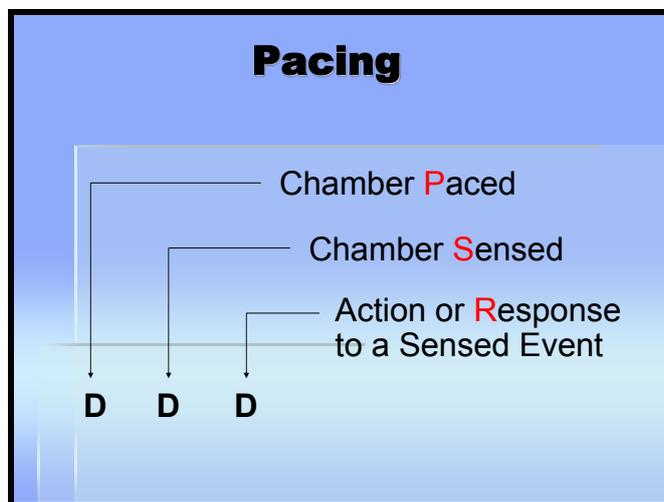
### The NBG Pacemaker Code

| I                | II                | III                        | IV                     | V                         |
|------------------|-------------------|----------------------------|------------------------|---------------------------|
| Chamber(s) Paced | Chamber(s) Sensed | Mode(s) of Response        | Programmable Functions | Antitachycardia Functions |
| V=Ventricle      | V=Ventricle       | T=Triggered                | R=Rate Modulated       | O=None                    |
| A=Atrium         | A=Atrium          | I=Inhibited                | C=Communicating        | P=Paced                   |
| D=Dual (A&V)     | D=Dual (A&V)      | D=Dual Triggered/Inhibited | M=Multiprogrammable    | S=Shocks                  |
| O=None           | O=None            | O=None                     | P=Simple Programmable  | D=Dual (P&S)              |

**Figure 16:** NBG Code.[www.cardiacrhythm.co](http://www.cardiacrhythm.co)

**CODES: WHAT DOES IT ALL MEAN?**

- Defines the chambers that are paced/sensed
- Defines how the pacemaker will respond to intrinsic events
- **PACING** : first letter is chamber being **paced**
- **SENSING**: relates to the chamber in which the pacemaker is attempting to **sense** the patient's intrinsic rhythm.
- **RESPONSE**: relates to the pacemakers **response** to the sensed intrinsic beat, either triggered or inhibited



**Figure 17 & 18:** PSR. Pacing ppt. P.Nekic 2011

| 1 <sup>st</sup> Letter              | 2 <sup>nd</sup> Letter | 3 <sup>rd</sup> Letter     |
|-------------------------------------|------------------------|----------------------------|
| <b>Chambers Paced</b>               | <b>Chambers Sensed</b> | <b>Response to Sensing</b> |
| A= Atrium                           | A= Atrium              | T=Triggered                |
| V=Ventricle                         | V= Ventricle           | I= Inhibit (Demand Mode)   |
| D= Dual (both Atrium and Ventricle) | D= Dual                | D=Dual                     |
|                                     | O= none                | O= none (Asynchrony)       |

Remembering the letters **PSR** helps to remember the function of each letter.

Therefore when you collate the information in the tables above you end up with different codes and or modes of pacing. The most common modes are outlined in the table below.

## MODES OF PACING

| CODE | Chamber Paced (1st Letter)  | Chamber Sensed (2 <sup>nd</sup> Letter) | Response to sensing Trigger or Inhibited (3 <sup>rd</sup> Letter) | MEANING  |
|------|-----------------------------|---|---|--|
| AOO  | Atrial pacing               | None                                    | None  | Asynchronous atrial pacing occurs at a set rate, regardless of intrinsic atrial activity.  |
| VOO  | Ventricular Pacing          | None                                    | None  | Asynchronous ventricular pacing occurs at a set rate, regardless of intrinsic Ventricular activity.                                  |
| DOO  | Ventricular & atrial pacing | None                                    | None  | Asynchronous atrial & ventricular pacing at a set rate regardless of intrinsic atrial & ventricular activity                         |
| AAI  | Atrial pacing               | Atrial sensing                          | Inhibits pacing   | A sensed P wave will cause the pacemaker to withhold atrial pacing. Absence of intrinsic p wave will lead to atrial pacing           |
| VVI  | Ventricular pacing          | Ventricular sensing                     | Inhibits pacing   | A sensed R wave will cause the pacemaker to withhold ventricular pacing. Absence of intrinsic R wave will lead to ventricular pacing |
| DDD  | Atrial & ventricular pacing | Atrial & ventricular sensing            | Inhibition of pacing & trigger of pacing impulses                 | Intrinsic P & R waves cause pacemaker to withhold pacing. Pacing impulses will be triggered when programmed intervals are exceeded   |



## What does it all mean? : DDD

### DDD MODE:

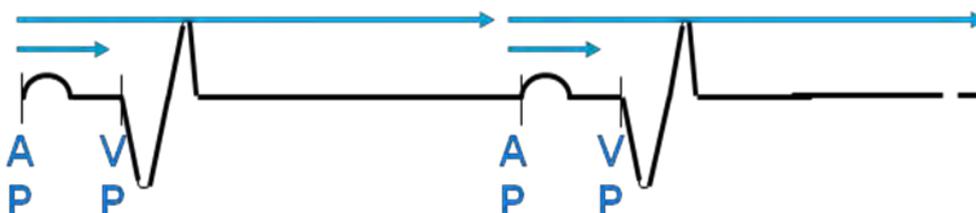
- The *first* letter is **D**, so both the Atrium and the Ventricles are being **paced**.
- The *second* letter is also **D** which means that the pacemaker is looking for **sensed** intrinsic beats in both the Atrium and the Ventricle
- The *third* letter **D** means that the pacemaker can both **Trigger** a Ventricular pace in **response** to a sensed Atrial event, and **inhibit** the Atrial and/or Ventricular pace if it senses an intrinsic event in that chamber before its internal timing tells it to pace.
- An atrial sense:
  - Inhibits the next scheduled atrial pace
  - Re-starts the lower rate timer
  - Triggers an AV interval (called a Sensed AV Interval or SAV)
- An atrial pace:
  - Re-starts the lower rate timer
  - Triggers an AV delay timer (the Paced AV or PAV)
- A ventricular sense:
  - Inhibits the next scheduled ventricular pace

### Examples of DDD mode and how it works

DDD mode can have four possible outcomes for pacing depending on the patient's condition or underlying rhythm

#### ❖ **Atrial and ventricular pacing**

- Atrial pace re-starts the lower rate timer (Long arrow) and triggers an AV delay timer (PAV) (shorter arrow)
  - The PAV expires without being inhibited by a ventricular sense, resulting in a ventricular pace



- Both the atrium and the ventricles are being paced, first the atrium and then the ventricle.

The pacemaker begins by pacing in the atrium. 2 timers are started:

- The lower rate timer
- The AV Interval timer (we call this timer the PAV or Paced AV interval)
- The AV Interval timer expires WITHOUT BEING INHIBITED by a ventricular sense – so the pacemaker paces in the ventricle.
- The lower rate timer continues. If it expires without being inhibited by an atrial event (as shown above), the pacemaker paces in the atrium, and the cycle begins again.

Why does the pacemaker's AV interval timer expire without being inhibited?

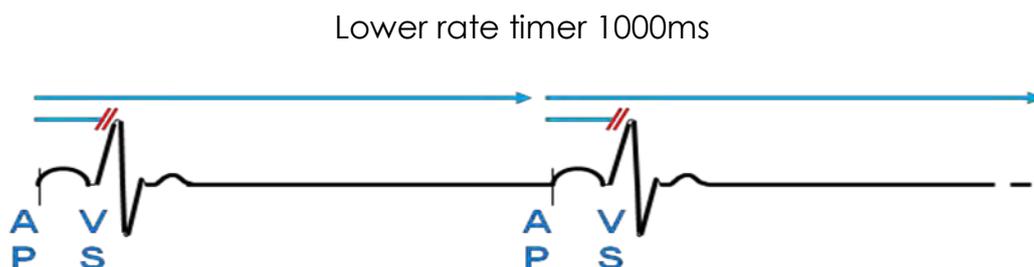
- Perhaps the patient has a heart block
- Perhaps the patient has delayed AV conduction — the patient's P-R interval is longer than the PAV programmed into the pacemaker

Why does the pacemaker's atrial escape interval expire?

- The patient's sinus rate is less than the pacemaker's programmed rate e.g. sinus bradycardia

#### ❖ Atrial pacing and ventricular sensing

- Atrial pace re-starts the lower rate timer and triggers an AV delay timer (PAV)
  - The PAV expires without being inhibited by a ventricular sense, resulting in a ventricular pace



In this example we see atrial pacing with an intrinsic ventricular response (VS).

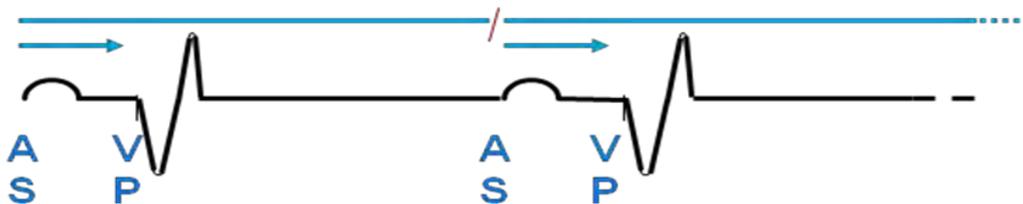
- The pacemaker begins by pacing in the atrium. The 2 timers are started:
  - The lower rate timer (longer arrow)
  - The AV Interval timer (this is the PAV or Paced AV interval) (shorter arrow)
- The AV Interval timer IS INHIBITED by a ventricular sense – so the AV timer is reset, but the lower rate timer continues.
- It expires without being inhibited by an atrial event, so the pacemaker paces in the atrium, and the cycle begins again.

Atrial pacing and ventricular sensing can occur if:

- Patient's intrinsic AV conduction occurs faster than the PAV interval, but the patient's sinus rate (his A-to-A interval) is still longer than the lower rate interval programmed into the pacemaker.

#### ❖ Atrial sensing, ventricular pacing

- The intrinsic atrial event (P-wave) inhibits the lower rate timer and triggers an AV delay timer (SAV)
  - The SAV expires without being inhibited by an intrinsic ventricular event, resulting in a ventricular pace



In this example we see P-waves followed by ventricular pacing.

- This is also called “tracking,” and is pretty common in pacemakers programmed to the DDD mode.
- An intrinsic P-wave inhibits the scheduled atrial output.
- The lower rate timer is reset to zero and begins again.
- The AV interval timer (this time called a Sensed AV or SAV – because it follows a sensed atrial event) begins.
- This timer expires before a ventricular sense occurs, so a ventricular pace occurs, and the lower rate timer continues, and before it can expire, another intrinsic atrial event is sensed and the cycle begins again.
- Another way to describe this is that the patient's A-A interval is shorter than the Lower Rate Interval, but his intrinsic P-R interval is longer than the SAV.

#### ❖ Atrial and ventricular sensing

- The intrinsic atrial event (P-wave) inhibits the lower rate timer and triggers an AV delay timer (SAV)
- Before the SAV can expire, it is inhibited by an intrinsic ventricular event (R-wave)



In this example we see the pacemaker inhibited by the patient's intrinsic atrial rate and intrinsic AV conduction.

- The patient's A-A interval is shorter than the Lower Rate interval, as his P-R interval is shorter than the programmed AV interval.

Are all four outcomes of DDD possible for all patients?

- No, patients with complete heart block cannot have AS-VS or AP-VS

### **Core Pace Module 6. Single and Dual Pacemaker timing ppt presentation 2003**

- When atrial beats are unsynchronized or absent, as in atrial fibrillation, atrioventricular block, or sinus arrest, cardiac output decreases because less blood than usual is ejected from the atria during ventricular diastole. This concept is important because almost 30% of normal cardiac output is due to the atrial "kick," or atrial systole, that occurs during ventricular filling when the 2 chambers perform in sync.
- For maximum effectiveness, paced beats and intrinsic beats must be synchronized.
- To synchronize the beats, the pacemaker first analyses the intrinsic rhythm and then stimulates the heart only as needed.

### **Demand Pacing**

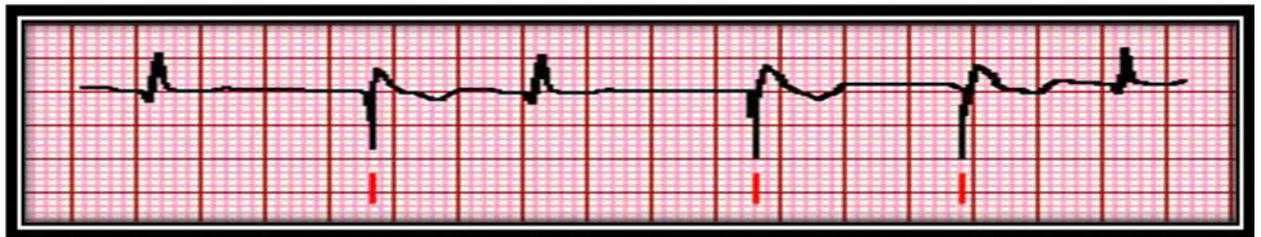
- Output is inhibited when the pacemaker senses intrinsic activity
- Pacemaker rate can be set to allow intrinsic rhythm to occur. If the pt's heart rate drops below the set pacemaker rate the pacemaker will pace the pt @ that rate

### **Asynchronous Pacing DOO**

- Pacemaker will not sense the pt's intrinsic rhythm & will pace the pt regardless of any intrinsic activity
- BEWARE if the mode is set in DOO or if the sensitivity number is set too high ( 20mV) you will cause asynchronous pacing
- Asynchronous pacing is DANGEROUS as it can cause fatal arrhythmias (VT & VF)
- Used in OT to prevent interference from diathermy

## VDD

- Allows for pacing in patients with ventricular pacing wires only.
- Only paces the ventricles
- Atrial and ventricular sensing
- Inhibited response to sensing in the ventricle and triggered response to sensing in the atrium
- Will pace the ventricle depending on what it senses in the atria and ventricle
- If it senses ventricular activity then it won't pace
- If it doesn't sense ventricular activity it will be triggered to pace the ventricle after it senses the hearts intrinsic atrial activity



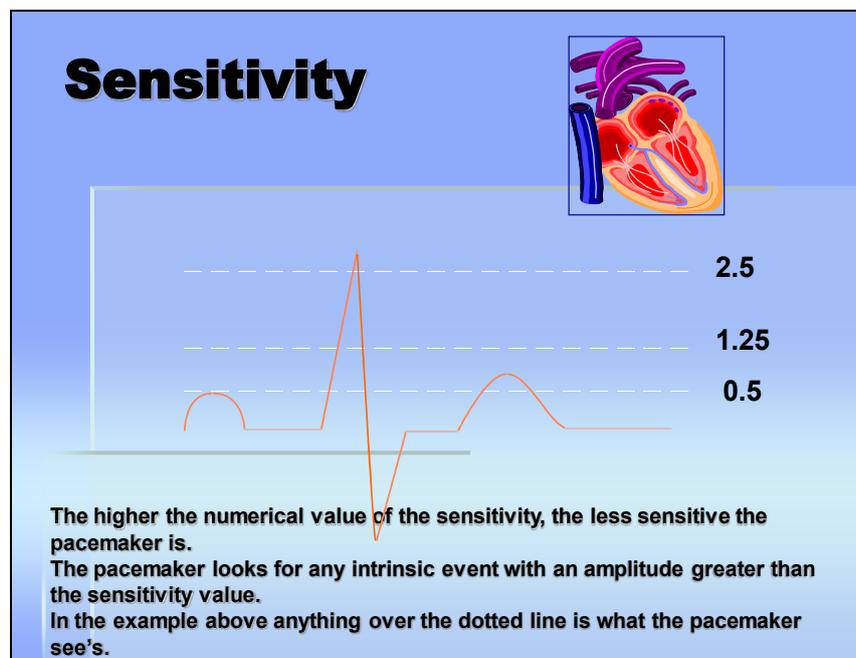
**Figure 19:** [uptodate.com](http://uptodate.com).

A single pacemaker spike (marked by red lines) is followed by a QRS complex which is wide and bizarre and resembles a ventricular beat. There are some normal intervening QRS complexes that suppress the pacemaker when they occur faster than the rate set for the pacemaker.

## SENSITIVITY

### ■ SENSITIVITY

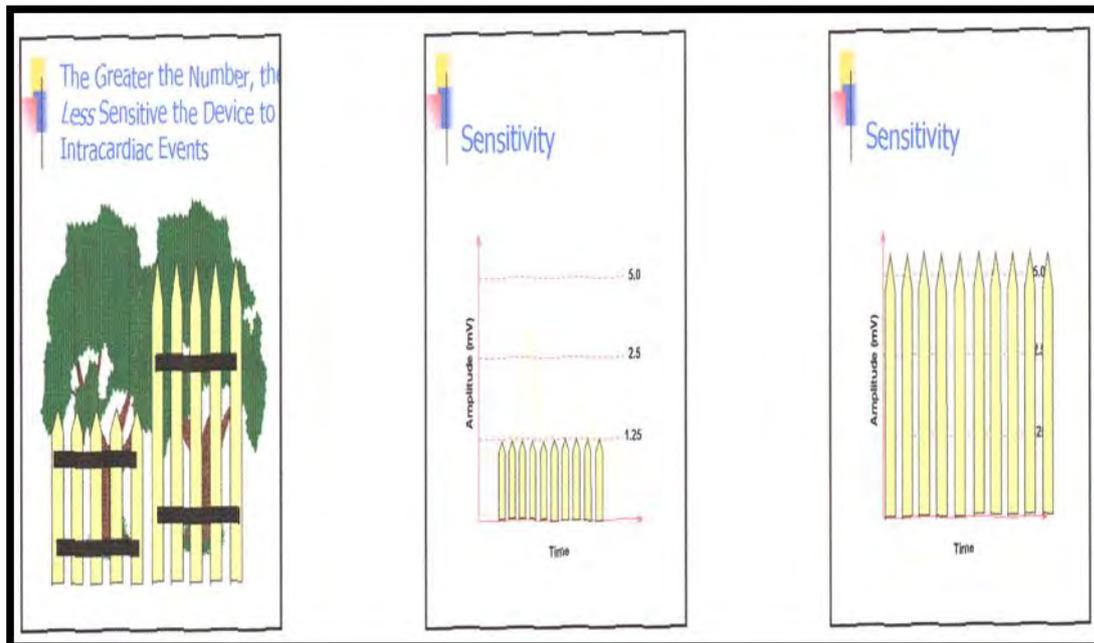
- Is the pacemaker's ability to sense a patient's intrinsic rhythm or when *natural* depolarisation is occurring
  - **The sensitivity number represents the minimum size, in millivolts, of an electrical signal that will be detected by the pacemaker**
- The **higher** the sensitivity (**number**) the **less** likely the pacemaker will **see** the patients rhythm



**Figure 20:** Temporary Cardiac Pacing.ppt P.Nekic

- Looking at the ECG trace the p waves (which represent atrial excitation) only have amplitude of 2-3mm. The sensitivity setting for atrial pacing is 0.2 -10mV. If the sensitivity setting goes above the amplitude of the intrinsic p wave the pacemaker will no longer be able to see the intrinsic p wave so then it will pace the atrium in a asynchronous mode, i.e it will pace the atrium regardless of the patients underlying rhythm

- The same goes for the QRS complex (which represents ventricular contraction). The sensitivity setting for ventricular pacing is 2-20mV. So if the sensitivity setting goes above the amplitude of the QRS complex it will pace the ventricle asynchronously.



- In the above example the higher the fence the less the pacemaker sees. The fence, i.e. the sensitivity setting, blocks the pacemaker's ability to see the patient's underlying rhythm. If the fence/sensitivity is put up to the highest setting the pacemaker becomes asynchronous and the pacemaker will pace regardless
- If the sensitivity setting is set at a lower setting or the fence is lower then the pacemaker will see the patient's underlying rhythm so the pacemaker will pace
- It is better to have intrinsic activity as it stimulates better contractions, and more effective forward flow of blood, from the chambers of the heart, especially when the atria and ventricles are intrinsically beating in time.

## OUTPUT

- **OUTPUT**
  - Is the electrical stimulus that the pacemaker box generates to pace the myocardium.
  - Intended to trigger a depolarization in the chamber of the heart being paced
- May also refer to the voltage, amperage and/or pulse width measurement or settings of a particular pacing stimulus.
- Once the pacemaker has been programmed, we must tell it how much energy to use so a pacing stimulus is delivered. Many variables can affect the amount of energy necessary to pace the heart such as the type of electrodes, scar tissue and electrolyte disturbances. We need to determine the amount of energy that assures the pacemaker stimulates the heart to depolarize.



## THRESHOLDS

### OUTPUT THRESHOLDS

- The output threshold is the minimum amount of energy required to “capture” the heart.
- *To find output threshold*
  - If the patient is not being paced, then increase the pacemaker rate to 10 above the patient's rate
  - If the patient is already in a paced rhythm, turn the pacemaker rate down and observe the ECG monitor for the patient's intrinsic heart rhythm.
  - If the patient is still pacing at a rate of 60, **abort** the checking of the output threshold
  - Explain to the patient that they may briefly become ‘light-headed’ during the checking procedure.
  - Obtain a rhythm strip.
  - Decrease the output setting until loss of capture occurs.
  - Increase the output setting until you just see that capturing is occurring. This is called the stimulation **Threshold**.

It is usually measured in milliamps (mA) for temporary pacemakers and volts (V) for permanent pacemakers

- You then set the output at double the threshold and add one as a safety margin
- **Eg.** Threshold is 3 V  
 $3 \times 2 = 6$   
Add one (for safety margin)  $6 + 1 = 7$  Therefore you set the output at 7 V.

## **SENSITIVITY THRESHOLDS**

- The sensitivity threshold is the maximum sensitivity at which the pacemaker can sense intrinsic events.
- The minimum atrial or ventricular intra cardiac signal amplitude required to inhibit or trigger a demand pacemaker, expressed in millivolts
  
- *To find threshold:*

\*NB if patient has no intrinsic rate with an adequate output this test cannot be performed.

- Reduce the pacemaker rate to just below the patient's intrinsic rate.
- Obtain a rhythm strip.
- Decrease the output setting to the lowest number possible, thereby avoiding potentially dangerous competition between the pacemaker and the patient's intrinsic heart rate.
- Decrease the pacemaker's sensitivity (i.e. ↑ number)
- Observe the pacemaker for the sensing light to stop flashing.
- You then ↓ the number on the pacemaker box until the sensing light just start to flash. This is called the sensitivity **threshold**.
- You then set the sensitivity on the pacemaker at half the sensitivity threshold and minus one, as a safety margin.
- **Eg.** Sensitivity 6mV  
 $6 \div 2 = 3$   
Minus one (for safety margin)  
 $3 - 1 = 2$

## Management

### To commence pacing

- Insert lead pins
- Ensure correct polarity
  - blue to blue
  - red to red
- Tighten lead pins into locking device
- Connector pins on the wires must be fully inserted in the patient connector block
- Ensure correct chamber
  - atrial wires on right of the sternum
  - ventricular wires on the left side
- Check the battery indicator light is yellow and not red
- Set the Pacing rate (heart rate)
- Set the Sensitivity
- Set the Output/stimulation threshold
- Set the AV Delay

### Common settings

- **Atrial**
- DDD
- Rate 80- 100
- Sensitivity 0.2ms
- Output 5.0V/10mA
- AV delay 150 ms
- **Ventricular**
- DDD
- Rate 80- 100
- Sensitivity 2.0ms
- Output 5.0/10mA
- AV delay 150 ms



## Battery

- AA alkaline battery
- Once low battery indicator light appears, will continue pacing for approx 24 hours.
- If battery needs to be replaced it will continue to pace for 30 secs once the battery is removed

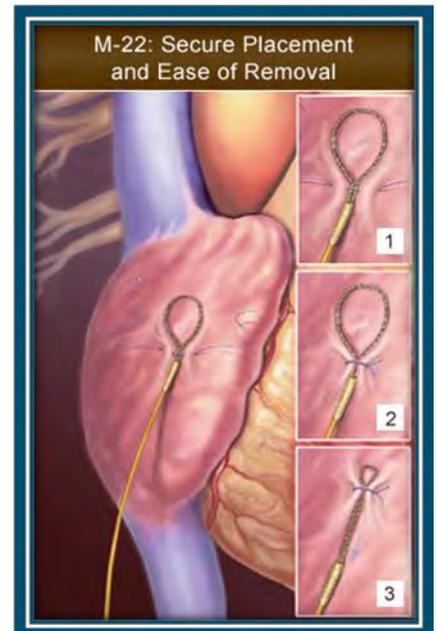


## General management

- Full physical assessment
- Assess vital signs, skin colour, level of consciousness, and peripheral pulses to determine the effectiveness of the paced rhythm
- Monitor the ECG reading, noting capture, sensing, intrinsic beats, and competition of paced and intrinsic rhythms
- Check wires & leads are connected appropriately
- Check underlying rhythm, Daily ECG if patient not compromised
- If the pacemaker is sensing correctly, the sense indicator on the pulse generator should flash with each beat.
- Assess the patient for both electrical and mechanical capture. When you observe a pacer spike on the ECG followed by a complex, you have electrical capture
- Check thresholds each shift and document. Output thresholds are important as the threshold may change. If the threshold gradually increases and is approaching maximum output the patient may need a permanent pacemaker if there is a heart block
- Check pacing wire insertion site for signs of infection
- If pacing wires not in use should be wrapped in gauze & taped to patients chest

## Removal of pacing wires

- Routinely removed on Day 3–5
- Patient must be in sinus rhythm
- Patients on Warfarin must have INR less than 2.5
- Patient in bed before removal as tamponade is complication post removal
- They are removed by constant gentle traction, allowing the motion of the heart to assist dislodgement from the epicardium.
- Patient should be on bed rest for 2 hours post removal
- Equipment: gloves, stitch, cutter, gauze, opsite.
- Pull out wires you will feel heart pulsating & slight resistance
- Check end of wires are intact



## Precautions

- Do not attempt to change battery while pacing a dependent patient.
- Asynchronous operation has the potential to induce life threatening arrhythmias. Ensure a defibrillator is at hand, and return to synchronous operation as soon as possible
- Ensure that implanted temporary pacing wires are properly insulated when not connected to the pacemaker, as these provide a direct electrical connection to the myocardium....
- ONLY handle the pacing wires with GLOVES
- For EMERGENCIES always keep a spare pacing box on the emergency trolley (battery included)
- Requires 9v battery
- Prior to turning on check settings are appropriate
- Check pacemaker mode is on DDD on return from OT
- DDD is the safest mode to use for post op cardiac patients unless otherwise indicated

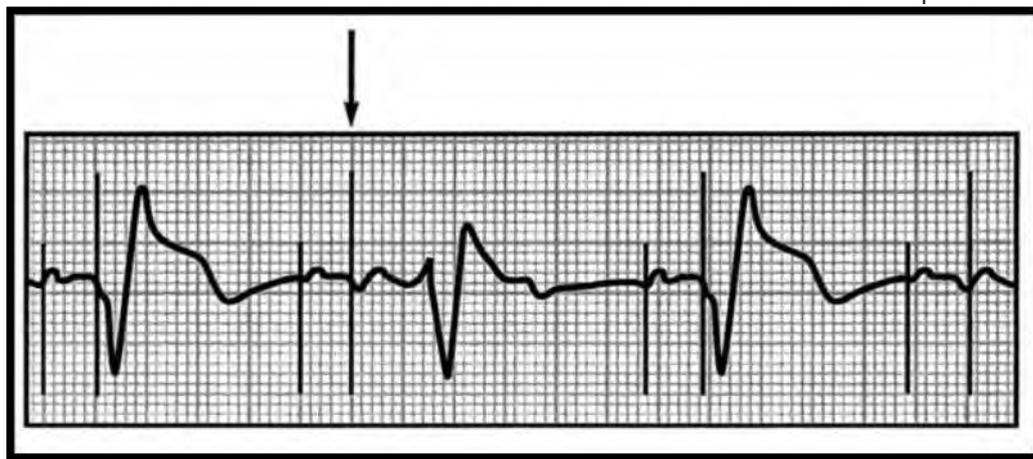
## Troubleshooting/complications

### Failure to capture

Failure to capture occurs when

- A pacer spike is present but is not followed by a corresponding waveform (P wave or QRS complex).

Arrow indicates electrical stimulus without ventricular capture.



**Figure 22:** Critical Care Nurse.

- Capture occurs when the pacemaker stimulus causes the entire chamber to depolarize, hopefully generating a contraction.
- The ECG for failure to capture differs from the failure to fire by the presence of pacemaker spikes
- The pacemaker stimulus is delivered, however the patient's heart does not depolarize

### Causes

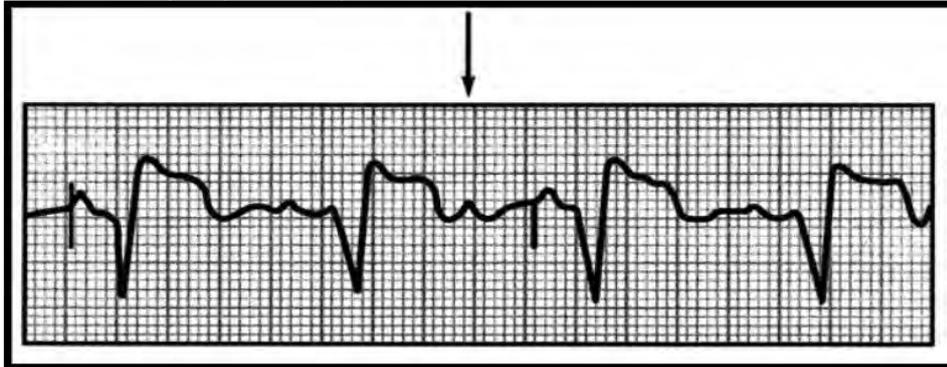
- Inappropriate output setting
- Increased resistance to conduction
- QRS complex not visible
- Faulty cable connection
- Dislodged/fractured lead
- Tissue is refractory

## Failure to sense

Failure to sense occurs

- When the generator does not detect intrinsic beats and initiates an inappropriate impulse that may or may not capture.

Arrow indicates an atrial beat not sensed by the pulse generator, which is followed by a pacer spike.



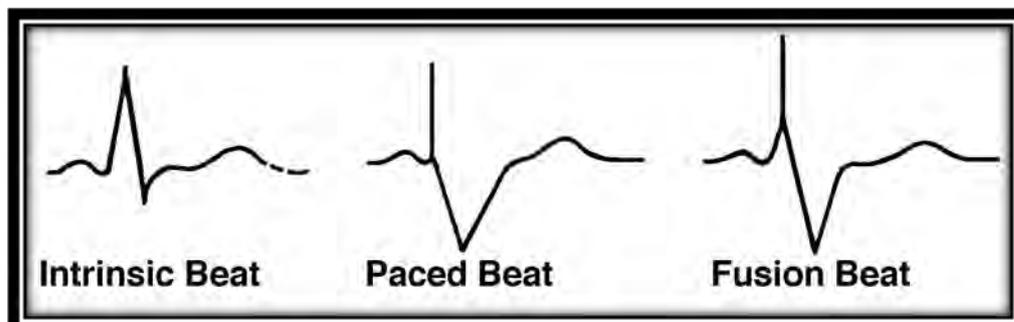
**Figure 23:** Critical Care Nurse.

### Causes

- Inappropriate sensitivity setting
- Battery depletion
- Decreased QRS voltage
- Fusion beat
- Dislodged/fractured lead

### Fusion/Pseudo fusion Beats

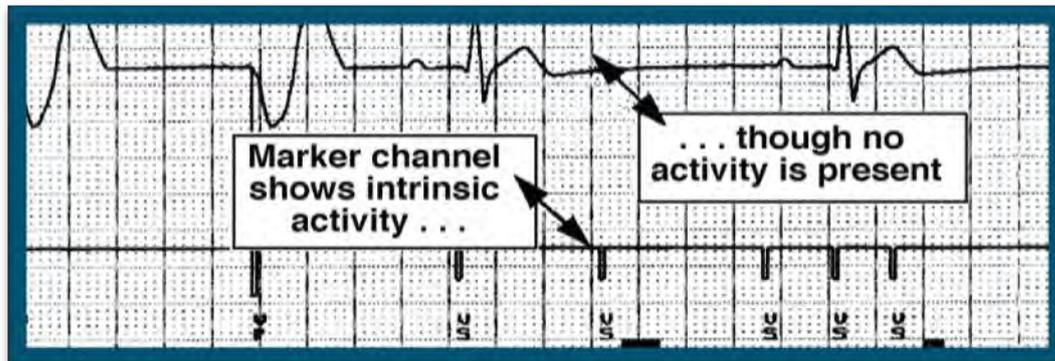
- Spontaneous cardiac depolarization which occurs coincidentally with a paced depolarization.
- The paced and natural depolarization waveforms collide or fuse, causing distortion of the surface ECG complex.



**Figure 24:** Dual Chamber Temporary Pacing. Operations & Troubleshooting

## Over sensing

- Inhibition of the pacemaker by events the pacemaker should ignore, e.g. EMI, T-waves, and myopotential

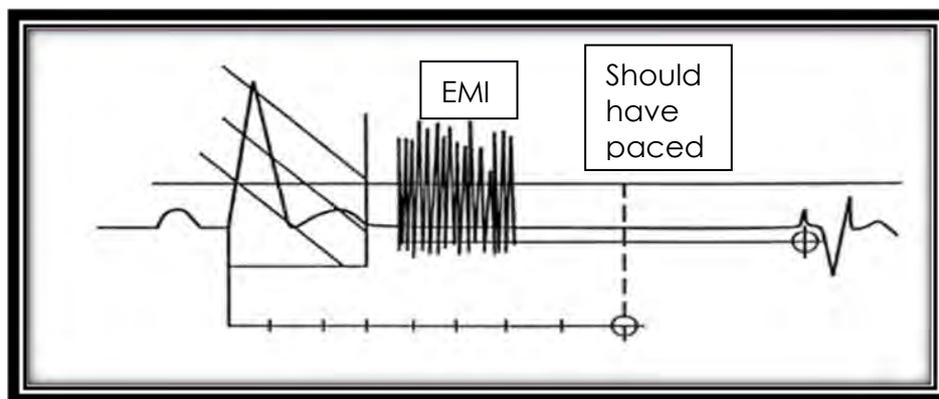


### Causes

- Inappropriate sensitivity setting
- Myopotential inhibition
- EMI
- T-waves outside of refractory period
- Dislodged/fractured lead

## Electromagnetic Interference (EMI)

- Radiated or conducted energy – either electrical or magnetic which can interfere with the function of the pacemaker in the Demand mode

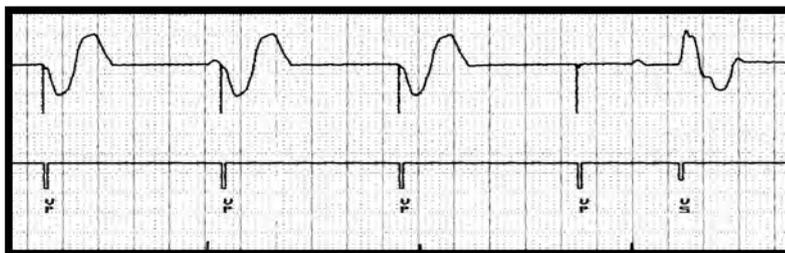


**Figure 25:** Dual Chamber Temporary Pacing. Operations & Troubleshooting

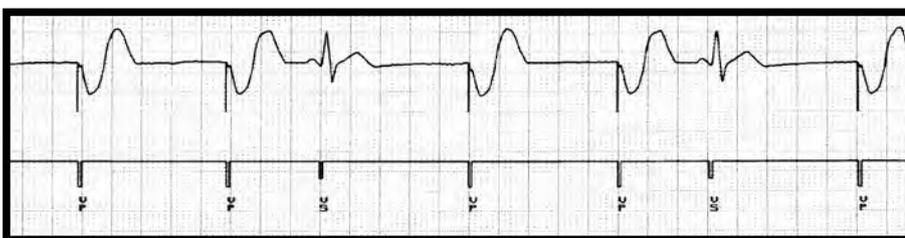


## Learning activities

1. What are the indications for temporary epicardial pacing?
2. What is an A-V interval?
3. What is asynchronous pacing and when should it be used?
4. Explain DDD mode
5. Define PSR
6. Explain output
7. Explain sensitivity
8. When how and why should thresholds be performed?
9. What are the safety precautions for pacing?
10. Provide an explanation for why the pacemaker did not "capture"  
(think of the electrical concepts)



11. Which beats are paced?



12. What is electrical and mechanical capture and how do you know you have it?
13. How do you know the pacemaker is sensing?
14. What is the management if the pacemaker has no output?

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