AMERICAN COLLEGE OF EMERGENCY PHYSICIANS
SCIENTIFIC ASSEMBLY
1999

Technology for the Dysrhythmic Heart: Pacemakers and Other Electrifying Devices

The use of technology for acute and chronic electrical therapy of dysrhythmias is complex and its role is expanding. The present technology available and its uses will be explained. Diagnosing dysfunction of the devices will be stressed.

- Discuss the normal functioning of artificial pacemakers and how to recognize and assess malfunction.
- List the indications for outpatient Holter monitoring and the appropriateness of ordering this from the emergency department.
- Discuss the technology and use of the implanted cardioverter-defibrillator and potential problems.

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FACULTY

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Notes

Technology for the Dysrhythmic Heart: Pacemakers and Other Electrifying Devices

Steven Pace MD FACEP
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Fort Lewis, WA

Objectives:

- Discuss the technology and use of the implanted cardioverter-defibrillator and potential problems.
- List indications for outpatient Holter monitoring and the appropriateness of ordering this from the emergency department.
- Discuss the normal functioning of artificial pacemakers and how to recognize and assess malfunction.

Electrifying Devices

- **Implantable Cardioverter-Defibrillators**
- **Holter Monitoring**
- **Implanted Transvenous Pacemakers**

Cardioverter-Defibrillators

- **Implanted electronic device**
- **High risk patients**
  - **Ventricular tachycardia - VT**
  - **Ventricular fibrillation - VF**

ICD Patients in the ED

- **Patients in cardiac arrest with an ICD in place**
- **Patients who present after ICD shocks**

ICD Capabilities

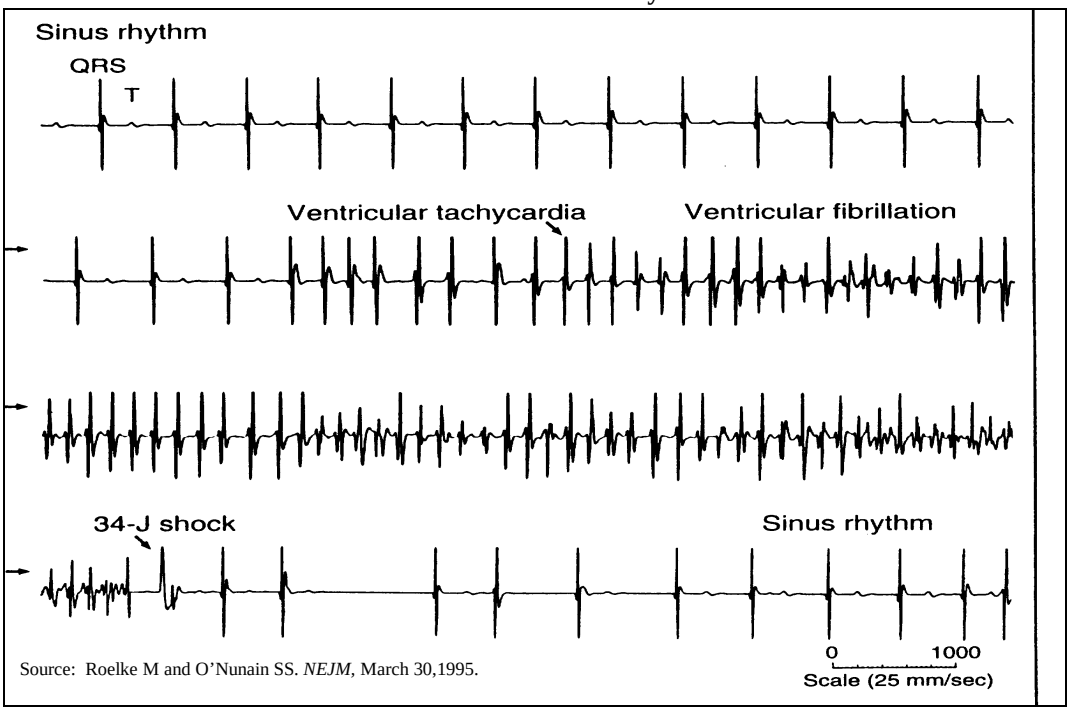
- **Tiered therapy**
  - **pacing**
  - **cardioversion**
  - **defibrillation**
- **Diagnostic memory**
- **Programmability**

Implanted Cardioverter-Defibrillators

Overview

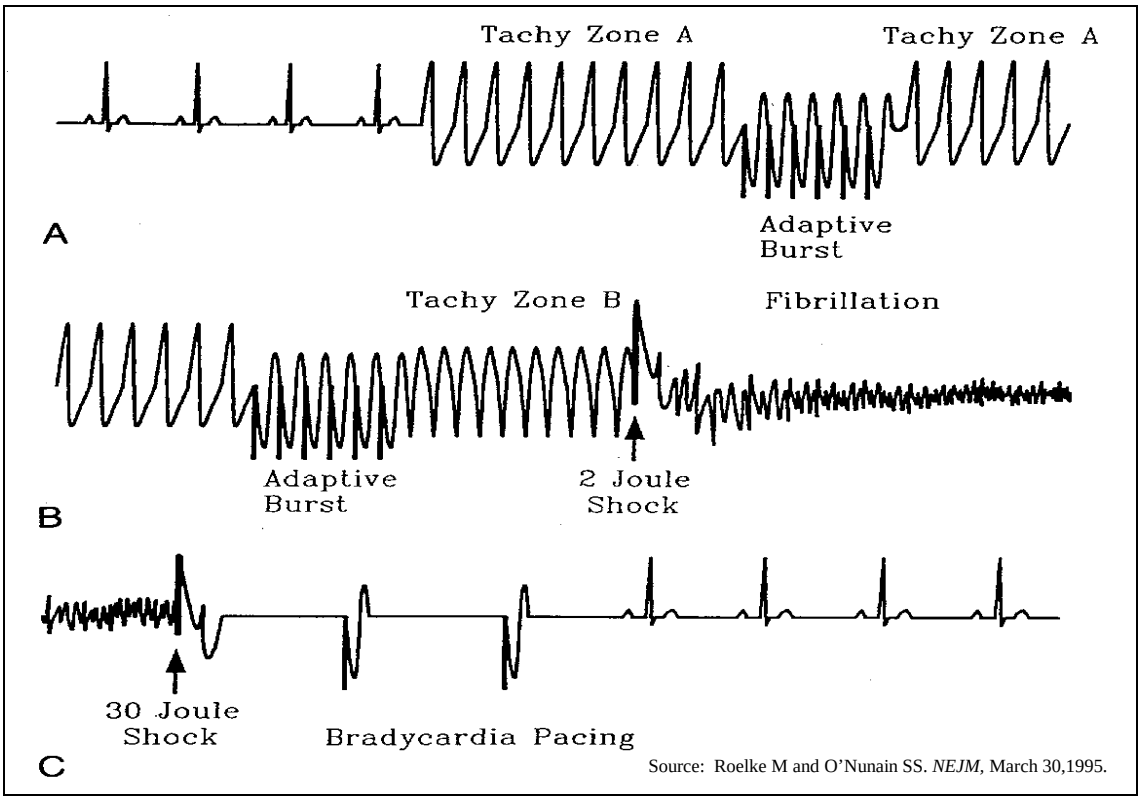
Implanted cardioverter-defibrillators (ICD) are electronic devices used to treat potentially fatal ventricular tachydysrhythmias (ventricular tachycardia and ventricular fibrillation) in patients at high risk for these life-threatening events. Most models also provide VVI (ventricular demand, fixed rate) pacing capability. Emergency physicians must be capable of evaluating and treating patients with these devices. For example, patients may present in cardiac arrest with a device in place, or a patient may present after simply having undergone a firing of the device.

Defibrillation Only



Source: Roelke M and O'Nunain SS. *NEJM*, March 30,1995.

Tiered Therapy
Pace - Cardiovert - Defibrillate - Pace



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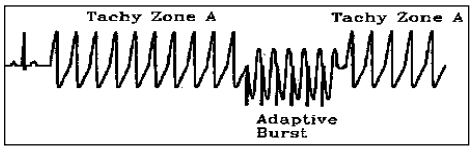
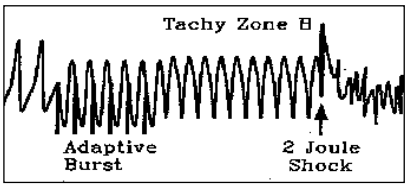
Tiered Therapy



Tachycardia Pacing

Tiered Therapy

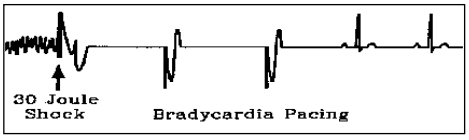


Tachycardia Pacing and Cardioversion

History

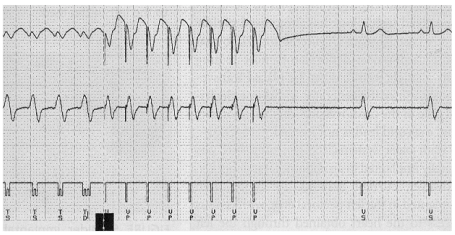
The first modern electric defibrillation was performed by Beck during cardiac surgery in 1947. External transthoracic (closed chest) defibrillation for cardiac arrest was reported by Zoll in 1956. Early external defibrillators (1950's and 1960's) were bulky, not very portable, and required wall power. In the 1970's Dr. Mirowski developed an implantable defibrillation device first tested in animals followed by human use in 1980. In 1983 ICD use in 51 patients was reported to decrease mortality by 50% (Mirowski 1983). In 1985 the FDA approved the device for human use and synchronous cardioversion became possible. Recent development has progressively decreased the size of the device and the complexity of insertion while simultaneously increasing battery life and overall capabilities. Over 50,000 patients (80% male, average age 59 years) currently have an ICD device and numbers are increasing rapidly.

Tiered Therapy



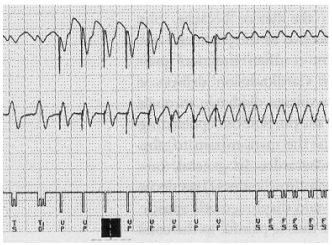
Defibrillation and Bradycardia Pacing

Anti-Tachycardia Pacing by ICD



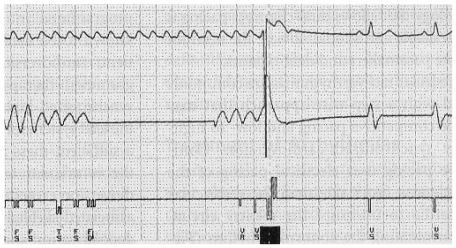
from Groh in *Am Fam Phy* 1998: 57;299

Anti-Tachycardia Pacing Causes VF



from Groh in *Am Fam Phy* 1998: 57;300

Successful Defibrillation by ICD



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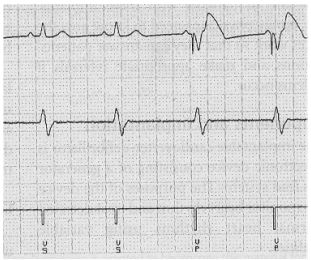
Ventricular Demand Pacing by ICD

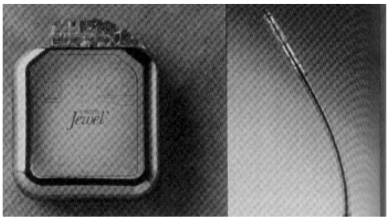


from Groh in *Am Fam Phy* 1998: 57;298

Biomechanics

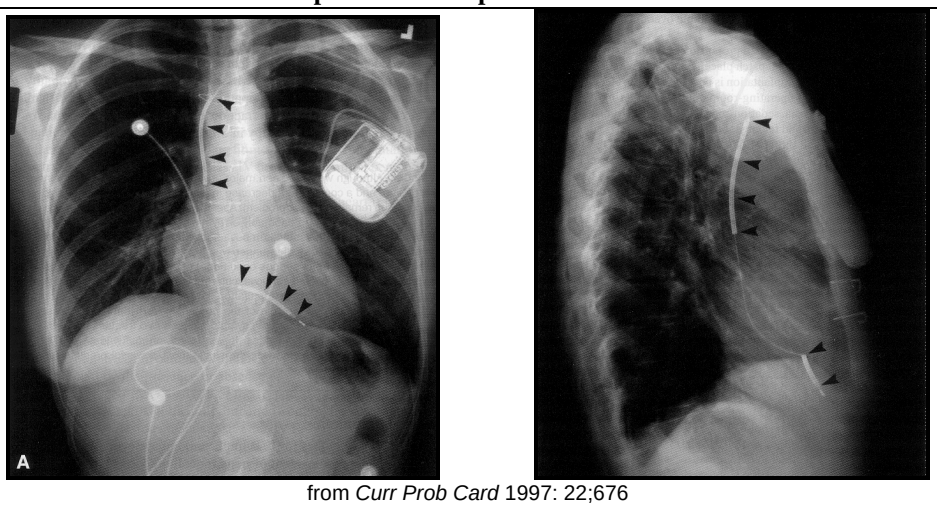
All devices share three common features; a pulse generator, an attached lead system, and electrodes that are capable of sensing and shocking. Early devices were large (300 cc), required abdominal wall implantation, and open-heart surgery for placement of epicardial leads. Operative morbidity and mortality significantly decreased overall efficacy. These early devices provided high energy output for treating only ventricular fibrillation with committed therapy resulting in shocks even if ventricular fibrillation spontaneously terminated before defibrillation. Current devices are small (50-70 cc) and may be implanted subcutaneously or in the pectoral muscle under local anesthesia. Epicardial placement has been replaced with transvenous one, two, or unipolar lead systems. Unipolar catheters use the "can" as an electrode. These newer devices defibrillate, cardiovert, pace bradycardic and tachycardic rhythms, allow for extensive telemetry and diagnostic capabilities, and are programmable. The sensor typically recognizes the dysrhythmia (e.g., VF) and delivers the first shock over a 10-20 second time period. A series of 4 defibrillatory shocks are delivered if there is no change in rhythm. Energy levels are programmed to individual characteristics. Tiered therapy will use as little as 0.5 Joules to pace VT, 1-20 Joules to cardiovert, and approximately 25 Joules to defibrillate.

Pectoral Unipolar ICD Device



from Groh in *Am Fam Phy* 1998: 57;300

Pectoral Implant with Unipolar Transvenous Lead



from *Curr Prob Card* 1997: 22;676

Treatment for VF and VT

- **Implantable cardioverter-defibrillator**
- **Empiric amiodarone or sotalol**
- **EP guided drug therapy**
- **Catheter ablation**
- **Cardiac surgery (CABG, aneurysm)**
- **Type I antiarrhythmic drugs**

Notes

Efficacy

Early studies demonstrated that the devices were capable of terminating potentially lethal dysrhythmias. Sudden death rates of 2% at one year and 6% at five years were compared to total mortality of 25% to 40% at one to two years in a group of similar patients without devices. However, previous studies may lead to erroneous conclusions for many reasons. The use of historical controls, misclassification of deaths, and considering every ICD discharge to have prevented a death are criticisms which limit the validity of previous studies. A multi-center, prospective, randomized, controlled trial comparing ICD with antidysrhythmic (sotalol or amiodarone) was terminated prematurely in April 1997 because a clear benefit was shown with the device.

The Antiarrhythmics Versus Implantable Defibrillators (AVID) Trial investigators had enrolled more than 1000 patients. Study subjects included patients who had experienced ventricular fibrillation or sustained, serious ventricular tachycardia. After one year, patients in the defibrillator group experienced a 38% reduction in deaths compared with the group of patients on antiarrhythmic agents. The defibrillator group had a 25% reduction in deaths in years two and three of the study. Even though benefit of the ICD over drug therapy declined with time, the results significantly favored device over drug therapy. Total mortality was the primary endpoint and secondary data included quality of life and cost.

MADIT (Multicenter Automatic Defibrillator Implantation Trial) was designed to test the hypothesis that an ICD in patients at high risk for sudden death (patients with CAD and previous MI, LV dysfunction, and non-sustained VT) will do better with a device as opposed to conventional drug therapy ranging from nothing to amiodarone. Subjects underwent electrophysiologic testing and if non-inducible (no VT occurred) were

ICD Efficacy

- **Early studies**
  - **mortality 2% at 1 year and 6% at 5 years**
- **Historical controls (matched, unmatched)**
  - **25-40% at 1-2 years**
- **Criticisms**
  - **hypothetic deaths (discharge=save)**
  - **misclassified deaths**

ICD Efficacy

- **AVID**
  - **Antiarrhythmics Vs implantable defibrillators**
- **MADIT**
  - **Multicenter automatic defibrillator implantation trial**
- **CABG Patch Trial**

AVID Study

Antiarrhythmic Versus Implantable Defibrillator Study

- **Total mortality**
- **Quality of life**
- **Cost**

AVID Study Results

- **1016 patients (45% with VF)**
- **ICD vs amiodarone or sotalol**
  - **38% reduction in death after 1 year**
  - **31% reduction 3 years**
  - **overall 75% Vs 64% survival at 3 years**
- **Study terminated prematurely**

MADIT Trial

Multicenter Automatic Defibrillator Implantation Trial

- **high risk previous MI patients with hx of non-sustained VT and decreased LV EF**
- **patients with VF or syncope excluded**
- **EP testing with inducible, non-suppressible VT randomized to drug or ICD**

Notes

given beta-blocker or no drug therapy. If VT was inducible and not responsive to procainamide patients were randomized to ICD or pharmacologic therapy (e.g., amiodarone). Preliminary results favored the ICD device with 50% fewer deaths and the FDA expanded indications of ICD placement to reflect this data.

CABG Patch Trial - High-risk patients after CABG with LVEF < 36% and age < 80 years old are randomized to ICD or no therapy. This is the only study that randomizes patients to a no treatment arm. Preliminary results indicate no benefit from the ICD suggesting revascularization is paramount.

Indications –
Rapidly changing technology, in addition to results of recent and ongoing trials, constantly alters the indications for placement of ICD's. Currently, survivors of VF or sustained VT without AMI are candidates for ICD placement. Patients with non-sustained VT, a history of coronary disease (previous MI), and decreased ejection fraction who are inducible at electrophysiologic testing but not suppressible with drug therapy also benefit.

Contraindications

- VT or VF during acute phase of Q-wave myocardial infarction within 72 hours.
- non-cardiac terminal illness with a life expectancy of less than six months.
- NYHA class IV congestive heart failure
- an identifiable cause of dysrhythmia such as electrolyte disorder, AMI, or drug toxicity.
- very frequent VT/VF such that battery life would be rapidly depleted.

Morbidity
Short-term complications are those associated with operative implantation and post-operative recovery. Peri-operative deaths (MI, VF, CHF, vascular injury), infection, hemorrhage, and thromboembolic disease all

MADIT Trial Results

- **196 patients after 27 months**
  - **15 deaths in ICD patients (n=95)**
  - **39 deaths in drug patients (n=101)**
- **Study terminated prematurely**

CABG Patch Trial

- **CABG Patch Trial**
  - **patients with CAD, depressed LVEF, and abnormal signal averaged ECG**
  - **randomized to ICD or not intraoperative**
- **No benefit from ICD after CABG in 1013 patients**

ICD Indications

- **Cardiac arrest survivors**
- **Sustained VT and serious symptoms**
- **Syncope of uncertain nature with heart disease and inducible VT**
- **Non-sustained VT, hx MI, and low LVEF inducible at EP testing but not suppressible with drug therapy.**

ICD Contraindications

- **Acute Q-wave MI in last 72 hours**
- **Non-cardiac terminal illness (6 mo)**
- **NYHA class IV heart failure**
- **Identifiable cause of VT/VF**
- **Frequent VT/VF which depletes battery**

ICD Complications

Short-Term
Morbidity and Mortality
(perioperative, epicardial leads)

- **2-4% mortality**
- **15% morbidity**
  - **MI, VF, CHF, vascular injury, infection, hemorrhage, thromboembolism**

contribute to a short-term morbidity of 15% with an average mortality of 2-4% for epicardial implants. Now that thoracotomy is no longer necessary these complication rates have improved. For non-thoracotomy lead systems, morbidity is 5-8% and mortality < 1%.

Long-term complications include inadvertent shocks, component failure, interference with cardiac pacemakers, and psychological disorders. 15% of devices will suffer lead failure (lead fracture or failure of insulation) over the life of the device.

ICD Complications

Short-Term
Morbidity and Mortality
(non-thoracotomy lead systems)

- **Mortality < 1%**
- **Morbidity 5-8%**

ICD Complications

Long-Term

- **Inadvertent shocks**
  - **atrial fibrillation and sinus tachycardia**
  - **electromagnetic interference**
- **Component failure**
- **Interference with cardiac pacemaker**
- **Psychological**

ED Evaluation of a Patient with ICD

The unstable patient.

Patients with an ICD may present severely hypotensive or even in cardiac arrest. The management of this situation varies little from what is typical but the presence of the ICD may require special consideration. If the patient must be defibrillated or cardioverted the external paddles should be placed such that they do not overlie the device. Higher energies than usual may be required due to diversion of current through the device and away from the myocardium. If the device is firing inappropriately discharges may be interrupted by placing a standard donut type magnet over the pulse generator (can). This blocks the ability of the device to sense dysrhythmia thus eliminating the input required to trigger a shock. Rescuers who make contact with the device while it is firing may sense a mild electric shock sensation in the hands and arms. No serious problems have been reported in attendant health care personnel. Typical devices deliver 6 shocks and then remain inactive until a change in rhythm is sensed. In the 30-60 seconds after a cardiac arrest, rescuers may allow ICD to complete

ICD Case Scenario

75 yo female with history of CAD and cardiomyopathy presents after cardiac arrest with multiple episodes of VF converted to VT with manual countershock followed by ICD dicharges resulting in VF. CPR is ongoing.

ICD Case Scenario

- **Problems with inappropriate discharges**
  - **ICD discharges are harmful**
  - **possible rescuer injury**
  - **manual paddle placement**

ICD Case Scenario

- **If VT or VF is present assume device is malfunctioning**
  - **disable ICD with placement of donut magnet to avoid further discharges**
- **Paddle placement**
  - **avoid generator can**
  - **use AP position if anterior-lateral fails**

delivery of shocks before attempting other therapy. Unstable patients who have resuscitative personnel and equipment available may have their devices shut off with a magnet. Properly functioning devices manufactured since 1993 will again function normally upon removal of the magnet. Some older devices could be permanently activated and deactivated with external magnet placement. A series of beeps would guide the physician during this process. This feature has been abandoned.

The stable patient who has received a shock.

ICD Case Scenario

65 year old male with CAD S/P CABG 4 years earlier had ICD placed 2 years ago for recurrent VT with syncope. Today experienced 2 ICD discharges. PE is normal and ECG reveals atrial fibrillation.

ICD - Stable Patient

Was the shock appropriate?

- **History**
  - **number of shocks**
  - **symptoms before, after, and associated activities**
- **Examination**
  - **typical cardiovascular**
  - **inspect pocket**

ICD - Stable Patient

- **Laboratory**
  - **ECG**
  - **CXR**
  - **electrolytes**
  - **drug levels**

ICD - Stable Patient

- **Multiple shocks are caused by**
  - **recurrent VT treated repeatedly**
  - **VT that requires >1 shock to convert**
  - **atrial fibrillation, sinus tach, or PSVT**
  - **oversensing**
  - **random component failure**

ICD - Stable Patient

Admission

- **multiple shocks (deactivate ICD)**
- **serious symptoms**
- **correctable causes for VT/VF**
  - **electrolytes**
  - **drugs**
  - **ischemia**

ICD - Stable Patient

Cardiology Consultation

- **Interrogation**
- **Review current drug therapy**

Patients will occasionally present to the ED after having received a shock. Evaluation is similar to that in any patient with potential cardiac disease with some particular attention to device related function and potential malfunction. History should include the number of shocks, initial symptoms, and associated activities. The important question to ask and answer is whether the shock was appropriate. Did the patient experience palpitations or syncope? Sources for inappropriate shocks include sinus tachycardia, atrial flutter, or atrial fibrillation. Inspection of the device pocket accompanies the usual cardiovascular examination. Laboratory evaluation will include ECG, CXR (looking for possible lead fracture or displacement), electrolytes, and appropriate drug levels. Patients should be admitted for serious symptoms, multiple

shocks, or a correctable cause for the dysrhythmia (electrolyte disorder, drug toxicity, ischemia). Cardiology consultation will be needed for device interrogation which need not necessarily be immediate. Patients are often instructed that unless they have experienced multiple shocks or significant symptoms (e.g., syncope, light-headedness, chest pain) they may wait to report a shock to their cardiologist when the office is open during regular clinic hours.

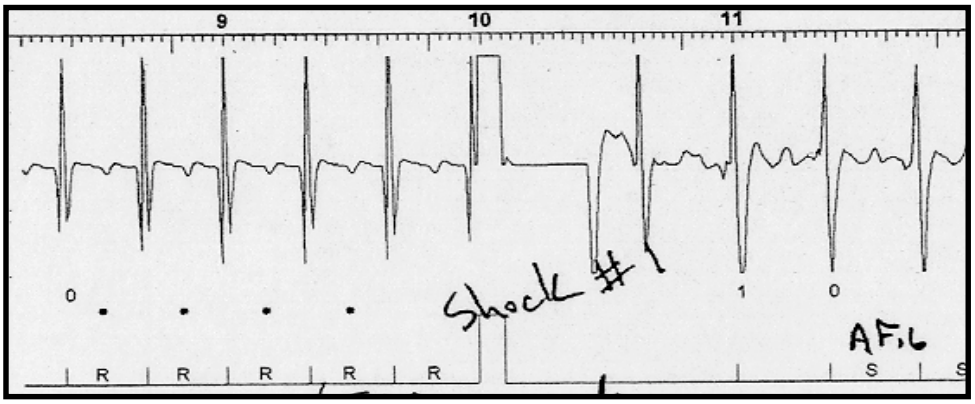
ICD Case History

- **14 yo male with a history of congenital heart disease undergoes surgery for aortic stenosis and suffers peri-operative AMI resulting in dilated carrdiomyopathy.**
- **On Christmas Day two years later he suffers a cardiac arrest with return of spontaneous circulation in ED.**

ICD Case History

- **An ICD is placed and he does so well that he returns to "shooting hoops."**
- **He returns to the ED a few months after ICD placement complaining of several shocks without preceding symptoms.**

Inadvertent Discharge



Other considerations.

ICD - Stable Patient

Other Considerations

- **Local trauma**
- **MRI**
- **CT**
- **Electrocautery**
- **Electromagnetic interference**

- The patient who presents after local trauma. with impact to the device may damage the pulse generator or dislodge electrode leads. The titanium cans are extremely hard and can withstand significant impact. Radiography may help identify lead problems but the only way to be certain a device remains functional is with interrogation. Local trauma that renders the device dysfunctional is unlikely.
- MRI scanning may disable and alter programming of ICD's and this diagnostic procedure cannot be used in patients with ICD's.
- CT scanning may be performed but scatter may alter image quality.
- Electrocautery may trigger a device firing and the device should be deactivated if this is performed.
- Large external magnets such as those found in audio speakers and arc welding may inhibit ICD's. Cellular telephones may also interfere if placed very close to the device.

ICD - Stable Patient

Infection

- **1-7% incidence over life of device**
- **early Vs late (>60 days)**
- **pocket exhibits inflammatory signs**
- **potentially serious problem requires aggressive antibiotic treatment**

ICD - Stable Patient

Psychological

- **anxiety about death**
- **negative effect on body image**
- **panic attacks**
- **obsession with device**
- **"phantom" discharges**

Expected Advances

- **Continued decreased size**
- **Extended memory**
- **Improved detection algorithms**
- **Improved lead systems**
- **Dual chamber pacing**
- **Preventive pacing techniques**

ICD Summary

- **Rapid technological evolution**
- **Growing numbers of patients**
- **Results of randomized, controlled trials to define the best patients to treat are on the horizon**
- **Emergency management of unstable and stable patient**

ICD Summary

- **Unstable patient**
  - **paddle placement**
  - **magnet use to suppress ICD discharges**
- **Stable patient**
  - **routine evaluation**
  - **admit for multiple shocks or serious symptoms**

Holter Monitoring

Holter Monitoring

Ambulatory Electrocardiographic Monitoring (AEM)

- **2 lead cardiac monitoring**
- **24-72 hours**
- **3 types of recorders**

Definition Holter monitoring or ambulatory electrocardiographic monitoring (AEM) is a process whereby a patient wears a set of ECG leads (usually V_1 and V_5 or V_5 and an inferior limb lead) with a recording device for a period of 24 to 72 hours. Recorders may be of 3 types (continuous recorders, intermittent or event recorders, and real-time analytic recorders).

Purpose: AEM is used to detect arrhythmias and ST segment shifts. The procedure can be used for a number of reasons:

- To detect rhythm disturbances as a cause of cardiac or neurologic symptoms (e.g., syncope, dizziness).
- To detect and assess arrhythmias believed to be associated with an increased risk of cardiovascular or neurologic events (e.g., atrial fibrillation).

- To accurately interpret ambulatory ST-T wave changes occurring throughout a diurnal time period.
- Assessment of anti-arrhythmic and anti-ischemic therapy.
- Investigation of the effects of new therapeutic modalities (e.g., implantable cardioverter-defibrillator devices).

Purpose of AEM

- **Dysrhythmia recognition**
  - **symptomatic**
  - **asymptomatic with prognostic importance**
  - **anti-arrhythmic therapy**

Purpose of AEM

- **ST segment shifts and T wave inversions**
  - **anti-ischemic therapy**
  - **in conjunction with exercise testing**
  - **diurnal variations**
  - **prognostic indicator**

Training
The ACP/ACC/AHA Task Force on Clinical Privileges in Cardiology has determined that minimum training in AEM will include interpretation of 75 recordings over a 24-36 month period under the supervision of a staff cardiologist among other requirements. Few emergency physicians will meet this requirement.

Training Required for AEM

ACP/ACC/AHA Task Force

- **75 recordings**
- **24-36 months**
- **Staff cardiology supervision**

Interpretation
Abnormalities considered to be potential causes of syncope.

- Sinus arrest for more than 2 seconds and a history of recurrent syncope.
- Any arrhythmia in conjunction with altered consciousness.
- Symptomatic SVT.
- VT that is symptomatic or sustained.

Abnormalities *not* considered diagnostic unless accompanied by serious symptoms.

- Short runs of SVT.
- Frequent (>30/hr) or complex PVC's.
- Asymptomatic sinus bradycardia (<50 beats/min).
- First degree atrioventricular block or Mobitz type I second degree AV block.

Interpretation of AEM

- **Causative abnormalities**
  - **sinus arrest >2 sec with hx syncope**
  - **any arrhythmia with syncope**
  - **SVT with symptoms**
  - **VT with symptoms or sustained**

Interpretation of AEM

- **Abnormalities that are not causative**
  - **short runs of SVT**
  - **PVC's**
  - **asymptomatic sinus bradycardia < 50**
  - **1° AVB**
  - **2° AVB (Mobitz type I)**

Pitfalls

- Pitfalls in arrhythmia monitoring include artifact, and; rhythm and conduction disturbances are common in asymptomatic individuals, there is poor correlation

Notes

between rhythm disturbances and symptoms, and 24 hour monitoring rarely reveals symptomatic dysrhythmia.

- Pitfalls in ST segment monitoring include artifact, changes with hyperventilation and changes in body position, diurnal variations, and age related anomalies.

Pitfalls in AEM

Arrhythmia Detection

- **<5% will exhibit dysrhythmogenic syncope during monitoring**
  - **many will have syncope without rhythm disturbance**
- **only 5-10% of ventricular dysrhythmias will be symptomatic**

Pitfalls in AEM

Arrhythmia Detection

- **false positives in asymptomatic patients**
- **poor correlation between arrhythmia and symptoms**
- **24^{o} monitoring rarely reveals symptoms with arrhythmia**

ED Utility of AEM

Initiating Holter monitoring (AEM) from the ED may be appropriate and efficient but the patient must be at minimal risk for life-threatening dysrhythmia (e.g., ventricular tachycardia) and cardiologic follow-up should be pre-arranged to provide accurate interpretation of the recording. The emergency physician may initiate AEM as a diagnostic modality to detect dysrhythmia in the evaluation of patients with syncope, palpitations, dizziness, and chest discomfort. Consider the evaluation of a patient who presents with syncope or palpitations and the history, physical examination, and ECG reveal no significant abnormalities. If there is no compelling reason (e.g., age or prior history of cardiac disease) to suspect a life-threatening dysrhythmia the patient may be discharged from ED.

ED Utility of AEM

- **Indications**
  - **Syncope**
  - **Palpitations**
  - **Dizziness**
  - **Chest discomfort**

ED Utility of AEM

- **History, physical examination, and ECG are non-diagnostic.**
- **VT/VF are unlikely.**
  - **younger and no hx cardiac disease**
- **AEM with cardiology follow-up.**

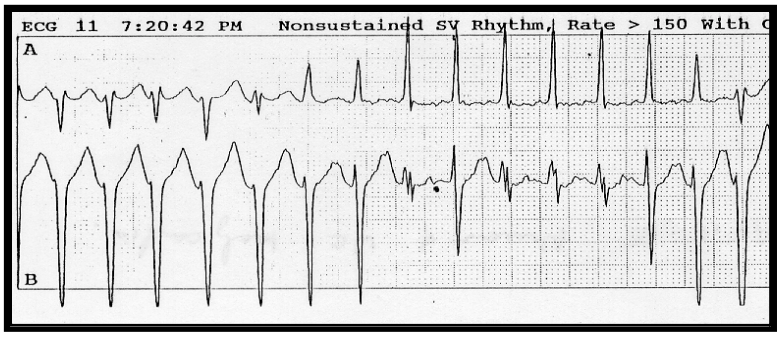
AEM Case History

- **An asymptomatic 35 yo naval aviator undergoes routine electrocardiogram for flight physical.**
- **One abnormal beat suggests presence of pre-excitation.**

AEM Case History

- **The patient underwent electrophysiologic testing and radio-frequency catheter ablation.**
- **He successfully returned to active flight status and his duties as an aviator.**

AEM Monitoring Reveals
Atrial Fibrillation with accessory pathway



Artificial Pacemakers

Indications

Implanted Cardiac Pacemakers

- **1 million in use**
- **500 implanted per million each year**
  - **60% dual chamber**
  - **70% rate adaptive**
  - **30% both**

Approximately 1 million people in the United States have permanent pacemakers and 600 new pacemakers are implanted per million population annually. Indications for placement include sinus node dysfunction, atrioventricular block, fascicular block, neurocardiogenic (cardioinhibitory) syncope, and cardiomyopathy. Need for pacemaker placement in an individual patient with the previously listed disorders is a complex decision based on many considerations such as; degree of symptomatology, degree of bradycardia and other electrophysiologic parameters, presence of cardioinhibitory reflexes, and severity of left ventricular dysfunction. A Joint Task Force of the American College of Cardiology and the American Heart Association (Gregoratos 1998) has developed guidelines listing each of the above indications with further recommendations specifying under what circumstances a pacemaker is generally necessary, perhaps helpful, or generally not necessary. There has been criticism in the literature that pacemakers are sometimes implanted needlessly.

Pacemaker Indications

- **sinus node dysfunction**
- **atrioventricular block**
- **fascicular block**
- **neurocardiogenic syncope**
- **cardiomyopathy**

Biomechanics

Pacemaker Biomechanics

- **Pulse Generator**
  - **Lithium-iodide battery**
  - **Hermetically sealed metal container with battery and electronic circuitry**
- **Leads**

The current devices consist of a lithium-iodide battery that generates the pacemaker output or impulses. Batteries have a life of 4-12 years depending upon patient characteristics. The generated impulse passes through leads which conduct the impulse to the myocardium. These leads also allow sensing of myocardial depolarizations and electronic circuitry modulates pacemaker response in response to sensing. The circuitry and battery are enclosed in a hermetically sealed metal container weighing 20-30 grams.

Pacemaker Nomenclature

Pacemaker Nomenclature

I Chamber Paced
II Chamber Sensed
III Response to Sensing
IV Programmability, Rate Modulation
V Antitachycardia Features

Standard nomenclature for pacemaker capabilities has been developed and standardized by the North American Society of Pacing and Electrophysiology and the British Pacing and Electrophysiology Group. A series of 5 letters describes the abilities of each pacemaker.

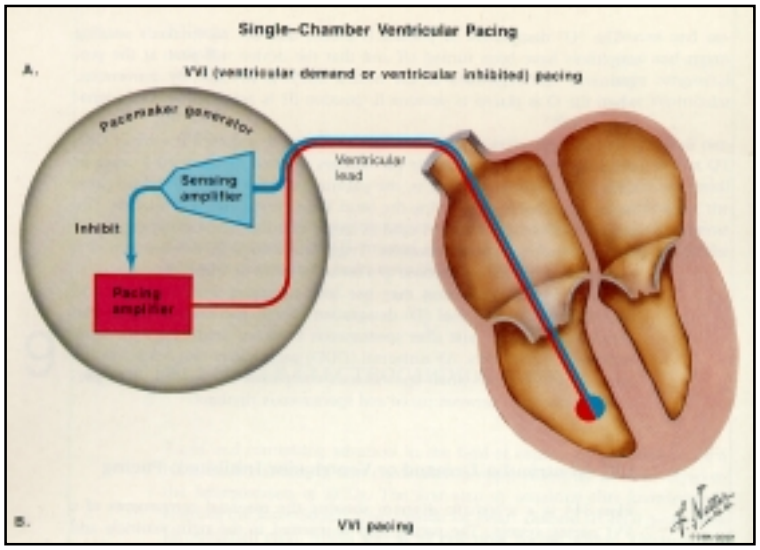
Standardized Pacemaker Nomenclature

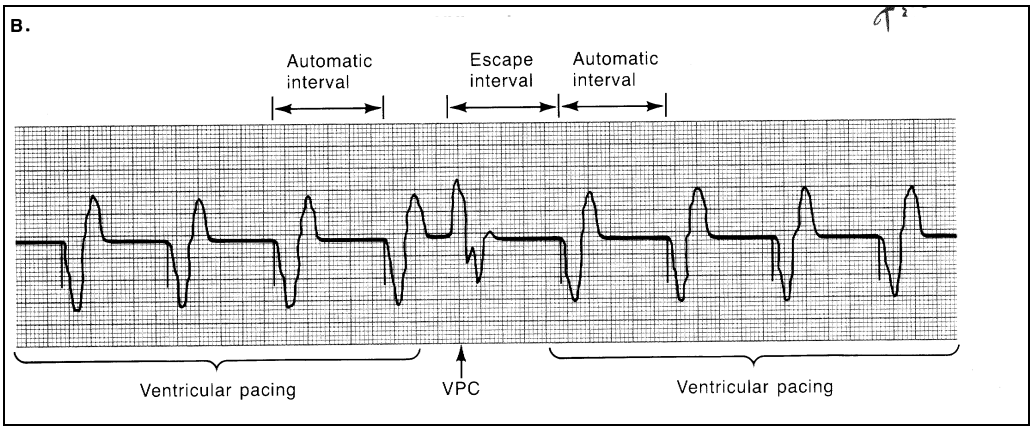
I	II	III	IV	V
Chamber Paced	Chamber Sensed	Response to Sensing	Rate Modulation, Programmability	Antitachycardia Features
0 = none	0 = none	0 = none	0 = none	0 = none
A = atrium	A = atrium	I = inhibited	S = simple programmable	P = antitachycardia pacing
V = ventricle	V = ventricle	T = triggered	M = multi-programmable	S = shock
D = dual	D = dual	D = dual	C=communicating	D = dual
			R=rate modulation	

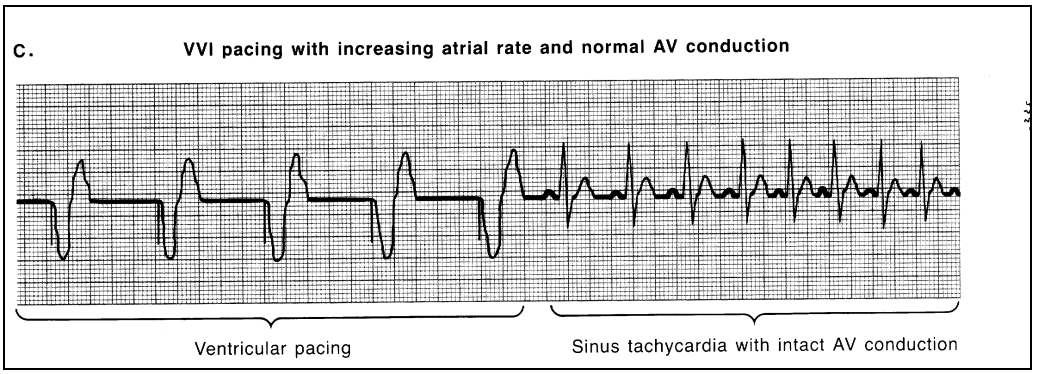
Pacing Modes

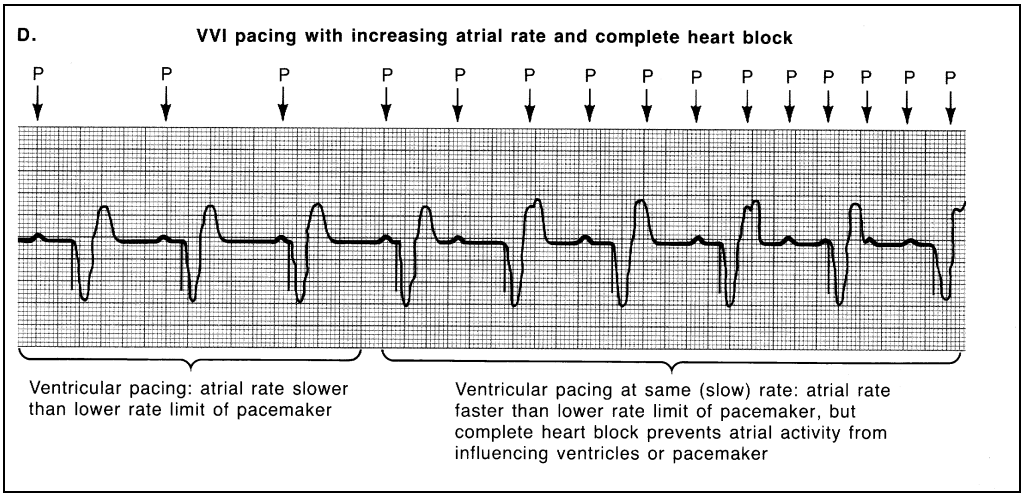
- VVI pacing is another common mode for implanted pacemakers. Single chamber sensing and pacing reduces complexity, cost, frequency of follow-up and prolongs battery life. In patients with sick sinus syndrome, VVI pacemakers are more often associated with atrial fibrillation, stroke, and overall mortality when compared to DDD mode. Patients with preserved atrial function may experience pacemaker syndrome as a result of atrial contraction against closed tricuspid and mitral valves.

VVI Pacing

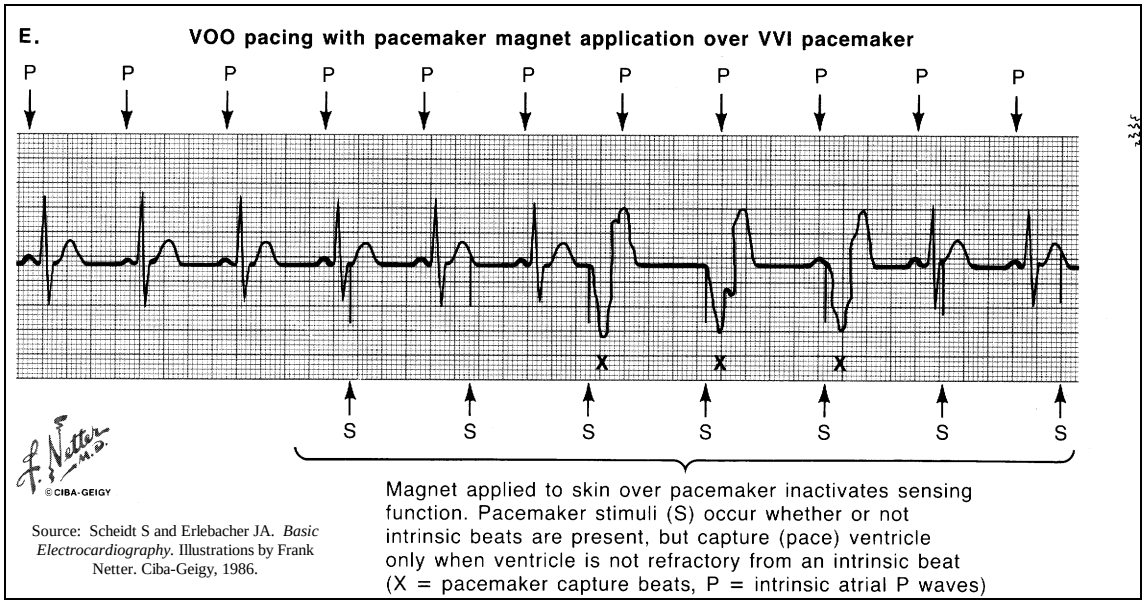






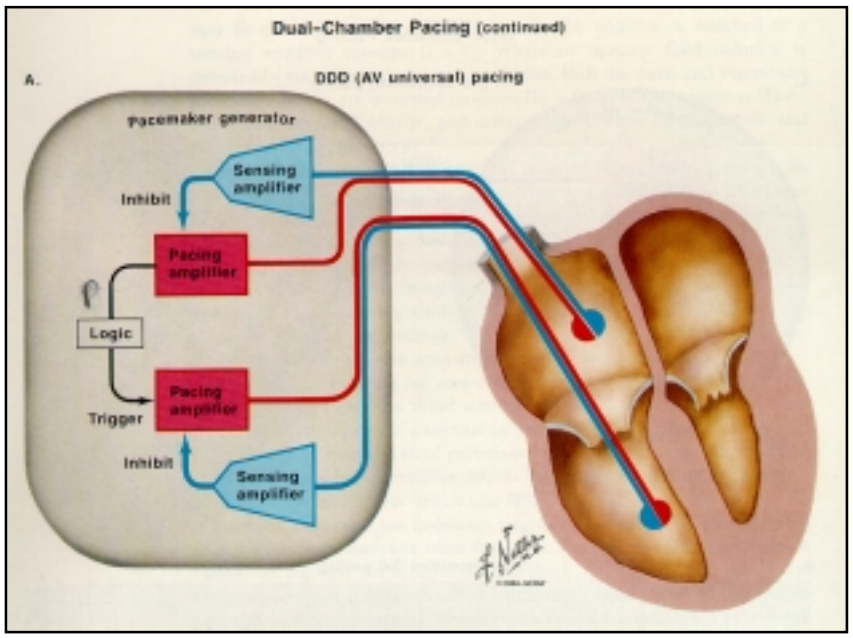


Source: Scheidt S and Erlebacher JA. *Basic Electrocardiography.* Illustrations by Frank Netter. Ciba-Geigy, 1986.



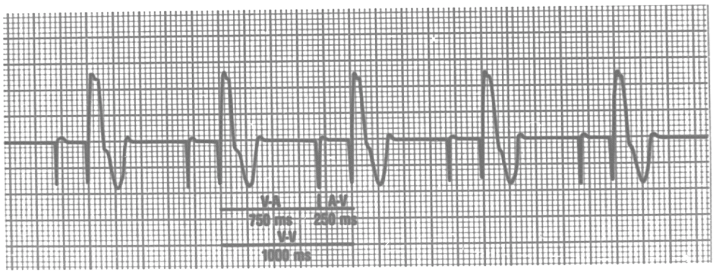
Source: Scheidt S and Erlebacher JA. *Basic Electrocardiography.* Illustrations by Frank Netter. Ciba-Geigy, 1986.

- DDD pacing is most commonly used today. Dual chamber pacing and sensing allows versatility and the advantage of preserved atrial contribution to ventricular filling. Exercise responsiveness is maintained if sinus node function is preserved and sinus rate increases with exercise. Atrio-ventricular synchrony is maintained thus avoiding pacemaker syndrome (see below). Dual chamber pacemakers are more complex than single chamber pacemakers and battery life may be shorter. Dual chamber devices may initiate a pacemaker mediated tachycardia and they are susceptible to cross-talk between chambers.



A PACE / V PACE

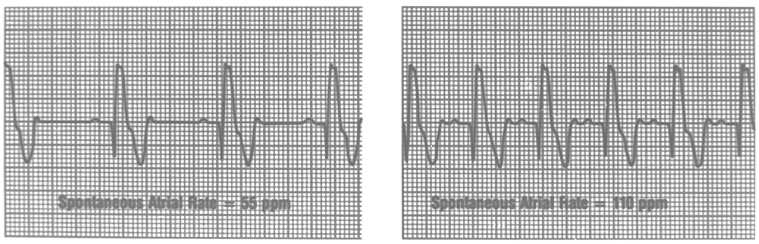
A-V Sequential Pacing



7006/DDD/60/250/150

A SENSE / V PACE

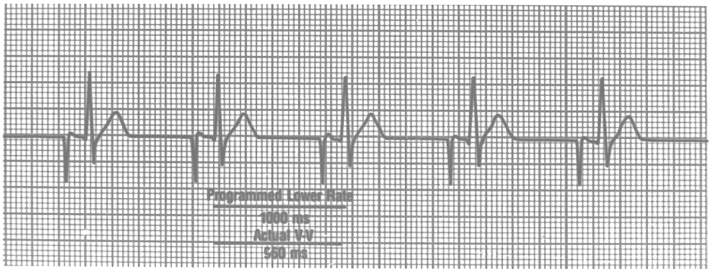
Atrial Synchronous Pacing



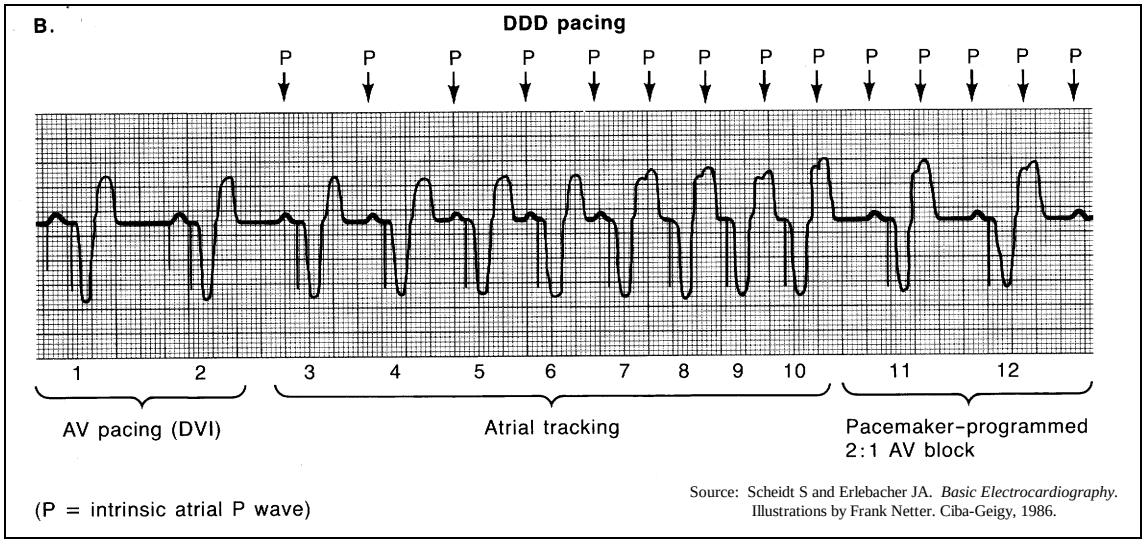
7006/DDD/50/150/150

A PACE / V SENSE

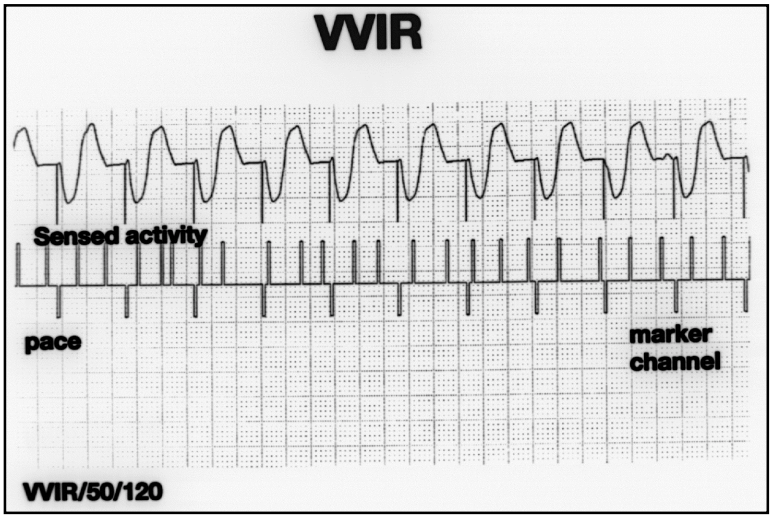
Atrial Pacing With Normal A-V Conduction



7006/DDD/60/200/150



- Rate-Adaptive pacemakers (DDDR, VVIR, DDIR, AAIR) allow for variable rate pacemaker output according to physiologic demands of the patient. This allows for exertional adjustments of the heart rate. Various types of sensors respond to physical, electrical, or chemical stimuli. Most commonly body motion is sensed which triggers increased rate of pacer impulses. Exercise changes in the QT interval, changes in respiratory rate, or even temperature of venous blood are stimuli for various sensors.

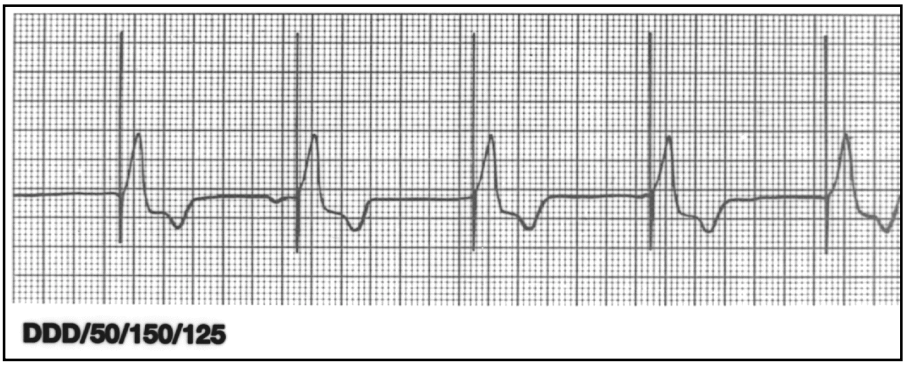


Pacemaker Complications

- Malfunction

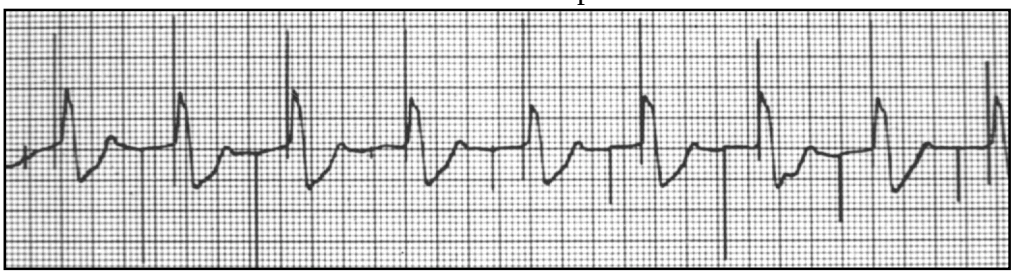
  Failure to pace or provide output. Component failure (rare), total battery depletion, lead fracture, lead disconnection, and oversensing may all result in failure of pacer output. Lead migration can result in lead fracture or even migration into the left ventricle.

No Atrial Output

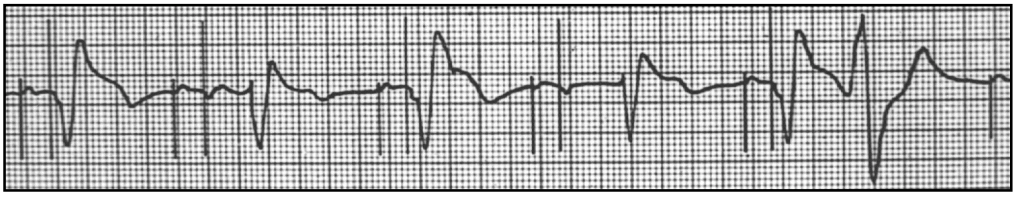


Failure to capture. Lead dislodgment, lead insulation break, exit block, metabolic derangement, and battery depletion may result in failure to capture.

Atrial Non-Capture

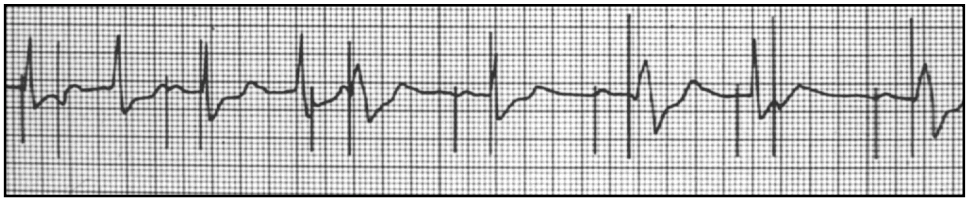


Ventricular Non-Capture



Failure to sense. Undersensing may be caused by lead dislodgment, poor lead position, lead insulation defect, or low-amplitude cardiac signal.

Ventricular Undersensing

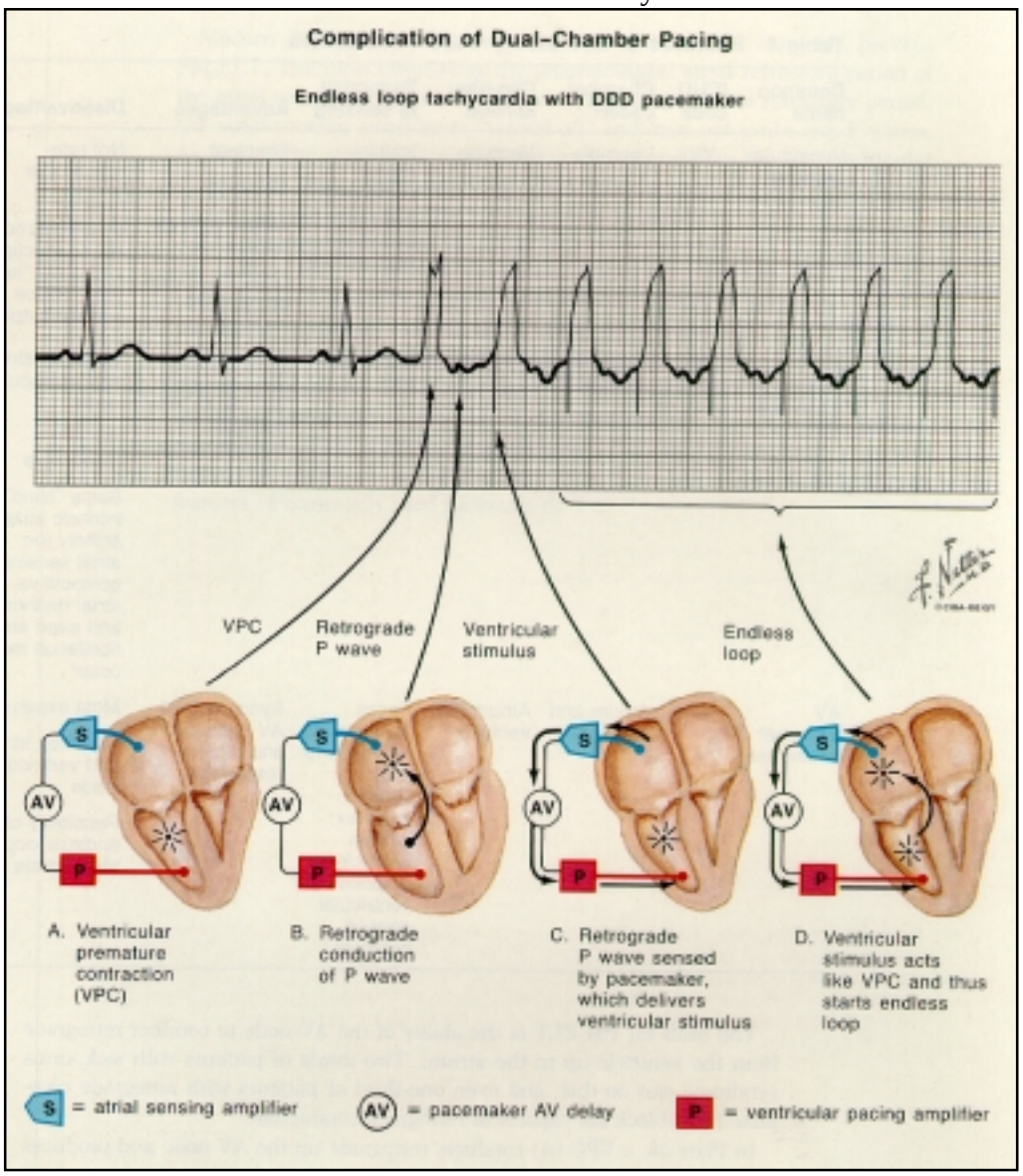


- Pacemaker Induced Dysrhythmia:

  Runaway Pacemaker is the result of inappropriate, rapid discharge of the device. Lead disconnection may be necessary in extreme circumstances. Older models will sometimes develop this complication with battery depletion.

  Pacemaker Mediated Tachycardia is a problem peculiar to dual chamber devices where a re-entrant tachycardia results for a retrograde P-wave being sensed by the pacemaker as a physiologic atrial depolarization. Atrial depolarization is tracked by ventricular pacing and an "endless loop" or re-entrant tachycardia occurs. This problem is often initiated by a PVC. Emergent therapy requires magnet placement over the device to inhibit sensing and disrupt the cycle. Later, the device can be re-programmed to increase the ventricular refractory period.

Pacemaker Mediated Tachycardia



- Pacemaker Syndrome

  Pacemaker syndrome is the term used to describe symptoms that occur as a result of the adverse hemodynamics associated with a normally functioning ventricular pacemaker. This problem occurs with single chamber ventricular pacemakers basically due to loss of atrial filling and its subsequent decreased cardiac output causing neurologic symptoms such as light-headedness and syncope. AV dissociation may be noted on ECG and cannon A-waves may be seen on physical examination. Dual chamber pacemakers generally avoid the problem by providing AV synchrony although lack of atrial filling will occur in any patient with atrial fibrillation.
- Infections of the skin and pocket occur with some frequency affecting up to 2-3% of patients with pacemakers. Treatment may require explantation of the device in less than 1% of cases. An irritative dermatitis can occur as well. This problem is easily treated with topical corticosteroids. Endocarditis may also occur (Arbor 1994).
- Vascular complications such as venous thrombosis and occlusion may develop. Everything from isolated thrombosis of the axillary vein to superior vena cava syndrome has been reported. There is a high incidence (>30%) of asymptomatic subclavian vein thrombosis but fewer than 5% will become symptomatic.

Pacemaker Patient Evaluation

- **Assess hemodynamic status**
- **Cardiopulmonary examination**
- **ECG (including magnet)**
- **Electrolytes**
- **Appropriate drug levels**
- **Radiography**

Patient Evaluation

Standard patient evaluation includes assessment of hemodynamic status (including mental capacity and vital signs), cardiopulmonary examination, electrocardiography, electrolytes, and appropriate drug levels.

Pacemaker Malfunction - Unstable Patients

Unstable patients must have hemodynamic stability restored.

Bradycardic patients may be treated with atropine, transcutaneous or transvenous pacing. If a problem with over-sensing is suspected (bradycardic patient with pacemaker that is not firing) magnet placement over the device will inhibit all sensing and convert pacemaker to VOO, AOO, or DOO function.

Unstable Patient

- **Bradycardia**
  - **atropine**
  - **transcutaneous pacing**
  - **transvenous pacing**
  - **magnet placement**

Unstable Patient

- **Tachycardia**
  - **cardioversion/defibrillation paddle placement must avoid generator box or risk pacemaker dysfunction**
  - **pacemaker mediated tachycardia may be treated with magnet placement**

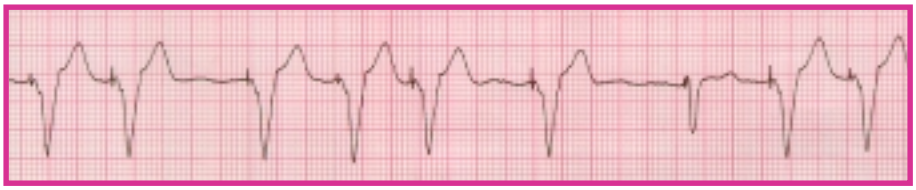
Tachycardic patients may be cardioverted or defibrillated as usual with special care to avoid paddle placement over the pacemaker metal box. Realize that external cardioversion or defibrillation may render an implanted pacemaker dysfunctional. *Pacemaker mediated tachycardia* is a re-entrant tachycardia seen with dual chamber pacemakers that may be treated with external magnet placement which inhibits pacemaker sensing and disrupts the

tachycardia.

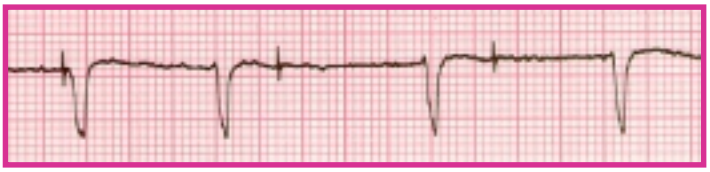
Pacer Malfunction Case Study

- **56 year old male with CAD and DDD pacer placed for brady/asystole presents with palpitations and mild dyspnea**
- **Meds include amiodarone, atenolol**
- **On exam he appears stable without chest pain or CHF**

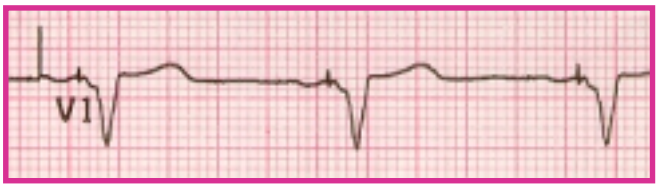
Presenting ECG – lead V_1



Magnet Placement – lead V_1



Atrial fibrillation resolved – lead V_1

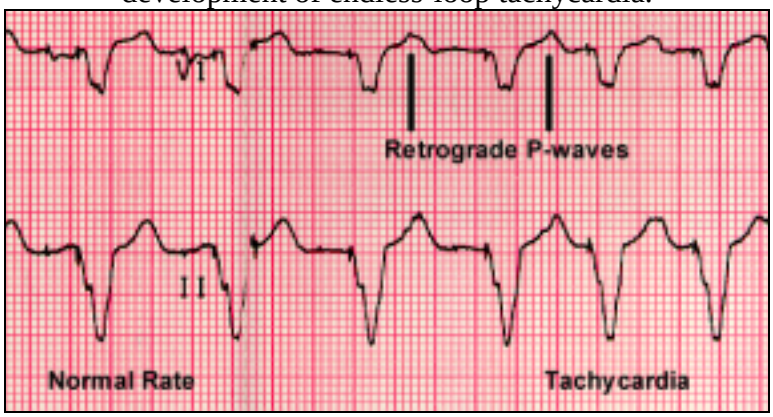


Pacer was interrogated and ventricular rate (max) was decreased.

Pacemaker Mediated Tachycardia - Case History

58 year old male with history of coronary heart disease and recent palpitations with exercise. Tracing below was recorded during Bruce treadmill protocol.

Retrograde P-wave triggers ventricular firing, another retrograde P-wave, and development of endless-loop tachycardia.



Pacemaker sensing may be inhibited, and tachycardia terminated in emergent circumstances, by placing a magnet over device. In this case pacer was reprogrammed

Pacemaker Malfunction - Stable Patients

Stable patients should undergo the standard evaluation described above and will often require pacemaker interrogation by a cardiologist or technician. Telephonic interrogation is possible. Electrocardiography (with and without magnet placement) may help the emergency physician diagnose some causes of dysfunction. Sensing and capture may be evaluated if pacer spikes are seen on the ECG without magnet placement. A left bundle branch block with left axis deviation would be the normal appearance of a pacer lead in the right ventricle. Another axis may indicate lead migration away from cardiac apex and a right bundle branch block could indicate a left ventricular location. Magnet placement should result in a fixed rate pacer discharge where capture may be assessed. Magnet rates also help diagnose battery failures (according to manufacturer charts). Patients with significant presenting symptoms (e.g., syncope) will need to be admitted until the pacemaker can be interrogated and the cause elucidated. ECG evaluation of ischemia is complicated by the typical LBBB configuration (with a superior QRS axis due to typical RV apex location of pacer lead) and even if intrinsic beats are present ST segments and T waves may be abnormal due to activity of pacemaker and myocardial "memory."

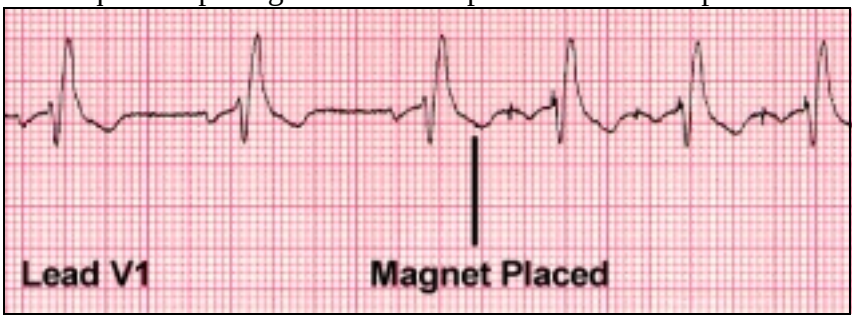
Stable Patient

- **Pacemaker Interrogation**
  - **cardiologist**
  - **technician**
  - **telephonic**
- **Admit patients with significant symptoms (e.g. syncope) until PMK is interrogated and cause established.**

Pacemaker Testing with Magnet Placement
Case History

A 65 year old female with a DDD pacemaker presents with 4 days of intermittent light-headedness and feeling "woozy." Physical examination is unremarkable. 12-lead ECG reveals a normal sinus rhythm with right bundle branch block and left anterior fasicular block. Pacemaker magnet test during ECG monitoring reveals:

AV sequential pacing with 100% capture at 100 beats per minute.



Magnet placement should result in a fixed rate pacer discharge where capture may be assessed. Magnet rates may diagnose battery failures (according to manufacturer charts).

Special Considerations

- *Electrocautery* may cause temporary sensing problems or reprogramming. After electrocautery is used in the vicinity of a pacemaker it should be checked for proper functioning.
- *Transthoracic defibrillation* may damage a pacemaker. Paddles should be placed away from the impulse generator.
- *Magnetic resonance imaging* will disable pacemaker sensing temporarily and may induce dysrhythmias. Patients with artificial pacemakers should not undergo MRI. Some pacemakers may be temporarily reprogrammed such that patients may safely undergo the procedure.
- *Therapeutic radiation* may cause damage to silicone and silicone oxide insulators within electronic circuit boards that renders pacemakers dysfunctional.
- *Non-medical equipment and devices* (e.g., heavy electric motors, arc welding) that emit magnetic fields may temporarily disable pacemakers. Cellular phones and airport security have recently been implicated in occasional device malfunction.

Special Considerations

- **transthoracic defibrillation**
- **magnetic resonance imaging**
- **therapeutic radiation**
- **electric motors**
- **arc welding**
- **cell phones and security devices**

Magnet Therapy

Unstable Patients

- Inappropriate, recurrent ICD Discharges
- Pacemaker-medicated tachycardia
- Symptomatic bradycardia in patient with implanted pacemaker that is not firing

Stable Patient

- Patient with implanted pacemaker – ECG with and without magnet present.

Complications

- may shut off the old ICD's
- possible R on T resulting in ventricular tachydysrhythmia (theoretical)
- inhibiting appropriate ICD discharges
- inhibiting appropriate ICD discharges

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