Cardiac Assist Devices

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Types

Pacemakers
AICDs
VADs
History

- First pacemaker implanted in 1958
- First ICD implanted in 1980
- Greater than 500,000 patients in the US population have pacemakers
- 115,000 implanted each year
Pacemakers Today

- Single or dual chamber
- Multiple programmable features
- Adaptive rate pacing
- Programmable lead configuration
Internal Cardiac Defibrillators (ICD)

- Transvenous leads
- Multiprogrammable
- Incorporate all capabilities of contemporary pacemakers
- Storage capacity
Temporary Pacing Indications

- Routes = Transvenous, transcutaneous, esophageal

- Unstable bradydysrhythmias
- Atrioventricular heart block
- Unstable tachydysrhythmias

*Endpoint reached after resolution of the problem or permanent pacemaker implantation
Permanent Pacing Indications

- Chronic AVHB
- Chronic Bifascicular and Trifascicular Block
- AVHB after Acute MI
- Sinus Node Dysfunction
- Hypersensitive Carotid Sinus and Neurally Mediated Syndromes
- Miscellaneous Pacing Indications
Chronic AVHB

- Especially if symptomatic

Pacemaker most commonly indicated for:

- Type 2 $2^\circ$
  - Block occurs within or below the Bundle of His

- $3^\circ$ Heart Block
  - No communication between atria and ventricles
Chronic Bifascicular and Trifascicular Block

- Differentiation between uni, bi, and trifascicular block
- Syncope common in patients with bifascicular block
- Intermittent 3º heart block common
AVHB after Acute MI

- Incidence of high grade AVHB higher
- Indications for pacemaker related to intraventricular conduction defects rather than symptoms
- Prognosis related to extent of heart damage
Sinus Node Dysfunction

- Sinus bradycardia, sinus pause or arrest, or sinoatrial block, chronotropic incompetence
- Often associated with paroxysmal SVTs (bradycardia-tachycardia syndrome)
- May result from drug therapy
- Symptomatic?
- Often the primary indication for a pacemaker
Hypersensitive Carotid Sinus Syndrome

• Syncope or presyncope due to an exaggerated response to carotid sinus stimulation

• Defined as asystole greater than 3 sec due to sinus arrest or AVHB, an abrupt reduction of BP, or both
Neurally Mediated Syncope

- 10-40% of patients with syncope
- Triggering of a neural reflex
- Use of pacemakers is controversial since often bradycardia occurs after hypotension
Miscellaneous

- Hypertrophic Obstructive Cardiomyopathy
- Dilated cardiomyopathy
- Cardiac transplantation
- Termination and prevention of tachydysrhythmias
- Pacing in children and adolescents
Indications for ICDs

- Cardiac arrest due to VT/VF not due to a transient or reversible cause
- Spontaneous sustained VT
- Syncope with hemodynamically significant sustained VT or VF
- NSVT with CAD, previous MI, LV dysfunction and inducible VF or VT not suppressed by a class 1 antidysrhythmic
Device Selection

- Temporary pacing (invasive vs. noninvasive)
- Permanent pacemaker
- ICD
Pacemaker Characteristics

• Adaptive-rate pacemakers
• Single-pass lead Systems
• Programmable lead configuration
• Automatic Mode-Switching
• Unipolar vs. Bipolar electrode configuration
ICD selection

- Antibradycardia pacing
- Antitachycardia pacing
- Synchronized or nonsynchronized shocks for dysrhythmias
- Many of the other options incorporated into pacemakers
Approaches to Insertion

a. IV approach (endocardial lead)

b. Subcostal approach (epicardial or myocardial lead)

c. Noninvasive transcutaneous pacing
   Alternative to emergency transvenous pacing
Mechanics

❤️ Provide the rhythm heart cannot produce
❤️ Either temporary or permanent
❤️ Consists of external or internal power source and a lead to carry the current to the heart muscle
❤️ Batteries provide the power source
❤️ Pacing lead is a coiled wire spring encased in silicone to insulate it from body fluids
Unipolar Pacemaker

Lead has only one electrode that contacts the heart at its tip (+) pole
The power source is the (-) pole
Patient serves as the grounding source
Patient’s body fluids provide the return pathway for the electrical signal
Electromagnetic interference occurs more often in unipolar leads
Unipolar Pacemaker

Pulse generator (+)

Direction of current flow

Pacing lead

Electrode (-)
Bipolar Pacemaker

If bipolar, there are two wires to the heart or one wire with two electrodes at its tip

Provides a built-in ground lead

Circuit is completed within the heart

Provides more contact with the endocardium; needs lower current to pace

Less chance for cautery interference
To pulse generator

Pacing lead

Electrode (+)

Electrode (-)
Indications

1. Sick sinus syndrome (Tachy-brady syndrome)
2. Symptomatic bradycardia
3. Atrial fibrillation
4. Hypersensitive carotid sinus syndrome
5. Second-degree heart block/Mobitz II
Indications

6. Complete heart block
7. Sinus arrest/block
8. Tachyarrhythmias
   Supraventricular, ventricular
   To overdrive the arrhythmia
Atrial Fibrillation

* A fibrillating atrium cannot be paced
* Place a VVI
* Patient has no atrial kick
Types

1. Asynchronous/Fixed Rate

2. Synchronous/Demand

3. Single/Dual Chamber
   Sequential (A & V)

4. Programmable/nonprogrammable
Asynchronous/Fixed Rate

❤ Does not synchronize with intrinsic HR
❤ Used safely in pts with no intrinsic ventricular activity
❤ If pt has vent. activity, it may compete with pt’s own conduction system
❤ VT may result (R-on-T phenomenon)
❤ EX: VOO, AOO, DOO
Synchronous/Demand

Contains two circuits

* One forms impulses
* One acts as a sensor

When activated by an R wave, sensing circuit either triggers or inhibits the pacing circuit

Called “Triggered” or “Inhibited” pacers

Most frequently used pacer

Eliminates competition;

Energy sparing
Examples of Demand Pacemakers

DDI
VVI/VVT
AAI/AAT

Disadvantage: Pacemaker may be fooled by interference and may not fire
Dual Chamber: A-V Sequential

Facilitates a normal sequence between atrial and ventricular contraction

Provides atrial kick + ventricular pacing

Atrial contraction assures more complete ventricular filling than the ventricular demand pacing unit

Increase CO 25-35% over ventricular pacing alone
A-V Sequential

Disadvantage: More difficult to place
More expensive
Contraindication: Atrial fibrillation, SVT
Developed due to inadequacy of “pure atrial pacing”
Single Chamber

Atrial
Ventricular
“Pure Atrial Pacing”

Used when SA node is diseased or damaged but AV conduction system remains intact

Provides atrial kick

Atrial kick can add 15-30% to CO over a ventricular pacemaker

Electrode in atrium: stimulus produces a P wave
Problems with Atrial Pacing

Electrode difficult to secure in atrium
Tends to float
Inability to achieve consistent atrial “demand” function
Ventricular Pacemakers

If electrode is placed in right ventricle, stimulus produces a left BBB pattern
If electrode is placed in left ventricle, stimulus produces a right BBB pattern
Programmability

Capacity to noninvasively alter one of several aspects of the function of a pacer

Desirable since pacer requirements for a person change over time

Most common programmed areas
  Rate
  Output

AV delay in dual chamber pacers

R wave sensitivity

Advantage: can overcome interference caused by electrocautery
3-Letter or 5-Letter Code

❤ Devised to simplify the naming of pacemaker generators
First letter

Indicates the chamber being paced

A: Atrium
V: Ventricle
D: Dual (Both A and V)
O: None
Second Letter

Indicates the chamber being sensed

A: Atrium
V: Ventricle
D: Dual (Both A and V)
O: Asynchronous or does not apply
Third Letter

Indicates the generator’s response to a sensed signal/R wave

I: Inhibited
T: Triggered
D: Dual (T & I)
O: Asynchronous/ does not apply
Fourth Letter

Indicates programming information

O: No programming
P: Programming only for output and/or rate
M: Multiprogrammable
C: Communicating
R: Rate modulation
Fifth Letter

This letter indicates tachyarrhythmia functions

B: Bursts
N: Normal rate competition
S: Scanning
E: External
O: None
Table 4-4. Generic Code for Identification and Description of Pacemaker Function

<table>
<thead>
<tr>
<th>First Letter</th>
<th>Second Letter</th>
<th>Third Letter</th>
<th>Fourth Letter</th>
<th>Fifth Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac</td>
<td>Cardiac</td>
<td>Response</td>
<td>Programmable</td>
<td>Antitachycardia</td>
</tr>
<tr>
<td>chamber</td>
<td>chamber in</td>
<td>of generator</td>
<td>functions of</td>
<td>functions</td>
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<tr>
<td>paced</td>
<td>which</td>
<td>to sensed</td>
<td>the generator</td>
<td>of the</td>
</tr>
<tr>
<td></td>
<td>electrical</td>
<td>R wave</td>
<td></td>
<td>generator</td>
</tr>
<tr>
<td></td>
<td>activity is</td>
<td>and P wave</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>sensed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V—Ventricle</td>
<td>V—Ventricle</td>
<td>T—Triggering</td>
<td>P—Programmable</td>
<td>B—Bursts</td>
</tr>
<tr>
<td>A—Atrium</td>
<td>A—Atrium</td>
<td>I—Inhibited</td>
<td></td>
<td>N—Normal</td>
</tr>
<tr>
<td>D—Dual</td>
<td>D—Dual</td>
<td></td>
<td>M—Multiprogrammable</td>
<td>rate competition</td>
</tr>
<tr>
<td>(atrium and</td>
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<tr>
<td>ventricle)</td>
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<tr>
<td>O—None</td>
<td>O—None</td>
<td></td>
<td>O—None</td>
<td>E—External</td>
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<tr>
<td>(asynchronous)</td>
<td>(asynchronous)</td>
<td>(fixed</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>function)</td>
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</tr>
</tbody>
</table>

*a Stimulation delivered at normal rate

*b Sufficient for normal activity
### Types of Pulse Generators

<table>
<thead>
<tr>
<th>Letter</th>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>O</td>
<td>Asynchronous (fixed rate) atrial pacing</td>
</tr>
<tr>
<td>V</td>
<td>O</td>
<td>Asynchronous (fixed rate) ventricular pacing</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
<td>Noncompetitive (demand) atrial pacing, electrical output inhibited by intrinsic atrial depolarization (P wave)</td>
</tr>
<tr>
<td>V</td>
<td>V</td>
<td>Noncompetitive (demand) ventricular pacing, electrical output inhibited by intrinsic ventricular depolarization (R wave)</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
<td>Triggered atrial pacing, electrical output triggered by intrinsic atrial depolarization (P wave)</td>
</tr>
<tr>
<td>V</td>
<td>V</td>
<td>Triggered ventricular pacing, electrical output triggered by intrinsic ventricular depolarization (R wave)</td>
</tr>
<tr>
<td>D</td>
<td>V</td>
<td>Paces (sequential) in atrium and ventricle, does not sense P waves, does sense R waves</td>
</tr>
<tr>
<td>D</td>
<td>D</td>
<td>Paces and senses in atrium and ventricle</td>
</tr>
<tr>
<td>V</td>
<td>D</td>
<td>Paces in ventricle, senses in atrium and ventricle, synchronized with atrial activity and paces ventricle after a preset atrioventricular interval</td>
</tr>
</tbody>
</table>
Examples

AOO
A: Atrium is paced
O: No chamber is sensed
O: Asynchronous/does not apply

VOO
V: Ventricle is paced
O: No chamber is sensed
O: Asynchronous/does not apply
Examples

VVI

V: Ventricle is the paced chamber
V: Ventricle is the sensed chamber
I: Inhibited response to a sensed signal

Thus, a synchronous generator that paces and senses in the ventricle
Inhibited if a sinus or escape beat occurs
Called a “demand” pacer
Examples

DVI
D: Both atrium and ventricle are paced
V: Ventricle is sensed
I: Response is inhibited to a sensed ventricular signal

For A-V sequential pacing in which atria and ventricles are paced. If a ventricular signal, generator won’t fire

Overridden by intrinsic HR if faster
Examples

**DDD**
- Greatest flexibility in programming
- Best approximates normal cardiac response to exercise

**DOO**
- Most apparent potential for serious ventricular arrhythmias

**VAT**
- Ventricular paced, atrial sensed
- Should have an atrial refractory period programmed in to prevent risk of arrhythmias induced by PACs from ectopic or retrograde conduction
- AV interval is usually 150-250 milliseconds
Other Information

Demand pacer can be momentarily converted to asynchronous mode by placing magnet externally over pulse generator in some pacers.

Dual chamber pacers preferable for almost all patients except those with chronic atrial fibrillation (need a working conduction system).

Asynchronous pacer modes not generally used outside the OR.

OR has multiple potential sources of electrical interference which may prevent normal function of demand pacers.
Other Information

VVI: Standard ventricular demand pacemaker

DVI: AV pacemaker with two pacing electrodes

Demand pacer may be overridden by intrinsic HR if more rapid

Demand pacer can be momentarily converted to asynchronous mode by placing magnet externally over pulse generator
Sensing

Ability of device to detect intrinsic cardiac activity
Undersensing: failure to sense
Oversensing: too sensitive to activity
Undersensing: Failure to sense

Pacer fails to detect an intrinsic rhythm
Paces unnecessarily
Patient may feel “extra beats”
If an unneeded pacer spike falls in the latter portion of T wave, dangerous tachyarrhythmias or V fib may occur (R on T)
TX: Increase sensitivity of pacer
Oversensing

Pacer interprets noncardiac electrical signals as originating in the heart.

Detects extraneous signals such as those produced by electrical equipment or the activity of skeletal muscles (tensing, flexing of chest muscles, SUX).

Inhibits itself from pacing as it would a true heart beat.
Oversensing

On ECG: pauses longer than the normal pacing interval are present
Often, electrical artifact is seen
Deprived of pacing, the patient suffers ↓ CO, feels dizzy/light-headed
Most often due to sensitivity being programmed too high
TX: Reduce sensitivity
Capture

Depolarization of atria and/or ventricles in response to a pacing stimulus
Noncapture/Failure to Capture

Pacer’s electrical stimulus (pacing) fails to depolarize (capture) the heart
There is no “failure to pace”
Pacing is simply unsuccessful at stimulating a contraction
ECG shows pacer spikes but no cardiac response
↓ CO occurs
TX: ↑ threshold/output strength or duration
Pacer Failure

A. Early
   electrode displacement/breakage
B. Failure > 6 months
   Premature battery depletion
   Faulty pulse generator
Pacer Malfunctions per ECG

- Failure to capture
- Failure to sense
- Runaway pacemaker
Pacer Malfunction SX

1. Vertigo/Syncope
   *Worsens with exercise
2. Unusual fatigue
3. Low B/P/ ↓ peripheral pulses
4. Cyanosis
5. Jugular vein distention
6. Oliguria
7. Dyspnea/Orthopnea
8. Altered mental status
EKG Evaluation

Capture: Should be 1:1
(spike:EKG complex/pulse)
*Not helpful if patient’s HR is > pacer rate if synchronous type
EKG Evaluation

Proper function of demand pacer
  Confirmed by seeing captured beats on EKG when pacer is converted to asynchronous mode
Place external converter magnet over generator
Do not use magnet unless recommended
Output: amt of current (mAmps) needed to get an impulse
Sensitivity: (millivolts); the lower the setting, the more sensitive
Anesthesia for Insertion

MAC

To provide comfort
To control dysrhythmias
To check for proper function/capture

Have external pacer/Isuprel/Atropine ready

Continuous ECG and peripheral pulse
Pulse ox with plethysmography to see perfusion of each complex
(EKG may become unreadable)
Pacemaker Insertion
Interference

Things which may modify pacer function:
- Sympathomimetic amines may increase myocardial irritability
- Quinidine/Procainamide toxicity may cause failure of cardiac capture
- ↑K+, advanced ht disease, or fibrosis around electrode may cause failure of cardiac capture
Anesthesia for Pt with Pacemaker

a. Continuous ECG and peripheral pulse
b. Pulse ox with plethysmography to see perfusion of each complex (EKG may become unreadable)
c. Defibrillator/crash cart available
d. External pacer available
e. External converter magnet available
Anesthesia for Pt with Pacemaker

If using Succinylcholine, consider defasciculating dose of MR

Fasciculations may inhibit firing due to the skeletal muscle contractions picked up by generator as intrinsic R waves

Place ground pad far from generator but close to cautery tip

Cover pad well with conductive gel

Minimizes detection of cautery current by pulse generator

If patient has a transvenous pacemaker, increased risk of V. fib from microshock levels of electrical current
Anesthesia for Pt with Pacemaker

Cautery may interfere with pacer:
- May inhibit triggering (pacer may sense electrical activity and not fire)
- May inadvertently reprogram
- May induce arrhythmias secondary to current
- May cause fixed-rate pacing
Automatic

Implantable

Cardiac

Defibrillators
Figure 1  The Ventak P AICD
Parts of AICD

- Pulse generator with batteries and capacitors
- Electrode or lead system
  Surgically placed in or on pericardium/myocardium
- Monitors HR and rhythm
- Delivers shock if VT or Vfib
Placement of AICD

Pulse Generator

Typical Implant System
AICD Indications

» Risk for sudden cardiac death caused by tachyarrhythmias (VT, Vfib)
» Reduces death from 40% to 2% per year
Defibrillator Codes

First letter: Shock Chamber

A: atrium
V: ventricle
D: dual
O: none
Defibrillator Codes

Second letter: Antitachycardia Chamber
  A: atrium
  V: ventricle
  D: dual
  O: none

Third letter: Tachycardia Detection
  E: EKG
  H: Hemodynamics
Defibrillator Codes

Fourth letter:  Antibradycardia Pacing Chamber
A: atrium
V: ventricle
D: dual
O: none
Settings

Gives a shock at 0.1-30 joules
  Usually 25 joules
Takes 5-20 seconds to sense VT/VF
Takes 5-15 seconds more to charge
2.5-10 second delay before next shock is administered
Total of 5 shocks, then pauses
If patient is touched, may feel a buzz or tingle
If CPR is needed, wear rubber gloves for insulation
Tiered Therapy

Ability of an implanted cardioverter defibrillator to deliver different types of therapies in an attempt to terminate ventricular tachyarrhythmias

EX of therapies:
- Anticardiac pacing
- Cardioversion
- Defibrillation
- Antibradycardia pacing
Anesthesia

MAC vs General

Usually general due to induction of VT/VF so AICD can be checked for performance

Lead is placed in heart

Generator is placed in hip area or in upper chest
VADs

Ventricular assist devices
Implantable pumps used for circulatory support in pts with CHF
Blood fills device through a cannulation site in V or A
Diaphragm pumps blood into aorta or PA
Set at predetermined rate (fixed) or automatic (rate changes in response to venous return)
Electromagnetic Interference on Pacers and AICDs

Electrocautery
May inhibit or trigger output
May revert it to asynchronous mode
May reprogram inappropriately
May induce Afib or Vfib
May burn at lead-tissue interface
Electromagnetic Interference on Pacers and AICDs

Defibrillation

May cause permanent damage to pulse generator
May burn at lead-tissue interface

Radiation Therapy

May damage metal oxide silicon circuitry
May reprogram inappropriately
Electromagnetic Interference on Pacers and AICDs

PET/CT (Contraindicated)
- May damage metal oxide silicon circuitry
- May reprogram inappropriately

MRI (Contraindicated)
- May physically move pulse generator
- May reprogram inappropriately
- May give inappropriate shock to pt with AICD

PNSs
- May cause inappropriate shock or inhibition
- Test at highest output setting
Deactivating a Pacemaker

Deactivate to prevent inappropriate firing or inhibition

Can be deactivated by a special programmer/wand or by a magnet placed over generator for 30 seconds

Put in asynchronous mode or place external pacer on patient
If Pt has a Pacemaker/AICD

Not all models from a certain company behave the same way with magnet placement!

*For all generators, call manufacturer*

*Most reliable method for determining magnet response!*
Coding Patient

If patient codes, do not wait for AICD to work
Start CPR & defibrillate immediately
Person giving CPR may feel slight buzz
   A 30-joule shock is < 2 j on pt’s skin
External defibrillation will not harm AICD
Change paddle placement if unsuccessful attempt
Try A-P paddle placement if A-Lat unsuccessful
Pts with Pacemakers/AICDs/VADs

Obtain information from patient regarding device

Ask how often patient is shocked/day

High or low K+ may render endothelial cells more or less refractory to pacing

A properly capturing pacemaker should also be confirmed by watching the EKG and palpating the patient’s pulse
Anesthetic Considerations

Avoid Succinylcholine
Keep PNS as far from generator as possible
Have backup plan for device failure
Have method other than EKG for assessing circulation
Have magnet available in OR
Electrocautery Use

Place grounding pad as far from generator as possible
Place grounding pad as near to surgical field as possible
Use bipolar electrocautery if possible
Have surgeon use short bursts of electrocautery
  (<1 sec, 5-10 seconds apart)
Maintain lowest possible current
Electrocautery Use

If cautery causes asystole, place magnet over control unit & change from inhibited to fixed mode
Change back afterwards
Be alert for R on T phenomenon
Postoperative Considerations

Avoid shivering

Have device checked and reprogrammed if questions arise about its function
Examples of Rhythms

Sensing

Patient’s own beat is sensed by pacemaker so does not fire
Examples of Rhythms

Undersensing

Pacemaker doesn’t sense patient’s own beat and fires (second last beat)
Examples of Rhythms

Oversensing

Pacemaker senses heart beat even though it isn’t beating.
Note the long pauses.
Examples of Rhythms

Capture

Pacemaker output (spike) is followed by ventricular polarization (wide QRS).
Examples of Rhythms

Noncapture

Pacer stimulus fails to cause myocardial depolarization
Pacer spike is present but no ECG waveform

Oversensing-Fails to fire

Undersensing-Fails to sense ECG

Pacer spikes after the QRS

Fires but fails to capture
Examples of Rhythms

100 % Atrial Paced Rhythm with 100% Capture
Examples of Rhythms

100% Ventricular Paced Rhythm with 100% Capture
Examples of Rhythms

100% Atrial and 100% Ventricular Paced Rhythm with 100% Capture
Examples of Rhythms

50% Ventricular Paced Rhythm with 100% Capture
Examples of Rhythms

25% Ventricular Paced Rhythm with 100% Capture (Note the sensing that occurs. Pacer senses intrinsic HR and doesn’t fire).
Examples of Rhythms

AICD Shock of VT
Converted to NSR

Figure 2  Example of AICD conversion of ventricular tachycardia on surface ECG
Examples of Rhythms

Heterotopic Heart Transplant
Examples of Rhythms
Examples of Rhythms

DDD Pacemaker
References


