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**Pacemakers**

**1. What is a pacemaker?**

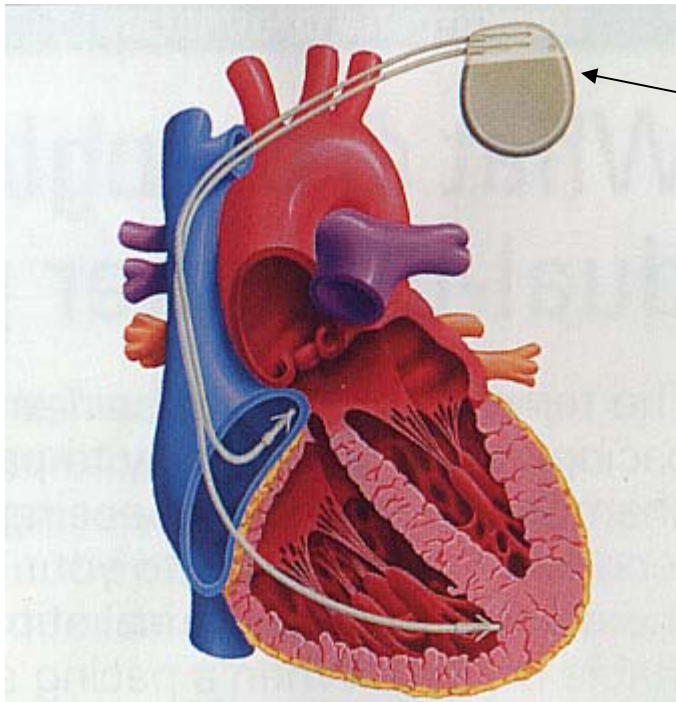
A pacemaker is an electronic device that provides an electrical signal to make the heart beat when it’s own, built-in pacemakers fail. The anatomical, built-in pacemakers provide what’s called the “intrinsic” rhythm, and they can be disrupted by various conditions – ischemia for example, or by an MI.

## 2. What does “intrinsic” mean?

Intrinsic means “built in”. In this situation, it means: “coming from the patient’s own built-in, natural pacemakers” : the SA or AV nodes; or sometimes from lower down in the ventricles.

## 3. How exactly do pacemakers work on the heart?

The pacemaker essentially does two things : it senses the patient’s own rhythm using a “sensing circuit”, and 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 control 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.



Here’s the “box”, implanted.

How many pacing wires?

<http://www.borleyrectory.com/myessays/pacemaker.htm>

## 4. What are the parts of a pacemaker?

The pacemaker box itself is called the “pulse generator” – the generator is connected to either one or two wires, which carry the electrical signals to the heart muscle. Permanent pacing generators are implanted in the chest under the skin – nowadays they’re very small – and the wires leading to the heart are threaded through the subclavian vein.

## 5. Are there different kinds of pacemakers?



Pacemakers can be either temporary or permanent. The temporary pacemakers that we see in the MICU are made up of a control box and one single output wire leading to the inner wall of the RV (thus called a ventricular wire, or “V-wire”), and provide simple rate control by pacing the ventricles. Permanent pacemakers come in several flavors, but the main difference between them is that some have only one wire leading to the RV, and some have two – one to the right atrium (RA), and another one to the RV. A pacing system that paces both the RA and the RV is called an “atrioventricular” pacer, and paces both right heart chambers in sequence. The signal affects the left-side chambers and stimulates them to contract as well. The signal from the wire generates a visual signal on the EKG that looks like, and is called a “spike”.

Here's an example of a temporary, external, single-wire pacing box. The wire has two pole connections, so one pair of connectors: single wire box.

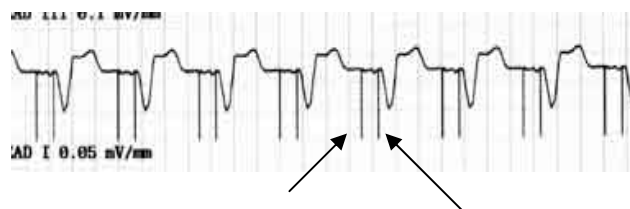
<http://www.pacemedicalinc.com/4543.htm>

Here's a nice example of single-wire pacing, with spikes coming at a rate in the 70's. The reason we can tell that there's only one wire going is simply that there's only one spike. Two-wire systems generate two spikes.

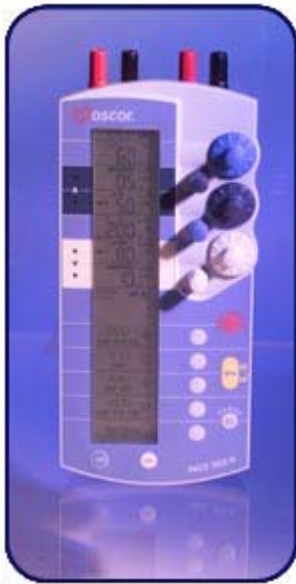


These spikes go both up and down in front of the QRS's, which you see sometimes – a “normal variant”.

How many spikes this time?



Everybody see the two spikes? The arrows aren't perfect – but clearly there are two pacing functions going on here: the first spike is generating atrial kick, and the second is kicking the ventricles: two spikes, two wires.



Two sets of connectors: two wires. So what kind of box is this?

<http://www.oscor.com/default.asp?owc/temp%20pacing.asp~main>

#### 6. What is the advantage of two wires over one?

If you pace the ventricle alone, the patient doesn't get the "atrial kick" – the push of the atria into the ventricles. This can actually add 20-25% to the cardiac output, and improve the blood pressure accordingly. A nice example of this was a patient we saw recently who had a temporary V-wire in place. When she was paced at a rate of 70, she only got a blood pressure of about 85, systolic. But when the pacer rate was turned down, her intrinsic rate took over at about a rate of 60 – sinus rhythm, which meant that she started getting her atrial kick again – and her blood pressure rose, even with the slower rate, to about 105. Also a nice example of how the fastest rate will capture: first the wire, then the intrinsic one.

#### 6. How are pacemakers inserted?

A temporary pacing wire is threaded through an introducer placed in a central line site, usually the right internal jugular or subclavian. (The right IJ is the straightest shot down into the RV, which is where you want your temporary wire to go.) Nowadays we rarely use transvenous wire insertion at the bedside – we apply the transcutaneous pacer, or "Zoll" instead. Once in a great while a transthoracic wire placement is attempted, usually at the end of a code when nothing else is working...

#### 7. What do they mean by transvenous, transcutaneous, and transthoracic?

Transvenous means that the pacing wire is threaded down the jugular vein through an introducer (the same as a PA line introducer). The introducer is put in first, like any central neck IV line, and the wire is passed through it, like a PA line is, until it makes contact with the inner wall of the RV. Then the wire is attached to a generator box, and the heart is paced using the wire. We hardly ever do this at the bedside anymore, since the coming of the Zoll external pacer.

Transcutaneous pacing means using external pacing pads connected to a device like the Zoll machine, or one of the defibrillators that has external pacing ability.

Transthoracic pacing means using wires inserted either during cardiac surgery – small wires that sit on the outer wall of the heart – “epicardial” wires, that lead out of the chest, to a control box - or doing a maneuver that involves pushing a pacing wire into the RV up through the chest wall, subxiphoid, during a code. I’ve only ever seen this tried once and it didn’t work. According to a web source that we looked at, the procedure isn’t very popular, can create a whole slew of nasty complications, and usually isn’t any use anyhow.

**8. How does the generator box work?**

The generator box consists of a small computerized chip controller that’s run by a battery. The box senses and paces through the same set of wires that lead to the endocardium.

**9. How long does the battery last?**

As I understand it, implantable pacers use lithium batteries that last anywhere from 6 to 10 years. The battery in a temporary pacing box is a regular hardware-store type 9-volt battery.

**10. How much electricity does the pacemaker use to actually pace the heart?**

The output of the pacemaker is measured in two ways: “signal amplitude”, and “pulse width”.

**11. In English, please?**

Signal amplitude means “how much juice the box puts out through the wire with every pulse”. This is measured in milliamperes, and is called MA – there’s a twisty dial to control the MA on the front of the temporary pacer box. Pulse width means “how long each pulse lasts”. The electrical pulse has to be strong enough, and last long enough, to capture the myocardium.

**12. What is “capture threshold”?**

Capture threshold is the minimum amount of electricity that the box has to emit to pace the heart – as above, it’s measured in milliamps, and the twisty knob is turned up until the heart is paced 100% - then turned down again until the minimum is determined.

**13. Why do paced beats generated by a ventricular wire look like PVCs?**

The reason that PVCs look “wide and bizarre” is because they originate down at the bottom of the heart, at the opposite end from where they usually come - the path of depolarization is backwards as a result. Think of the normal lead II signal, going from northwest to southeast: Oregon to Florida. A paced signal is going backwards, upwards (“retrograde”) - the reverse of the normal QRS waveform. Since the v-wire generates a rhythm by emitting electricity from a wire whose tip is embedded in the wall of the RV, the deflection follows the same path as a PVC – so it looks like one.

Here's the two-wire pacing strip again: one wire is in the right atrium, and the other's in the right ventricle. With two wires, the ventricular path is still backwards, just as with one – makes sense, right?



#### 14. What does “asynchronous” mean, and what does “demand” mean?

A temporary control box can be set to run - just run - at a fixed rate, ignoring any signals that the patient's heart may be making (asynchronous); or it can be set to pace only if the intrinsic heart rate gets too slow (“pacing on demand”). Needless to say, you would use the first way of pacing only if the patient's heart rate was either much too slow, as may happen if the patient wipes out some of her conduction system by infarct, or if the rhythm just isn't there, as in asystole, maybe for the same reason. There's a second twisty dial that controls how sensitive the box will be to the patient – for full control, you would turn it all the way until the control knob's arrow pointer was all the way towards the word “asynchronous”. Insensitive. Take the pacing generator out of the emergency pacing tackle box a few times, and get familiar with it.

Here's the strip we looked at on page 3. This is fixed-rate pacing. Not necessarily asynchronous, but this is what it would look like:



This same dial can also be turned in the other direction, away from “asynchronous” – this increases the sensitivity of the box, so that it will start sensing the patient's own rate. If you want the box to start pacing the patient only when the intrinsic rate gets too slow – “on demand”, then you adjust the sensitivity of the box so that it can see the patient's rhythm. This will “inhibit” the box from firing when it sees intrinsic beats. The cardiology people are usually responsible for these settings, but the idea is pretty simple: it's better if the patient's own rhythm controls the heart, especially if all you have is a V-wire (no atrial kick with only a v-wire, remember) – but if it slows down below a certain point, the box will wake up and take over. The intrinsic rhythm stops or slows, and the interval is long enough for the pacer to turn on.

Remember that the wire has to generate a rate that's fast enough to make an adequate blood pressure. If the demand rate is set so that the box only kicks in at a rate of 60, that may not be enough, especially if you're only working with the one wire.

### 15. What do those letters: VVI, DDD, etc., stand for?

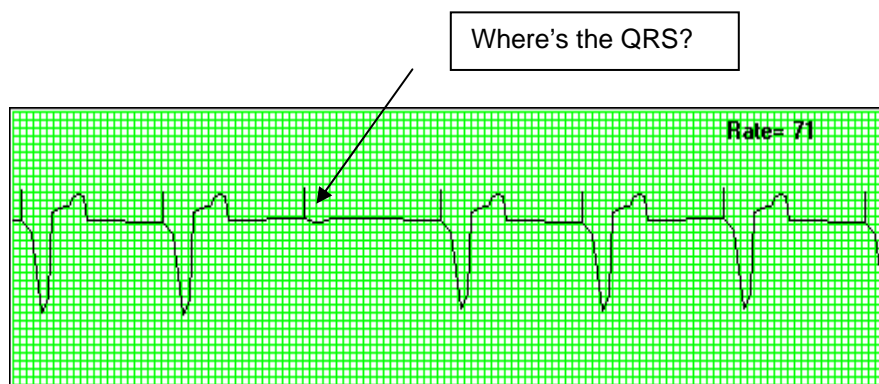
We really only see two kinds of pacemakers in the MICU – single v-wire pacing (usually temporary wires placed for bradycardias and the like), and permanently implanted A-V pacers. Single v-wire systems are called VVI pacers, and the A-V pacers are called DDD.

The first letter stands for the chamber that is paced, the second letter is for the chamber that is sensed, and the third letter stands for the response the pacer makes to a sensed intrinsic beat. So a VVI-mode pacer paces the RV, senses the RV, and is Inhibited from firing if it senses an intrinsic beat. DDD pacers pace both chambers (D stands for “dual”), they sense both chambers, and each of the two wires is inhibited by an intrinsic beat.

This can produce a very cool result: a patient may generate her own P-waves, but fail to conduct them – maybe she has a fritzed-out AV node. The A-wire will be inhibited by the patient’s P’s, but the v-wire will sense, and follow them. So the patient will be in a “sinus rhythm, with v-pacing”, and will be able to increase and decrease heart rate in a normal way in response to exercise, and the like. Excellent!

### 16. What is “failure to capture”?

Here the idea is that the pacing box sends an impulse to the heart at the right time, but the heart doesn’t respond. The box is sensing that the intrinsic heart rate is too slow, but the output signal isn’t making the myocardium respond. You see this on a rhythm strip when there are clear pacing spikes coming from the box – at the right time after either an intrinsic beat or a paced one – but they’re not followed by a QRS response. There can be all sorts of reasons for this: broken wires, pacemaker box failure, acidosis, alkalosis, bad connection to an external pacing box, battery failure, the moon in Virgo... this can be serious if the patient is depending on the pacemaker to maintain a blood pressure. Various maneuvers can be made with the pacer control box to re-establish proper capture – the quickest one is usually to turn up the MA output. Call the team. While you’re waiting, have atropine at the bedside, and the Zoll nearby in case “bad” capture goes to “no” capture!



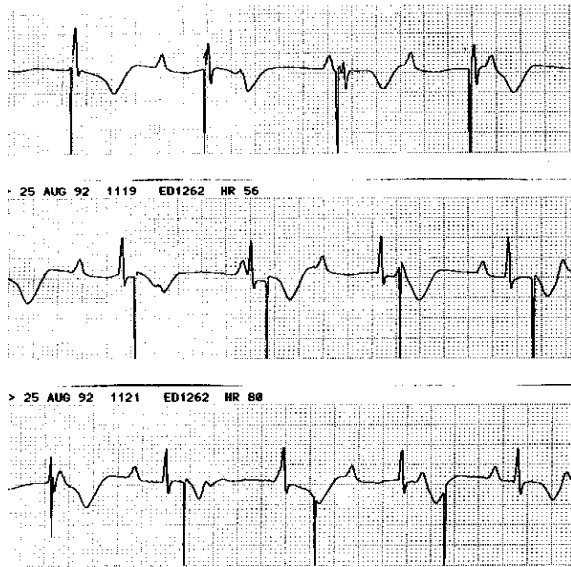
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The point to remember: the pacer spikes are coming at the **right** time relative to the patients rate, or lack of a rate – but they’re not capturing.

### 17. What is “failure to sense”?

Remember, the pacemaker has both a sensing circuit and an output, or pacing circuit. The pacer has to sense whether or not the patient is generating a rhythm, so it will know when to pace and when not to. In this case the pacemaker will generate spikes that do capture, but the spikes come at the wrong time, and the box is clearly unable to see what the patient’s heart is doing. Clearly a bad thing – it can result in the infamous R-on-T situation, producing VT or VF.

The thing to keep in mind: the pacer spikes will be coming at the **wrong** time. This may just be an improper sensitivity setting on the box.



Here we are failing to sense. (It's usually a guy thing...) The spikes are certainly regular, but are they coming at the right time, relative to the patient? No – the box isn't seeing the patient's rhythm, and it's firing off blindly. (Three doctors go duck hunting...)

[www.monroecc.edu/depts/pstc/paracar5.htm](http://www.monroecc.edu/depts/pstc/paracar5.htm)

### 18. How can an implanted pacemaker be reprogrammed?

There's a machine that the physician uses to communicate with an implanted pacemaker.

### 19. What is the magnet thing?

You've probably seen the physicians do this mysterious maneuver with a ring-shaped magnet that gets placed on the patients' chest over the pacemaker. The idea here is that there is a switch inside the pacemaker with a ferrous reed, which is pulled from one position to the other by the magnet. This is involved in figuring out how much longer the pacers' battery has to live, and also changes the pacemaker into fully asynchronous mode for testing purposes.

### 20. What are some reasons for placing a permanent pacemaker?

There are lots of things that an unhappy heart can come up with that will indicate the need for a pacemaker: sick-sinus and tachy-brady syndromes will do it, certainly recurrent bradycardias that drop the BP will do it, heart blocks (especially which one?) – you get the idea. If the heart isn't generating a rate for whatever reason, pacing will probably be needed.

## 21. What is an AICD?

AICD stands for Automatic, Implantable, Cardioverter-Defibrillator. This is a variation on the idea of a pacemaker – the device has a sensing circuit and an output circuit, but instead of acting as a pacer, it spends its time waiting for the onset of some nasty tachyarrhythmia, like VT, or SVT – which it then tries to shock the patient out of. Apparently they will also sometimes try to override-pace a patient out of a rapid rhythm.

## 22. Can AICDs also function as pacers?

Apparently the newest generation of AICDs can do both.

## 23. What problems do AICDs have?

Clearly you wouldn't want to be defibrillated at the wrong time. I have no idea how common a problem this is – I have heard of it happening, and of patients having to come in and have the box reprogrammed, or shut off. Similarly to pacemakers, AICDs can fail to sense, or to capture...

## 24. How do you stop an AICD from shocking the patient incorrectly?

Apparently the ring magnet will shut off the cardioverter, but will allow the pacer function to keep going if necessary. We need to check into this...

## 25. Can you shock a patient with a pacemaker?

The last time this came up in the MICU, we called the CCU, and they told us that it's generally safe to shock a patient with an implanted pacemaker.

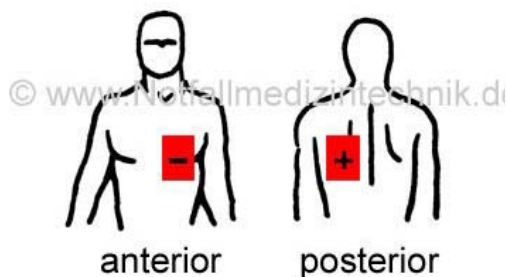
## 26. What is external pacing?

Transcutaneous pacing is the use of the Zoll machine, or its equivalent. External pacing capability is built into the defibrillators that we use in the unit. Large sticky pads are applied to the patient's chest and back (it's important to check the placement diagram on the pad package), and connected to the Zoll output cable. The cable delivers electricity to the pads, hopefully capturing and pacing a heart that's too slow.



There's been an important change in the way the pads are applied:

Here's the way we used to do it. These pads are in the same position used for cardioversion, defibrillation, those things...



Here's the way we do it now. The idea is sort of to "sandwich" the heart between the pads. Apparently works much more better.

This really is important: take the time to go over this stuff before you need to do in emergently. Grab the resource nurse, or a senior staff person, or another newbie, and take a good look at how the parts of the equipment fit together, how they work, where replacements are kept...

### 27. Who was Zoll, anyhow?



Dr. Zoll was apparently the medical researcher who did the original research and development of transcutaneous pacing, and who patented the machine in the early 1980's.

<http://zoll-aed.com/dr-zoll.jpg>

### 28. What else do I need to know about running the external pacer?

Our machine has only three controls that you have to worry about: one changes the box from monitor mode to pacing mode, and the other two are the pacer control knobs.

The basics are really not hard. Remember that the external pacing box should be able to see the patient, as well as pace the patient, so there is a sensing cable that attaches to three chest electrodes. You can pace the patient without this, so in an emergency just get the pads on and go - but having the ability to sense is better.

The pacing electrodes are the big white sticky things – one goes on the front of the chest, one goes on the patient's back – again, check the positioning diagram on the package that they come in. These connect to the cable that lets the box pace the patient: an output cable coming from the box.

### 29. How do I know if capture has been achieved?

This is a bit tricky, but obviously important. If there's time, make sure that the Zoll's sensing cable is attached to the patient – 3 electrodes in a standard lead II pattern, because it helps if the machine can see the patient's heart rate.

Now the knobs - start with both knob controls: rate, and power (MA) output - set at zero. Turn the heart rate knob up to a rate that you'd like to pace the patient at – this is pretty simple: if

the patient's rate is 20, pick something like 60 - 80 beats per minute. Now start turning up the power output knob – it sometimes takes a lot of power to capture – something like 100 to 150 MA.

### **30. What's the tricky part?**

Here's the tricky part. If you look at the patient's monitor for evidence of capture, you may be fooled. The electrical activity of the external pacer shows up clearly on the monitor as large funny-looking-beats, and they will occur at whatever rate of bpm that you chose. The appearance of these beats does not mean that the patient's heart has been captured! You need to actually have some way to tell that the heart is being paced - and generating blood pressure - at the rate you're trying to pace them at. So if the patient has an a-line, try looking at the waveform heart rate counter to match your desired rate, or the pulse oximeter heart rate counter – or feel the patient's pulse, which may be hard to do if they're hypotensive. See if the patient's blood pressure is responding. Don't assume that the electrical activity of the pacer means that the heart is being paced!

### **31. Does external pacing hurt?**

Yes, depending on how much juice they get, but also depending on how big the external pacing pad is. It seems that the larger electrode size does away with most of the pain involved. I hope so - it doesn't look very comfortable...

### **32. How long can a person stay on the external pacemaker?**

Probably not too long. In my experience, an hour or two if the patient really needs a wire. The whole point of the device is to provide temporary pacing in a critical situation until the patient can get a wire inserted in the cath lab. This has almost completely replaced the placement of transvenous pacing wires in code situations, although sometimes it's still tried. The external pacer may stay on in "demand mode" in a patient who doesn't need a wire, but whose rate only rarely goes too low – maybe while waiting for a digoxin level to come down. (Look up "digi-bind"). This is a medical judgment call.

### **33. How does the Zoll go into demand mode?**

Once you've determined that the MA is set high enough to capture 100% (all the time, reliably), try turning down the rate knob to let the patient's own heart rate take over (assuming they have a rate at all!) – if they do, and if that generates an adequate blood pressure, the Zoll's rate can be left at a number low enough not to interfere with the patient's intrinsic rate unless it drops too far – at which point the Zoll will kick in on "demand". The Zoll will also run "blind", that is, without the sensing cable attached: if you're in a real hurry, say, in an asystolic code, you can just slap on the pads, pick a rate, turn the MA up to max, and go. Establish capture first, and try to find the capture threshold later...

### **34. Any other Zoll tricks?**

A useful one is: if you have time, benzoin the skin under the outer part of the pacing pads – not on the gel part – because people tend to sweat the pads off. Dangerous. A quick additional point about this: if you should come across sticky defibrillation pads, which are used for patients that require repeated shocks (I've only ever seen them once here in the MICU), don't benzoin them on – it can cause arcing!

**35. Can you do CPR with the external pacer in place?**

The literature I've read says yes – but that you should turn the pacing box off. (Duh.)

**36. How effective is the Zoll?**

Apparently pretty effective - the survival rates are reported as ranging from 50-100%. The secret: get it up and running promptly. Did your patient just need a dose of atropine? Put the pads on, right now, and get the cables and box hooked up, ready to run. Any time wasted, any time the patient spends hypotensive or becoming even moderately acidotic increases the chance that the device won't work. And get a call in to the cath lab at the same time...