

Chapter 8: Pacemaker Rhythms

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After this chapter you should be able to Name the three components of a pacemaker system and the four common system types; explain sensing, inhibition, capture, threshold, and rate modulation; decode the NBG code, positions I through IV; recognize failure to pace, failure to capture, and failure to sense; distinguish electrical from mechanical capture and state how you confirm each. Reading: Aehlert, *ECGs Made Easy*, 7th ed., Chapter 8 (p. 207 to 224).

Note to students: Values in this guide follow **Aehlert, 7th edition**, because that is the edition this guide follows. The clearest conflict this week is the pacemaker code. This series teaches the **2002 revision**, in which position IV is **rate modulation**. Several teaching sites still publish the **1987** version, where position IV is programmability and a fifth position covers antitachyarrhythmia function. Both tables are online, they do not agree, and a student answering position IV from a 1987 table will get it wrong. Answer from the textbook. **What Chapter 7 gives you:** Chapter 7 trained you to ask whether the impulse got through. Chapter 8 is what happens when the answer is no often enough to matter, because high-grade AV block is one of the most common reasons a patient has a pacemaker at all. You are not learning a new heart this week, you are learning to read a machine added to a heart you already know.

At a Glance: this chapter in one box

The one sentence this chapter is built on

- **The spike is the machine talking, and the complex after it is the heart answering.** That defines spike, complex, and capture at once, and every malfunction here is a failure of one half of that exchange.

Numbers and facts you must know

- A pacing spike lasts roughly **2 ms**, about **one twentieth of a small box** at 25 mm/s. Nothing physiological is that narrow.
- Spike before the P wave is **atrial** pacing; spike before the QRS is **ventricular** pacing; both is **dual chamber**.
- A right ventricular paced QRS is **wide, 0.12 s or more**, and looks like left bundle branch block.
- NBG 2002: **I** chamber paced, **II** chamber sensed, **III** response to sensing, **IV** rate modulation.
- Sensitivity is a fence: a **higher** millivolt number means **less** sensitive.
- **Undersensing causes overpacing. Oversensing causes underpacing.**

Top 3 traps

- Calling an absence of spikes a malfunction. A quiet pacemaker is usually a happy pacemaker.
- Calling a wide paced QRS a ventricular rhythm, because you read the QRS before looking in front of it.
- Accepting electrical capture as proof of perfusion. The monitor is not the patient.

The Spike Is the Machine Talking, the Complex Is the Heart Answering

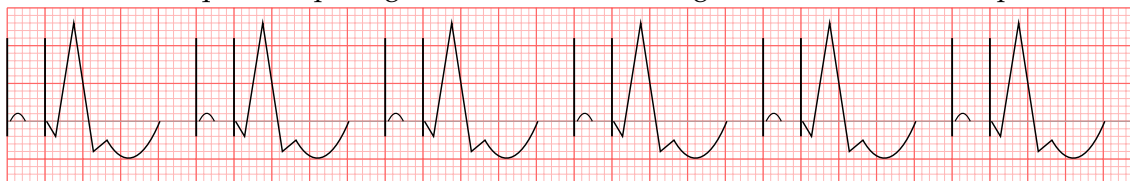
Learn that sentence first, because it does three jobs at once. The **spike** is the pacemaker's output, the **complex** behind it is the myocardium responding, and **capture** is the name for that response actually happening. One sentence, three definitions. It also hands you the malfunction list, because an exchange with two halves can only break in two places, plus one way for the timing to be wrong:

- The machine does not talk when it should: **failure to pace**, also called failure to fire or output failure.
- The machine talks and the heart does not answer: **failure to capture**.
- The machine talks at the wrong moment because it was not listening: **failure to sense**, or undersensing.

What a spike looks like. A near-vertical line about **2 ms** wide. A small box at 25 mm/s is 0.04 s, which is 40 ms, so a spike is roughly **one twentieth of one small box**. Own that number and you can never confuse a spike with a narrow QRS. Spikes may point up, point down, or run partly both ways, which tells you nothing clinically. Position is what matters.

Small spikes are still spikes. Bipolar leads, which most modern permanent systems use, make much smaller spikes than unipolar leads and may not be visible on every lead or at every gain setting. Hunt for a pencil tick before deciding the page is blank. **Absence of a visible spike never proves absence of pacing.**

The three-line recognition rule. Whatever waveform comes immediately after a spike identifies the chamber paced. Spike then P wave is atrial pacing. Spike then QRS is ventricular pacing. Both, in that order, is dual chamber, also called AV sequential, pacing. That is the entire recognition skill for this chapter.



AV sequential (dual chamber) pacing at 60. All three lines of the rule sit on this one strip: the first spike is followed by a P wave, the second by a wide QRS, and both together in that order are what dual chamber pacing looks like. Read the spike before you read the complex, or a wide paced QRS gets called a ventricular rhythm.

The AV delay is a manufactured PR interval. In a dual chamber system the gap between the atrial spike and the ventricular spike is an interval an engineer chose to imitate natural conduction timing. You already own the PR interval from Chapter 2, so this is not a new measurement, it is your old measurement produced deliberately instead of naturally.

Capture is defined by adjacency. The waveform must follow the spike **immediately**, with no gap for the eye to argue about. The spike is a knock on a door; capture is the door opening. A knock with nobody answering is a spike with no complex behind it.

You Already Know This: The Same Rule, For The Fourth Time

A right ventricular lead sits in the right ventricle, so a paced beat starts **below** the bundle branch bifurcation. It misses the on-ramp to the His-Purkinje highway and has to crawl muscle cell to muscle cell across to the left ventricle. Longer trip, so the QRS is **wide**; abnormal direction, so the pattern resembles **left bundle branch block**.

This is the **fourth** time this book has used that rule. Chapter 2 gave it to you as anatomy, Chapter 6 used it for ventricular beats, Chapter 7 used it to predict escape width below a block, and Chapter 8 uses it again. The only new ingredient is that a machine is why the beat started low.

Caveat. This holds for a **standard right ventricular lead**. A coronary sinus or left epicardial lead, which is what biventricular resynchronization adds, starts the beat somewhere else and gives a different pattern. "Paced beats look like left bundle branch block" is a statement about lead position, not a law of pacing.

Appropriate discordance. In a paced beat the ST segment and T wave are **expected** to point opposite the QRS. That is normal, and to a beginner it looks like an infarction, which is why you are being told now rather than

in Chapter 9: expect it instead of fearing it. You met the same phenomenon on a PVC in Chapter 6, where the discordant T wave was free confirmation rather than a second problem.

Pacemaker Systems: What Is Actually In The Patient

Every system is three parts, and the strip changes when any one fails. The **pulse generator** holds the battery and circuitry, and depletion shows up as failure to pace. The **leads** are the insulated wires, where a fracture or loose connection shows up as failure to pace and a dislodged lead shows up as failure to capture. The **electrodes** are the tips that touch myocardium, and a tip not in contact with muscle produces nothing no matter how good the generator is.

System type	Leads	Who it is for
Single chamber atrial	Right atrium	Sinus node disease with intact AV conduction
Single chamber ventricular	Right ventricle	AV block, or chronic atrial fibrillation, where no organized atrial activity exists
Dual chamber	Right atrium and right ventricle	AV block with usable atrial activity; preserves AV synchrony and the atrial kick from Chapter 1
Biventricular (CRT)	Adds a third lead to the left ventricle via the coronary sinus	Heart failure with a dyssynchronous contraction

Temporary or permanent. Temporary pacing is **transcutaneous** (pads on the chest, fast, uncomfortable, a bridge only), **transvenous** (a lead threaded through a central vein into the right ventricle), or **epicardial** (wires left on the heart surface after cardiac surgery). Permanent pacing means an implanted generator in a pocket under the skin below the clavicle.

Dual chamber is not automatically better. It preserves AV synchrony, but it needs organized atrial activity to synchronize with, and a patient in chronic atrial fibrillation has none. Single chamber ventricular pacing is the right device there. If a discussion post claims biventricular is universally best, ask which patient it is actually for.

Pacing Principles: Sensing, Inhibition, Capture, Threshold

Nearly all modern pacing is **demand pacing**, and the rule is one sentence: **the pacemaker fires only when it does not sense intrinsic activity**. Picture the backup generator in a hospital basement, silent while the grid is up and switching on the instant power drops below a set point. That image is inhibition.

- **Sensing**, the device watching for the patient's own beat. **Inhibition**, staying quiet because it saw one. **Triggering**, firing in response to an event sensed in the other chamber.
- **Threshold**, the minimum energy needed to achieve capture. It can rise over time as fibrous tissue builds at the electrode tip, so a device that captured fine last year may not today.
- **Rate modulation**, also called rate-responsive pacing, raises the paced rate when a sensor detects motion or increased respiration. That is NBG position IV.
- **Threshold and sensitivity are different dials.** Threshold is how loud the device must shout to be heard. Sensitivity is how good its hearing is. Output versus input, and mixing them up is the most common conceptual error in this chapter.

The Fence: One Picture For All Of Sensing

Think of the sensitivity setting, measured in millivolts, as a **fence**. The device only sees signals tall enough to clear it.

- Turn the millivolt number **UP** and you build a **higher fence**: harder to see over, so the device is **LESS sensitive** and starts missing the patient's own beats.
- Turn the millivolt number **DOWN** and you build a **lower fence**: easy to see over, so the device is **MORE sensitive** and starts noticing things that are not beats.

That is why the numbering feels backwards, and why one picture explains both malfunctions and both fixes. Under-

sensing means the fence is too high, so lower the number; oversensing means it is too low, so raise it.

The opposites rule, and it is a mirror: undersensing leads to overpacing; oversensing leads to underpacing. One line, four facts. Remember half and you can rebuild the other half on the spot. **The fastest visual tell, countable on the strip:** oversensing gives you **fewer** spikes than the patient needs, undersensing gives you **more**.

Undersensing is the person at a meeting who keeps interrupting because they are not listening. The device did not see the patient's own beat, so it fires on top of it. In a meeting that is rude; here it is dangerous, because a ventricular spike landing on the tail of a T wave is **R-on-T**, which can trigger ventricular tachycardia or torsades, the exact mechanism from Chapter 6.

Oversensing is the device being fooled. It counts something that was not a beat, concludes the patient already produced one, and withholds an impulse it should have delivered. The realistic culprits are electrical noise from **surgical electrocautery** and **skeletal muscle potentials** from the chest wall; a device can also read a large T wave as a QRS.

The NBG Code, 2002 Revision

Position	The question it answers	Letters
I	Which chamber is paced ?	O, A, V, D
II	Which chamber is sensed ?	O, A, V, D
III	What is the response to sensing?	O, T, I, D
IV	Is there rate modulation ?	O, R

A is atrium, V is ventricle, D is dual meaning both, O is none. In position III, T is triggered, I is inhibited, D means both responses are available.

Read the letters as a sentence by inserting the word "but." Three letters become one plain English claim:

- **AAI:** paces the atrium, **but** if it senses the atrium, it inhibits.
- **VVI:** paces the ventricle, **but** if it senses the ventricle, it inhibits, so it stays silent until the patient's own rate falls below the programmed rate.
- **DDD:** paces both chambers, **but** if it senses either, it can inhibit or trigger. That dual response preserves AV synchrony.
- **VOO** and **DOO:** pace, sense nothing, respond to nothing. They fire on a fixed schedule regardless of the patient, which is why they are called **asynchronous**.

The O-means-blind trick. A device with **O in position II must have O in position III**, because you cannot respond to something you never sensed. That is why VOO and DOO carry two O's, and it is a free correctness check: O in position II with any other letter in position III is an error.

The Three Malfunctions, And The Order You Check Them In

Malfunction	What you see	Common causes
Failure to pace (failure to fire, output failure)	No spike where a spike should be	Battery depletion, fractured lead, loose connection, <i>or</i> oversensing
Failure to capture	A spike present with nothing behind it	Lead dislodgement, threshold risen above programmed output, exit block
Failure to sense (undersensing)	A spike delivered when it should not have been, often on top of the patient's own beat	Sensitivity set to too high a number, lead problem, low-amplitude intrinsic signal

Three points that circulate wrong. One: exit block is a capture problem, not a sensing problem. The impulse is delivered but cannot exit the electrode into the surrounding myocardium, so a spike appears and nothing follows. That is failure to capture by definition. Two well-known emergency medicine reference sites file exit block under undersensing, and that is a category error.

Two: oversensing and failure to pace are not competing answers. Failure to pace is the **finding** on the strip; oversensing is one of its **causes**, and a dead battery is another. The strip gives you the finding, only device interrogation gives you the reason. When a question asks what you see on the tracing, answer with the finding.

Three: undersensing can masquerade as failure to capture. An undersensed spike often lands in the **refractory period**, right after the patient's own beat, and refractory tissue cannot depolarize no matter how much energy arrives. You get a spike with nothing after it, which looks exactly like failure to capture. It is **functional non-capture**, and the lead is fine. So the first question about a bare spike is not "did it capture," it is "**did this spike arrive when capture was even possible?**" Assess sensing before capture.

PACER: How To Assess Any Paced Strip

The mnemonic spells the word you are already staring at.

- **P Pacing spikes** present, and appropriate for where they sit?
- **A Aware:** is the device sensing the patient's intrinsic beats?
- **C Capture:** does each spike produce a waveform immediately behind it?
- **E ECG:** does the rest of the tracing show anything else worth reporting?
- **R Rest of the patient:** pulse, blood pressure, symptoms, level of consciousness.

A comes before C on purpose: that is the sensing-before-capture rule built into the mnemonic, so running PACER in order keeps you out of the functional non-capture trap.

Electrical Versus Mechanical Capture: The Clinical Centre Of This Module

Electrical capture is a wide QRS following the spike on the monitor. **Mechanical capture** is the myocardium actually contracting, producing a pulse and perfusing the patient. They are different findings, and **electrical capture alone is not enough**. In one published prehospital case series of **23 patients** on transcutaneous pacing, all 23 had palpable pulses matching the paced rate, and **19 of them showed false electrical capture** on the tracing. Read that as one case series rather than a population rate, and read the lesson plainly: the tracing was the unreliable half of the assessment and the patient was the reliable half.

The recognition trick: look for a tall, broad T wave. True capture gives a wide QRS with a visible ST segment and a notched or broad T wave behind it. False capture gives narrow sharp deflections that snap back to baseline quickly, with no proper ST segment and no real T wave. The reasoning is physiology you already have: **a real depolarization must be followed by a repolarization**, so no T wave means nothing depolarized. The limit: T waves can be buried in artifact or flattened by other causes, so this is a strong rule of thumb, not a law.

Confirming mechanical capture:

- A **palpable pulse**, and prefer the **femoral** over the carotid. During transcutaneous pacing the carotid sits right beside the pads, and the twitching sternocleidomastoid manufactures a convincing false pulse under your fingers.
- A **rising blood pressure**, a **pulse oximetry plethysmograph waveform** (a mechanical signal rather than an electrical one), and improved **skin colour** and **level of consciousness**.
- **Bedside echocardiography**, where you directly watch the ventricle contract.

That last bullet is your program answering an ECG question. You are training in cardiovascular and diagnostic medical sonography. Bedside echo is not somebody else's skill borrowed for the day, it is the most direct answer to "is this heart actually contracting." Put a probe on a paced patient, watch the walls move with the spikes, and you have settled a question the monitor cannot. This module is where your ECG course and your scanning courses meet.

“But the patient perked up” is not proof. Repeated electrical stimulation is itself arousing and can raise blood pressure on its own, so a patient can look better and still not be perfusing. Improvement is encouraging; it is not confirmation.

Complications, And Where Your Job Ends

Device and procedure complications include **lead dislodgement, infection or hematoma** at the generator pocket, and **pneumothorax** at implantation. **Pacemaker syndrome** is different: fatigue, dizziness, shortness of breath, and neck fullness following the loss of AV synchrony when the ventricle is paced without a coordinated atrial contribution. That is the atrial kick from Chapter 1 going missing.

Electromagnetic interference, taught honestly. The classic classroom list of cell phones, store security gates, and electric fences belongs to the 1990s. Modern devices are shielded, and repeating that list trains students to worry about the wrong things. What matters clinically is **surgical electrocautery** and **skeletal muscle potentials** from the chest wall, which a very sensitive device can misread as cardiac activity.

Where your job ends. If a paced tracing looks wrong, describe it accurately and report it promptly to the nurse or physician. Do **not** tell the patient that something is wrong with their pacemaker. Only interrogation by a qualified person can determine what the device is doing, and a patient told their pacemaker is failing by someone who cannot yet know has been handed fear, not information.

Common Trap

A strip from a patient with a known pacemaker shows no spikes anywhere. Is the device malfunctioning?

Almost certainly not. If the patient’s own rate is above the programmed lower rate limit the device is inhibited and **no pacing is expected**, which is demand pacing working as designed. **A quiet pacemaker is usually a happy pacemaker.** A second consequence students miss: with no spikes you **cannot assess output failure or capture failure at all**, because both need a spike to evaluate. The honest report is that no pacing activity is present, not that the pacemaker failed. Three independent references say this explicitly, which tells you how often it is answered wrong.

Common Trap

Ventricular paced rhythm at 70, a spike in front of every wide QRS, 100 percent electrical capture, and no palpable pulse. What is this?

Electrical capture without mechanical capture, which is **pulseless electrical activity**. The screen shows a machine talking and a heart appearing to answer, but nothing is being pumped. Treat the patient: start CPR and look for the cause. **The monitor is not the patient.** That is why “check a pulse, not the monitor” is a standing rule in every code.

Before You Move On

You should now be able to:

- read a pacing spike and say which chamber is being paced
- explain capture, and say why electrical capture alone is not enough
- use the fence picture to explain undersensing, oversensing, and why a lower millivolt number means more sensitive
- explain why a paced ventricular beat is wide, using the same rule that explained the last four chapters

The next chapter widens the view from one lead to twelve, and from rhythm to the wall of muscle underneath it.