ACP Academy

ECG Basics

INTRODUCTION:

An electrocardiogram (ECG) is a quick, non-invasive test that records the heart's electrical activity over time. For clinicians working across primary care, urgent care, and secondary settings, ECG interpretation is a vital skill, not just for cardiac diagnoses, but for safe, real-time clinical decision making.

From palpitations to chest pain, collapse to breathlessness, ECGs often hold the key to timely, life-saving intervention. Whether it's recognising ST-elevation in an acute MI, spotting AF in a breathless elderly patient, or identifying red flags like broad QRS complexes or high-grade heart blocks, ECGs demand both attention to detail and clinical context.

This guide provides a structured, stepwise approach to ECG interpretation; demystifying rate, rhythm, axis, intervals, and waveform abnormalities. It's built for clinicians, focused on what matters most in practice; speed, clarity, safety, and confidence. Whether in an OSCE or real-world setting, we've got you covered.

ELECTRODE PLACEMENT: GETTING IT RIGHT FROM THE START

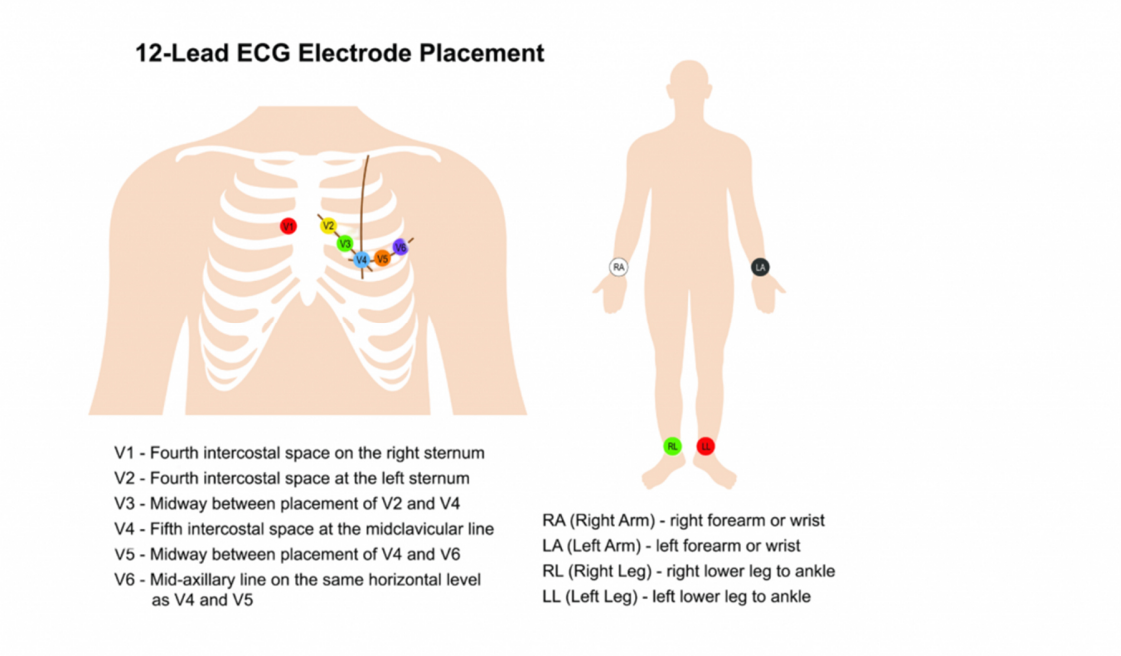
Correct placement of ECG electrodes is essential for accurate interpretation. A standard 12-lead ECG uses 10 physical electrodes:

- **4 limb electrodes**: Right arm (RA), left arm (LA), right leg (RL – neutral/ground), and left leg (LL)
- **6 chest (precordial) electrodes**: V1 to V6, placed across the anterior chest wall

Chest leads are positioned as follows:

- **V1**: 4th intercostal space, right sternal edge
- **V2**: 4th intercostal space, left sternal edge
- **V3**: Midway between V2 and V4

- **V4**: 5th intercostal space, midclavicular line
- **V5**: Horizontal with V4, anterior axillary line
- **V6**: Horizontal with V4/V5, mid-axillary line



Incorrect lead placement can significantly distort the ECG trace. It may falsely alter the height and morphology of waves, leading to missed or overcalled diagnoses — especially in suspected myocardial infarction. In practice, if ST elevation appears muted or absent due to poor lead placement, PPCI-capable hospitals may refuse urgent transfers, delaying time-critical reperfusion.

Ensure electrodes are placed on clean, dry skin — avoiding bony areas or excessive hair. A well-positioned ECG not only improves diagnostic accuracy but also instils confidence in your clinical handover and supports faster, safer patient care.

LEADS AND THEIR VIEWS: DIFFERENT CAMERA, SAME HEART

Think of each ECG lead like a camera lens, each one aimed at a specific region of the heart. When you record a 12-lead ECG, you're capturing 12 different angles of the same cardiac event, like "Bullet Time" from The Matrix. Each lead provides unique insight into electrical activity through its “viewpoint,” helping to localise pathology like ischaemia

or infarction.
The leads are grouped based on which part of the heart they visualise:

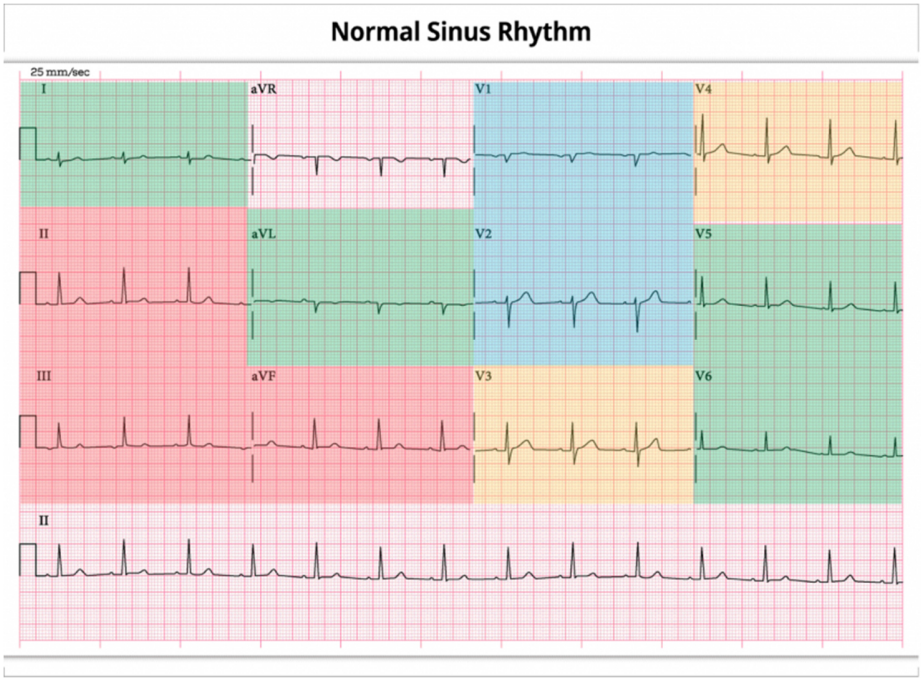
Septal leads (V1, V2 / Blue): These peer through the sternum at the interventricular septum.

Inferior leads (II, III, aVF / Red): These look up from below, viewing the inferior wall of the left ventricle, typically supplied by the right coronary artery.

Lateral leads (I, aVL, V5, V6 / Green): These face the left side of the heart, capturing the lateral wall — often reflecting changes in the circumflex artery territory.

Anterior leads (V3, V4 /Yellow): These take a front-on view of the heart, looking directly at the anterior wall, typically supplied by the left anterior descending (LAD) artery.

(Note that the colours on the diagram do not correlate with the colours of the ECG leads).



Each lead records the electrical impulse as it moves toward or away from the electrode. If the current travels toward a lead, you get a positive deflection, if it travels away, you get a negative one. That's why understanding lead orientation is key to interpreting abnormalities like ST-elevation, T wave inversion, or pathological Q waves. Misinterpretation often stems from not appreciating what each lead is "watching." For

instance, ST-elevation in II, III, and aVF, but nowhere else, tells you the issue is inferior and not global. Add reciprocal changes, and your case for an MI strengthens.

Mastering lead localisation refines your differential diagnosis, elevates your confidence, and can fast-track time-critical decisions, especially in pre-hospital or acute settings where “time is myocardium.”

MAKING WAVES: THE CARDIAC CYCLE

The ECG trace is a dynamic map of how electricity flows through the heart’s muscle tissue. Whether a waveform points **up (positive)** or **down (negative)** depends on whether the electrical activity is moving **towards or away** from the lead in question. Think of it like standing at the end of a tunnel: if a train (current) comes toward you, the headlights shine bright (positive deflection); if it moves away, it fades into the distance (negative deflection).

Let’s walk through the cardiac cycle:

P Wave – Atrial Depolarisation

The P wave represents the electrical spark from the sinoatrial (SA) node; the heart’s natural pacemaker, travelling across both atria. The impulse moves from top to bottom and right to left, which is toward leads such as II, causing a small positive deflection.

This is like flicking on the hallway lights before entering a room. You're preparing the chambers for action.

PR Interval – A Pause for Ventricular Prep

After the atria contract, the impulse slows briefly at the atrioventricular (AV) node, which gives the ventricles time to fill with blood. This delay forms the flat PR segment, sitting on the baseline. No muscle depolarisation happens here, it’s an electrical pause.

Meanwhile, the current races down the **Bundle of His**, splits into the **right and left bundle branches**, and travels rapidly through the **Purkinje fibres** like wiring across a scaffold, reaching the far corners of the ventricles in milliseconds.

QRS Complex – Ventricular Depolarisation

Now comes the action.

Q wave: A small initial downward deflection, the septum depolarises left to right, away from lead II.

R wave: The main upward spike. The large left ventricle depolarises toward the recording lead, causing a big positive deflection.

S wave: A small downward deflection as the final parts of the ventricle depolarise away from the lead.
Altogether, this is the ventricles saying "Go!", firing together like two pistons to generate contraction.

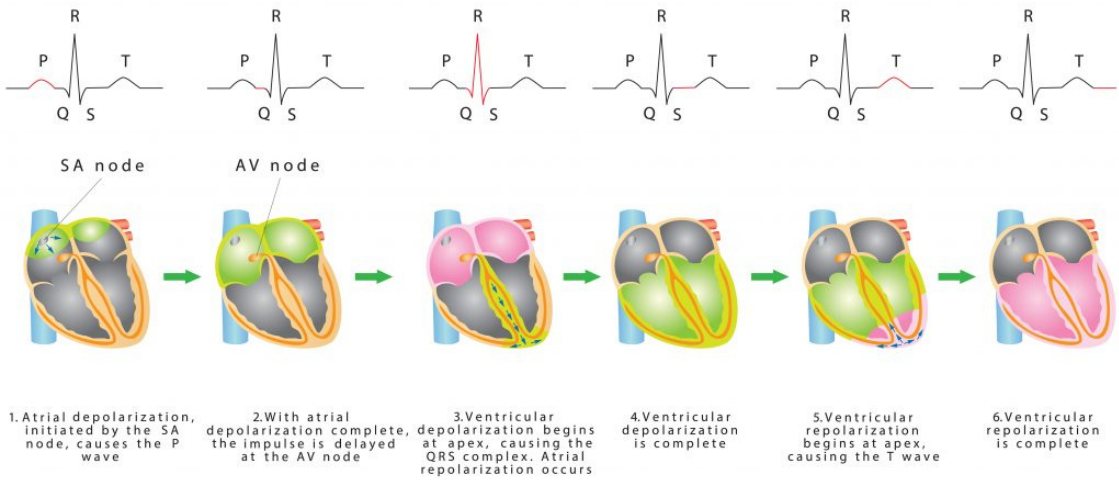
ST Segment – The Silent Phase

After contraction, there's a pause while the ventricles remain fully depolarised. This is the ST segment, again resting on the baseline. No net electrical movement means no deflection. It's electrically silent, like holding your breath between two waves.

T Wave – Ventricular Repolarisation

Finally, the ventricles repolarise, reset and recharge. Strangely, the current flows opposite to depolarisation, but because it moves away from the lead, and it's a reverse charge, the T wave ends up positive in most leads. It's like running backwards up a hill and still arriving at the top.

Together, the P-QRS-T complex shows the heart's electrical choreography. If the pattern or polarity shifts, something's disrupted, from electrolyte imbalance to infarction.



THE CARDIAC CYCLE

THE CARDIAC AXIS

Think of the heart's electrical activity like a flock of birds in flight. While each bird (myocyte) flaps in its own rhythm, the flock moves in a general direction. This is your cardiac axis: the average direction of depolarisation through the ventricles.

On a healthy ECG, the axis should lie between –30° and +90°, pointing down and slightly left, the path of least resistance through the muscular left ventricle. Most of the depolarisation heads that way, so leads like I and aVF catch a strong signal.

But if the flock veers off course?

- Left Axis Deviation (LAD) means the electrical flow is swinging more leftward (–30° to –90°). Common causes include left anterior hemiblock or inferior myocardial infarction, both of which block or damage parts of the usual route.
- Right Axis Deviation (RAD) pushes the axis beyond +90°, indicating right-sided strain. This is seen in pulmonary embolism, chronic lung disease, or right ventricular hypertrophy.

Axis deviation isn't a diagnosis, it's a directional clue. Like a compass needle twitching in a storm, it tells you something's not right in the terrain. And in ECG interpretation, it's often your first nudge toward a bigger story.

Axis Tips: Are They Leaving or Returning?

One of the quickest ways to assess cardiac axis is to look at **leads I and III** and use a bit of wordplay to help lock it in.

- If **lead I is positive** (the QRS points upwards) and **lead III is negative** (the QRS points downward), the electrical activity is moving **away from lead III** and toward the left. Think:
  → **"They're Leaving"** → **L** for **Left Axis Deviation**.
  This suggests the heart's electrical axis is shifted left often due to left anterior hemiblock, left ventricular hypertrophy, or an old inferior MI.
- If **lead I is negative** and **lead III is positive**, the axis is drifting rightward. The QRS is moving away from lead I, and coming back toward lead III. Think:
  → **"They're Returning"** → **R** for **Right Axis Deviation**.
  This could reflect right ventricular strain, a PE, or right ventricular hypertrophy.

This “Leaving vs Returning” mnemonic gives you a rapid visual clue without needing to calculate angles. A clinically handy trick when time (or brainpower!) is limited. Remember though: for precision, use leads I and aVF, but for speed, **I and III never lie.**

	Normal Axis 0 to 90	Left Axis Physiological 0 to -30	Left Axis Pathological -30 to -90	Right Axis 90 to 180	Extreme Axis -90 to -180	Indeterminate Axis ?
Lead I						
Lead II						
Lead III						

RHYTHM STRIP ANALYSIS: A STRUCTURED STORY

When faced with a rhythm strip, treat it like a mystery and follow your evidence-based trail. A structured approach is your best ally in separating the benign from the deadly.

Rhythm - It's called a "Rhythm strip", so start by asking: Is the rhythm regular or irregular? Regular rhythms keep time like a metronome. Irregular ones wobble, sometimes predictably (as in heart block), other times chaotically (think atrial fibrillation).

Rate - What's the heart rate? If the rhythm's regular, count the number of large squares between R waves and divide 300 by that number. For example, 4 large squares = 75 bpm.

P-Waves - Are there P waves before every QRS? This tells you if the atria are leading the charge. In sinus rhythm, the SA node fires first, so you'll see a visible P wave before every QRS. But if P waves are absent, don't jump straight to AF... If the rhythm is regular and P waves are hidden or inverted, consider a junctional rhythm. The AV node may be pacing the heart, and P waves might be retrograde, lost in or after the QRS.

P-R Interval (The Love Story) - A normal range is 120–200 ms (3–5 small squares). And this is where it gets interesting, especially with heart blocks.

In **First Degree** (**Type 1) AV block**, the PR interval **gradually lengthens** until a beat is dropped, then the cycle repeats. It's affectionately known as the **"auctioneer's rhythm"**: the P wave calls, the QRS shows up later... and later... and then suddenly doesn't show up at all — *"Going... going... gone!"*
Or think of it as a dysfunctional couple. The P wave is the reliable partner. The QRS is increasingly late, until, one night, they just don't come home.

In **Type 2 AV block (2:1 pattern)**, the P wave and QRS are drifting apart. Only every second P wave gets a response. It's an on/off relationship, half the time, QRS isn't picking up the phone.

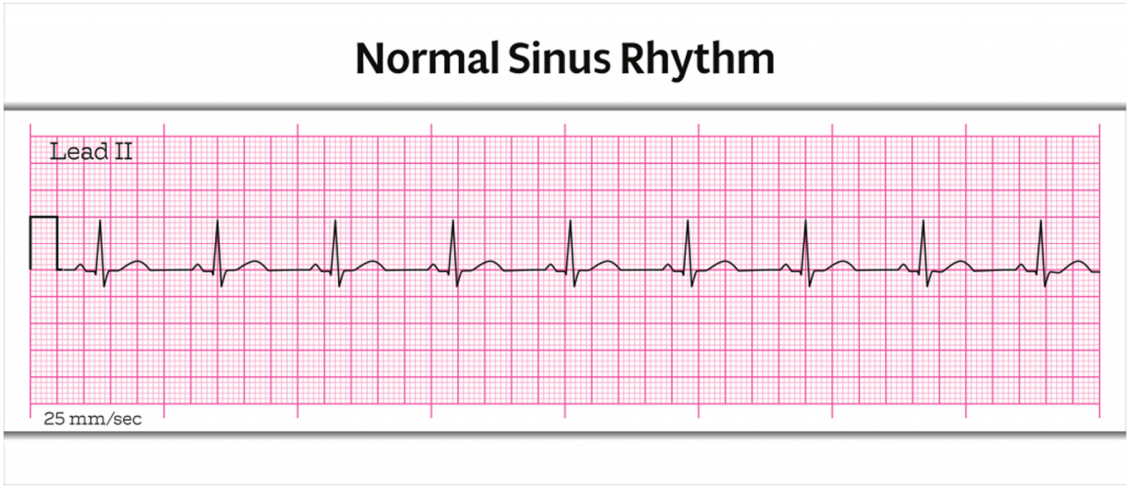
In **Type 2 AV block (2:2 pattern)**, the P wave is consistent and dependable. But the QRS replies inconsistently, vanishing unpredictably, like a partner who ghosts you for no clear reason.

In **Type 3 AV block (complete heart block)**, the couple has broken up entirely. The P wave and QRS complex are still living in the same house, but they're not speaking. Each is on their own schedule. The atria and ventricles are depolarising independently - Complete AV dissociation.

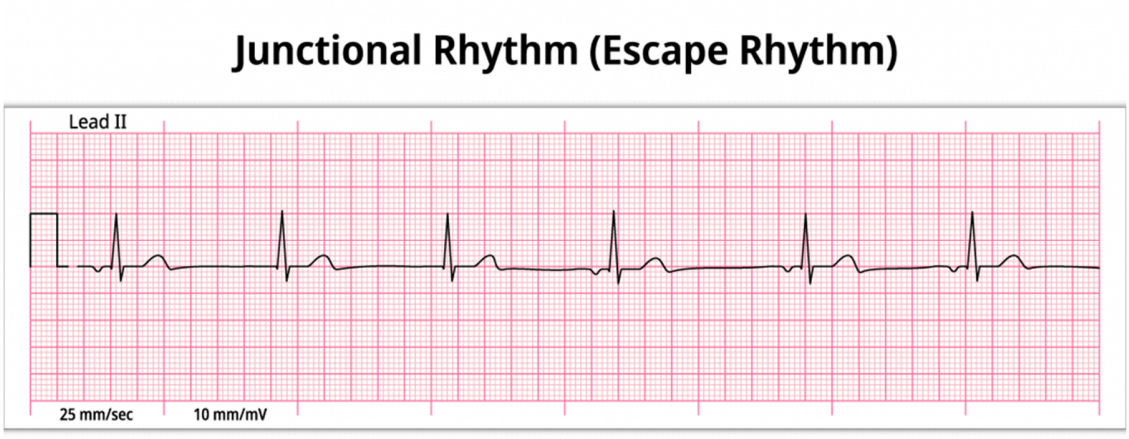
QRS Width. Narrow QRS complexes (<120 ms) suggest normal, swift conduction through the His–Purkinje system. Broad complexes may arise from ventricular origin or delayed conduction, a **red flag for VT or a bundle branch block**.
Finally, name the rhythm.

COMMON RHYTHMS TO IDENTIFY:

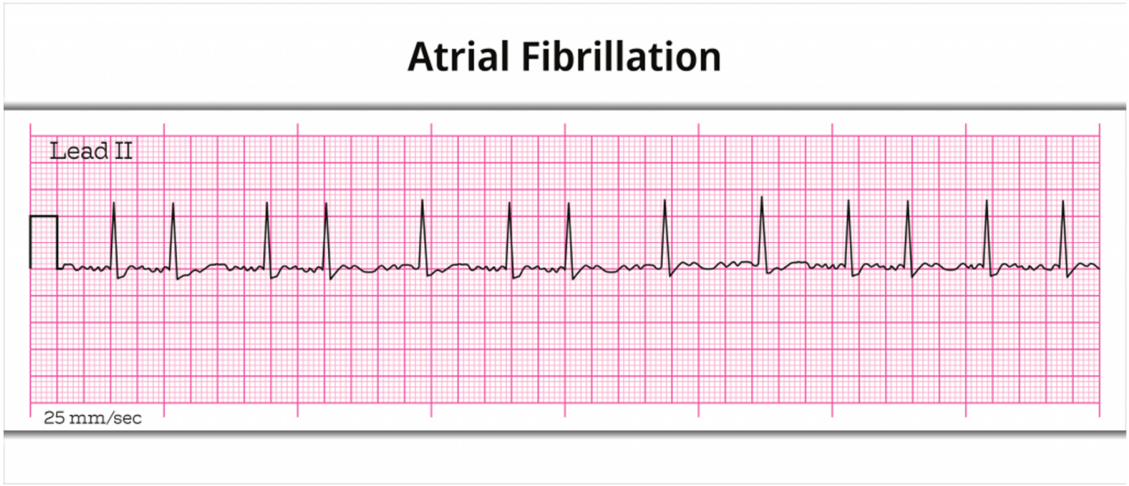
Sinus Rhythm: P before every QRS, regular, normal intervals, a well-rehearsed routine.



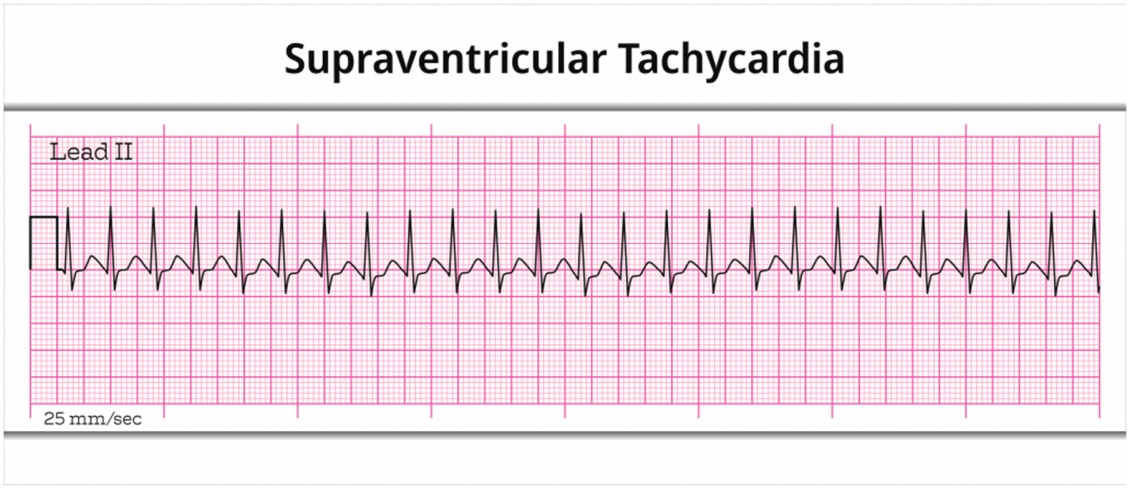
Junctional Rhythm: Regular rhythm with absent or inverted P waves, often buried in or following the QRS. Like a quiet understudy stepping in when the lead doesn't show, keeping the show going from backstage.



Atrial Fibrillation: Irregularly irregular, no P waves, chaotic baseline. Like a jazz band with no conductor.

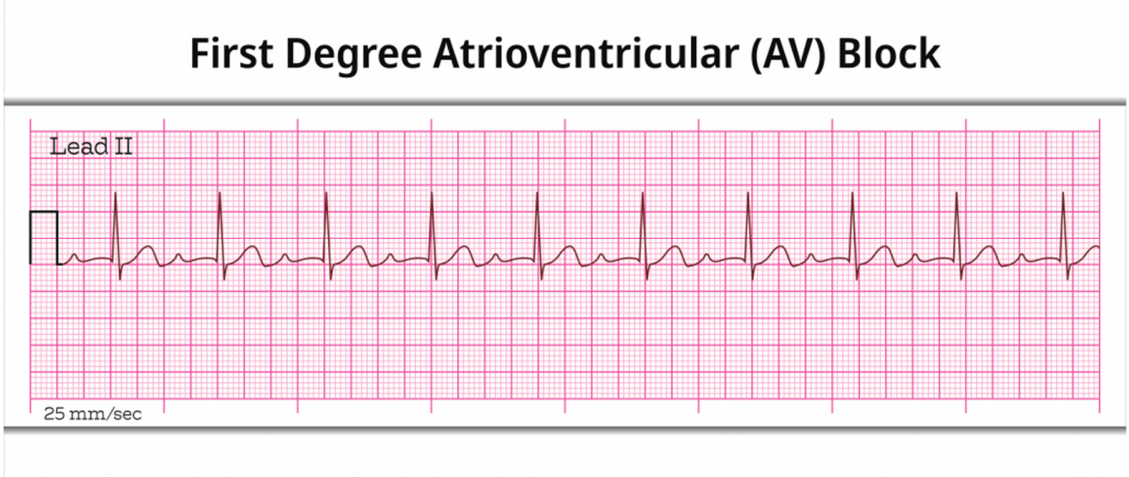


SVT: Fast, regular, narrow. P waves may be hidden. A rapid trick from above the ventricles.

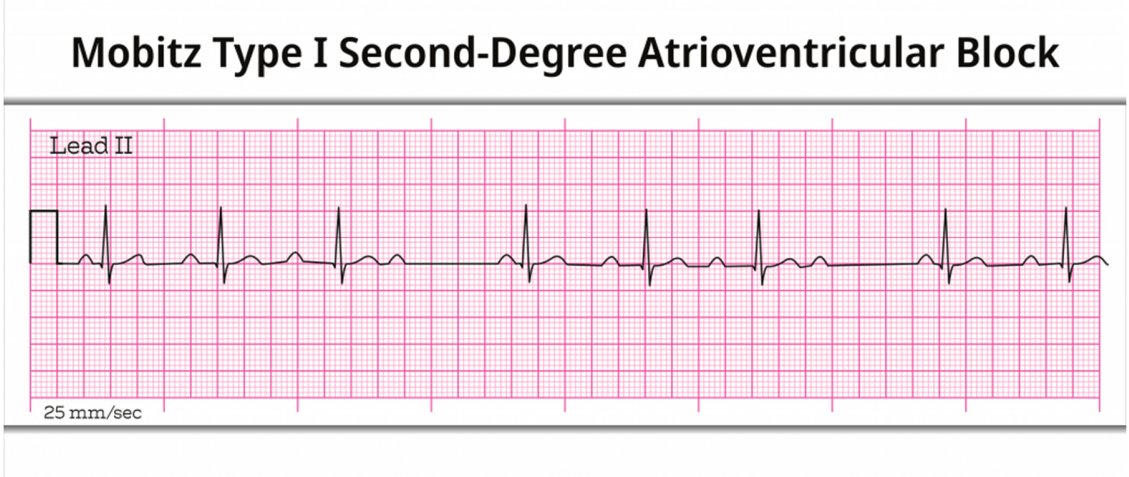


AV Blocks: (The Dysfunctional Couple)

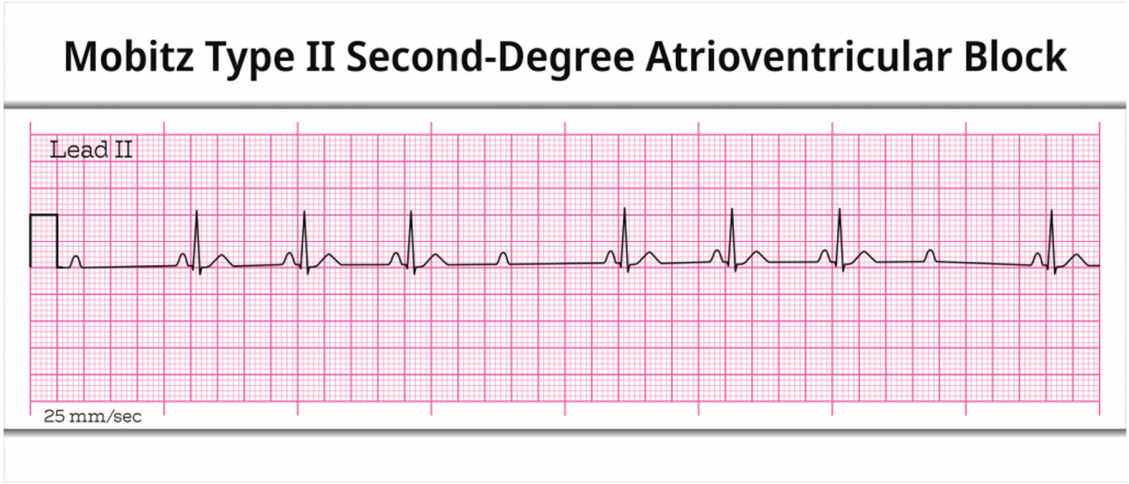
Type 1 AV Block: The P wave is the reliable partner. The QRS is increasingly late, until, one night, they just don't come home.



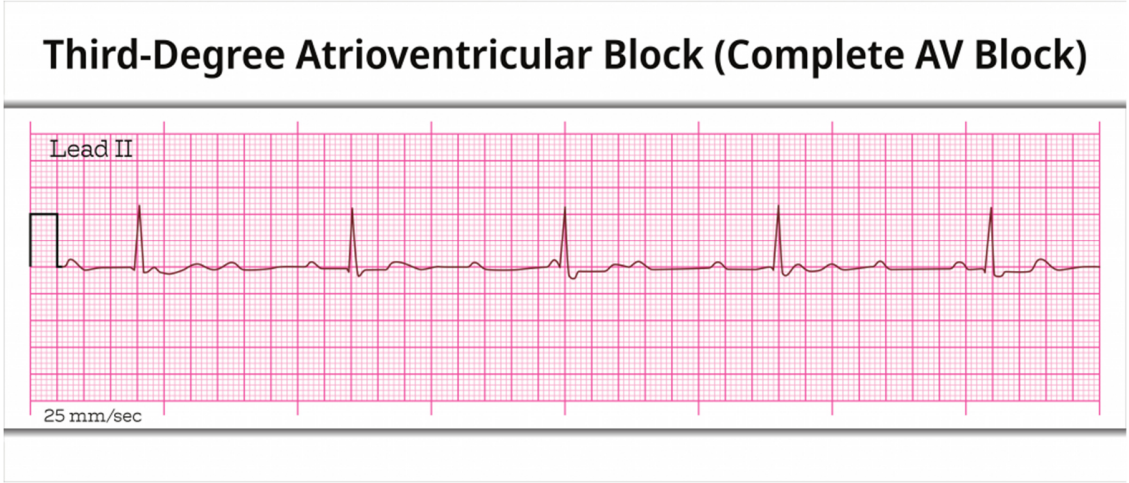
Type 2-1st Degree AV block (2:1 pattern), the P wave and QRS are drifting apart. Only every second P wave gets a response. It's an on/off relationship, half the time, QRS isn't picking up the phone.



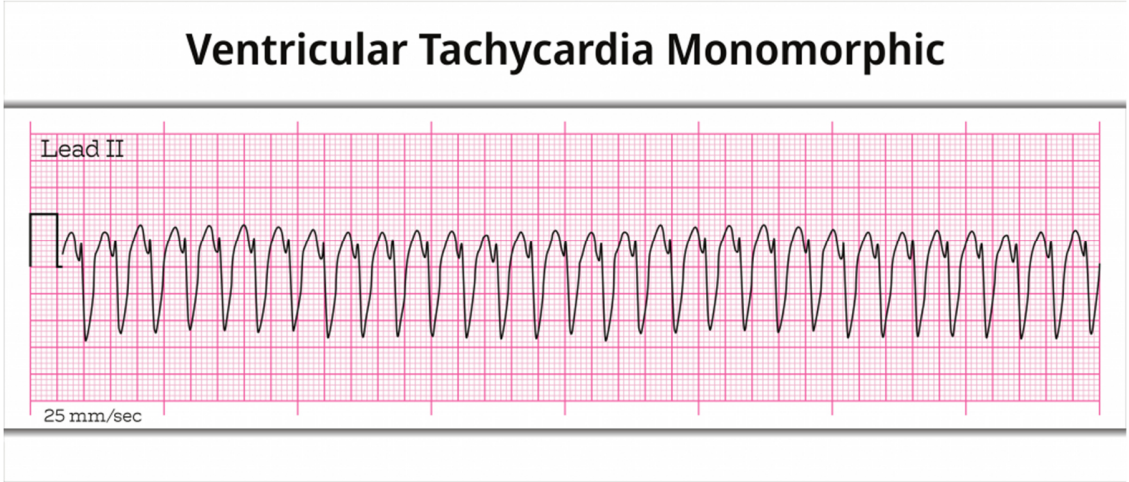
Type 2-2nd Degree AV block (2:2 pattern), the P wave is consistent and dependable. But the QRS replies inconsistently, vanishing unpredictably, like a partner who ghosts you for no clear reason.



Type 3 AV block (complete heart block), the couple has broken up entirely. The P wave and QRS complex are still living in the same house, but they're not speaking. Each is on their own schedule.



Ventricular Tachycardia: Broad, fast and regular. A dangerous solo act from the ventricles. Stand by with a defibrillator!

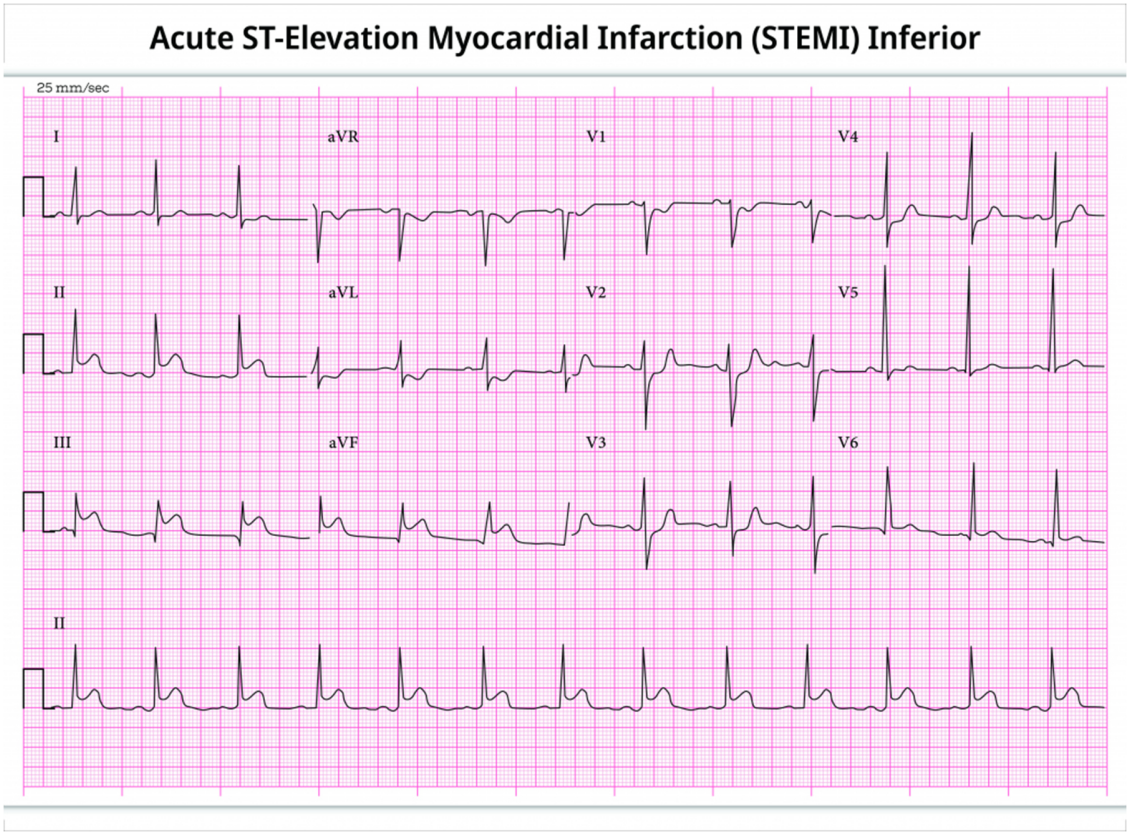


ECG RED FLAGS

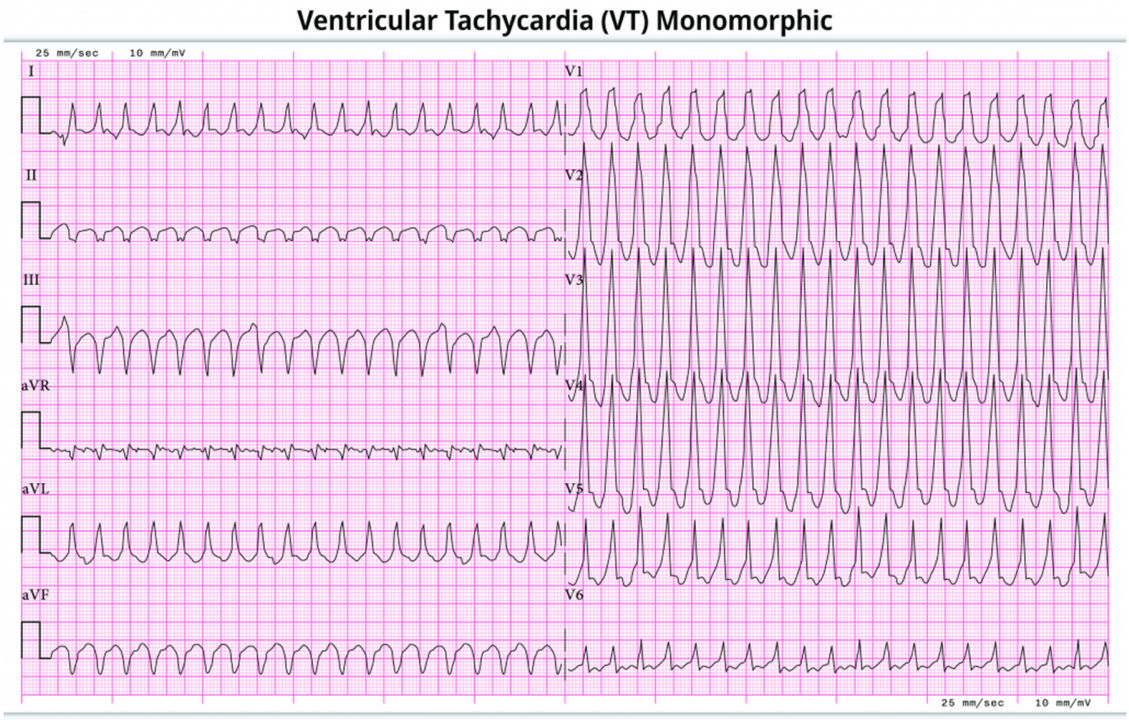
While many ECGs present subtle, benign patterns, others wave bright red flags. Signals that demand immediate attention. Recognising these is critical to safeguarding your patient.

ST elevation in two or more contiguous leads is a hallmark of **ST-Elevation Myocardial Infarction (STEMI)**. These aren't just squiggly lines, they're a heart muscle crying out for oxygen. If you see it, don't wait for a troponin! Activate the PPCI pathway. Remember: time is myocardium.

Note the ST-Elevation in Leads II, III and aVF (Inferior Leads)

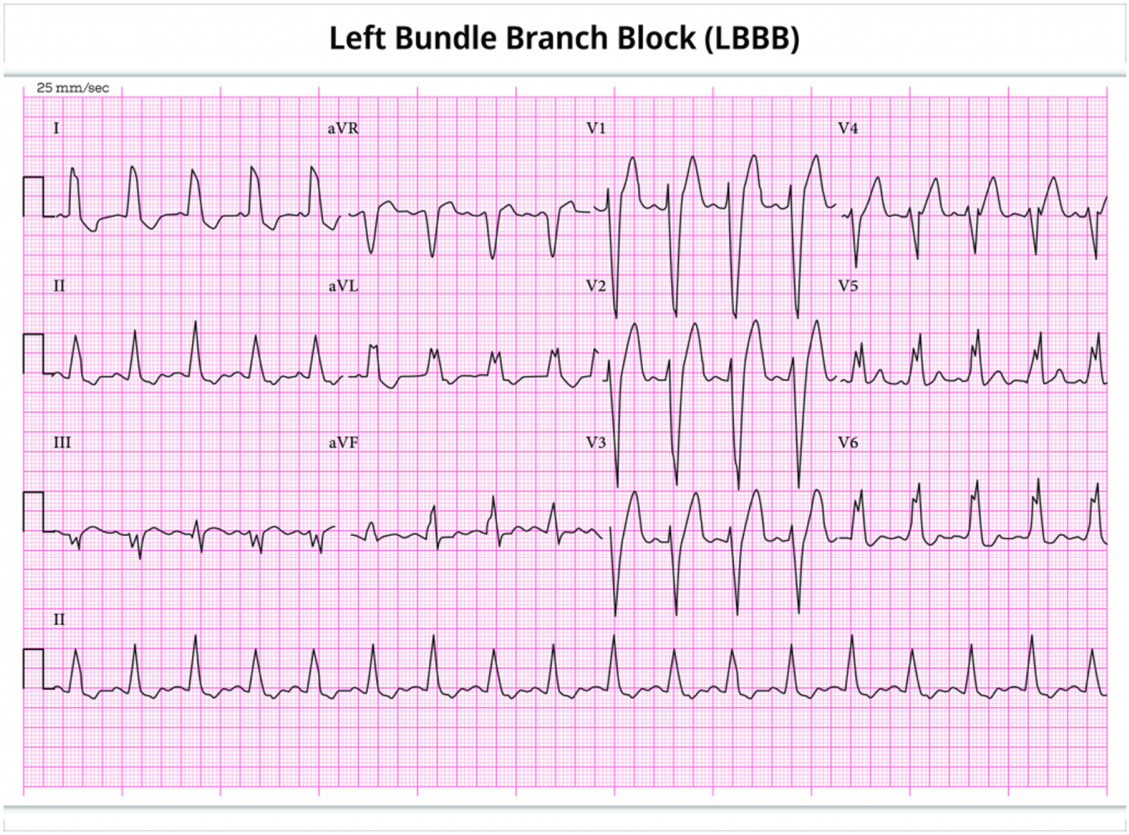


A **broad complex tachycardia** is **ventricular tachycardia** until proven otherwise. It may look organised, but it's dangerous, especially if the patient is hypotensive or showing signs of poor perfusion. If unsure, treat as VT. Better to err on the side of caution than miss a potentially fatal rhythm.



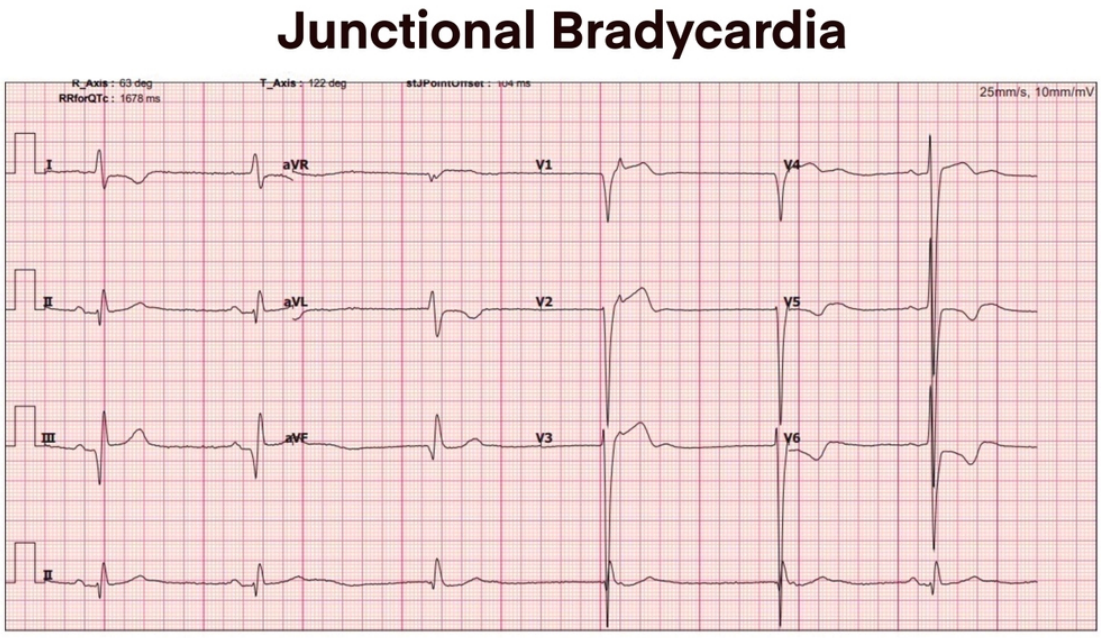
A **new left bundle branch block (LBBB)** with chest pain is a **STEMI equivalent**.
The LBBB may mask ST elevation and that's the danger.
If unsure, remember **WiLLiaM MoRRoW**:

In **R**ight **BBB**, you'll see an **M in V1** and a **W in V6** – MoRRoW.
In **L**eft **BBB**, look in **V1** and **V6**: you'll see a **W shape in V1** and an **M shape in V6** – WiLLiaM.

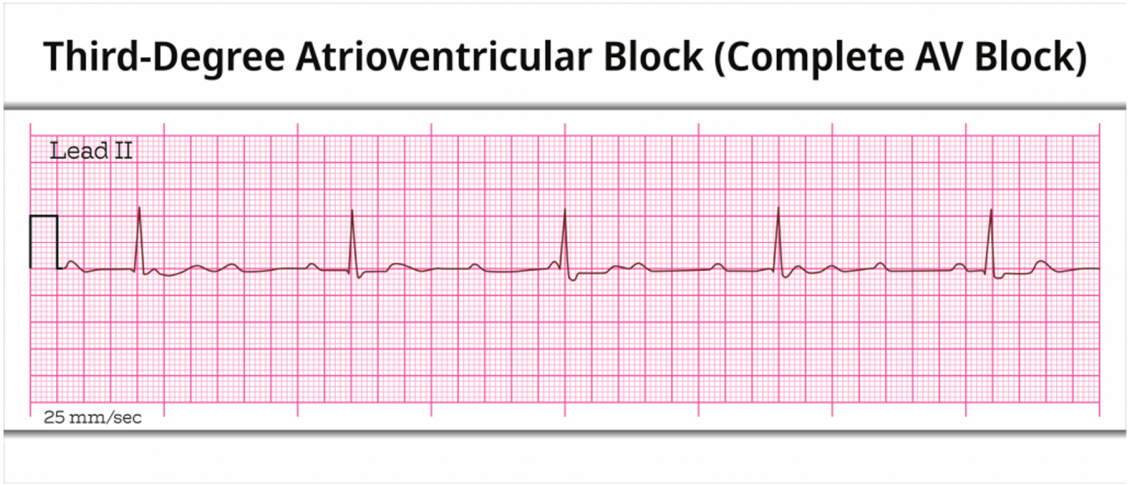


Bradycardia under 40 bpm with **syncope**, dizziness or hypotension may be a sign of **high-grade heart block**. Whether due to complete AV dissociation or sinus node dysfunction, the heart rate is too slow to sustain cerebral or coronary perfusion. Action is needed fast.

Remember to divide 300 by the number of big squares between the R-R to calculate the rate. What is the rate in the ECG below?

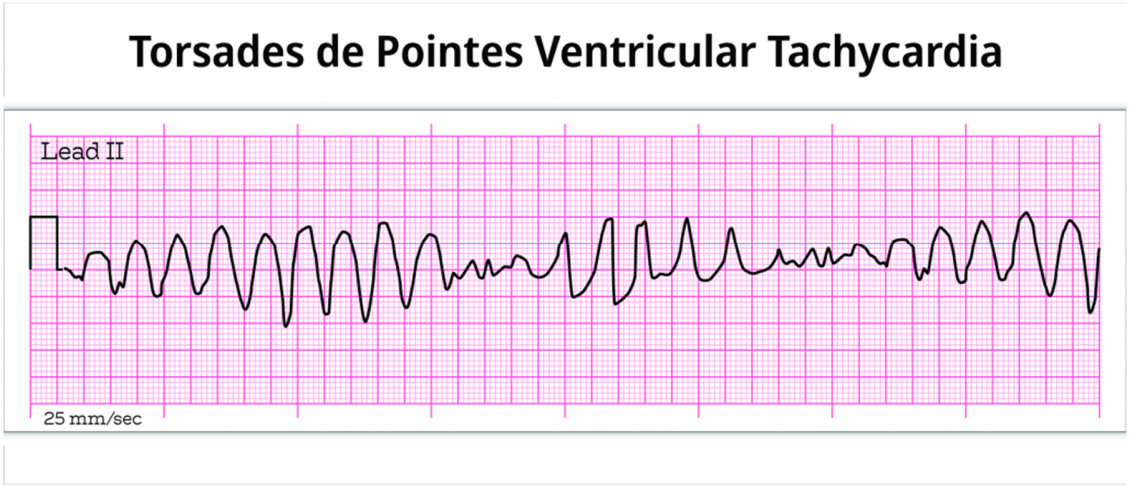


A **complete (3rd degree) heart block**? The atria and ventricles are working on entirely different schedules. There's no coordination, and output can drop dangerously. These patients often need pacing, temporary or permanent.



And don't forget the **QTc interval**. Anything over **500 ms** significantly raises the risk of **torsades de pointes** - a twisting, polymorphic VT that can deteriorate into

cardiac arrest. Drugs, hypokalaemia, hypomagnesaemia… know your culprits and correct them.



Red flags aren't subtle. See one? Act. Reassure later.

CONCLUSION: MAKING SENSE OF THE RHYTHM OF LIFE

Interpreting ECGs isn't about memorising patterns, it's about understanding what the heart is trying to tell you. Every P wave, every QRS, every subtle deviation is a clue. As clinicians, our role is to translate those electrical signals into safe, timely, and effective care.

You've explored the fundamentals, from electrode placement to axis, waveform to rhythm strip. You've learned to spot red flags that can't wait, and how to unravel complex rhythms using structure, analogies, and confidence. Whether it's a jazz-band atrial fibrillation, a soloing ventricle in VT, or a dysfunctional couple in heart block, ECGs are never just lines, they're stories waiting to be read.

Mastery comes not from rushing to diagnose, but from developing rhythm in your own approach. Be methodical. Be curious. And never ignore what doesn't quite fit.

So, whether you're on the wards, in primary care, working under pressure in resus or in a patient's living room at 3º'clock in the morning, keep the basics strong, the red flags sharp, and the patient at the centre.

Your stethoscope listens to the beat. Your ECG tells the full story.

You're ready to read it, so Read away, and Lead the way... You've got this!