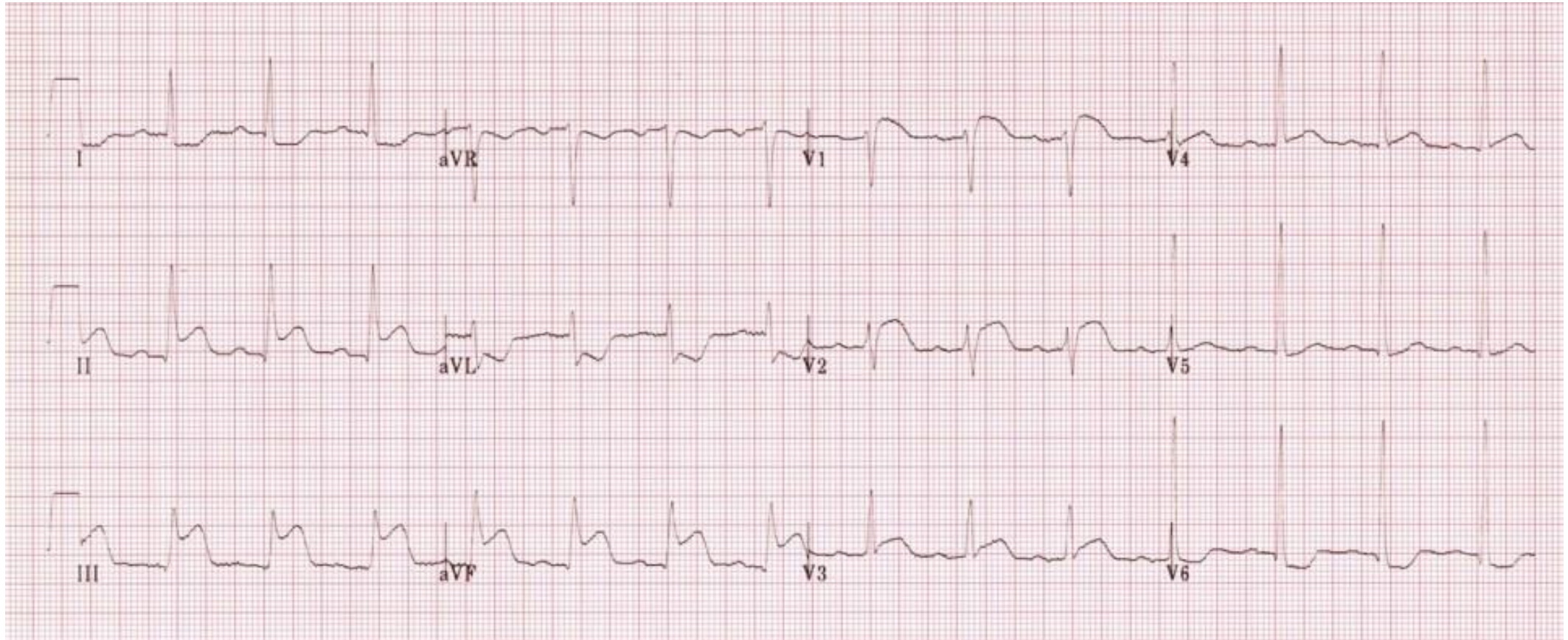


Case 1

Middle-aged patient presenting with chest pain and diaphoresis.

BP dropped to 80/50 following sublingual nitrates.



General:

Sinus rhythm, rate 84bpm.

Normal axis.

Borderline 1st degree AV block (PR 220ms).

Signs of inferior STEMI:

STE in inferior leads II, III, aVF.

Reciprocal STD in lateral leads I, aVL, V6.

Signs of associated right ventricular infarction:

STE in III > II.

STE in V1-2.

This patient also had STE in V4R, confirming the diagnosis of RV infarction:

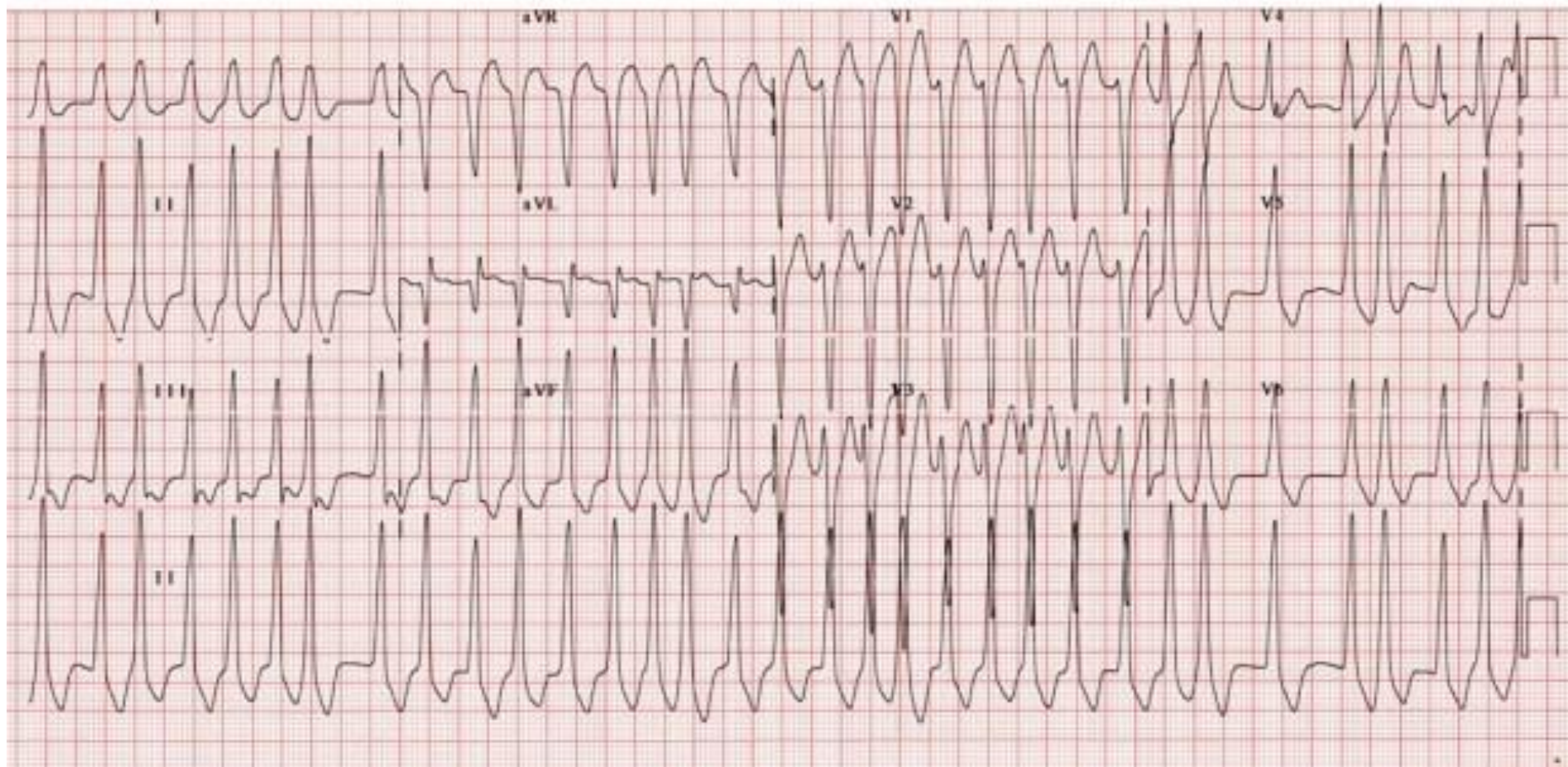
Clinical Pearls

RV infarction typically occurs in the context of inferior STEMI due to RCA occlusion.

These patients are preload sensitive and may have an exaggerated hypotensive response to nitrates.

Case 2

20-year old female presenting with palpitations and presyncope, BP
75/50. Describe her ECG.



Main Abnormalities: •

Irregularly irregular broad complex tachycardia.

Extremely [rapid ventricular rates](#) — up to 300 bpm in places (RR intervals as short as 200ms or 1 large square).

Beat-to-beat variability in the QRS morphology, with subtle variation in QRS width.

Explanation of ECG Findings:

Irregularly irregular rhythm is consistent with [atrial fibrillation](#).

There is a [left bundle branch block](#) morphology to the QRS complexes.

However, the ventricular rate is far too rapid for this to be simply AF with LBBB.

The rates of 250-300 bpm and the variability in QRS complex morphology indicate the existence of an [accessory pathway](#) between the atria and ventricles.

Diagnosis:

These findings indicate [atrial fibrillation](#) in the context of [Wolff-Parkinson-White syndrome](#).

Clinical Pearls:

Broad complex irregular tachycardia at very rapid rates? -> Suspect AF with WPW!

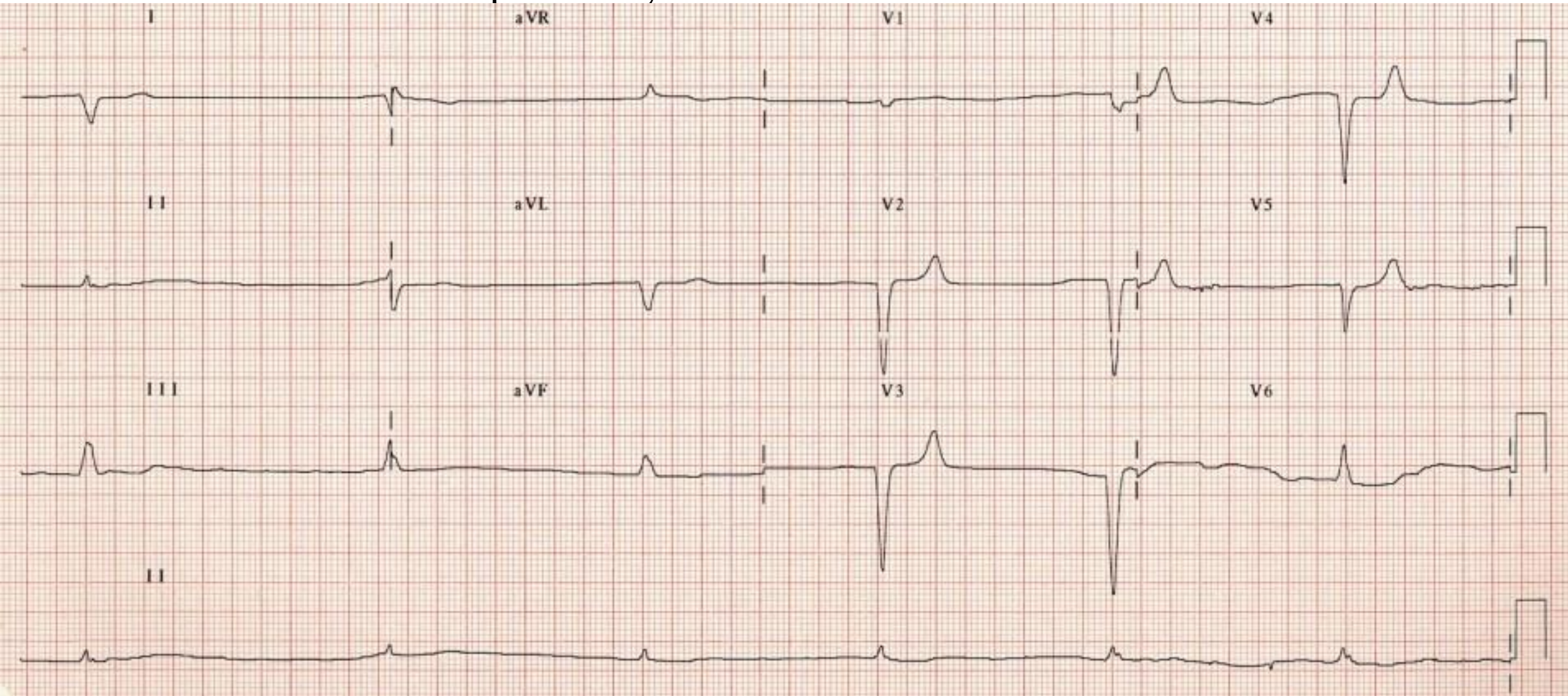
These patients can rapidly become haemodynamically unstable.

The options for chemical cardioversion are very limited, favouring DC cardioversion.

I would recommend immediate DC cardioversion in this patient. My approach would be to fluid load (0.5 – 1L crystalloid bolus), add in a push-dose pressor to elevate the BP (e.g. metaraminol 0.5 – 1mg IV) sedate with something that has minimal effects on BP (e.g. fentanyl or ketamine in cautious doses), and then shock at 200j biphasic. Consider using an AP pad position for maximal 1st shock success.

Case 3

Middle-aged diabetic patient presenting with shortness of breath. Clinical evidence of pulmonary oedema. Describe the ECG



Main Abnormal Findings

- [Severe bradycardia](#) of 36 bpm.
- Rhythm is difficult to ascertain — appears irregular (?slow AF) although there are some small-voltage P waves seen in V1-2.
- Broad QRS complexes with an [atypical LBBB morphology](#).
- Subtle symmetrical peaking (“tenting”) of the T waves in V2-5.

Diagnosis

- The combination of bradycardia, flattening and loss of P waves, QRS broadening and T wave abnormalities is highly suspicious for severe [hyperkalaemia](#). This patient had a potassium of 8.0 in the context of anuric renal failure.

Clinical Pearls : When you see the combination of...

- Bradycardia
- Blocks — e.g. AV block, bundle branch blocks
- Bizarre QRS complexes

.... think [hyperkalaemia](#)!

Case 4

20 year old male presenting with seizures. BP 80/50. Describe the ECG.



Main Abnormalities

- Broad complex tachycardia, rate ~ 130 bpm.
- The rhythm is likely sinus tachycardia with a [1st degree AV block](#) — note the [“camel hump”](#) appearance to the T waves indicating a hidden P wave.
- [Interventricular conduction delay](#) (QRS duration > 100ms, not typical LBBB / RBBB morphology)
- [Right axis deviation](#).
- Secondary R' wave in aVR > 3 mm.

Diagnosis

- In the context of a patient presenting with seizures and hypotension, the combination of...
- QRS broadening > 100 ms
- R' wave in aVR > 3 mm
- ... is highly suggestive of poisoning with a [sodium-channel blocking agent](#) — e.g. tricyclic antidepressant.
- The sinus tachycardia may be due to the [anticholinergic](#) effects of the TCA.

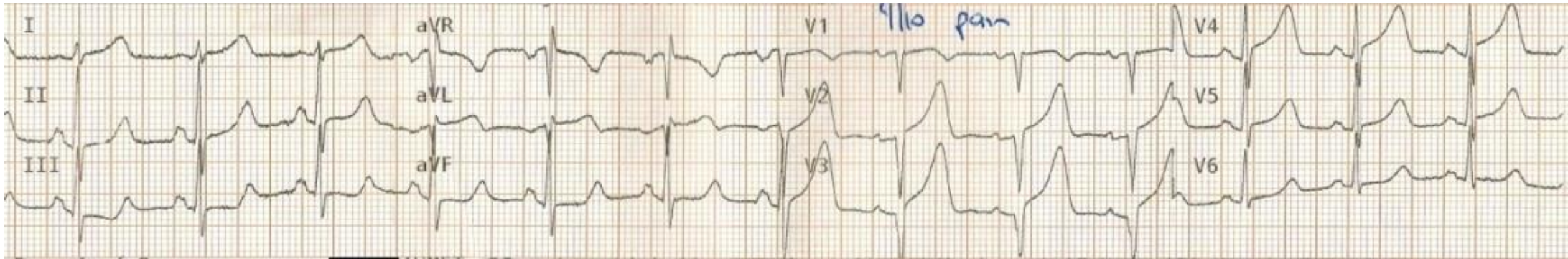
Clinical Pearls

- In the context of sodium channel blockade:
- A QRS duration > 100 ms is predictive of seizures.
- A QRS duration > 160 ms is predictive of cardiotoxicity.
- This patient is already manifesting life-threatening toxicity and needs aggressive resuscitation, including:
- Serum alkalinisation with NaHCO₃ to reverse pH-dependent toxicity.
- Intubation and hyperventilation aiming for alkaline arterial pH (e.g. 7.45 to 7.55).
- Seizure management with benzodiazepines.
- BP management with fluid boluses +/- pressors.

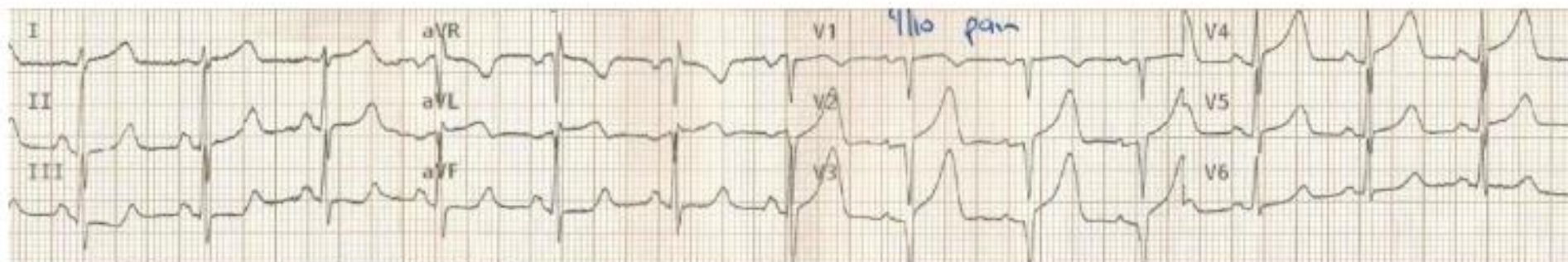
Case 5

This following sequence of ECGs is taken from a middle-aged patient presenting with chest pain and diaphoresis. Can you interpret each ECG tracing in the context of the patient's symptoms?

ECG 5a – Chest pain and diaphoresis (time = zero)



ECG 5a – Chest pain and diaphoresis (time = zero)



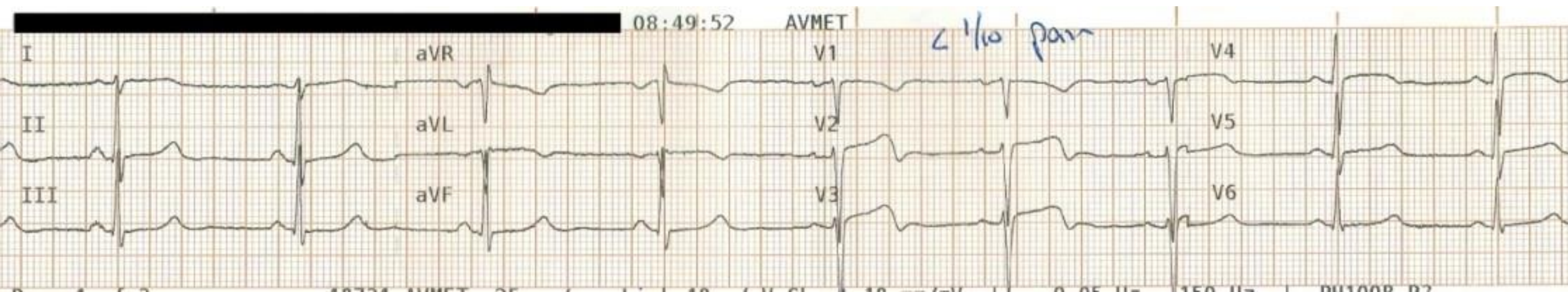
Reveal Answer

This ECG demonstrates an **anterolateral STEMI**

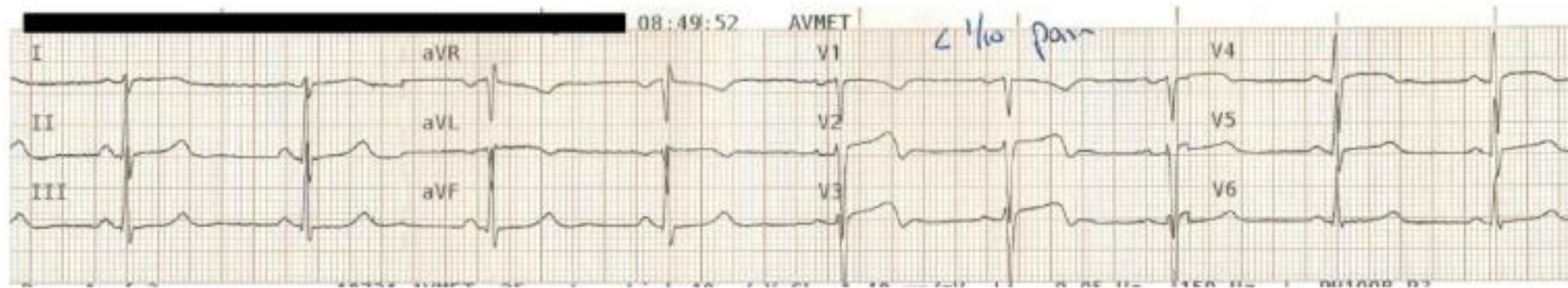
- ST elevation in V2-6, I and aVL
- Reciprocal ST depression in III and aVF
- Pathological Q waves in V2-3
- Hyperacute T waves in V2-4

This pattern of changes is consistent with acute occlusion of the **left anterior descending artery**.

ECG 5b – Resolution of chest pain (t+20 mins)



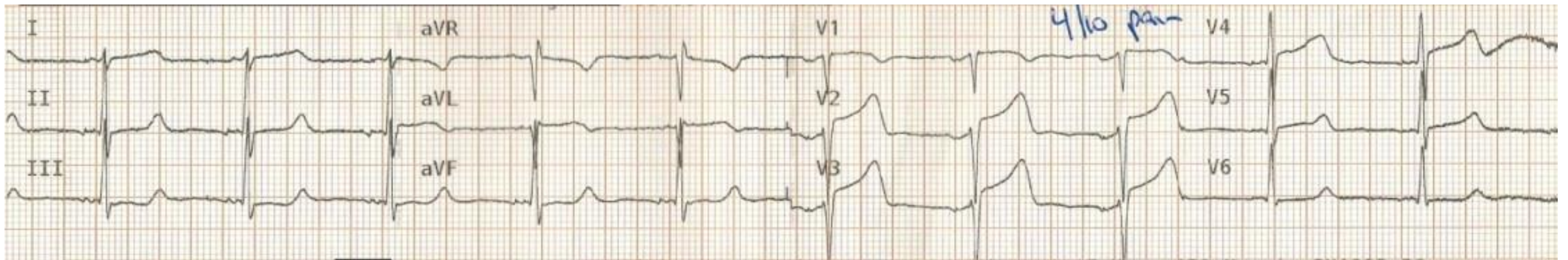
ECG 5b – Resolution of chest pain (t+20 mins)



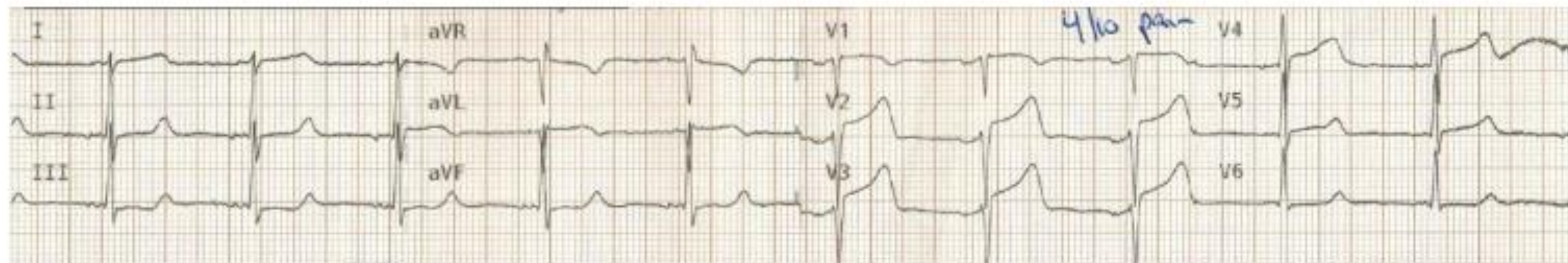
Reveal Answer

- There is transient improvement in the ST changes, with development of biphasic T waves in V2-3.
- This pattern of T wave changes in V2-3 is known as **Wellens' syndrome** and indicates *reperfusion* of a previously occluded LAD artery.
- The implication of this ECG pattern is that there is an underlying critical LAD stenosis that needs urgent intervention with angiography +/- stenting or CABG.

ECG 5c – Recurrence of chest pain (t+25 mins)



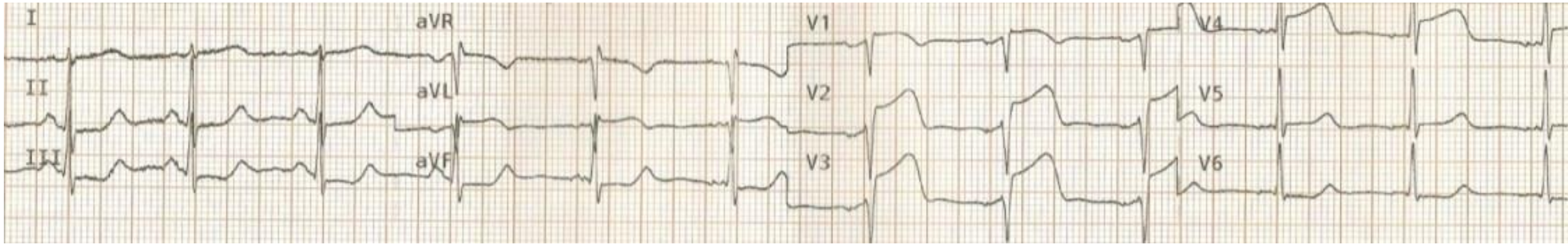
ECG 5c – Recurrence of chest pain (t+25 mins)



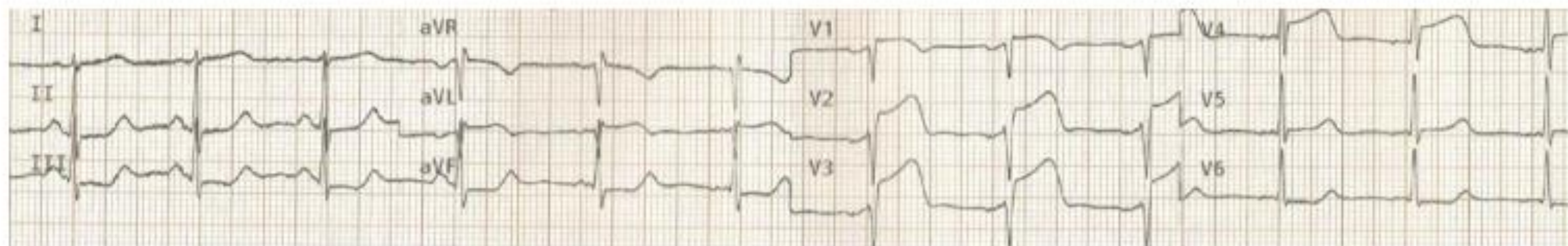
Reveal Answer

- The previously biphasic T waves are now upright again — this phenomenon is referred to as **pseudonormalisation** and is a marker of reocclusion of the culprit artery.
- Despite temporary restoration of blood flow in ECG 5b, the patient is now re-infarcting!

ECG 5d – Ongoing chest pain and diaphoresis (t+35 mins)



ECG 5d – Ongoing chest pain and diaphoresis (t+35 mins)



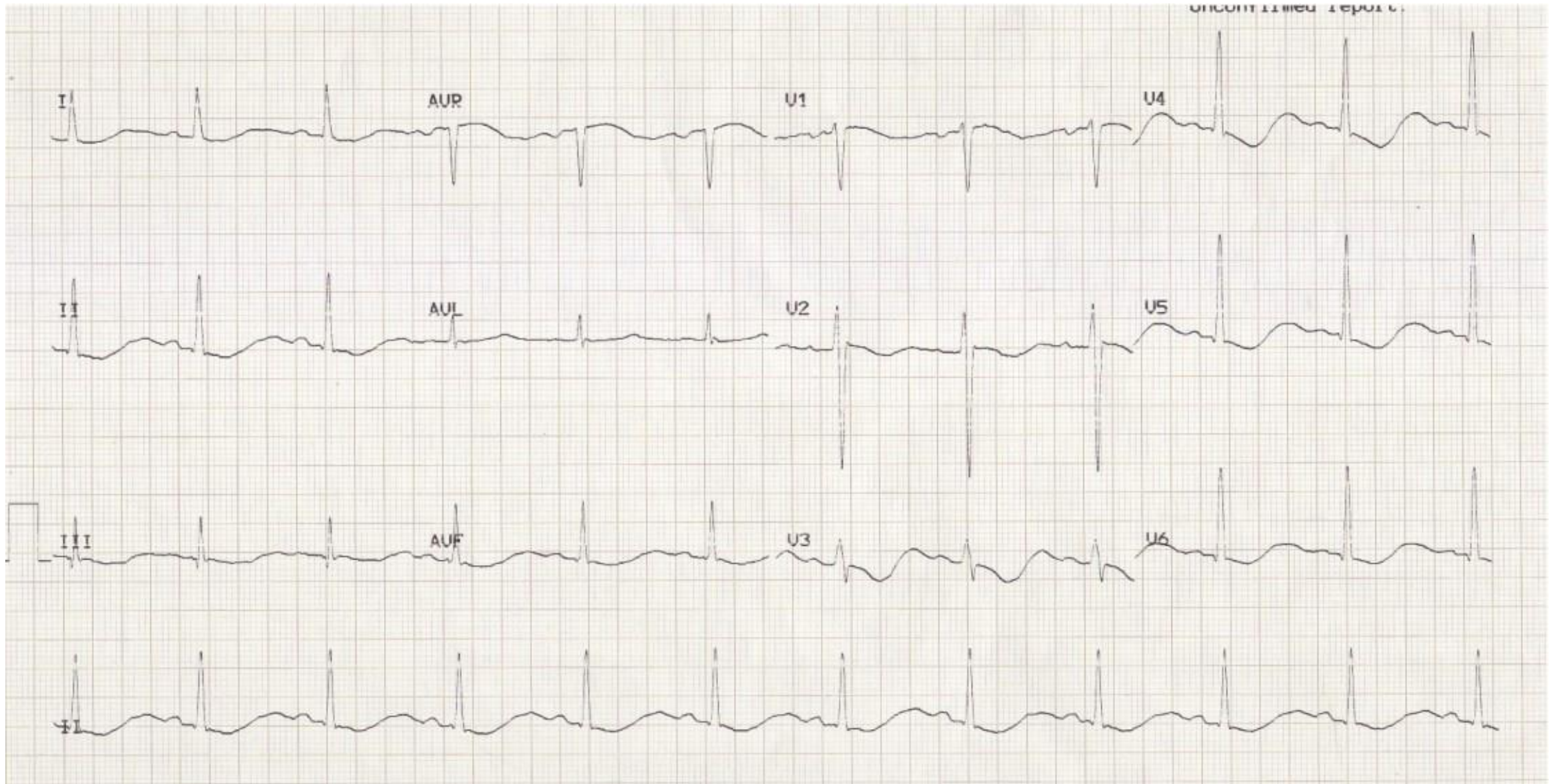
Reveal Answer

- This ECG demonstrates a frank **anterolateral STEMI** with evolving ST changes.

This patient had a VF arrest shortly after this ECG was taken, was placed on a mechanical CPR device and taken immediately to the cath lab where she was found to have a 100% proximal LAD occlusion. She was stented, successfully cardioverted and made a good neurological recovery.

Case 6

30-year old patient presenting with generalised weakness. Describe and interpret the ECG.



- **Main Abnormalities**
- The ECG shows widespread ST segment abnormalities.
- There is a biphasic appearance to the ST segments and T waves, with initial negative deflection (= ST segment depression / T wave inversion) followed by a terminal positive deflection (= U wave).
- All these waves merge into each other and it is difficult to tell where one wave ends and the other begins.
- There is gross prolongation of the QU interval (= time from onset of QRS complex to end of T/U wave).

Diagnosis

The combination of...

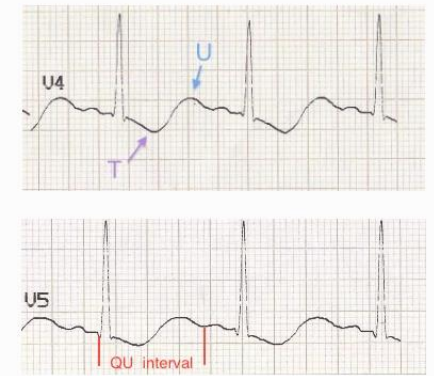
- Widespread ST depression / T wave inversion
- Prominent U waves
- Long QU interval (> 500 ms)

.... is highly suggestive of severe [hypokalaemia](#).

This patient had a serum K of 1.7 mmol/L in the context of decompensated [Conn's syndrome \(primary aldosteronism\)](#).

Clinical Pearls

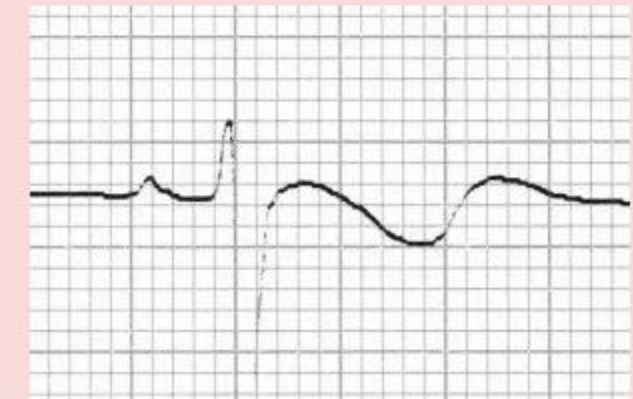
- Biphasic T waves may be seen with both myocardial ischaemia ([Wellens' syndrome](#)) and [hypokalaemia](#).
- The main differentiating factor (apart from the clinical picture) is the direction of the T waves:
 - Wellens' biphasic T waves go UP then down.
 - Hypokalaemic T waves go DOWN then up.



Wellens' Syndrome



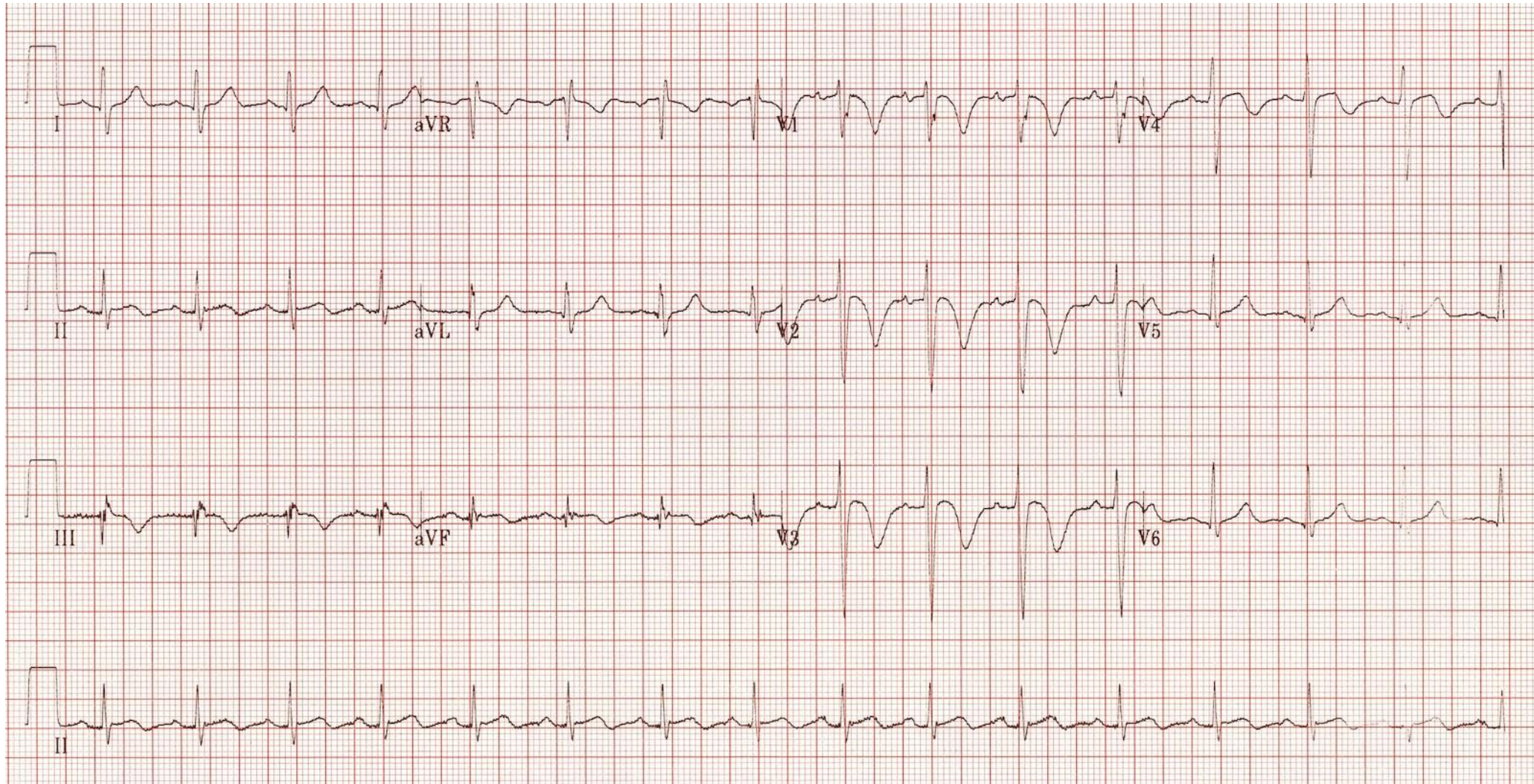
Hypokalaemia



Case 7

70-year old patient presenting with chest pain, dyspnoea and dizziness. BP 90/50. SaO₂ 83%

RA. Describe the ECG.



Main Abnormalities

- Sinus tachycardia ~ 100 bpm.
- Anterior T wave abnormalities: inverted in V1-3, biphasic in V4.
- Inferior T wave abnormalities: biphasic in III, aVF.
- Subtle ST elevation in III and aVF.

Significance of ECG Findings

This pattern of T wave inversions in the right precordial leads V1-4 plus the inferior leads (especially the rightward-facing lead III) is referred to as the [right ventricular strain pattern](#). It is a marker of [right ventricular hypertrophy](#) or dilatation.

Diagnosis

In a patient presenting with acute shortness of breath, the combination of...

- Sinus tachycardia
- RV strain pattern in V1-4 (+/- lead III)

... is highly suggestive of acute cor pulmonale due to massive [pulmonary embolism](#).

However, these ECG changes are not specific to PE and may be seen in other conditions associated with pulmonary hypertension and RV enlargement including:

- [Chronic lung disease](#) (COPD, lung fibrosis) with chronic cor pulmonale
- [Right ventricular hypertrophy](#) — e.g. due to congenital causes, valvular heart disease
- [Arrhythmogenic right ventricular cardiomyopathy](#)

Clinical Pearls

Other ECG findings associated with pulmonary embolism include:

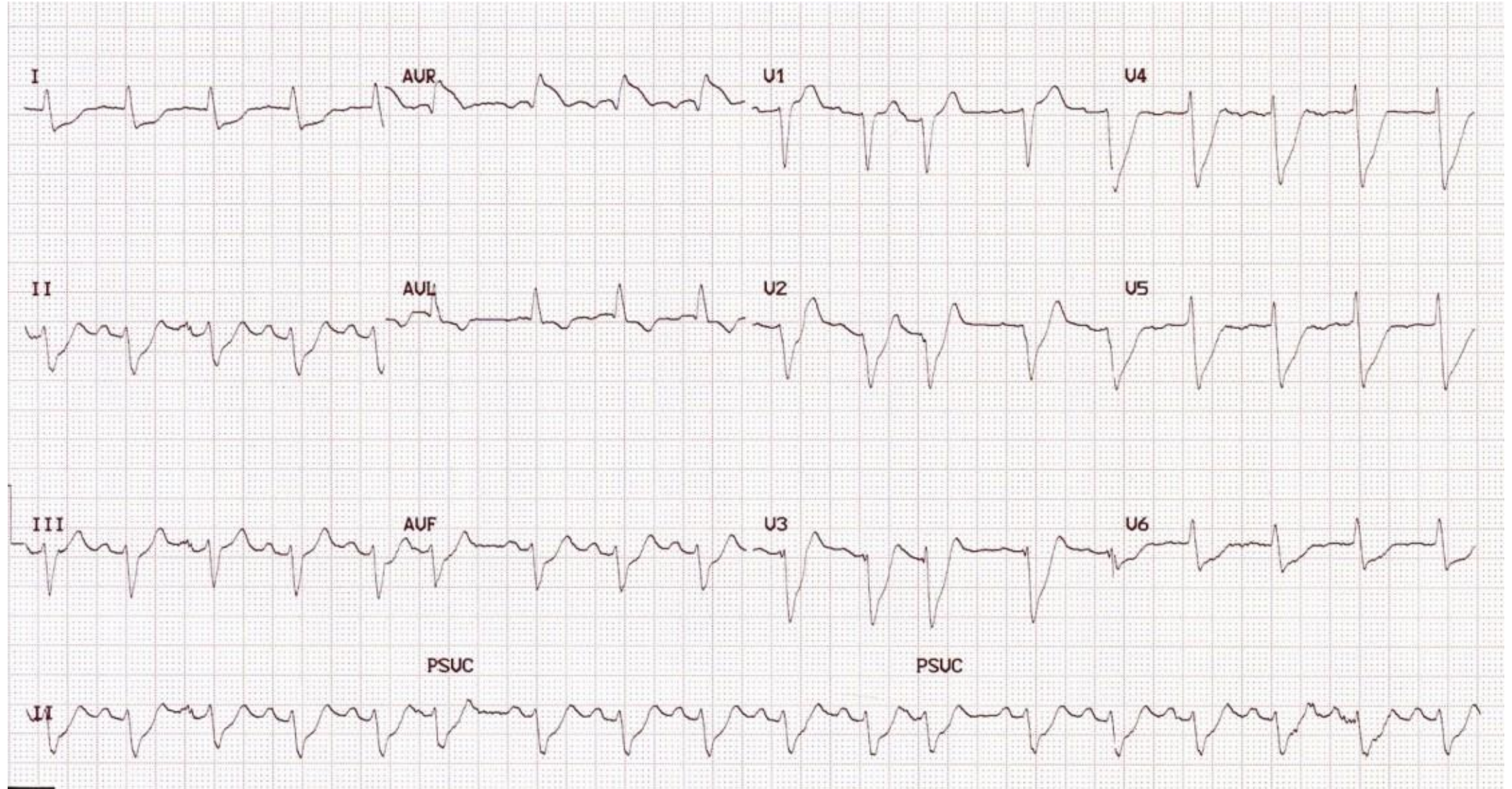
- New [right axis deviation](#)
- New [right bundle branch block](#)
- New [dominant R wave in V1](#)
- Non-specific ST segment changes

The oft-quoted SI QIII TIII pattern (deep S wave in lead I, Q wave in III, inverted T wave in III) is neither sensitive nor specific for PE and is infrequently seen (20% of cases).

Similarly, sinus tachycardia is not as ubiquitous in PE as people seem to think (< 50% of cases), and certainly should not be relied up to exclude PE.

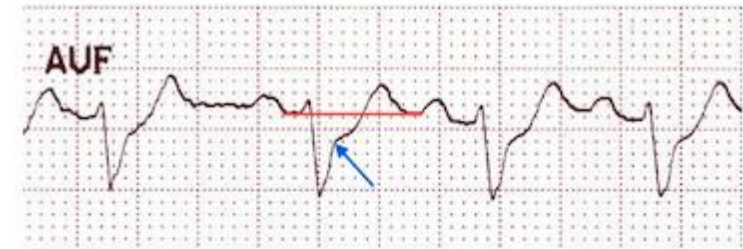
Case 8

70-year old patient presenting with severe chest pain, diaphoresis and syncope. BP 65/40.



Main Abnormalities

- Widespread ST depression affecting multiple precordial (V2-6) and limb leads (esp. I, II, aVF).
- To some extent this is masked by an indistinct J point, upsloping (rather than horizontal) ST depression and some baseline wander of the ECG.
- There is ~3 mm ST elevation in aVR.



ST depression in aVF relative to the T-P baseline. The blue arrow denotes the approximate position of the J point.

Diagnosis

In the context of ischaemic chest pain and cardiogenic shock, the combination of...

Widespread ST depression•

ST elevation in aVR > 1 mm•

ST elevation in aVR > V1•

... is extremely concerning for [left main coronary artery occlusion](#).

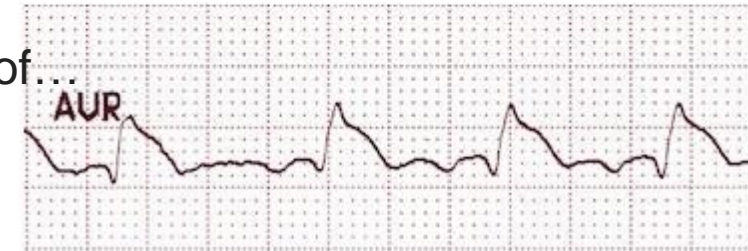
However, this pattern is not entirely specific for LMCA occlusion. It may be seen whenever there is diffuse severe subendocardial ischaemia, e.g.

Severe triple vessel disease•

Severe anaemia or hypoxaemia•

Following resuscitation from cardiac arrest•

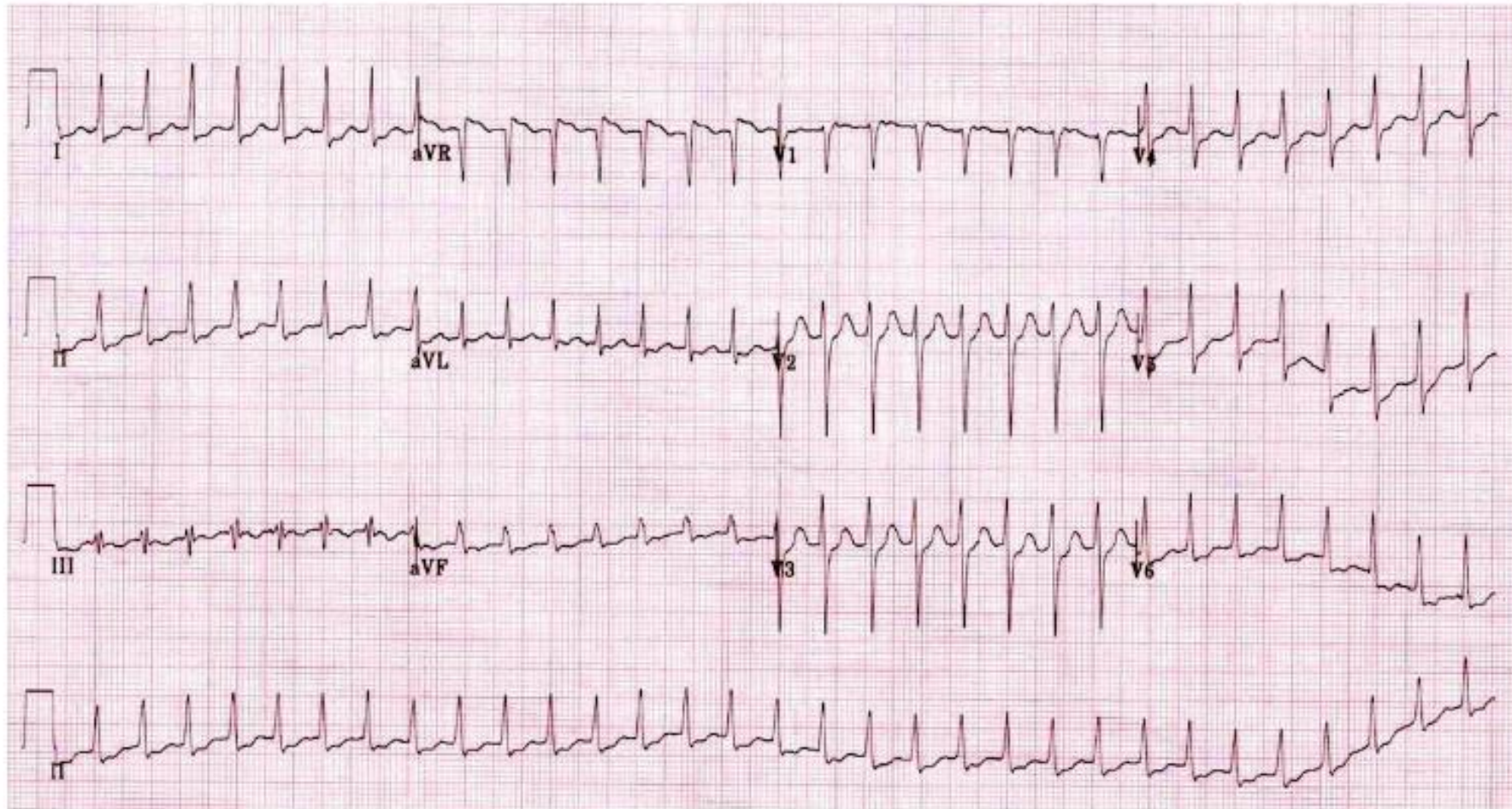
This patient developed progressive cardiogenic shock complicated by runs of [ventricular tachycardia](#). He was taken for immediate angiography where he was found to have a complete ostial occlusion of his left main coronary artery.



ST elevation in aVR

Pitfalls

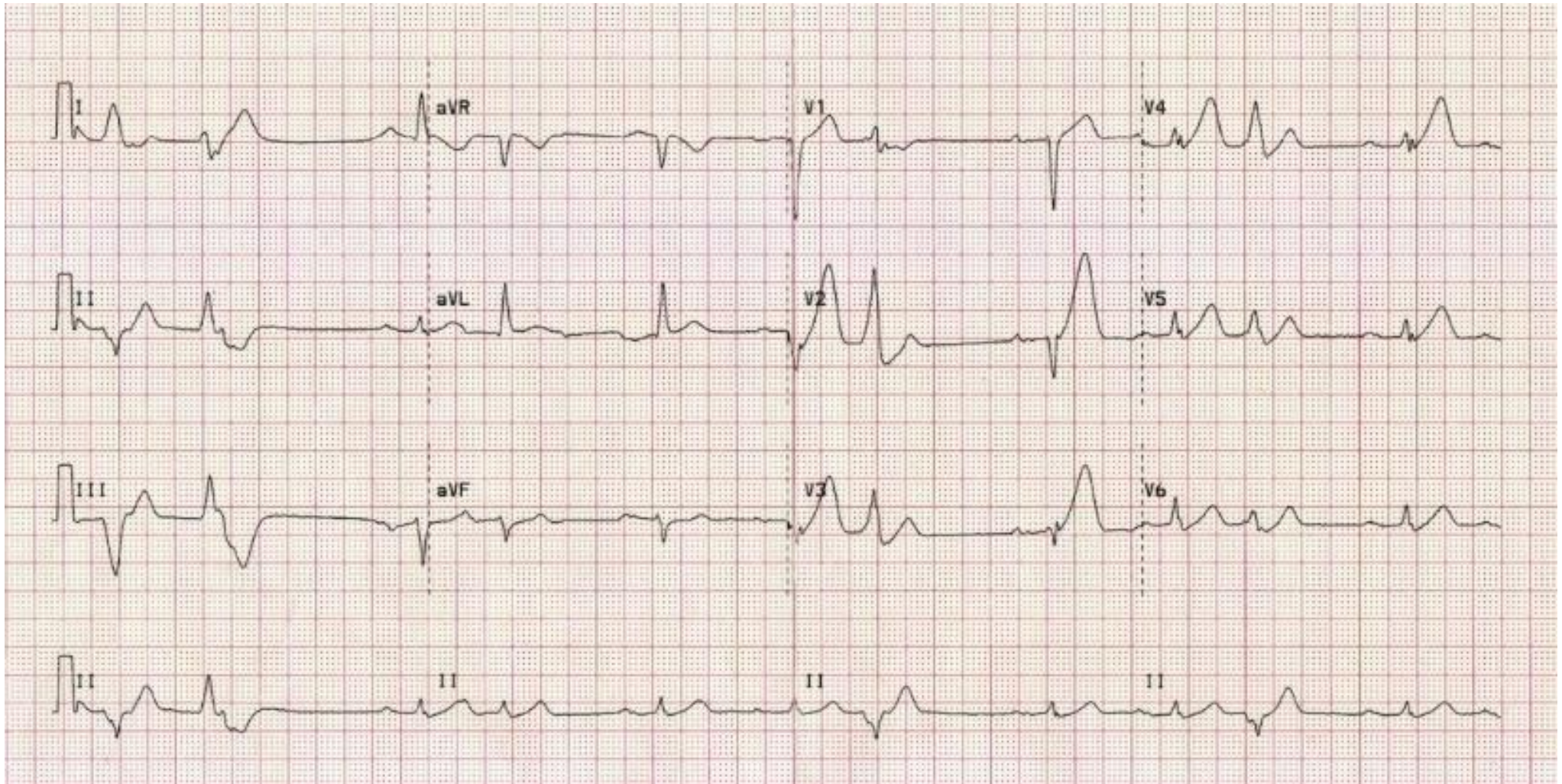
A similar ECG pattern of diffuse ST depression with ST elevation in aVR may also be seen with **supraventricular tachycardias** (AVNRT / atrial flutter). This **rate-related change** is usually benign and resolves with resolution of the SVT.



Rate-related change due to SVT

Case 9

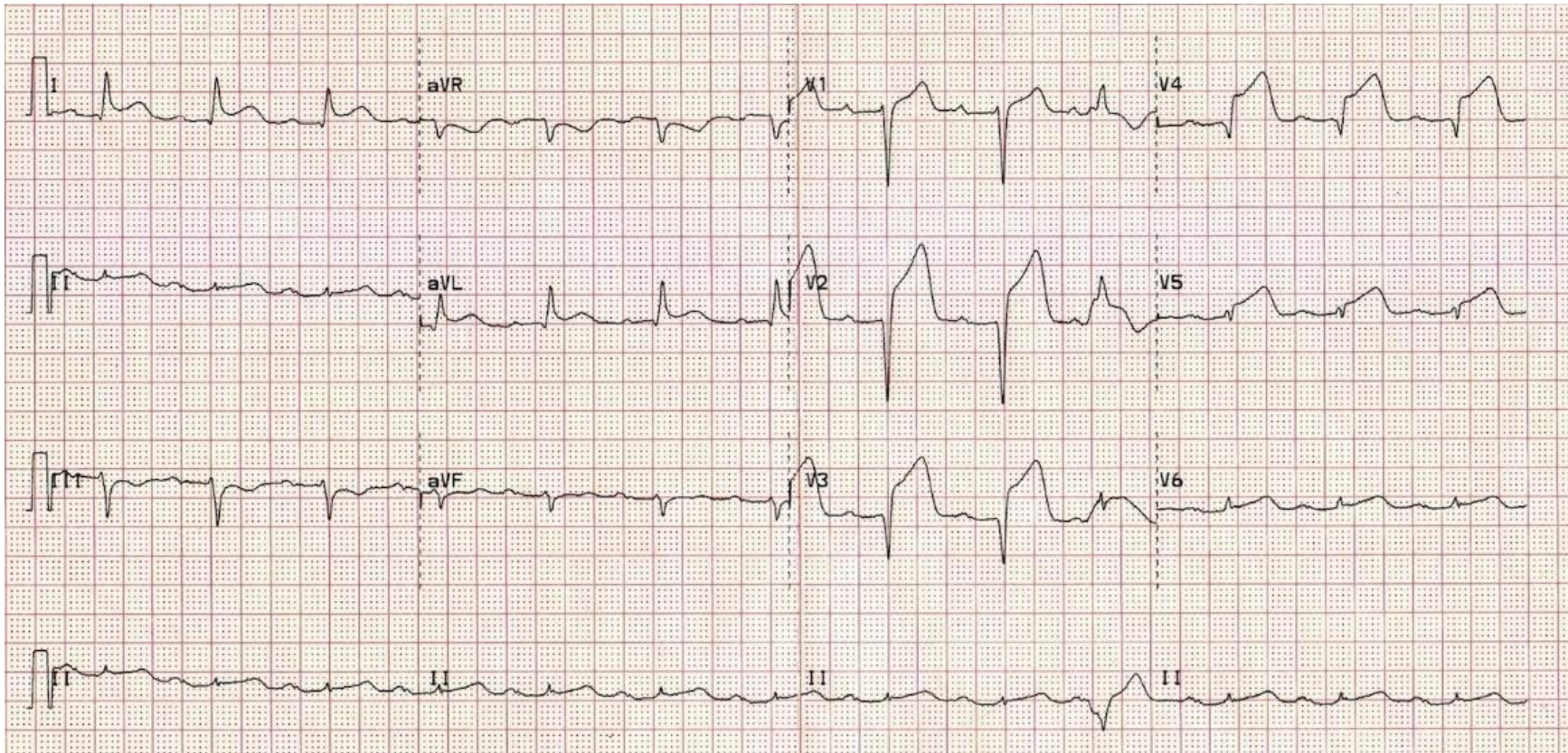
55-year old patient presenting with chest pain. Describe the ECG



This ECG is an example of [hyperacute anterolateral STEMI](#):

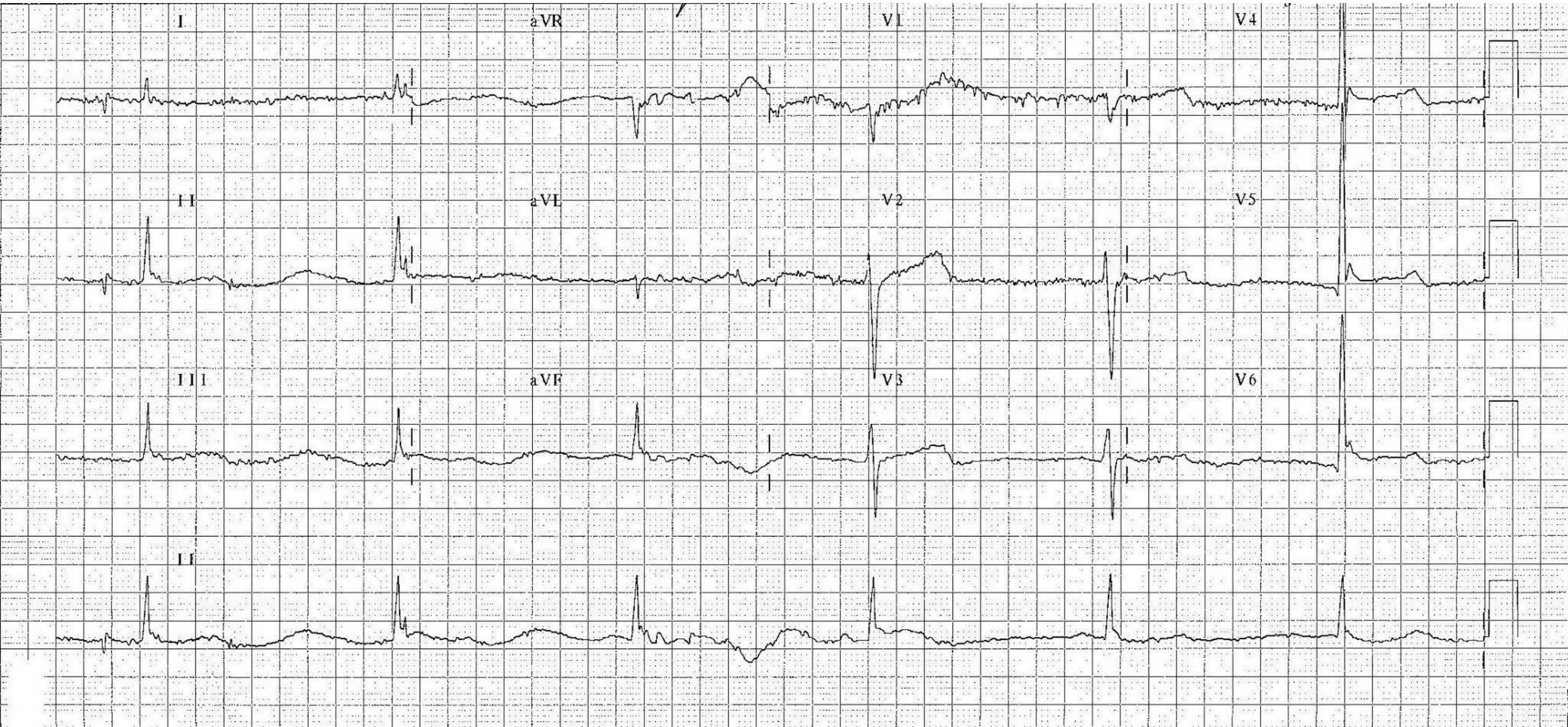
- There are markedly peaked, asymmetrical T waves ([= hyperacute T waves](#)) in V2-5.
- The associated loss of R wave height (analogous to early Q wave formation) causes the enlarging precordial T waves to tower over the diminishing R waves.
- There is also some subtle ST elevation in aVL, indicating [LAD occlusion proximal to the D1](#).
- There are frequent [ventricular ectopic beats](#), which are concerning in this context as they suggest underlying myocardial irritability and a risk of deterioration to malignant ventricular dysrhythmias such as [VF](#) or [VT](#).

Serial ECGs of this patient showed evolving anterolateral ST elevation (V1-6, I, aVL) with development of inferior reciprocal change (lead III).



Case 10

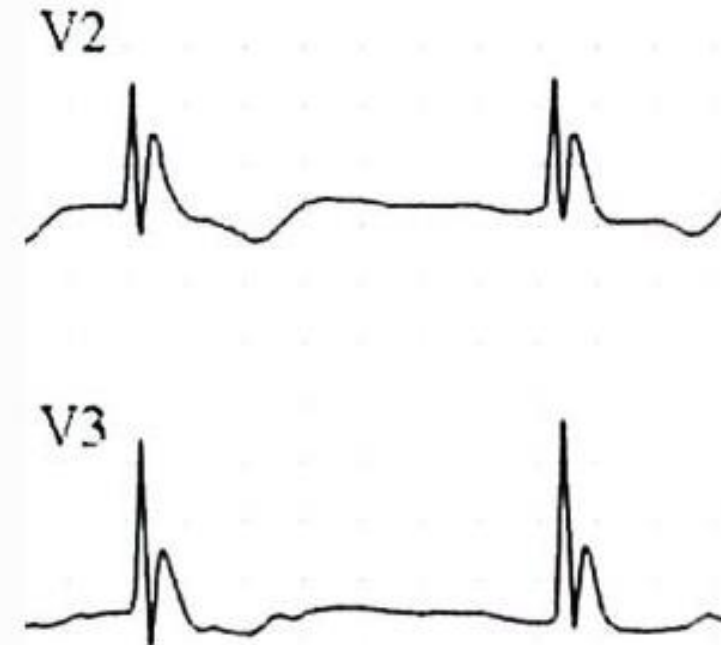
90-year old patient found on the floor at home. Describe what his ECG shows.



This ECG demonstrates all the classic features of [hypothermia](#):

- Bradycardia
- [Osborne waves \(J waves\)](#) = notching at the J point seen in V4-6
- Long [QT interval](#) (~ 600 ms)
- Shivering artefact

The rhythm is probably [sinus bradycardia](#) — mapping out the RR intervals reveals a regular rhythm despite the obliteration of the baseline by the shiver artefact.

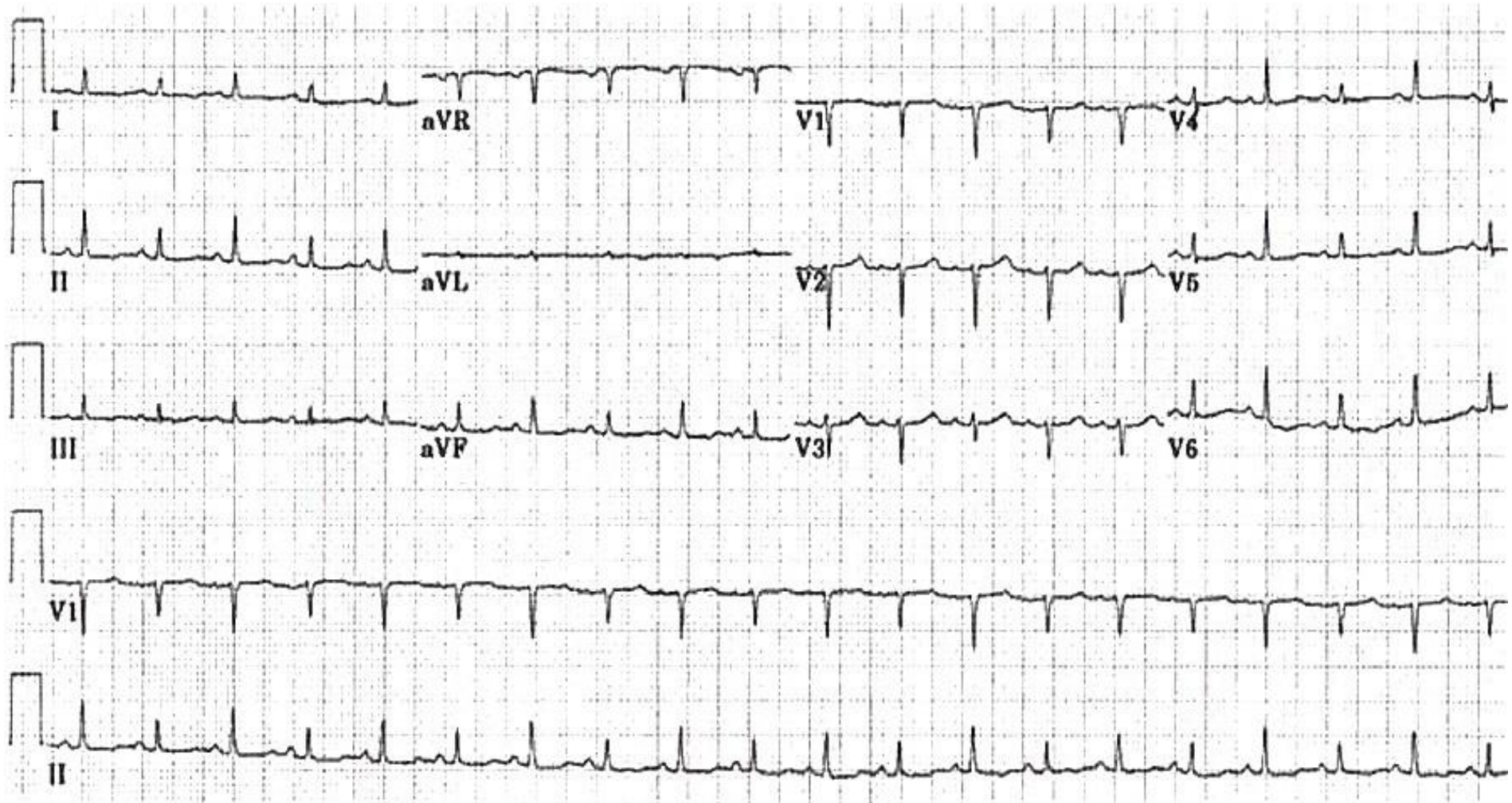


Typical Osborne waves (J waves)

Case 11

Middle aged female presenting with dyspnoea. Previous mastectomy for breast carcinoma.

What does the ECG show?.



Main Abnormalities

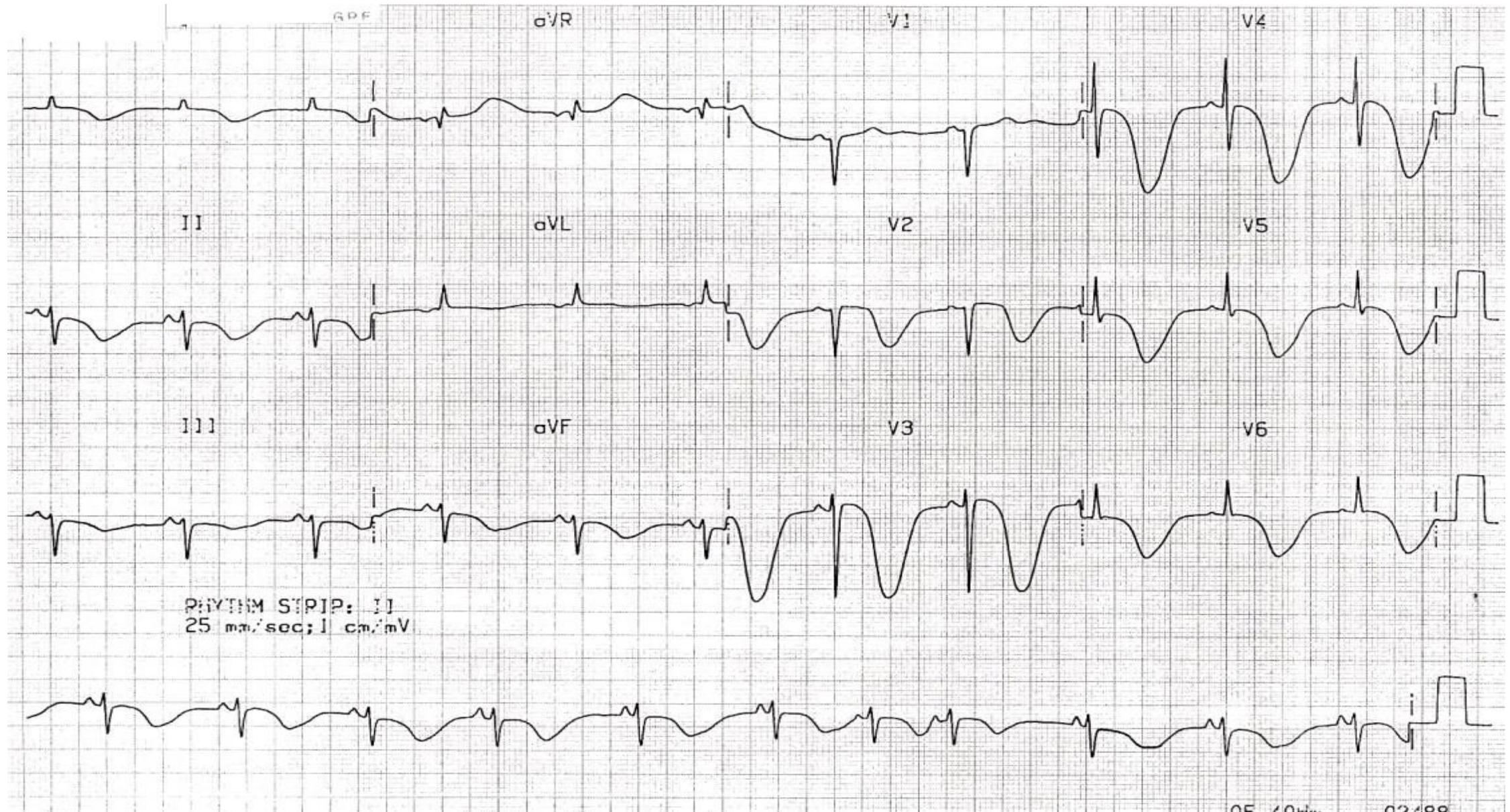
- [Sinus tachycardia](#)
- [Low QRS voltages](#) — Multiple limb lead QRS complexes < 5 mm in amplitude.
- [Electrical alternans](#) — There is a beat-to-beat variation in the QRS complex height. Taller complexes alternate with shorter ones.

The triad of tachycardia, low QRS voltages and electrical alternans is extremely suspicious for [massive pericardial effusion](#).

Given the clinical history, I would be concerned about the presence of a malignant pericardial effusion causing tamponade. The diagnosis can be rapidly confirmed on bedside echo (watch these videos from [The Ultrasound Podcast](#) to learn how: [Part 1](#), [Part 2](#)). There may also be clinical evidence of [pulsus paradoxus](#).

Case 12

Young male found collapsed at home, apparently intoxicated. What does the ECG show?



Main Abnormalities

- Giant T-wave inversions in multiple leads, most prominent in V2-6
- Marked [QT prolongation](#) > 600 ms

Diagnosis

This ECG pattern is characteristic of [raised intracranial pressure](#) and is classically seen in the context of **massive intracranial haemorrhage**, particularly:

- Aneurysmal subarachnoid haemorrhage
- Haemorrhagic stroke

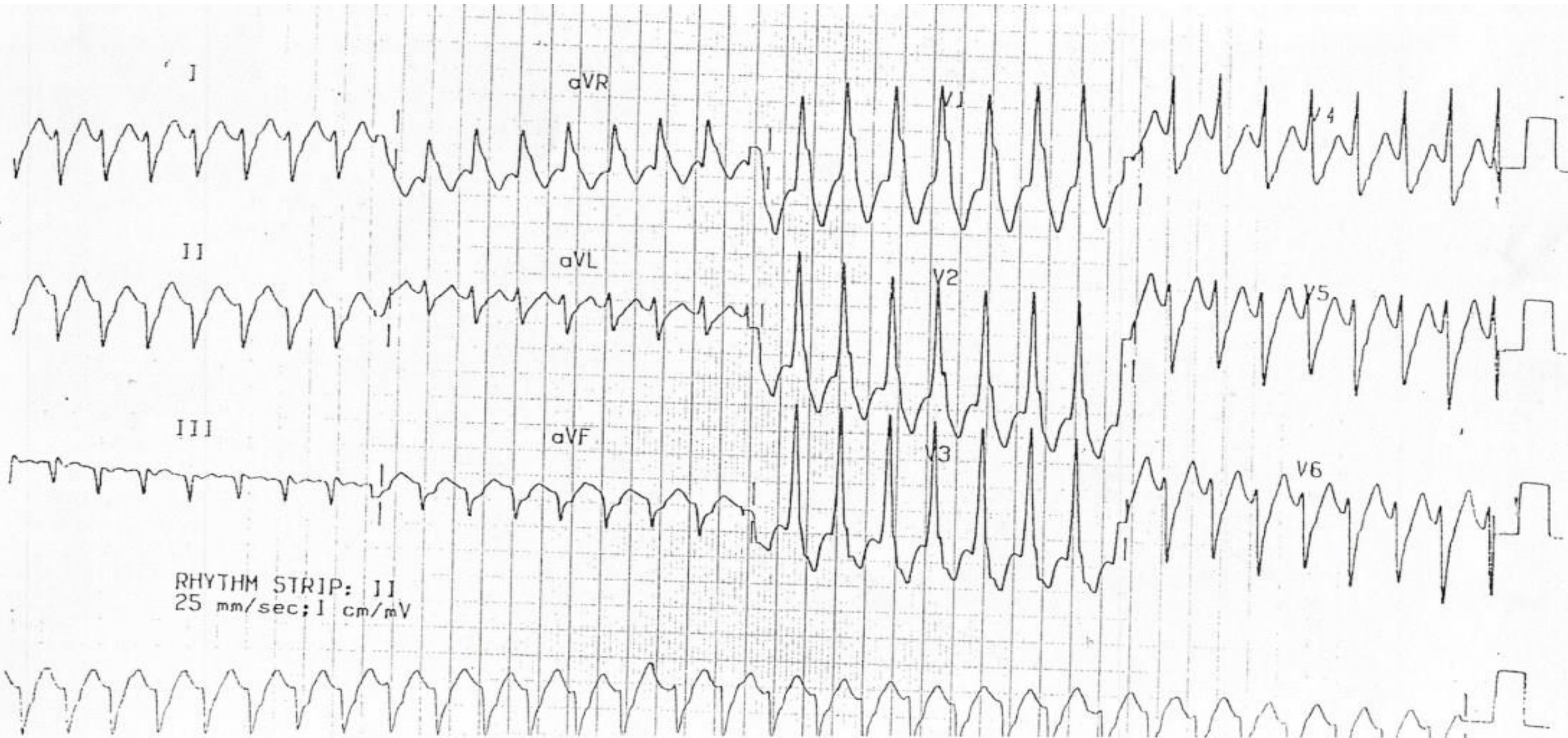
Similar ECG patterns have also been reported in patients with raised ICP due to:

- Large-territory ischaemic stroke causing cerebral oedema (e.g. MCA occlusion)
- Traumatic brain injury

The differential diagnosis for widespread T-wave inversions and QT prolongation includes myocardial ischaemia (e.g. [Wellen's syndrome](#)) and electrolyte abnormalities (e.g. [hypokalemia](#)). However, neither condition would cause the gigantic “cerebral T waves” seen here.

Case 13

Middle-aged patient presenting with palpitations and dizziness. What does the ECG show?



Diagnosis

This ECG shows a regular broad complex tachycardia with an RSR' pattern in V1.

The differential diagnosis could include:

- [Ventricular tachycardia](#).
- [SVT with aberrant conduction](#) — either due to [RBBB](#) or [WPW](#).

On closer inspection, the ECG demonstrates some classic features of **ventricular tachycardia**:

- [Northwest axis](#) — QRS is positive in aVR, negative in I and aVF.
- The **taller left rabbit ear** sign — There is an atypical RBBB pattern in V1, where the left “rabbit ear” is taller than the right.
- Negative QRS complex (R/S ratio < 1) in V6.

These findings indicate VT rather than SVT with aberrancy.

Clinical Pearls

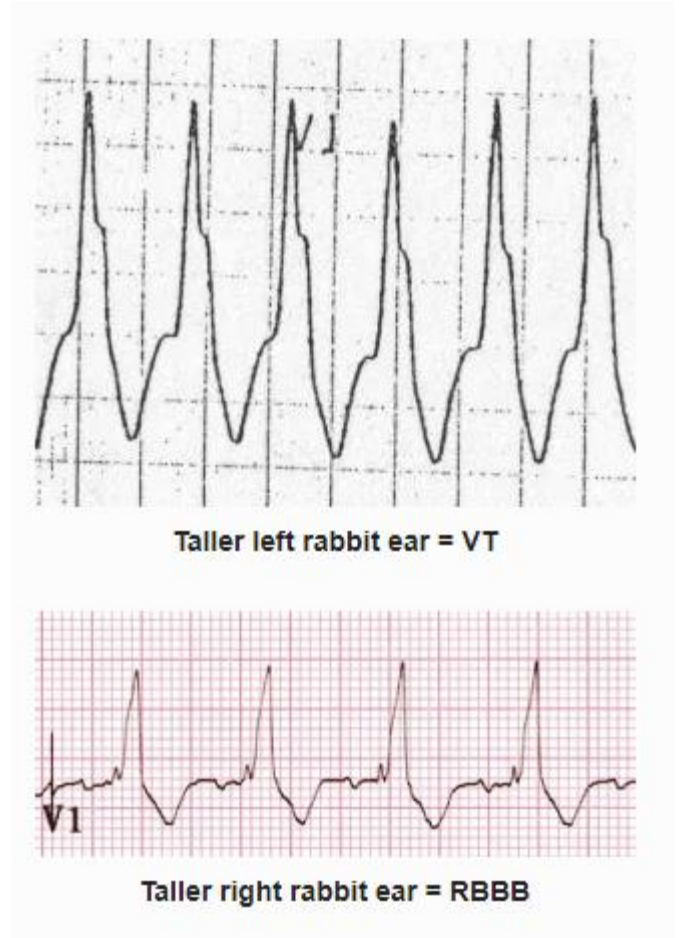
Other factors that increase the likelihood of VT in patients presenting with regular broad complex tachycardia include:

Age > 35 (positive predictive value of 85%).

Structural heart disease — e.g. IHD, CCF, cardiomyopathy.

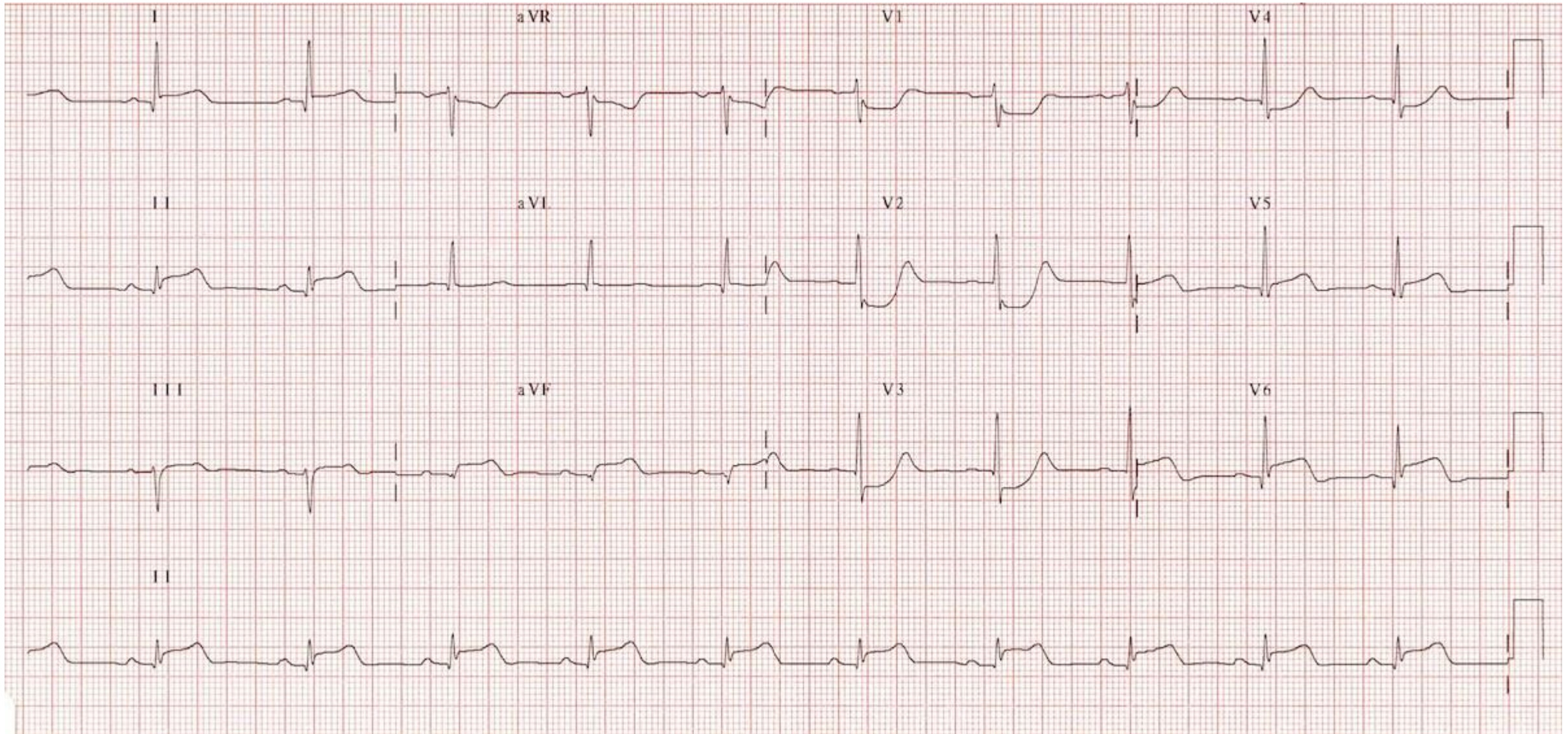
Family history of sudden cardiac death or arrhythmogenic conditions such as [HOCM](#), [Brugada syndrome](#) or [ARVC](#) that are associated with episodes of VT.

In any patient with a broad complex rhythm, also consider the possibility of toxic / metabolic conditions such as [hyperkalaemia](#) or [sodium-channel blockade](#).



Case 14

Middle aged patient presenting with central chest pain. What does the ECG show?



Evidence of [inferolateral STEMI](#)

- ST elevation in the inferior leads (II, III, aVF)
- ST elevation in the lateral leads (I, V5, V6)

Evidence of [posterior STEMI](#)

- Horizontal ST depression in V1-4 (maximal in V2-3)
- Dominant R wave in V2 (R/S ratio > 1)
- Upright T wave in V2

This pattern of infero-postero-lateral STEMI is most likely caused by occlusion of a dominant left circumflex artery.

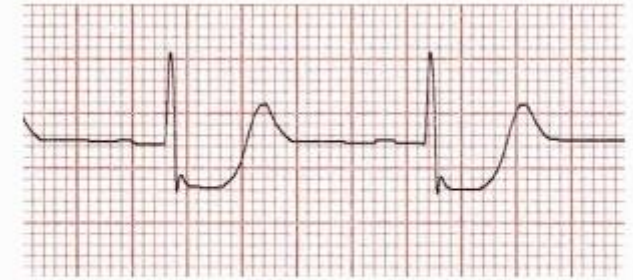
Tips for spotting posterior infarction

Look specifically at lead V2 for the combination of

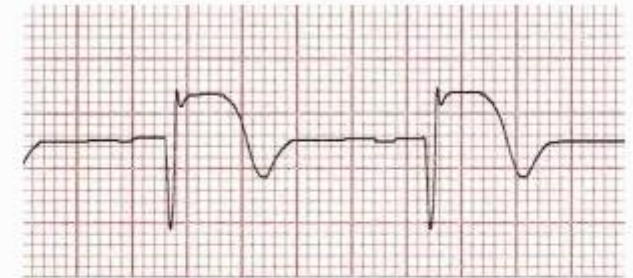
- Horizontal ST depression.
- Tall, broad R wave (>30ms wide, R/S ratio > 1) — this is a Q-wave equivalent.
- Upright T wave — particularly the terminal portion of the T wave.

One common trick is to turn the ECG over, hold it up to the light and look through it from behind. This inverts lead V2, which then takes on the appearance of a classic STEMI.

Look for evidence of posterior involvement in any patient with an [inferior](#) or [lateral STEMI](#). Sometimes it can be difficult to determine whether ST depression in V2-3 is due to posterior STEMI or simply subendocardial ischaemia affecting the antero-septal wall. The diagnosis can be confirmed by recording [posterior leads V7-9](#).



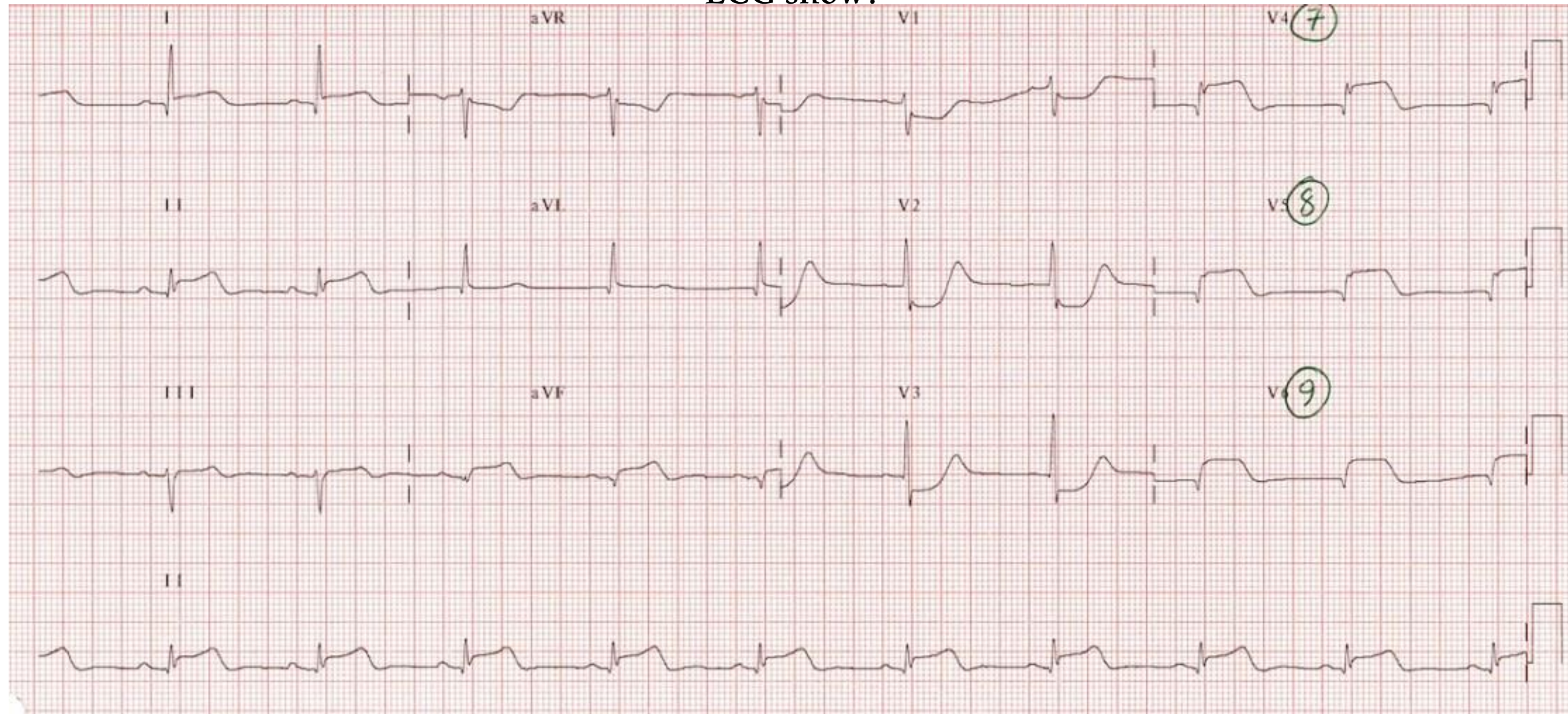
Typical appearance of posterior infarction in V2



V2 inverted — the complexes now resemble a typical STEMI

Case 15

Middle aged patient presenting with central chest pain. Posterior leads V7-9. What does the ECG show?



(same patient as [ECG 014](#))

Posterior leads confirm the presence of posterior wall infarction by demonstrating typical STEMI morphology:

- ST elevation in V7-9
- Q waves in V7-9
- Inversion of the terminal portion of the T wave ("[U wave inversion](#)") in V7-9

How To Record Posterior Leads

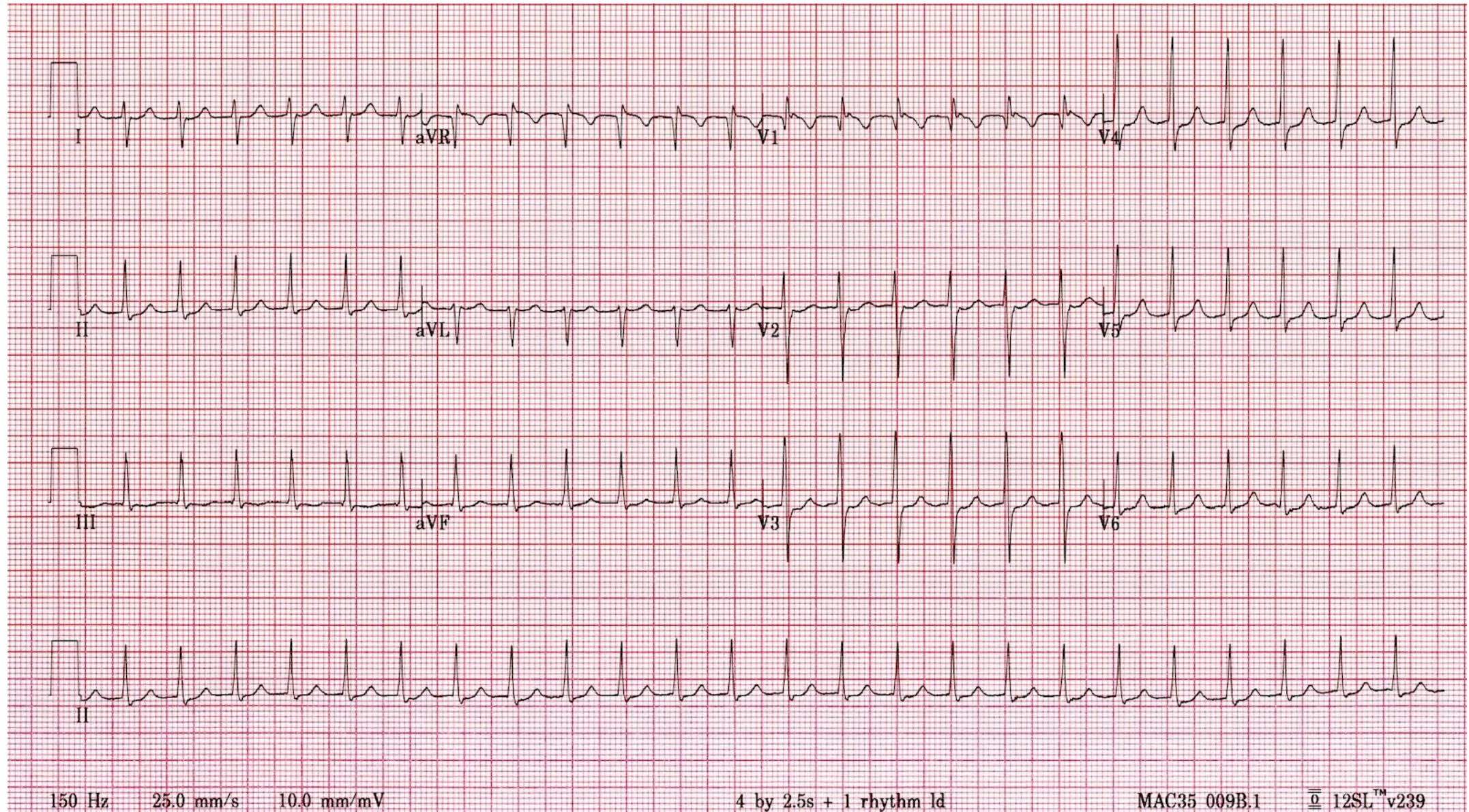
Simply move the V4-6 electrodes around to the back in the same horizontal plane as V6. Annotate the ECG accordingly.

Approximate positions for V7-9 are:

- V7 – posterior axillary line
- V8 – tip of scapula
- V9 – left paraspinal region

Case 16

20-year old patient with sudden onset of palpitations. What does the ECG show?



Main Abnormalities

- Narrow complex tachycardia at ~ 150 bpm.
- [Right axis deviation](#) = just rightward of +90 degrees.
- [Pseudo-R' waves](#) in V1-2 = retrograde P waves superimposed on the terminal QRS causing peaking of the [J-point](#).
- No clear sinus P waves or [flutter waves](#) seen.

Differential Diagnosis

When you see a regular narrow complex tachycardia at 150 bpm, you should think of four main diagnoses:

[Atrial flutter with 2:1 block](#) (*especially* in elderly, IHD, CCF)•

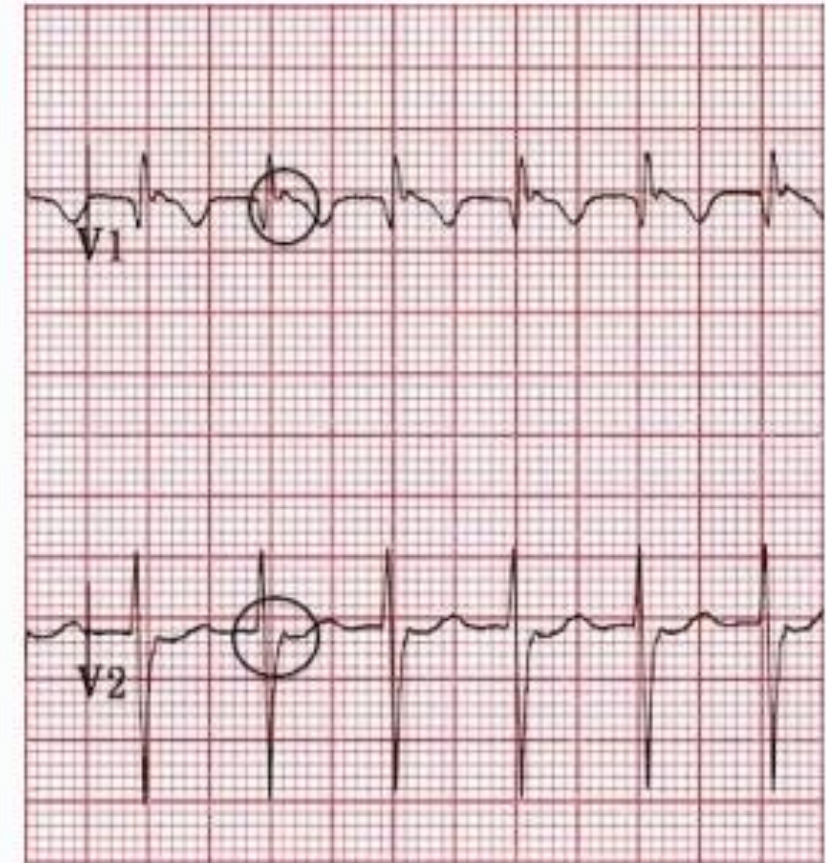
[AV-nodal reentry tachycardia](#) (“SVT”)•

[Orthodromic AV reentry tachycardia](#) in WPW•

[Sinus tachycardia](#) — should see P waves but [may be hidden in the T waves](#) (e.g. with concurrent [1st degree AV block](#)). There should also be some HR variability compared to the other 3 rhythms.

The patient's young age and presence of retrograde P waves (pseudo R' waves) suggest a paroxysmal reentry tachycardia involving the AV node — either [AVNRT](#) (“SVT”) or [orthodromic AVRT](#).

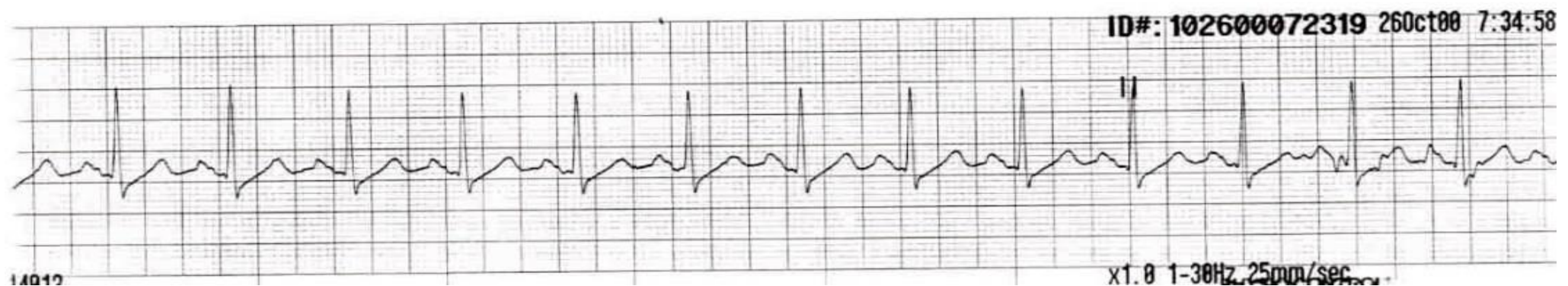
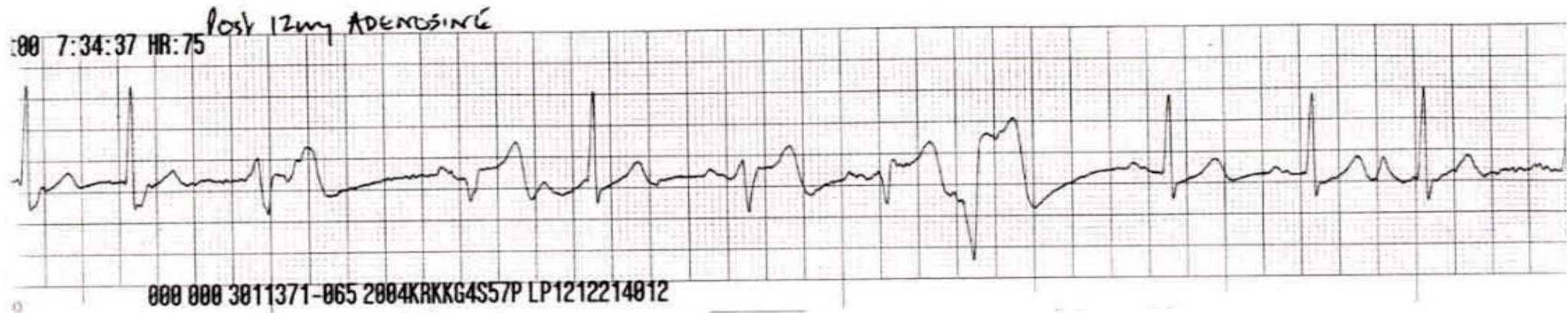
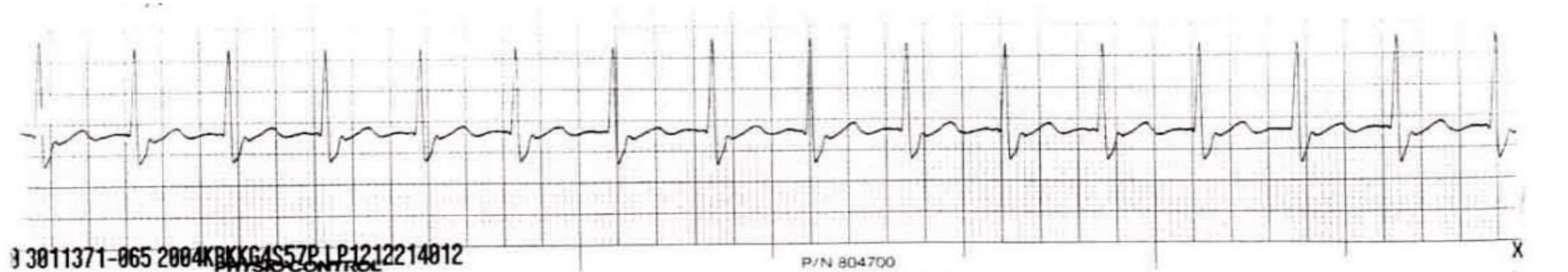
The next step is a therapeutic trial of vagal manoeuvres and/or adenosine... (see [Quiz ECG 017](#)).



Pseudo R' waves

Case 17

20-year old patient with sudden onset of palpitations. What does the rhythm strip demonstrate?



Top rhythm strip

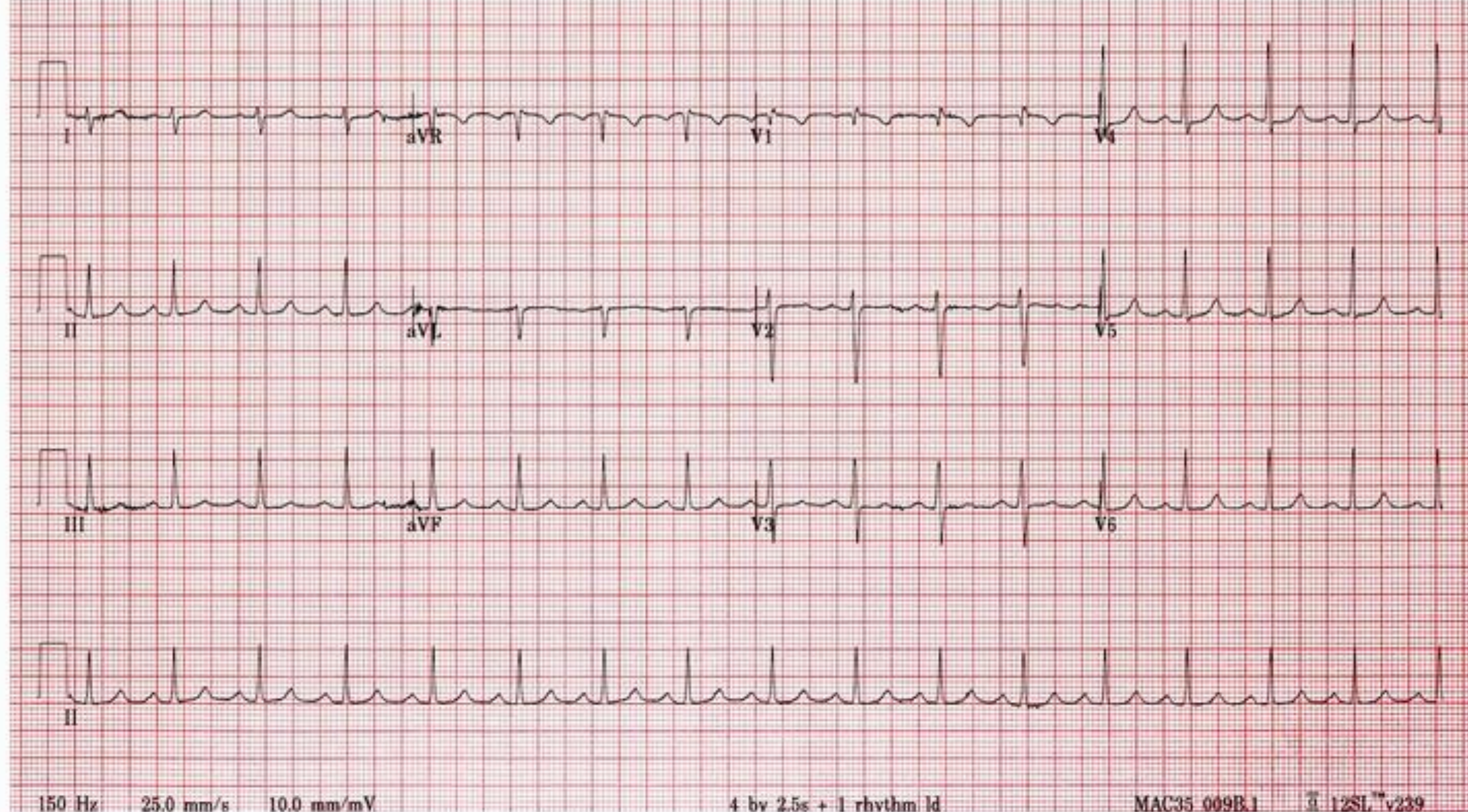
- Regular narrow complex tachycardia.
- Pseudo-R' waves (retrograde P waves) are seen deforming the J point.

Middle rhythm strip

- 12mg adenosine given
- A salvo of broad and bizarre-looking complexes interrupts the rhythm (this is a common phenomenon during chemical cardioversion with adenosine)

Bottom rhythm strip

- The patient has reverted to sinus rhythm.
- The pseudo-R' waves have now disappeared.
- There are no obvious **delta waves** of WPW, but this should be confirmed on a 12-lead ECG.

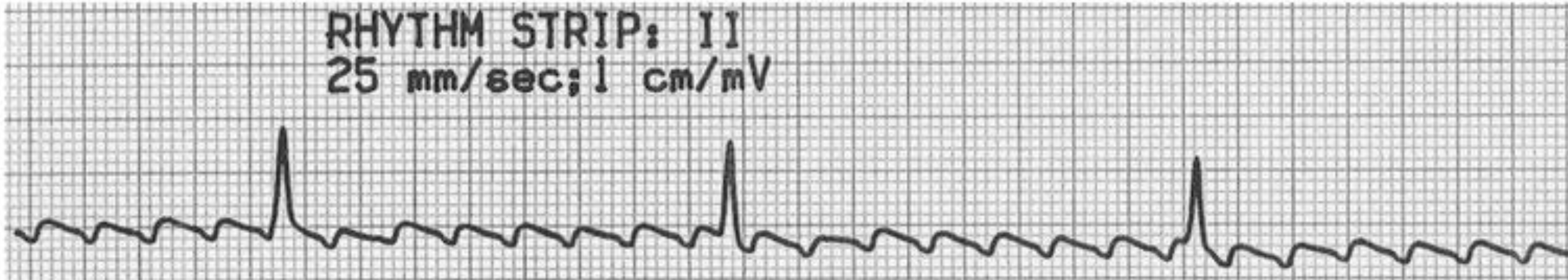


The 12-lead ECG confirms reversion to sinus rhythm and does not demonstrate any features of WPW. The diagnosis is **AV-nodal reentry tachycardia (AVNRT)**.

Case 18

75-year old patient with narrow complex tachycardia at 150 bpm.

Rhythm strip during administration of IV adenosine. What is happening here?

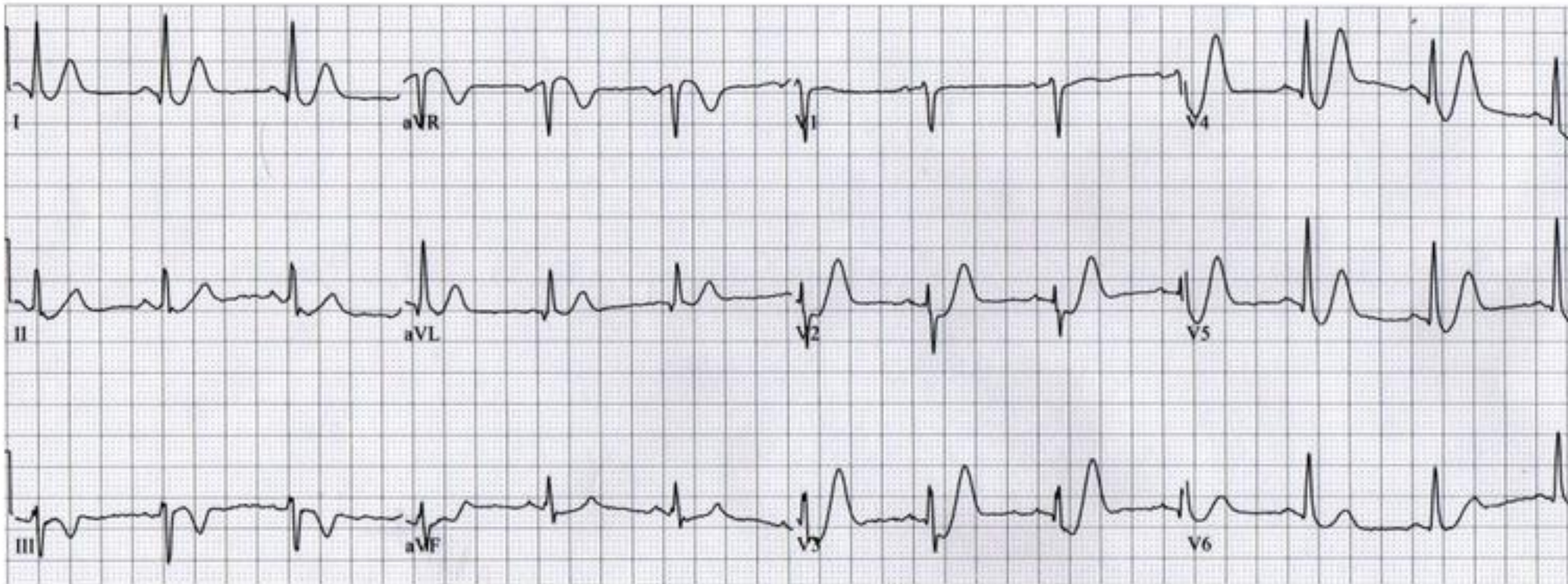


In comparison to the **previous example**, this patient does not cardiovert to sinus rhythm following an adenosine bolus.

Instead, the degree of AV block is transiently increased, revealed underlying **flutter waves** and confirming the diagnosis of **atrial flutter with a 2:1 block**.

Case 19

Middle aged patient presenting with chest pain and diaphoresis. What does the ECG show?

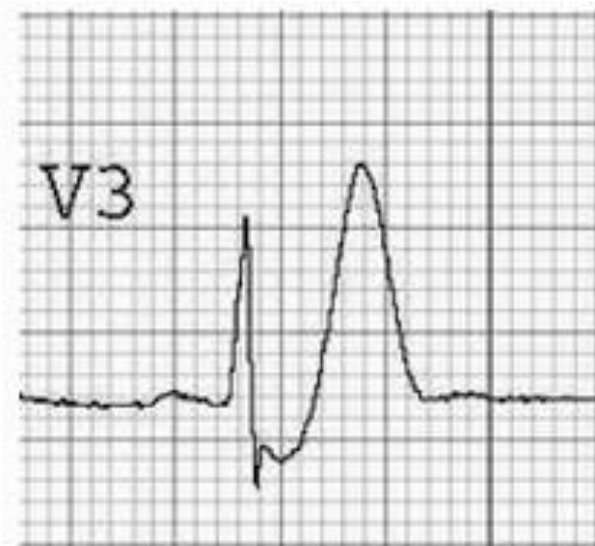


Main Abnormalities

- ST depression in V2-5, which slopes upwards and joins the ascending limb of the T wave.
- Prominent, "rocket-shaped" T waves in the precordial leads V2-5.
- Subtle ST elevation in aVR.

Diagnosis

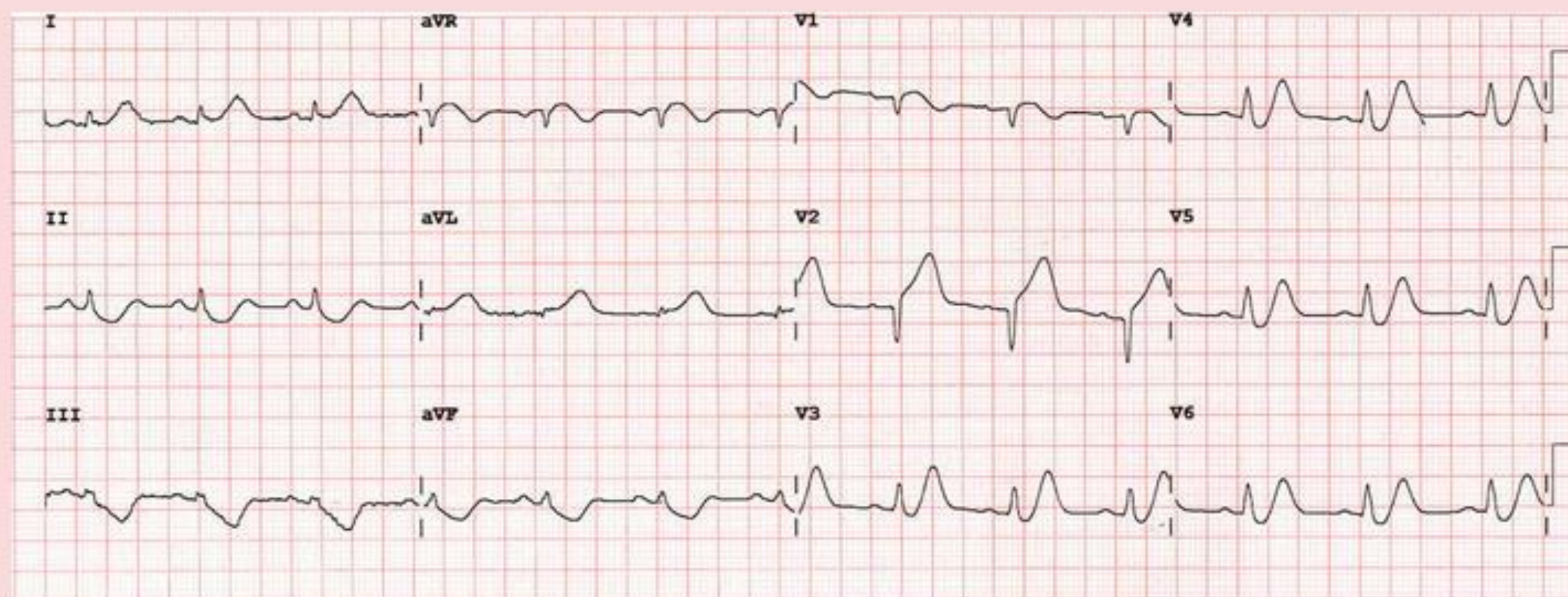
- This combination of ST depression with rocket-shaped T waves in the precordial leads V1-6 is referred to as the De Winter ECG pattern or "**De Winter's T waves**".
- It is becoming increasingly recognised as an anterior STEMI equivalent (~2% of LAD occlusions).
- **Some authors** are now recommending that this ECG pattern be treated identically to anterior STEMI, with urgent PCI or thrombolysis.



Typical De Winter's T Wave

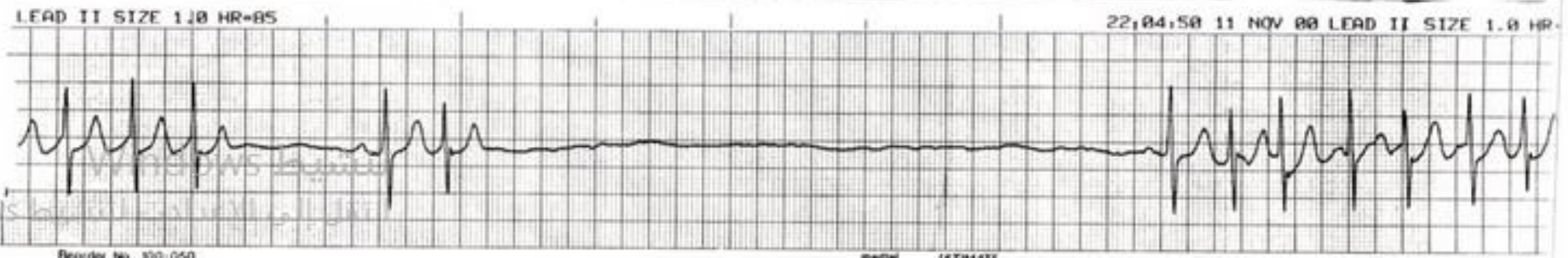
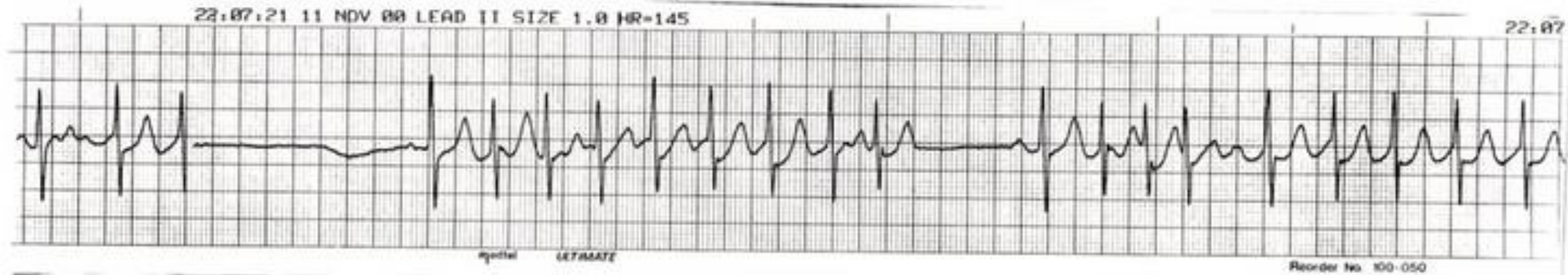
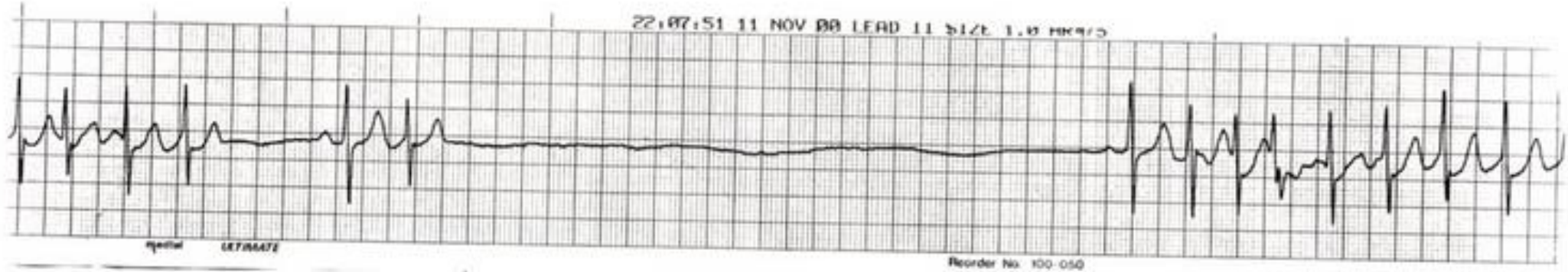
Clinical Pearls

The De Winter ECG pattern may evolve into (or even evolve from) a more classic STEMI pattern.



Case 20

80-year old patient with palpitations and syncope. What does the ECG show?



Main Abnormalities

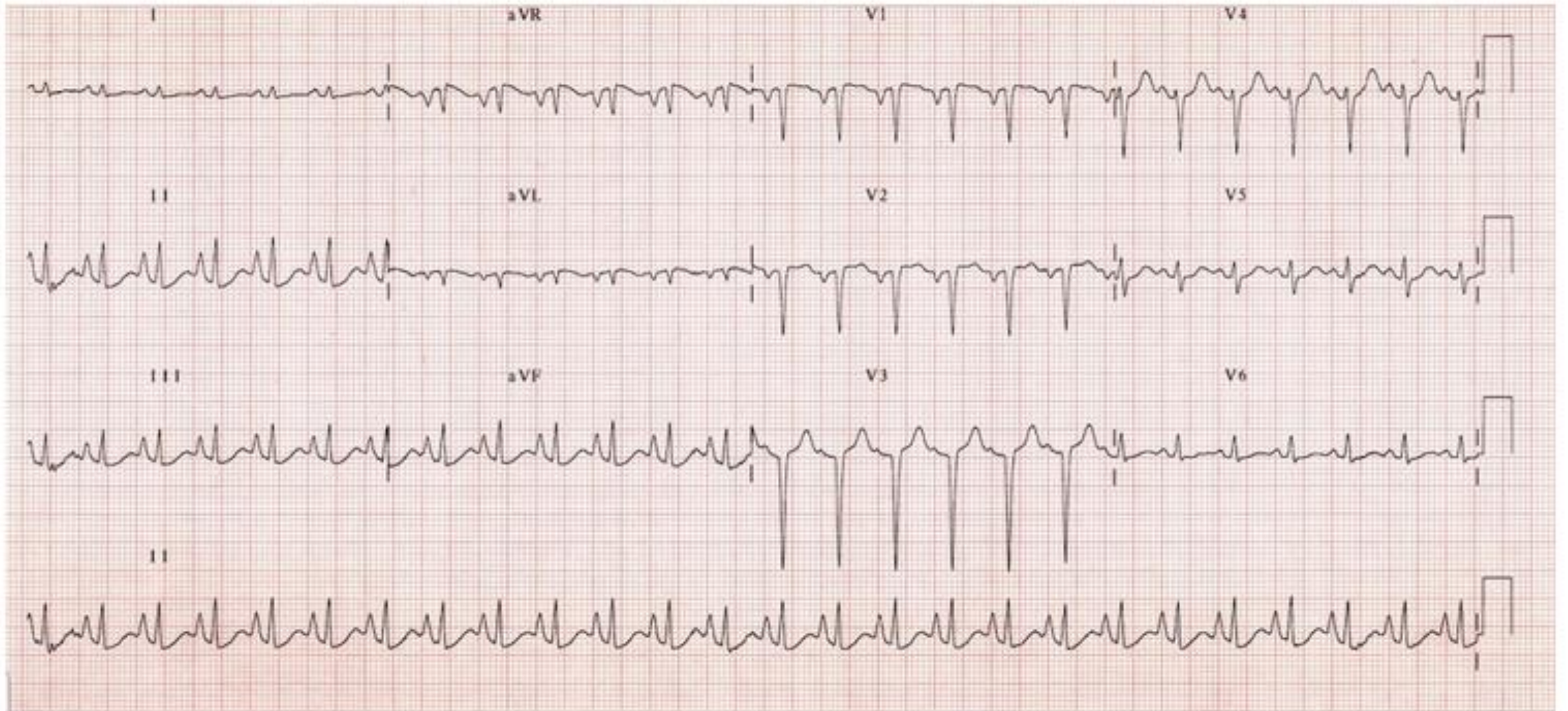
- Runs of tachycardia are interspersed with long sinus pauses (up to 6 seconds).
- The sinus rate is extremely slow, varying from 40 bpm down to around 10 bpm in places.
- Sinus beats are followed by paroxysms of junctional tachycardia at around 140 bpm.

Diagnosis

- This is a good example of sick sinus syndrome leading to the tachycardia-bradycardia syndrome.
- The flurries of junctional tachycardia are a compensatory phenomenon attempting to maintain cardiac output in the face of critically low sinus node rates.
- The syncope likely occurred due to a long sinus pause with temporary loss of cardiac output. This patient needs a pacemaker!

Case 21

75-year old smoker presenting with acute dyspnoea and productive cough. Describe the ECG.



This ECG demonstrates many of the features of **chronic pulmonary disease**:

- Rightward QRS axis (+90 degrees).
- Peaked P waves in the inferior leads > 2.5 mm (**P pulmonale**).
- Rightward P-wave axis (inverted in aVL).
- "Clockwise rotation" of the heart with a delayed R/S transition point (transitional lead = V5).
- Absent R waves in the right precordial leads (SV1-SV2-SV3 pattern).
- Low voltages in the left-sided leads (I, aVL, V5-6).

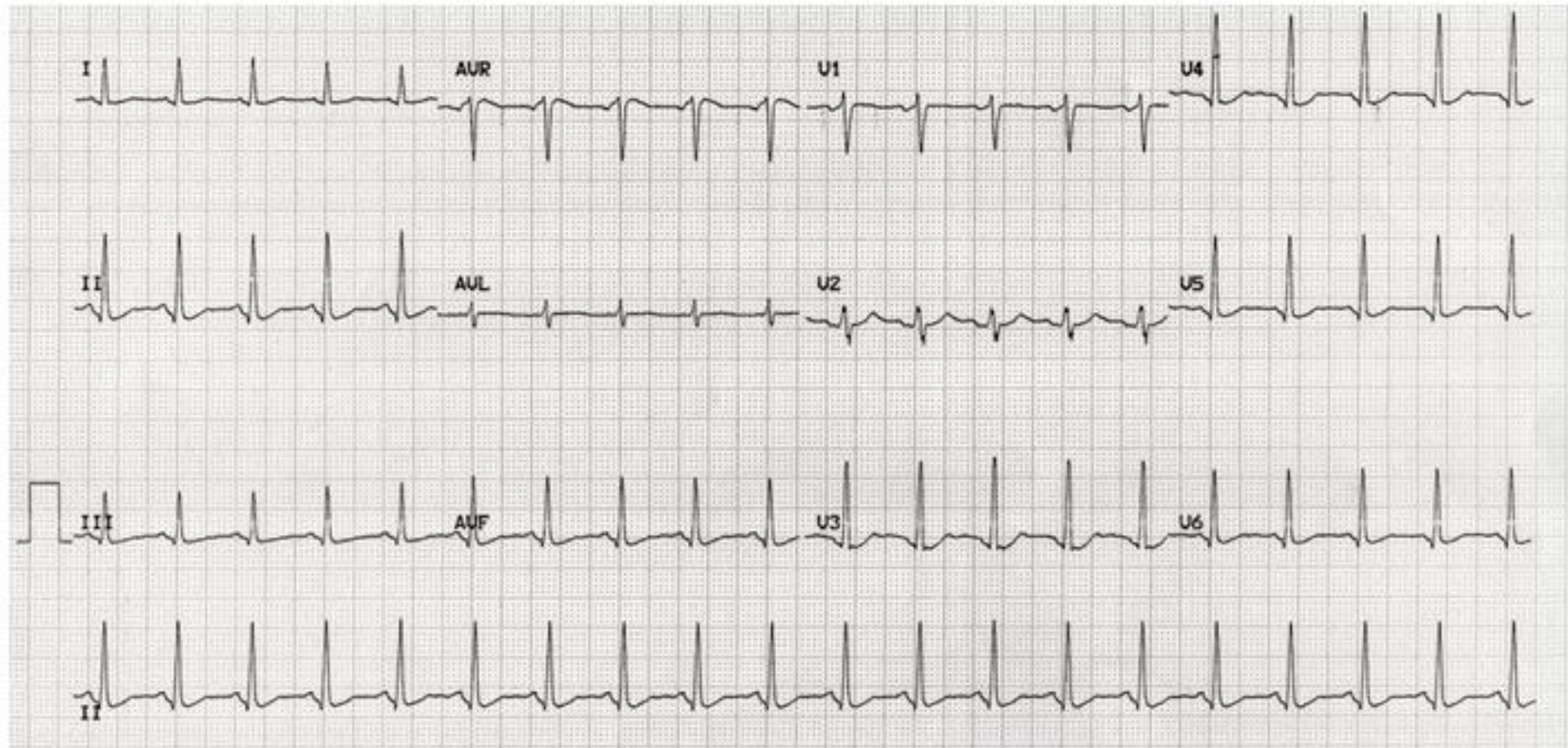
Tachycardia may be due to dyspnoea, hypoxia or beta-agonist treatment. This ECG pattern is a common finding in patients with COPD. The vertical axis (+90 degrees) is due to hyperinflation of the lungs causing vertical orientation of the heart.



Vertical heart orientation in COPD

Case 22

Post-intubation ECG of a young adult presenting with coma following a 6g quetiapine overdose. Describe the ECG.



Main Abnormalities This ECG displays the characteristic electrocardiographic features of quetiapine toxicity:

- Sinus tachycardia due to anticholinergic effects.
- Prolonged QT interval (QT interval > half the RR interval; QTc = 560ms).

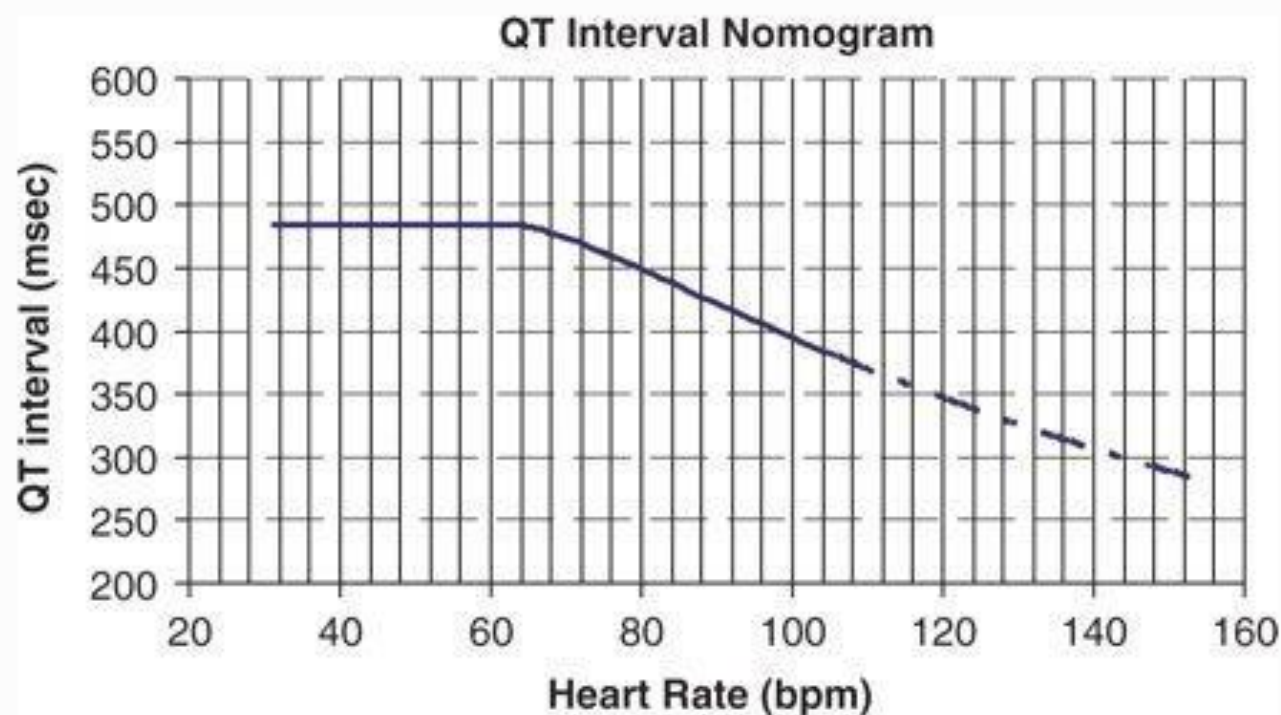
A similar pattern would be seen with other atypical antipsychotic agents such as olanzapine or clozapine.

Significance of QT prolongation

- QT prolongation is a common source of concern in patients with antipsychotic toxicity, because of the theoretical risk of Torsades de Pointes.
- A QTc interval > 500 ms is commonly cited as a marker of increased risk of TdP.
- However, tachycardia (which is almost ubiquitous in significant poisoning with quetiapine, olanzapine or clozapine) is actually protective against TdP.
- For this reason, TDP rarely occurs with quetiapine toxicity.

QT interval nomogram

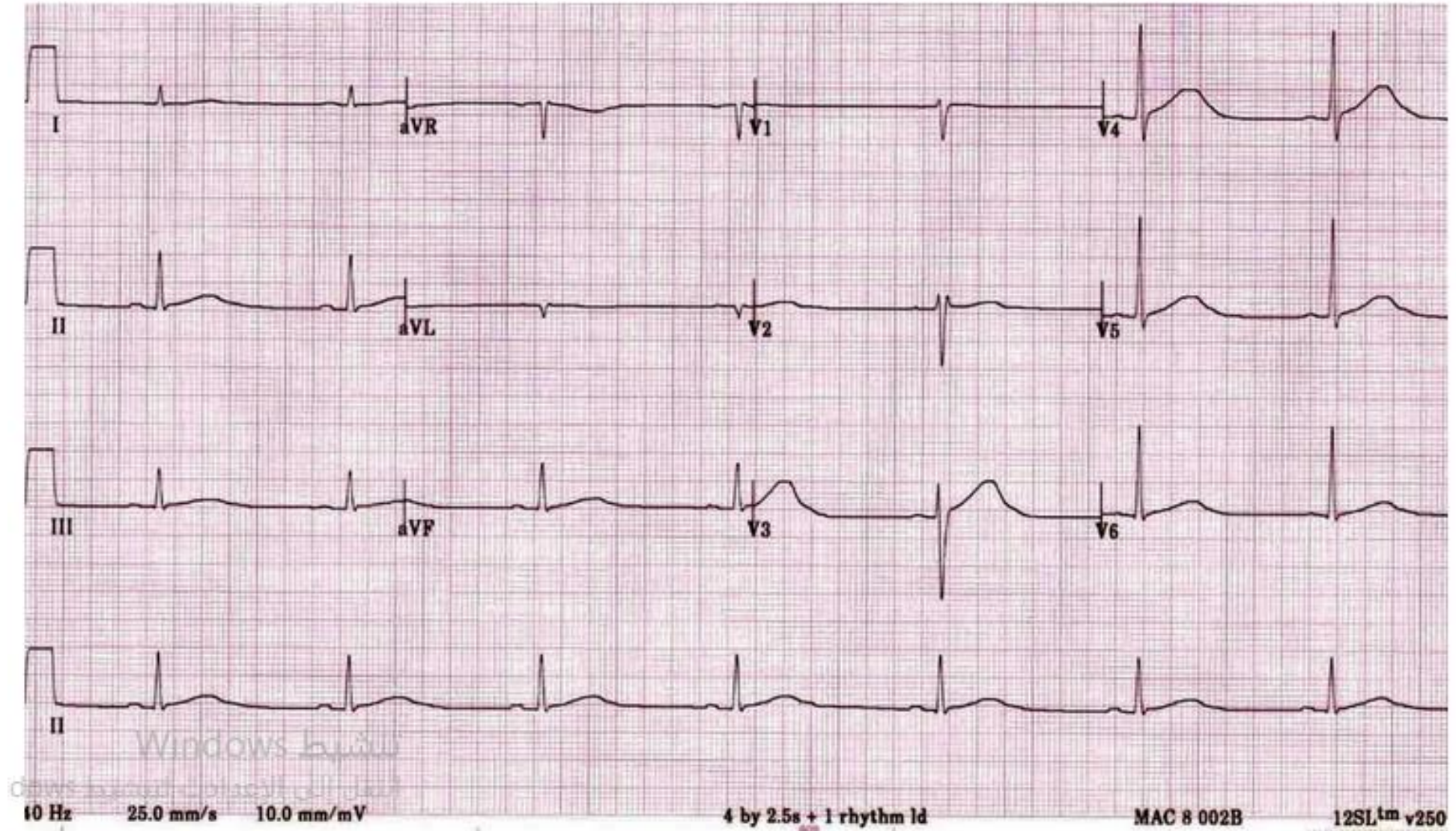
- Many Australian toxicologists use the QT interval nomogram to assess risk of TdP.
- The *absolute* QT interval is measured manually in multiple leads and the median QT interval plotted on the nomogram ([read how to do this here](#)).
- Plots *above* the line indicate significant QT prolongation and consequent risk of TdP.



By my measurements, our patient has an absolute QT of ~320 ms with HR 120 so plots below the line — i.e. *not* at significant risk of TdP.

Case 23

Elderly patient with accidental overdose of sotalol. Describe the ECG.



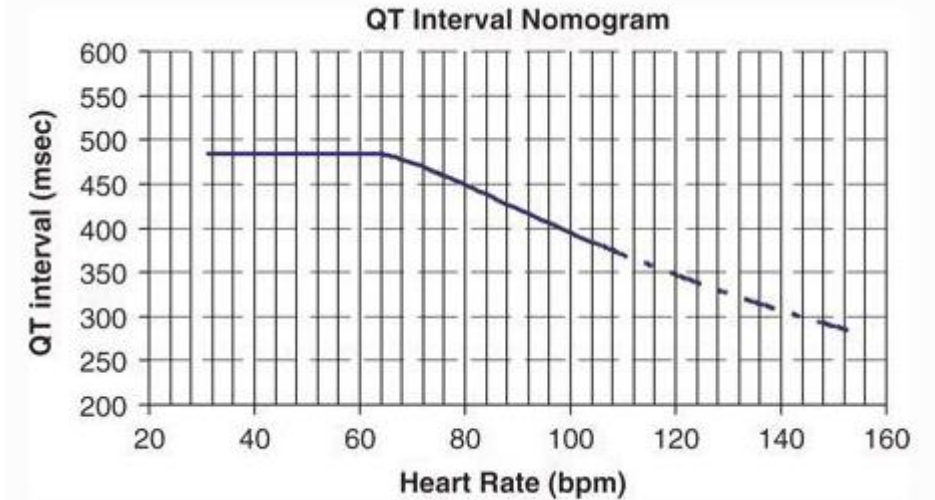
Main Abnormalities This ECG demonstrates the key features of sotalol toxicity:

- Sinus bradycardia (42 bpm)
- Very long QT interval (~600 ms).

Sotalol is a beta blocker with additional class III effects (potassium channel blockade), so it causes both bradycardia and QT prolongation in overdose.

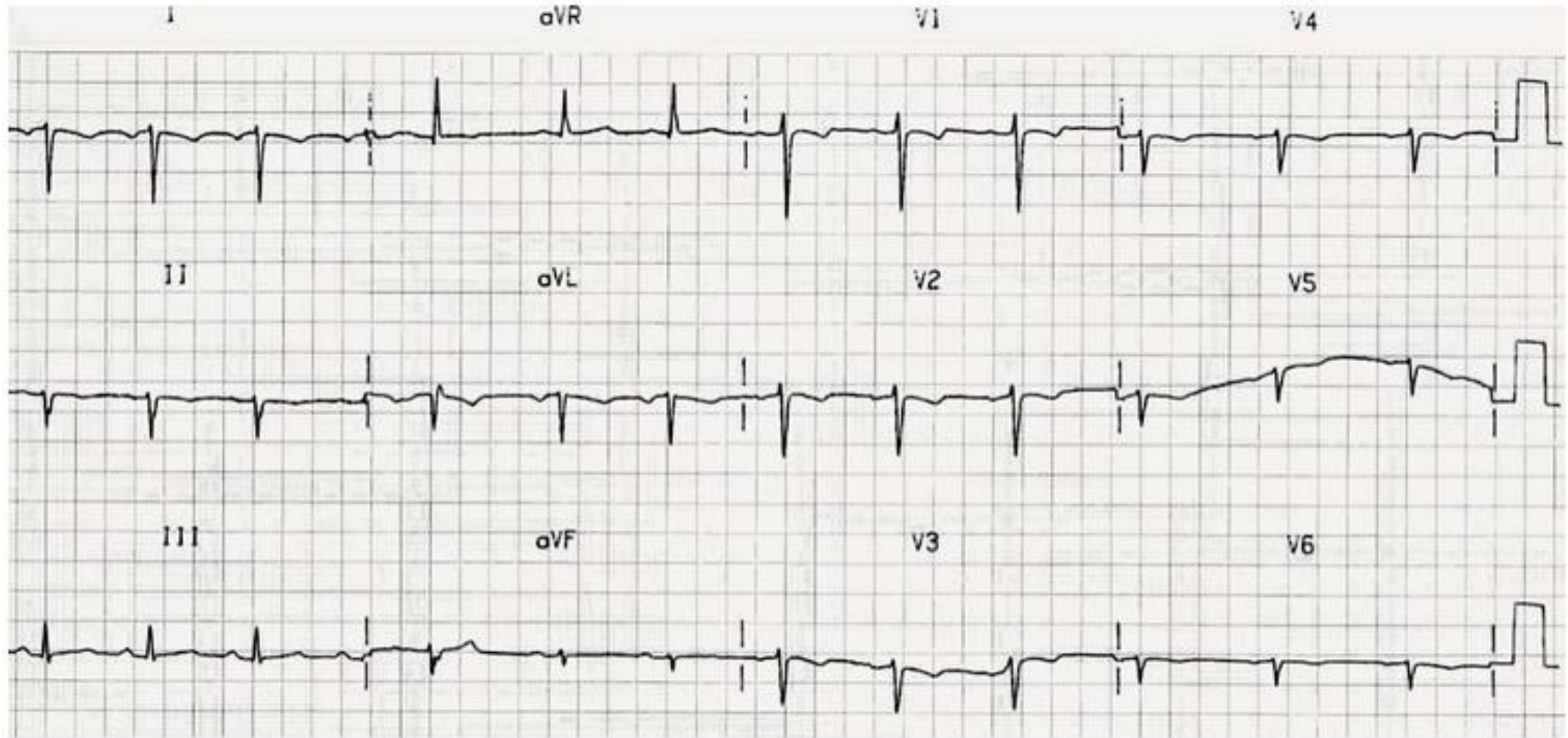
Risk of Torsades

- In comparison to the **previous case**, this patient is at significant risk of TdP.
- The combination of bradycardia and significant QT prolongation means that this patient plots well above the “at risk” line on the QT nomogram.
- Prophylaxis of TdP in this case would include correction of QT-dependent electrolytes (K, Mg, Ca) to the high-normal range and positive chronotropy (e.g. with isoprenaline) to move the patient below the at-risk line.



Case 24

Asymptomatic adult patient. Routine ECG. Describe the ECG.



Main Abnormalities

This ECG demonstrates the typical features of **dextrocardia**:

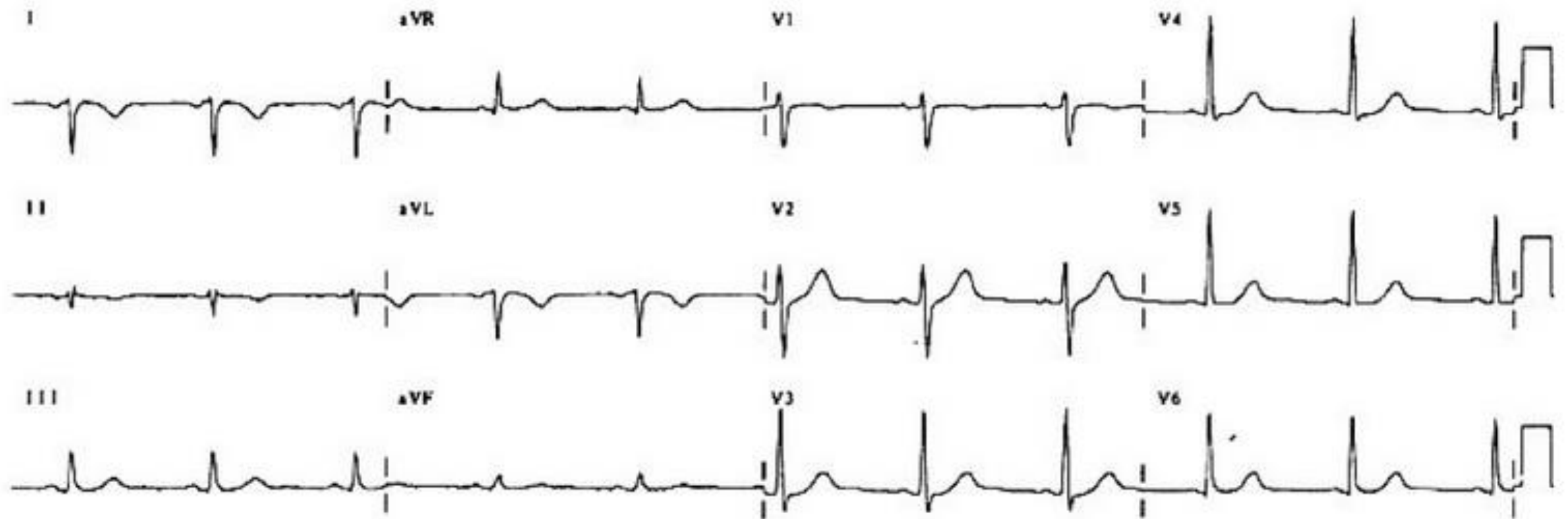
- Marked **right axis deviation** (+180 degrees).
- Lead aVR: Positive QRS complex (upright P and T waves).
- Lead I: inversion of all complexes, aka 'global negativity' (inverted P-QRS-T).
- Absent R-wave progression in the chest leads (dominant S waves throughout).

Differential Diagnosis

Accidental **reversal of the left and right arm electrodes** may produce a similar picture to dextrocardia in the limb leads, but with normal appearances in the precordial leads.

Case 25

Asymptomatic adult patient. Routine ECG. Describe the ECG.



Main Abnormalities This ECG is a classic example of limb lead misplacement with a **left arm / right arm lead reversal**:

- Positive P-QRS-T in lead aVR.
- Inverted complexes in leads I and aVL.
- Normal complexes in the precordial leads rules out **dextrocardia** (compare this to the **previous ECG**).

The most obvious abnormality on this ECG is the positive QRS complex in aVR. This is unusual and should always prompt a search for additional evidence of limb lead misplacement.

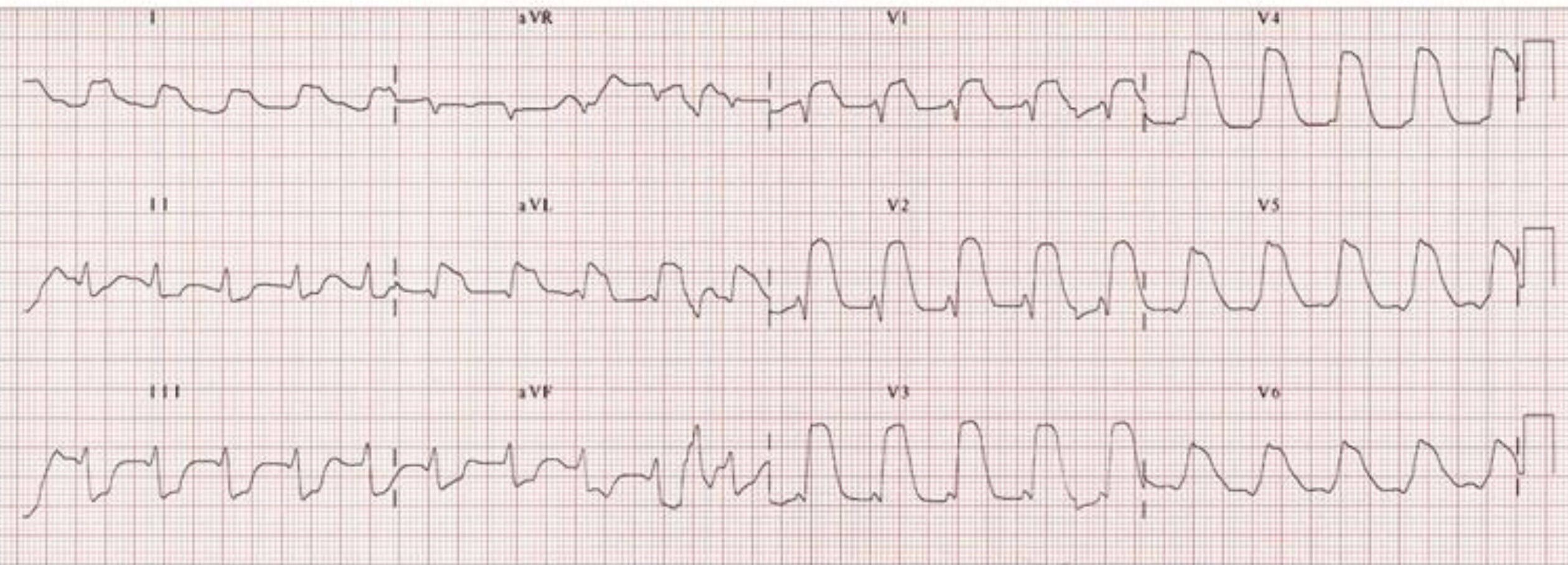
Effects of LA-RA lead reversal

Switching the LA and RA electrodes produces the following effects:

- Lead I becomes inverted.
- Leads II and III switch places.
- Leads aVL and aVR switch places (hence aVR becomes positive, aVL negative).
- Lead aVF remains unchanged

Case 26

70-year old patient presenting with chest pain and diaphoresis. Describe the ECG.



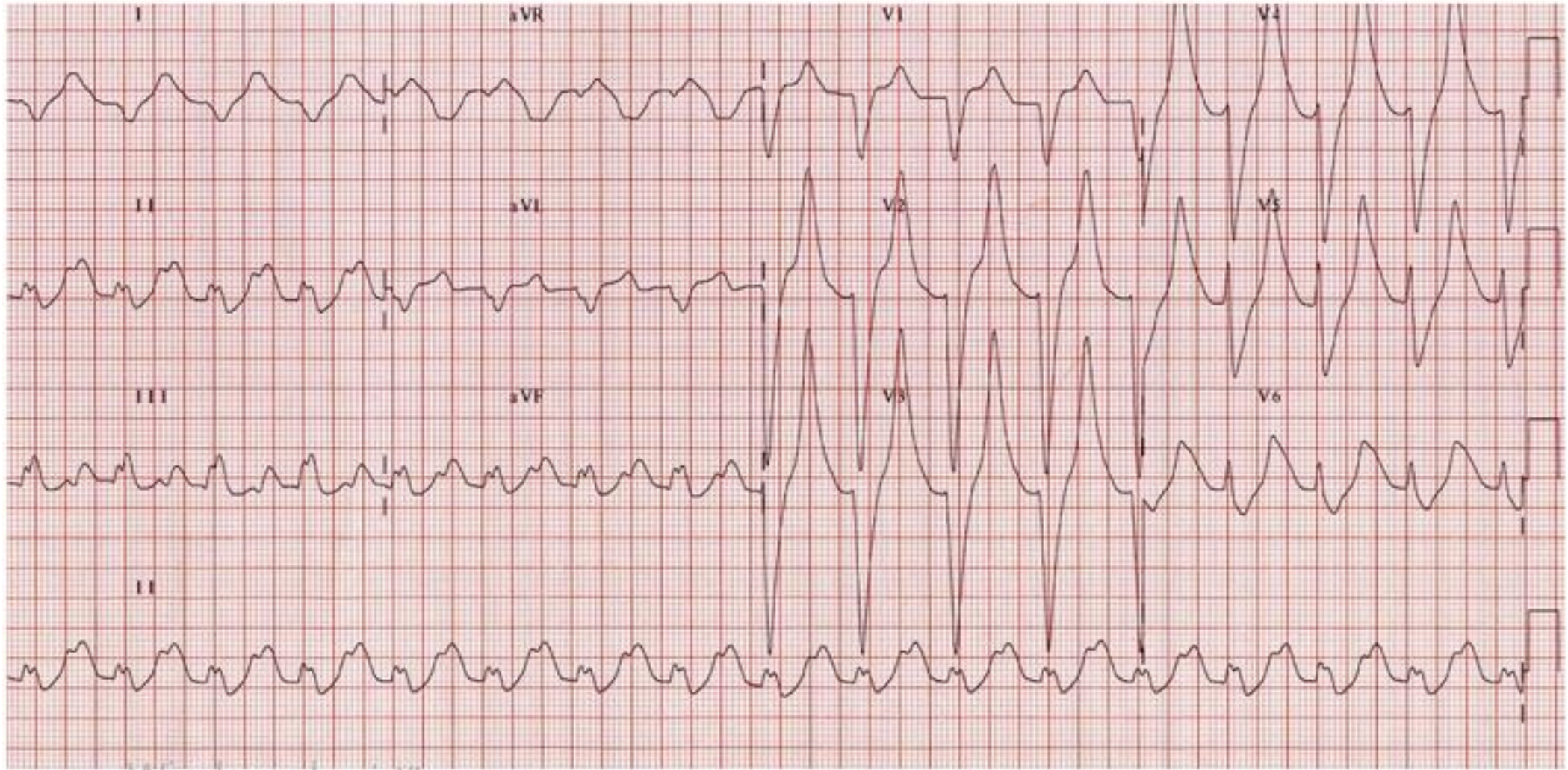
This is a very worrying ECG demonstrating massive **anterolateral STEMI** with “tombstone” morphology:

- Gross ST elevation in V1-6, I and aVL.
- Early Q wave formation in aVL.
- Reciprocal ST depression in inferior leads II, III and aVF.

This ECG pattern is seen in proximal LAD occlusion and indicates a large territory infarction with a poor LV ejection fraction and high likelihood of cardiogenic shock and death.

Case 27

Elderly patient feeling generally unwell. PMHx of T2DM, hypertension, IHD, CCF, osteoarthritis.
Describe the ECG.



Main Abnormalities

- Bizarre appearing complexes.
- Marked T wave peaking in V2-6.
- Gross QRS prolongation (~200 ms).
- Some leads (I, aVR) are starting to take on a sine wave appearance.

Diagnosis

The combination of...

- Bizarre complexes
- QRS prolongation
- Peaked T waves
- Sine wave appearance

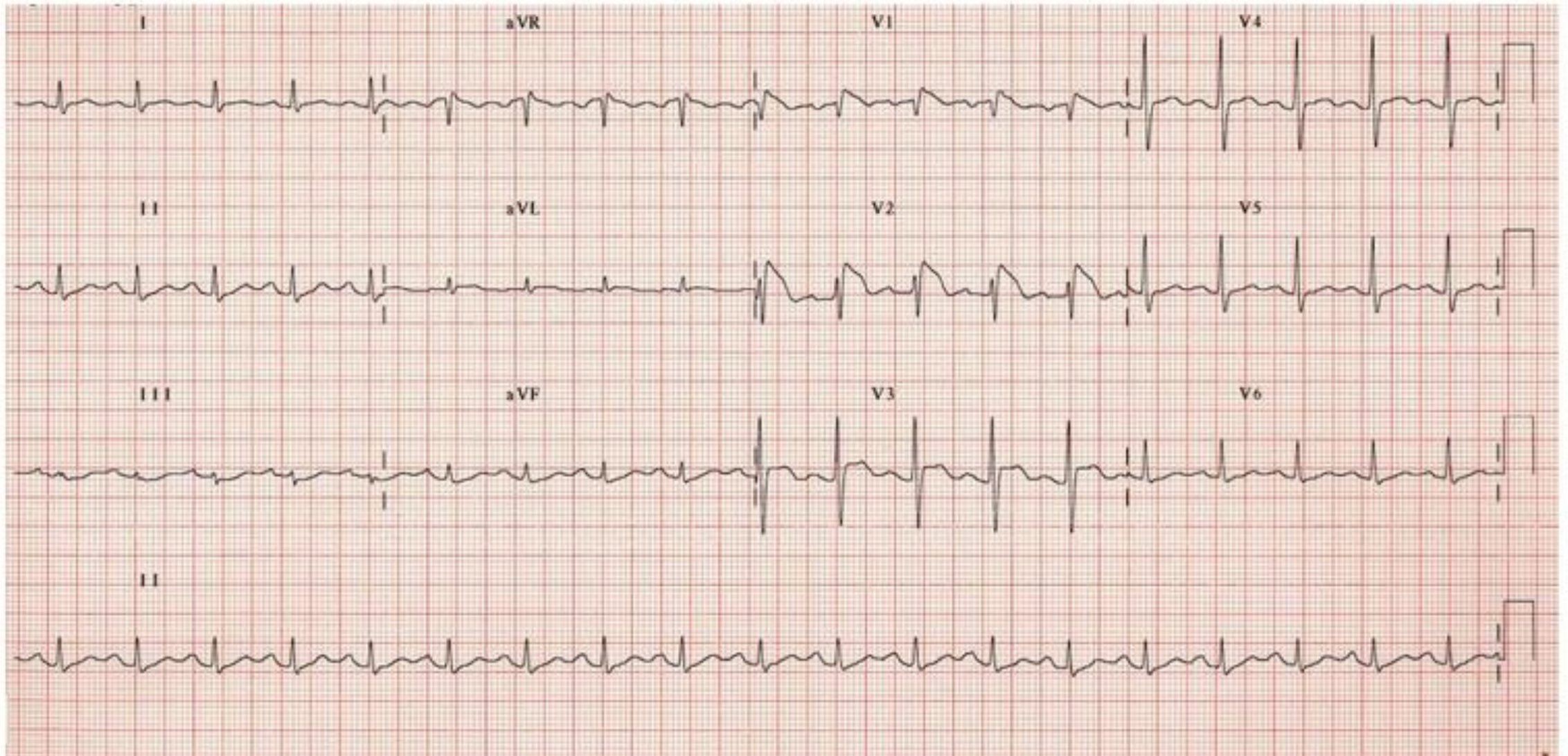
... are all strongly suggestive of **severe hyperkalemia**.

This patient had a serum K of 9.2 mmol/L!

In this elderly patient with multiple medical problems, causes could include renal failure (e.g. due to diuretics, NSAIDs, intercurrent illness) or treatment with ACE-inhibitors, spironalactone or K-supplements.

Case 28

30-year old Thai male presenting with syncope. Describe the ECG.



ECG Findings The patient is in sinus rhythm with no evidence of dysrhythmia or AV block.

The **QT interval** is normal and there is no evidence of **WPW syndrome**, **HOCM** or **ARVC**.

There is a characteristic pattern of abnormalities in V1-2:

- RSR' pattern / partial RBBB.
- ST elevation with a "coved" morphology.
- Inversion of the terminal portion of the T wave.

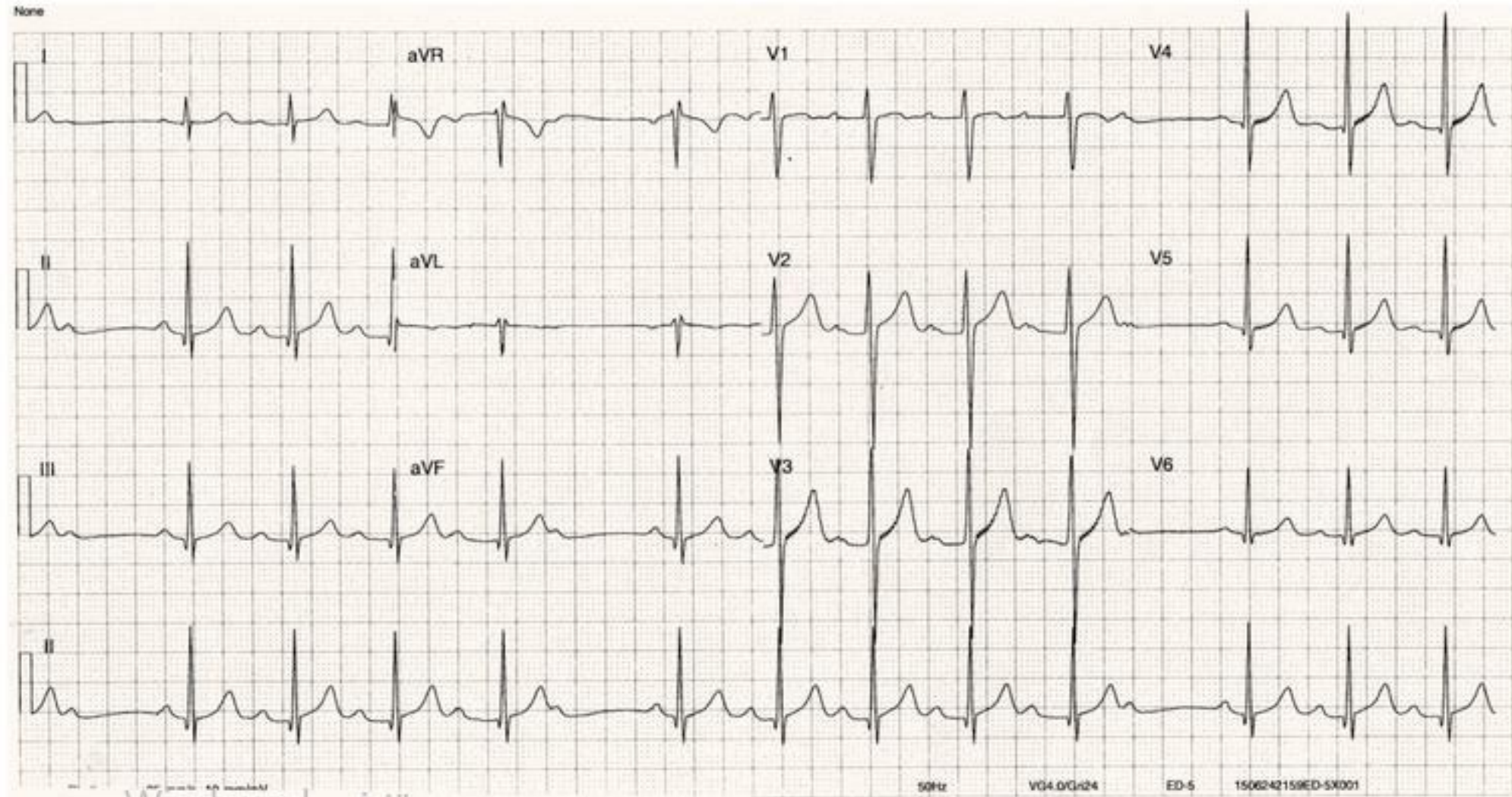
In a patient presenting with syncope, this ECG is diagnostic of the **Brugada syndrome**.



Classic appearance of Brugada syndrome in V2

Case 29

Asymptomatic 40-year old patient. Describe the ECG.



Main Findings

- Irregular narrow-complex rhythm (**overall rate = 72 bpm**).
- **Normal sinus P waves** are seen (upright in lead II), indicating a sinus origin of the rhythm.
- QRS complexes cluster in groups, separated by non-conducted P waves.
- The PR interval progressively prolongs within each group.
- The PR prolongation can be appreciated by comparing the first and last PR interval of each group.

Diagnosis

- This is the typical appearance of **2nd degree AV block with Mobitz I conduction (Wenchebach phenomenon)**.

Clinical Significance

In comparison to patients with **Mobitz II**, who typically require a pacemaker for prophylaxis of **complete heart block** and ventricular standstill, patients with Mobitz I do not necessarily need any intervention. This is provided that they are asymptomatic with a normal BP, and that reversible causes such as drug toxicity (**beta-blockers, digoxin**), **hyperkalaemia** and **myocardial ischaemia** have been excluded. The risk of progression to haemodynamically unstable AV block in these patients is very low.

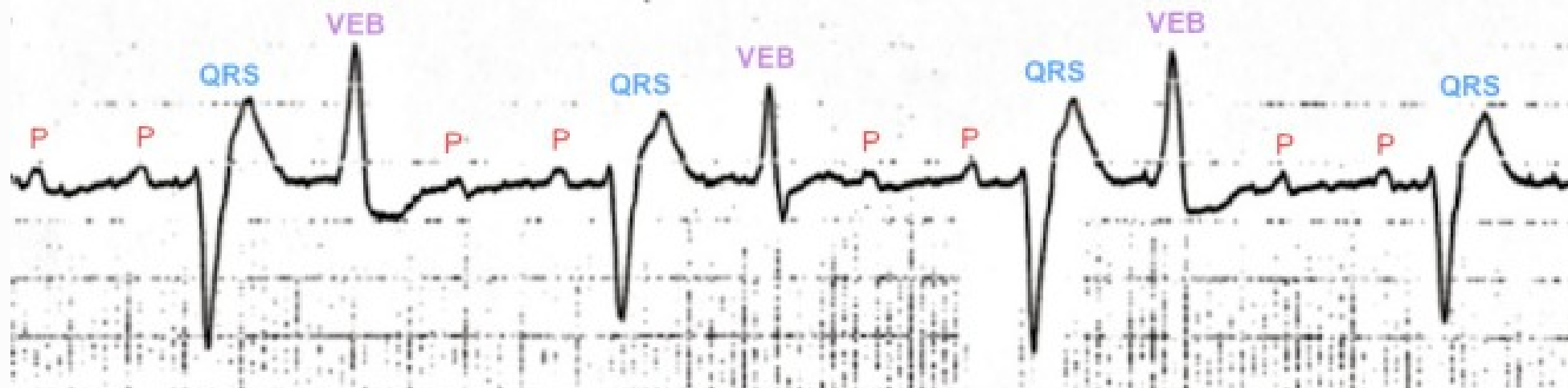
Case 30

85-year old patient presenting with nausea, vomiting and visual disturbance. Looks clinically dehydrated. Describe the ECG.



Main Abnormalities

- **Atrial tachycardia**, with regular P waves visible at ~ 160 bpm (many of the P waves are hidden within T waves and VEBs).
- Evidence of **high-grade AV block** — there is a 4:1 conduction ratio between P waves and QRS complexes, with a QRS rate of ~ 40 bpm.
- Frequent ventricular ectopic beats occurring in a pattern of **ventricular bigeminy**.
- **Alternating LBBB and RBBB morphology**, with the conducted QRS complexes demonstrating **RBBB morphology** (RSR' in V1) and the VEBs demonstrating **LBBB morphology** (dominant S wave in V1).



Diagnosis

The combination of...

- Atrial tachycardia
- Frequent ventricular ectopic beats
- High-grade AV block

... is almost pathognomonic of **severe digoxin toxicity**.

ECG Features of Digoxin Toxicity

Digoxin toxicity produces a wide variety of dysrhythmias, due to:

- **Increased automaticity** of atrial and ventricular tissues — via actions at the Na/K and Na/Ca exchangers causing increased intracellular calcium and therefore increased spontaneous depolarisation of cardiac pacemaker cells.
- **Decreased AV conduction** — via increased vagal tone at the AV node.

Digoxin toxicity therefore usually produces some combination of:

- **Increased atrial automaticity** — especially atrial tachycardia, but also atrial ectopics, AF, flutter.
- **Increased ventricular automaticity** — frequent VEBs and bigeminy, polymorphic VT.
- **AV blocks** — including 1st, 2nd and 3rd degree AV block.

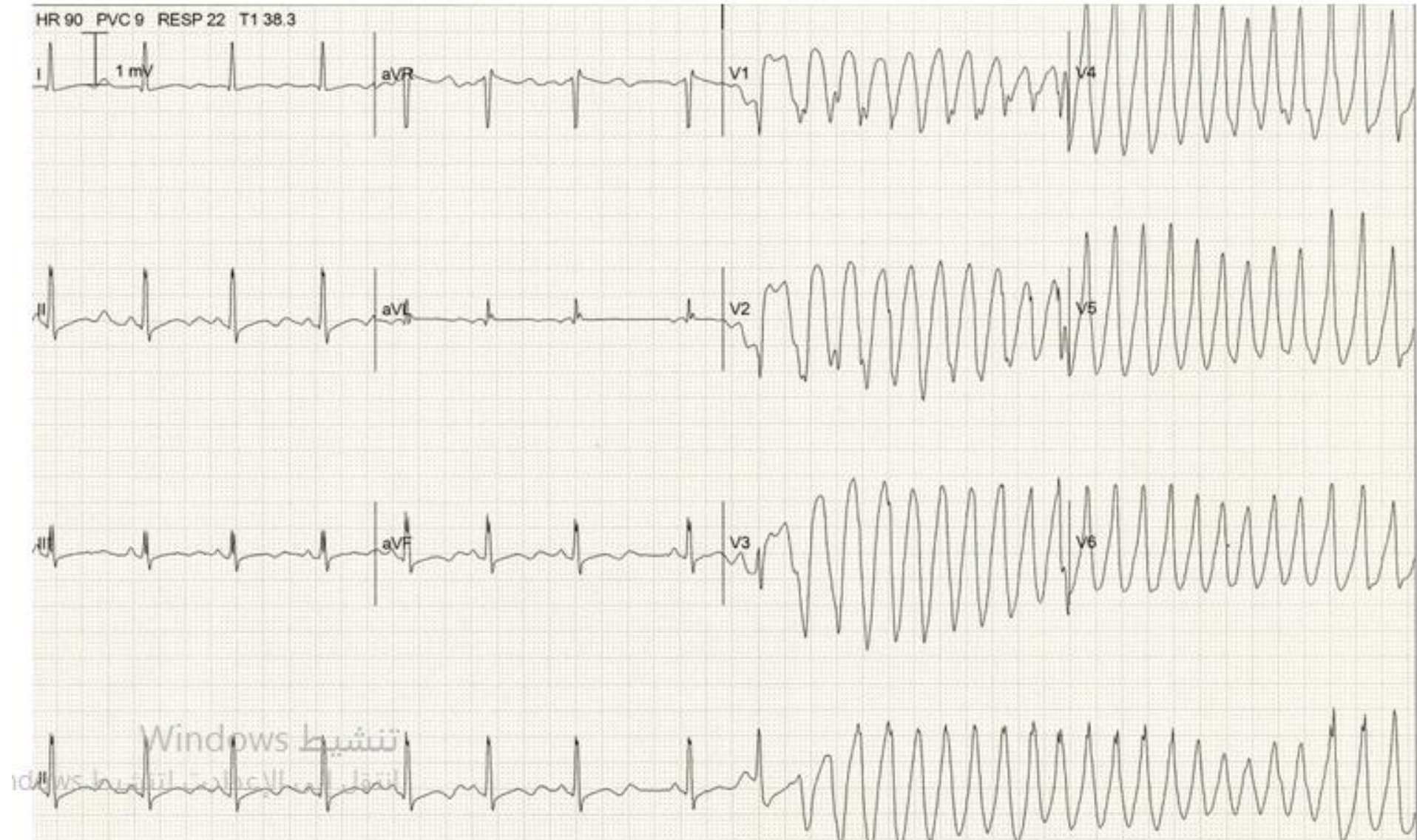
Characteristic ECG patterns include:

- Atrial tachycardia with high-grade AV block (= the classic dig-toxic rhythm).
- “Regularised AF” = AF with complete heart block + accelerated junctional escape rhythm, producing a paradoxically regular rhythm.
- Bidirectional VT = polymorphic VT with QRS complexes that alternate between left- and right-axis-deviation, or between LBBB and RBBB morphology.

NB. Digoxin toxicity should not be confused with digoxin effect (= “sagging” ST depression and T-wave inversion in patients on therapeutic doses of digoxin; not predictive of toxicity).

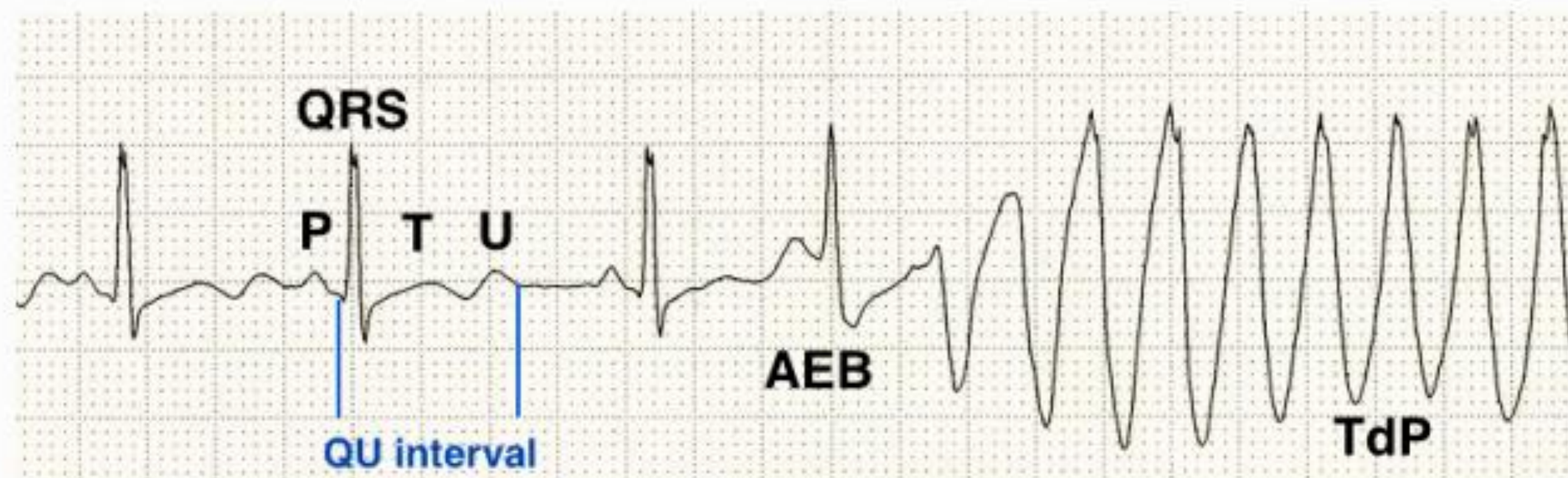
Case 31

Young adult patient presenting with syncope. History of eating disorder. Describe the ECG.



Main Abnormalities

- The first half of the ECG shows sinus rhythm with **prominent U waves** and a **long QU interval** (520ms).
- An **atrial ectopic beat** kicks off a run of **Torsades de Pointes** by landing on the T/U wave during the vulnerable phase of repolarisation and causing "R on T" (or "R on U") phenomenon.



Diagnosis

The combination of...

- Atrial ectopy
- Prominent U waves
- Long QU interval
- Torsades de Pointes

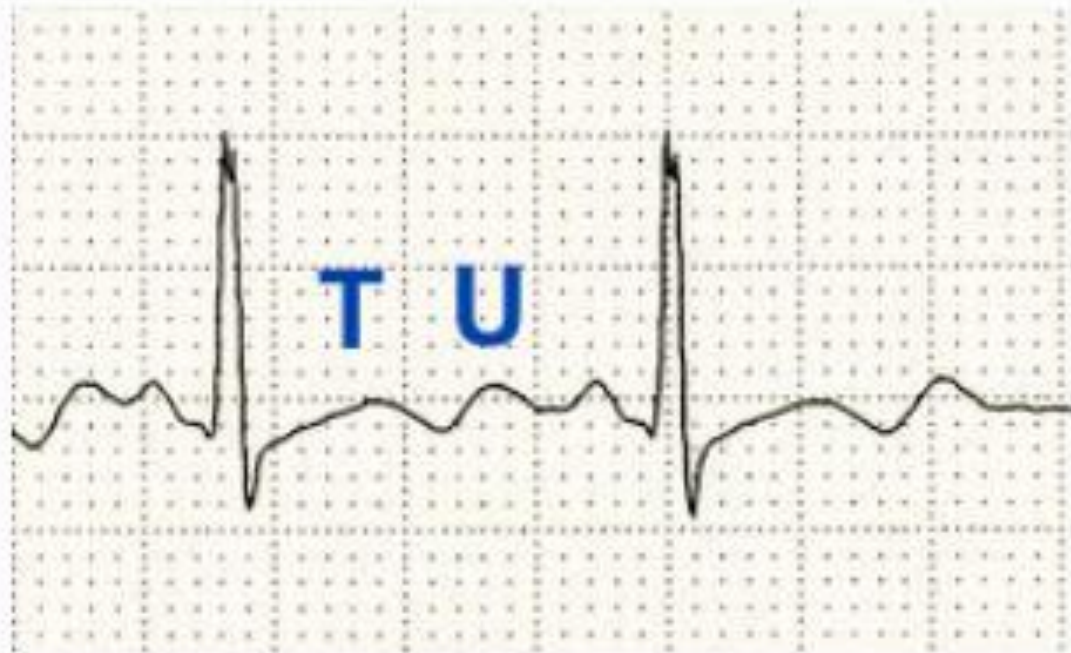
... is strongly suggestive of **severe hypokalaemia**. This patient had a K of 1.9 mmol/L.

Hypokalaemia occurs in eating disorders via multiple mechanisms including:

- Loss of K⁺ in bodily secretions — vomiting, purging with laxatives or diuretics.
- Reduced oral intake.
- Metabolic alkalosis from vomiting causing intracellular shifts of K⁺.
- Hypovolaemia causing secondary aldosteronism with renal loss of K⁺.

U wave morphology

The appearance of U waves in hypokalemia may vary. This example demonstrates discrete U waves that are clearly distinguishable from the T wave. Compare this with [Quiz ECG 006](#), where the whole ST-T-U complex is fused together to produce a “rollercoaster” appearance, with the U wave appearing as a positive deflection that emerges from a negative ST segment and T wave.



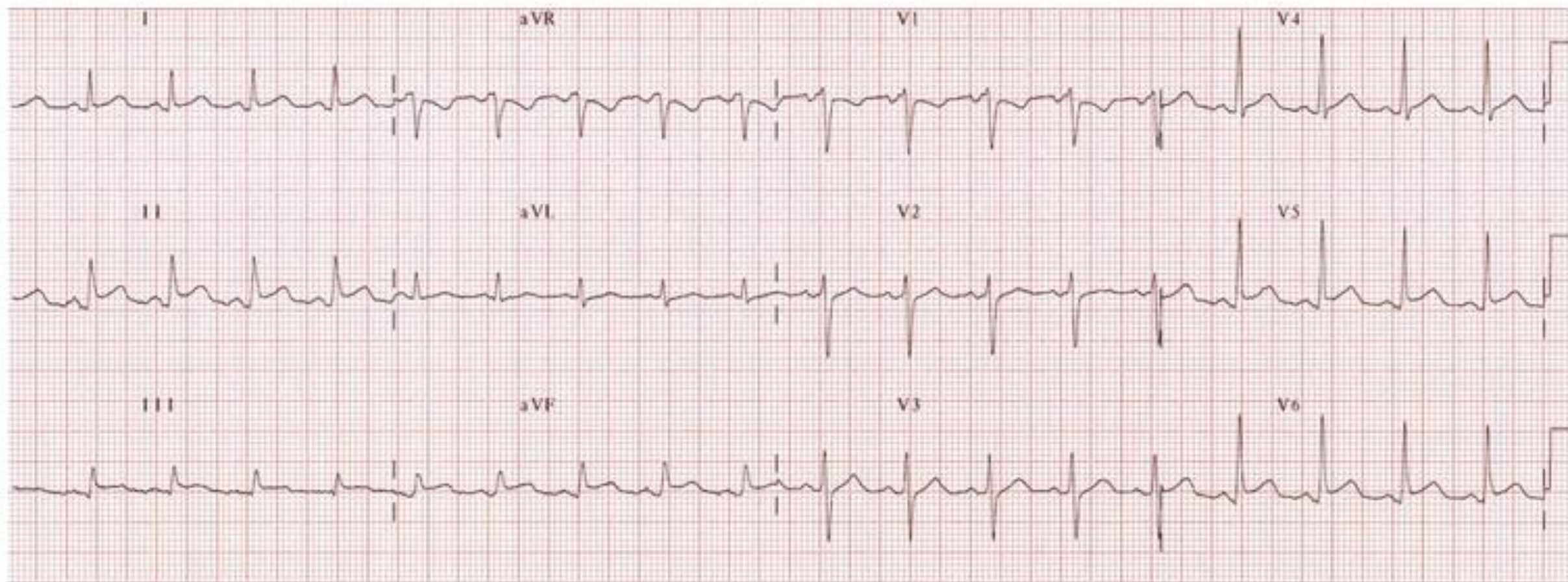
Discrete U waves



“Rollercoaster” U waves

Case 32

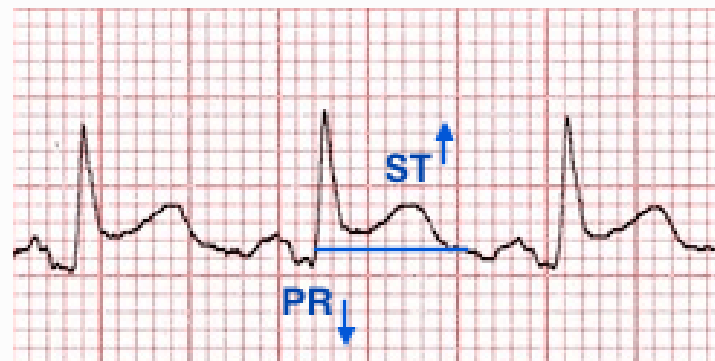
Young adult patient with pleuritic chest pain. Describe the ECG.



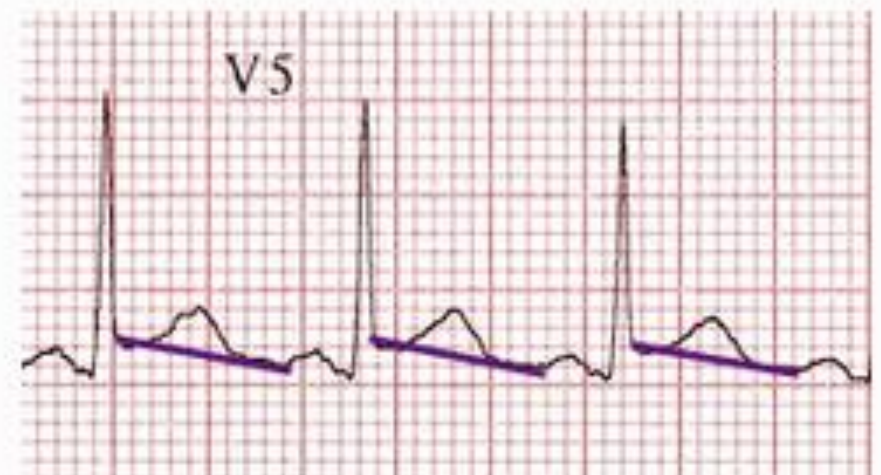
Main Abnormalities

This ECG demonstrates many of the classic features of **acute pericarditis**:

- Widespread concave ST elevation with PR depression — most notable in I, II, III, aVF, V5-6.
- PR elevation in the inverted leads aVR and V1.
- Downward sloping of the TP segment = "**Spodick's sign**".
- No reciprocal changes of STEMI.
- **ST segment / T wave ratio > 0.25** (favours pericarditis over **BER**)



ST elevation and PR depression



Spodick's sign

Pericarditis versus Benign Early Repolarisation

Pericarditis can be difficult to differentiate from **BER** as both conditions are associated with concave STE. One useful trick to distinguish between these two entities is to look at the **ST segment / T wave ratio**.

- The amplitude of the STE (from PR segment to J point) is measured in V6 and compared to the T wave amplitude.
- A ratio of > 0.25 suggests pericarditis
- A ratio of < 0.25 suggests BER

Example 1: Benign Early Repolarisation



- ST segment height = 1 mm
- T wave height = 6 mm
- ST / T wave ratio = 0.16
- The ST / T wave ratio < 0.25 is consistent with BER.

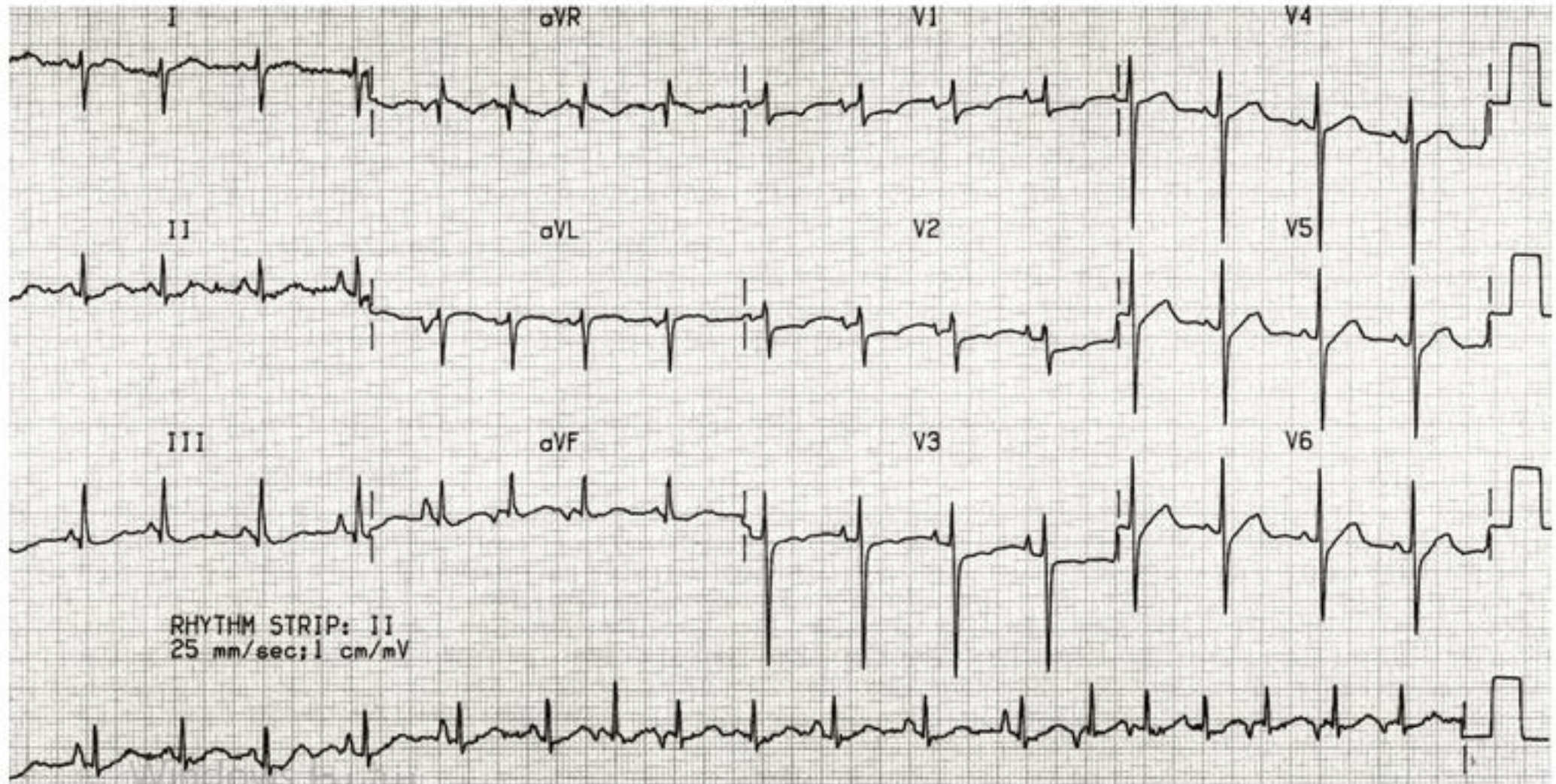
Example 2: Pericarditis



- ST segment height = 2 mm
- T wave height = 4 mm
- ST / T wave ratio = 0.5
- The ST / T wave ratio > 0.25 is consistent with pericarditis.

Case 33

75-year old patient presenting with acute dyspnoea, productive cough and wheeze. Describe the ECG.



Main Abnormalities

- Irregularly irregular narrow-complex tachycardia at ~ 110 bpm.
- At least 3 different P wave morphologies seen in the lead II rhythm strip, indicating multiple foci of activity within the atria.
- No flutter or fibrillatory waves — rules out AF or flutter with variable block.
- Evidence of right ventricular hypertrophy — RAD, dominant R wave in V1, deep S wave in V6.

Diagnosis

The combination of...

- Irregular narrow-complex tachycardia (> 100 bpm)
- Multifocal atrial activity (3 or more distinct P wave morphologies)
- No evidence of flutter / AF

... is diagnostic of multifocal atrial tachycardia (MAT).

ECG changes of right ventricular hypertrophy may represent *cor pulmonale* due to COPD.

Clinical Significance

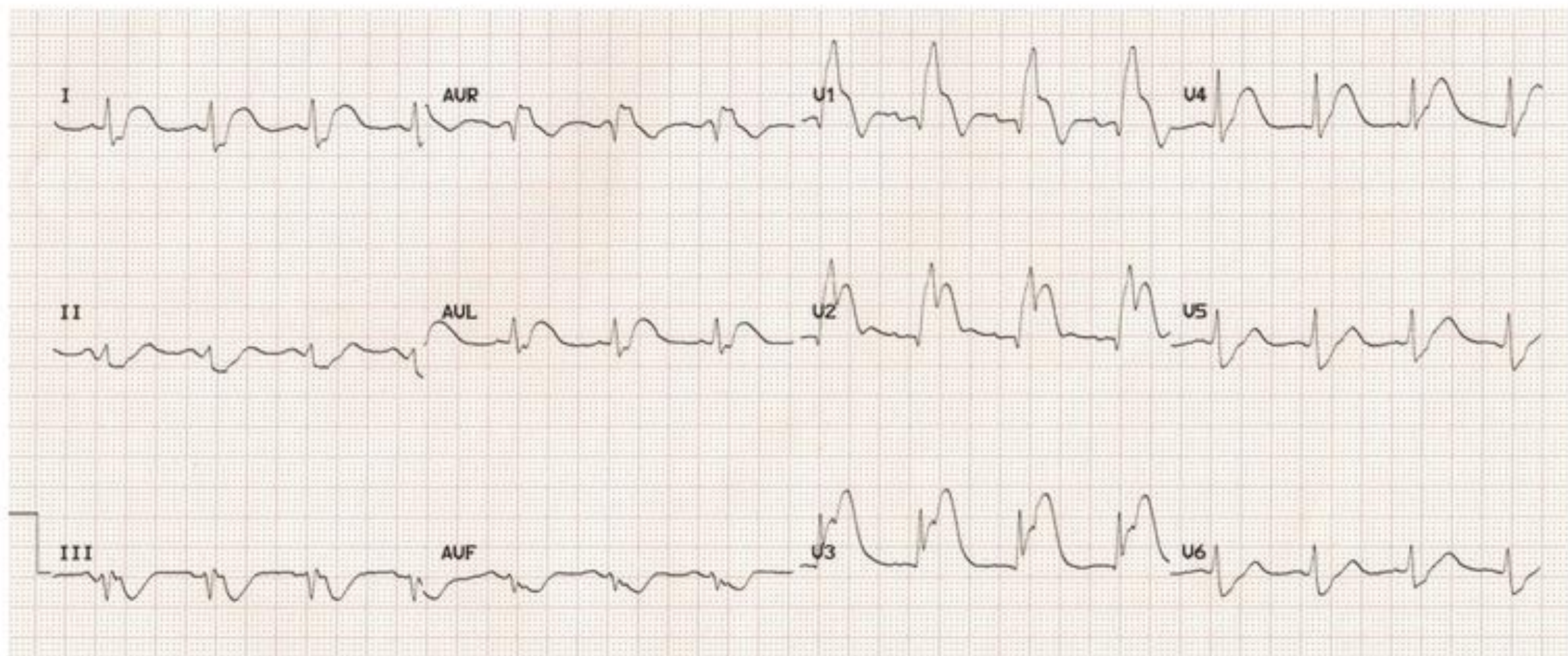
MAT typically occurs in patients with severe COPD, as the final common pathway of multiple arrhythmogenic mechanisms:

- Right atrial dilatation (from *cor pulmonale*).
- Increased sympathetic drive — due to hypoxia / hypercarbia.
- Bronchodilators — beta-agonist, theophylline.
- Electrolyte abnormalities — hypokalaemia and hypomagnesaemia (e.g. secondary to diuretics / beta-agonists).

MAT typically resolves with treatment of the underlying COPD exacerbation and correction of any electrolyte abnormalities, although it may evolve into AF or flutter.

Case 34

Middle-aged patient presenting with chest pain. Describe the ECG.

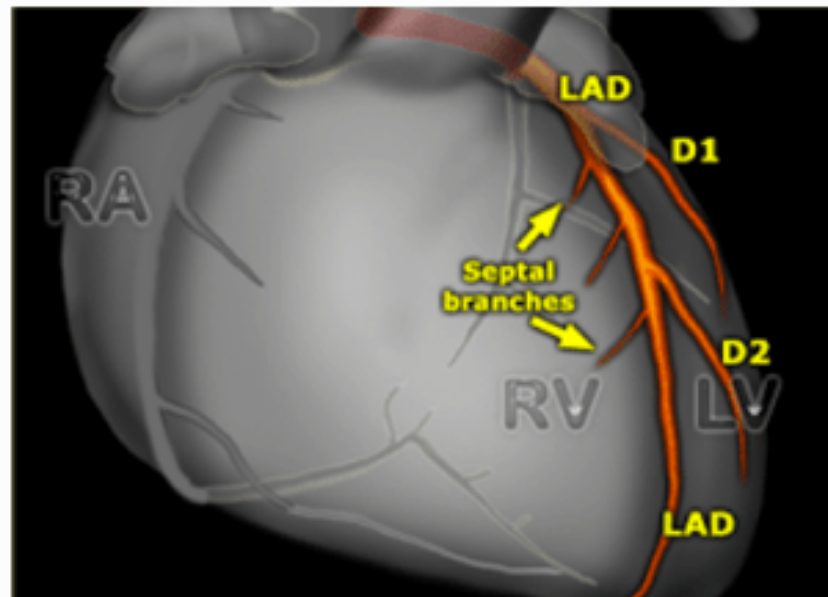


Main Abnormalities The ECG changes are partially masked by the presence of a **right bundle branch block**, but there is clear evidence of **anteroseptal STEMI**:

- Gross ST elevation in V1-3 (~ 5mm in V2).
- Convex ST elevation in I and aVL.
- Reciprocal ST depression and T wave inversion in the inferior leads (II, III, aVF).

Predicting the Site of LAD Occlusion

This ECG demonstrates some markers of a **very proximal LAD occlusion**, involving the two most proximal branches of the LAD — the first septal branch (S1) and the first diagonal branch (D1).



Signs of occlusion proximal to S1

Signs of occlusion proximal to D1

This patient arrived by ambulance following an out-of-hospital VF arrest and was taken straight to the cath lab where he was found to have a complete ostial occlusion of his LAD.

A Common Pitfall

This STEMI pattern is occasionally missed, when clinicians erroneously attribute the ST segment changes in V1-3 to RBBB alone.

However, the two patterns are quite different:

- Typical RBBB will have ST depression and TWI in V1-3.
- Superimposed septal STEMI will lead to ST elevation, Q wave formation, loss of the initial R wave and inversion of only the terminal portion of the T wave.



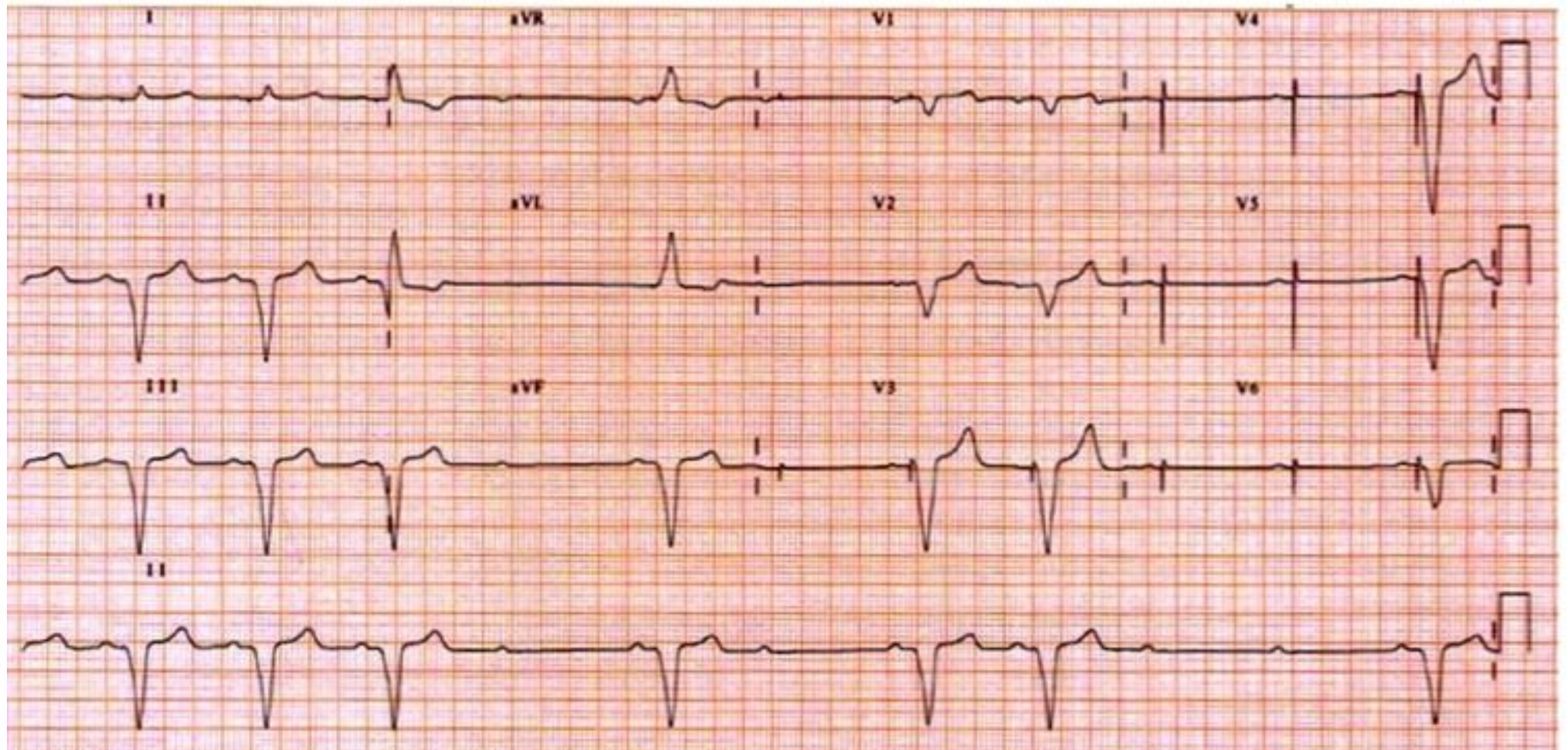
Typical RBBB



RBBB + STEMI

Case 35

80-year old patient presenting with syncope. Describe the ECG.



On first glance this ECG could easily be mistaken for an example of **Mobitz II AV block** — there are intermittent non-conducted P waves with a constant PR interval. However, regular **pacing spikes** can be seen following the P waves in leads V3-6.

This is an example of **pacemaker malfunction**, with intermittent **failure to capture**:

- Regular P waves are seen at ~65 bpm.
- Each P wave is followed by a pacing spike (best seen in V3-6, subtle pacing spikes also present in I, aVR, V1). This indicates that **atrial sensing** is intact. *NB. Pacing spikes will typically not be seen in all 12 leads.*
- Some of the pacing spikes are followed by typical **ventricular-paced** complexes. The **LBBB morphology** indicates that the pacing lead is in the right ventricle — the heart depolarises from right to left in the same way as LBBB. Also note the **negative concordance** in V1-6 (all QRS complexes are negative). This is often quoted as a feature of **ventricular tachycardia**, but simply indicates that the rhythm is arising from the anterior surface of the right ventricle — the heart is depolarising away from the V1-6 electrodes.
- Several of the P waves / pacing spikes are not followed by QRS complexes, producing a ventricular rate of ~ 40 bpm.
- Quite worryingly, there does not seem to be any native ventricular activity kicking in when the heart rate drops. The second half of the rhythm strip shows two sequential non-conducted P waves with no evidence of any **escape rhythm**. This suggests the presence of underlying **complete heart block** with inadequate escape mechanisms and significant risk of ventricular

standstill.

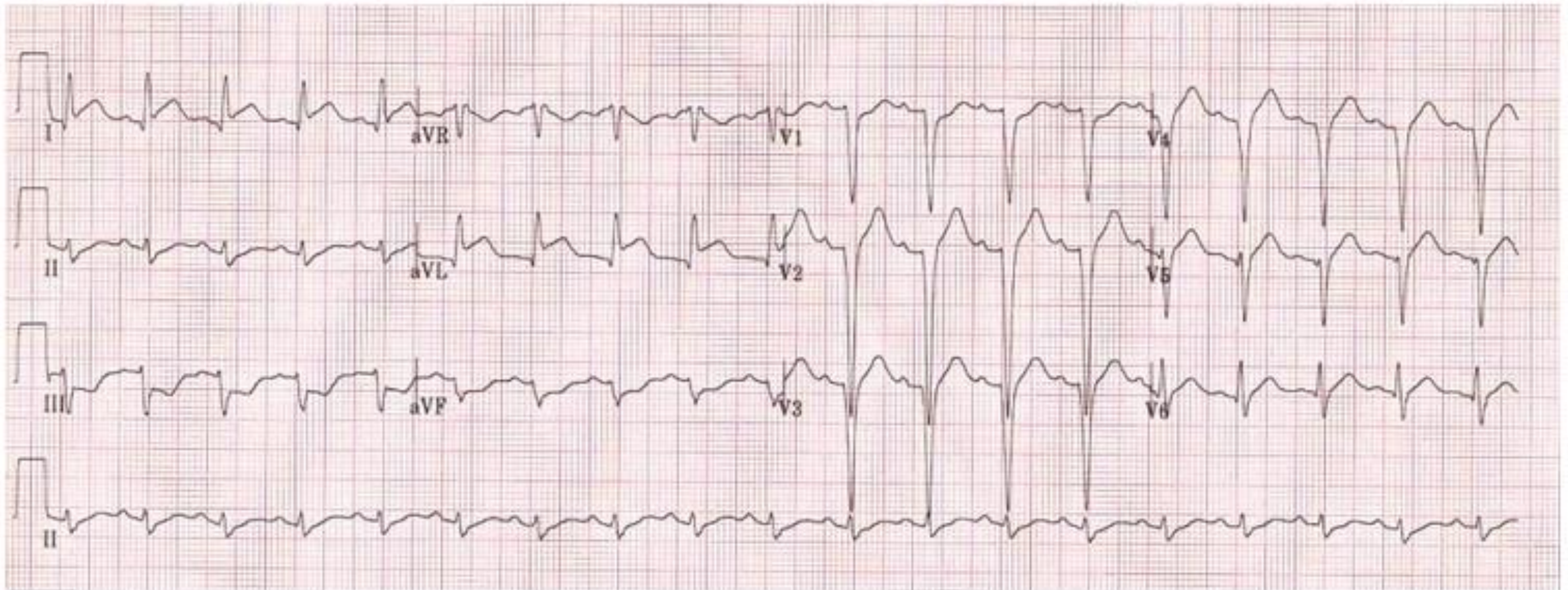
Failure to Capture

The problem here is failure of the pacemaker to “capture” (depolarise) the ventricular myocardium. Causes of this include:

- Pacemaker lead fracture or migration (e.g. due to **Twiddler's syndrome**).
- Refractory myocardium — due to electrolyte abnormality (esp. **hyperkalaemia**) or **myocardial ischaemia**.

Case 36

Middle-aged patient presenting with chest pain. Describe the ECG.



Main Abnormalities This ECG is a good example of **high lateral STEMI**:

- ST elevation is confined primarily to the high lateral leads I and aVL.
- There is reciprocal ST depression in the inferior leads II, III and aVF.
- The deep Q waves and poor R wave progression in V1-4 suggest prior **anteroseptal infarction** or **dilated cardiomyopathy**.

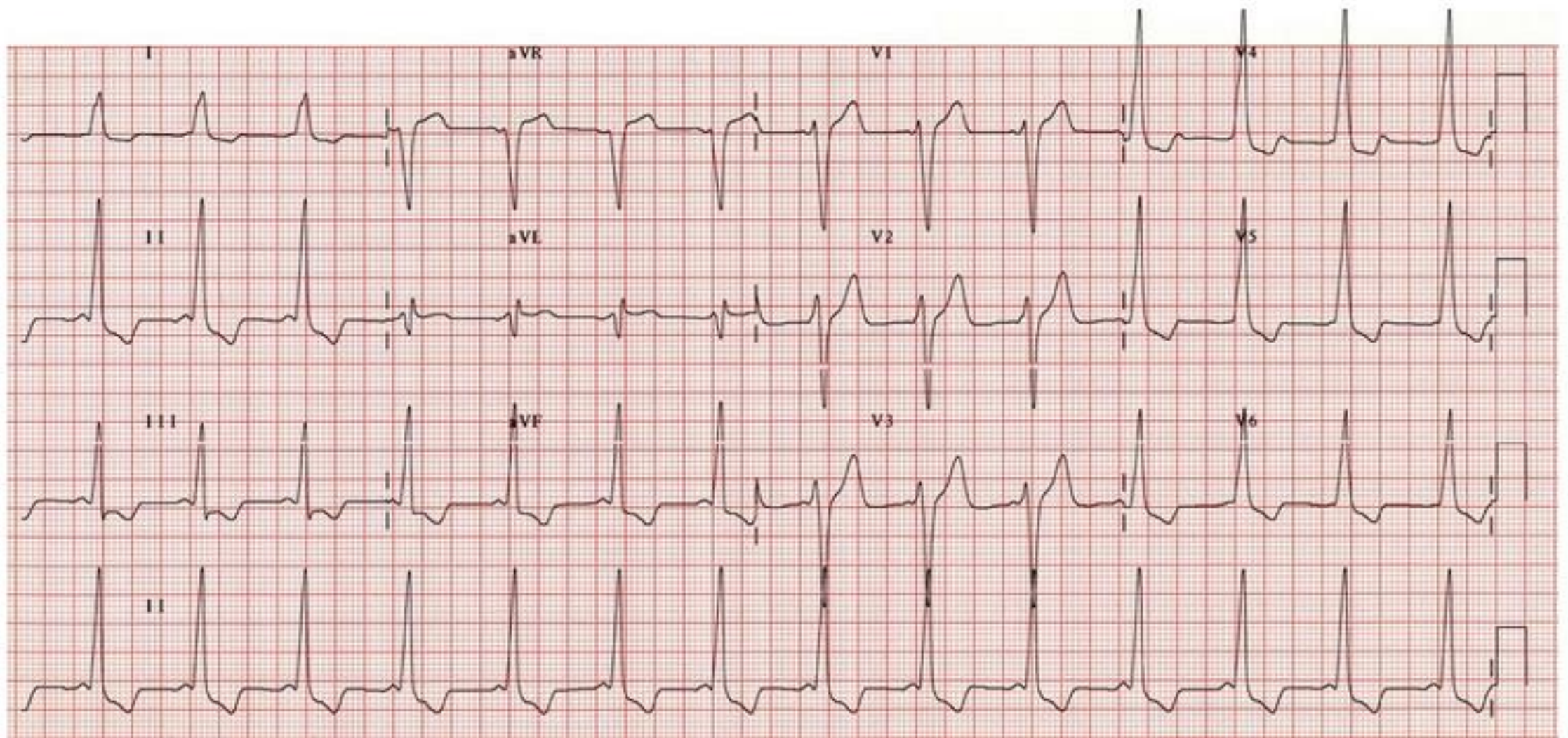
High lateral STEMI is classically associated with occlusion of the **first diagonal branch (D1) of the LAD**, but may also occur with occlusion of the obtuse marginal branch (OM) of the circumflex artery, or the ramus intermedius.

Clinical Pearls

High lateral STEMI may be extremely subtle. Sometimes the only clue is the presence of new inferior ST depression. Such localised ST depression should always be considered to be reciprocal change rather than "inferior ischaemia" as **subendocardial ischaemia does not localise**.

Case 37

15-year old patient presenting with rapid palpitations and dizziness. Symptoms resolved en route to hospital. Describe the ECG.



Main Abnormalities

This ECG is diagnostic of the **Wolff-Parkinson-White (WPW) syndrome**:

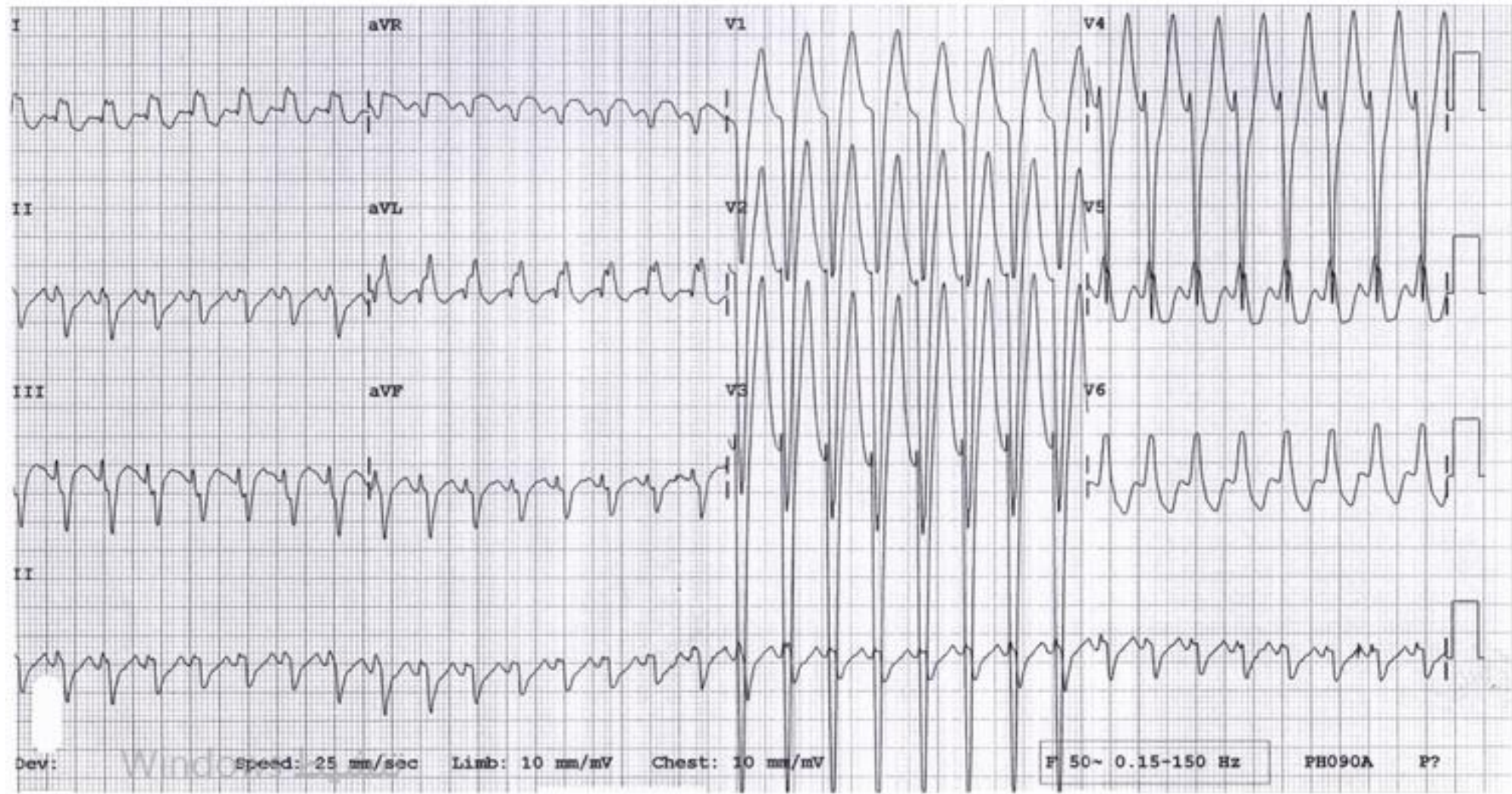
- Sinus rhythm with a very **short PR interval** ($< 120\text{ms}$).
- Broad QRS complexes.
- **Delta waves** = slurred upstroke to the QRS.

Other Features:

- Dominant S wave in V1 — this “type B” pattern indicates a right-sided accessory pathway.
- Tall R waves and inverted T waves mimic the appearance of **LVH** — this is an electrical phenomenon due to WPW and not a sign of ventricular hypertrophy.
- ST segments and T waves show typical “discordant” changes — they point in the opposite direction to the QRS complex, similar to **LBBB**.

Case 38

15-year old patient presenting with rapid palpitations and dizziness. Symptoms recur in ED.
Describe the ECG.



Main Abnormalities

- Very rapid, regular broad-complex tachycardia (~ 200 bpm).
- LBBB morphology (dominant S wave in V1).
- No clear atrial activity — no flutter waves or fibrillatory waves.
- No obvious **diagnostic features for VT**.

Differential Diagnosis

In a patient presenting with a regular broad-complex tachycardia and no evidence of atrial activity, the main diagnostic considerations are:

- **Ventricular tachycardia**.
- **SVT** with aberrant conduction due to **bundle branch block**.
- **SVT** with aberrant conduction due to **WPW**.

Although **diagnostic criteria** exist to aid in differentiation of these rhythms, none of them have 100% sensitivity or specificity — leading many authors to recommend treating as VT if uncertain.

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However, clinical context is everything...

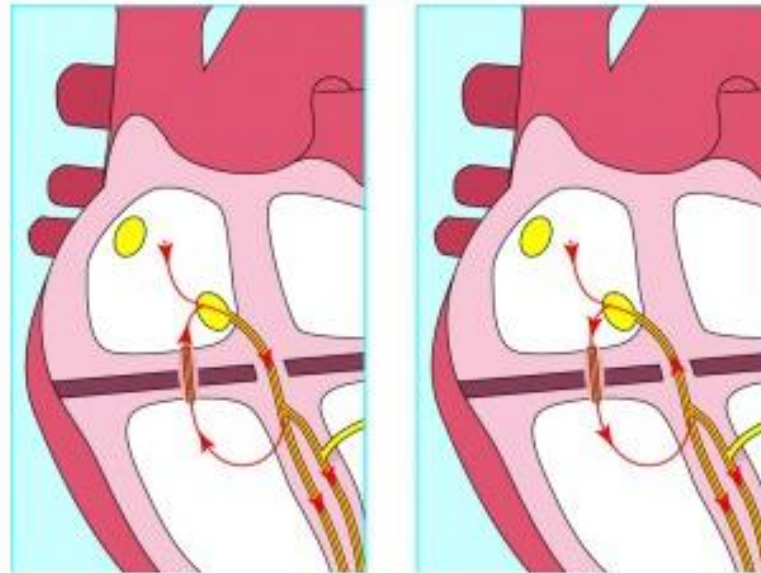
This patient has two strong indicators of SVT with aberrancy:

- Young age — the vast majority of BCTs in children are SVT with aberrancy.
- Evidence of WPW on **previous ECGs**.

Diagnosis

This is an example of **antidromic AV reentry tachycardia** — a reentrant SVT seen in WPW where the impulse travels from atria to ventricles via the accessory pathway, recycling backwards through the AV node (hence “antidromic”). Activation of the ventricles via the accessory pathway produces a broad complex that may be indistinguishable from VT. This is in comparison to orthodromic SVT, where the impulse travels forwards through the AV node producing a normal-looking, narrow QRS.

*This patient reverted back to sinus rhythm with vagal manoeuvres. The WPW pattern was once again visible on his **sinus rhythm ECG**.*

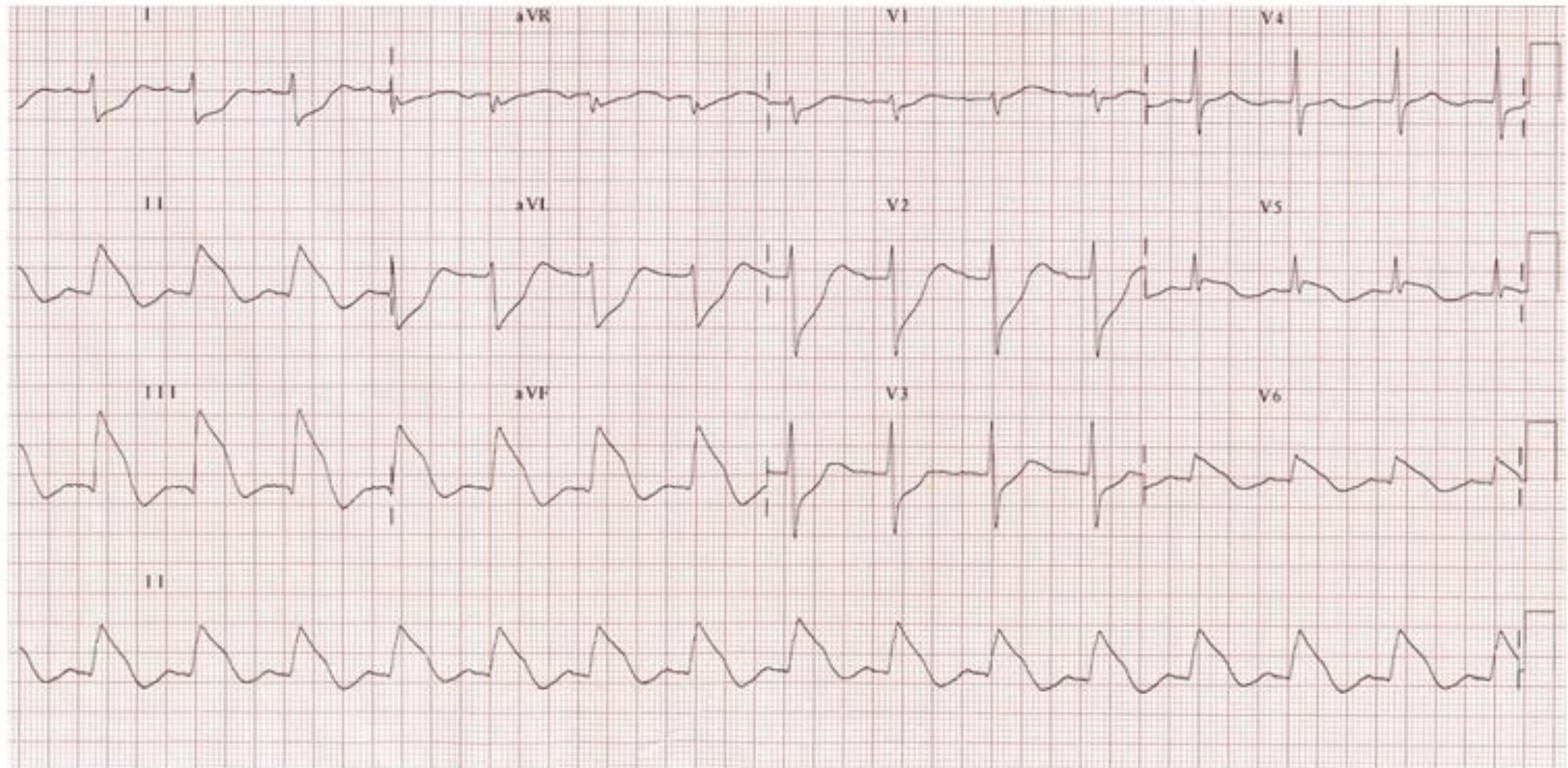


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**AVRT with orthodromic (left) and
antidromic (right) AV nodal conduction**

Case 39

Elderly patient presenting with chest pain. BP 80/50. Describe the ECG.



This ECG shows extensive **infero-postero-lateral STEMI** with “tombstone” morphology:

- Gross ST elevation in II, III, aVF consistent with **inferior infarction**.
- Reciprocal ST depression seen in I, aVL.
- ST elevation in V5-6 indicating **lateral wall involvement**.
- ST depression in V2 is suggestive of associated **posterior wall infarction** — the morphology is the exact inverse of the ST elevation in the inferior leads.

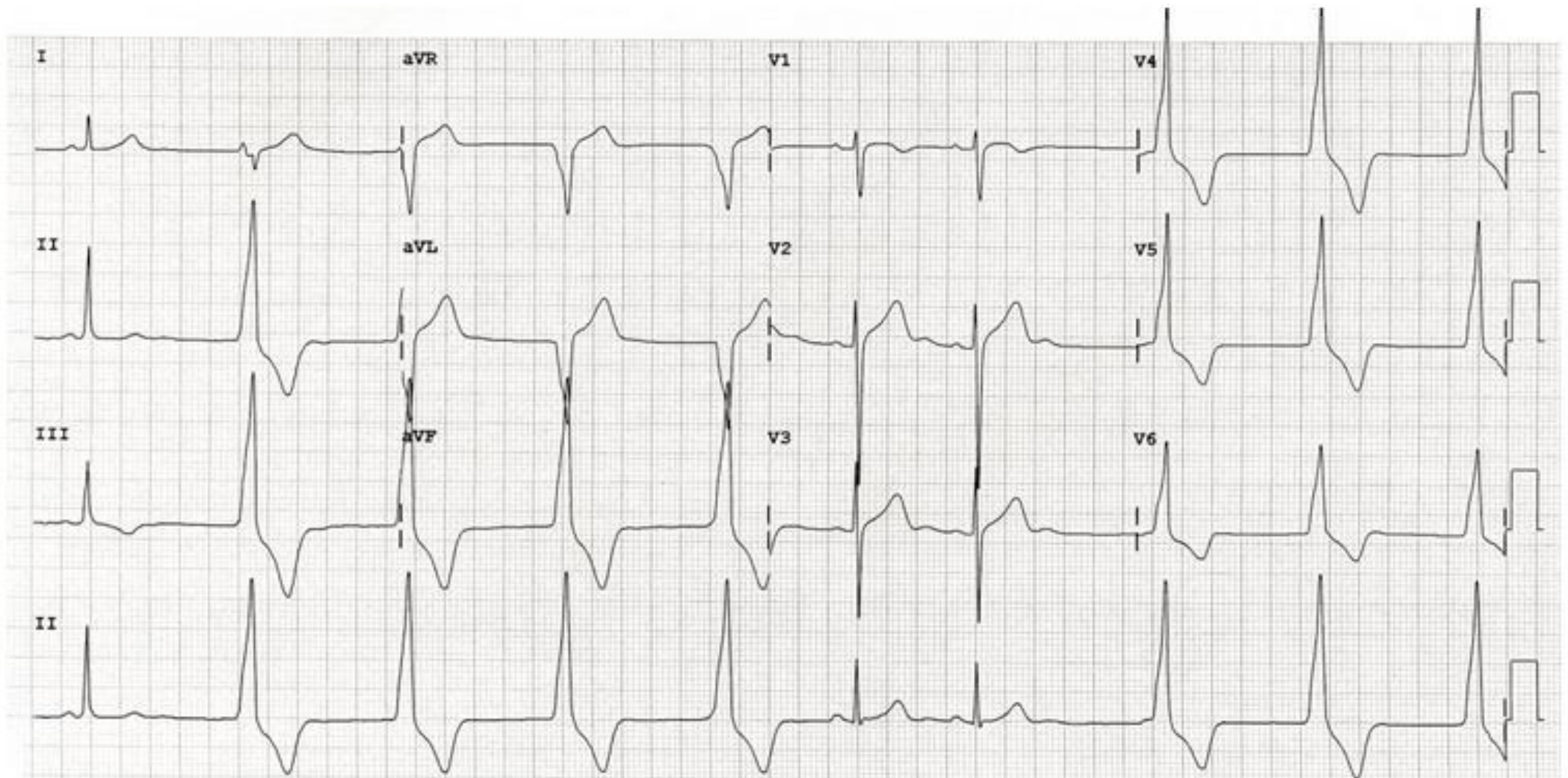
There are some additional features suggest of **right ventricular infarction**:

- STE in lead III > lead II.
- Deep ST depression in V2 with an isoelectric ST segment in V1.

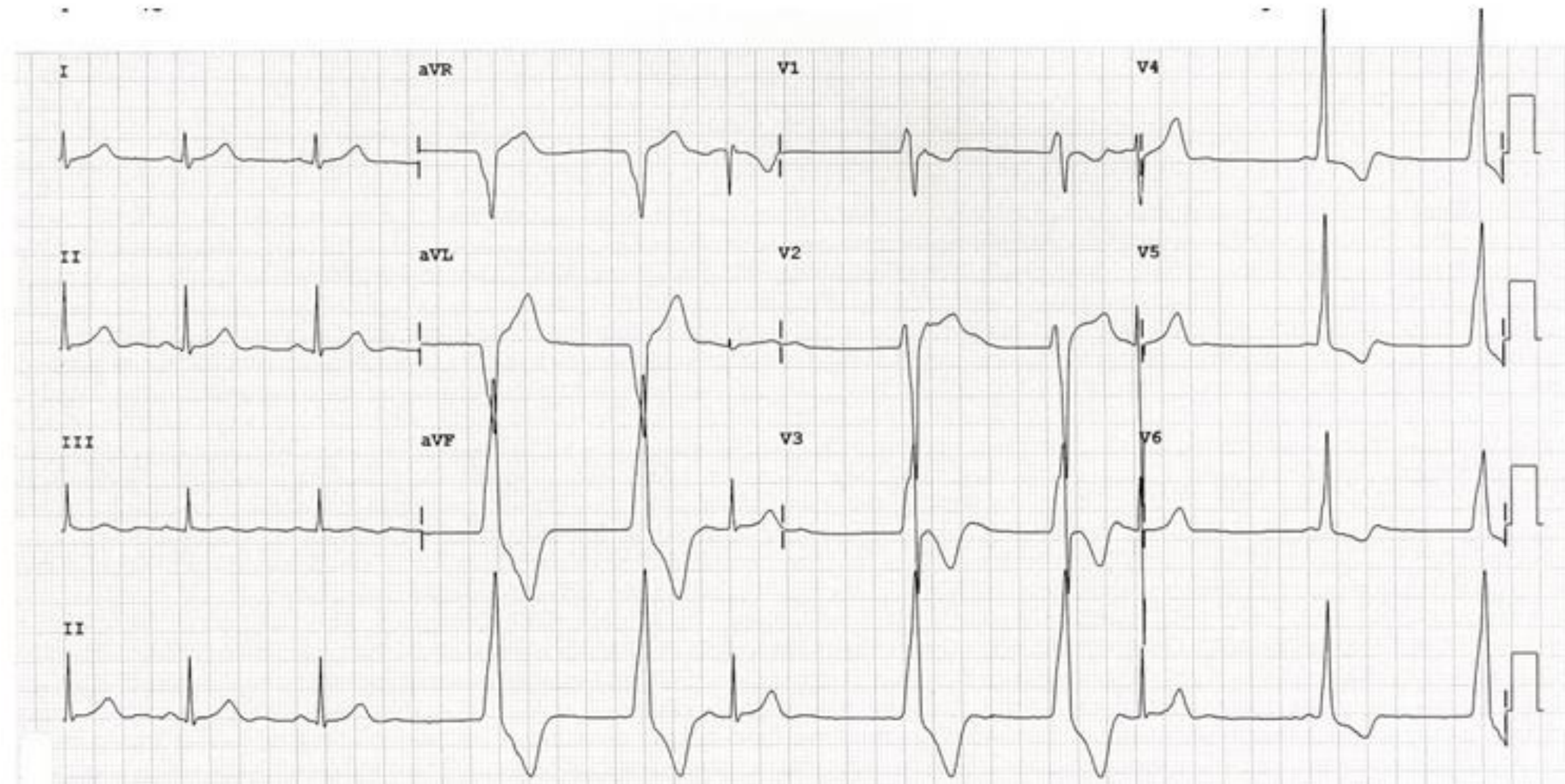
This is a huge infarct with a likely poor prognosis. Hypotension may be due to nitrate therapy causing exaggerated preload reduction in the context of RV infarction, or may simply reflect the large infarct size with development of early cardiogenic shock.

Case 40

36-year old old athlete, asymptomatic. Describe the ECG.



See additional ECG for this patient



Main Abnormalities

There are two competing rhythms at similar rates (= isorhythmic AV dissociation):

- **Accelerated idioventricular rhythm** (AIVR) — broad-complex ventricular rhythm at around 60 bpm.
- **Sinus bradycardia** with **sinus arrhythmia** — the sinus rate varies from 70 bpm down to < 50 bpm.

The QRS morphology varies depending on which focus is capturing the ventricles at any given moment.

Other Findings

Specific ECG findings that confirm the presence of simultaneous sinus and ventricular rhythms are:

- **Capture beats** — sinus beats that intermittently wrest control of the rhythm producing narrow complexes.
- **Fusion beats** (seen in the second ECG) — these are intermediate width complexes that occur when sinus and ventricular beats coincide.

*NB. Fusion and capture beats are often discussed in the context of VT. They are not specific to VT, but rather can be seen with any ventricular rhythm, including **paced rhythms** and **AIVR**.*

Explanation

- Competing sinus and ventricular pacemakers are present. There is underlying sinus arrhythmia, with sinus capture occurring when the sinus rate exceeds the idioventricular rate.
- This patient was a fit athlete with presumably high resting vagal tone that suppressed his sinus node output and allowed an ectopic ventricular pacemaker to emerge.

Definitions

- **Accelerated idioventricular rhythm**

An ectopic ventricular rhythm consisting of three or more ventricular complexes occurring at a rate of 50-110 bpm. The rate differentiates AIVR from **ventricular escape rhythms** (rate < 50 bpm) and **VT** (> 110bpm).

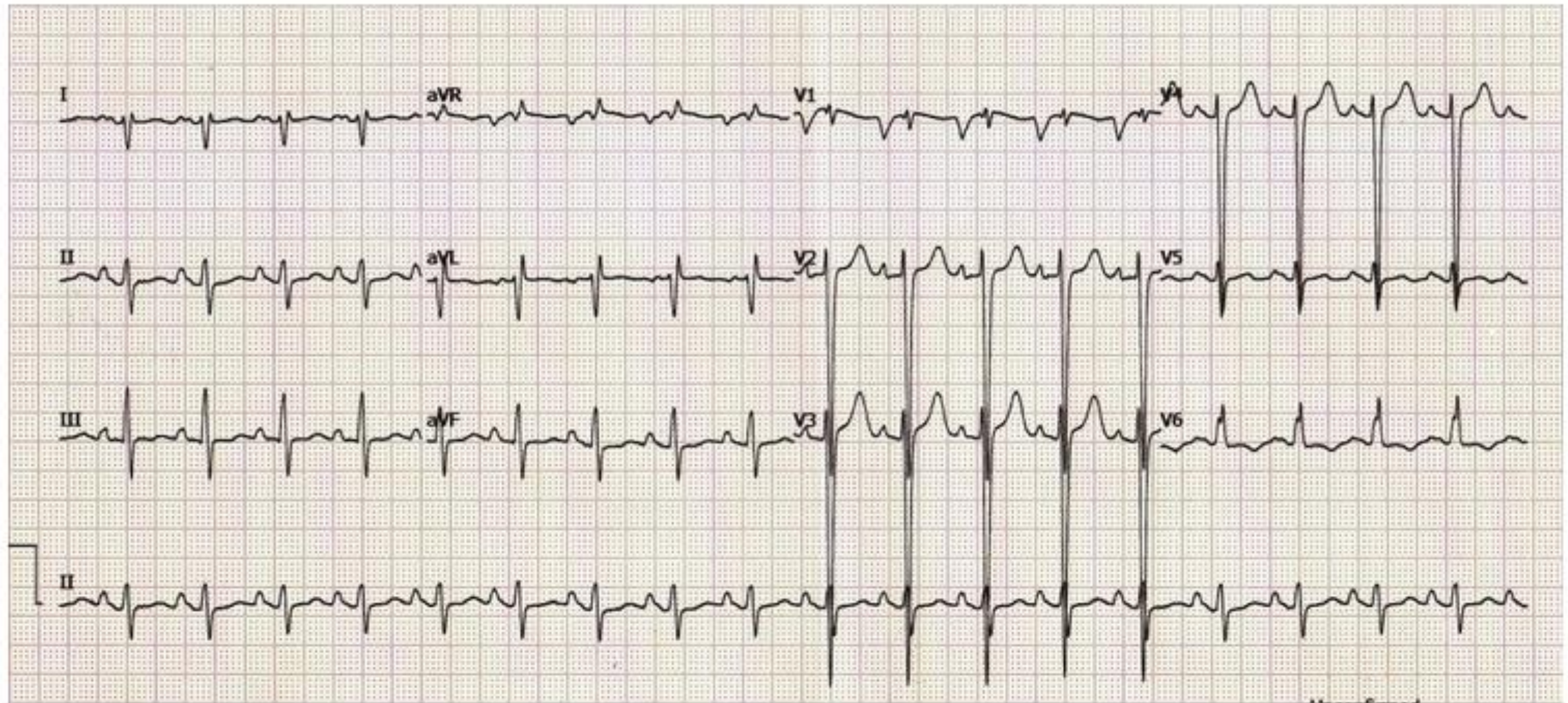
- **Isorhythmic AV dissociation**

AV dissociation with sinus and ventricular complexes occurring at similar rates, unlike **3rd degree heart block** where the atrial rate is usually faster than the ventricular rate.

Isorhythmic AV dissociation is usually due to functional block at the AV node from retrogradely conducted ventricular impulses ("interference-dissociation"), which leaves the AV node refractory to the anterograde sinus impulses.

Case 41

70-year old patient presenting with acute pulmonary oedema. Describe the ECG



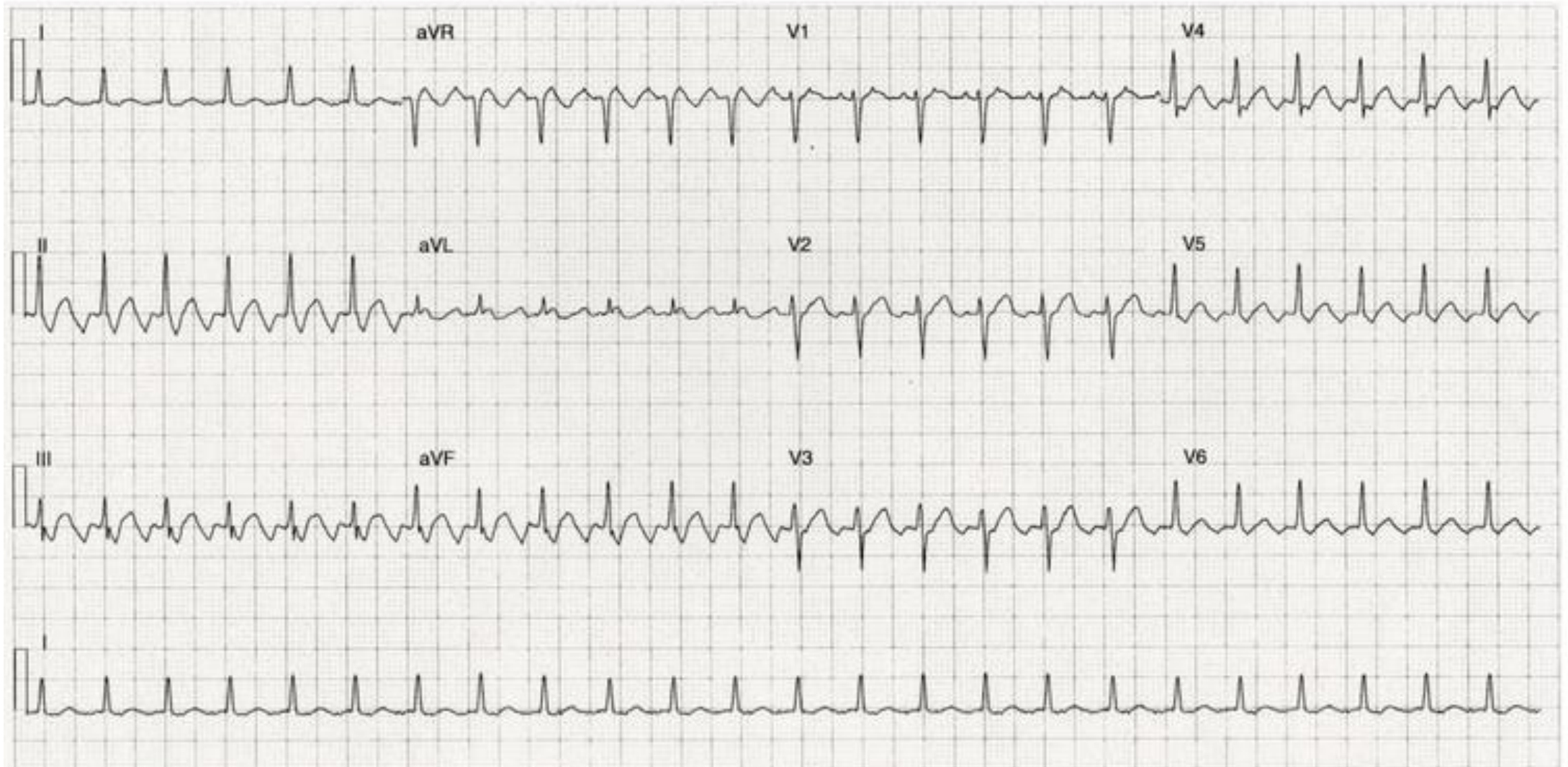
This is an ECG example of **dilated cardiomyopathy** demonstrating signs of enlargement of all four cardiac chambers:

- There is marked **LVH** with very deep S waves in V2-4.
- **Right axis deviation** suggests associated **RV enlargement** (= **biventricular enlargement**).
- Evidence of **left atrial enlargement** (deep, wide terminal portion of the P wave in V1).
- Peaked P waves in lead II suggestive of **right atrial enlargement** (~ 2.5mm in height).

This patient had four-chamber dilatation on echocardiography with severe congestive cardiac failure (awaiting cardiac transplantation).

Case 42

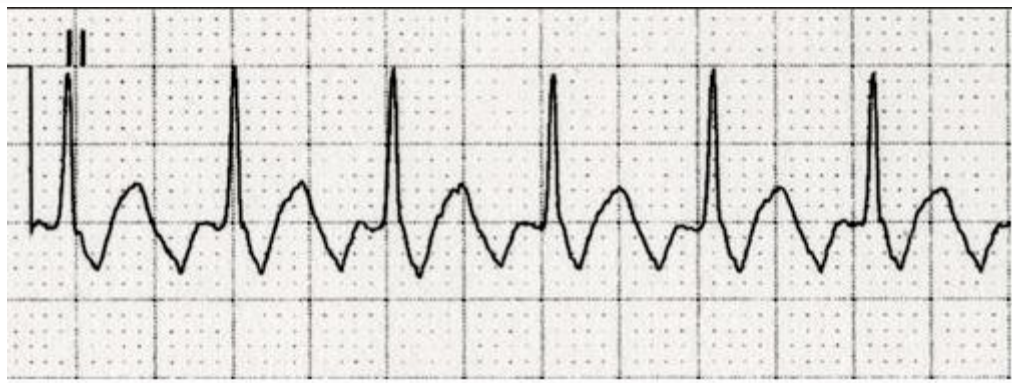
75-year old patient presenting with palpitations. Describe the ECG



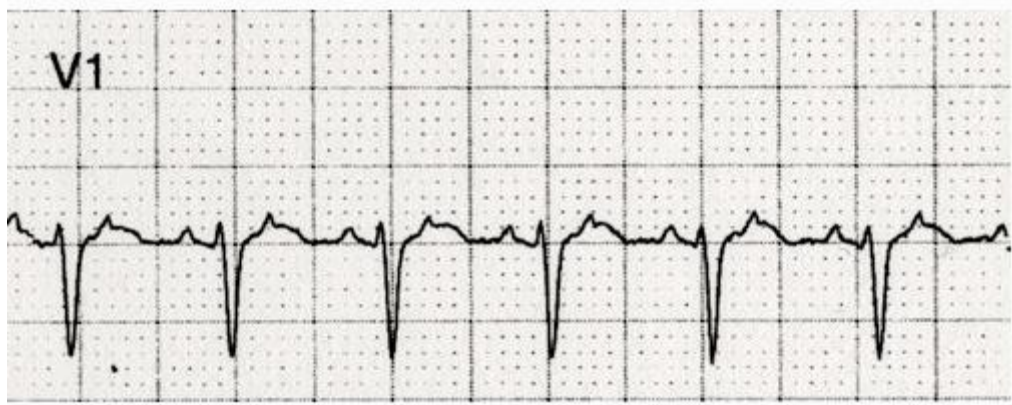
Main Abnormalities

This is a typical example of **atrial flutter with 2:1 AV block**

- Narrow complex tachycardia at 150 bpm.
- Sawtooth flutter waves are seen in the inferior leads II, III, aVF.
- Upright flutter waves in V1 appear either as pseudo-P waves or as notches in the T wave.
- There is a clear 2:1 relationship between the flutter waves (300 bpm) and QRS complexes (150 bpm).



Inverted flutter waves in lead II.



Upright flutter waves in V1.

Tips for Spotting Atrial Flutter

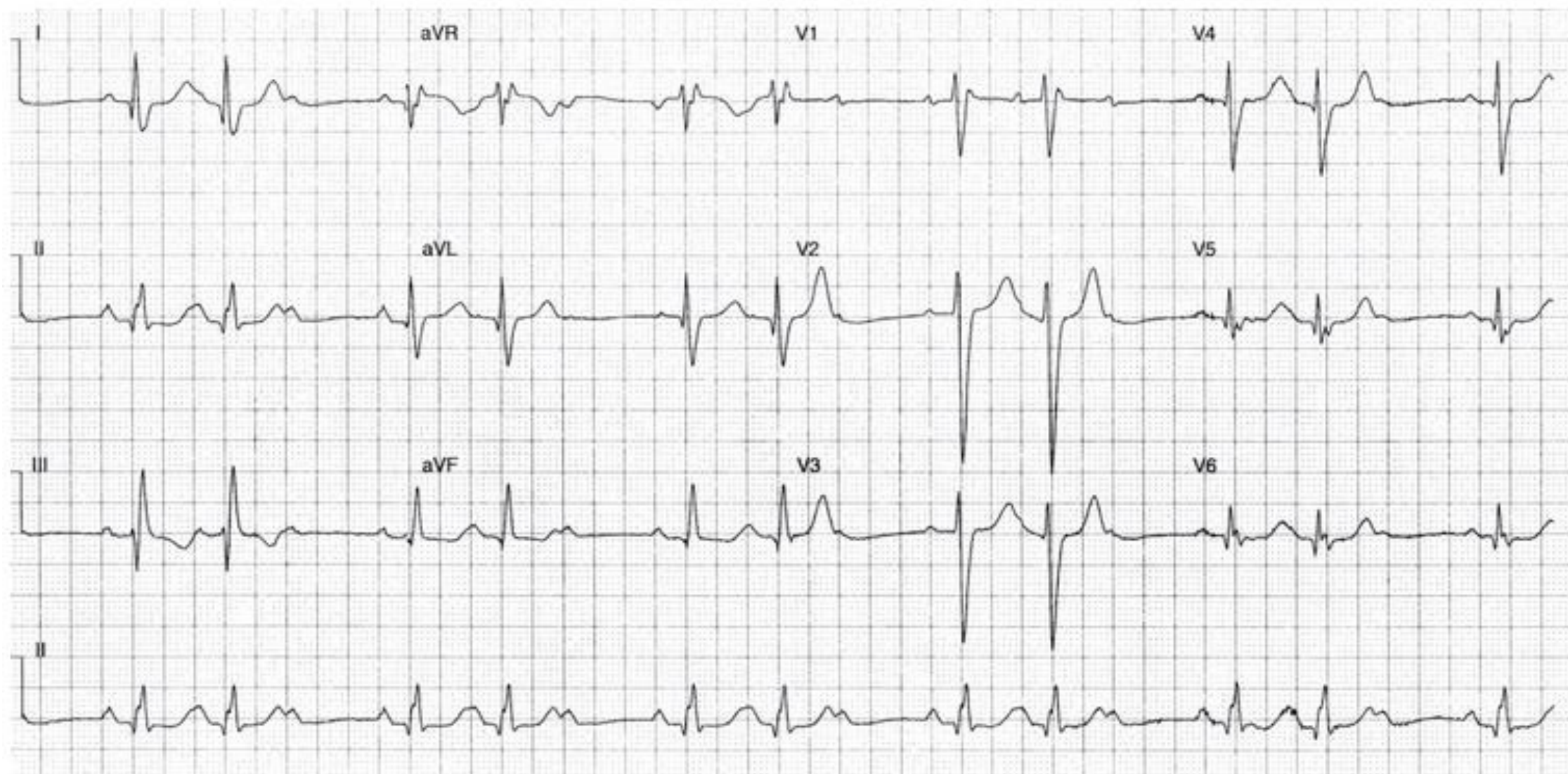
- Suspect flutter with 2:1 block in any patient with a regular NCT at 150 bpm.
- Scrutinise leads II and V1 for flutter waves.
- Flutter waves are typically sawtooth in lead II and resemble P waves in V1.
- Try turning the ECG upside down — this can make the flutter waves in lead II easier to see.



Inverting the ECG makes flutter waves in lead II easier to see

Case 43

Middle-aged patient presenting with syncope. Describe the ECG



Main Abnormalities

Sinus rhythm with evidence of 2nd degree AV block

- The QRS complexes cluster in groups separated by non-conducted P waves.
- There is a 3:2 relationship between the P waves and QRS complexes.
- With fixed ratio blocks like this, it can sometimes be difficult to distinguish between Mobitz I and Mobitz II conduction, as there are not always enough successive PR intervals to judge whether progressive PR prolongation is occurring.
- The PR interval seems relatively constant between the first and second beats of each group, suggesting Mobitz II conduction.
- However, the clustering of QRS complexes into repeating groups with P:QRS ratios of 3:2, 4:3, 5:4, etc. is a characteristic feature of Mobitz I.
- There is an atypical RBBB — typical RSR' pattern in V1 with slurred S wave in lead I, but atypical morphology elsewhere.

Pragmatically, I wouldn't get too focussed on trying to work out the rhythm from a single tracing. I would just record multiple ECGs aiming to capture any longer P:QRS cycles to assess whether successive PR prolongation is present (Mobitz I) or absent (Mobitz II).



Progressive PR prolongation with Mobitz I



Constant PR interval with Mobitz II

Another clue to aid differentiation is QRS width:

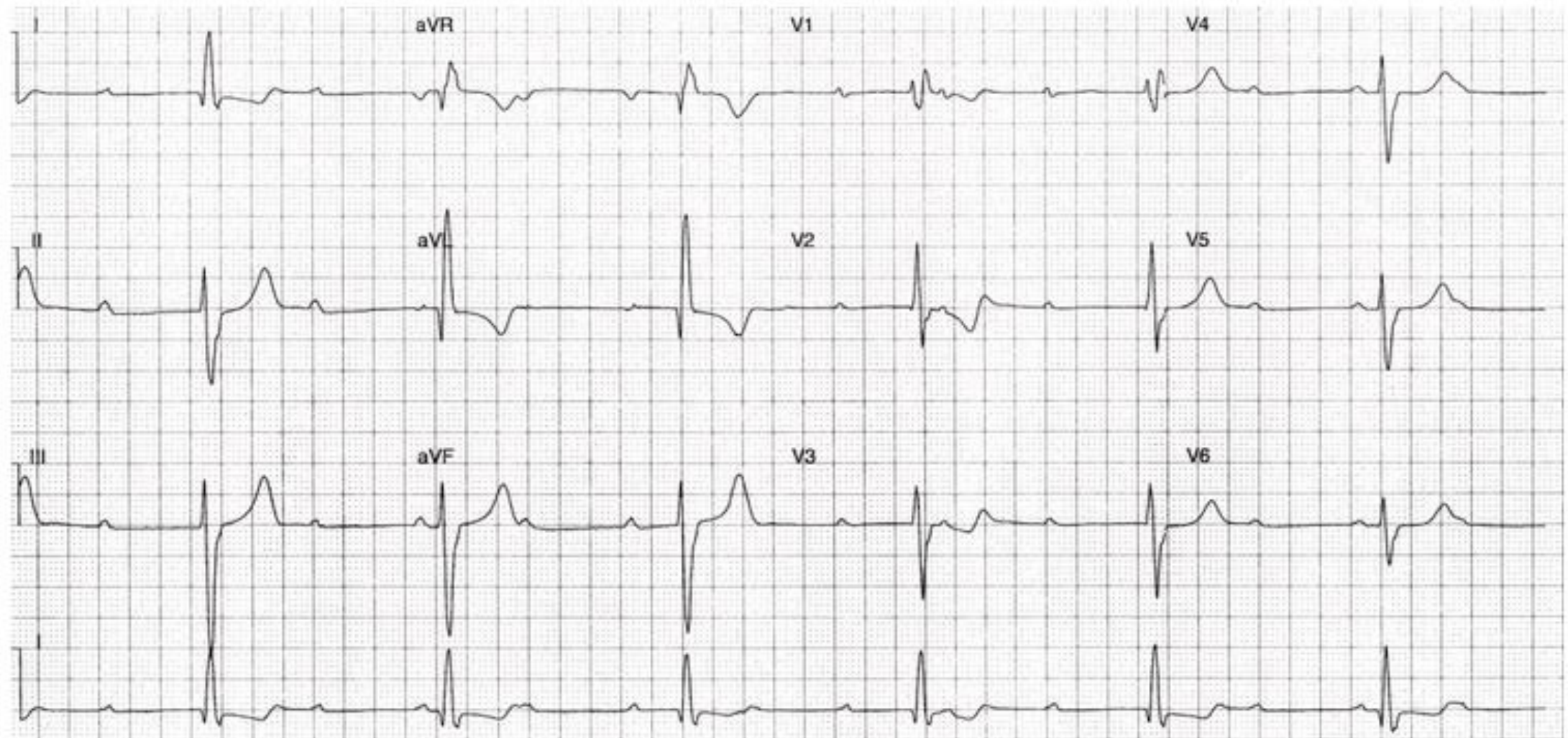
- Mobitz I is typically due to block at the level of the AV node — hence QRS complexes are usually (but not always) narrow.
- Mobitz II typically occurs on a background of widespread conducting system disease (**LBBB** or **bifascicular block**). The block is typically at the level of the fascicles — hence QRS complexes are usually (but not always) broad.

Clinical Pearls

- There is some prognostic value in differentiating between Mobitz I and II — Patients with Mobitz II have a much higher rate of complete heart block and are more likely to require a permanent pacemaker.
- However, in the acute situation it is more important to *look at the patient* rather than to fixate on the ECG.
- Treatment decisions such as whether to commence temporary pacing will be largely determined by the patient's clinical stability.

Case 44

Middle-aged patient presenting with syncope. Becomes hypotensive in ED (BP 80/50). Describe the ECG



There is sinus rhythm with **complete heart block**:

- **Normal P waves** (upright in II, inverted in aVR) are present at a rate of ~ 85 bpm.
- There is no relationship between the P waves and QRS complexes — the PR intervals vary randomly.
- A **ventricular escape rhythm** is present at ~ 36 bpm.

The broad QRS complexes, RBBB morphology and left axis deviation (resembling **trifascicular block**) indicate a ventricular escape rhythm arising in the left posterior fascicle. Note how the QRS axis and morphology have changed significantly from the **previous ECG**.

This patient had complete heart block due to cardiac sarcoidosis.

Clinical Pearls

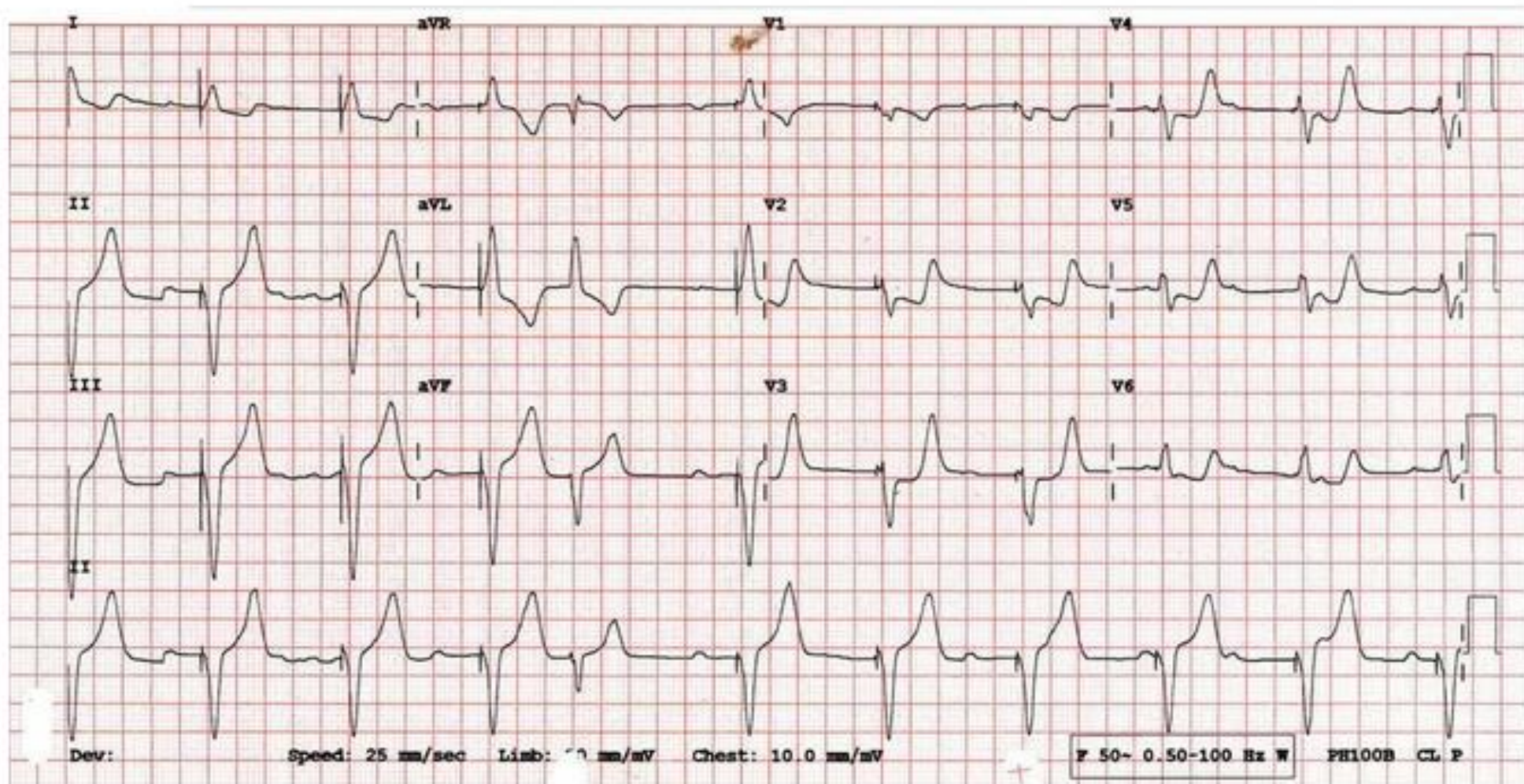
- Sarcoidosis should always be considered as a differential diagnosis in younger patients presenting with complete heart block, particularly if other manifestations of sarcoidosis are present such as **bilateral hilar lymphadenopathy** or **cutaneous lesions** (erythema nodosum, lupus pernio).
- One of the most common reversible causes of complete heart block is **severe hyperkalaemia** — always get an urgent K⁺ (e.g. run a VBG) on patients presenting with CHB. You look a bit silly inserting an unnecessary pacing wire when you could have corrected the problem with some calcium gluconate!

Causes of Complete Heart Block

- AV nodal blocking drugs (e.g. **calcium-channel blockers**, **beta-blockers**, **digoxin**)
- Severe **hyperkalaemia**.
- **Inferior myocardial infarction** — due to increased vagal tone.
- **Anterior myocardial infarction** — due to septal necrosis.
- Idiopathic fibrosis of the conducting system (Lenegre's or Lev's disease).
- Cardiac surgery (especially surgery occurring close to the septum, e.g. mitral valve repair)
- **Infiltrative myocardial disease** (amyloidosis, haemochromatosis, sarcoidosis).
- **Inflammatory conditions** (rheumatic fever, myocarditis, Lyme disease).
- Autoimmune (SLE, systemic sclerosis).

Case 45

64-year old female presenting with severe chest pain and diaphoresis. Describe the ECG



This ECG shows a **ventricular paced rhythm** with positive **Sgarbossa criteria**:

- There is **concordant ST depression** in V2-5. This violates the **expected pattern of discordance** for a V-paced rhythm and is a marker of superimposed **myocardial infarction**.
- The morphology in V2-5 is reminiscent of **posterior STEMI**, with horizontal ST depression and prominent upright T waves.
- Multiple non-conducted P waves are seen, indicating the presence of underlying **high-grade AV block** (probably the indication for pacemaker insertion). However, the **fusion complex** (beat #5 on rhythm strip) suggests that P waves are occasionally transmitted, arguing against **complete heart block**.

This patient did indeed have an isolated **posterior infarction**, due to complete occlusion of a posterolateral branch of the RCA. She was successfully treated with PCI.

Sgarbossa Criteria

These criteria allow for detection of myocardial infarction in patients with **LBBB** and **V-paced rhythms** (previously thought to be “impossible”).

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rhythms (previously thought to be “impossible”).

Normal Pattern in LBBB / VPR

- The expected finding in patients with uncomplicated LBBB / V-paced rhythm is **discordance** — i.e. the ST segments and T waves point in the opposite direction to the QRS complex.

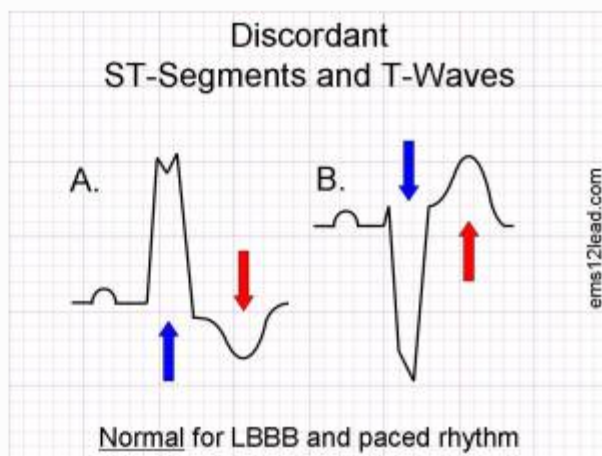


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How To Spot Superimposed MI

Superimposed myocardial infarction is suspected if there is either:

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How To Spot Superimposed MI

Superimposed myocardial infarction is suspected if there is either:

- Loss of the usual pattern of discordance — i.e. **concordant ST changes**.
- **Excessive discordant ST elevation** — i.e. out of proportion to what would be expected for LBBB / paced rhythm.

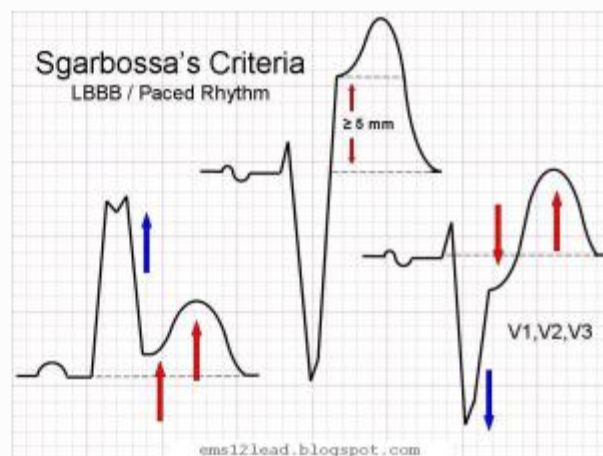


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Sgarbossa Criteria

Diagnosis of MI in LBBB / VPR requires at least one of the following criteria to be present:

- Concordant ST depression > 1 mm in V1-3.
- Concordant ST elevation > 1 mm in any lead.
- Excessively discordant ST elevation in any lead >5 mm (original Sgarbossa criteria) or >25% of the corresponding S-wave depth (**modified Sgarbossa criteria** = more specific).

Changes only have to be present in a single lead to be diagnostic of MI.

Read more about Sgarbossa criteria [here](#).

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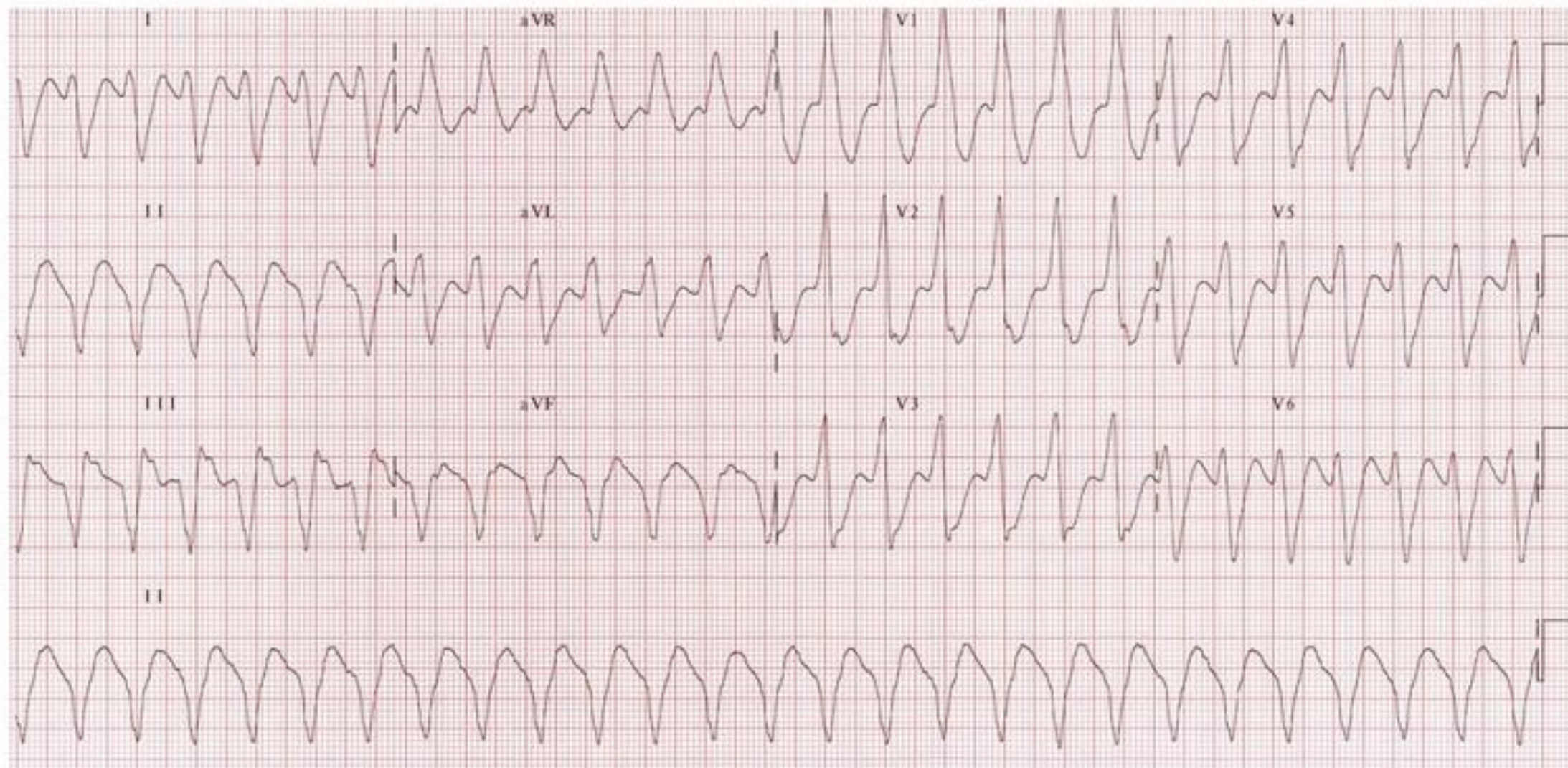
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Case 46

Middle-aged patient presenting with palpitations. Describe the ECG



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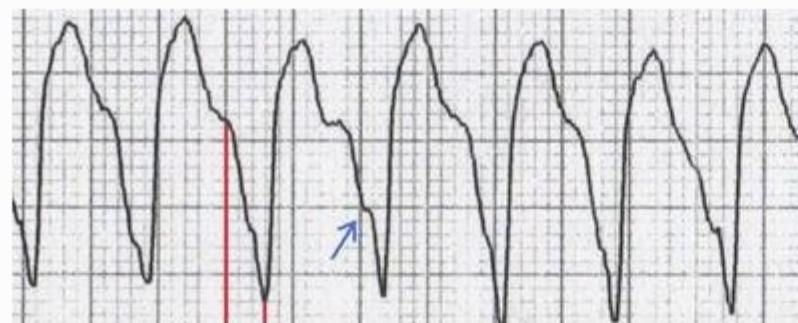
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This ECG contain

- Regular bradycardia
- Very broad QRS complex
- **Northwest axis**
- Brugada's sign
- Josephson's sign



Northwest Axis



Brugada's sign (red callipers) and Josephson's sign (blue arrow)

Also note the presence of morphology criteria favouring VT over RBBB:

- Tall monophasic R wave in V1

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Also note

- Tall
- Don

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V1

Monophasic R wave in V1 with VT

V6

Dominant S wave in V6 with VT

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This pattern in V1 and V6 is very different from the expected morphology in RBBB.



RSR' pattern in V1 with RBBB



Dominant R wave with wide slurred S wave in V6

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Tips for Spotting VT when RBBB morphology present

[NB. RBBB morphology = QRS > 120ms with dominant R wave in V1]

Suspect VT in any patient with a regular broad complex tachycardia (especially if > 160 ms wide).

Look at aVR

Look at V1

Look at V6

If still uncertain...scrutinise the ECG for:

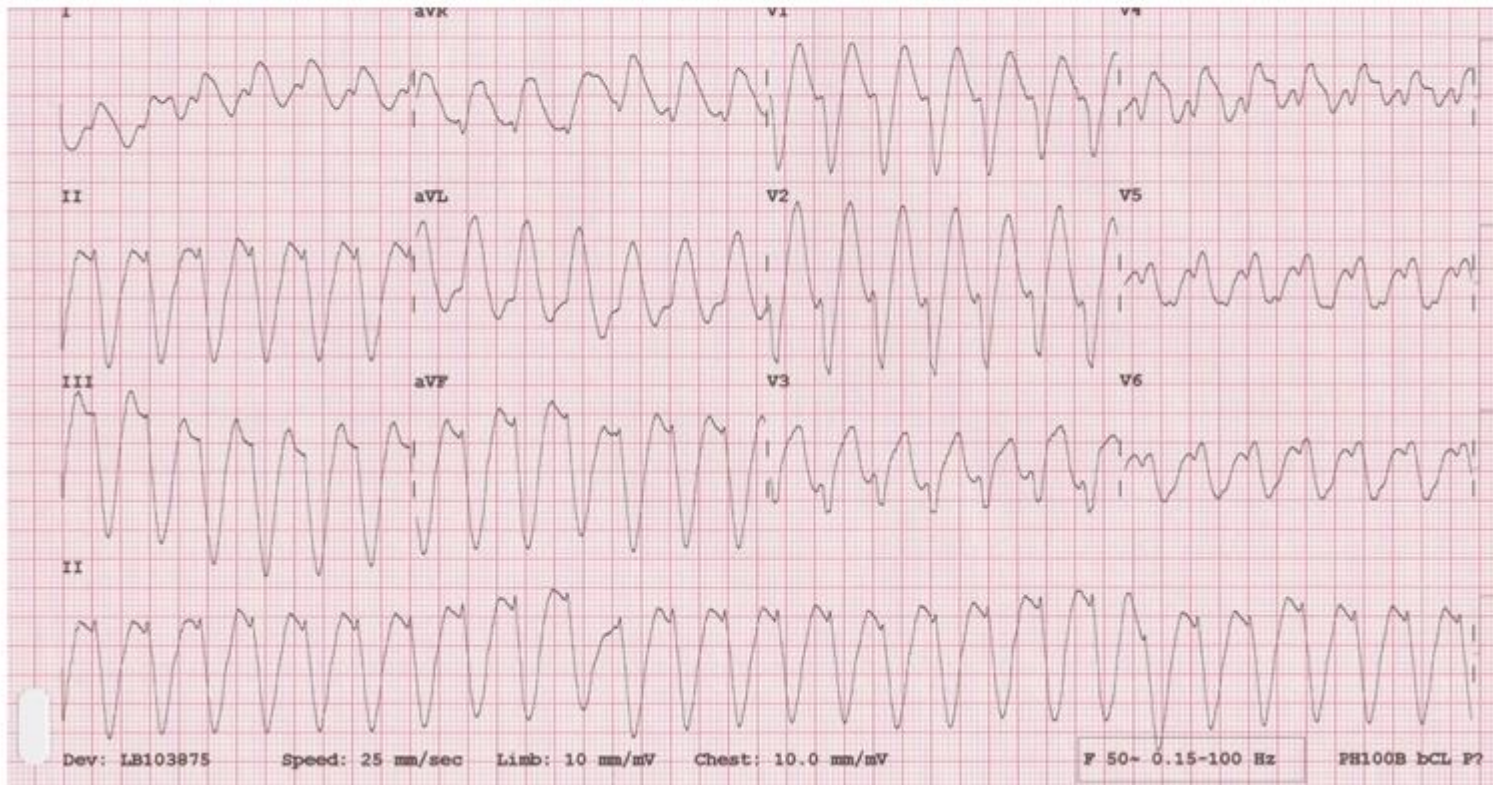
For more tips on spotting VT, [read this article](#).

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Case 47

Middle-aged patient presenting with palpitations. Describe the ECG



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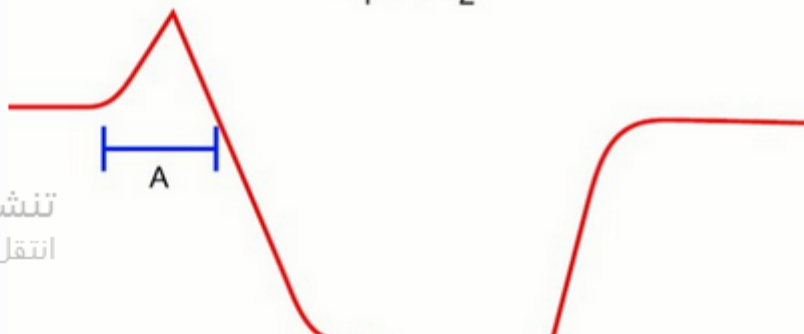
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Reveal Answer

This is another example of **ventricular tachycardia**, this time with a LBBB morphology (compare this with **ECG 046**).

- Regular broad complex tachycardia at ~ 160 bpm.
- **Features of VT in V1**: Initial R wave > 30 ms wide, RS interval > 70 ms (= Brugada sign).
- **Features of VT in V6**: Dominant S wave in V6, absence of typical LBBB morphology.
- Abnormal axis with positive aVR, although does not quite meet criteria for **northwest axis**.

NB. Note that a positive Brugada sign only requires an RS interval of >70 ms when LBBB morphology is present, compared to >100 ms when RBBB morphology is present.

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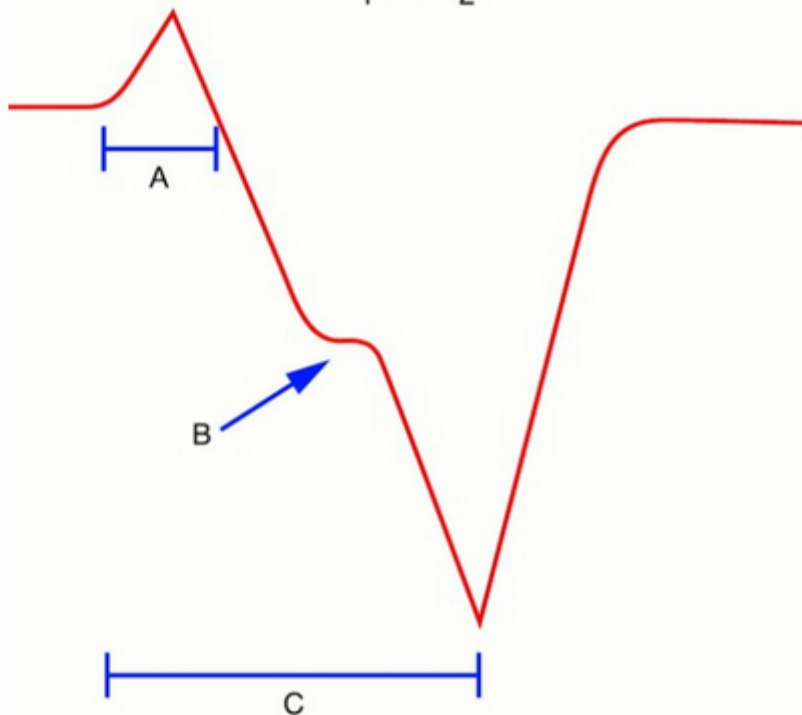
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 V_1 and V_2 

A: > 30 ms FAVOURS VT

B: NOTCHING, SLURRING FAVOURS VT

C: > 70 ms FAVOURS VT

VT – appearance in V_1 . Reproduced from Wellens (2001).

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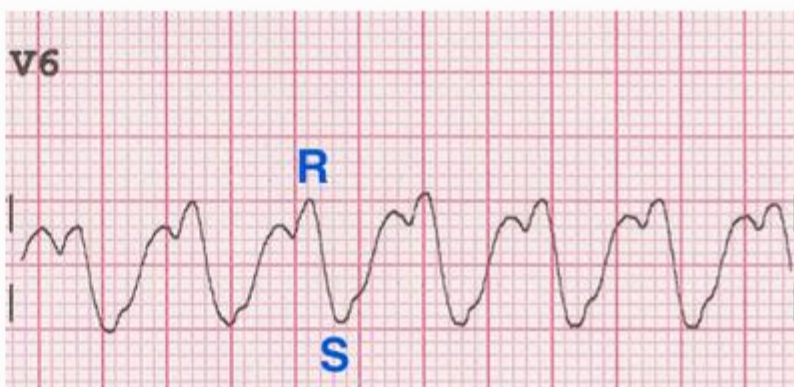
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A: > 30 ms FAVOURS VT

B: NOTCHING, SLURRING FAVOURS VT

C: > 70 ms FAVOURS VT

VT – appearance in V1. Reproduced from Wellens (2001).



VT – appearance in V6.

Again, these features are very different to the expected pattern in LBBB, which has:

- Dominant S wave in V1, but with an R/S interval < 70 ms and minimal initial R wave.
- Dominant R wave in V6 (often slurred).

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LBBB – appearance in V1.



LBBB – appearance in V6.

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Windows Tips for Spotting VT when LBBB morphology present

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Tips for Spotting VT when LBBB morphology present

[NB. LBBB morphology = QRS > 120ms with dominant S wave in V1]

Suspect VT in any patient with a regular broad complex tachycardia (esp if > 160 ms wide).

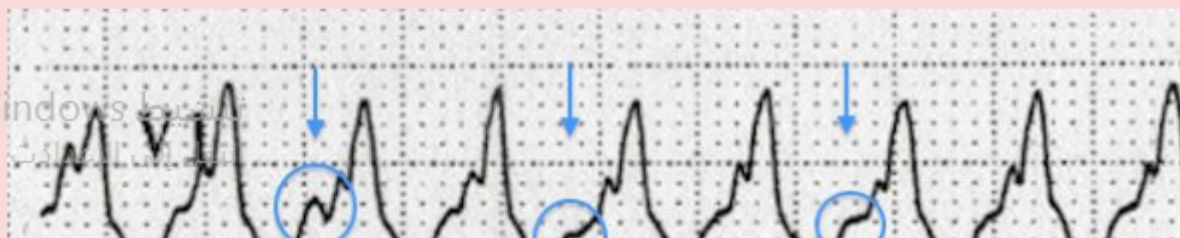
Look at aVR

Look at V1

Look at V6

If still uncertain, scrutinise the ECG for:

- AV dissociation — P waves randomly deforming the QRS complexes and T waves.
- Fusion and capture beats.



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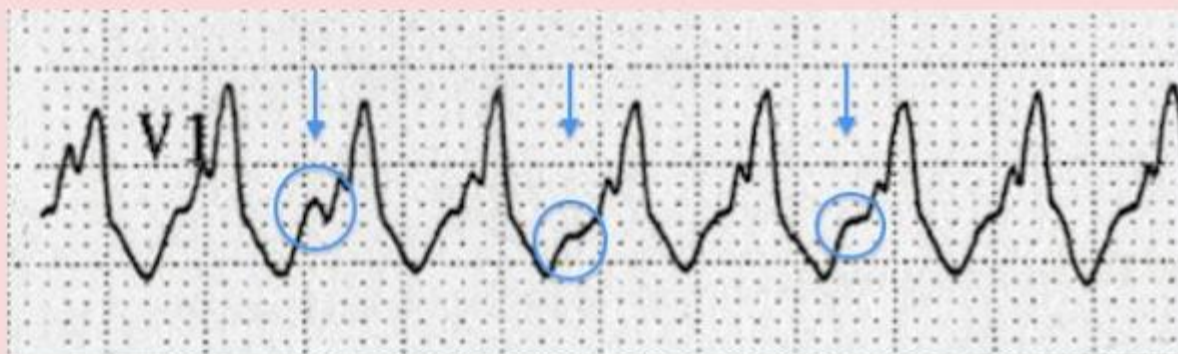
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AV dissociation: superimposed P waves at a different rate to the QRS complexes



The first of the narrower complexes is a fusion beat, the next two are capture beats.

For more tips on spotting VT, [read this article](#).

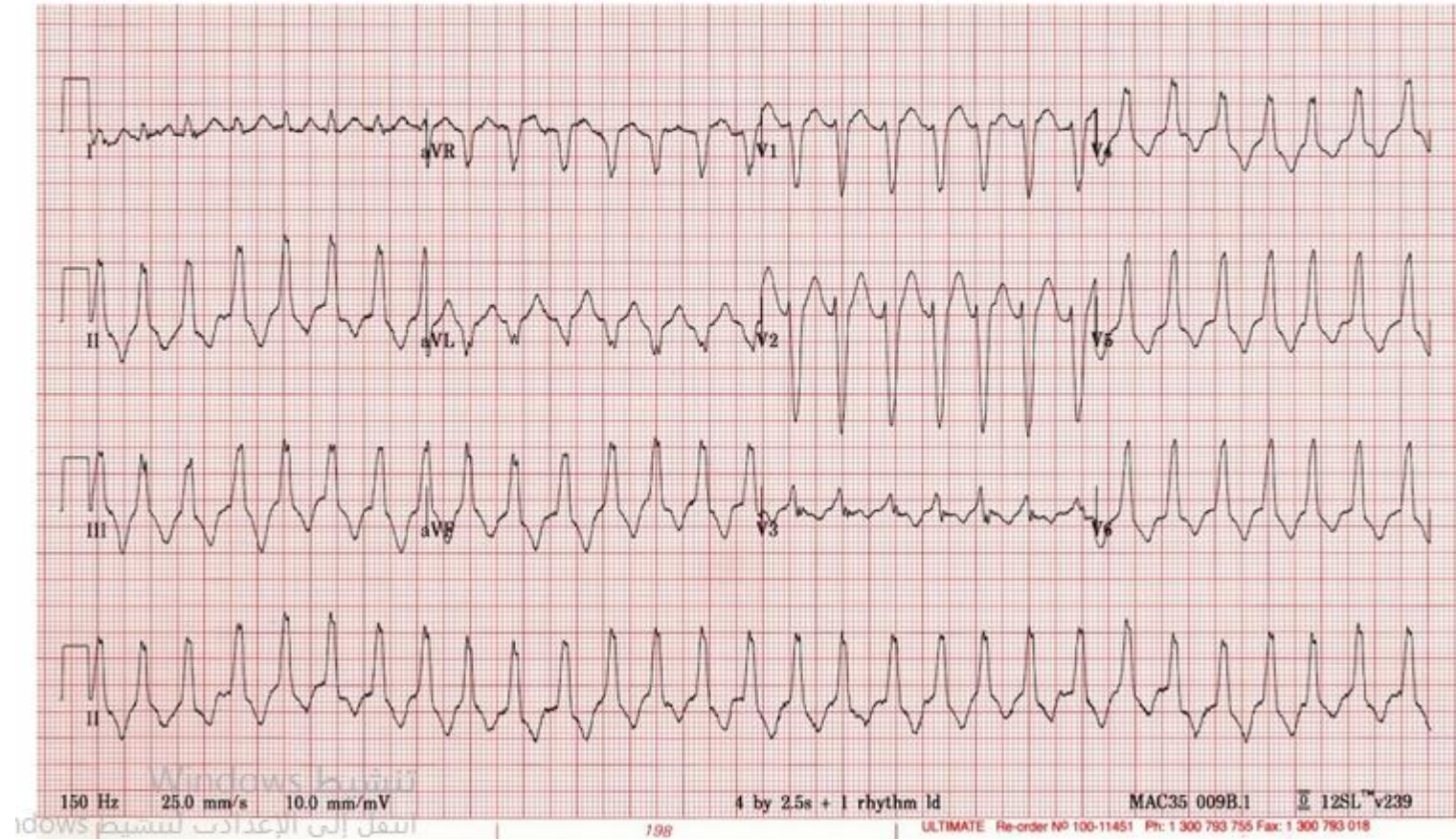
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Case 48

30-year old female presenting with sudden onset of palpitations. Normally well. Describe the ECG.



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On first glance this would appear to be **SVT** with **LBBB** as there is:

- Regular broad-complex tachycardia.
- No atrial activity seen.
- Typical LBBB morphology in aVR, V1 and V6.
- No obvious diagnostic features for VT — compare this with **ECG 047**.

However, there is **one feature** here that is unusual for LBBB, can you spot it?

Reveal Answer

- There is an **inferior axis (+90 degrees)**, which is atypical for LBBB.
- LBBB normally has a **leftward axis**.

This combination of...

- Broad complex tachycardia with typical LBBB morphology.
- Inferior axis (+90 degrees).

is suggestive of a specific type of VT known as **right ventricular outflow-tract tachycardia** (RVOT).

RVOT is a relatively common form of right ventricular VT occurring in two main groups:

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RVOT is a relatively common form of right ventricular VT, occurring in two main groups:

- Patients with structurally normal hearts (= 70% of idiopathic VT).
- Patients with **arrhythmogenic right ventricular cardiomyopathy**.

It may be very difficult to differentiate RVOT from SVT with LBBB.

[NB. Left bundle branch block *morphology* simply indicates that the heart is depolarising from *right to left*. Hence, similar QRS patterns are seen with **LBBB**, **RVOT** and **RV-pacing**]

Tips for Spotting RVOT

- Suspect RVOT when you see LBBB morphology + inferior axis.
- Record a long rhythm strip looking for fusion and capture beats.

I have diagnosed this only a couple of times in the past. Each time I had to stand by the monitor with my finger on the "print" button waiting for a fusion or capture beat to appear before anyone would believe me!

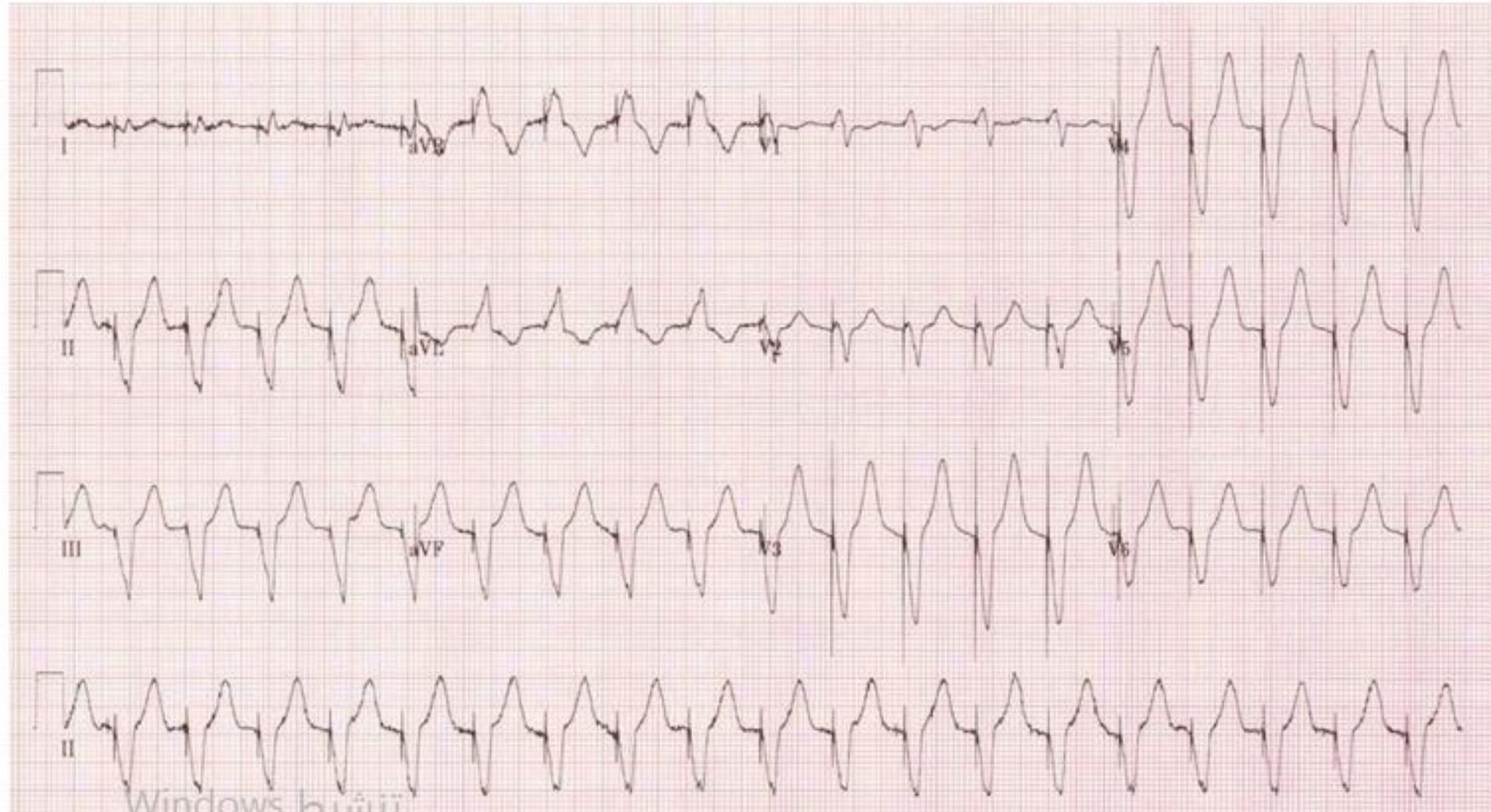
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Case 49

Elderly male presenting with dizziness. Describe the ECG



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Main Abnormalities

- Broad complex tachycardia at ~ 120 bpm.
- Pacing spikes precede each QRS complex.
- LBBB morphology (dominant S wave in V1-2) indicates a pacing electrode in the *right* ventricle.
- *Negative concordance* is seen in V1-6 (all precordial leads show negative complexes). This is an often-cited feature of VT, but also occurs with paced rhythms. It simply indicates that ventricular depolarisation is spreading from anterior to posterior (away from V1-6), e.g. due to a pacemaker electrode stimulating the anterior wall of the RV.

These features are consistent with a **pacemaker malfunction** resulting in a rapid ventricular-paced rhythm.

Differential Diagnosis

The differential diagnosis of this rhythm includes:

- **Pacemaker-mediated tachycardia**
- **Sensor-induced tachycardia**
- Atrial tachycardia (e.g. sinus, AF) driving the pacemaker to its maximum rate — may be appropriate response to exercise, shock, sepsis, etc.

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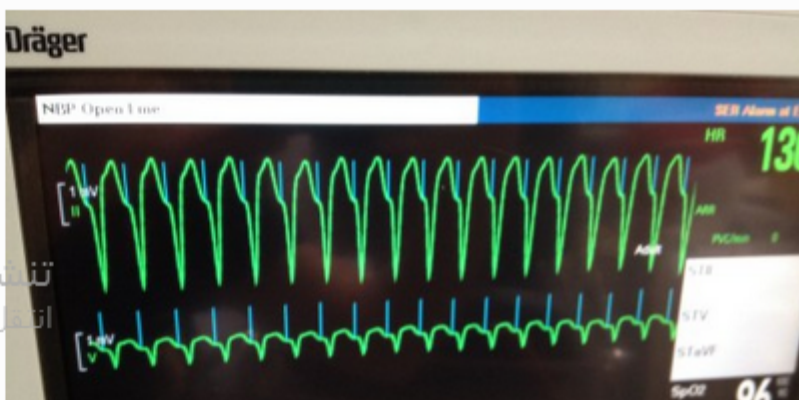
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- Atrial tachycardia (e.g. sinus, AF) driving the pacemaker to its maximum rate — may be appropriate response to exercise, shock, sepsis, etc.

Pacemaker Mediated Tachycardia (PMT)

This is a re-entrant rhythm involving the pacemaker circuit. It behaves very much like the **atrioventricular re-entry tachycardia (AVRT)** seen with **WPW syndrome**, except that in this case the “accessory pathway” is formed by the pacemaker circuit. PMT is triggered when ventricular impulses pass retrogradely through the AV node and depolarise the atria. This retrograde P wave is sensed by the pacemaker, which then immediately paces the ventricles. This is followed by another retrograde P wave that maintains the circus movement. This rhythm can be terminated by activating magnet mode (which switches off sensing), or by reprogramming the pacemaker box (e.g. increasing the refractory period to “block out” the retrograde P waves).



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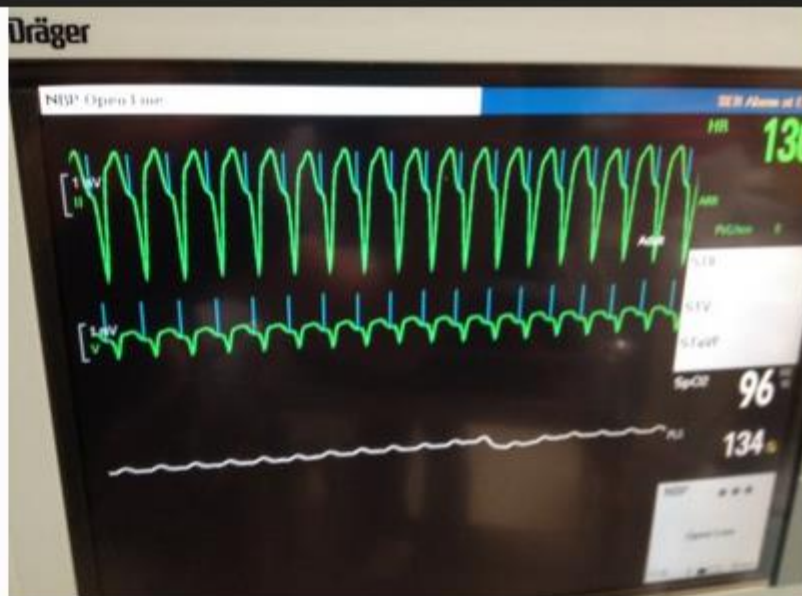
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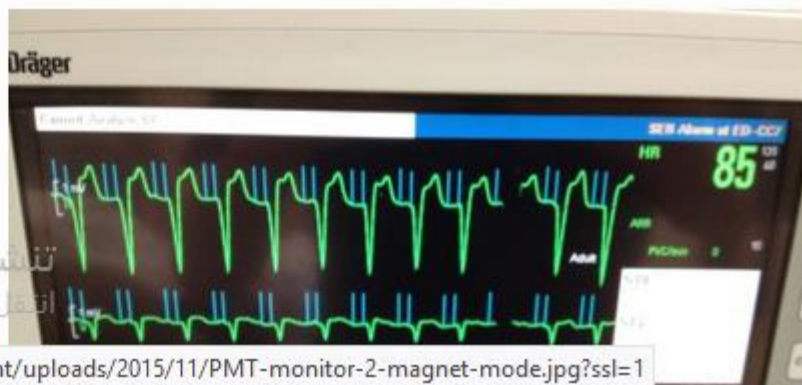
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Pacemaker Mediated Tachycardia



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Pacemaker Mediated Tachycardia



Activation of magnet mode terminates PMT and switches to AV sequential pacing (no sensing).

Sensor Induced Tachycardia (SIT)

- Modern pacemakers are programmed to allow increased heart rates in response to physiological stimuli such as exercise, tachypnoea, hypercapnia or acidaemia.

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to an occasional pacing (no pacing).

Sensor Induced Tachycardia (SIT)

- Modern pacemakers are programmed to allow increased heart rates in response to physiological stimuli such as exercise, tachypnoea, hypercapnia or acidaemia.
- Sensors may “misfire” in the presence of distracting stimuli such as vibrations, loud noises, fever, limb movement, hyperventilation or electrocautery (e.g. during surgery).
- This misfiring leads to pacing at an inappropriately fast rate.
- The ventricular rate cannot exceed the pacemaker’s upper rate limit.
- Similar to PMT, these may also terminate with application of a magnet, or with removal of the inciting stimulus.

Tips for Dealing with Rapid Paced Rhythms

- If the patient is attached to critical care monitoring, ensure that you **switch off respiratory impedance monitoring mode** (where the monitor senses respiratory rate via the ECG electrodes). This gives off an electrical signal that is **known to interfere with pacemakers**. If this doesn’t work, try changing monitors to one that does not use respiratory impedance technology.
- **Apply a magnet** to the pacemaker box. This activates **magnet mode**, which resets the

Tips for Dealing with Rapid Paced Rhythms

- If the patient is attached to critical care monitoring, ensure that you **switch off respiratory impedance monitoring mode** (where the monitor senses respiratory rate via the ECG electrodes). This gives off an electrical signal that is **known to interfere with pacemakers**. If this doesn't work, try changing monitors to one that does not use respiratory impedance technology.
- **Apply a magnet** to the pacemaker box. This activates **magnet mode**, which resets the pacemaker to provide temporary asynchronous pacing (AOO, VOO or DOO).
- Arrange for an **urgent pacemaker check**. A pacemaker technician may be able to adjust the settings to terminate the dysrhythmia and prevent its recurrence.
- If a pacemaker technician is not readily available, then a **trial of AV nodal blocking drugs** (e.g. beta blockers, verapamil) may be successful in terminating PMT.

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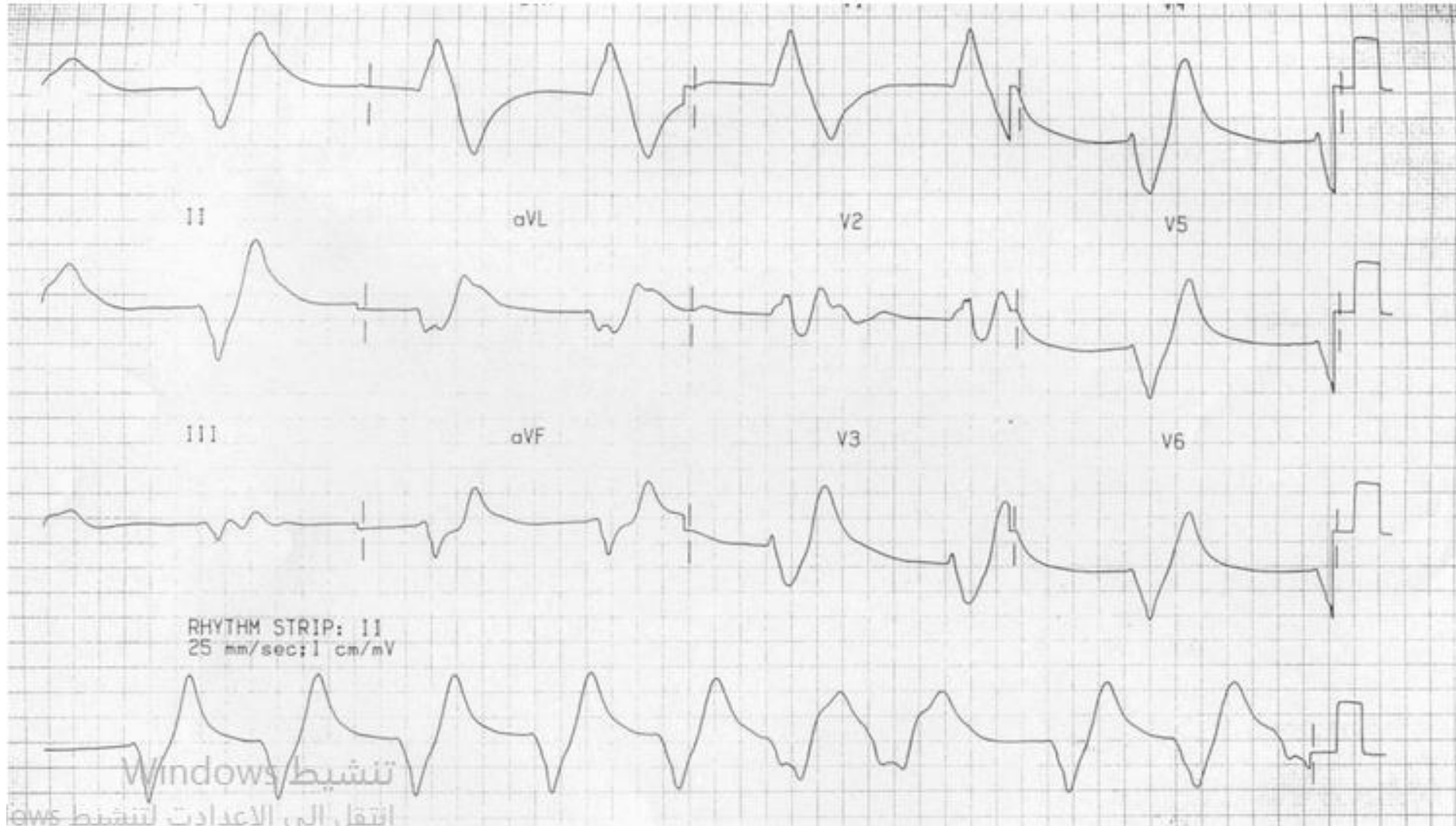
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Case 50

Elderly patient presenting with collapse. Clinically dehydrated. Describe the ECG.



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This is a classic **sine wave** ECG of **critical hyperkalaemia**

- Bradycardia (~ 55 bpm).
- Bizarre-looking QRS complexes.
- Gross QRS prolongation (> 300 ms).
- Massively peaked T waves.

This patient had a K⁺ of 9.9 mmol/L!

Clinical Pearls

Any time you see an ECG that is...

- **Blocked** (AV block, bundle branch block)
- **Bradycardic** (sinus brady, slow AF, junctional bradycardia)
- **Bizarre** in appearance

... consider **hyperkalaemia** and check the K⁺ urgently!

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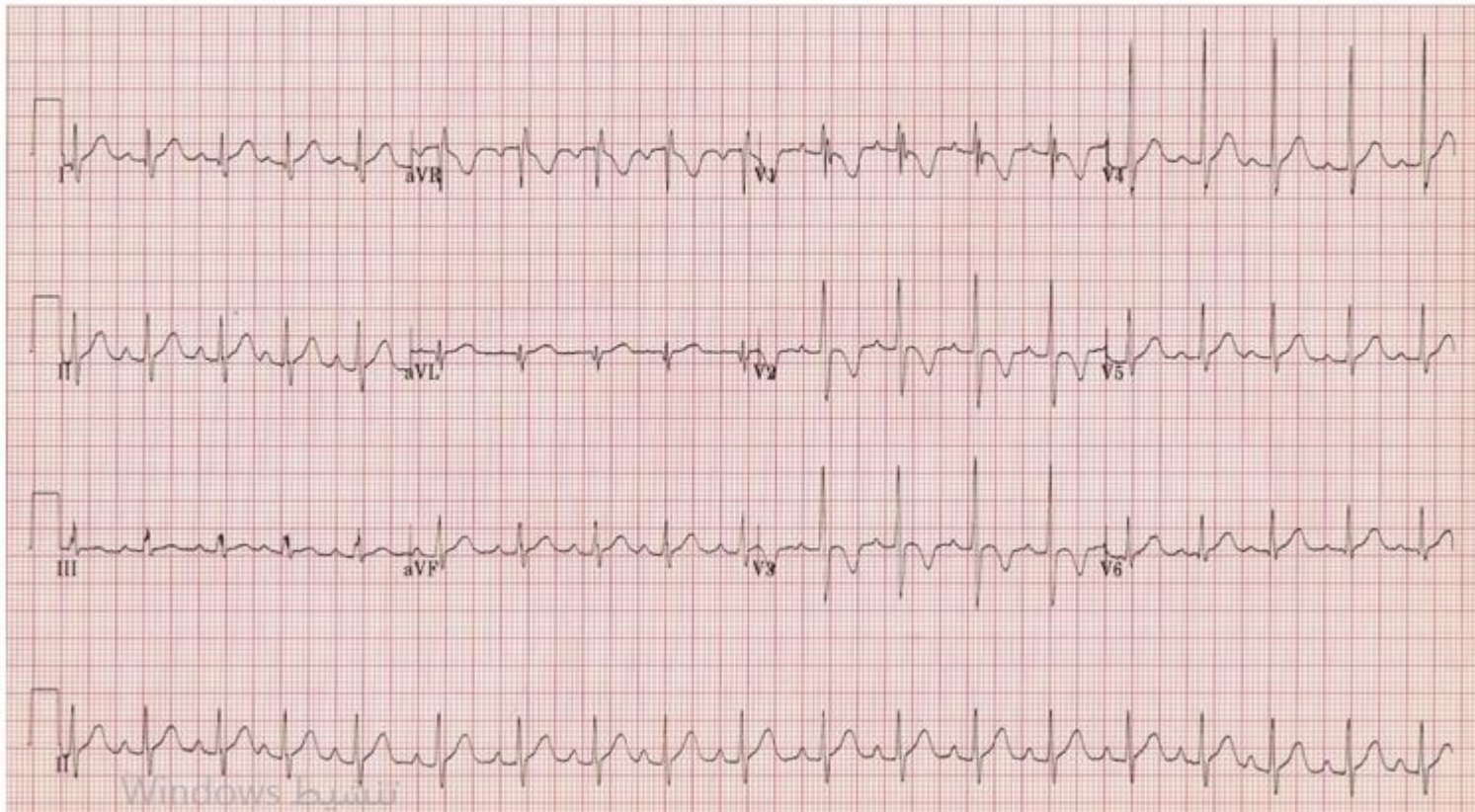
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Case 51

2-year old boy presenting with febrile seizure. Interpret the ECG.



This is a **normal paediatric ECG**, displaying multiple age-appropriate features:

- Heart rate of 110 bpm (normal for age).
- Dominant R waves in V1-3.
- Partial RBBB (RSR' pattern in V1).
- Juvenile T-wave pattern (T wave inversion in V1-3).

Any of the following findings may be normal on the **paediatric ECG**:

Heart rate and rhythm

- Heart rate >100 beats/min.
- Marked sinus arrhythmia.

Right-sided predominance

- Rightward QRS axis > +90°
- Dominant R wave in V1
- RSR' pattern in V1
- T wave inversions in V1-3 ("juvenile T-wave pattern")

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- T wave inversions in V1-3 ("juvenile T-wave pattern")

P waves

- Slightly peaked P waves (< 3mm in height is normal if ≤ 6 months)

Intervals

- Short PR interval (< 120ms) and QRS duration (<80ms)
- Slightly long QTc (≤ 490 ms in infants ≤ 6 months)

Pseudo-infarction patterns

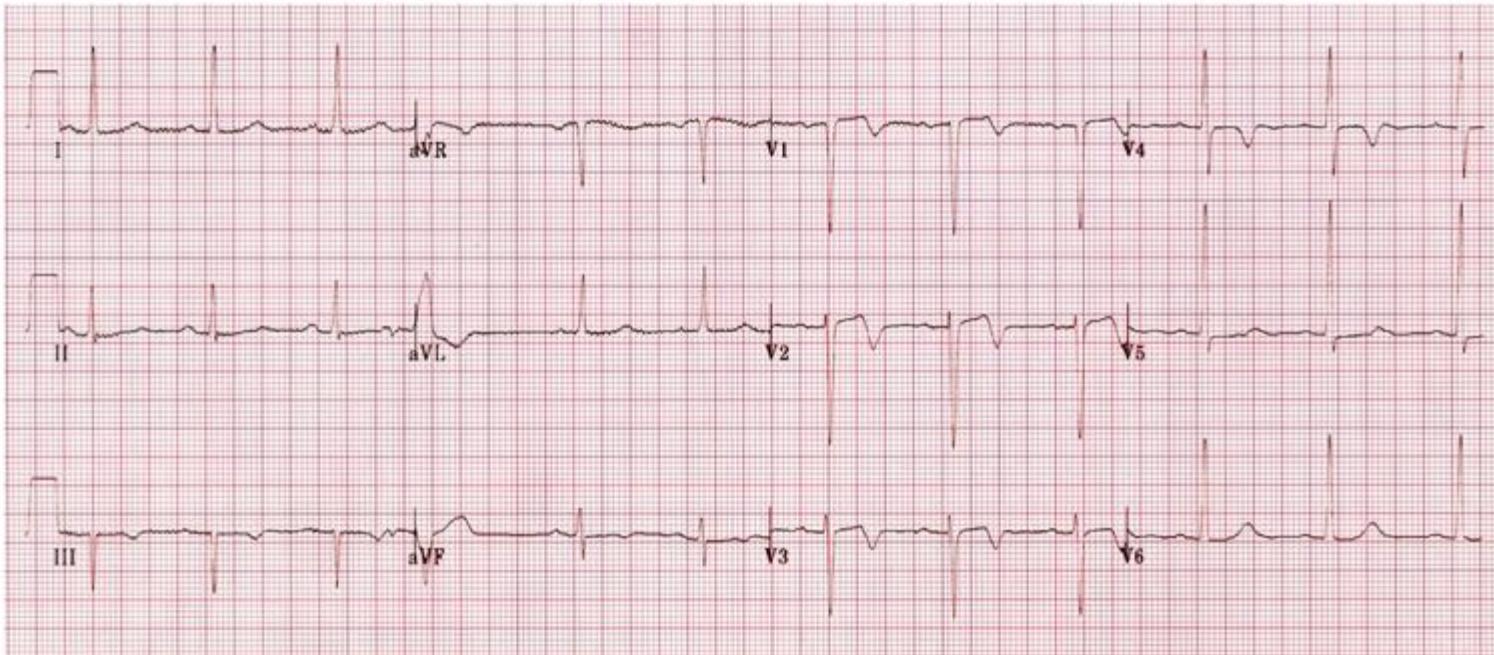
- Q waves in the inferior and left precordial leads.

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Case 52

Middle-aged patient presenting with central chest pain. Now asymptomatic. Interpret the ECG.



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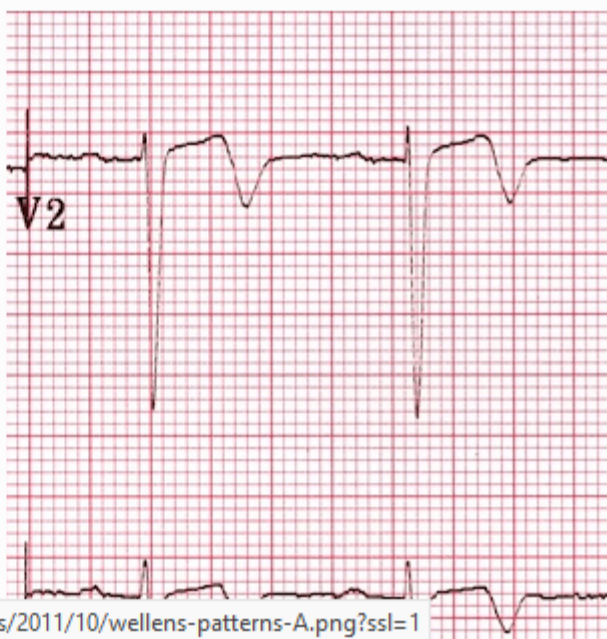
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- This is classic ECG of **Wellens' syndrome**, demonstrating characteristic biphasic T waves in V1-3.
- This ECG pattern is highly predictive of a significant occlusive lesion of the LAD.
- The biphasic T waves are a marker of reperfusion and may occur after an aborted **anterior STEMI**.
- Despite often being pain free and having normal cardiac enzymes at presentation, these patients are at risk of sudden LAD re-occlusion leading to massive anterior STEMI and are best managed with early angiography and PCI / CABG.



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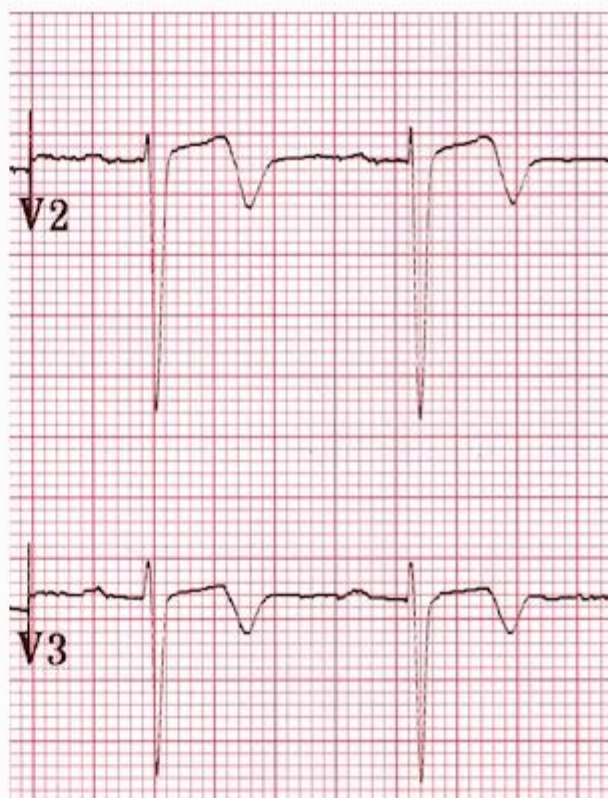
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**Biphasic T waves in Wellens' syndrome**

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Biphasic T waves in Wellens' syndrome

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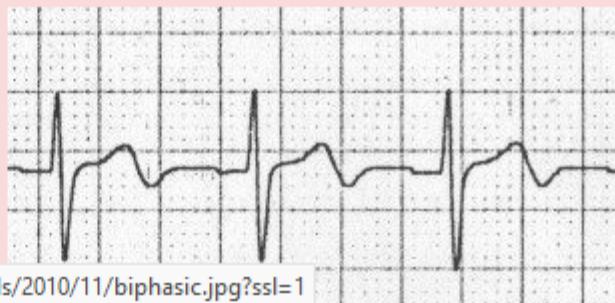
Clinical Pearls

Biphasic T waves may be seen with both **Wellens' syndrome** and **hypokalaemia**.

The main differentiating factor (apart from the clinical picture) is the direction of the T waves:

- Wellens' biphasic T waves go UP then down.
- Hypokalaemic T waves go DOWN then up.

Wellens' Syndrome



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Wellens' Syndrome



Hypokalaemia

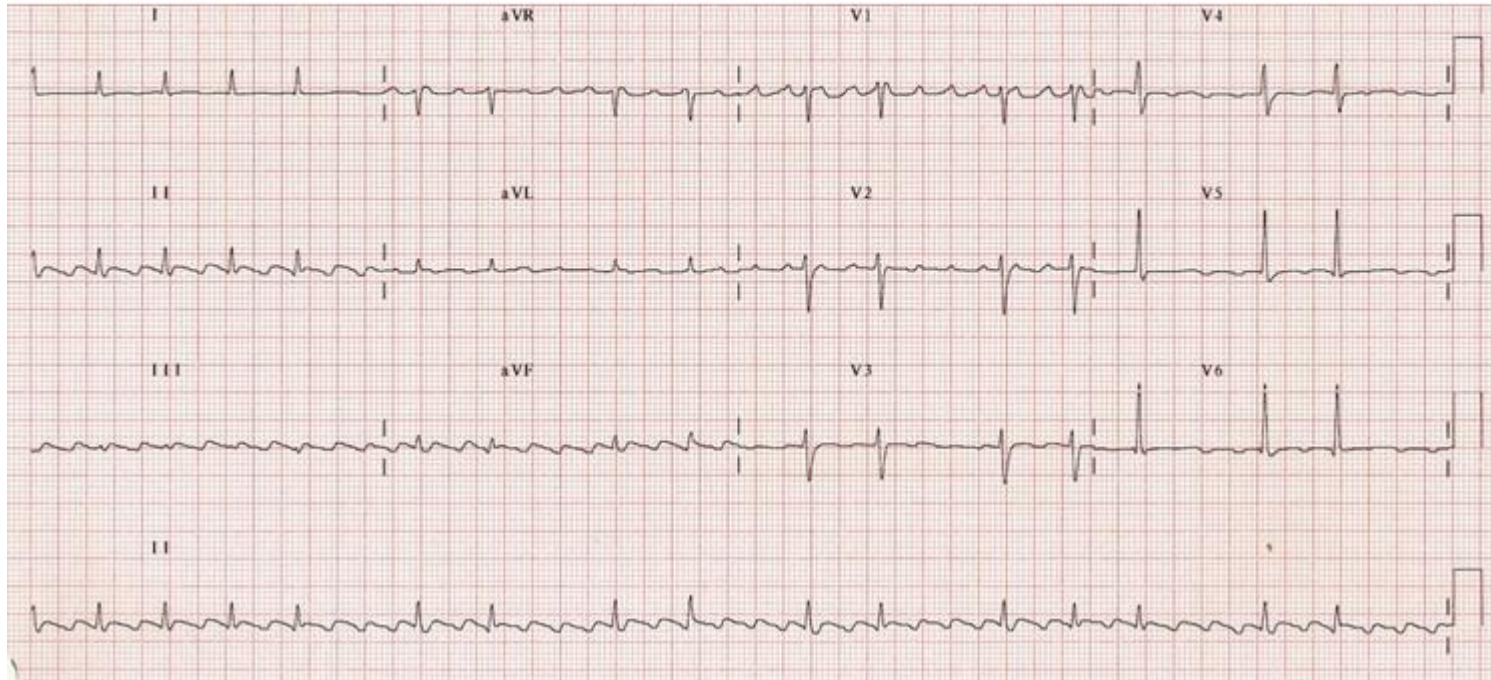


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Case 53

Elderly patient presenting with nausea and palpitations. Interpret the ECG.



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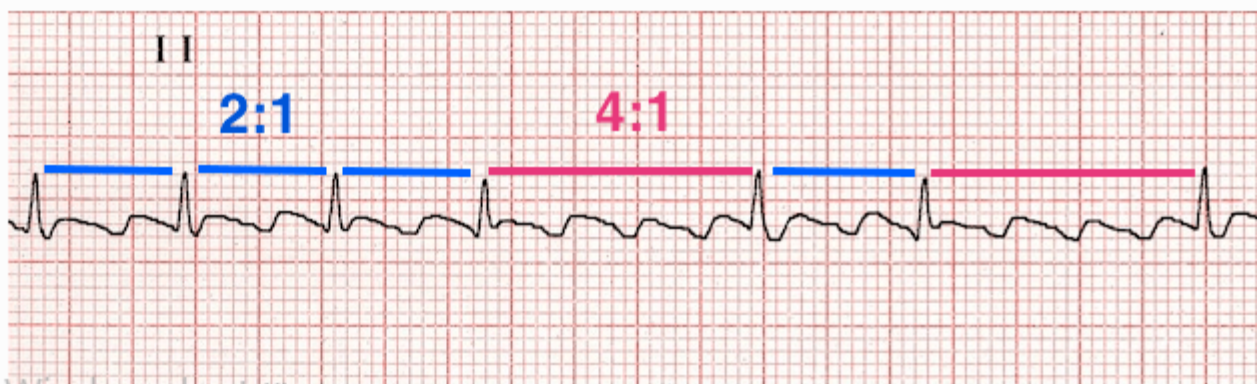
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This rhythm is frequently misidentified as **atrial fibrillation**. However, note in this case:

- Well-defined sawtooth waves in II, III, aVF with regular rate (~300bpm) and consistent morphology.
- Positive flutter waves ("pseudo-P waves") in V1-2.
- The rhythm is *not* irregularly irregular. There are repeating patterns of identical R-R intervals that crop up throughout the rhythm strip, corresponding to AV conduction ratios of either 2:1 or 4:1.

This is **atrial flutter with a variable block**.



Recurring RR intervals in flutter with variable block

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Recurring RR intervals in flutter with variable block

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Clinical Pearls

- Misidentifying this rhythm as AF is not normally a big problem as both conditions are managed similarly — i.e. rate control, anticoagulation.
- However, **flutter will cardiovert with lower energy than AF** — e.g. 50 j compared with 100-200 j.

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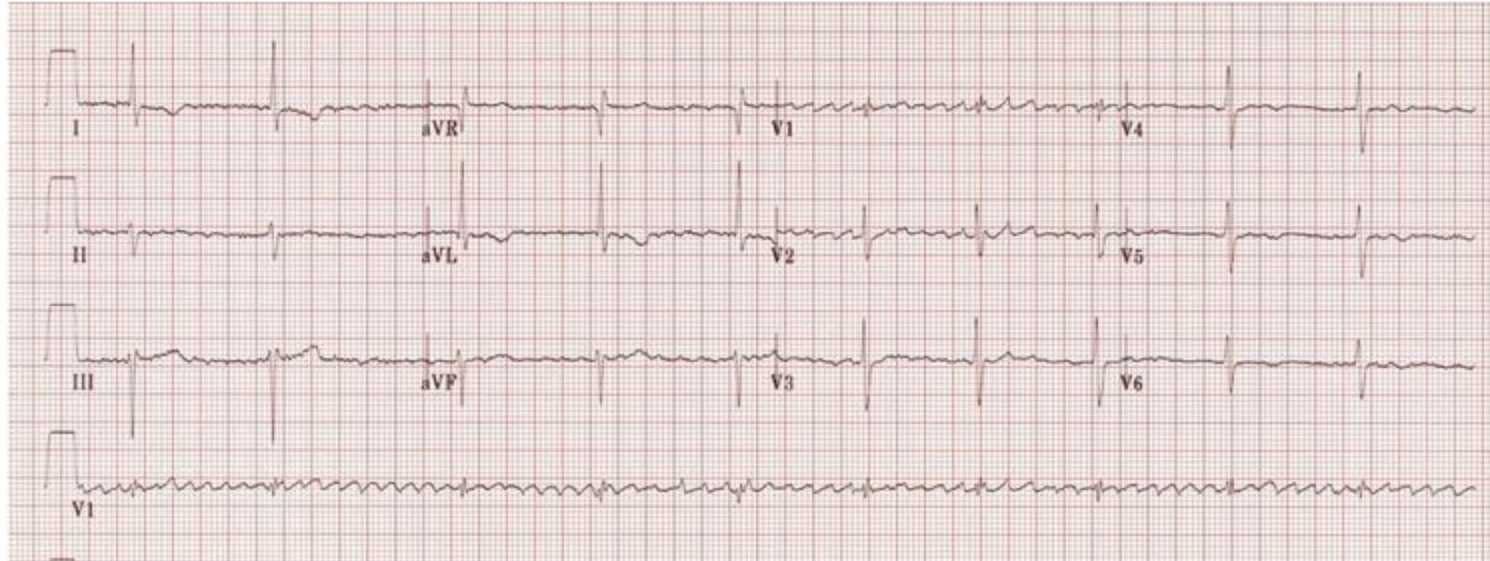


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Case 54

Elderly patient presenting with nausea and visual disturbance. Interpret the ECG.



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This is a tricky ECG!

There is evidence of **atrial fibrillation**, as evidenced by the irregular baseline with fibrillatory waves most prominent in V1-2.

NB. Fibrillatory waves are characteristically seen in V1-2 (which overlie the atria), as opposed to tremor artefact which may be seen in multiple leads without a predominance for V1-2.

However, the ventricular rhythm is regular. How can this be? AF is irregular by definition...

This is an example of **"regularised AF"** due to **digoxin toxicity**:

- The underlying rhythm is AF, which is being treated with digoxin.
- There is **complete heart block**, prevent atrial impulses from reaching the ventricles.
- There is an **accelerated junctional rhythm** maintaining cardiac output.

If this all seems like too much of a coincidence, then consider the pathophysiology of digoxin toxicity...

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Mechanisms of Digoxin Toxicity

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Mechanisms of Digoxin Toxicity

Digoxin toxicity produces a wide variety of dysrhythmias, due to:

- **Increased automaticity** of atrial, junctional and ventricular tissues — via actions at the Na/K and Na/Ca exchangers causing increased intracellular calcium and therefore increased spontaneous depolarisation of cardiac pacemaker cells.
- **Decreased AV conduction** — via increased vagal tone at the AV node.

Digoxin toxicity therefore usually produces some combination of:

- **Increased atrial automaticity** — especially atrial tachycardia, but also **atrial ectopics**, **AF**, **flutter**.
- **Increased junctional automaticity** — especially **accelerated junctional rhythms**.
- **Increased ventricular automaticity** — frequent **VEBs and bigeminy**, **polymorphic VT**.
- **AV blocks** — including **1st**, **2nd** and **3rd degree** AV block.

Characteristic ECG patterns include:

- **Atrial tachycardia with high-grade AV block** (= the classic dig-toxic rhythm).
- **Regularised AF** = AF with complete heart block + accelerated junctional escape rhythm, producing a paradoxically regular rhythm

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Characteristic ECG patterns include:

- **Atrial tachycardia with high-grade AV block** (= the classic dig-toxic rhythm).
- **Regularised AF** = AF with complete heart block + accelerated junctional escape rhythm, producing a paradoxically regular rhythm.
- **Bidirectional VT** = polymorphic VT with QRS complexes that alternate between left- and right-axis-deviation, or between LBBB and RBBB morphology.

*NB. Digoxin toxicity should not be confused with **digoxin effect** (= "sagging" ST depression and T-wave inversion in patients on therapeutic doses of digoxin; not predictive of toxicity).*

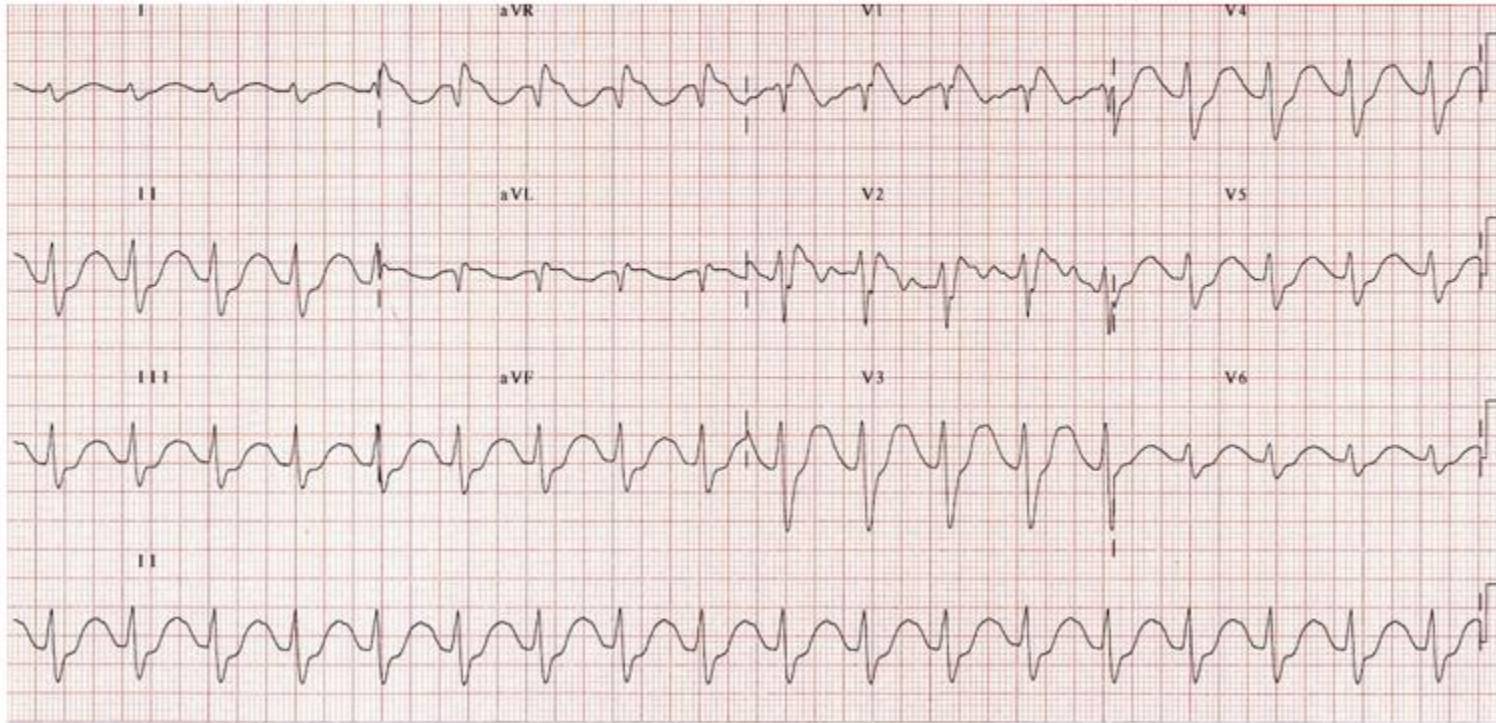
Clinical Pearls

- Check for tremor artefact before you start diagnosing regularised AF!
- If the ECG pattern appears genuine and the clinical picture is compatible with digoxin toxicity (GI upset, xanthopsia, current digoxin treatment), then check an urgent digoxin level.

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Case 55

Middle-aged patient presenting with drowsiness. BP 85/50. Pupils dilated. Interpret the ECG.



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Main Abnormalities

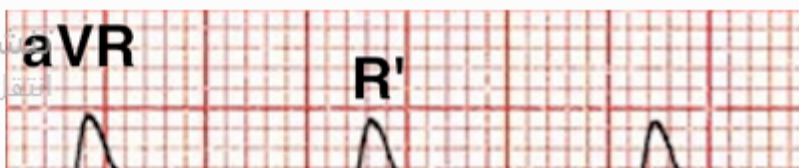
This is a classic ECG of **tricyclic antidepressant toxicity**, demonstrating multiple characteristic abnormalities.

Signs of sodium-channel blockade

- Broad QRS complexes (120 ms, or 3 small squares).
- Positive R' wave in lead aVR > 3 mm.
- Prolonged PR interval (240 ms).
- Long QT interval (> 1/2 the RR interval).
- **Brugada-like** pattern in V1.

Signs of anticholinergic toxidrome

- Sinus tachycardia (~ 110 bpm), with P waves embedded in each T wave.



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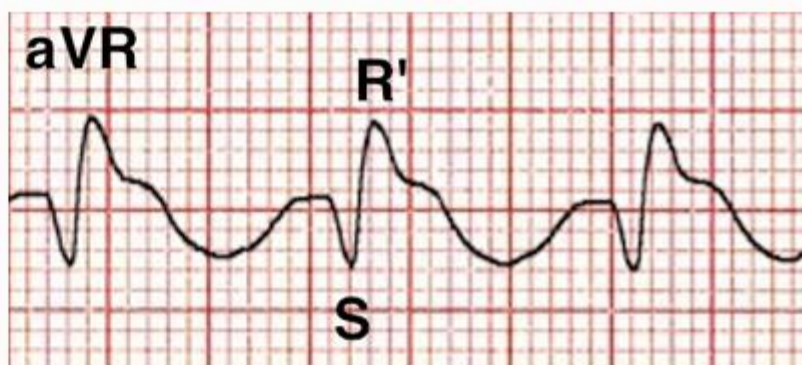
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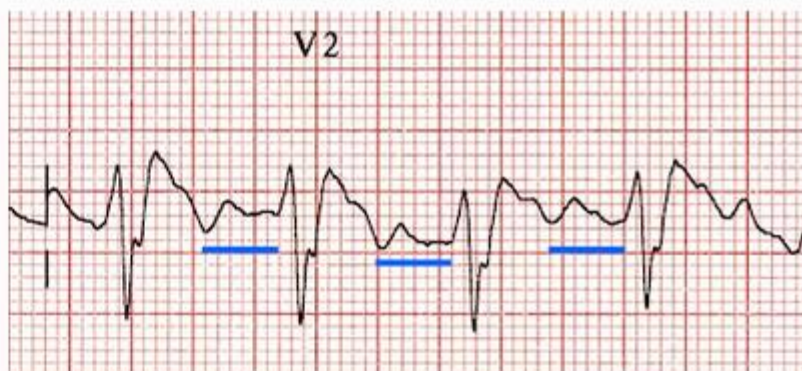
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Positive R' wave in aVR > 3mm



P waves visible in V2 with long PR interval

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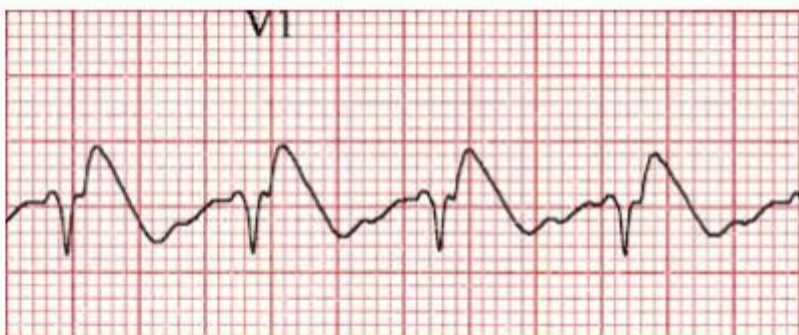
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P waves visible in V2 with long PR interval



Pseudo-Brugada pattern in V1

This patient had taken a life-threatening overdose of dosulepin (a TCA).

How to Spot Sodium-Channel Blockade

- QRS prolongation ($> 100\text{ms}$ or 2.5 small squares), typically measured in lead II.
- A terminal or secondary R wave (R' wave) in aVR $> 3\text{ mm}$.
- An R'/S ratio in aVR > 0.7 .

Prognostic Value of the ECG

In patients with TCA overdose, the degree of QRS prolongation correlates with the degree of clinical

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This patient had taken a life-threatening overdose of dosulepin (a TCA).

How to Spot Sodium-Channel Blockade

- QRS prolongation ($> 100\text{ms}$ or 2.5 small squares), typically measured in lead II.
- A terminal or secondary R wave (R' wave) in aVR $> 3\text{ mm}$.
- An R'/S ratio in aVR > 0.7 .

Prognostic Value of the ECG

In patients with TCA overdose, the degree of QRS prolongation correlates with the degree of clinical toxicity:

- QRS width $> 100\text{ ms}$ is predictive of seizures.
- QRS width $> 160\text{ ms}$ is predictive of cardiotoxicity (e.g. broad-complex dysrhythmias, hypotension).

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Clinical Pearls

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- QRS width > 160 ms is predictive of cardiotoxicity (e.g. broad-complex dysrhythmias, hypotension).

Clinical Pearls

- The combination of PR prolongation and sinus tachycardia with TCA overdose often makes the P waves difficult to see, and may lead the rhythm to be incorrectly identified as VT. This patient needs bicarbonate and hyperventilation, not electricity and amiodarone!
- The clinical significance of a **TCA-induced Brugada ECG pattern** remains controversial — i.e. is it purely a manifestation of severe sodium-channel blockade, or does it represent “unmasking” of underlying **Brugada syndrome**? These issues are discussed [here](#).

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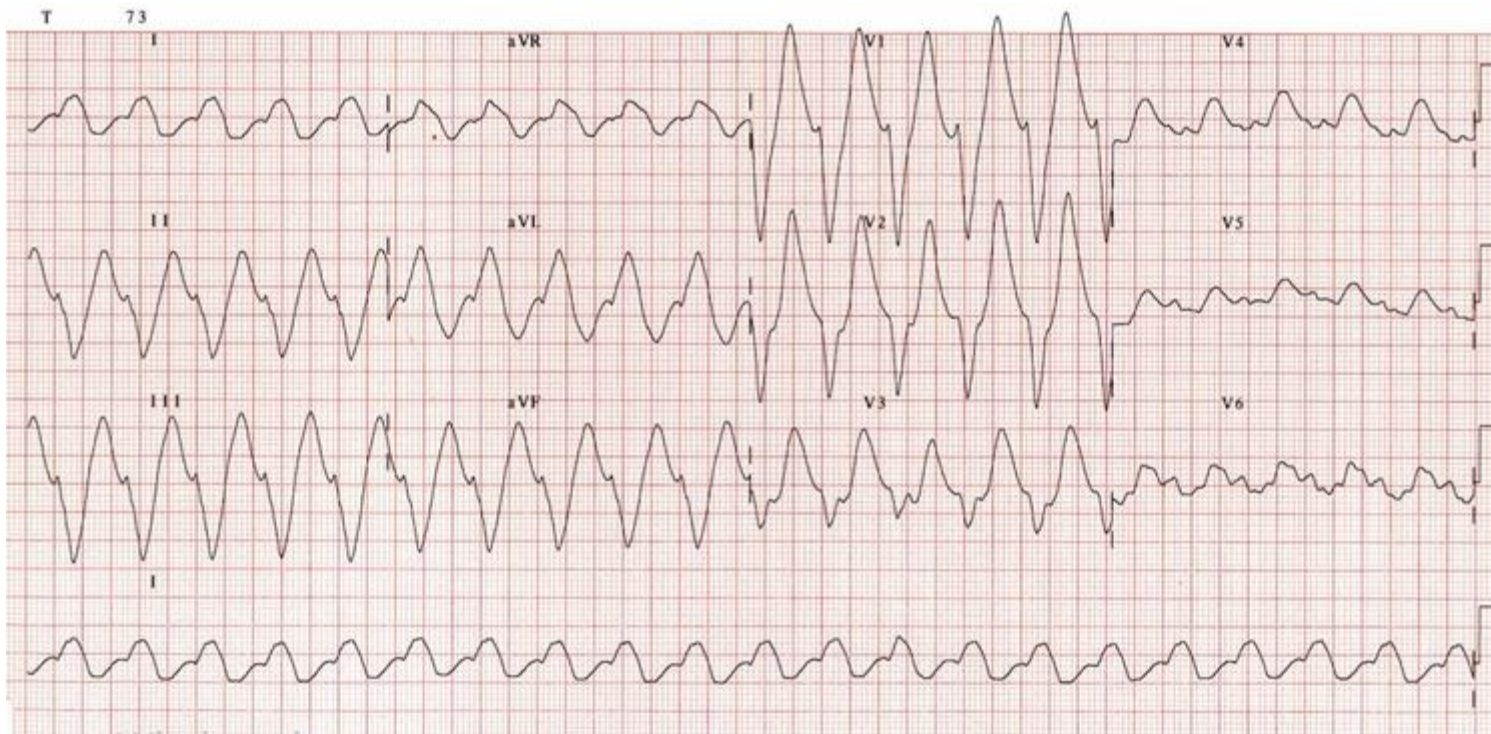
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Case 56

Middle-aged patient presenting with drowsiness. Brief seizure in ED. BP unrecordable. Interpret the ECG.



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+ Reveal Answer

This is a repeat ECG of the **previous patient** with **massive TCA overdose**, taken a short while later.

- There is now evidence of advanced **sodium-channel blockade**, with grossly prolonged QRS and QT intervals and further evolution of the R' wave in aVR.
- The ECG is beginning to take on bizarre morphology and a sine wave appearance reminiscent of **severe hyperkalaemia**.
- In some leads (II, III, aVF), the QRS morphology resembles **ventricular tachycardia**.

These features are all due to sodium-channel blockade, and resolved following aggressive treatment with IV bicarbonate, intubation and hyperventilation.

[Show post-treatment ECG](#)

Clinical Pearls

- Advanced sodium-channel blockade can resemble either **VT** or **hyperkalaemia**.

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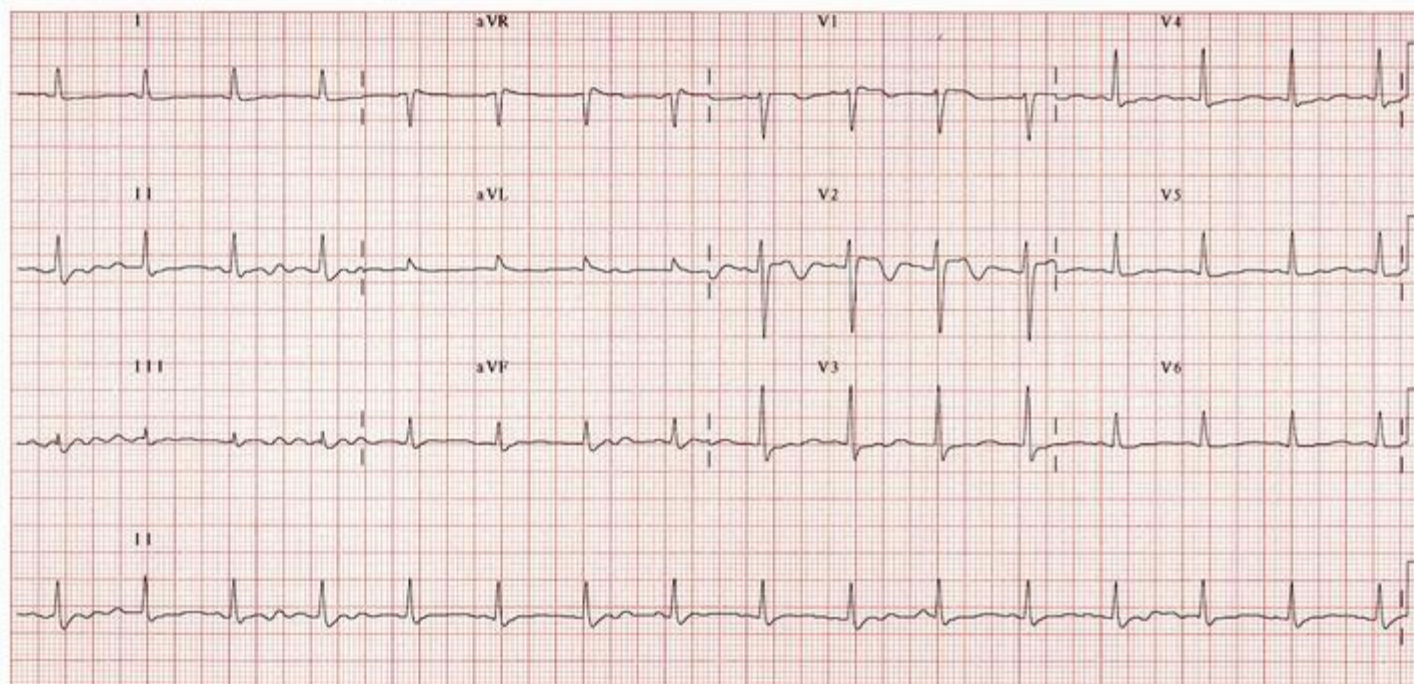
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Show post-treatment ECG



Resolving TCA toxicity – QRS complexes narrowing and R' wave disappearing with treatment.

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Clinical Pearls

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Resolving TCA toxicity – QRS complexes narrowing and R wave disappearing with treatment.

Clinical Pearls

- Advanced sodium-channel blockade can resemble either **VT** or **hyperkalaemia**.
- Standard VT treatments such as DC cardioversion and amiodarone are likely to be ineffective and potentially harmful if the broad complex rhythm is due to sodium-channel blockade. Consider the clinical context and look for clues of TCA toxicity (e.g. **anticholinergic toxidrome**).
- In arrested / peri-arrest patients with a broad or bizarre-looking ECG, consider empirical treatment for both **hyperkalaemia** (with calcium) and **sodium-channel blockade** (with bicarbonate and hyperventilation).

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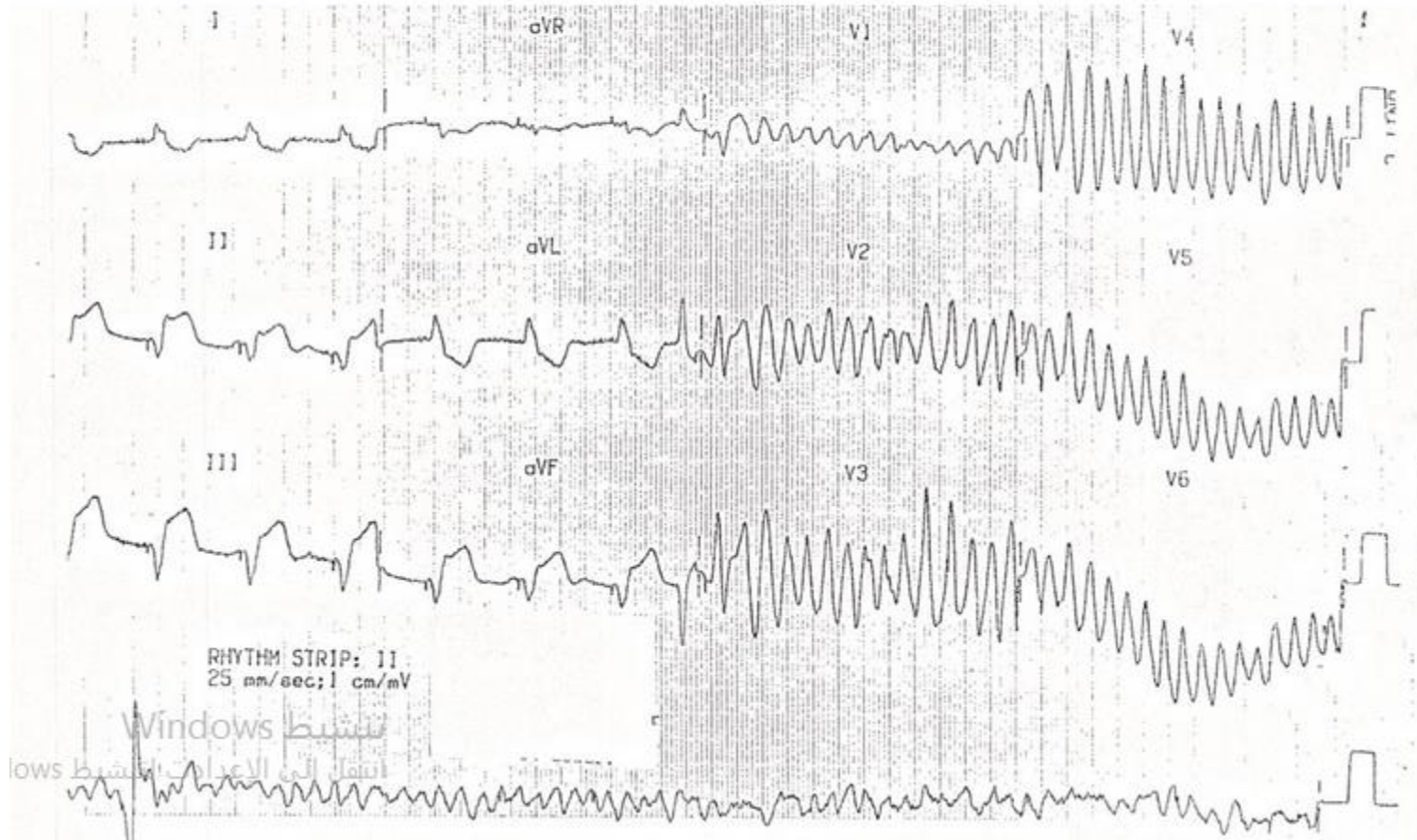
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Case 57

Middle-aged patient presenting with chest pain and diaphoresis. Becomes unresponsive during recording of ECG. Interpret the ECG.



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Main Abnormalities This is a fascinating ECG with multiple abnormalities:

- The first half of the tracing shows a **ventricular paced rhythm** with positive **Sgarbossa criteria** indicating superimposed **inferior STEMI**.
- There is **excessively discordant ST elevation** (> 25% of Q/S wave depth) in II, III and aVF with reciprocal change in I and aVL.
- A ventricular ectopic (beat #8) occurs at a vulnerable time, resulting in a run of **ventricular flutter** (very rapid VT at rates > 200-300 bpm).
- This rapidly degenerates to **ventricular fibrillation** (seen in the rhythm strip, which is recorded *after* the other 12 leads).
- The artefact at the start of the rhythm strip may represent a precordial thump!

Clinical Pearls

- While most rhythm strips are recorded simultaneously with the 12-lead ECG, some older machines may record the rhythm strip *after* the other 12 leads.
- Consider this as a possibility if your rhythm strip doesn't seem to "line up" with the rest of the ECG.

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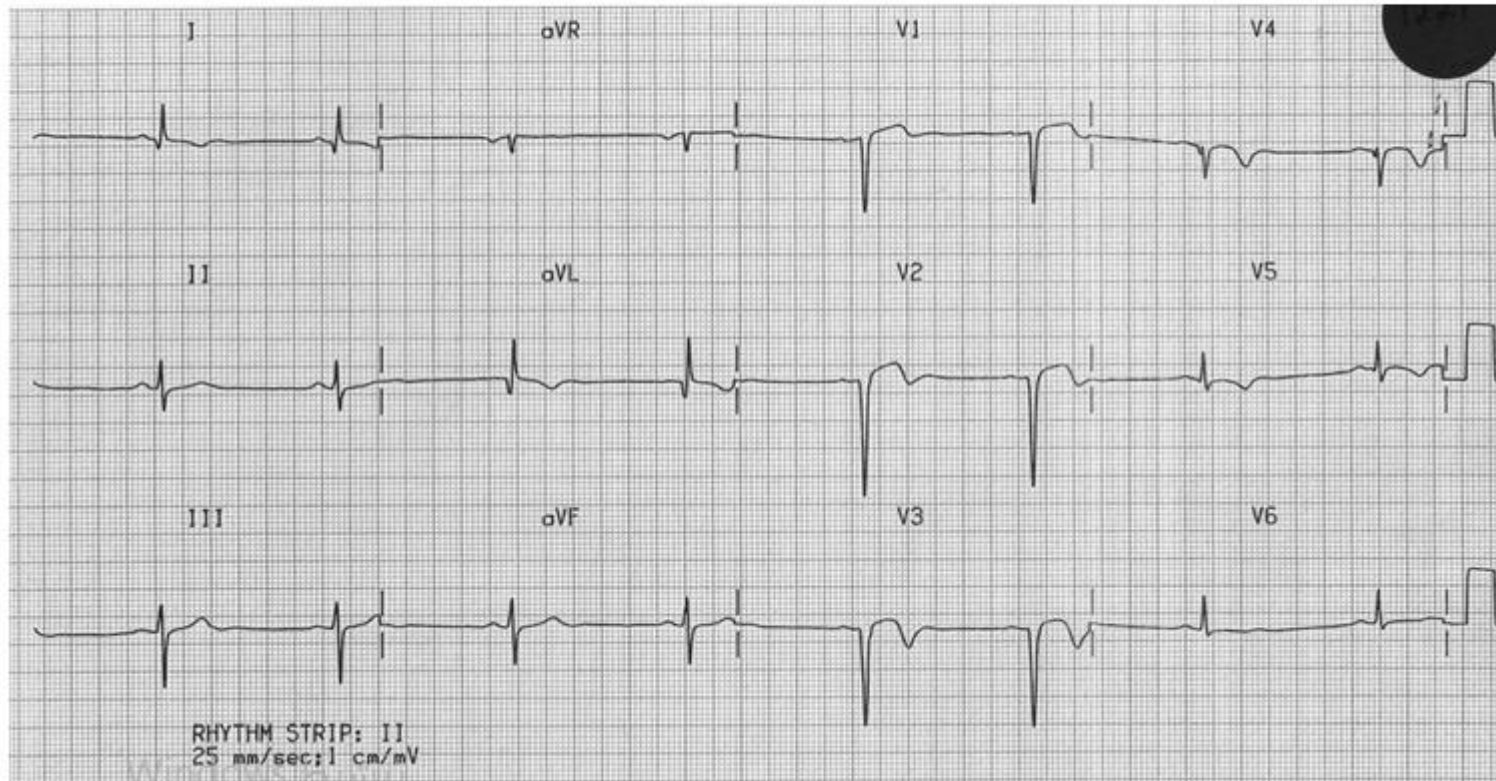


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Case 58

Elderly patient presenting with chest pain. Interpret the ECG.



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This ECG shows changes consistent with an old **anterolateral infarction** — the so-called **left ventricular aneurysm** pattern.

- ST elevation in V1-3 associated with deep Q waves (= **LV aneurysm morphology**).
- **Pathological Q waves** also seen in I, aVL and V4.
- **Poor R wave progression** (= R wave height < 3 mm in V3).
- Biphasic / inverted T waves in V1-5, I and aVL.

Clinical Pearls

- The LV aneurysm pattern refers to the combination of residual ST elevation, deep Q waves and inverted or biphasic T waves seen in patients following an acute myocardial infarction. This ECG pattern is associated with transmural scarring and paradoxical movement of the LV on wall on echocardiography.
- Around 60% of patients with anterior STEMI develop some degree of chronic ST elevation on their ECG, which can cause diagnostic confusion.
- If these patients present with chest pain, the safest approach is to take serial ECGs looking for signs of evolving STEMI such as evolving ST elevation or **pseudo-normalisation of T waves**.

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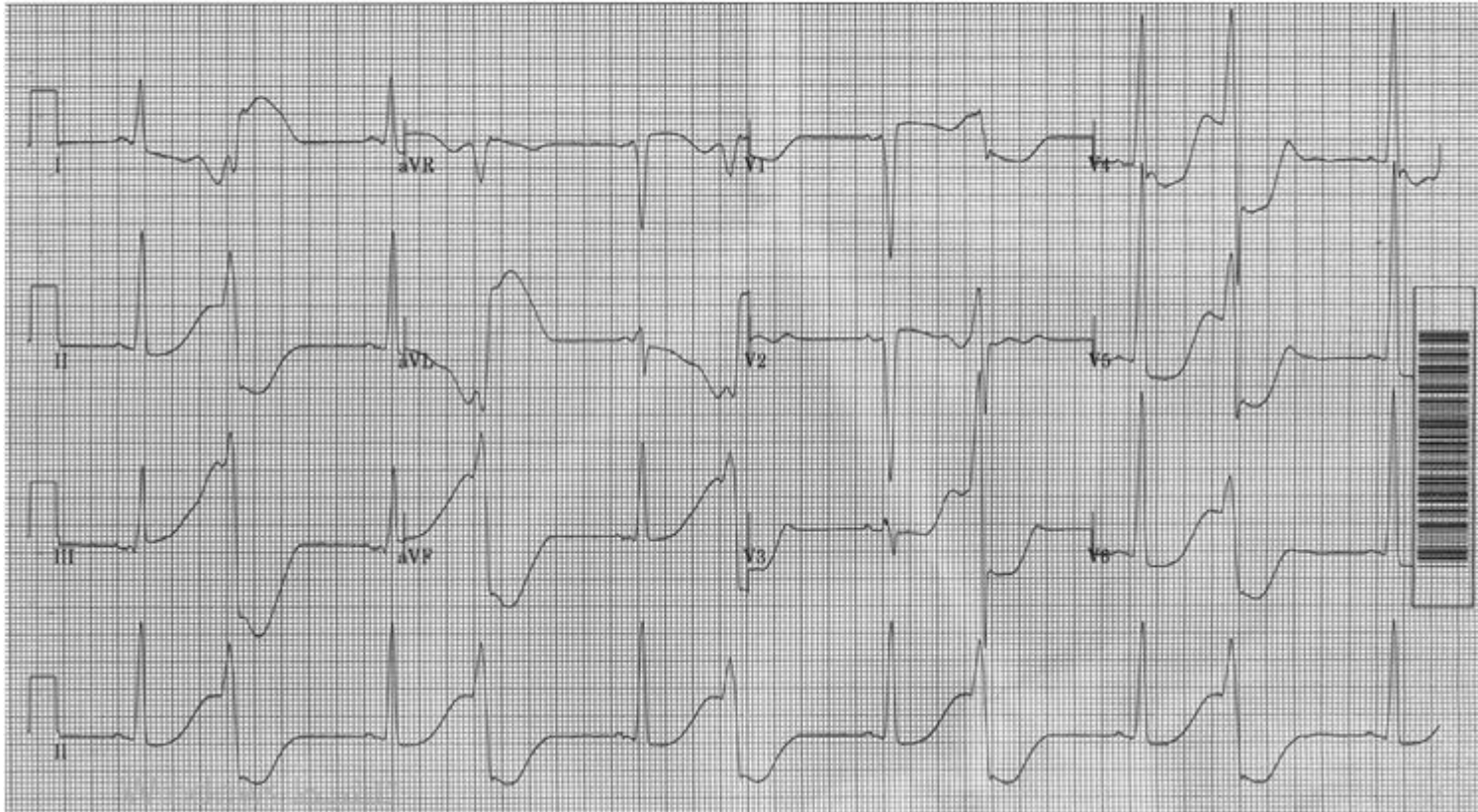
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Case 59

57-year old man with ROSC following VF arrest. Interpret the ECG.



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Main Abnormalities

- Sinus rhythm with frequent ventricular ectopics in a pattern of **ventricular bigeminy**.
- Grossly prolonged QT interval (> 600 ms).
- "R on T" phenomenon is present, with each VEB falling on the end of the T wave — this ECG pattern is very high risk for deterioration to **torsades de pointes** and **ventricular fibrillation**.
- Relatively short PR interval and possible **delta waves** (leads I, II, V6) are suggestive — but not diagnostic — of **WPW syndrome**.
- Voltage criteria for **left ventricular hypertrophy** are present in multiple leads.

This patient had suffered a cardiac arrest in the context of severe **hypertrophic cardiomyopathy** and **long QT syndrome**.

(NB. ~1/3 of patients with HOCM will have some evidence of WPW on their ECG).

Can you guess what happened next?

+ Reveal Answer

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pt:expand(document.getElementById("ddet1550887036")) TdP cardiac arrest!

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This patient had suffered a cardiac arrest in the context of severe **hypertrophic cardiomyopathy** and **long QT syndrome**.

(NB. ~1/3 of patients with HOCM will have some evidence of WPW on their ECG).

Can you guess what happened next?

+ Reveal Answer

- The patient had a further TdP cardiac arrest!
- This was treated with IV magnesium and potassium, with restoration of sinus rhythm.

This interesting case is discussed in more detail [here](#).

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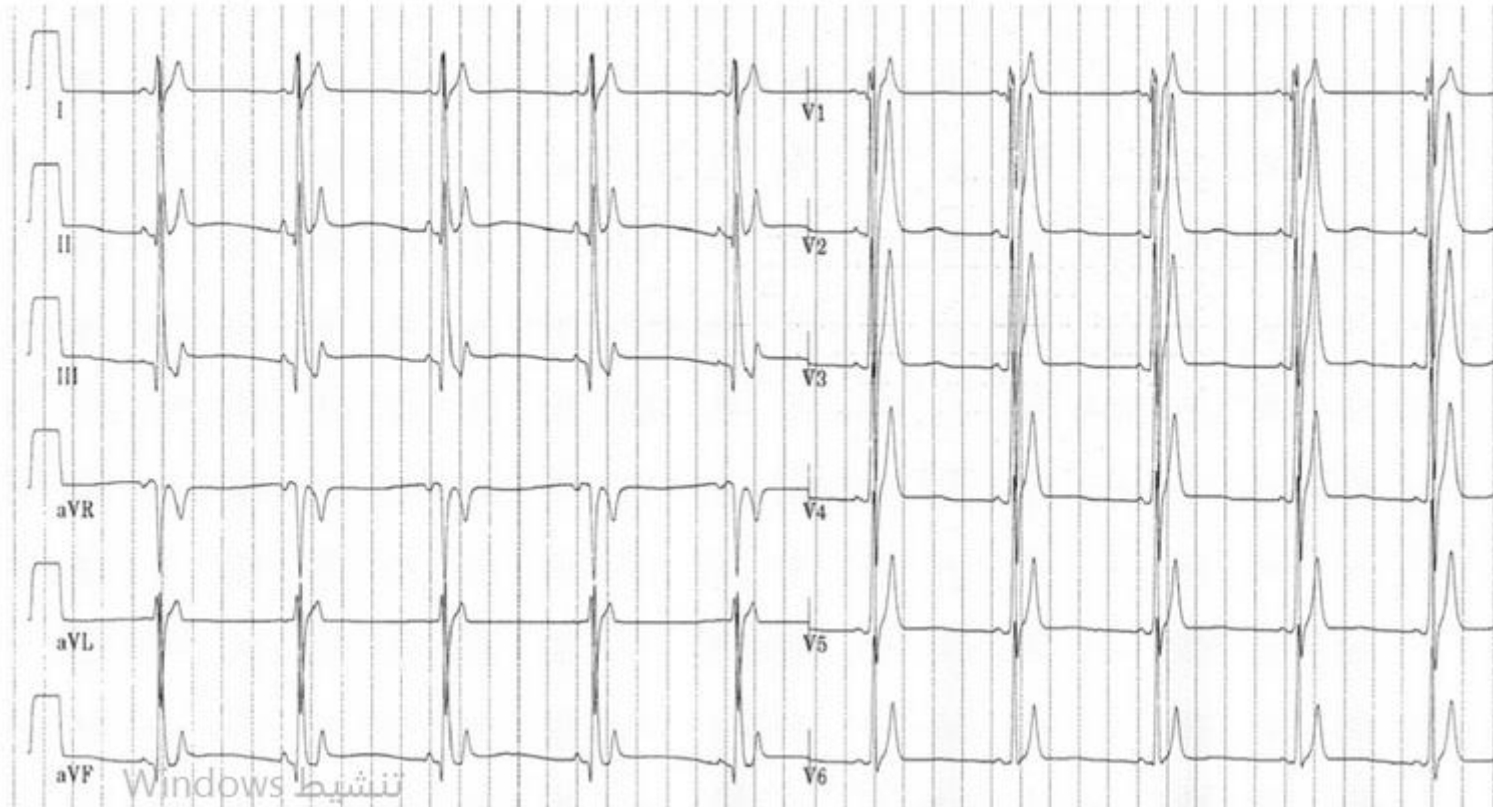
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Case 60

16-year old male presenting with syncope. Describe and interpret his ECG.



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Main Abnormalities

- Markedly peaked T waves in V2-6.
- Extremely short QT interval (~240 ms).

In a patient presenting with syncope, this ECG pattern is very suspicious for the **short QT syndrome**.

Short QT Syndrome

- This is a recently-described arrhythmogenic condition associated with paroxysmal **atrial** and ventricular fibrillation.
- The hallmark is a significantly shortened QT interval (at least < 360 ms, often < 330 ms) with associated T-wave peaking.
- SQTS is a genetically-inherited **cardiac channelopathy** on the same spectrum as other familial arrhythmogenic diseases such as **Long QT Syndrome** (LQTS), **Brugada Syndrome** and **Catecholaminergic Polymorphic Ventricular Tachycardia** (CPVT).

When to Suspect SQTS

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arrhythmogenic diseases such as **Long QT Syndrome (LQTS)**, **Brugada Syndrome** and **Catecholaminergic Polymorphic Ventricular Tachycardia (CPVT)**.

When to Suspect SQTS

- Any patient with a QT interval < 330 ms.
- QT interval < 360 ms and convincing symptoms (syncope, cardiac arrest) or family history.

Differential Diagnosis

- Peaked T waves and short QT interval may be seen with **severe hyperkalaemia**.
- A shortened QT interval may also be seen with **severe hypercalcaemia**.

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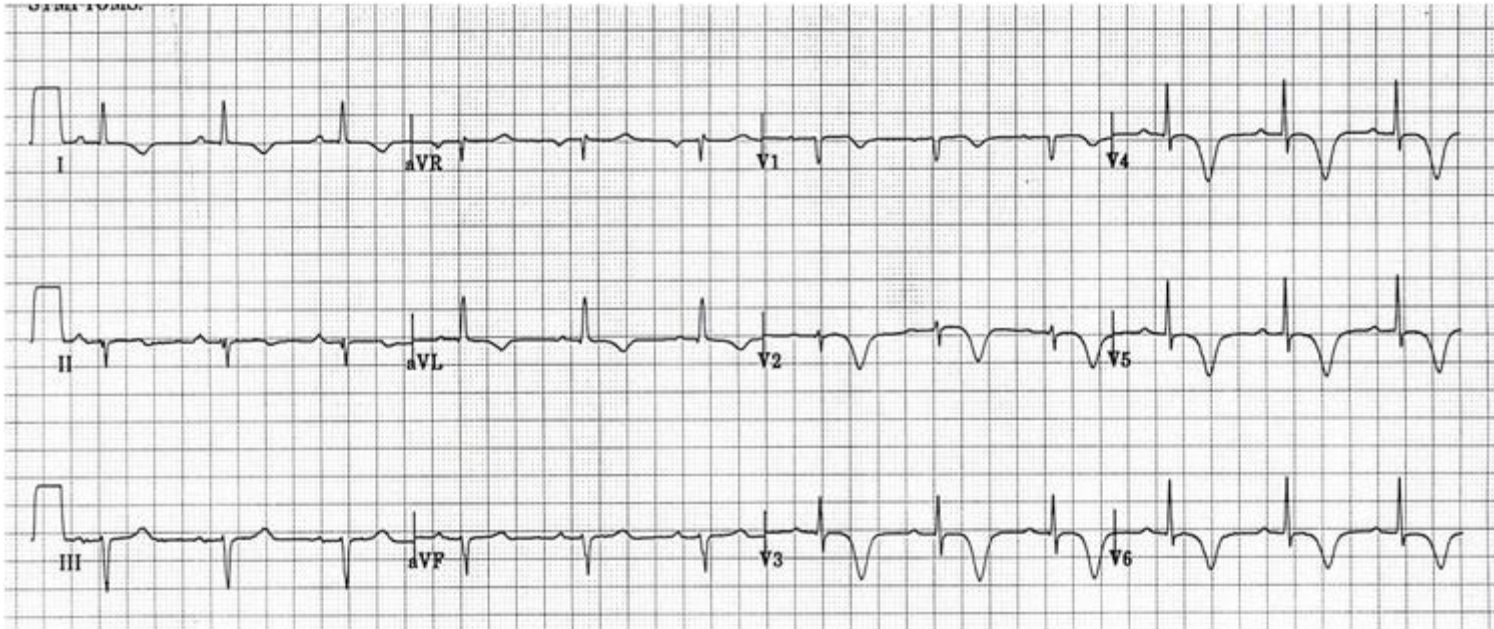
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Case 61

Middle-aged patient presenting with an episode of chest pain. Currently asymptomatic. Describe and interpret his ECG



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Reveal Answer

- This pattern of deeply inverted T waves in the anterolateral leads V2-6, I and aVL is characteristic of **Wellens syndrome**.
- This ECG pattern is highly predictive of a significant occlusive lesion of the LAD.
- The inverted T waves are a marker of reperfusion and may occur after an aborted **anterior STEMI**.
- Despite often being pain free and having normal cardiac enzymes at presentation, these patients are at risk of sudden LAD re-occlusion leading to massive anterior STEMI and are best managed with early angiography and PCI / CABG.

Differential Diagnosis

A similar pattern of deep anterolateral T-wave inversions may also be seen with:

- Apical **hypertrophic cardiomyopathy** – suspect if associated **LVH**
- **Raised intracranial pressure** – patient will be comatose (see **Quiz ECG #12**)

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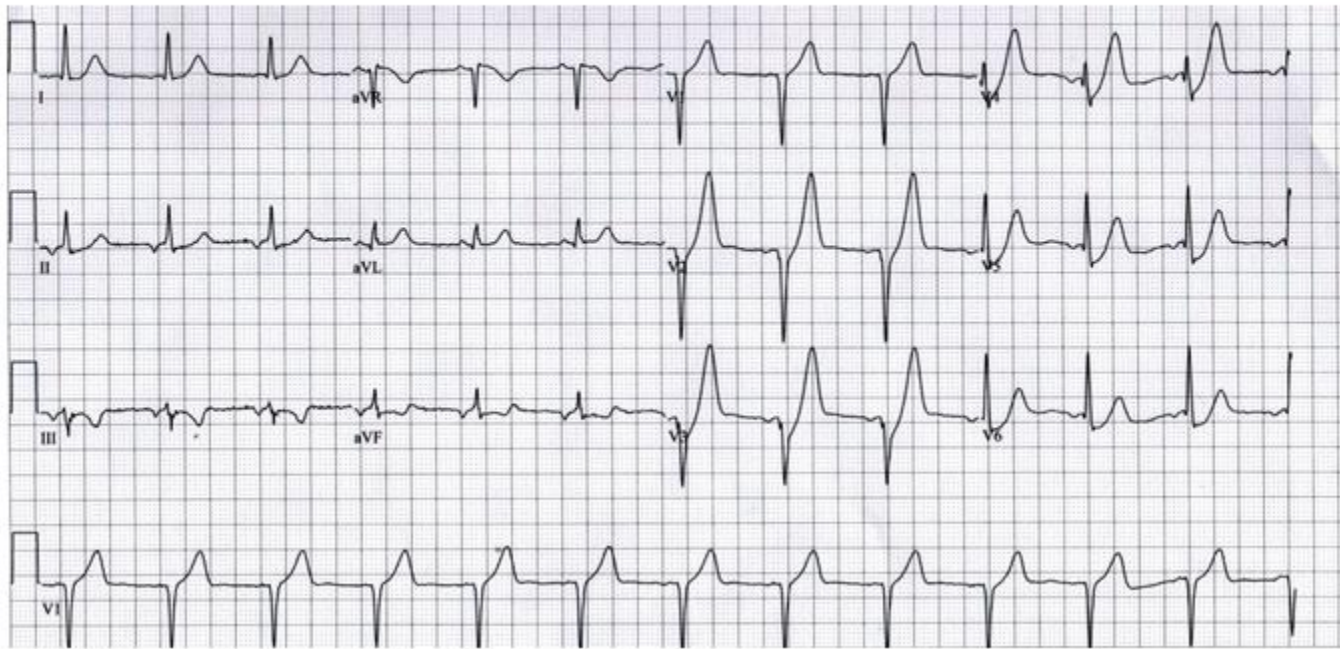
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Case 62

Middle aged patient presenting with chest pain and diaphoresis. Describe and interpret his ECG



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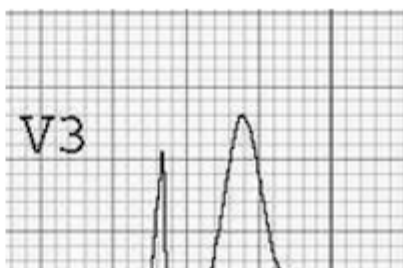
Reveal Answer

Main Abnormalities

- ST depression in V2-6, which slopes upwards and joins the ascending limb of the T wave.
- Prominent, "rocket-shaped" T waves in the precordial leads V2-5.
- Subtle ST elevation in aVR.

Diagnosis

- This combination of ST depression with rocket-shaped T waves in the precordial leads V1-6 is referred to as the De Winter ECG pattern or "De Winter's T waves" (also see [ECG #19](#))
- It is becoming increasingly recognised as an anterior STEMI equivalent (~2% of LAD occlusion)
- [Some authors](#) are now recommending that this ECG pattern be treated identically to anterior STEMI, with urgent PCI or thrombolysis.



Typical De Winter's T Wave

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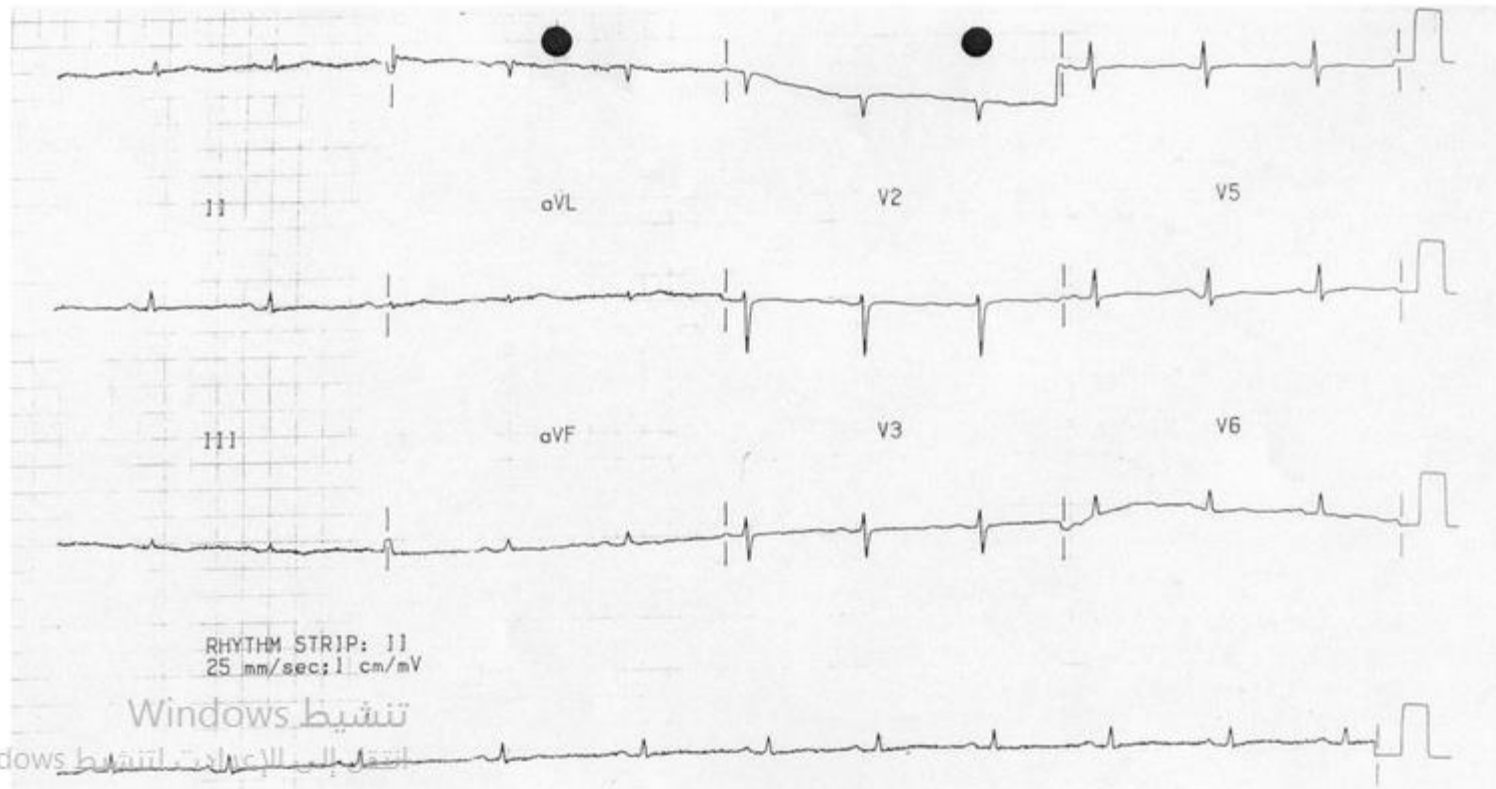
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Case 63

Elderly patient presenting with reduced level of consciousness, hypothermia and hypotension refractory to inotropes. Describe and interpret his ECG



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The most striking abnormality on this ECG is **extremely low QRS voltage**, in this case due to **severe myxoedema**.

Definition

The QRS is said to be low voltage when:

- “
- The amplitudes of all the QRS complexes in the limb leads are < 5 mm; or
 - The amplitudes of all the QRS complexes in the precordial leads are < 10 mm

Mechanisms

Low voltage is produced by...

- “
- The “damping” effect of increased layers of fluid, fat or air between the heart and the recording electrode.
 - Loss of viable myocardium.
 - Diffuse infiltration or myxoedematous involvement of the heart.

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Specific causes of low volt

- Pericardial effusion
- Pleural effusion

- Obesity

- Emphysema
- Pneumothorax

- Myxoedema

- Pneumothorax

Infiltrative / Connective Tissue Disorders

- Myxoedema
- Infiltrative myocardial diseases — i.e. **restrictive cardiomyopathy** due to amyloidosis, sarcoidosis, haemochromatosis
- Constrictive pericarditis
- Scleroderma

Loss of viable myocardium

- Previous massive MI
- End-stage dilated cardiomyopathy

The most important cause is **massive pericardial effusion**, which produces a triad of:

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The most important cause is **massive pericardial effusion**, which produces a triad of:

- “
- Low voltage
 - Tachycardia
 - Electrical alternans

Patients with this triad need to be immediately assessed for clinical or echocardiographic evidence of tamponade.

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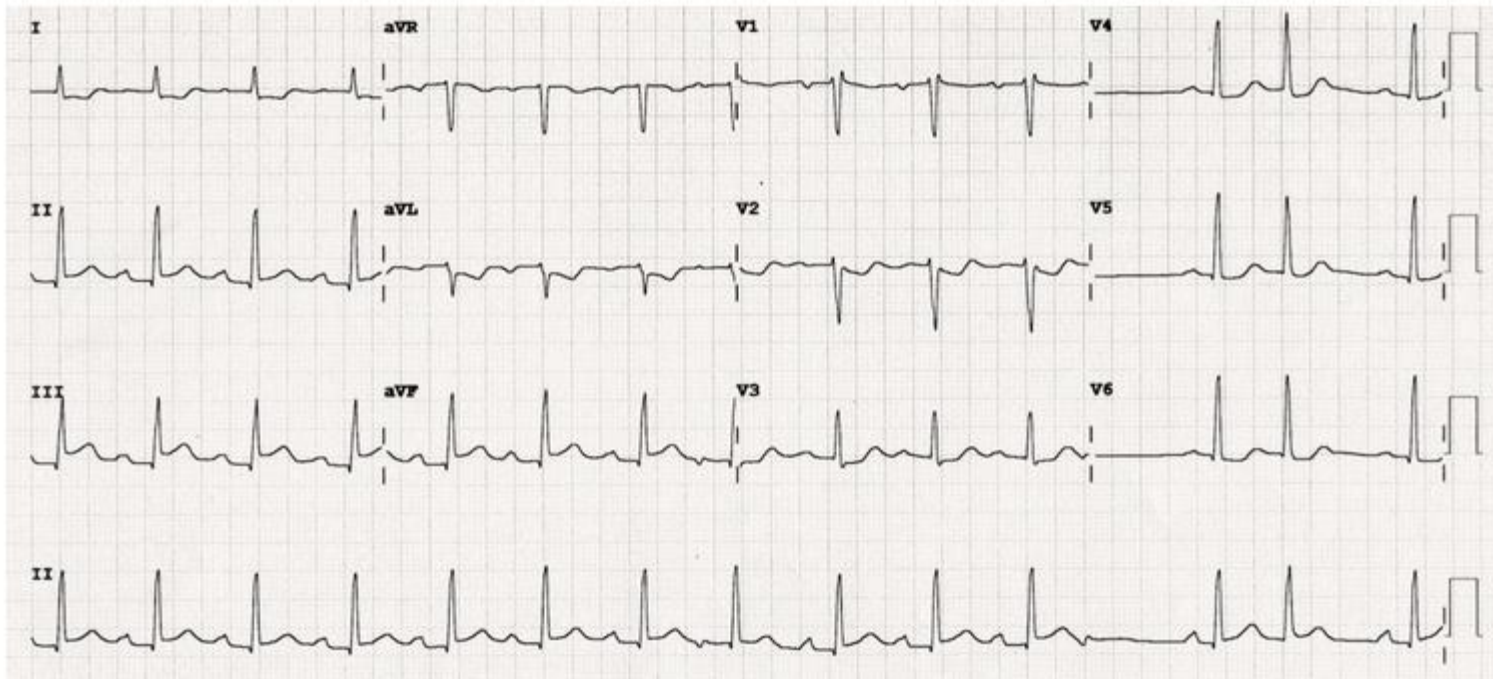
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Case 64

Chest pain and diaphoresis. BP 80/50. Describe and interpret his ECG



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Key Abnormalities

- There is ST elevation in the inferior leads II, III and aVF.
- The concave morphology might lead you to suspect **pericarditis** — however, there is reciprocal change in the high lateral leads I and aVL, confirming the diagnosis of **inferior STEMI**.

There are additional features suggestive of **right ventricular infarction**:

- ST elevation in III > II
- Isoelectric ST segment in V1 with ST depression in V2

Other Abnormalities

- There is a break in the rhythm towards the end of the rhythm strip, with what appears to be a non-conducted P wave, suggesting the development of **2nd degree AV block** — e.g. a slowly-evolving **Wenckbach cycle**.
- The 13th QRS complex appears to be a supraventricular ectopic beat (**PAC** or **PJC**).

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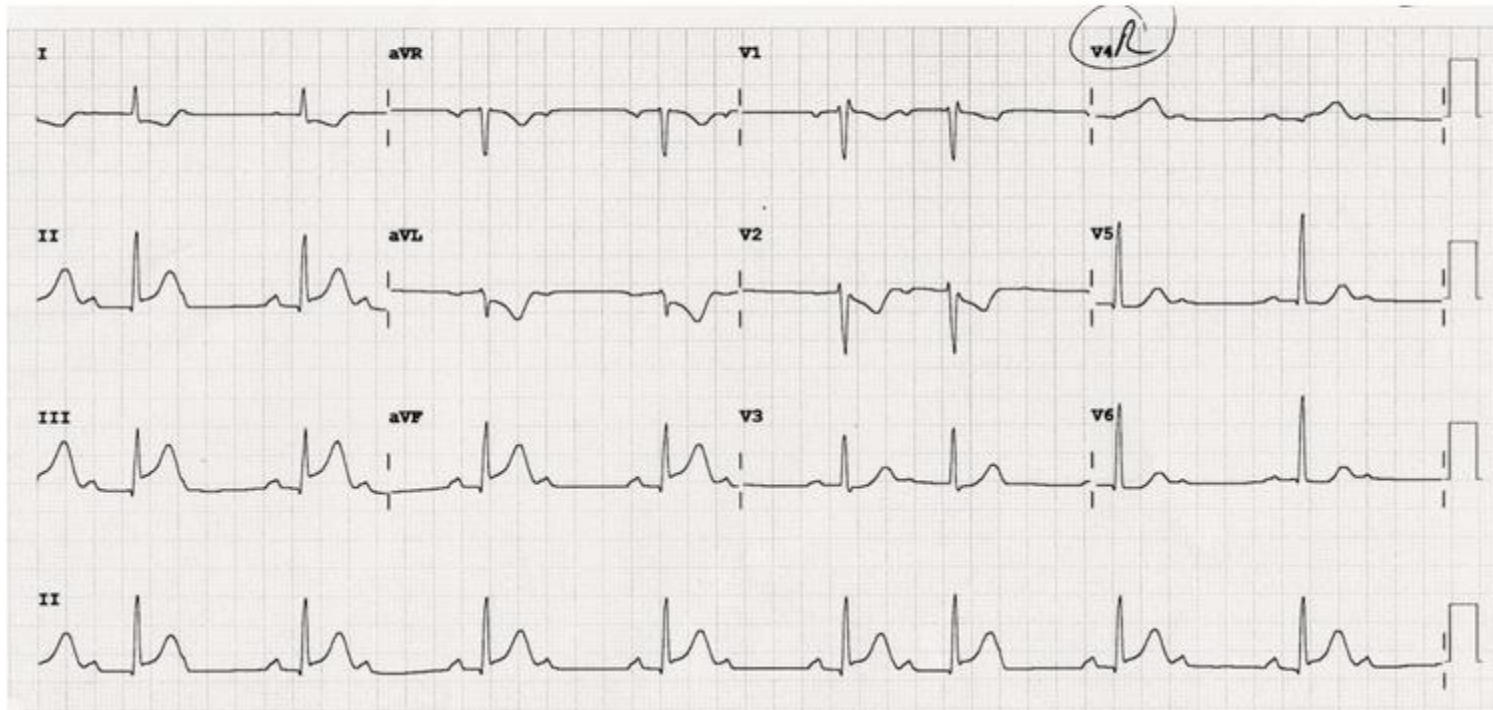
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Case 65

Chest pain and diaphoresis. BP 80/50. Describe and interpret his ECG



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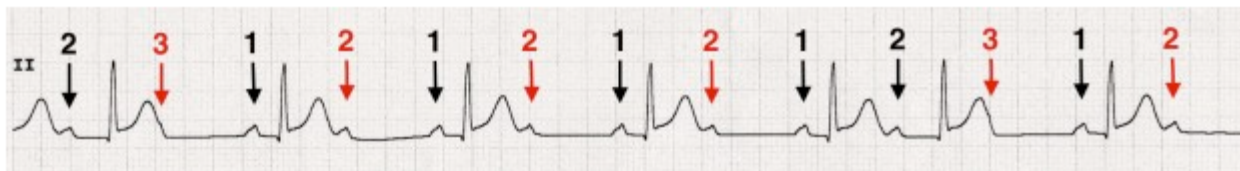
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This is a repeat ECG of the **previous patient**, demonstrating:

- **Inferior STEMI** — STE in II, III, aVF with reciprocal change in I and aVL.
- Evidence suggesting **RV infarction** — STE in III > II.
- Evidence confirming **RV infarction** — STE and **hyperacute T wave** in V4R.
- Evolving second degree AV block with alternating **2:1 block** and **3:2 Wenckebach cycles**.

This ECG pattern is diagnostic of a right coronary artery occlusion.

Rhythm Strip Explanation



- Arrows indicate the position of P waves.
- Black arrows indicate conducted P waves.
- Red arrows indicate **non-conducted P waves** — some of these are concealed within the preceding T wave, causing a small bump at the back of the T wave.
- Complexes cluster together in groups with either **2:1 conduction** or as **3:2 Wenckebach cycles**, with

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- Arrows indicate the position of P waves.
- Black arrows indicate conducted P waves.
- Red arrows indicate *non-conducted* P waves — some of these are concealed within the preceding T wave, causing a small bump at the back of the T wave.
- Complexes cluster together in groups with either **2:1 conduction** or as **3:2 Wenckebach cycles**, with prolongation of the PR interval prior to the non-conducted P wave.
- The number above each P wave denotes its position in the sequence.

Bradycardia and AV Block in Inferior STEMI

Up to 20% of patients with inferior STEMI will develop either second- or third degree heart block.

There are two presumed mechanisms for this:

- **Ischaemia of the AV node** due to impaired blood flow via the **AV nodal artery**.
This artery arises from the RCA 80% of the time, hence its involvement in inferior STEMI due to RCA occlusion.
- **Bezold-Jarisch reflex** = increased vagal tone secondary to ischaemia.

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STEMI due to RCA occlusion.

- **Bezold-Jarisch reflex** = increased vagal tone secondary to ischaemia.

- The conduction block may develop either as a step-wise progression from **1st degree heart block** via **Wenckebach** to **complete heart block** (in 50% of cases) or as abrupt onset of second or third-degree heart block (in the remaining 50%).
- Patients may also manifest signs of sinus node dysfunction, such as sinus bradycardia, sinus pauses, **sinoatrial exit block** and sinus arrest. Similarly to AV node dysfunction, this may result from increased vagal tone or ischaemia of the SA node (the SA nodal artery is supplied by the RCA in 60% of people).
- Bradyarrhythmias and AV block in the context of inferior STEMI are usually transient (lasting hours to days), respond well to atropine and do not require permanent pacing.

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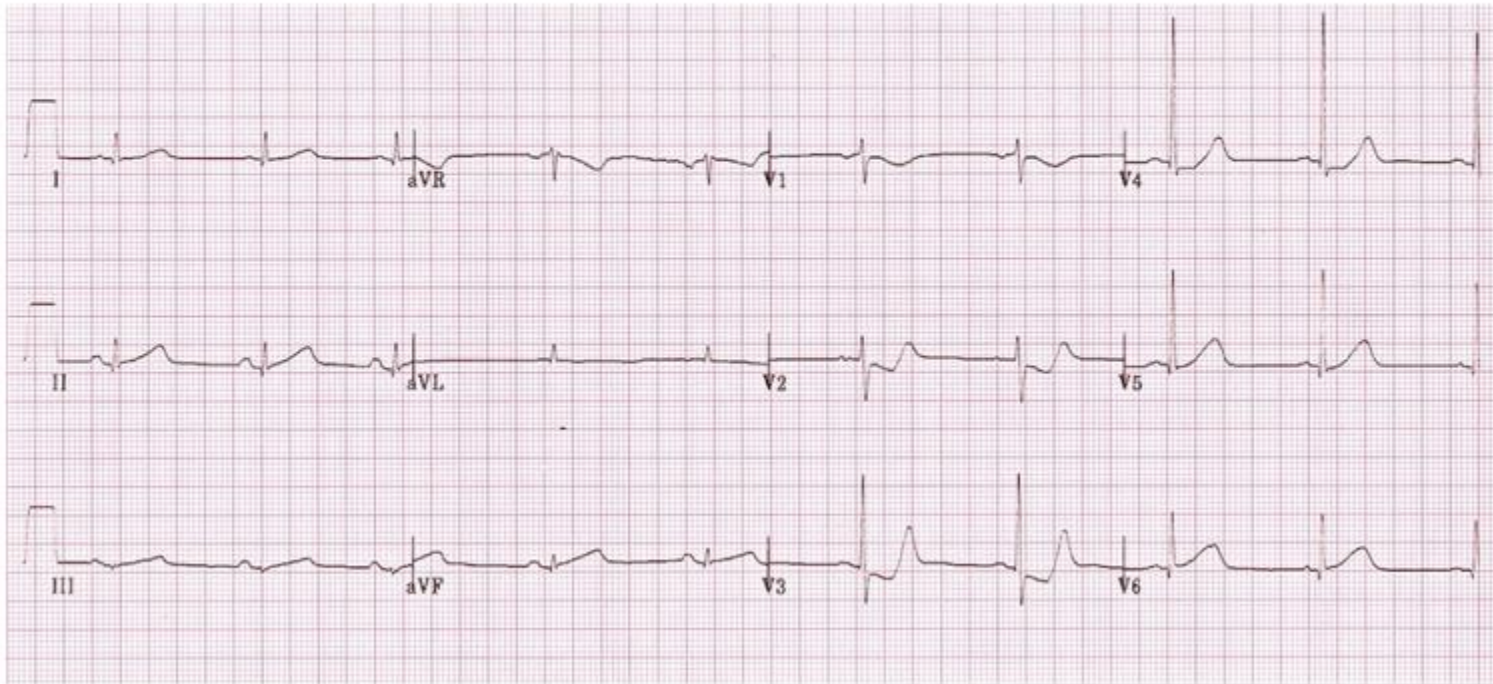
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Case 66

Elderly patient presenting with chest pain and diaphoresis. Describe and interpret his ECG



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Reveal Answer

This ECG demonstrates an **infero-posterior STEMI**, as manifest by:

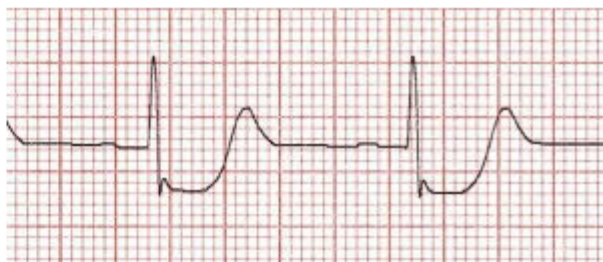
- Subtle **inferior STE** and hyperacute T waves (T waves > QRS complexes)
- ST depression and terminal T-wave positivity in V2-3 = **posterior wall involvement**

See **Quiz ECG 14** for another example of posterior infarction.

Tips for spotting posterior infarction

Look specifically at leads V2-3 for the combination of:

- Horizontal ST depression.
- Tall, broad R wave (>30ms wide, R/S ratio > 1) — this is a Q-wave equivalent.
- Upright T wave — particularly the terminal portion of the T wave.



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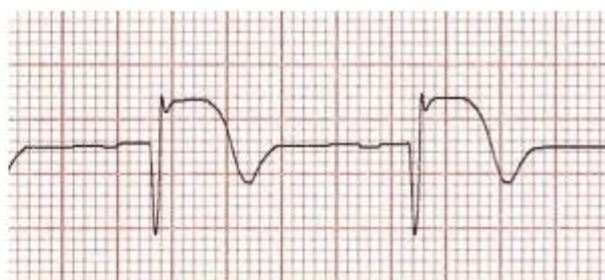
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- Tall, broad R wave ($>30\text{ms}$ wide, R/S ratio > 1) — this is a Q-wave equivalent.
- Upright T wave — particularly the terminal portion of the T wave.



Typical appearance of posterior infarction
in V2-3

One common trick is to turn the ECG over, hold it up to the light and look through it from behind. This inverts lead V2, which then takes on the appearance of a classic STEMI.



Inverted ECG — the complexes now
resemble a typical STEMI

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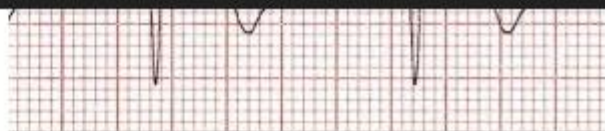
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Inverted ECG — the complexes now resemble a typical STEMI

In this ECG example, V3 is the most characteristically abnormal lead.

Look for evidence of posterior involvement in any patient with an **inferior** or **lateral STEMI**.

Sometimes it can be difficult to determine whether ST depression in V2-3 is due to posterior STEMI or simply subendocardial ischaemia affecting the anteroseptal wall. The diagnosis can be confirmed by recording **posterior leads V7-9**.

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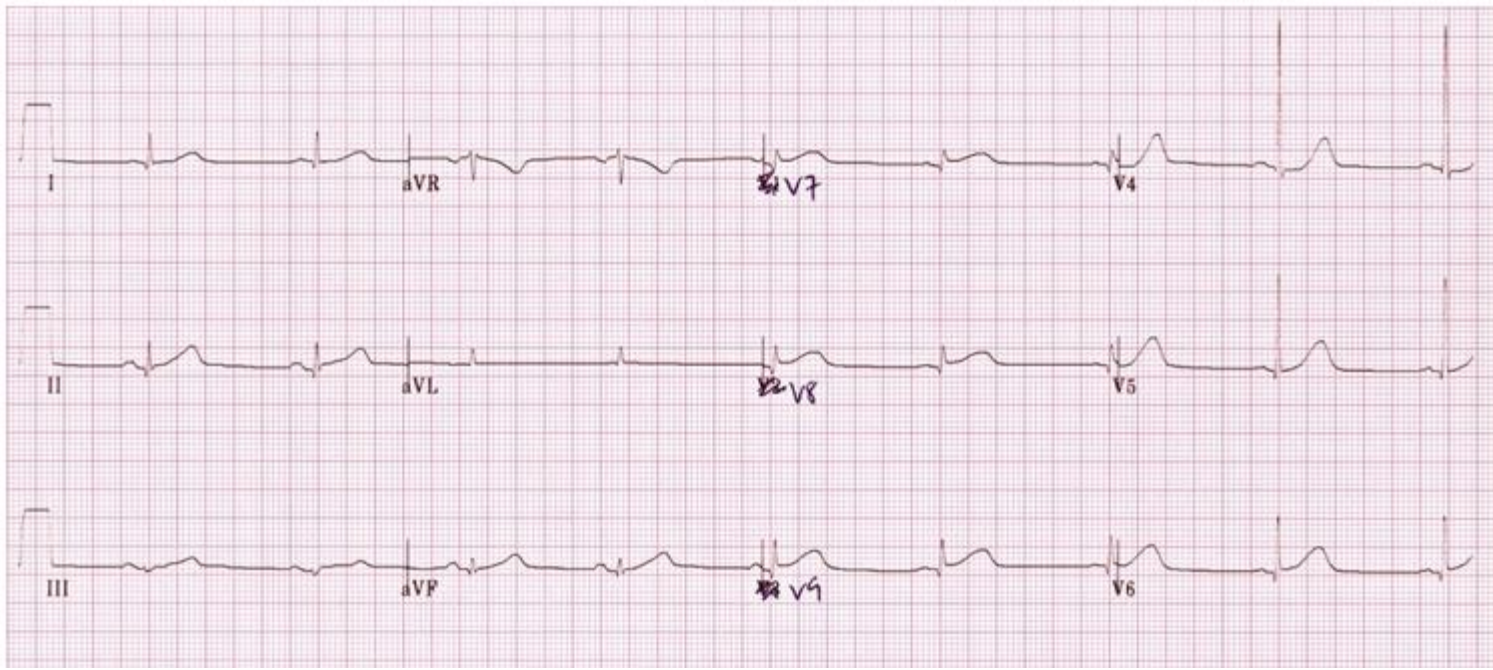
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Case 67

Elderly patient with chest pain and diaphoresis. Describe and interpret his ECG



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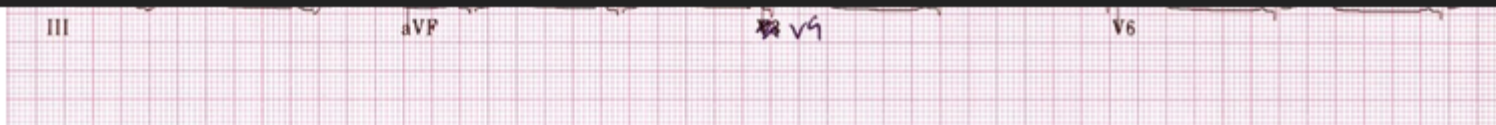
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Reveal Answer

- This is the same patient as [ECG 066](#).
- **Posterior leads V7-9** show subtle ST elevation with early Q-wave formation, confirming the presence of **posterior infarction**.

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About Edward Burns

Ed Burns is an Emergency Physician working in Prehospital & Retrieval Medicine in Sydney, Australia. He has a passion for ECG interpretation and medical education. Ed is the force behind the LITFL ECG library | + Edward Burns

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Case 68

Severe chest pain and hypotension (70/40) in an elderly man. Describe and interpret his ECG



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This ECG shows:

- ST elevation in aVR.
- ST depression in multiple leads (V5-6, I, II, aVL, aVF).
- Evidence of **anteroseptal STEMI** – ST elevation with Q wave formation in V1-3.

In the context of ischaemic chest pain and cardiogenic shock, the combination of...

- Widespread ST depression
- ST elevation in aVR > 1 mm
- ST elevation in V1-3

... is concerning for **proximal LAD occlusion** (compare this to the **LMCA pattern** seen in **Quiz ECG 008**).

While this pattern of diffuse ST depression with STE in aVR is often referenced as a marker of **LMCA / proximal LAD occlusion**, may be seen whenever there is diffuse severe subendocardial ischaemia, e.g.

- Severe triple vessel disease
- Severe anaemia or hypoxaemia
- Following resuscitation from cardiac arrest

Outcome

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... is concerning for **proximal LAD occlusion** (compare this to the **LMCA pattern** seen in **Quiz ECG 008**).

While this pattern of diffuse ST depression with STE in aVR is often referenced as a marker of **LMCA / proximal LAD occlusion**, may be seen whenever there is diffuse severe subendocardial ischaemia, e.g.

- Severe triple vessel disease
- Severe anaemia or hypoxaemia
- Following resuscitation from cardiac arrest

Outcome

*This patient actually had **severe multi-vessel disease**. Angiography demonstrated a chronic total occlusion of his circumflex artery, with critical stenoses of his proximal LAD, RCA and ramus intermedius. Surprisingly, in this case the culprit vessel was thought to be the RCA, which had been collateralising his chronically occluded circumflex. He went on to receive a CABG x 4.*

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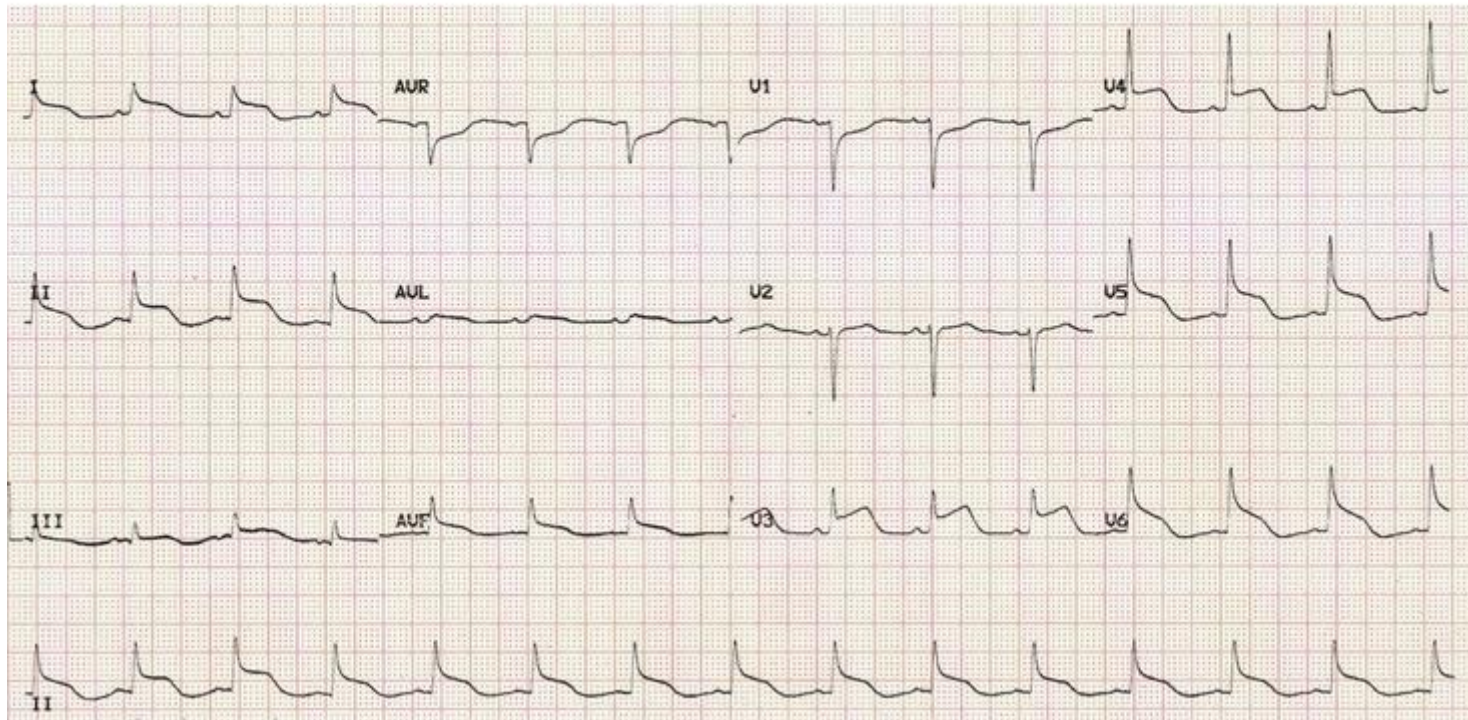
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Case 69

18-year old female with severe traumatic brain injury, ICP 40mmHg. Fluctuating BPs. Describe and interpret her ECG



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Reveal Answer

- The ECG shows diffuse ST elevation.
- The morphology is atypical, there is no clear anatomical predominance for a vascular territory and no obvious reciprocal changes (except the inverted leads V1 and aVR).
- This is an example of a pseudo-infarction pattern due to **raised intracranial pressure**.
- Compare this with **Quiz ECG 012** (raised ICP causing giant T wave inversions).

ECG changes with elevated ICP

Raised ICP is associated with certain characteristic ECG changes:

- “
- Widespread giant **T-wave inversions** (“cerebral T waves”).
 - **QT prolongation**.
 - Bradycardia (*the **Cushing reflex** – indicates imminent brainstem herniation*).

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Other possible ECG changes that may be seen:

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Other possible ECG changes that may be seen:

- “
- ST segment elevation / depression — *this may mimic myocardial ischaemia or pericarditis.*
 - Increased **U wave** amplitude.
 - Other rhythm disturbances: sinus tachycardia, junctional rhythms, premature ventricular contractions, atrial fibrillation.

In some cases, these ECG abnormalities may be associated with echocardiographic evidence of regional ventricular wall motion abnormality — so-called **neurogenic stunned myocardium** or **neurogenic stress cardiomyopathy**. The presumed mechanism is massive release of catecholamines, similar to **Takotsubo syndrome**.

This patient developed labile blood pressures and transient wall motion abnormalities plus these ECG changes during a sustained spike in her ICP. The ECG changes and wall motion abnormalities improved once her ICPs came under control.

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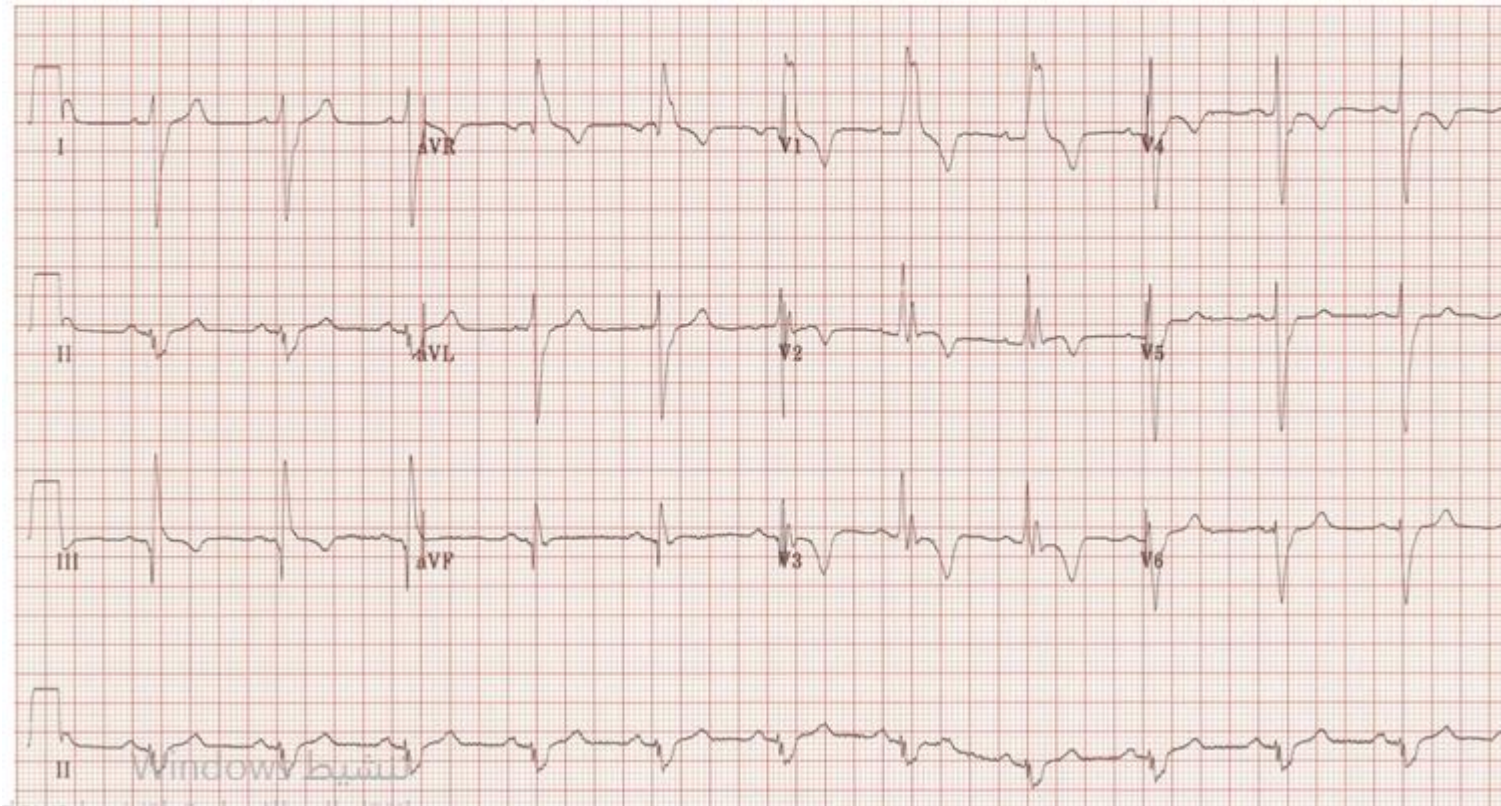
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Case 70

Elderly patient presenting with sudden onset of chest pain and shortness of breath. Hypoxic (SaO₂ 82% RA) and hypotensive (80/50). Describe and interpret his ECG



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There are multiple features suggestive of **right ventricular hypertrophy** or **strain**:

- **Right axis deviation**
- **Dominant R wave in V1**
- **Right bundle branch block**
- **Right ventricular strain pattern** — T wave inversions in V1-4, lead III
- **S_I Q_{III} T_{III} pattern**
- **Clockwise rotation of the heart**, with a persistent S wave in V6

Given the clinical history, the most likely scenario is **acute right heart strain** due to **massive pulmonary embolism**.

A similar ECG pattern may also be seen with **chronic cor pulmonale**, pulmonary hypertension or **RV hypertrophy** (e.g. due to congenital heart disease).

ECG changes in pulmonary embolism include:

- **Sinus tachycardia** — the most common abnormality; seen in 44% of patients.
- **Complete or incomplete RBBB** — associated with increased mortality; seen in 18% of patients.
- **Right ventricular strain pattern** — T wave inversions in the right precordial leads (V1-4) ± the inferior leads (II, III, aVF). This pattern is seen in up to 34% of patients and is associated with high

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ECG changes in pulmonary embolism include:

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- **Right axis deviation** – seen in 16% of patients. Extreme right axis deviation may occur, with axis between zero and -90 degrees, giving the appearance of left axis deviation ("pseudo left axis").
- **Dominant R wave in V1** – a manifestation of acute right ventricular dilatation.
- **Right atrial enlargement (P pulmonale)** – peaked P wave in lead II > 2.5 mm in height. Seen in 9% of patients.
- **S_I Q_{III} T_{III} pattern** – deep S wave in lead I, Q wave in III, inverted T wave in III. This "classic" finding is neither sensitive nor specific for pulmonary embolism; found in only 20% of patients with PE.
- **Clockwise rotation** – shift of the R/S transition point towards V6 with a persistent S wave in V6 ("pulmonary disease pattern"), implying rotation of the heart due to right ventricular dilatation.
- **Atrial tachyarrhythmias** – **AF**, **flutter**, **atrial tachycardia**. Seen in 8% of patients.
- **Non-specific ST segment and T wave changes**, including ST elevation and depression. Reported in up to 50% of patients with PE.

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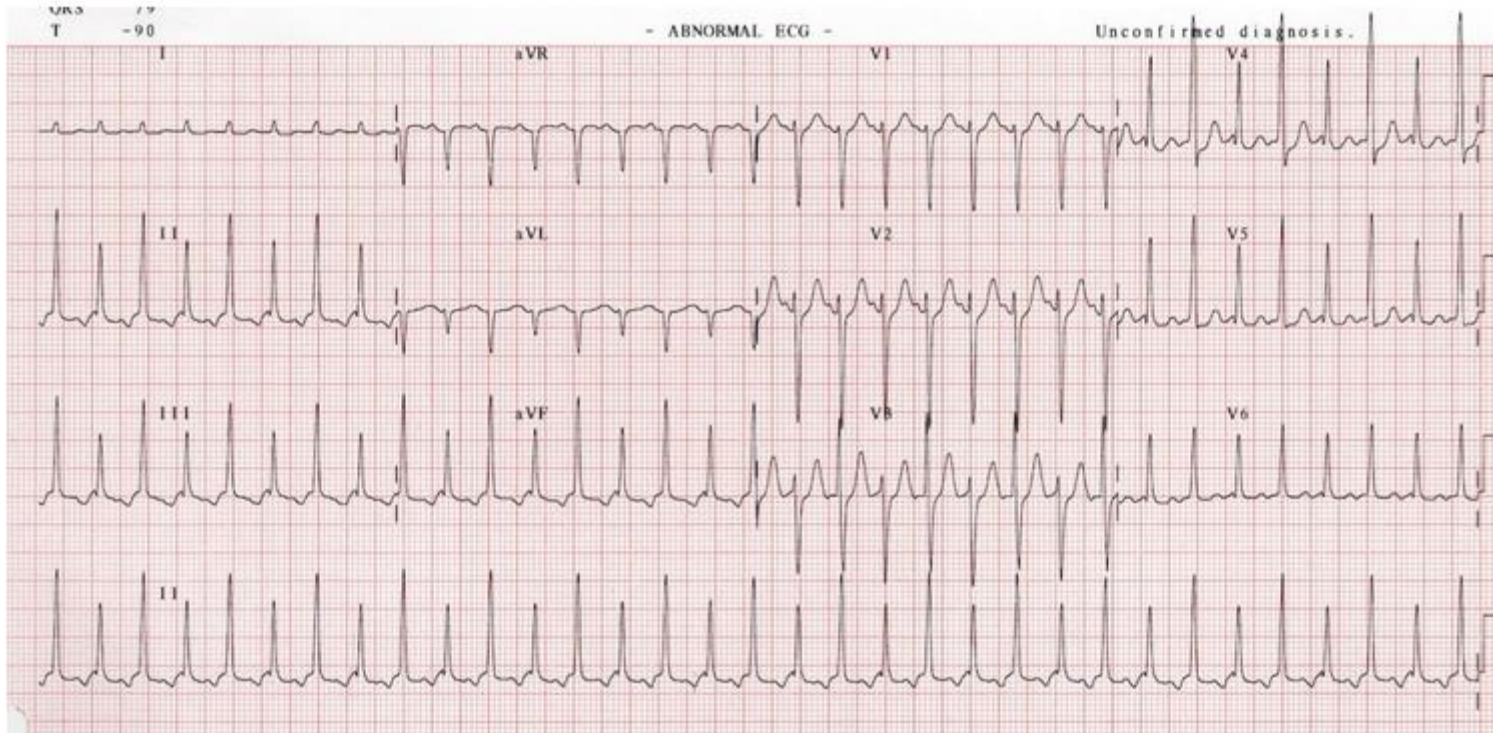
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Simultaneous T wave inversions in the inferior (II, III, aVF) and right precordial leads (V1-4) is the most specific finding in favour of PE.

Case 71

Palpitations. Describe and interpret this ECG



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Reveal Answer

QRS alternans – due to **AVNRT** (i.e. electrical phenomenon), not **pericardial effusion** as normal voltages.

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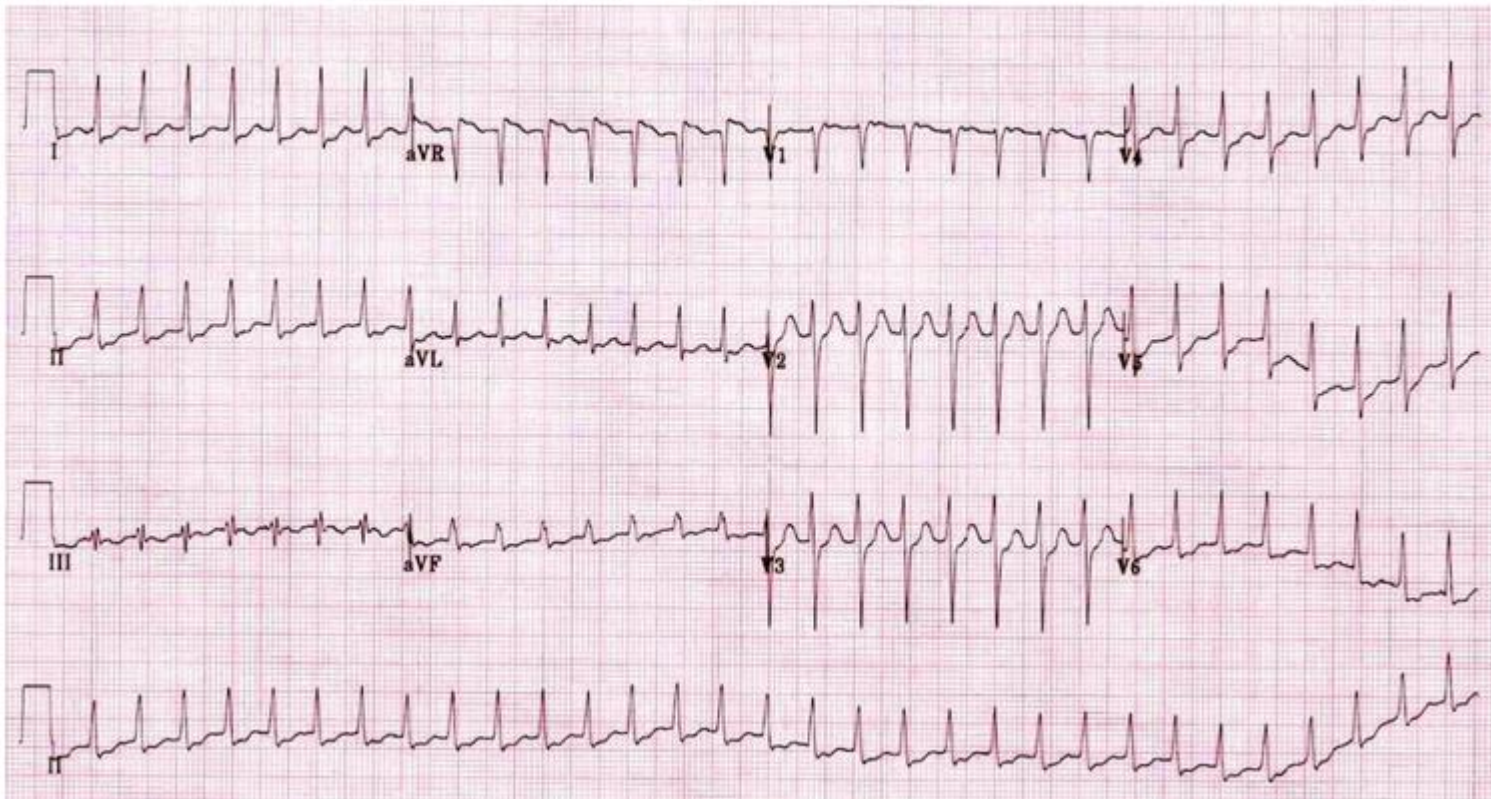


About Edward Burns

Ed Burns is an Emergency Physician working in Prehospital & Retrieval Medicine in Sydney, Australia. He has a passion for ECG interpretation and medical education. Ed is the force behind the LITFL ECG library.

Case 72

Palpitations, chest heaviness



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Reveal Answer

Rate-related ST change with **SVT** = not necessarily ischaemic.Mimics appearance of **LMCA occlusion**.

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