Bradycardia and Pacemakers and ECGs for Residents

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Symptoms in Arrhythmia

- "Because it may be difficult for both patients and their physicians to attribute ambiguous symptoms such as fatigue to bradycardia, special vigilance must be exercised to acknowledge the patient's concerns that may be caused by a slow heart rate.*"

- Palpitations: an unpleasant awareness of the forceful, irregular, or rapid beating of the heart
  - Thumping, flip-flopping sensation, fullness in the throat, neck or chest, a pause "as if my heart stopped"

Pacing Guideline 2002*; Zipes text 2004, p. 760.

Symptoms in Bradycardia

- Syncope or near syncope, transient dizziness or lightheadedness, or confusional states resulting from cerebral hypoperfusion
- Fatigue, exercise intolerance, and congestive heart failure

At rest or with exertion

- Definite correlation of symptoms with a bradyarrhythmia is required.
- NOT physiological sinus bradycardia (as in highly trained athletes)

Arrhythmia Device Guideline 2008, p. e355.

More History in Bradycardia

- Syncope
  - Arrhythmic syncope is often rapid onset and brief duration without aura, not followed by postictal confusional state, maybe associated with injury; seizure activity is uncommon, as is tongue-biting or incontinence, may be flushed and tachycardic afterward
  - Neurocardiogenic syncope may be preceded by nausea, abdominal cramping, diarrhea, sweating, or yawning, and may be followed by bradycardia, pallor, sweat and fatigue
- Inquire about: medications, predisposing or precipitating factors

Pacing Guideline 2002; Zipes text 2004, p. 760.

Differentiating Bradycardias

- **Two mechanisms**
  - **Sinus node dysfunction** ↔
  - **AV node dysfunction** ↔

Disorders of:

Impulse formation and

Impulse conduction

ECG Interpretive tip: Find all of the P waves

- **Sinus bradycardia** ↔
- **AV block** ↔

Too few P waves

Adequate P waves but too few QRS complexes

Causes of Sinus Bradycardia

- High level aerobic conditioning
- Hypothyroidism, hypothermia, hypoxemia
- Negative chronotropic agents – beta-blockers (including some eye drops), diltiazem, verapamil, digitalis, antiarrhythmics with beta-blocking properties
- Intrinsic sinus node or cardiac disease

Causes of AV Block

- Normal variant; Congenital (isolated, corrected transposition)
- Iatrogenic –vagal, negative dromotropic agents
  –Surgery (VSD, AVR), septal ablation, radiofreq
- Coronary artery disease (acute ant or inf MI)
- Valve disease – calcific aortic stenosis (?Lev)
- Degenerative conduction system disease (Lenegre)
- Cardiomyopathy – sarcoid, primary dilated, amyloid, hemachromatosis, progressive muscular dystrophy,
- Inflammation/infection/metabolic – acute myocarditis, Chaga's cardiomyopathy, lyme disease; lupus, dermatomyositis, scleroderma, Reiter's syndrome, Marfan's syndrome, rheumatoid heart disease, ankylosing spondylitis; hyperkalemia or mag
- Hereditary with DCM
  - Autosomal dominant DCM lamin A/C defect
  - Emerin defects also manifest AV conduction disease
- Isolated CHB in neonate or fetus is ominous, highly associated with anti-Ro and anti La, and with 6% and 43% mortality, respectively; in children, antibody association was 5% and mortality was 0

OSA

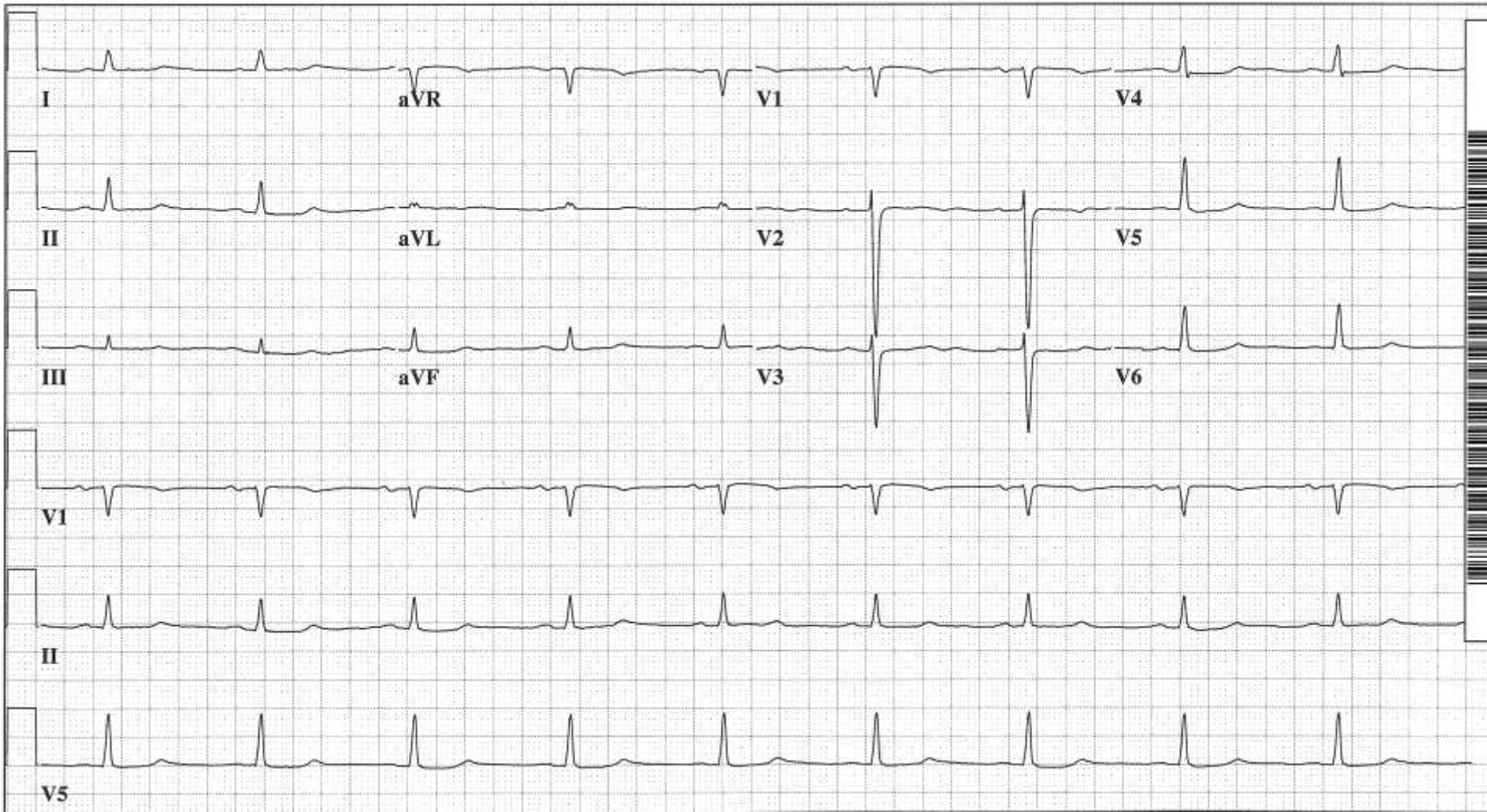
Arbustini E et al. JACC 2002; 39:981; Jaeggi ET et al. JACC 2002; 39:130

ECG Diagnosis of Bradycardia

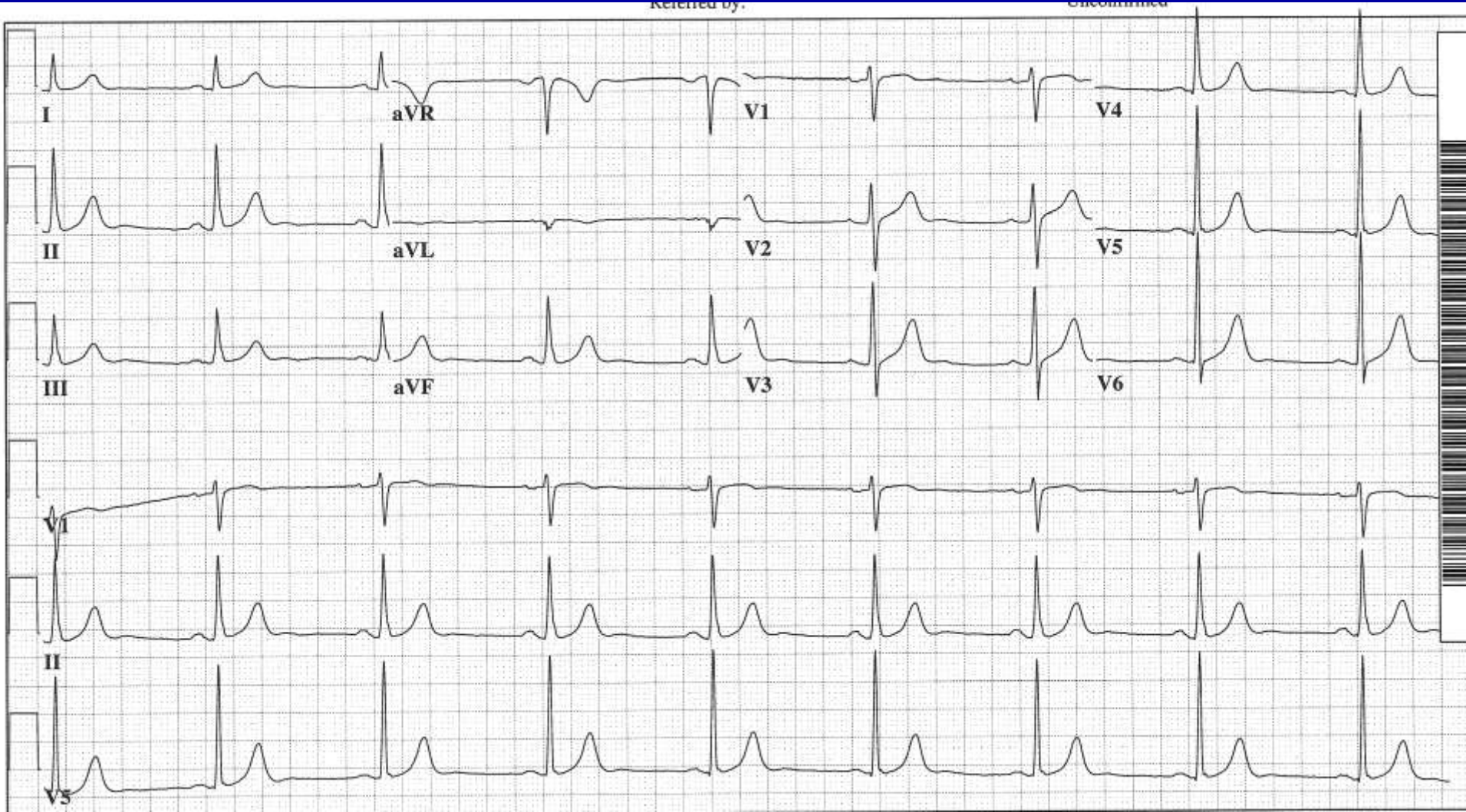
- Not enough QRS complexes = Ventricular rate is too slow

- Sinus default
- AV Node default

Sinus Bradycardia

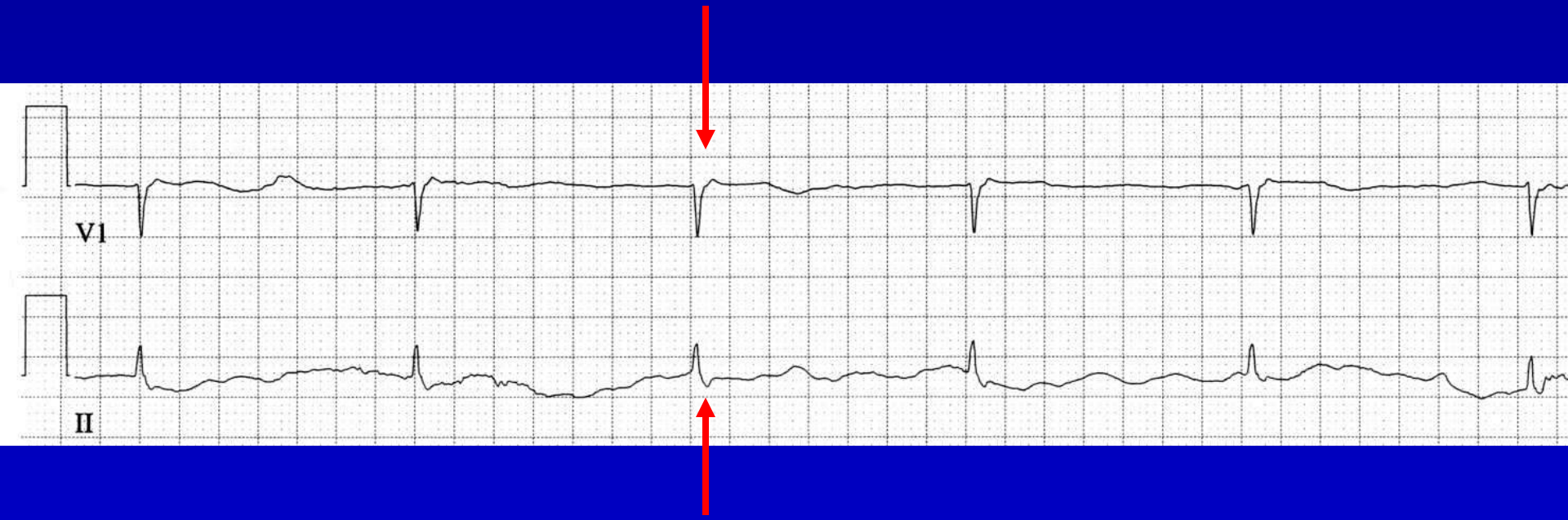


Sinus Bradycardia



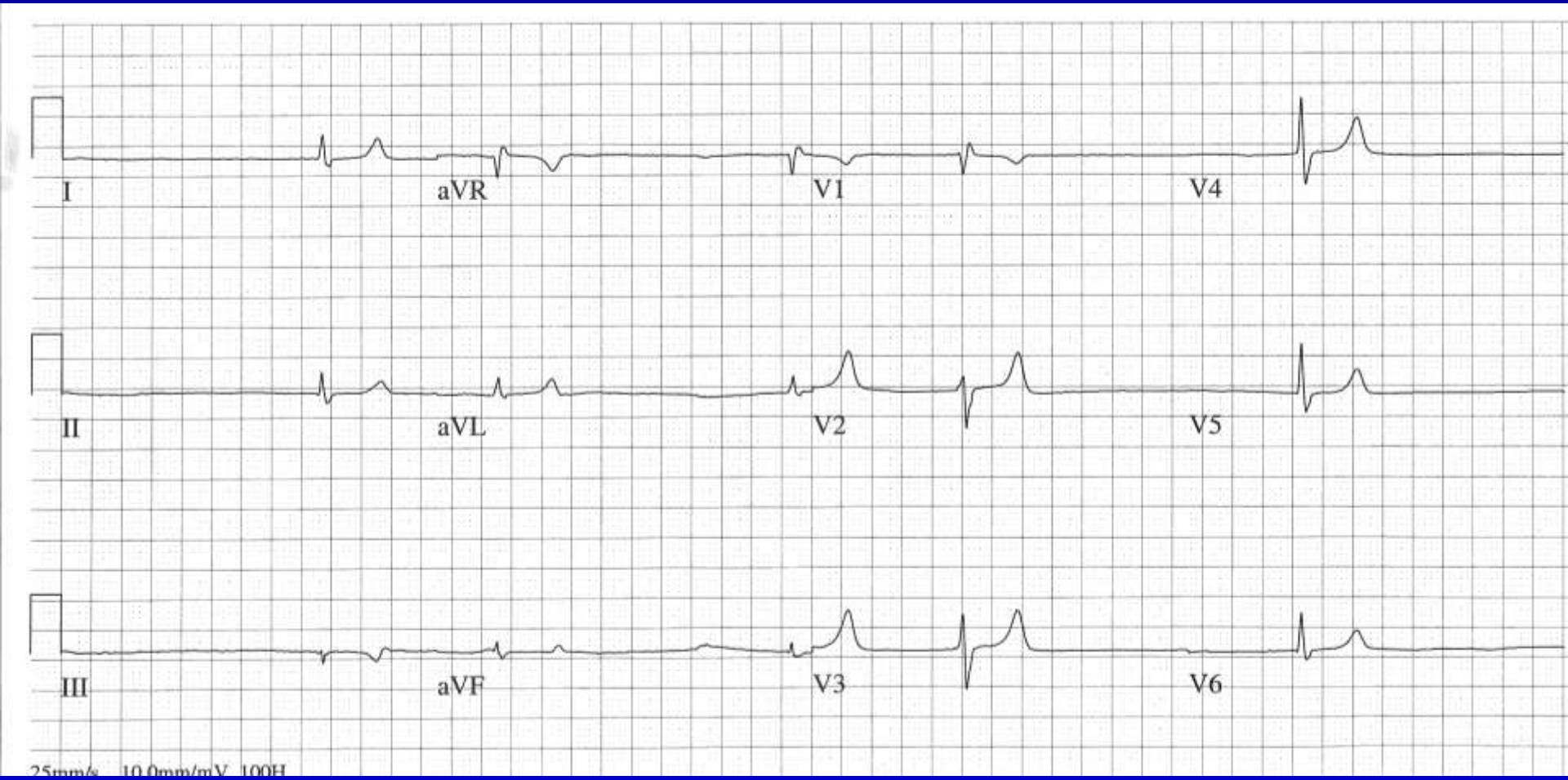
Sinus Pause

Junctional Rhythm



Retrograde P wave

Junctional Escape Rhythm



AV Node Anatomy

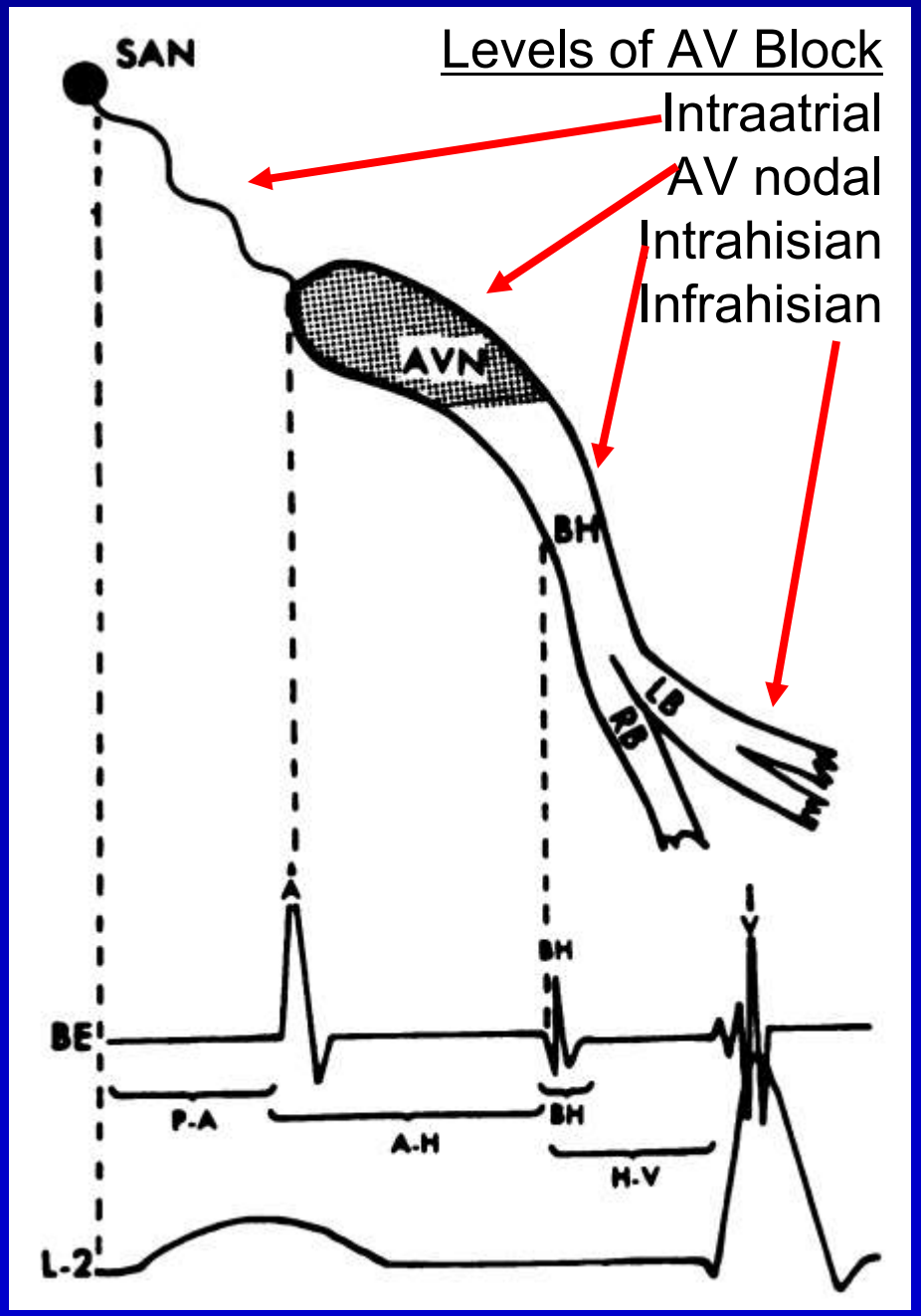
Intervals

PR	0.120-0.200 sec
PA (HRA-LRA)	0.025-0.045 sec
AH (LRA-HB)	0.050-0.130 sec
BH (intraHis)	0.015-0.020 sec
HV	0.035-0.055 sec
Sum	0.110-0.230 sec

Conduction Velocity

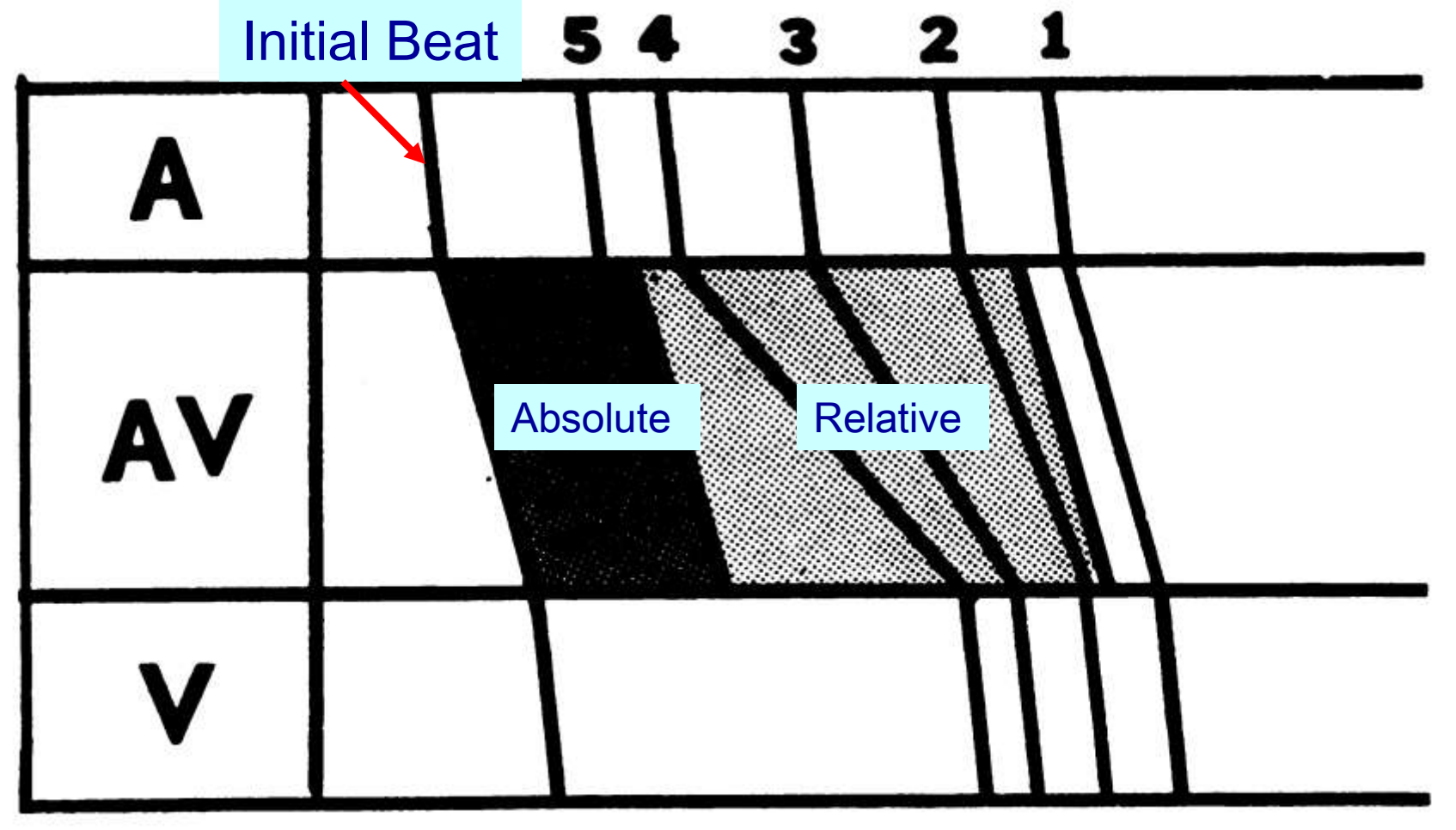
SA Node	<0.05 m/s
Atrial myocardium	0.3-0.4 m/s
AV Node	0.1 m/s
His-Purkinje system	2.0-3.0 m/s
Ventricular myocardium	0.3-0.4 m/s

(Braunwald, 2001, p.669)



Surawicz B et al. Chou's ECG… 2001, p.439

AV Node Property: Decremental Conduction



Wagner GS. Marriott's Practical Electrocardiography 1994, p.390

Degrees of AV Block

Degree	Which Conduct	PR interval	RR interval
First	All	Constant and long	Regular
Wenckebach (Mobitz I)	Some	Variable, pattern	Grouped beats
2:1	Some	Constant	Regular
Mobitz II	Some	Constant	Irregular, multiples
Third (Complete)	None	Variable, random	Regular

First Degree AV Block

PR interval
Constant
and Long

Second Degree AV Block, Wenckebach (Mobitz I)

- Some beats don't conduct, so more P's than QRS's
- Progressive Prolongation of the PR interval for the conducted beats
  - increment of prolongation actually decreases
  - progressive shortening of the RR interval
- After pause is shortest PR interval
  - may be a junctional or ventricular escape beat

Second Degree AV Block, Wenckebach (Mobitz I)

0.32 0.40 0.45 block 0.32 0.38 block 0.32 0.40

2:1 2:1

Grouped beats

Second Degree AV Block, Wenckebach (Mobitz I)

Low grade block

3:2

Non-simultaneous

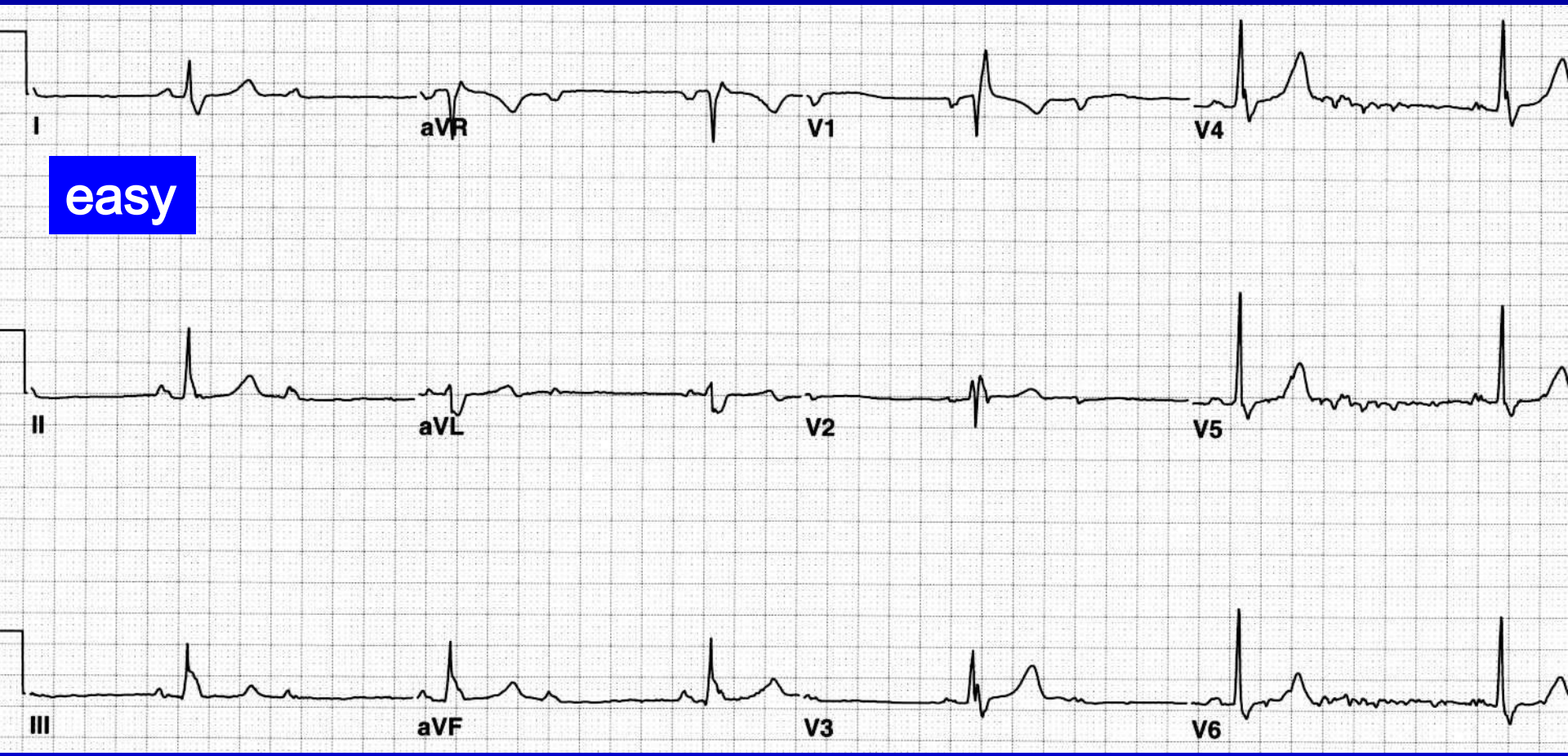
Wenckebach Details

- Block is usually in the AV node
- Blocked beat will have no His bundle potential
- If intrahisian, there will be split His potentials and blocked beat will have no second His potential (worsen with Atropine)
- If associated with BBB, still 75% are AV node, and only 25% infranodal
- Exceptions to the usual periodicity are more common than the rule

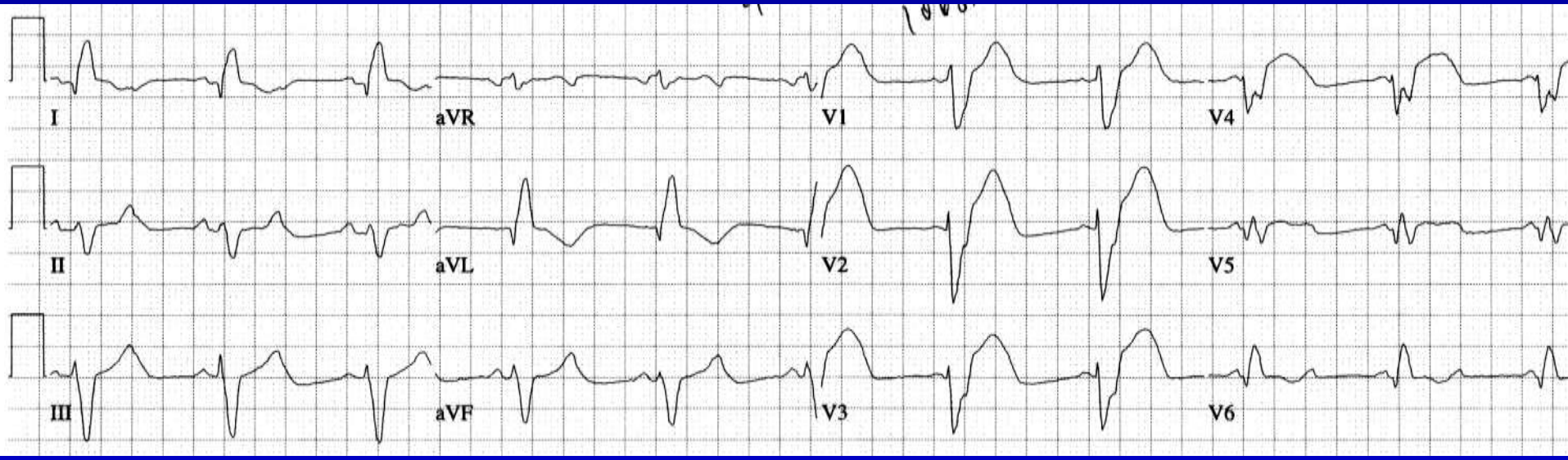
Second Degree AV block, 2:1

- Can be either mechanism of Wenckebach or mechanism of Mobitz II, can't tell
  - if QRS is wide, could be either
  - if QRS is narrow, usually is Wenckebach
- Can be tricky to diagnose, must find the nonconducted P waves (otherwise the mistaken diagnosis will be mere bradycardia)
- "It is advisable to be noncommittal as to the type of Mobitz block when dealing with 2:1 AV block"

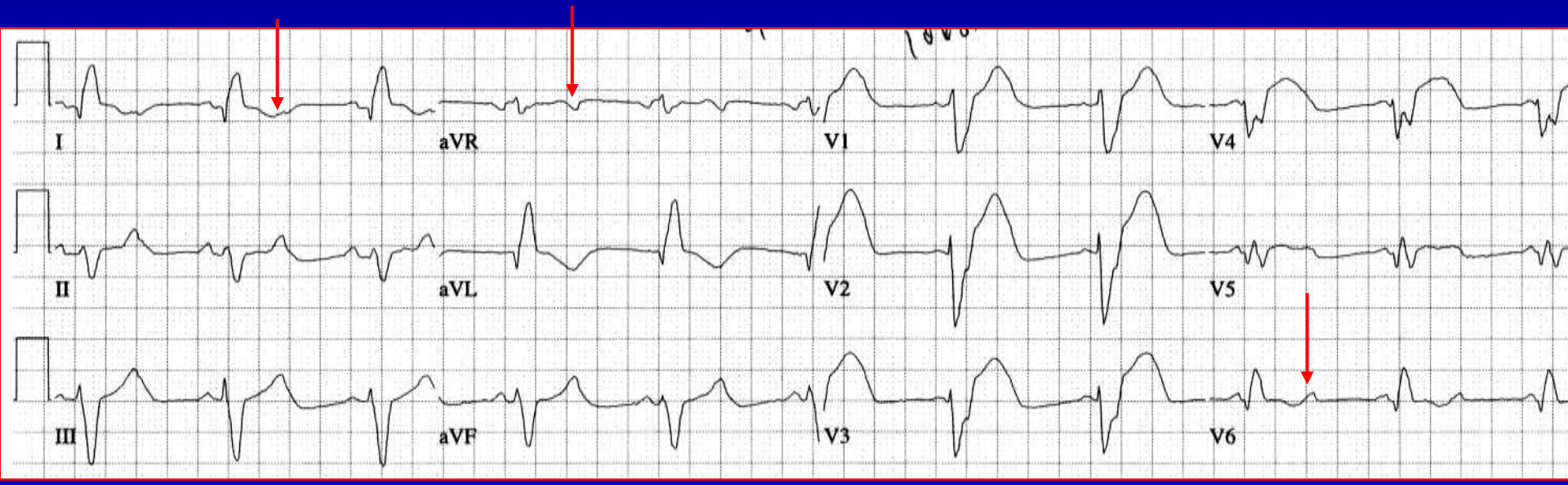
Second Degree AV block, 2:1



Second Degree AV block, 2:1



Second Degree AV block, 2:1



- Not so easy… could misdiagnose as NSR rate 64.
- But actually is sinus tachycardia at rate of 128 (patient is likely sick) with 2:1 block.
- The extra P waves are best seen at the 3 red arrows, and are same shape and axis as the sinus P waves.
- Wide QRS indicates disease below the bundle of His.

Second-Degree AV Block, Mobitz II

- Intermittent blocked P waves
- PR interval constant for conducted beats
- Most are associated with BBB
- About 1/3 of patients with Mobitz II have block located in the His bundle, so QRS is narrow
- Rarely Mobitz II is due to block in the AV node

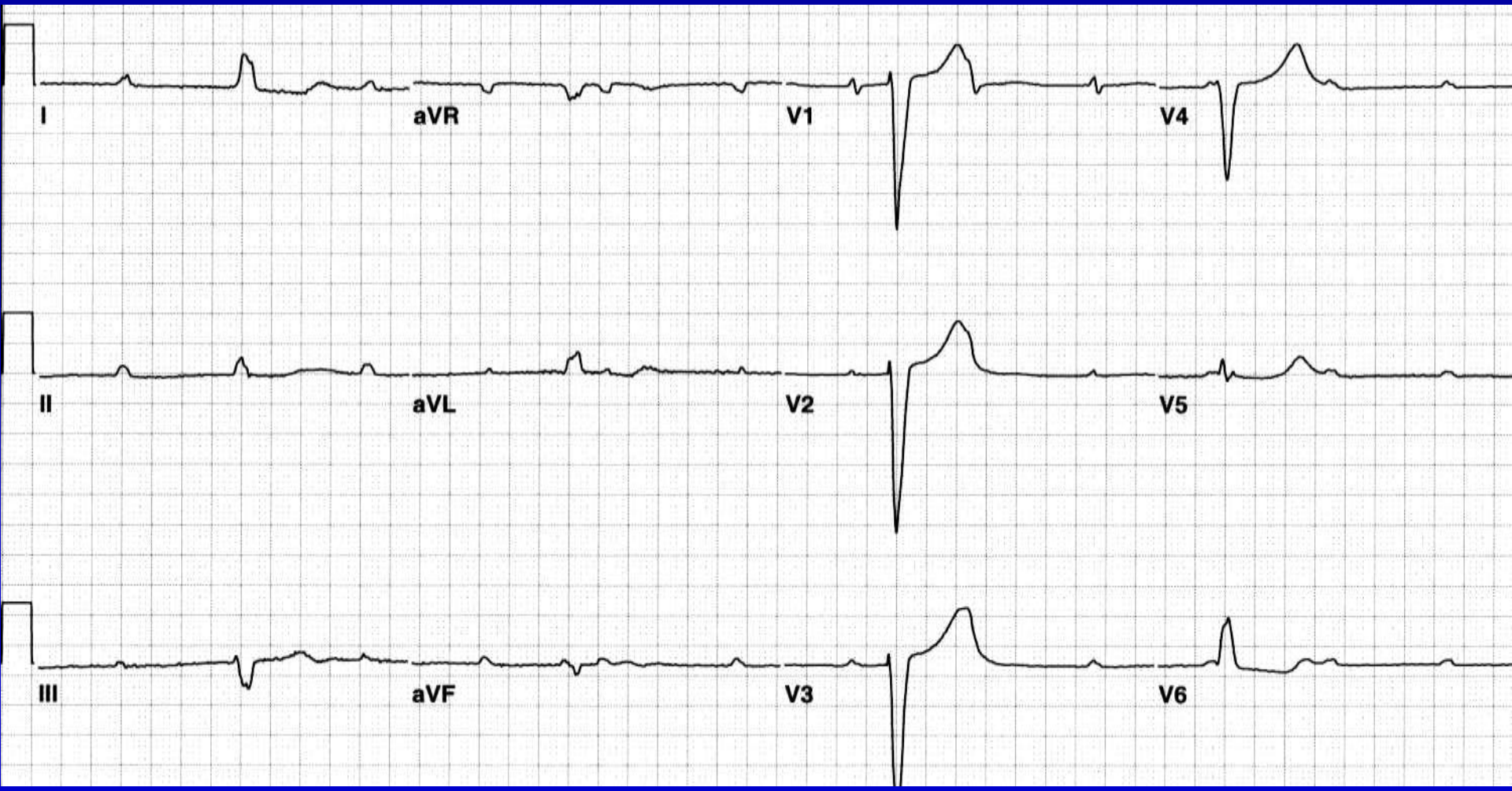
Advanced AV block

- Sometimes only occasional ventricular captures are observed, sometimes more frequently
- One definition: 2 consecutive nonconducted sinus beats

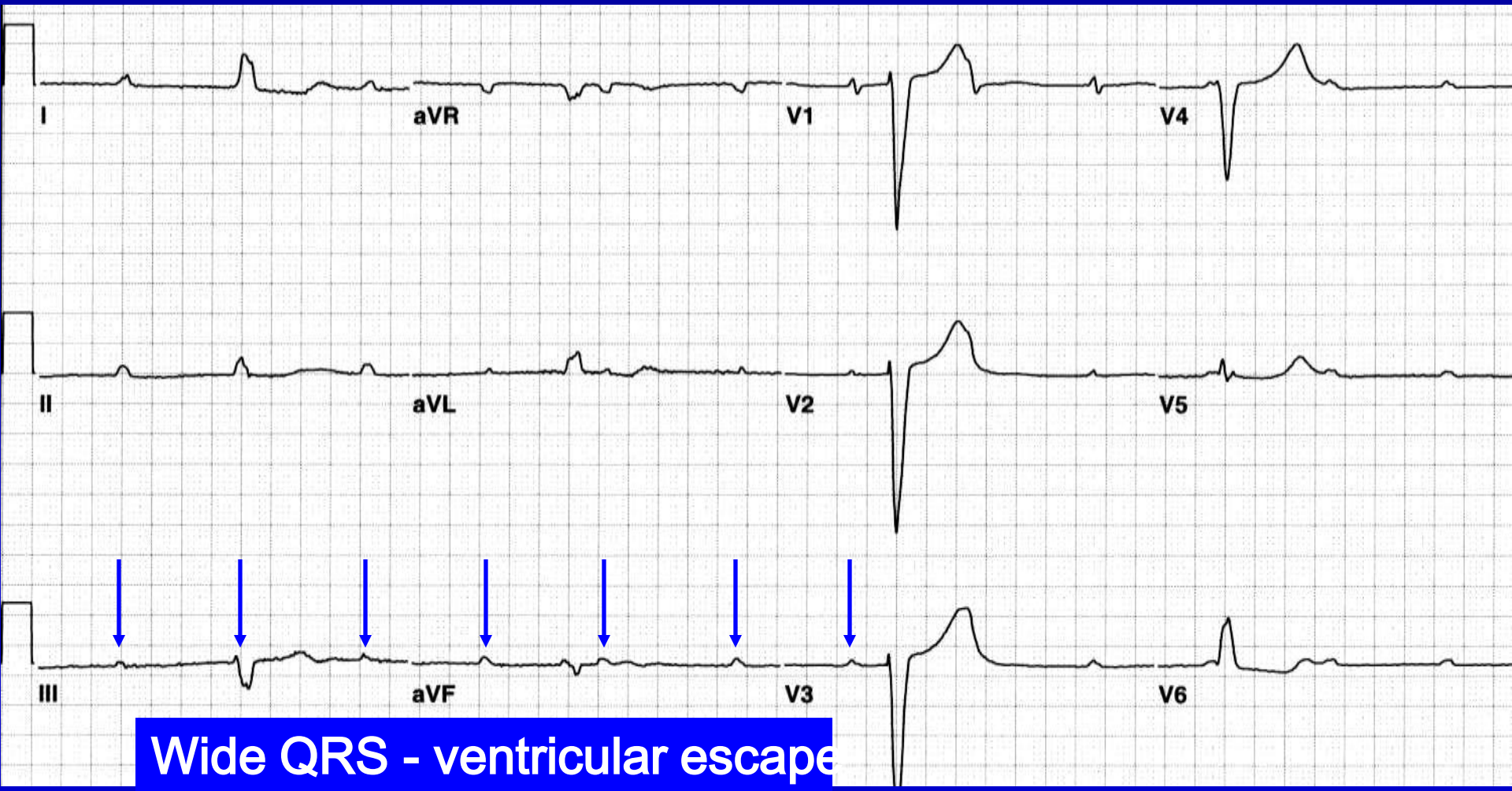
Third Degree AV block - 2

- Site of block: AV junction, His bundle, or bundle branches (either bilateral bundle branch, or trifascicular block)
- Adult acquired chronic: 50-60% are infrahisian and escape complexes are wide
- Acute block from drugs, infection or inferior MI: usually proximal to His bundle
- Anterior MI: usually distal to His bundle

Third Degree AV block (Complete Heart Block)

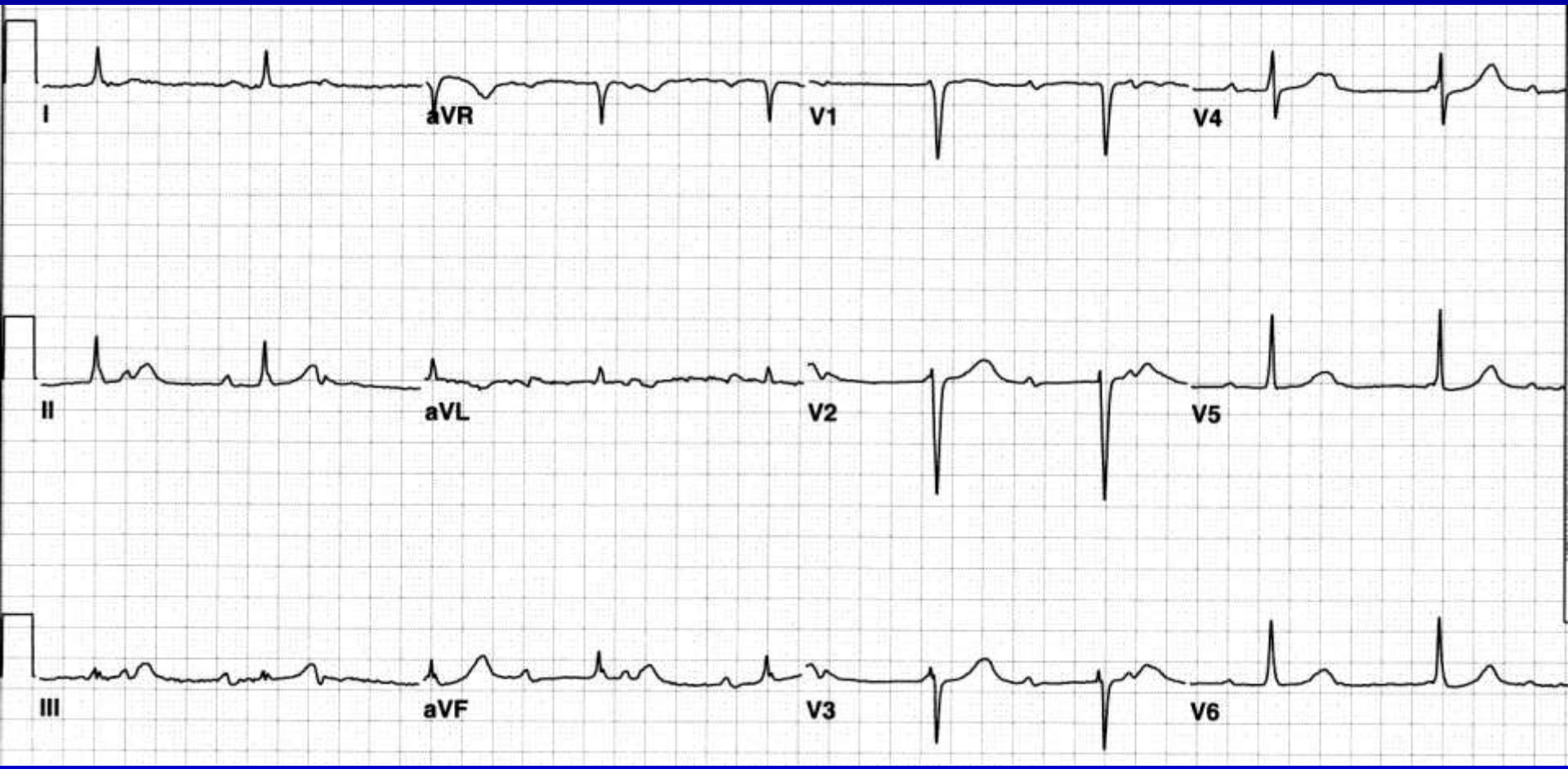


Third Degree AV block (Complete Heart Block)

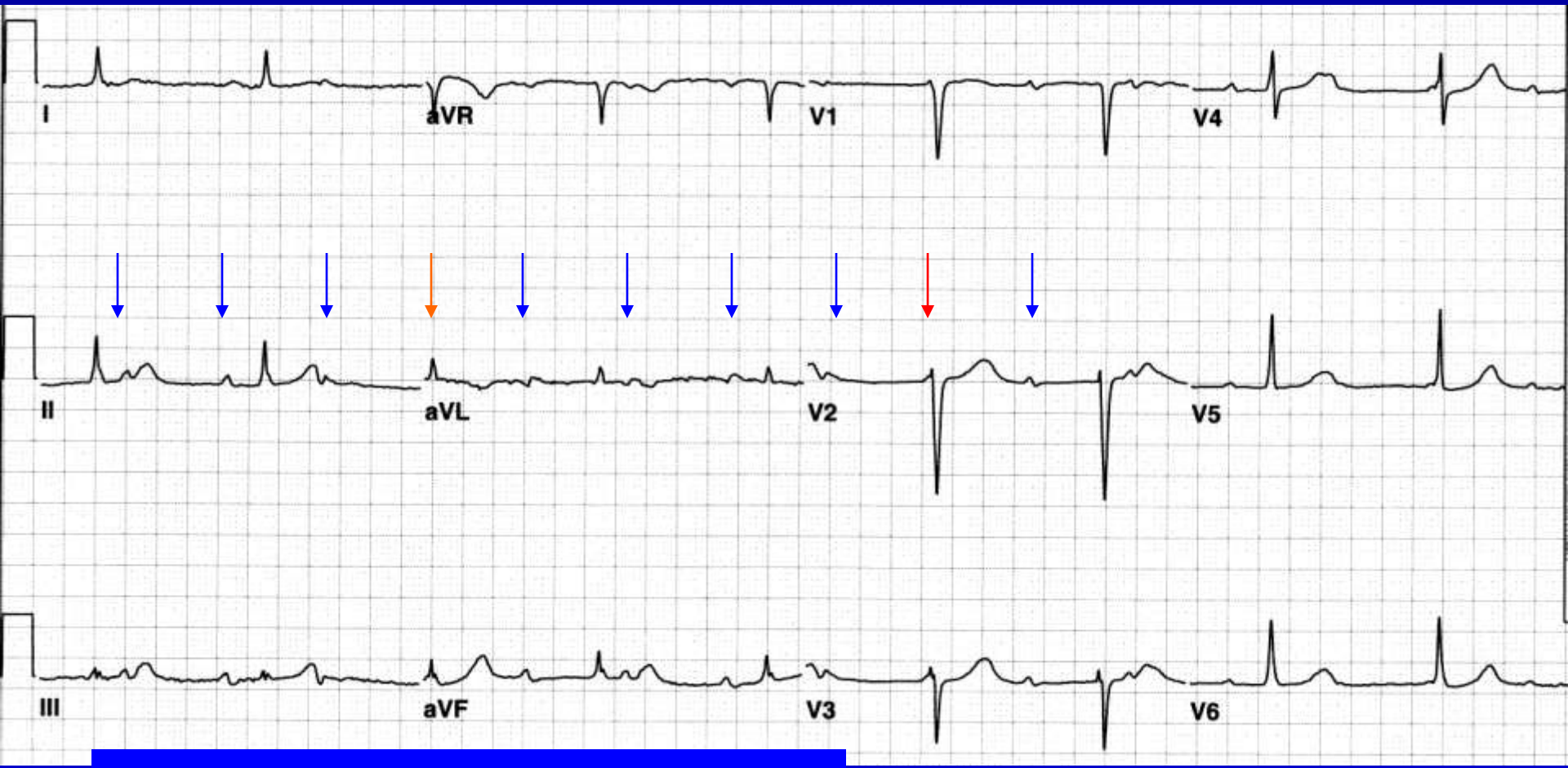


Wide QRS - ventricular escape

Third Degree AV block (Complete Heart Block)

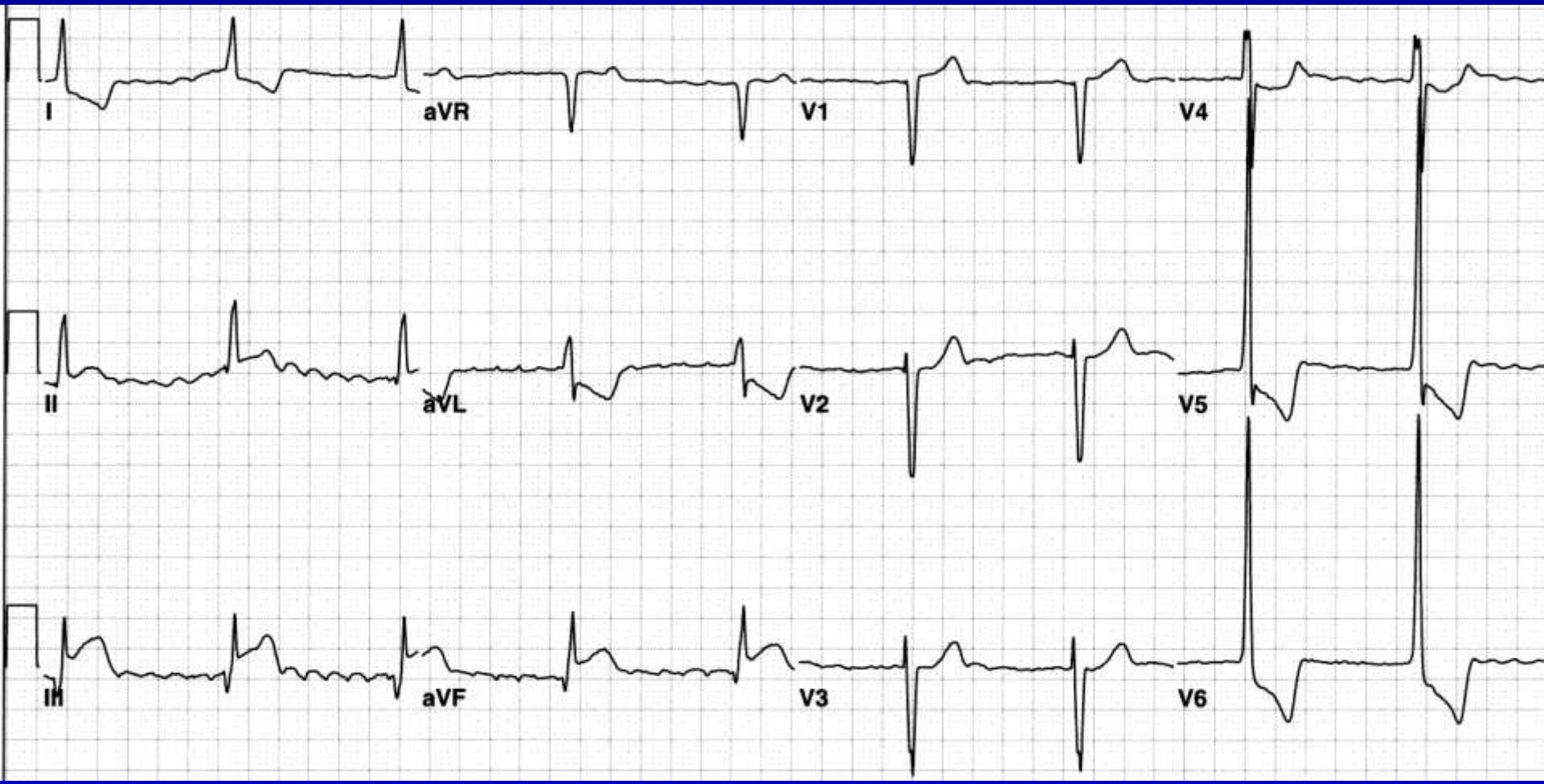


Third Degree AV block (Complete Heart Block)



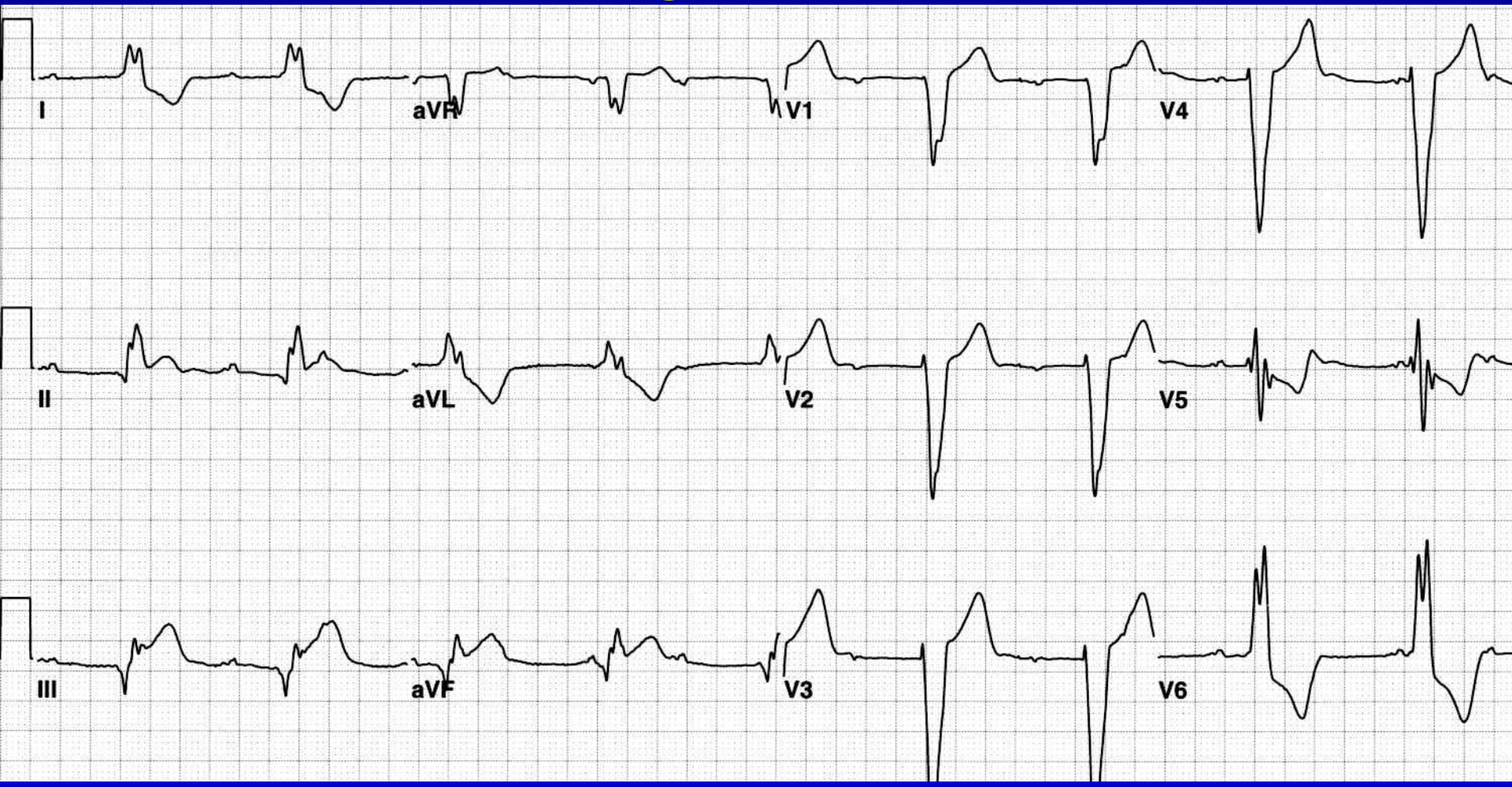
Narrow QRS - junctional escape

Third Degree AV block

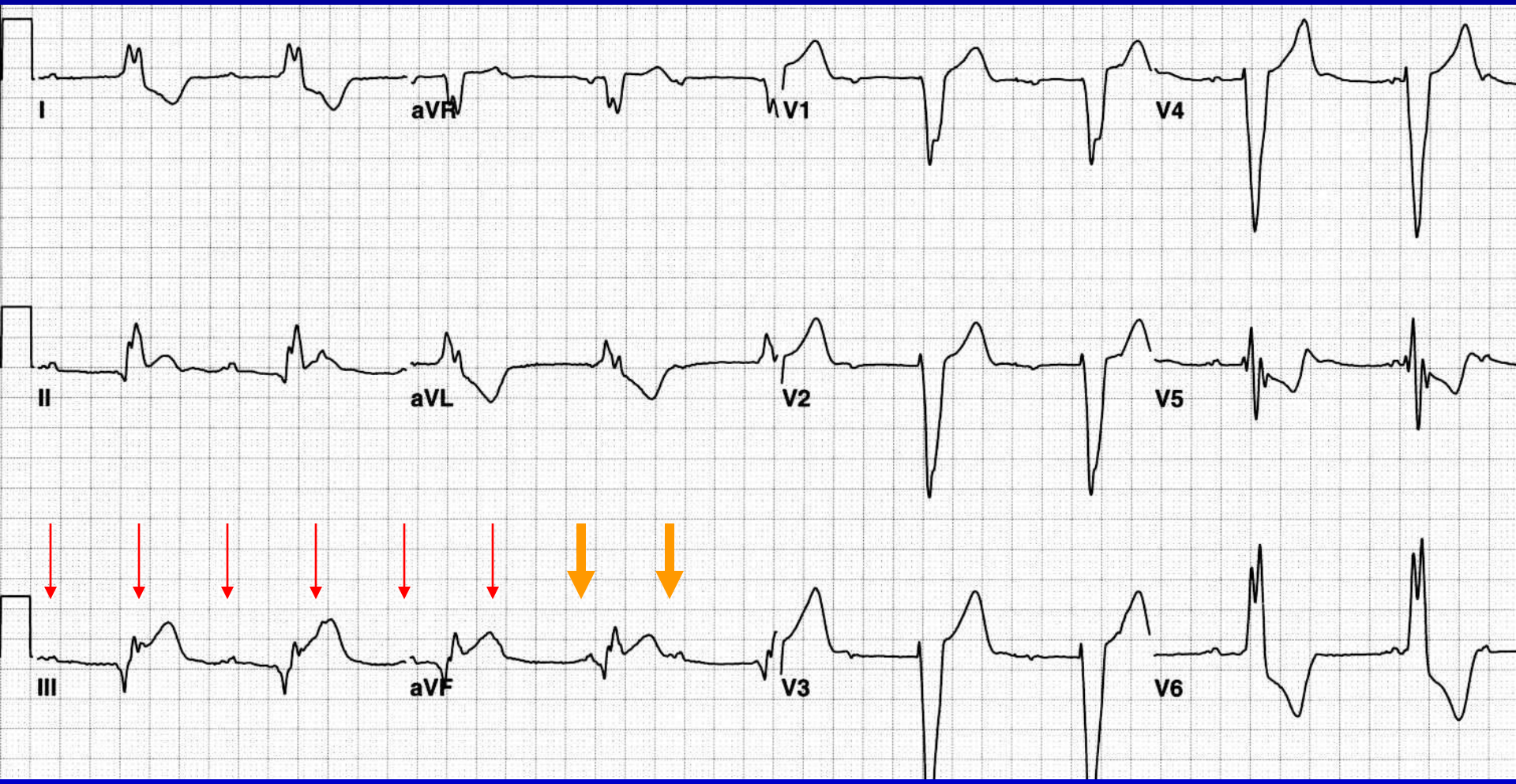


Atrial fibrillation with narrow QRS - junctional escape.
Acute inferior injury pattern!

Third Degree AV block

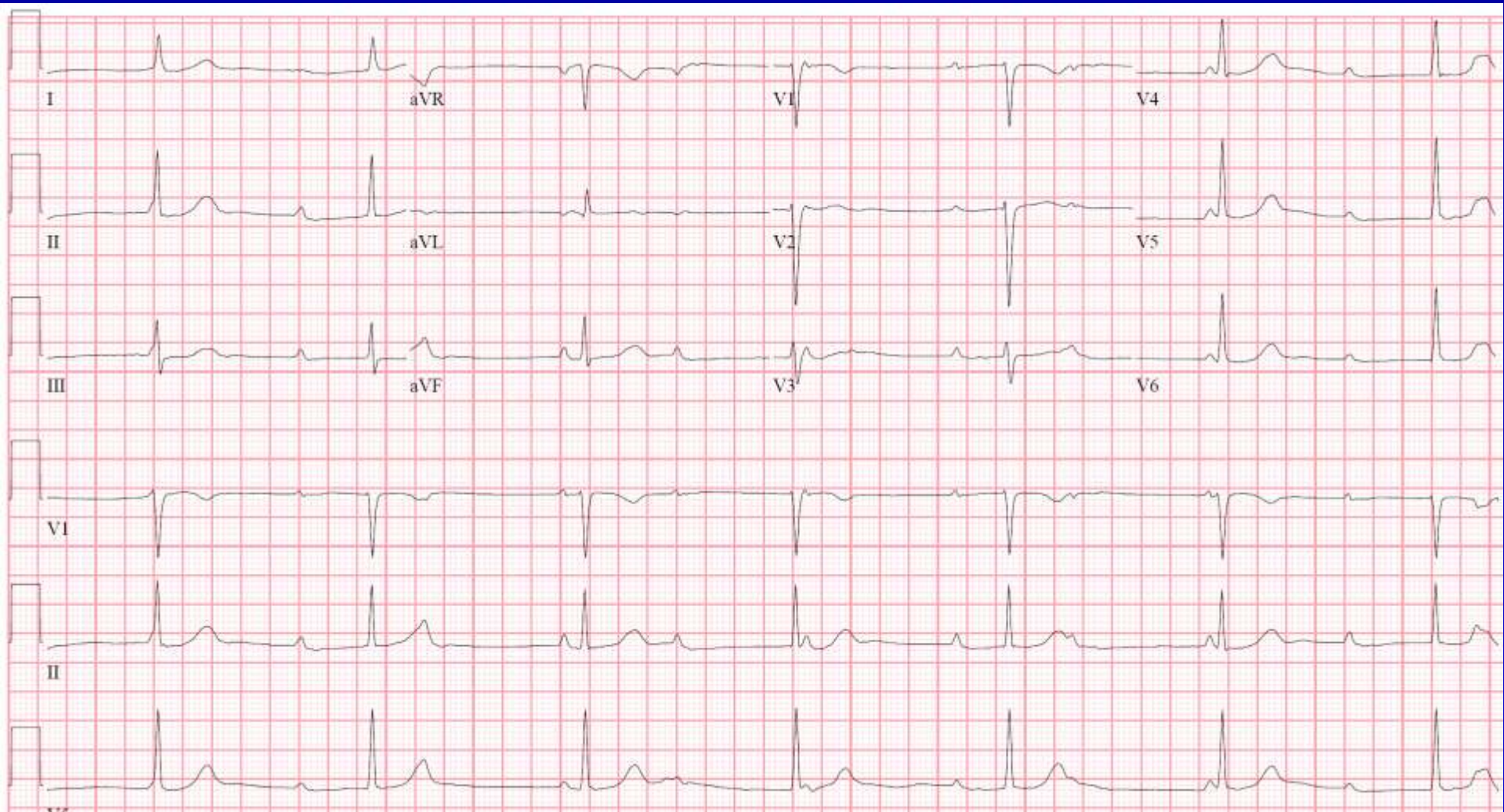


Third Degree AV block



Wide QRS (LBBB pattern) - ventricular escape.
Acute inferior injury pattern!

Bradycardia – too slow = <60



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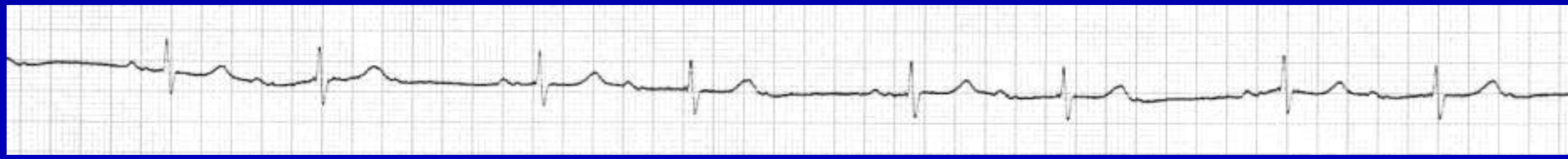

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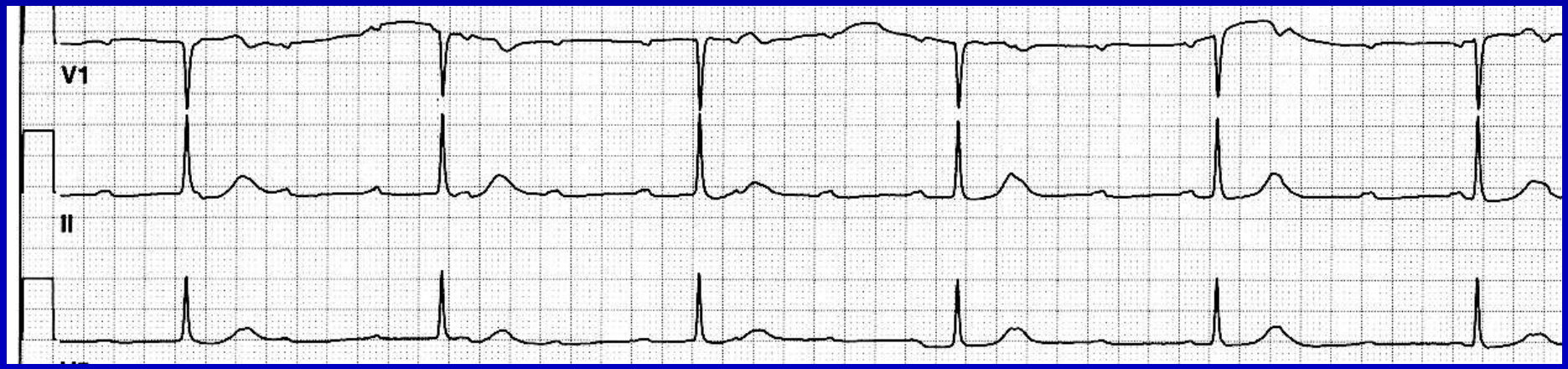


Indications for Temporary Pacemakers

- Transcutaneous pacing (poor stepchild; painful; only for brief use or prophylaxis)
- Transvenous pacing
  - Generally for sinus bradycardia (<50) with hypotension (SBP<80) and sx unresponsive to drug therapy
  - Mobitz II second degree AV block
  - Third degree AV block

Hurst, 11th ed. 2004. p. 1306.

Indications for Temporary Pacemakers

- Less invasive means (e.g., pharmacologic agents and antidotes, transcutaneous cardiac pacing) have been tried without success or that success is judged to be short-lived
- The patient is experiencing profound symptomatology (e.g., severe chest pain, dyspnea, or altered state of consciousness; hypotension; shock; pulmonary edema; or acute myocardial infarction)

Harrigan RA et al. J Emerg Med. 2007;32:105.

Recommendations for Treatment of Atrioventricular and Intraventricular Conduction Disturbances During STEMI

INTRAVENTRICULAR CONDUCTION	Atrioventricular Conduction: Normal		First degree AV block: ANTERIOR MI		First degree AV block: NON-ANTERIOR		Mobitz I second degree AV block: ANTERIOR MI		Mobitz I second degree AV block: NON-ANTERIOR		Mobitz II second degree AV block: ANTERIOR MI		Mobitz II second degree AV block: NON-ANTERIOR	
Normal	**ACTION**	**CLASS**	**ACTION**	**CLASS**	**ACTION**	**CLASS**	**ACTION**	**CLASS**	**ACTION**	**CLASS**	**ACTION**	**CLASS**	**ACTION**	**CLASS**
	Observe	I	Observe	I	Observe	I	Observe	IIb	Observe	IIa	Observe	III	Observe	III
	A	III	A	III	A	III	A*	III	A	III	A	III	A	III
	TC	III	TC	IIb	TC	IIb	TC	I	TC	I	TC	I	TC	I
	TV	III	TV	III	TV	III	TV	III	TV	III	TV	IIa	TV	IIa
Old or New	Observe	I	Observe	IIb	Observe	IIb	Observe	IIb	Observe	IIb	Observe	III	Observe	III
Fascicular block	A	III	A	III	A	III	A*	III	A	III	A	III	A	III
(LAFB or LPFB)	TC	IIb	TC	I	TC	IIa	TC	I	TC	I	TC	I	TC	I
	TV	III	TV	III	TV	III	TV	III	TV	III	TV	IIa	TV	IIb
Old bundle	Observe	I	Observe	III	Observe	III	Observe	III	Observe	III	Observe	III	Observe	III
branch block	A	III	A	III	A	III	A*	III	A	III	A	III	A	III
	TC	IIb	TC	I	TC	I	TC	I	TC	I	TC	I	TC	I
	TV	III	TV	IIb	TV	IIb	TV	IIb	TV	IIb	TV	IIa	TV	IIa
New bundle	Observe	III	Observe	III	Observe	III	Observe	III	Observe	III	Observe	III	Observe	III
branch block	A	III	A	III	A	III	A*	III	A	III	A	III	A	III
	TC	I	TC	I	TC	I	TC	I	TC	I	TC	IIb	TC	IIb
	TV	IIb	TV	IIa	TV	IIa	TV	IIa	TV	IIa	TV	I	TV	I
Fascicular	Observe	III	Observe	III	Observe	III	Observe	III	Observe	III	Observe	III	Observe	III
block + RBBB	A	III	A	III	A	III	A*	III	A	III	A	III	A	III
	TC	I	TC	I	TC	I	TC	I	TC	I	TC	IIb	TC	IIb
	TV	IIb	TV	IIa	TV	IIa	TV	IIa	TV	IIa	TV	I	TV	I
Alternating	Observe	III	Observe	III	Observe	III	Observe	III	Observe	III	Observe	III	Observe	III
left and right	A	III	A	III	A	III	A*	III	A	III	A	III	A	III
bundle branch	TC	IIb	TC	IIb	TC	IIb	TC	IIb	TC	IIb	TC	IIb	TC	IIb
block	TV	I	TV	I	TV	I	TV	I	TV	I	TV	I	TV	I

A, and A*: atropine administered at 0.6 to 1.0 mg intravenously every 5 minutes to up to 0.04 mg/kg

STEMI Guideline 2004, p. 117.

Temporary Pacemakers in STEMI

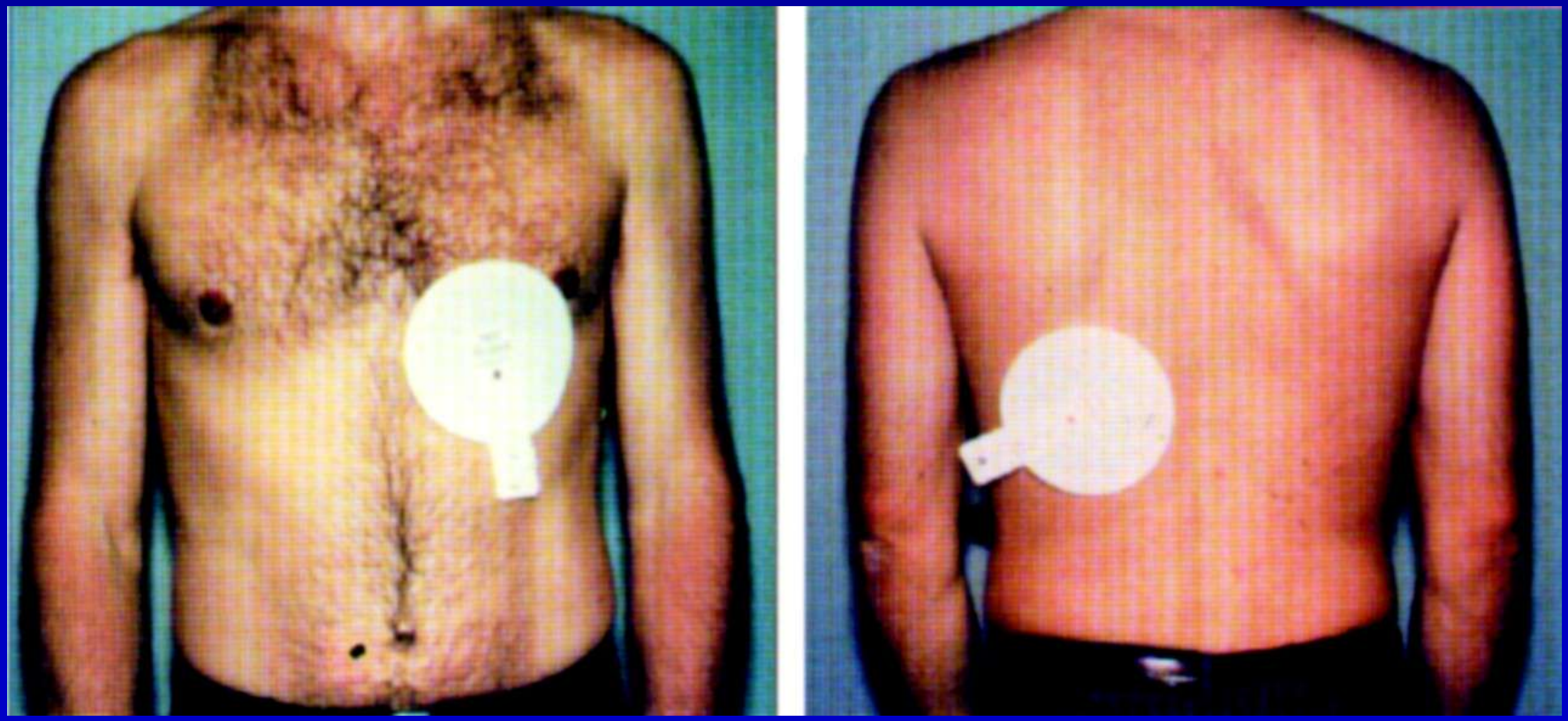
- Transcutaneous Class I:
  - Mobitz I or II second degree AV block, any MI type
  - Hemiblock with either first degree and anterior MI or Mobitz I or II and any MI type
  - Old BBB with either first degree or Mobitz I or II and any MI type
  - New BBB or bifascicular block (RBB and hemiblock) with nl PR or first degree or Mobitz I and any MI type (TV for Mobitz II)
- Transvenous Class I: Any MI and alternating BBB, and Mobitz II with new BBB or bifascicular block

STEMI Guideline 2004.

Defibrillator with pacemaker function and transcutaneous pacemaker pads

Gammage, M. D Heart 2000;83:715-720

Typical anteroposterior positioning of transcutaneous pacing electrodes



Gammage, M. D Heart 2000;83:715-720

The anterolateral position for transcutaneous pacing electrodes

Gammage, M. D Heart 2000;83:715-720

Temporary Transvenous Pacemaker Insertion

- Call the cardiology fellow
- Emergent:

Temporary Pacemaker Insertion

Pacemaker generator.

(A) Pacing indicator.

(B) Sensing indicator.

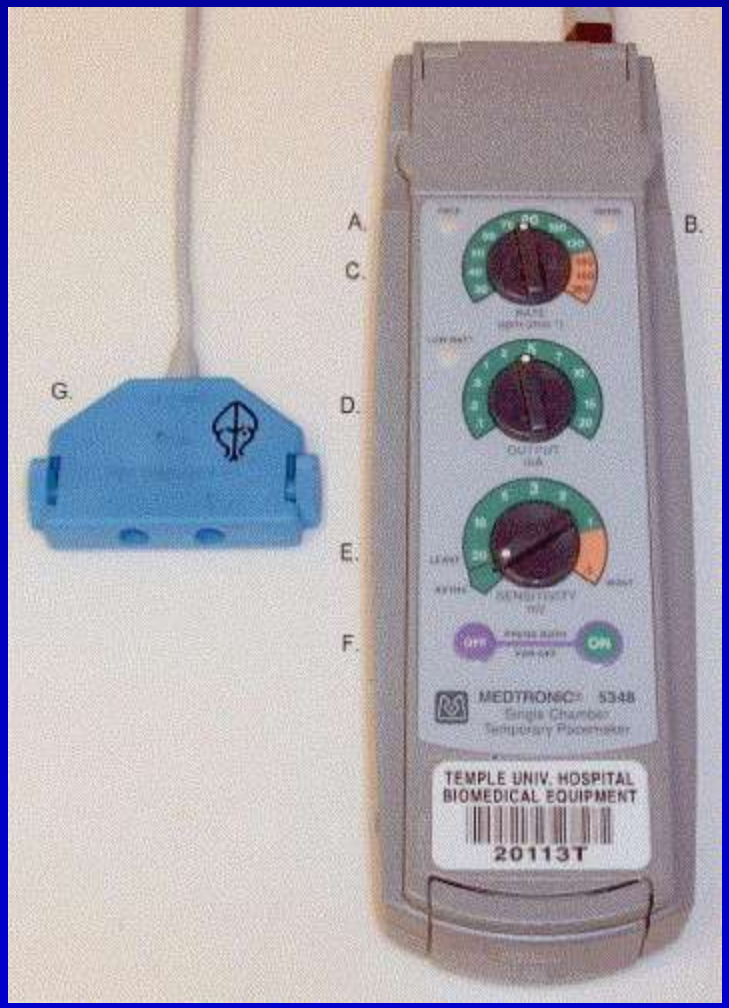
(C) Rate control knob.

(D) Pacing output control knob.

(E) Sensitivity control knob.

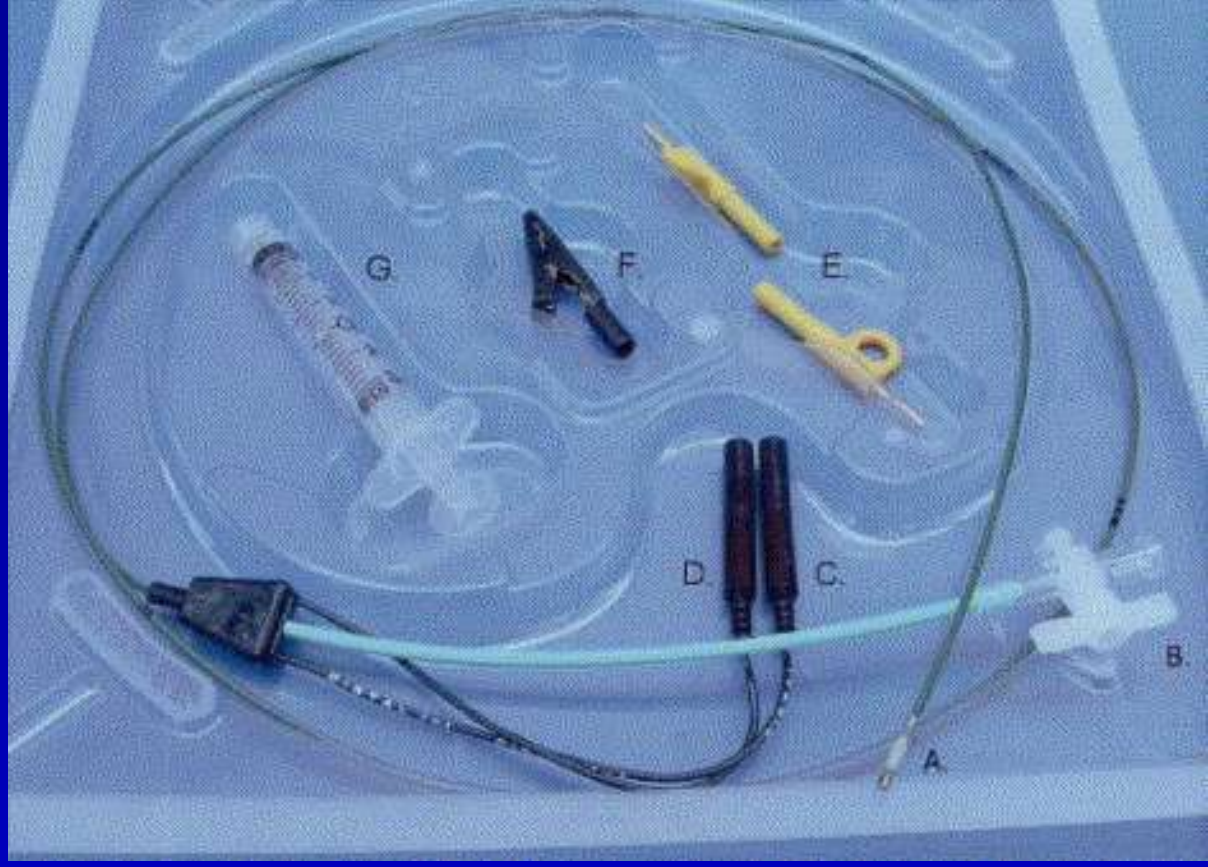
(F) On/off control.

(G) Adaptor for connection to pacing electrode



Harrigan RA et al. J Emerg Med. 2007;32:105.

Temporary Pacemaker Insertion

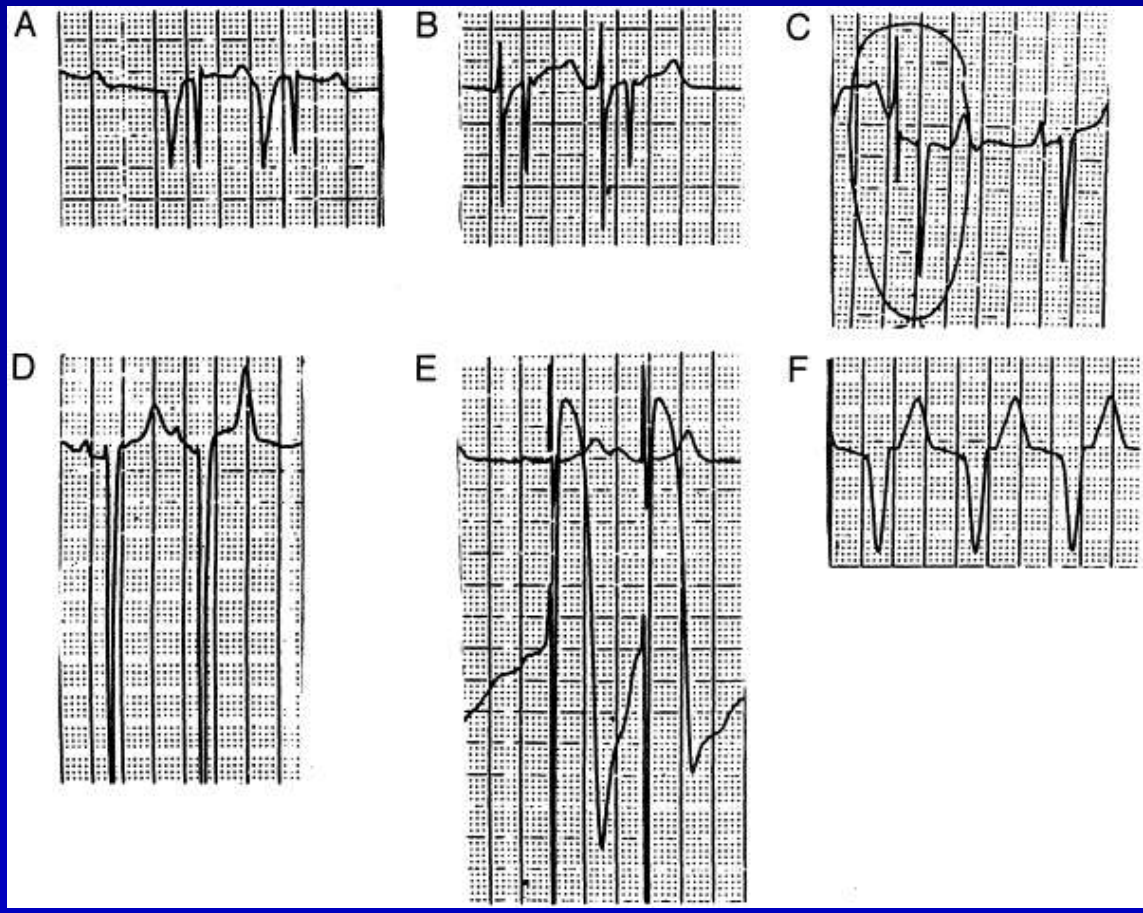


Transvenous pacemaker catheter. (A) Catheter tip with balloon; (B) balloon inflation port; (C) negative electrode; (D) positive electrode; (E) adapters to attach electrodes to external pacing generator; (F) alligator clip to attach negative electrode to ECG V lead; and (G) syringe for balloon inflation.

Harrigan RA et al. J Emerg Med. 2007;32:105.

Temporary Pacemaker Insertion

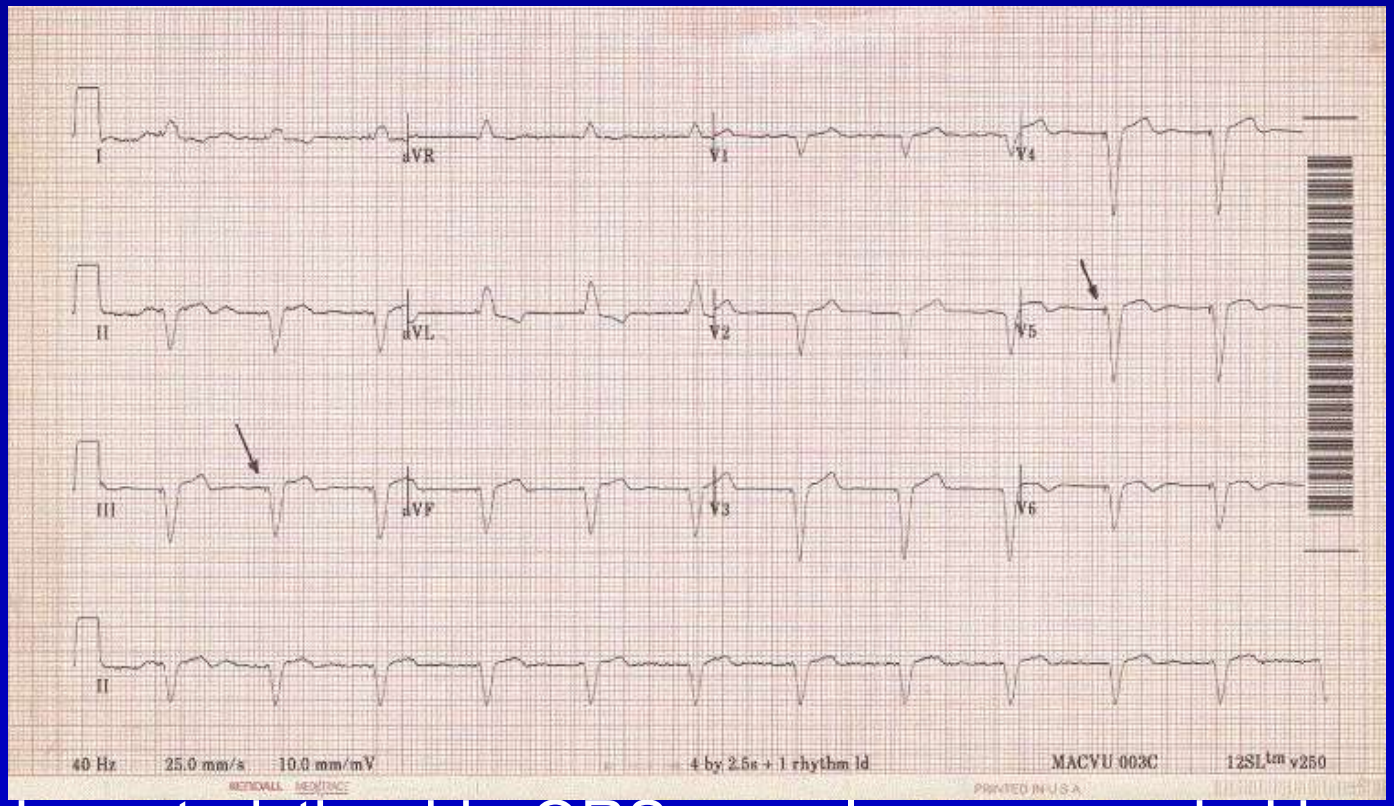
ECG recordings from within the right heart during transvenous pacemaker placement.



(A) High right atrium; (B) mid-to-low right atrium; (C) low right atrium-to-tricuspid annulus; (D) right ventricle; (E) contact with right ventricular endocardium; and (F) surface ECG demonstrating pacemaker capture. Reprinted with permission from (2): Wald DA. Therapeutic procedures in the emergency department patient with acute myocardial infarction. Emerg Med Clin North Am 2001;19:451–67.

Harrigan RA et al. J Emerg Med. 2007;32:105.

Temporary Pacemaker Insertion



Note the characteristic wide-QRS complexes preceded by narrow pacemaker spikes (arrows). V1–V3 resemble a classic LBBB, yet V4–V6 differ in that the QRS complexes maintain a principally negative deflection. Also note the leftward (superior) frontal plane QRS axis deviation

Harrigan RA et al. J Emerg Med. 2007;32:105.

Temporary Pacemaker Thresholds

- **Pacing threshold** = minimum current for capture.
- Start with high level of current output and pacing rate at least 10 beats/min above the native rate.
- Slowly reduce output until capture is lost.
- Repeat several times to verify threshold value.
- Set current to roughly 2–2.5 times the threshold.
- Ideal pacing threshold is < 1 mA, so the pacing output is usually set to no more than 2–3 mA;
- Reposition electrode if threshold is above 5–6 mA

Harrigan RA et al. J Emerg Med. 2007;32:105.

Few Temporary Pacer Tips

- Hemodynamic compromise or syncope are the principal indications
- Prefer right side of neck (save left for permanent)
- Set energy at 3x threshold, hopefully threshold is 0.1 mA; check at least daily
- 12-lead ECG should be LBBB and LAD
- Prevent migration and loss of capture
  - Use suture to attach electrode to cordis
  - Create a loop with the electrode to prevent its being pulled out

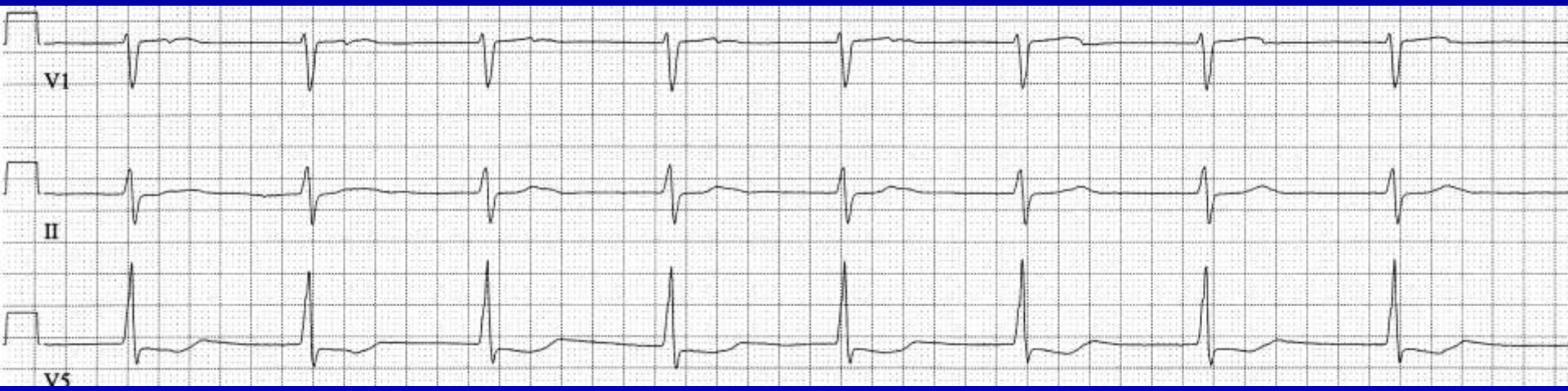
Terminology in AV Dissociation

- **Usurpation**:
  - The ventricular rhythm is too fast, usurping the normal atrial mechanism
  - Ventricular rate is generally normal or fast
- **Default**:
  - The atrial rhythm is too slow, defaulting to the normal escape ventricular mechanism
  - Ventricular rate is generally slow

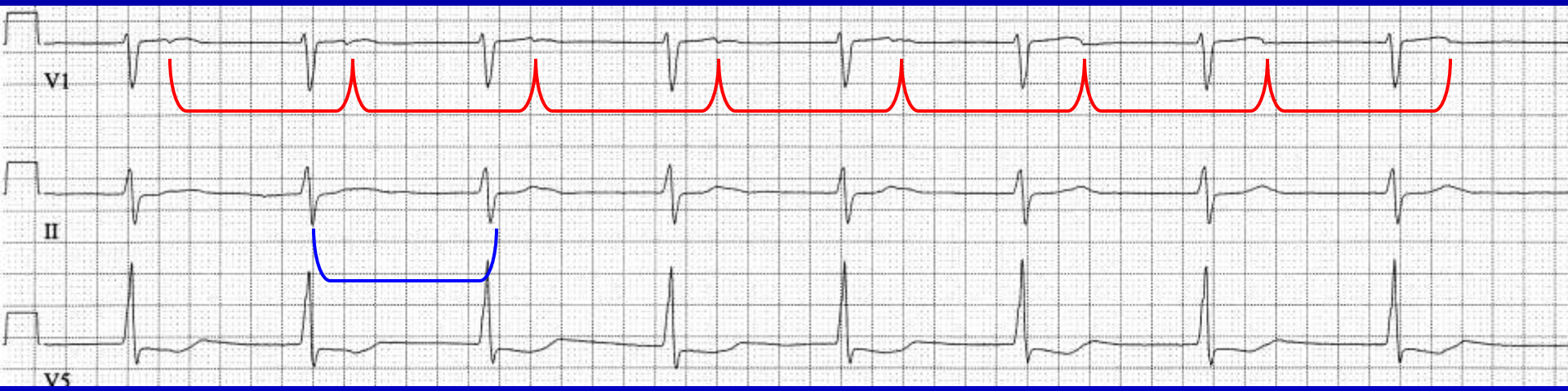
- **Complete** AV dissociation: there is no connection between atrial and ventricular complexes
- **Incomplete** AV dissociation: there is evidence of AV conduction causing an early QRS complex
- **Interference** dissociation: incomplete AV dissociation

- **Isorhythmic** AV dissociation: the PR interval varies but the atrial and venticular rates are identical

What is the rhythm?



Junctional rhythm, sinus bradycardia, AV dissociation



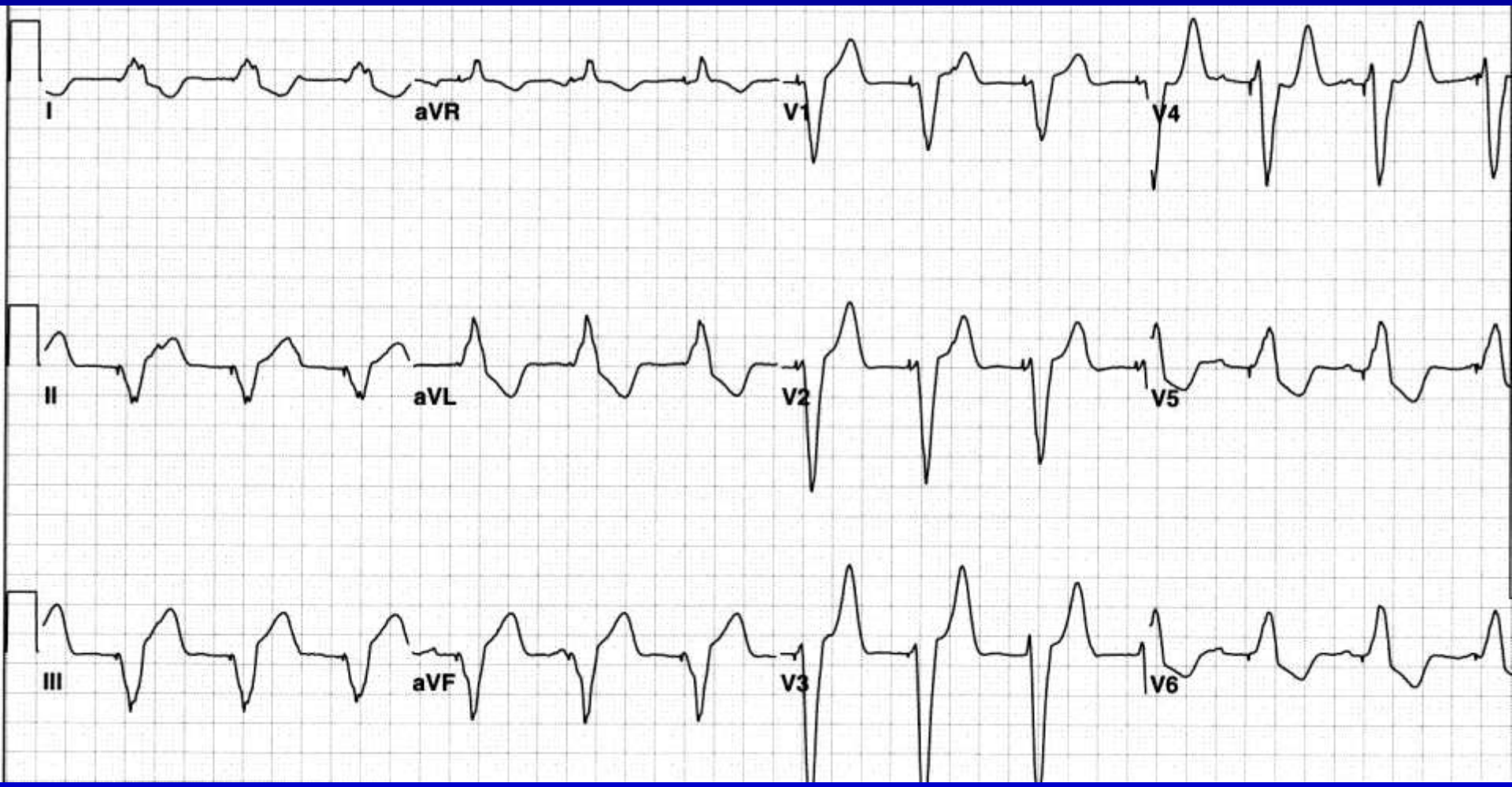
Pacemaker ECG

- Artificial Pacemakers generate an electric voltage of generally less than 1 msec - ECG appears unnaturally short and spikey
- Pacer spike can be in atrium or ventricle or both.
- Capture: pacer spike precedes a P or a QRS
- Sense: no pacer spike shortly after a P or a QRS

Pacemaker Features that Cause Confusion in ECG Interpretation

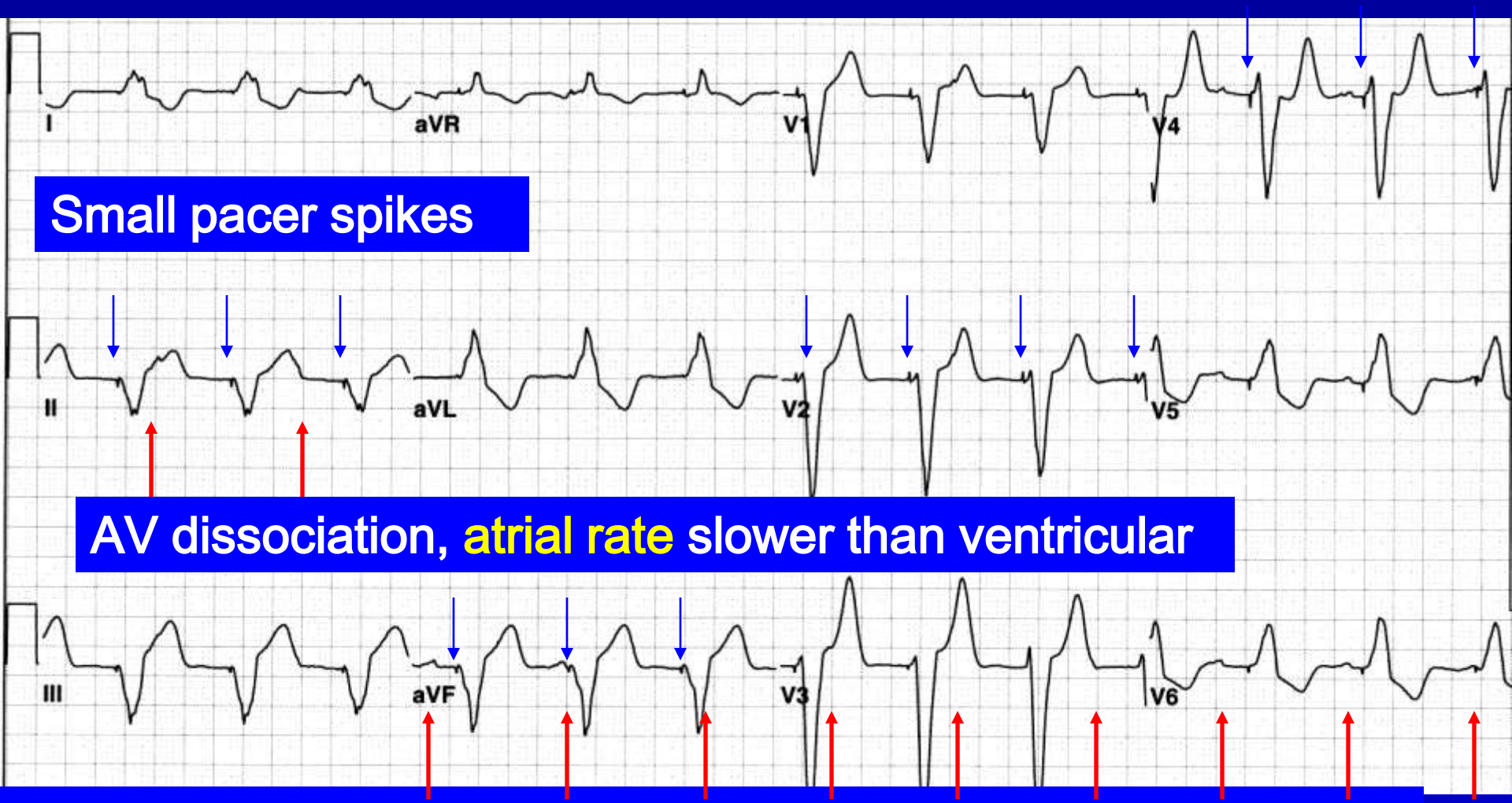
- Rate-responsive pacing
- Ventricular safety pacing
- Ventricular auto-pacing (?)
- Other interesting features, including response to PVC and intentional firing in QRS
- Prior “committed” AV seqential pacing
- Magnet response signals

Pacemaker ECG



Pacemaker ECG

Variable S1 intensity

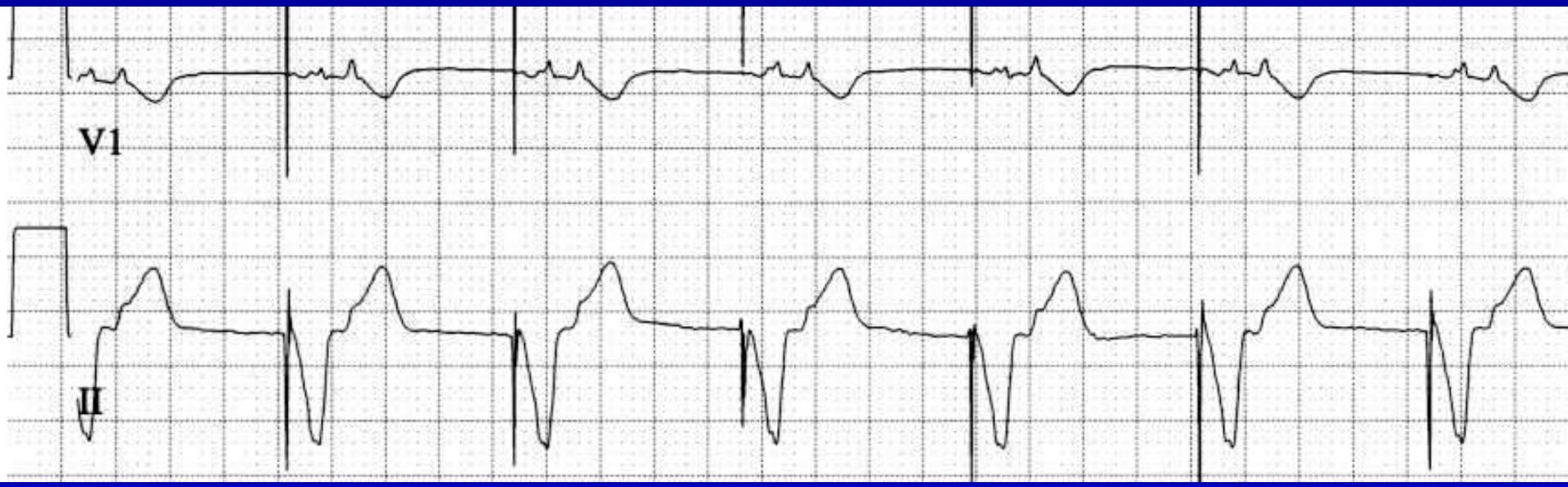


Small pacer spikes

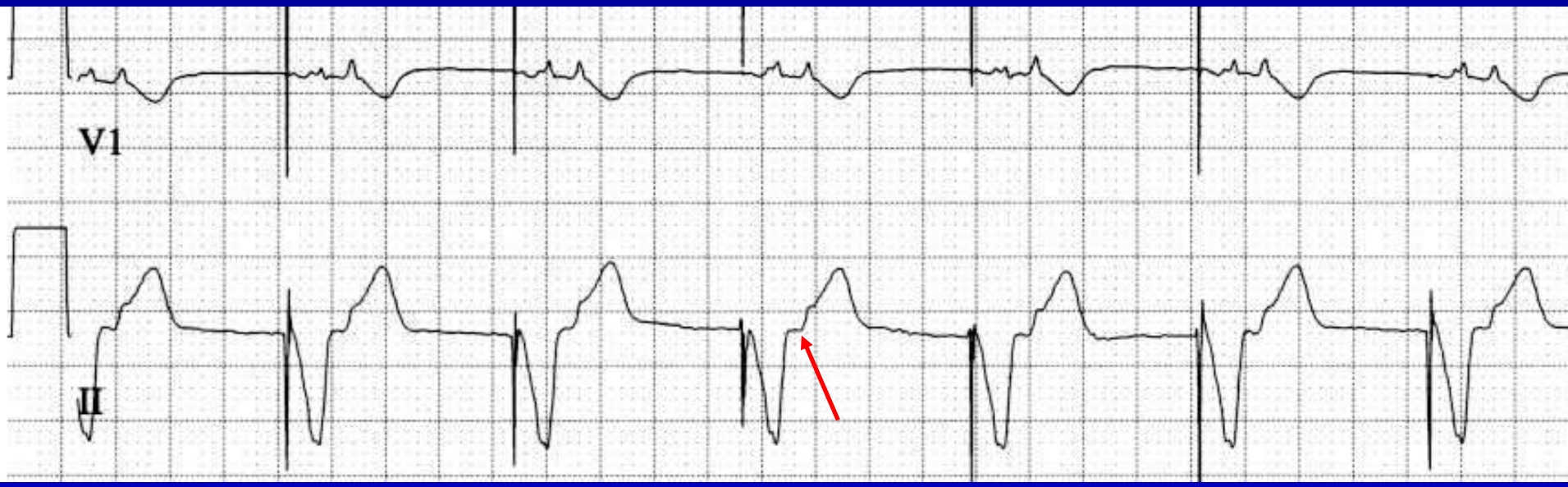
AV dissociation, atrial rate slower than ventricular

LBBB and left axis deviation is typical pattern for transvenous pacemaker tip at RV apex

Pacemaker ECG



Pacemaker ECG



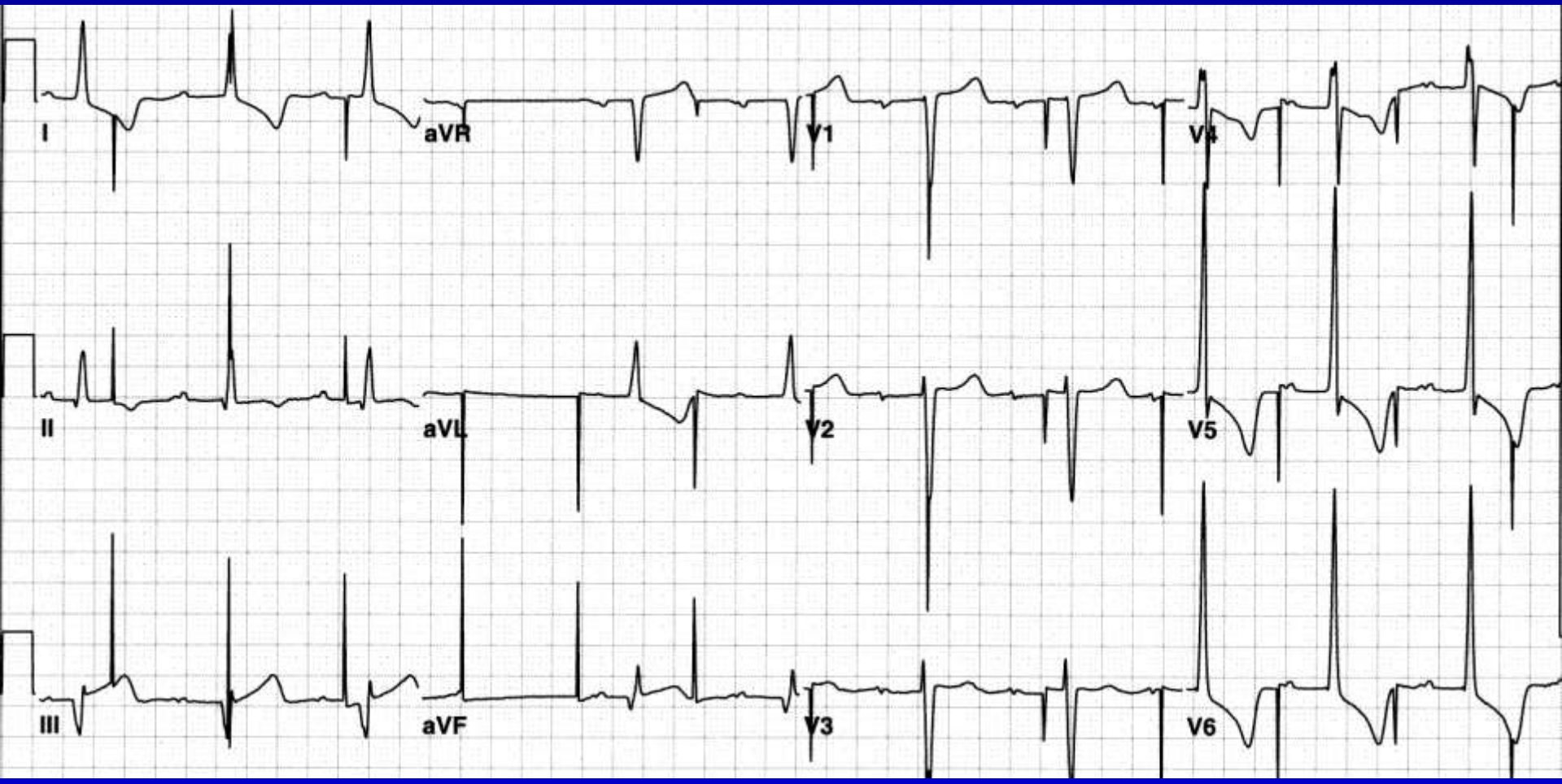
Note:
Spike before each QRS
No P before any QRS
Hidden P at end of QRS, best seen in II
Ventricular pacemaker, 100% capture, with 1:1 retrograde conduction (VA conduction)

Pacemaker ECG

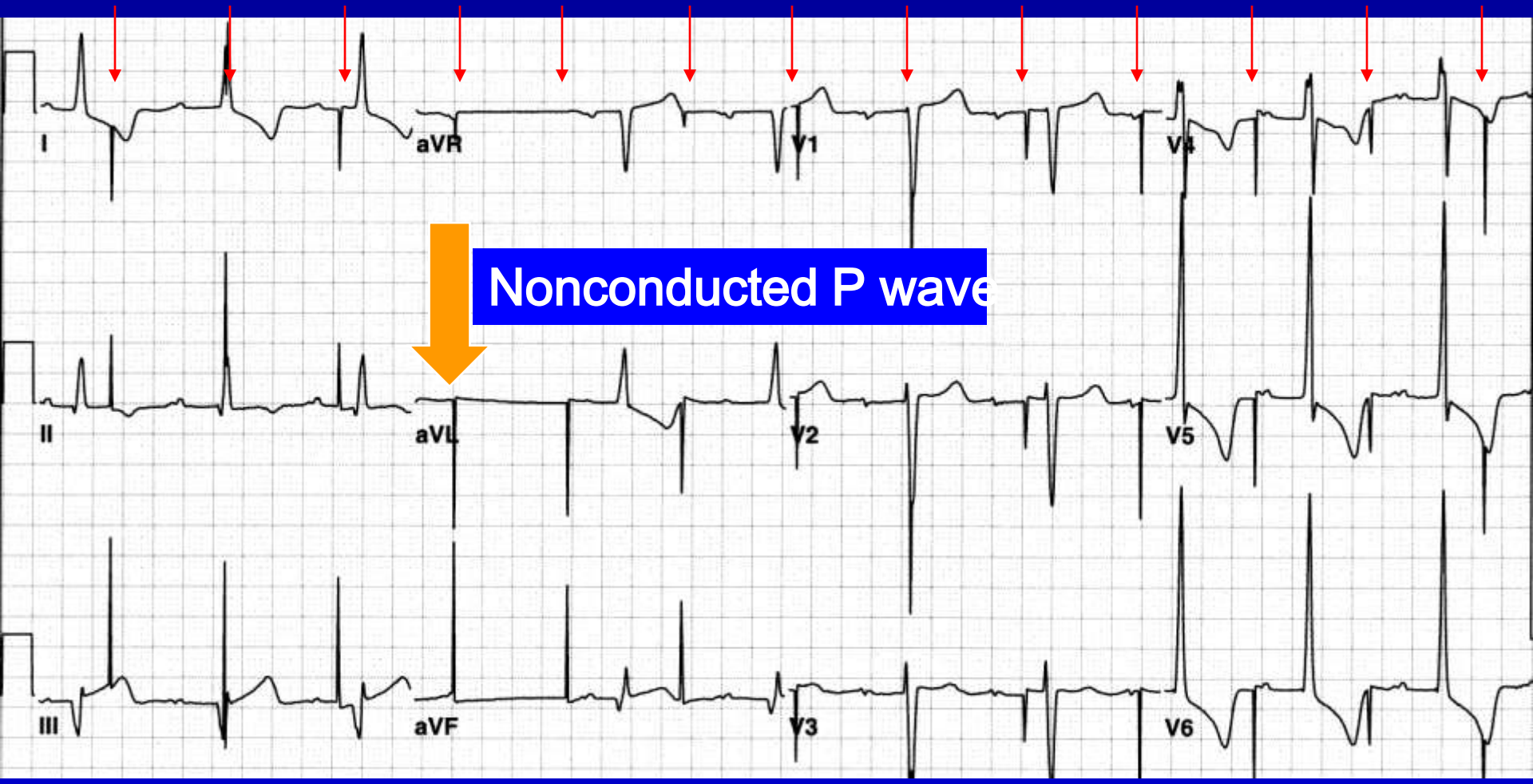
Pacemaker ECG

Note:
All QRS initiated by large pacer spike except the last.
Last paced beat is a fusion beat.
Red arrows show P waves

Pacemaker ECG

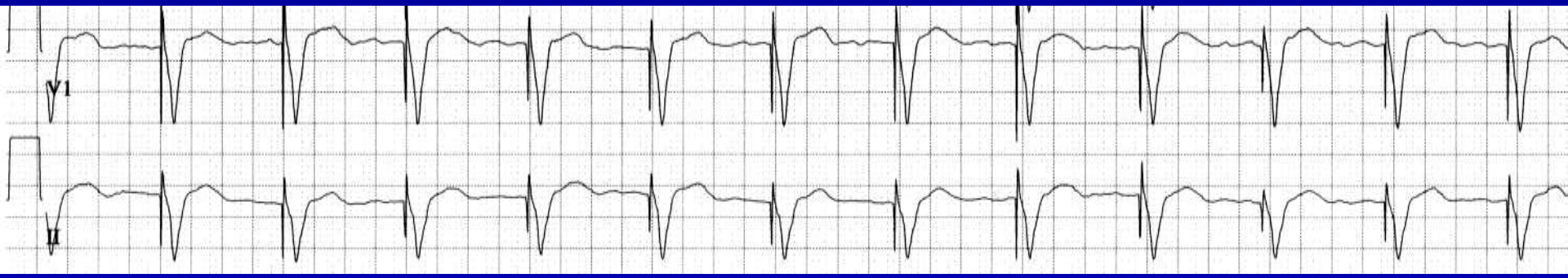


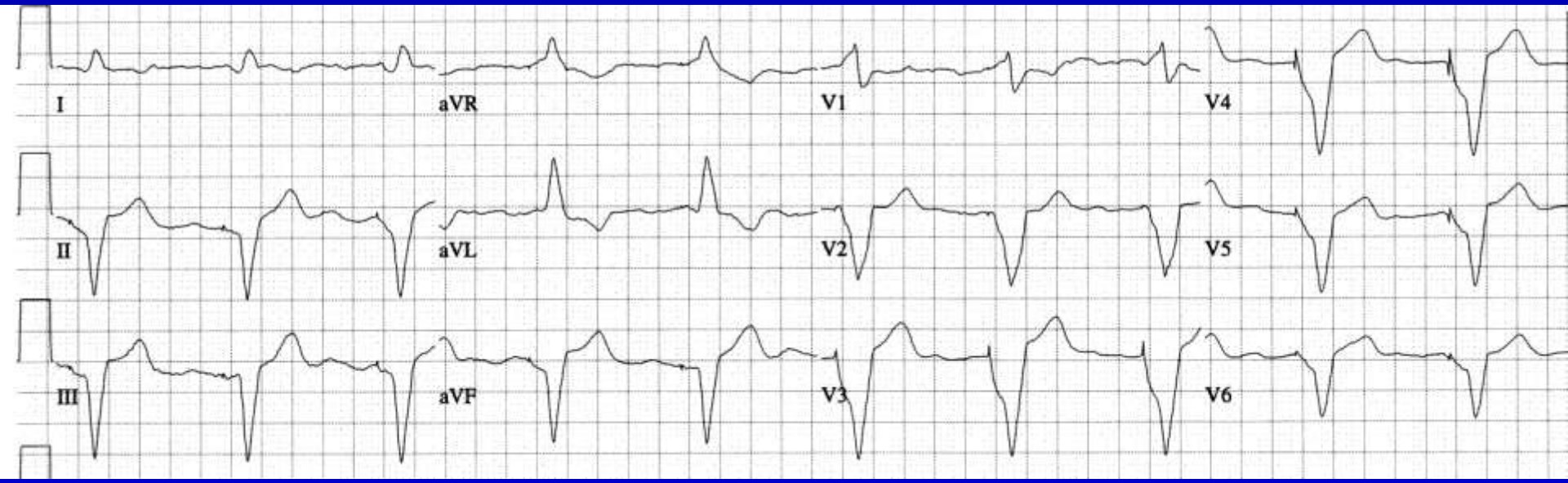
Pacemaker ECG



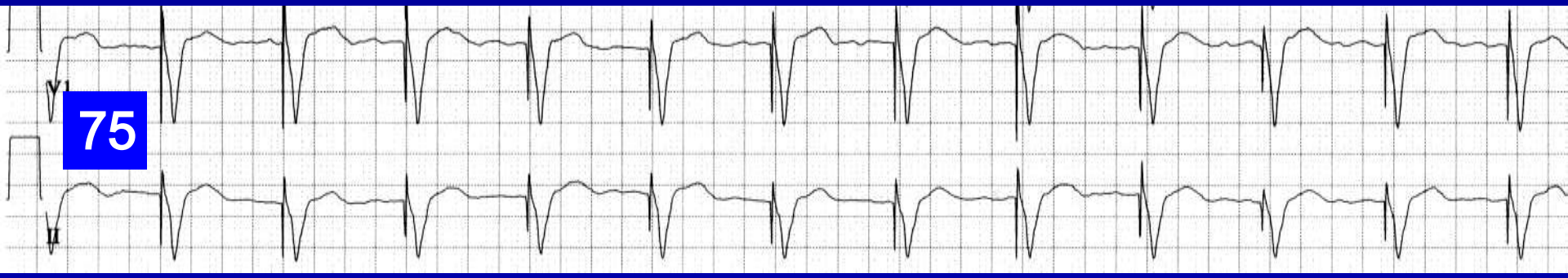
Note: Pacer spikes aren't suppressed by QRS or P waves
Pacer spikes aren't followed by QRS or P waves
Native: NSR rate 65, FAV, IMI recent LVH, Wenckebach

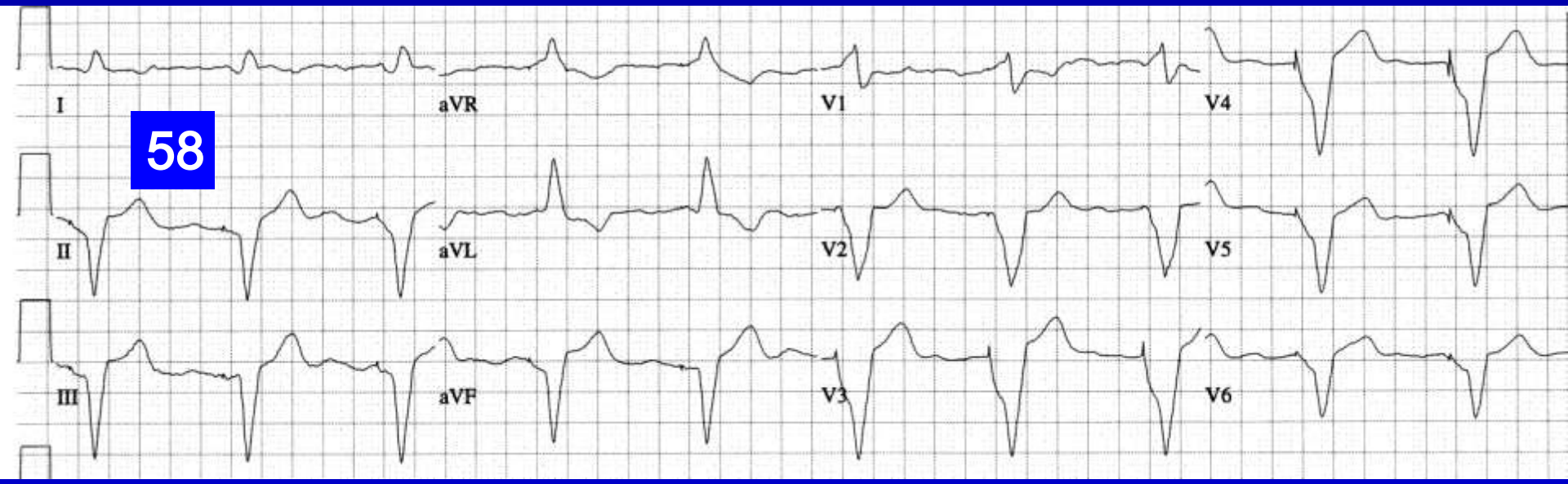
Pacemaker ECG





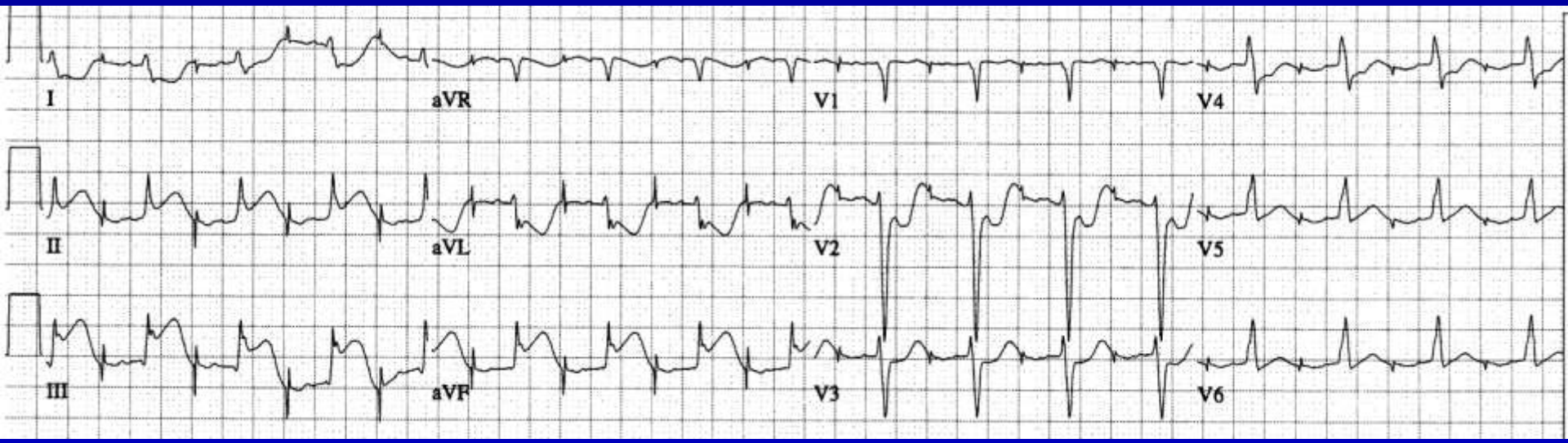
Pacemaker ECG



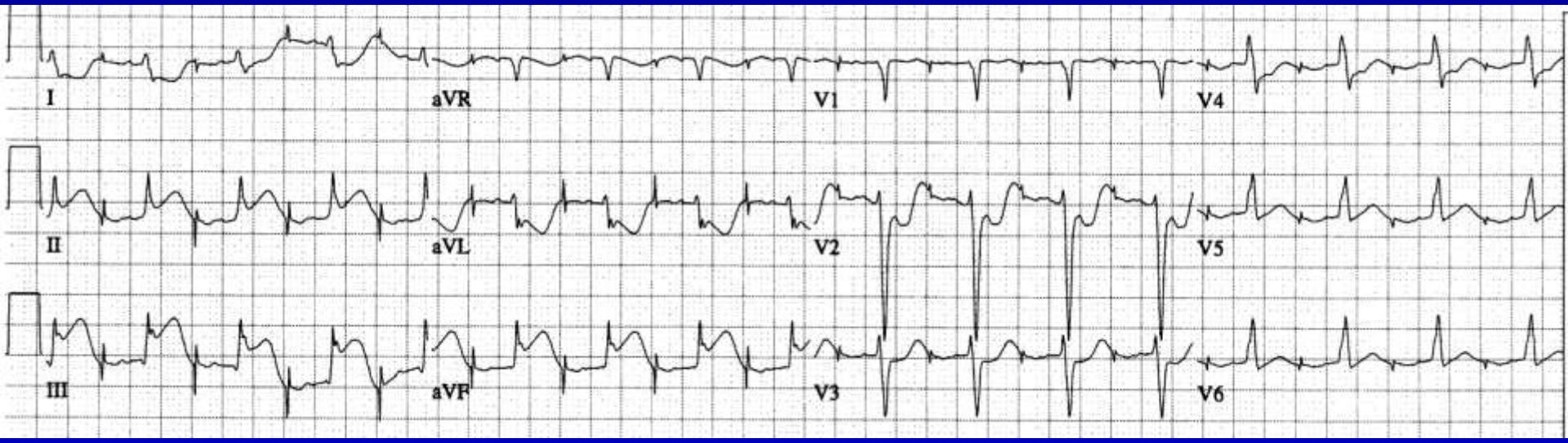


Note: Both patients have atrial fibrillation without AV conduction

Pacemaker ECG



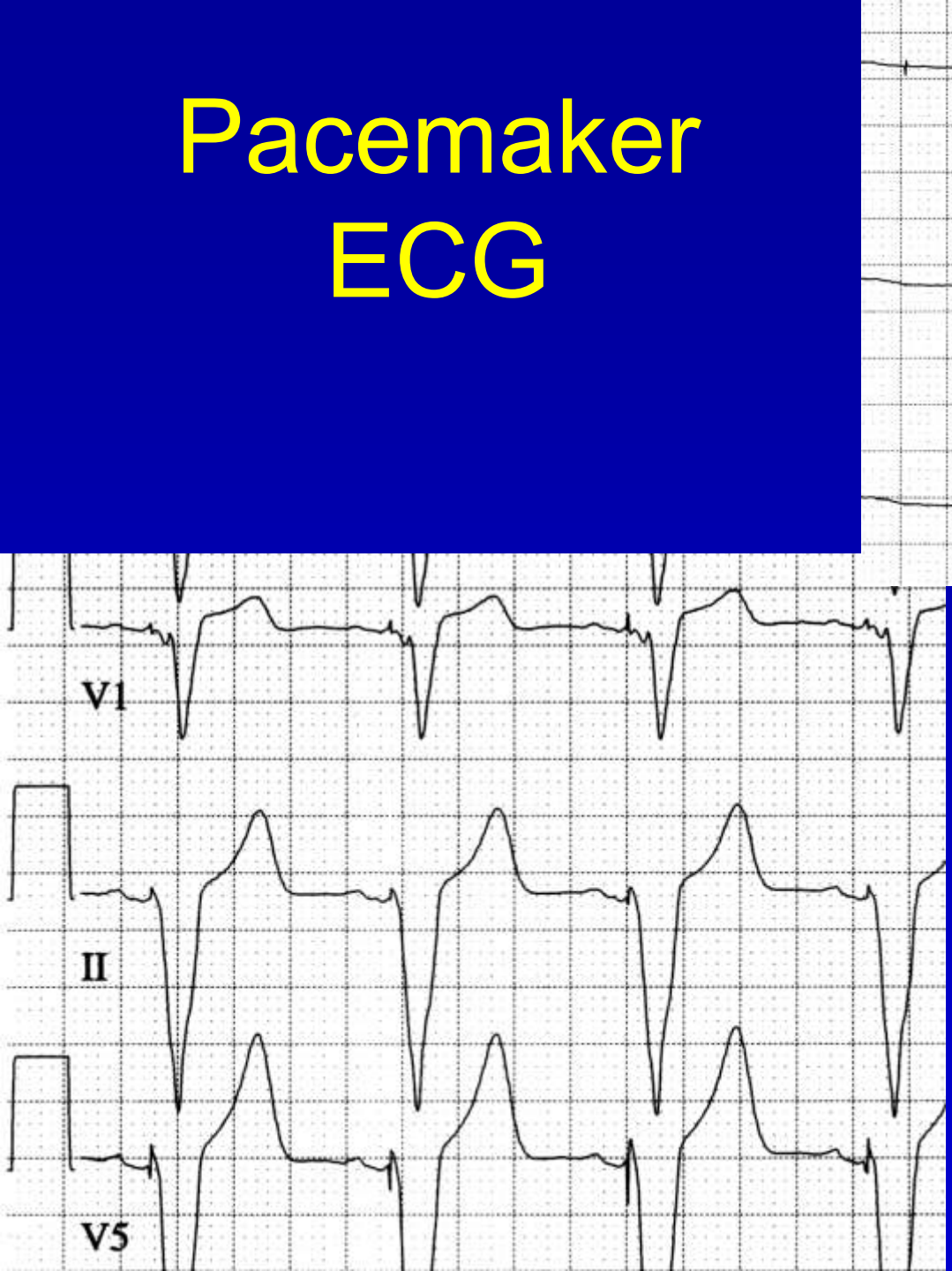
Pacemaker ECG



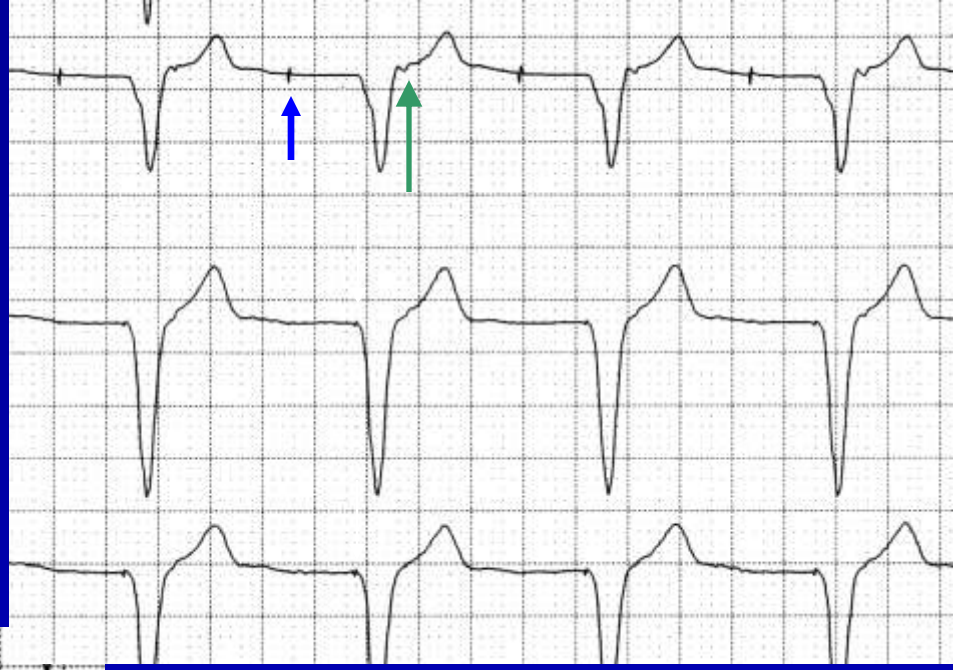
Note:

- Pacer spike followed by P wave - Atrial pacemaker
- Atrial pacer rate is fast at 100 bpm
- Prolonged constant PR interval - First degree AV block
- ST elevation in II, III and F, inferior transmural injury
- Reciprocal change in I and L
- ST depression in V2, posterior injury

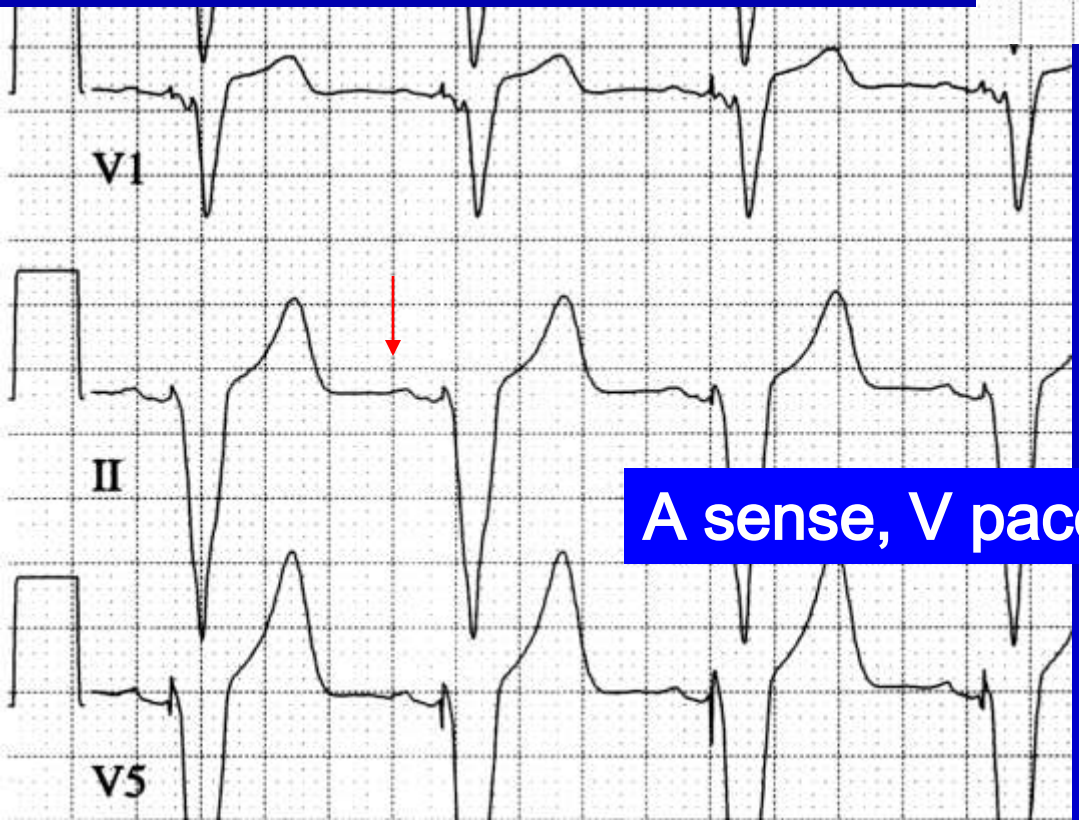
Pacemaker ECG



Pacemaker ECG

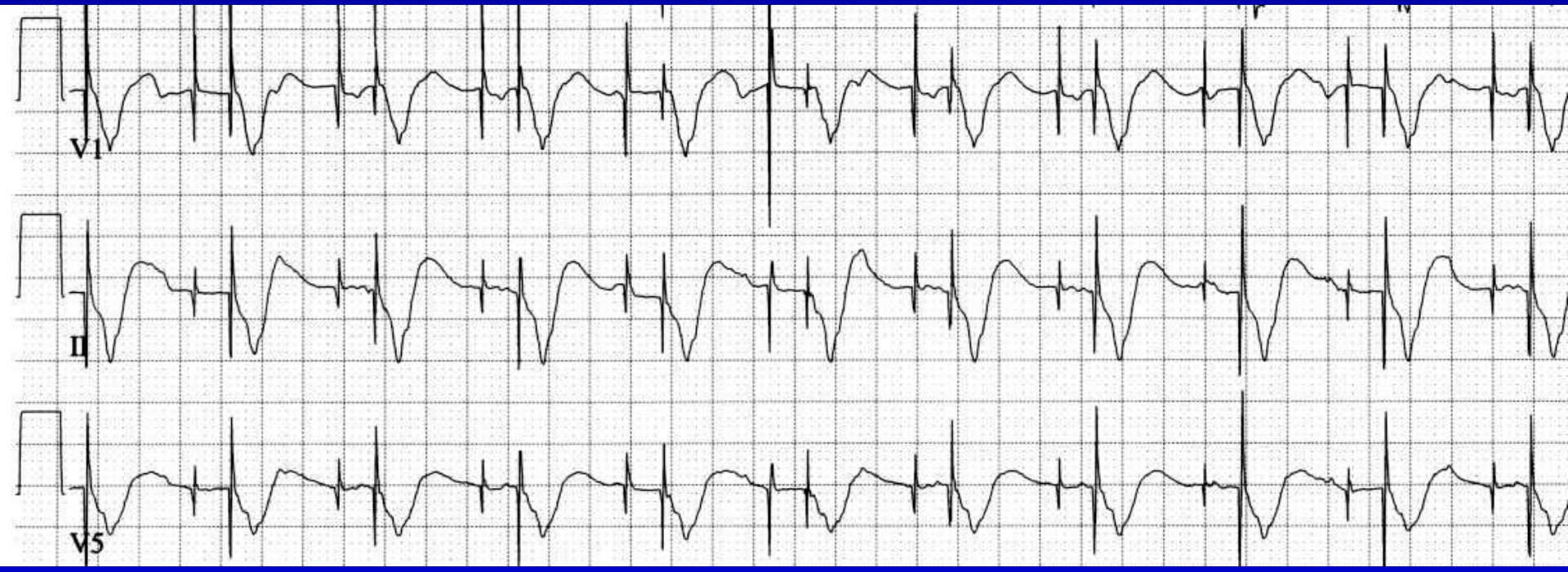


A pace, noncapture
V pace, capture
retrograde A wave



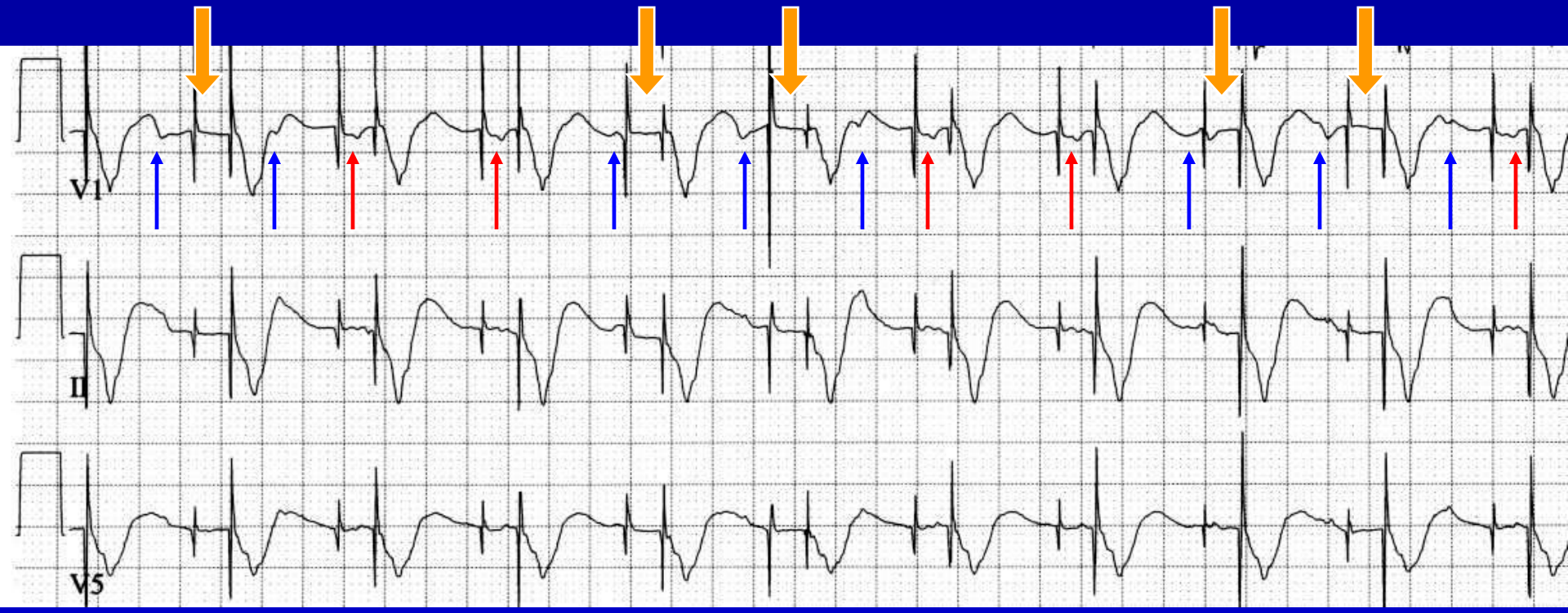
A sense, V pace

Pacemaker ECG



Pacemaker ECG

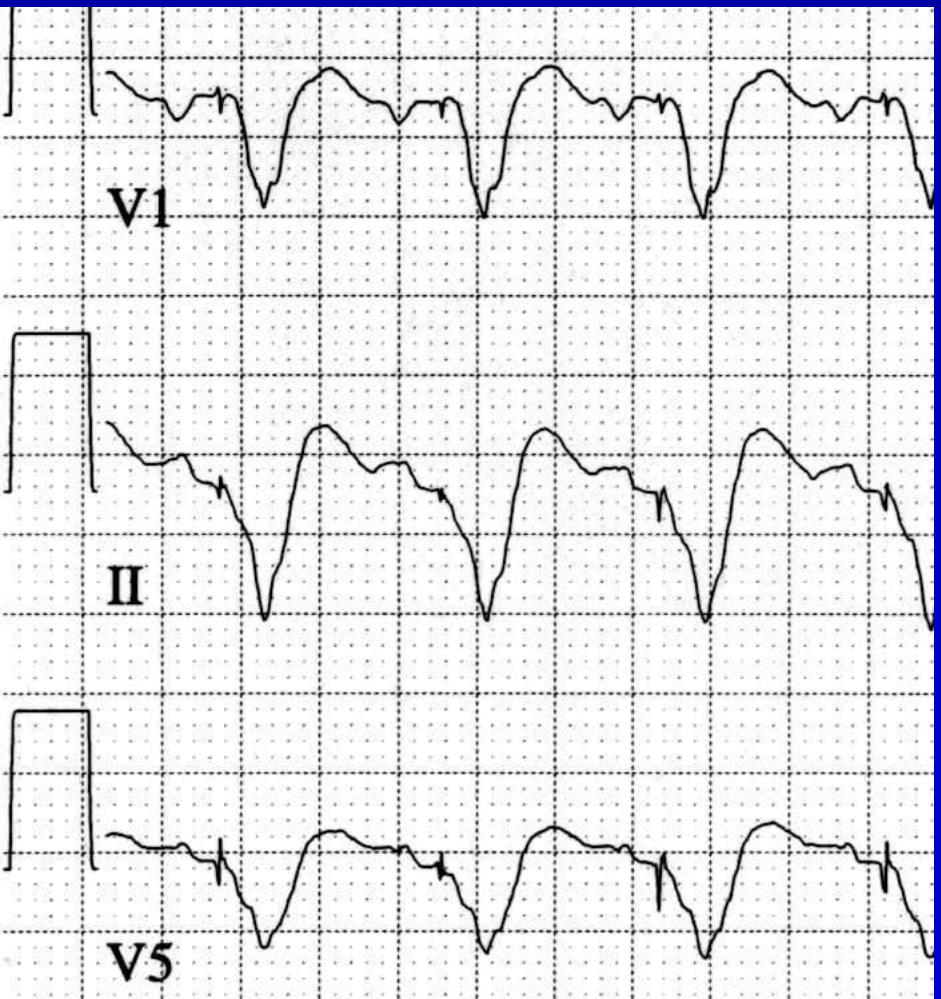
Nonconducted atrial spikes due to refractory atrium

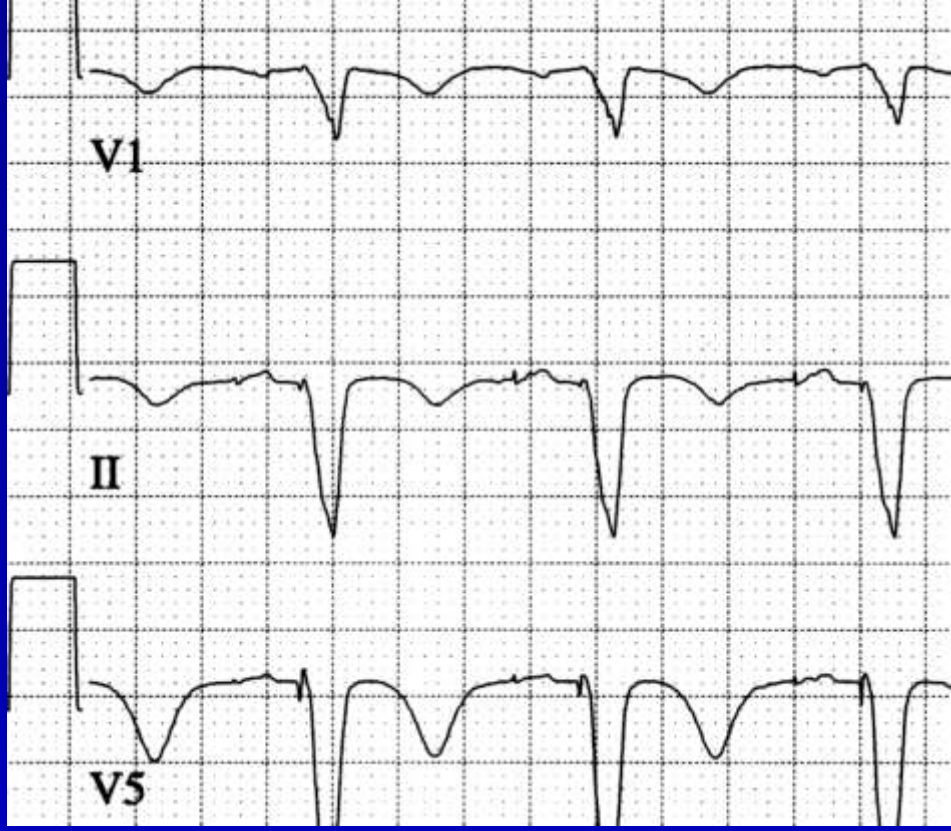


Red arrow - conducted atrial spikes

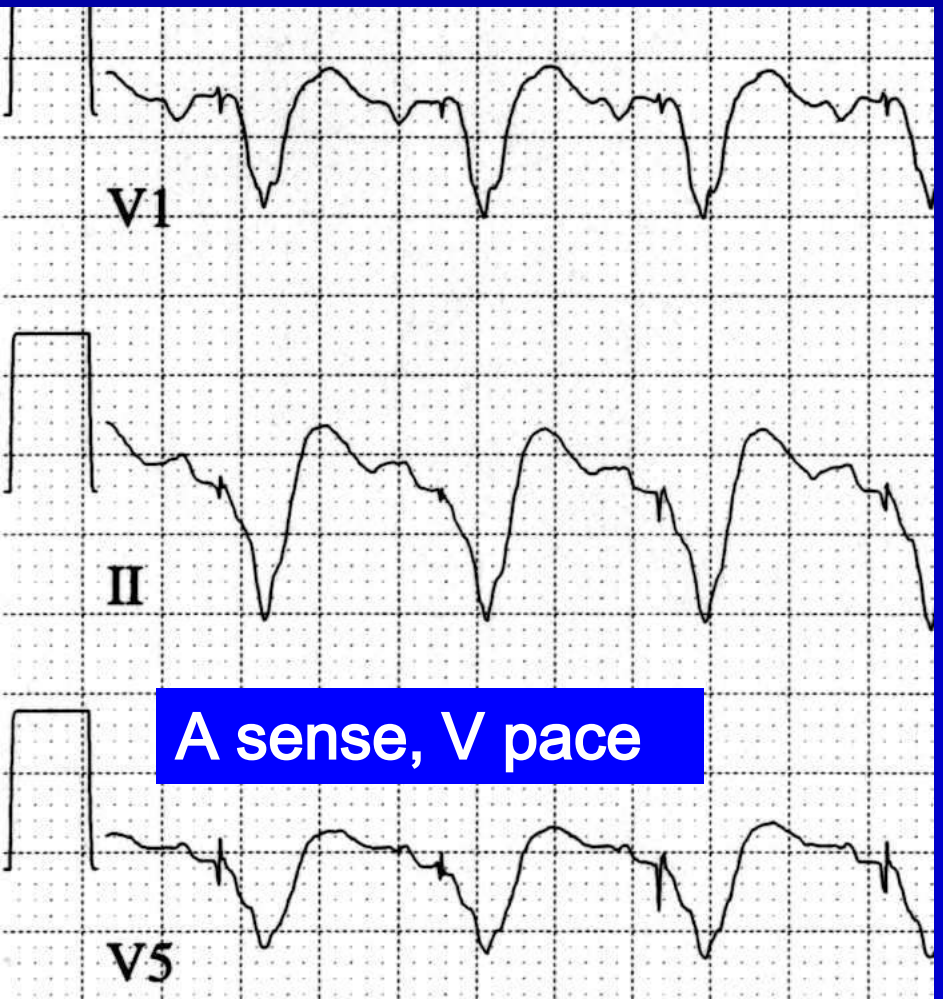
Blue arrow - native P waves

Pacemaker ECG

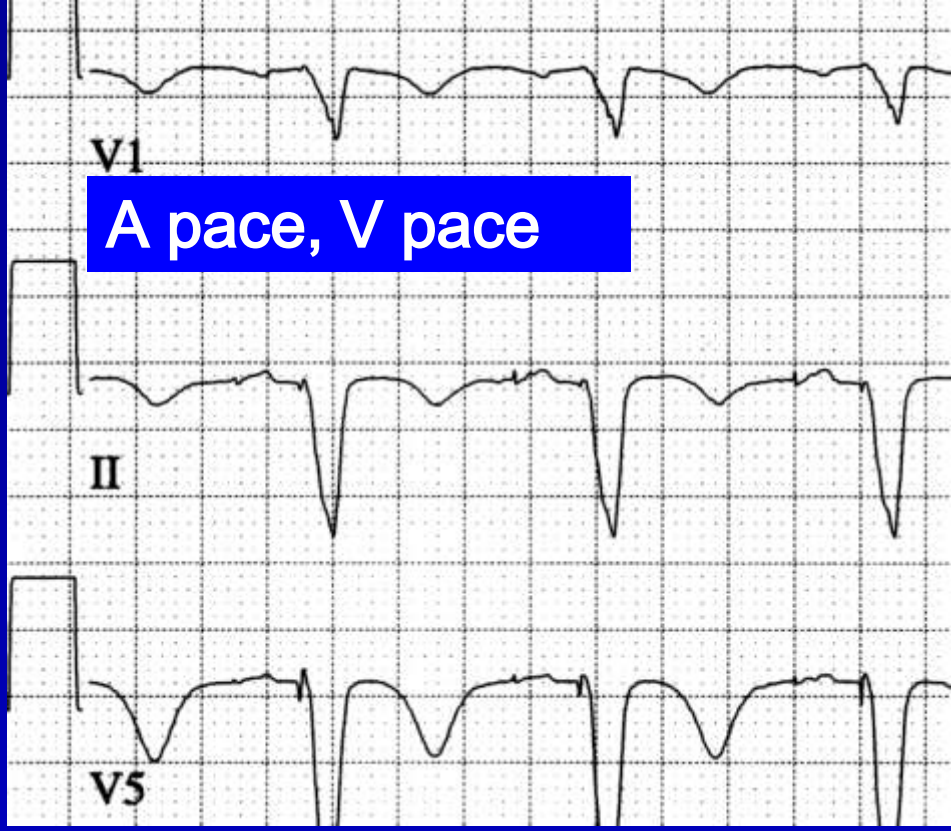




Pacemaker ECG

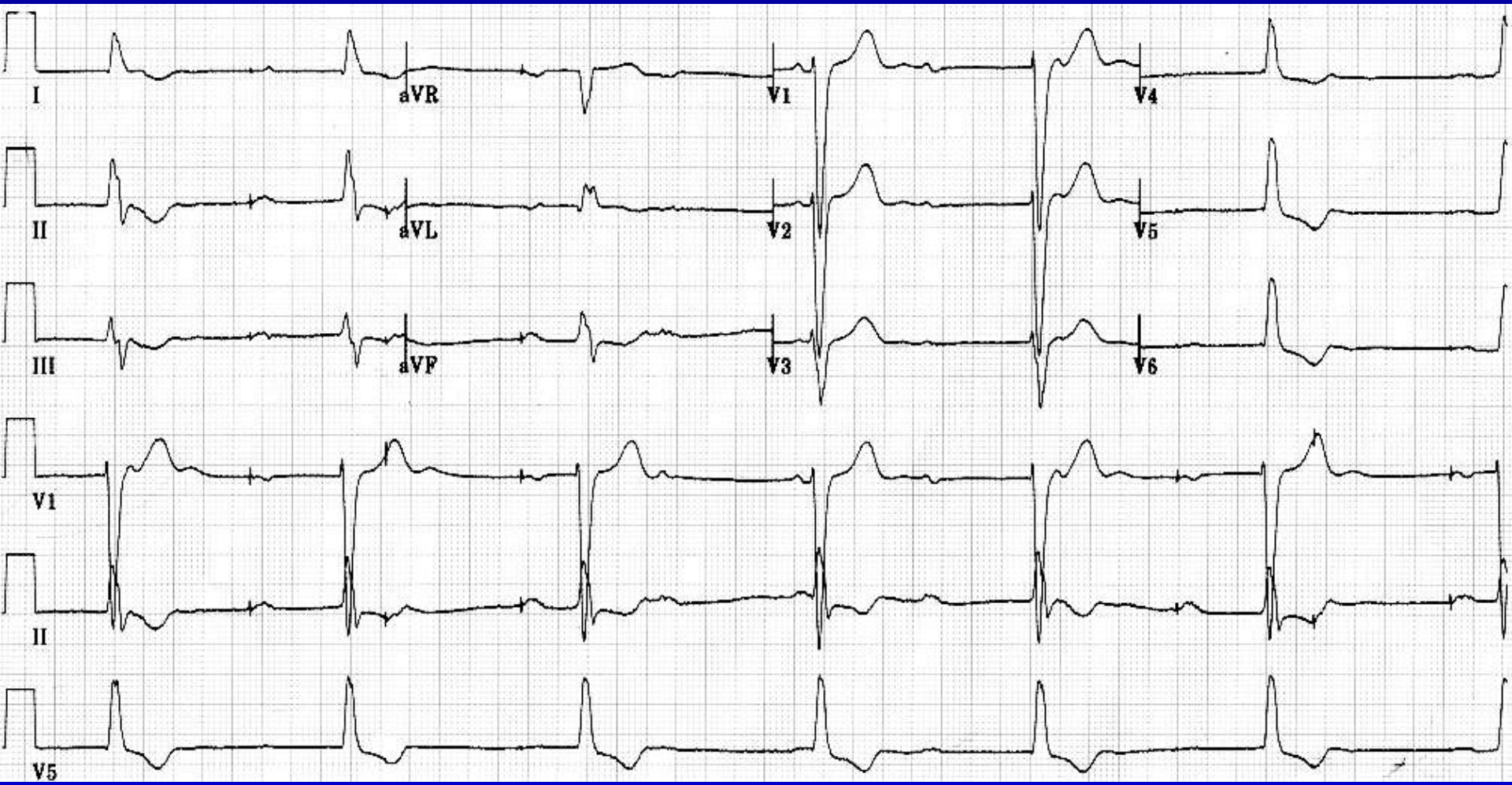


A sense, V pace

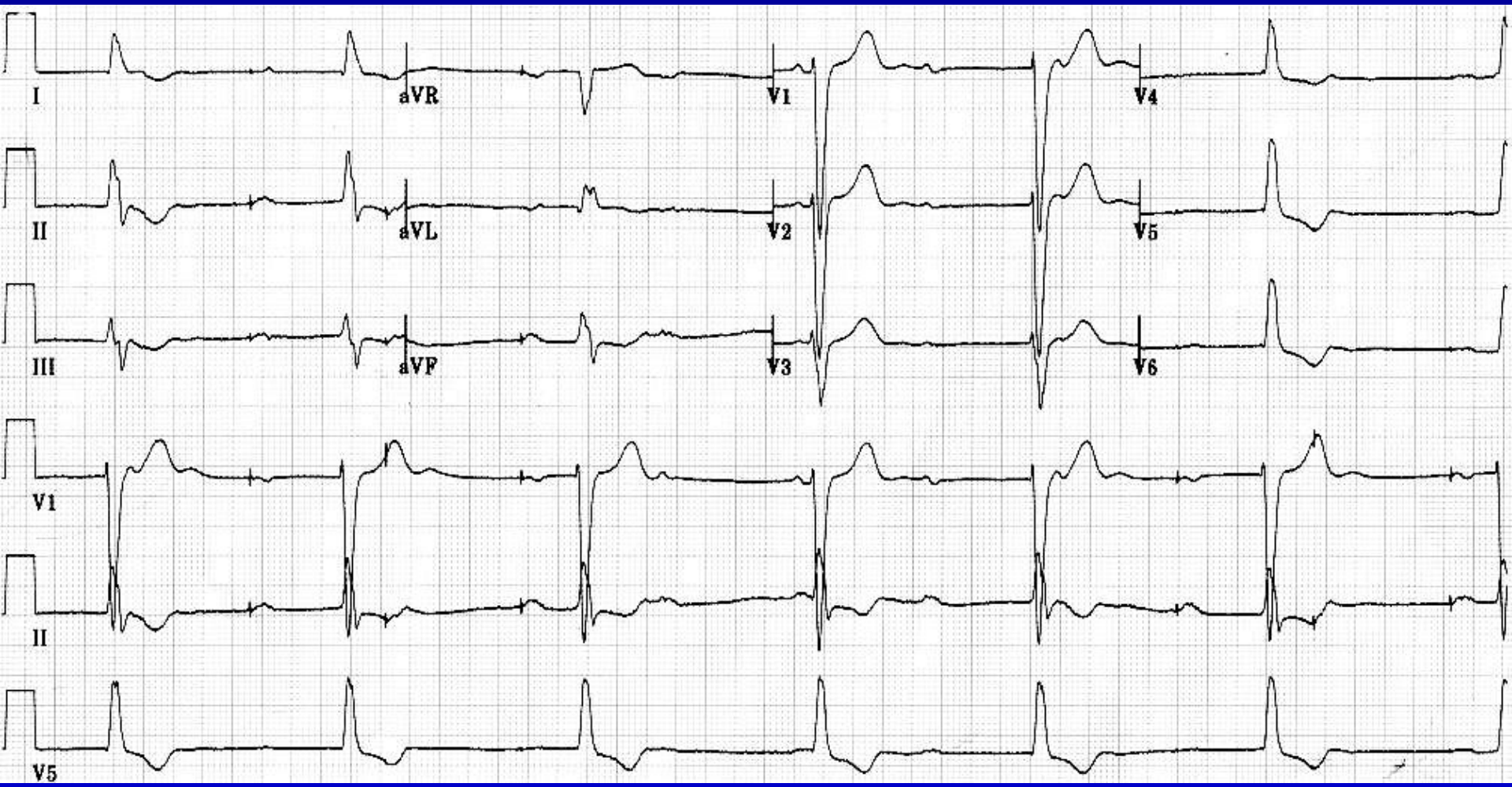


A pace, V pace

Case 15

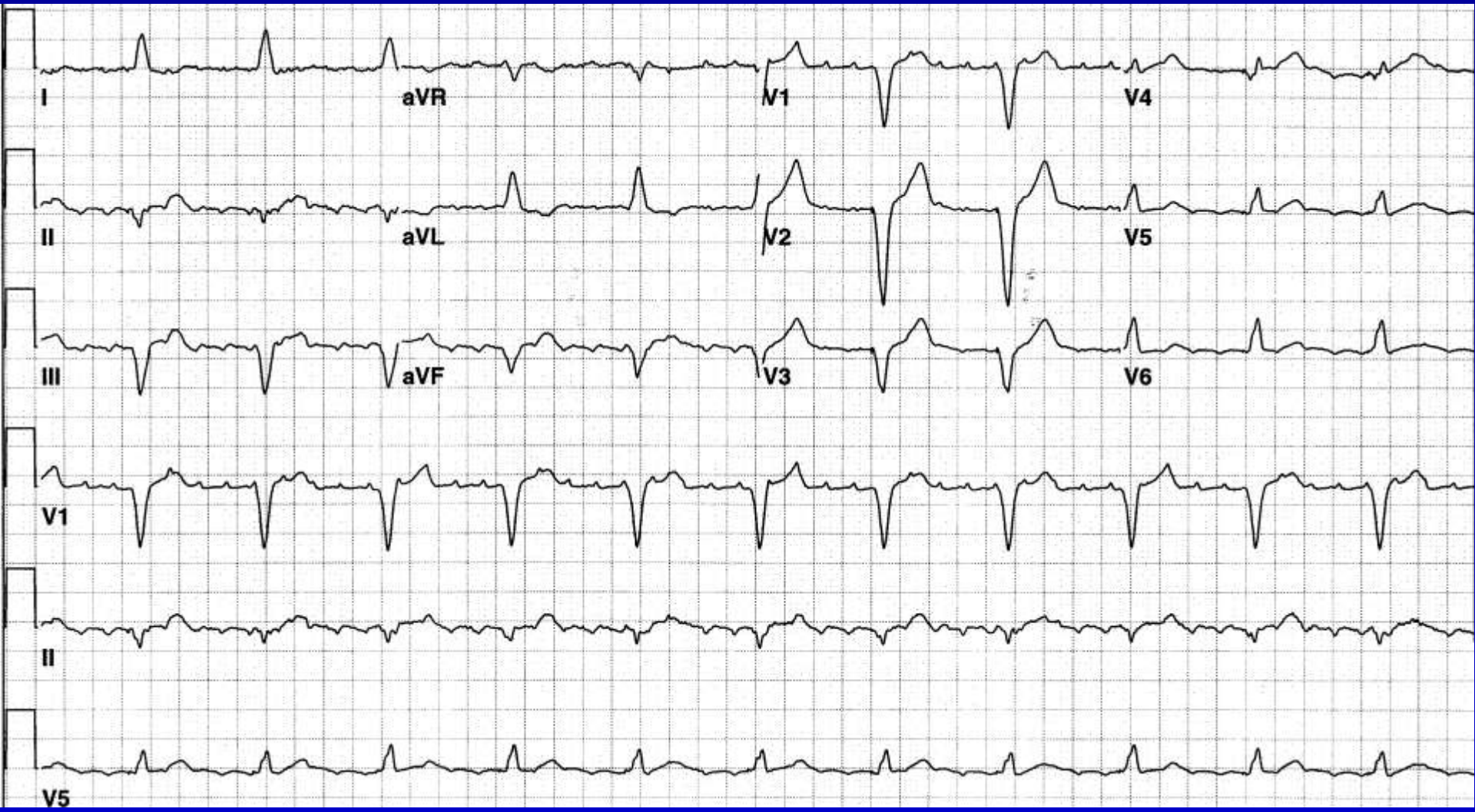


Case 15

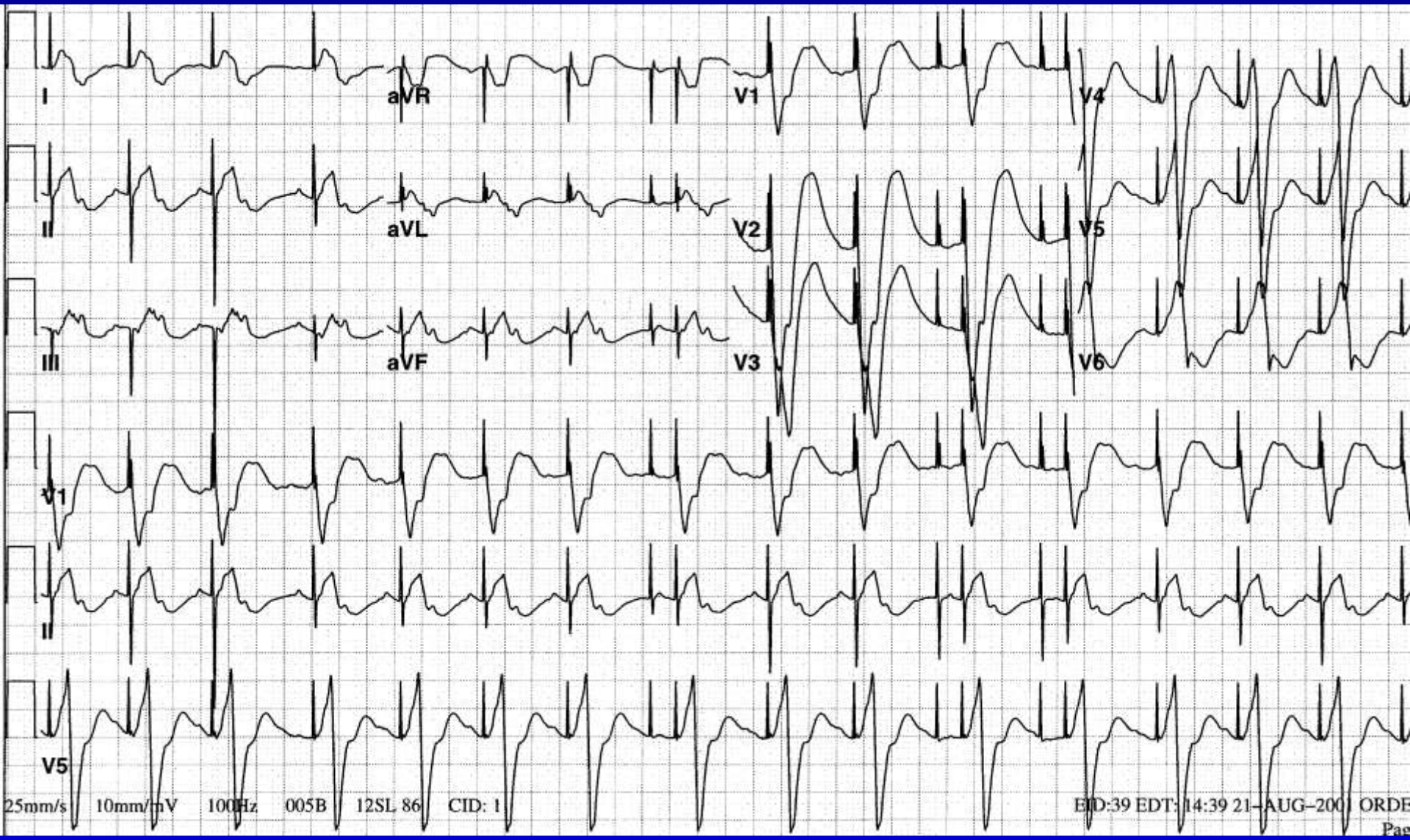


- Complete heart block with ventricular escape rhythm
- Atrial pacemaker with normal sense and capture
- Sinus rhythm rate 65

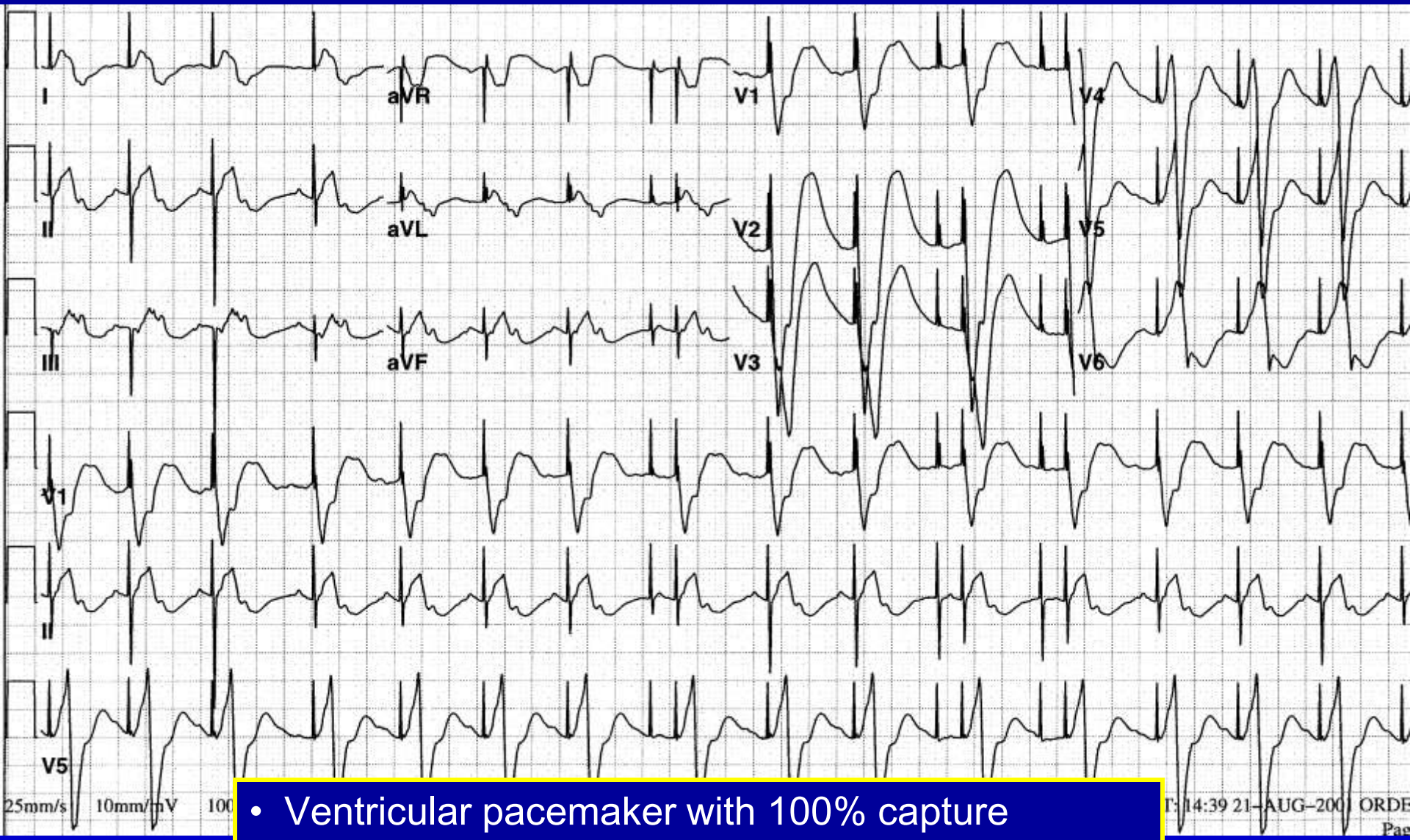
Case 23



Case 28

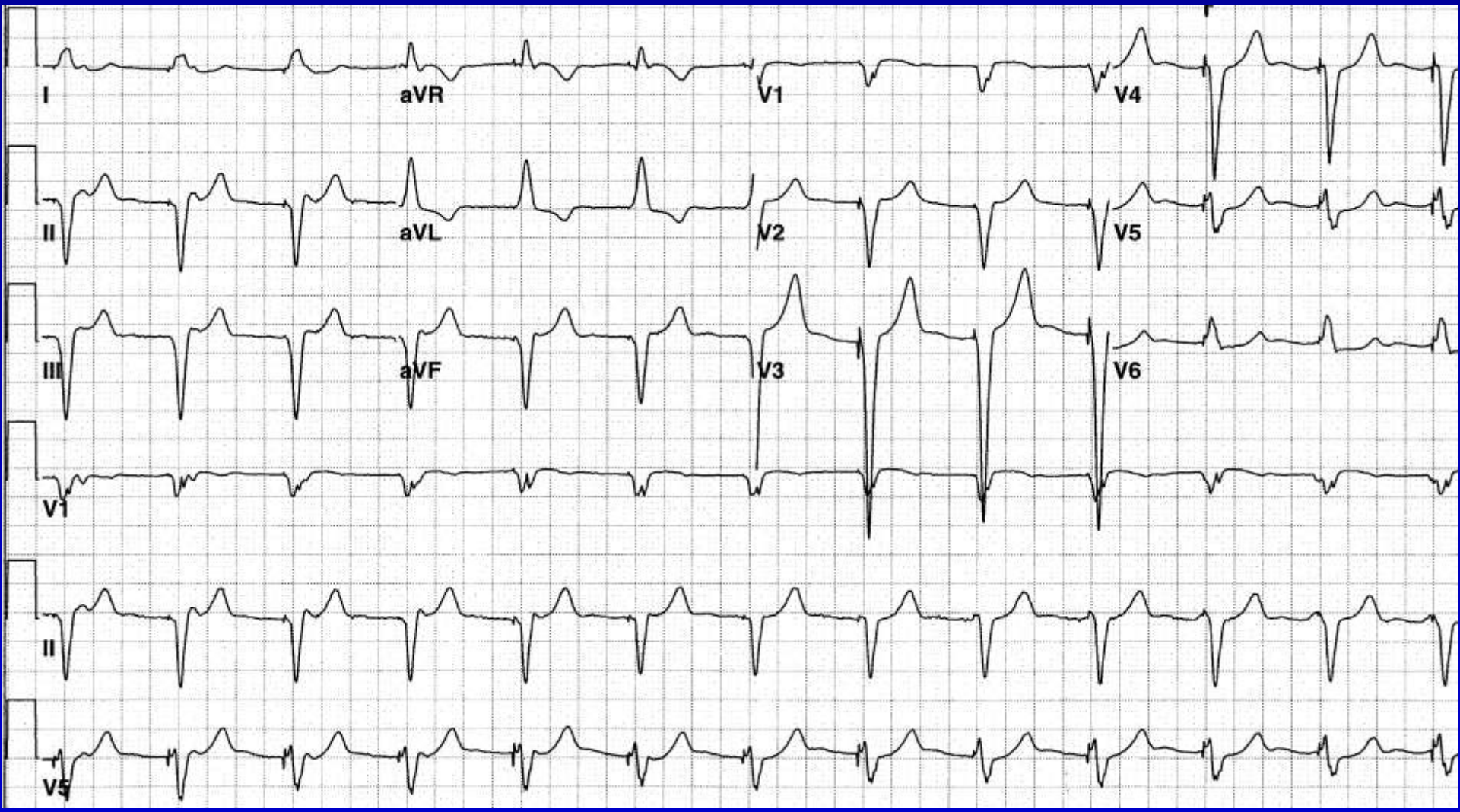

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5
25mm/s
10mm/mV
100Hz
005B
12SL 86
CID: 1
EDT:14:39 21-AUG-2001

Case 28

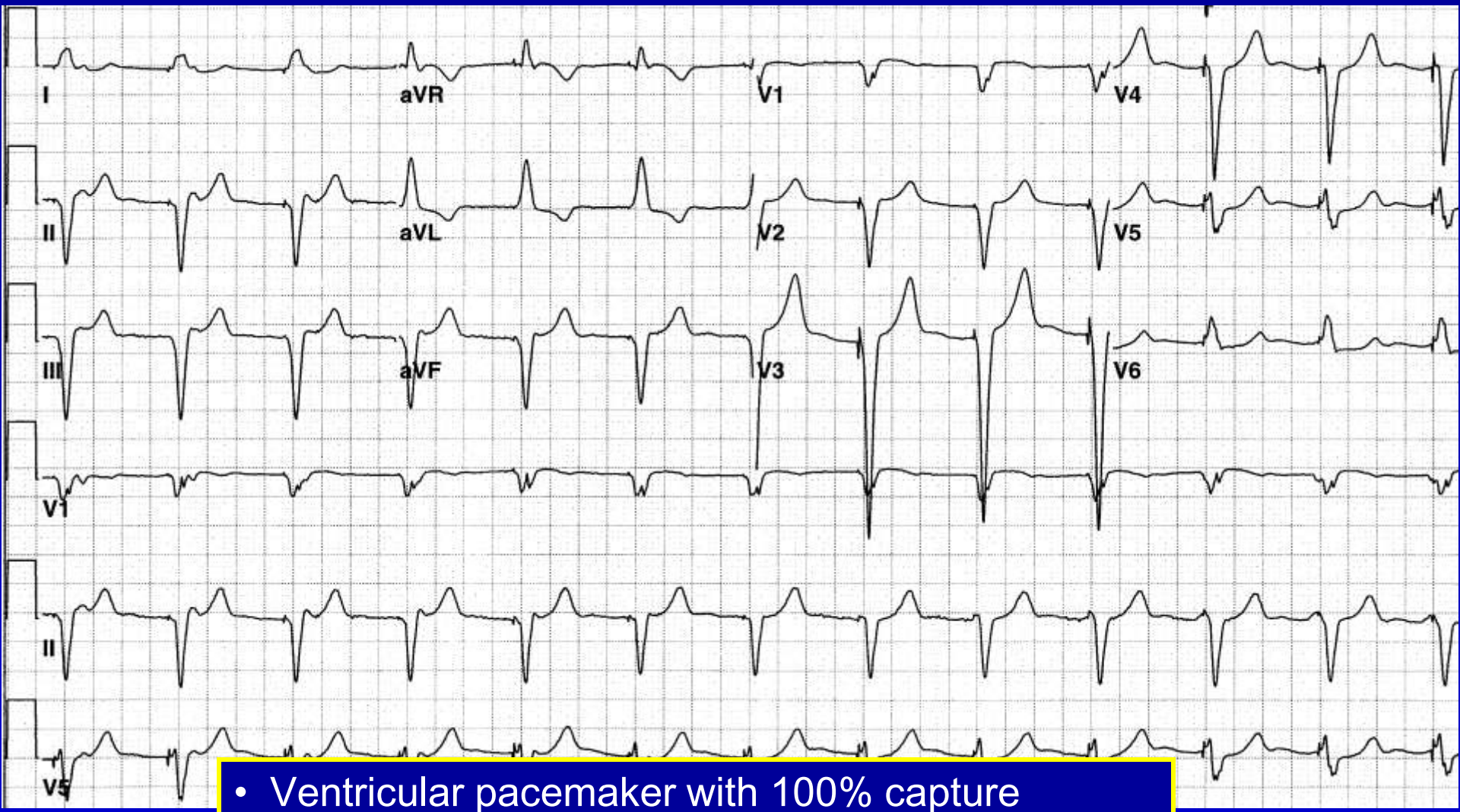


- Ventricular pacemaker with 100% capture
- Atrial pacemaker with normal sense and capture
- Sinus arrhythmia

Case 34

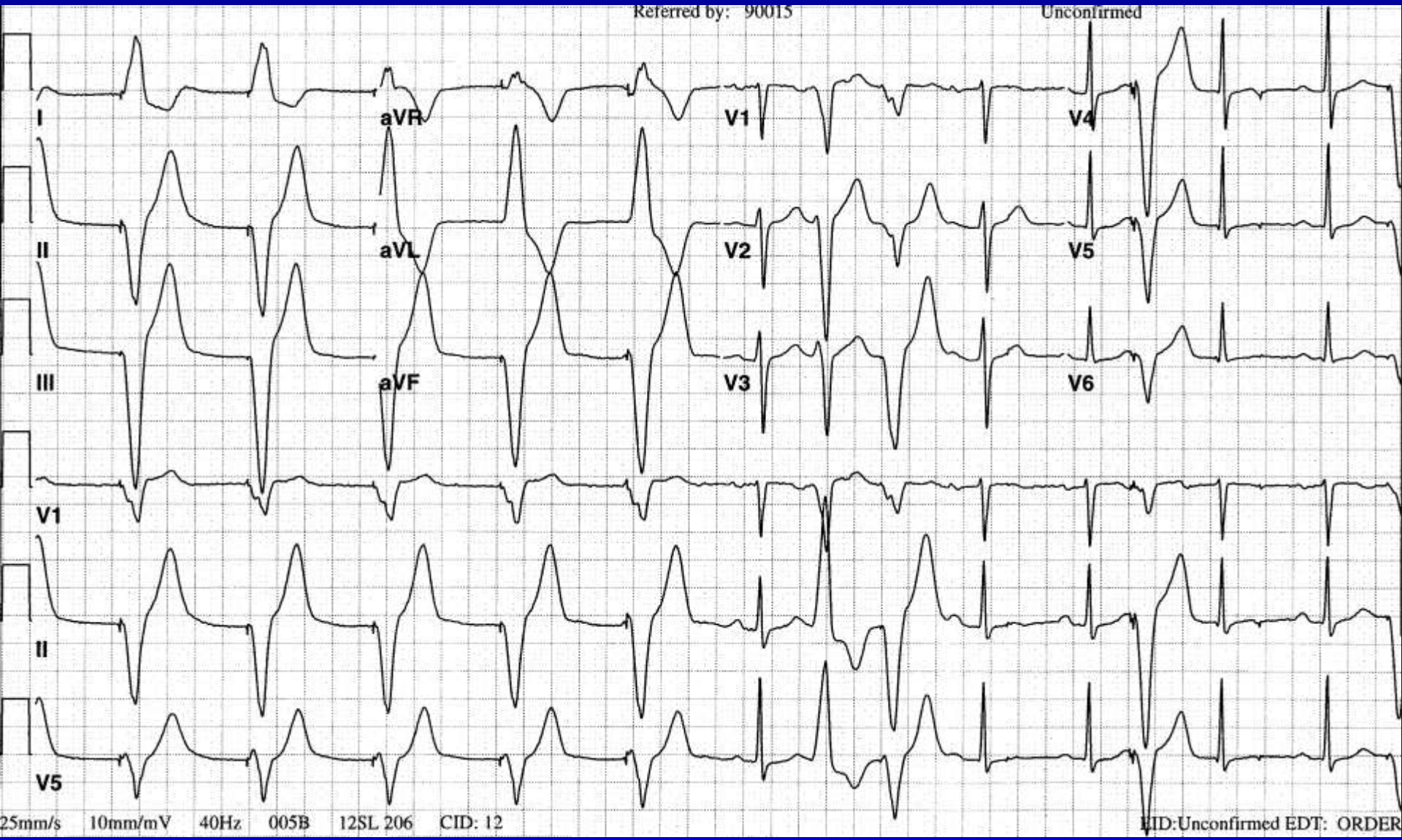


Case 34

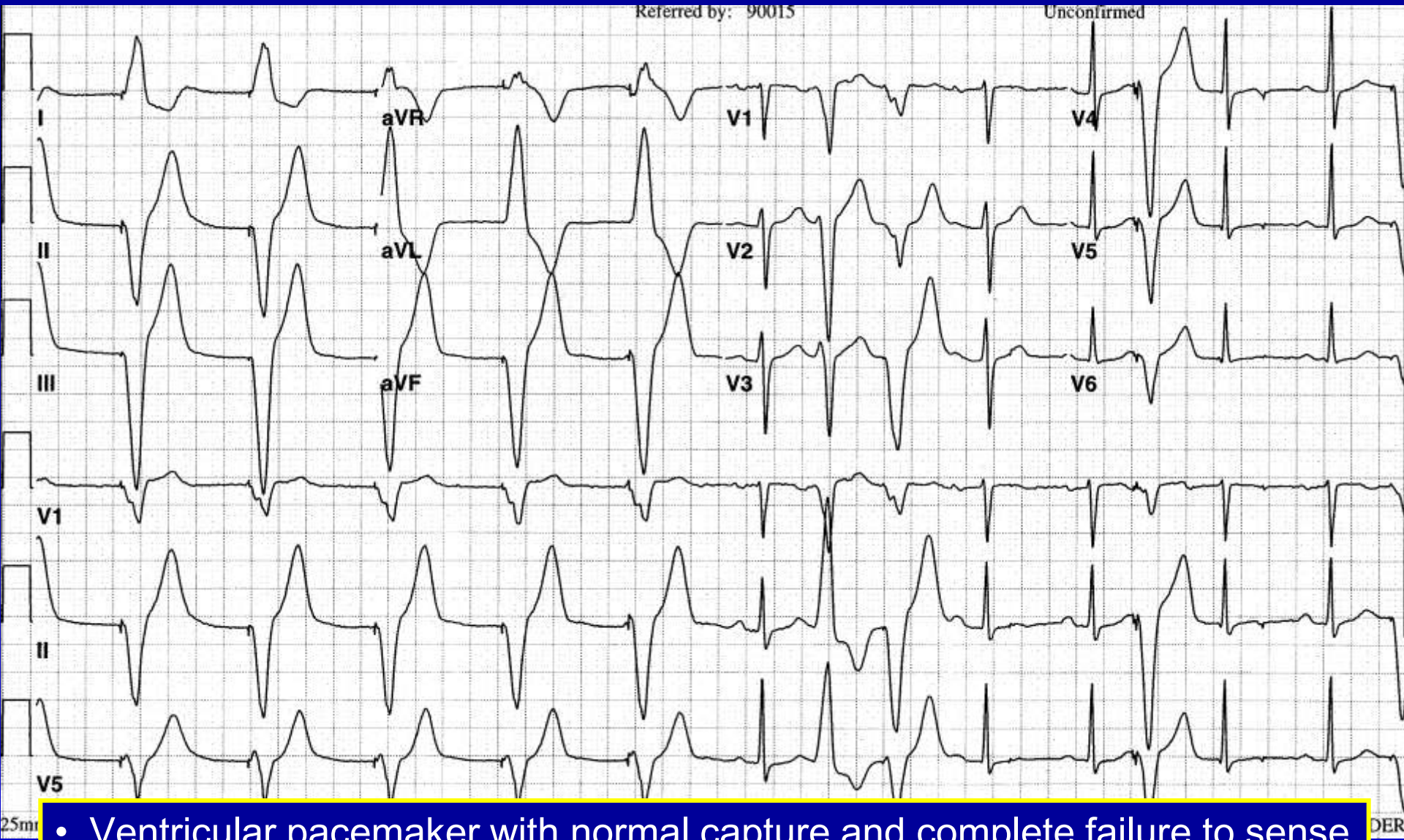


- Ventricular pacemaker with 100% capture
- Sinus rhythm rate 80
- AV Dissociation, consider AV block

Case 37

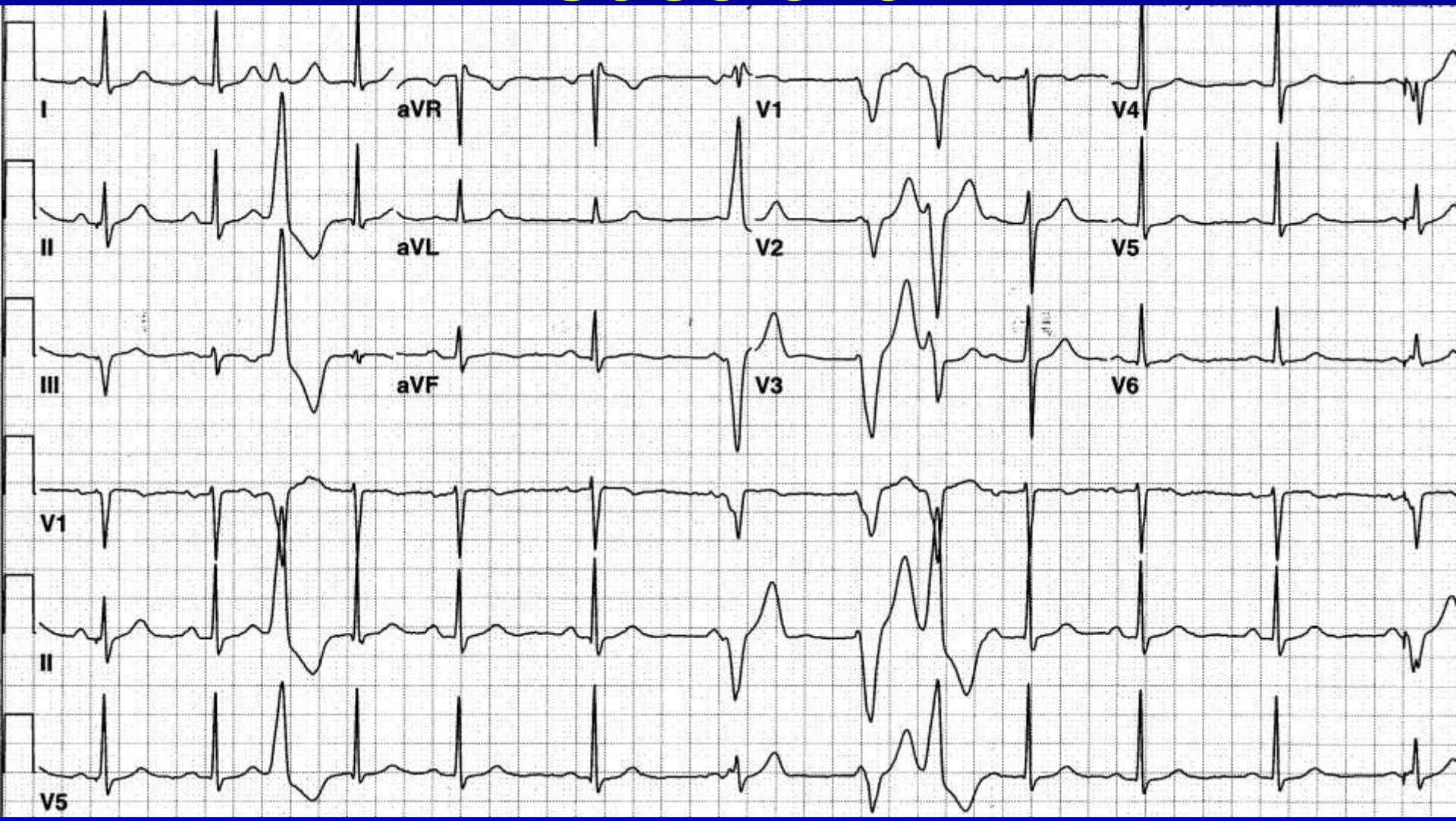

Referred by: 90015
Unconfirmed
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5
25mm/s
10mm/mV
40Hz
005B
12SL 206
CID: 12
EID:Unconfirmed EDT: ORDER

Case 37

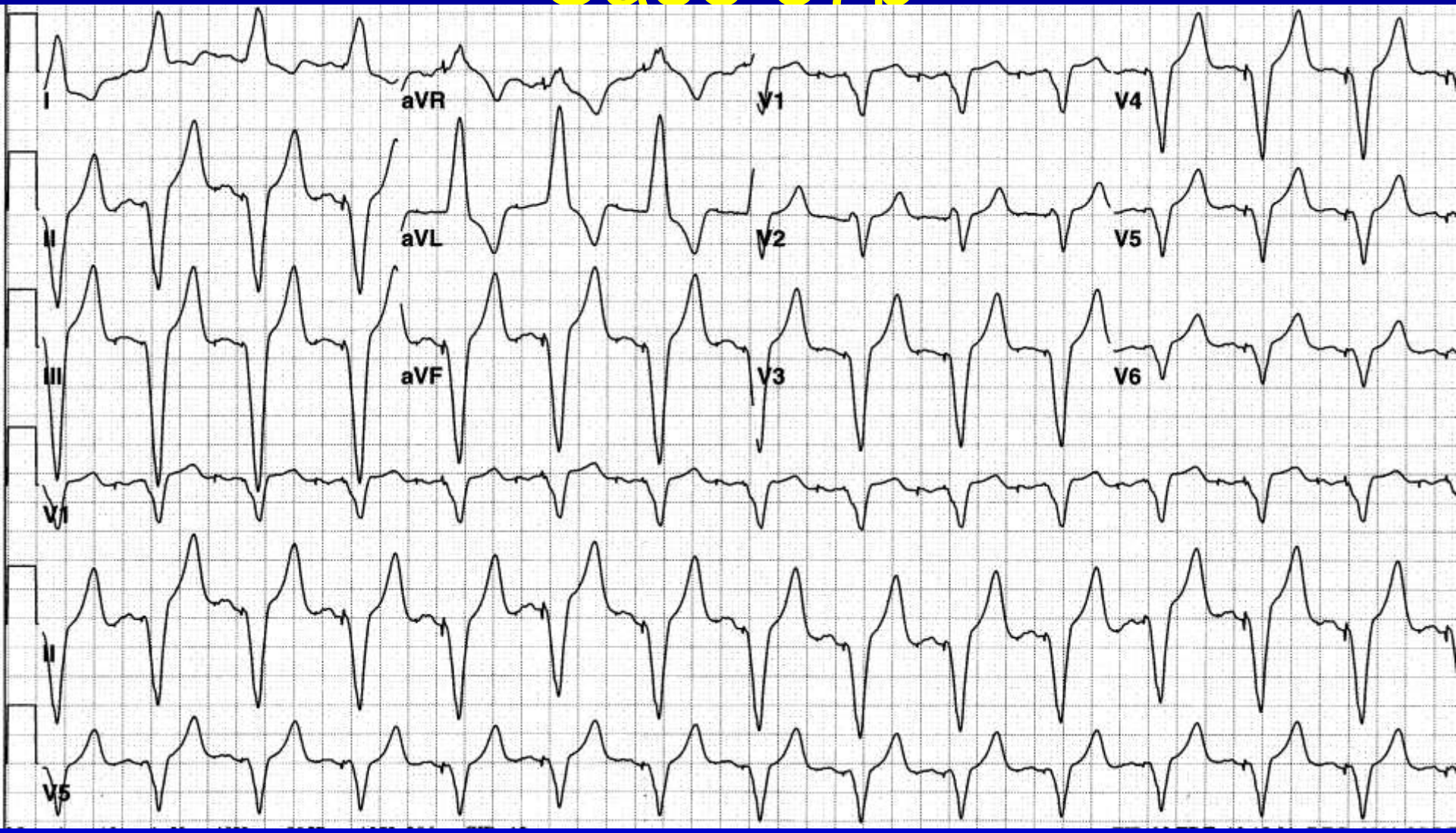


- Ventricular pacemaker with normal capture and complete failure to sense
- NSR rate 80, interpolated PVC's and concealed retrograde conduction

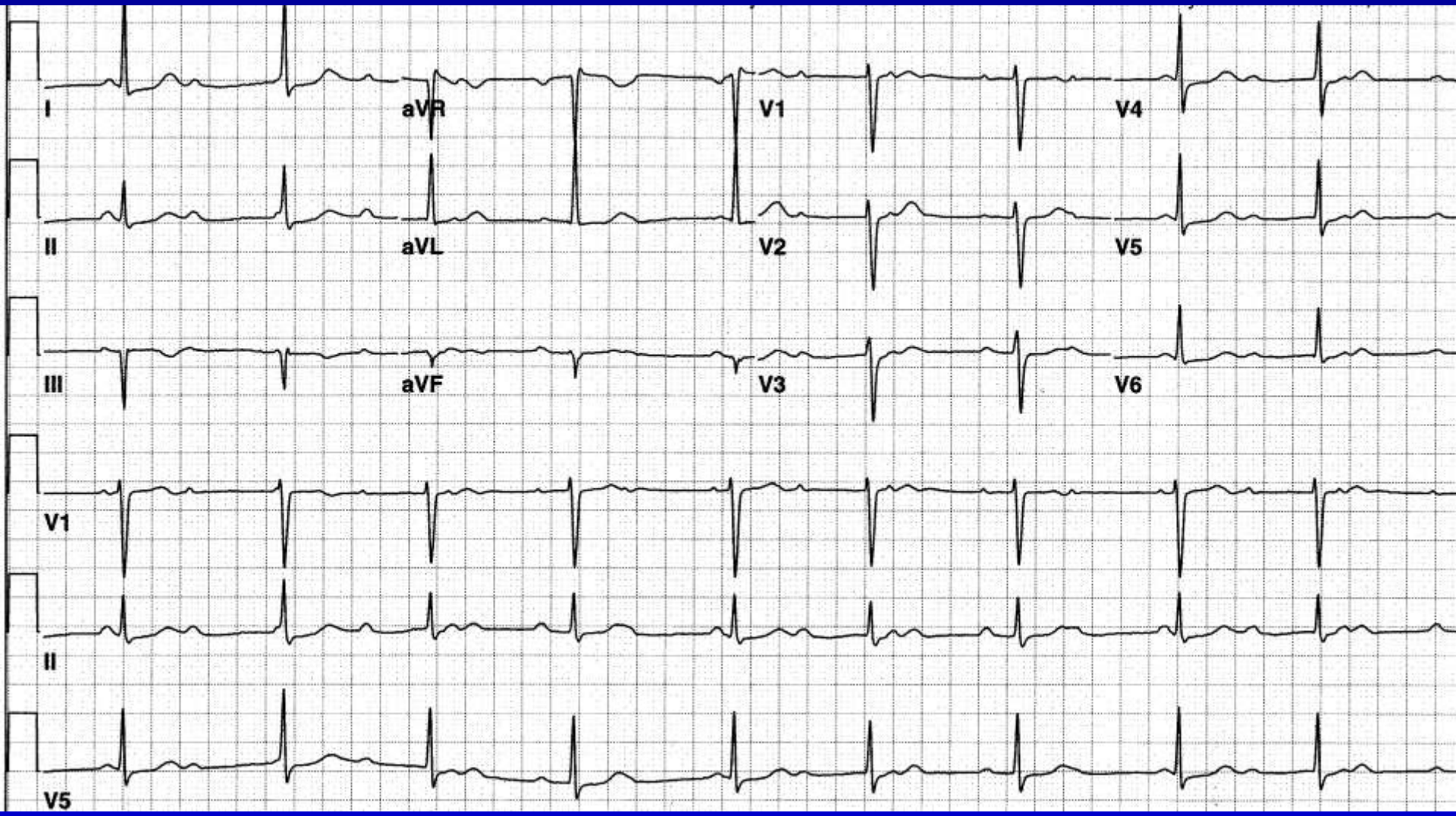
Case 37a



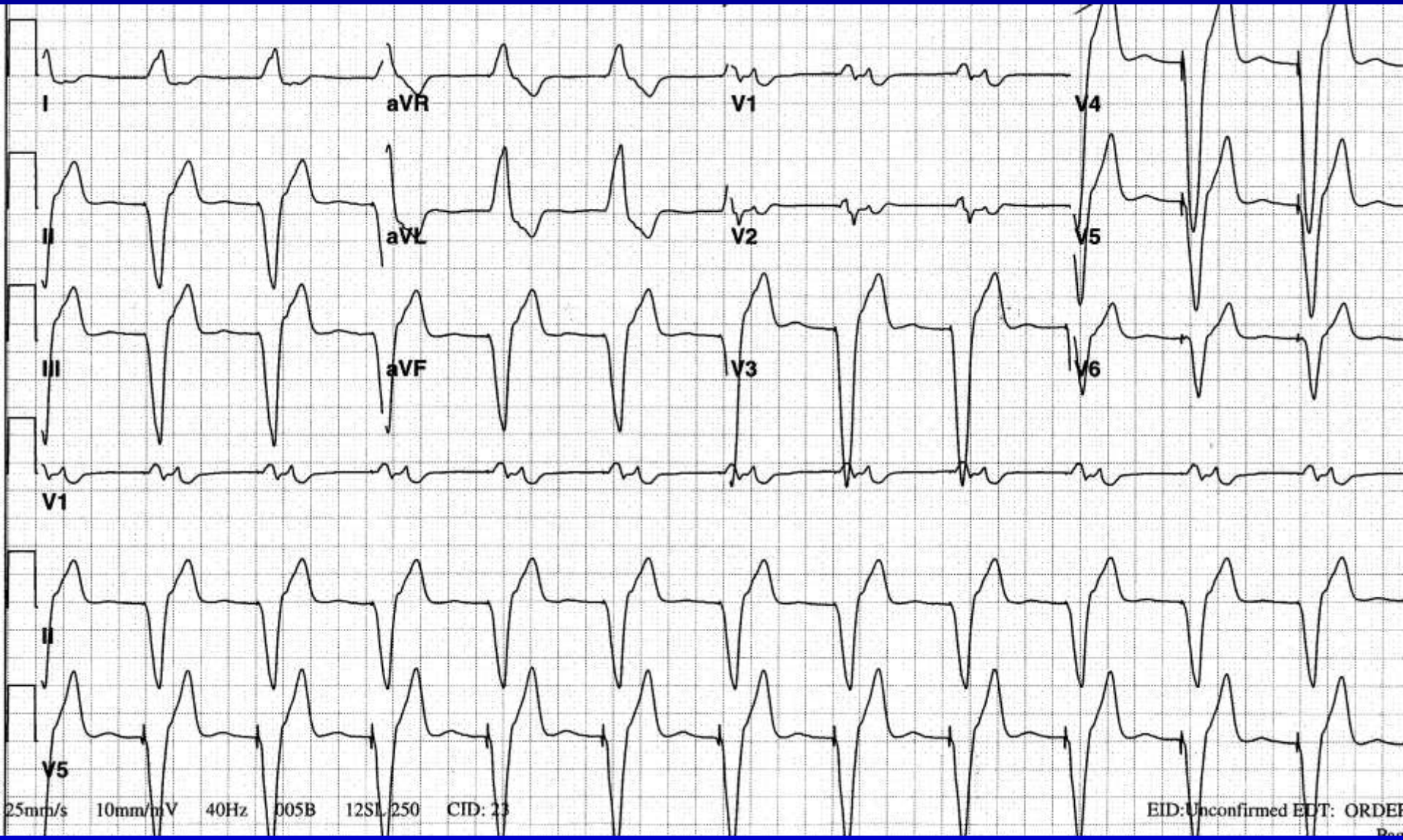
Case 37b



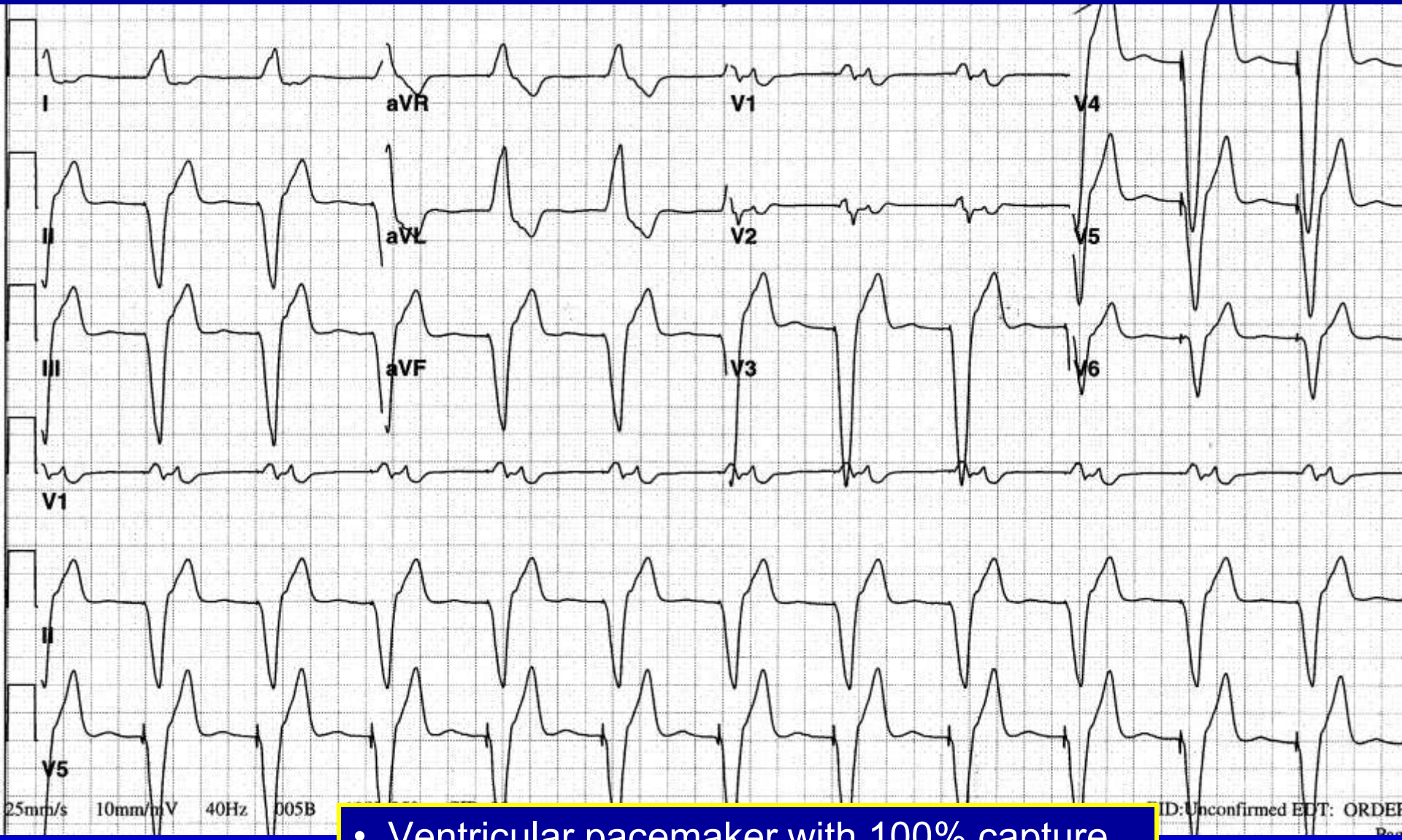
Case 37c



Case 40

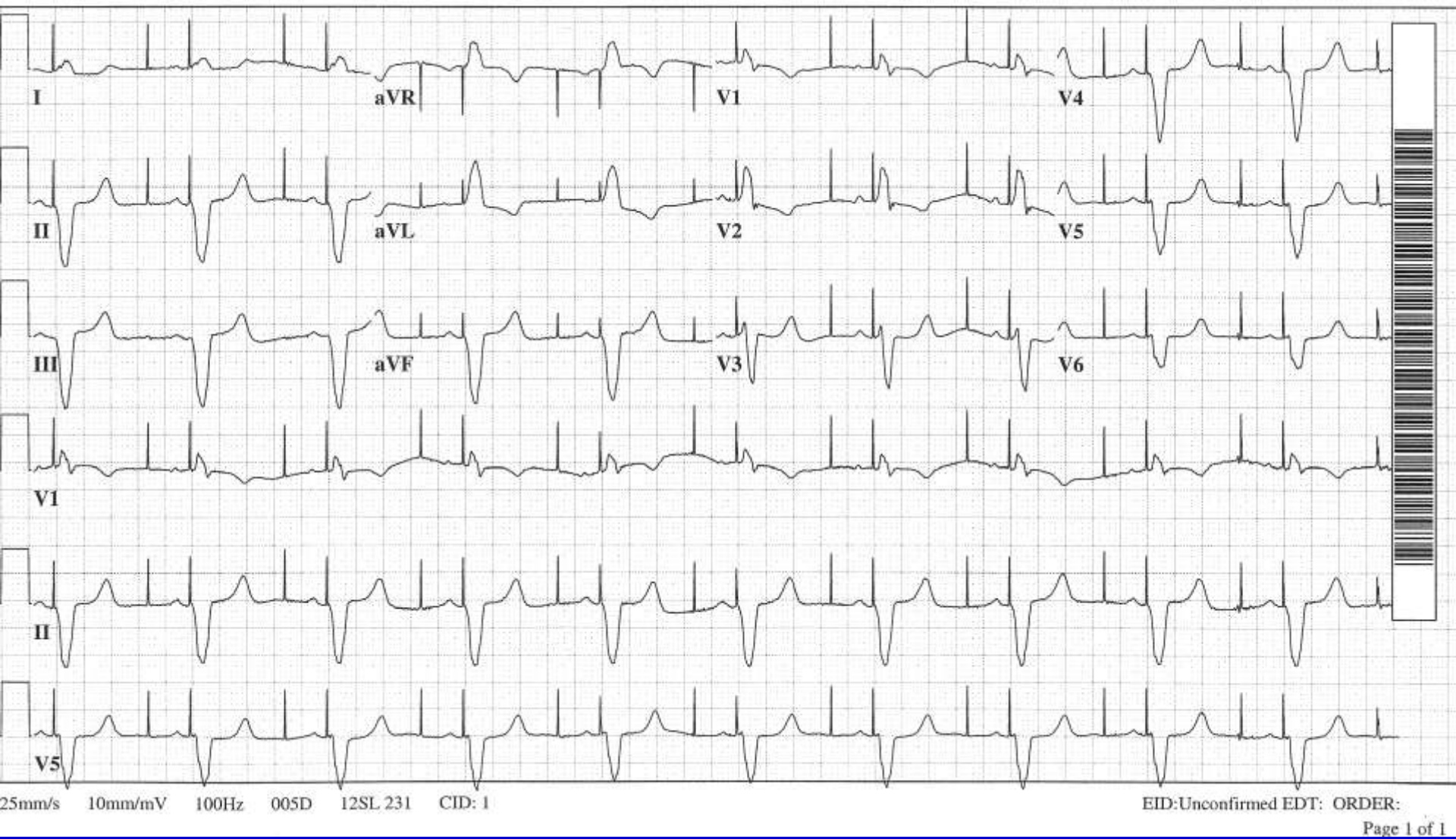

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5
25mm/s 10mm/mV 40Hz 005B 12SL 250 CID: 23
EID: Unconfirmed EDT: ORDER

Case 40

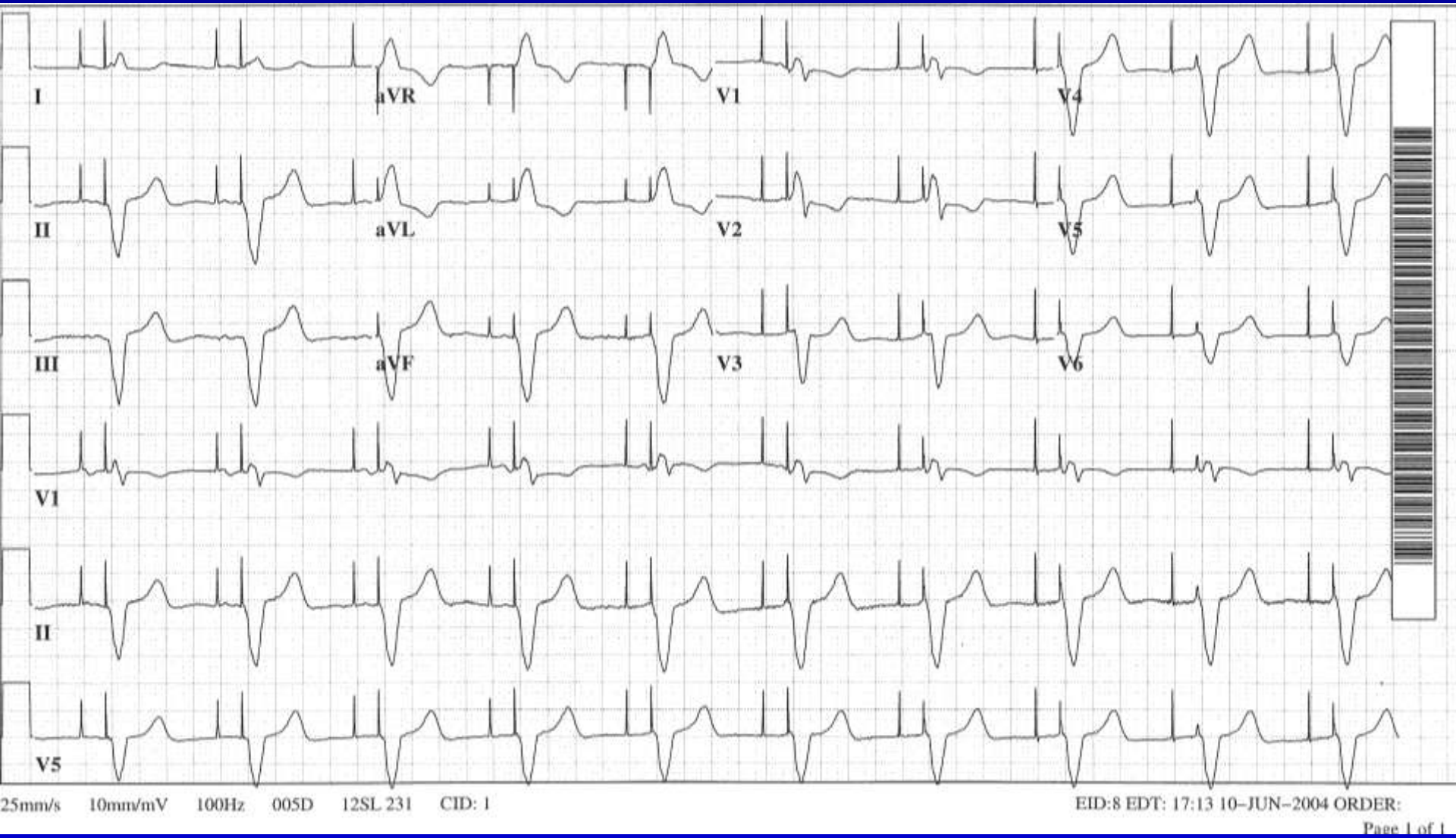


- Ventricular pacemaker with 100% capture
- Retrograde conduction, 1:1

February 4, 2006



May 23, 2004


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5
25mm/s 10mm/mV 100Hz 005D 12SL 231 CID: 1
EID:8 EDT: 17:13 10-JUN-2004 ORDER:
Page 1 of 1

September 17, 2003