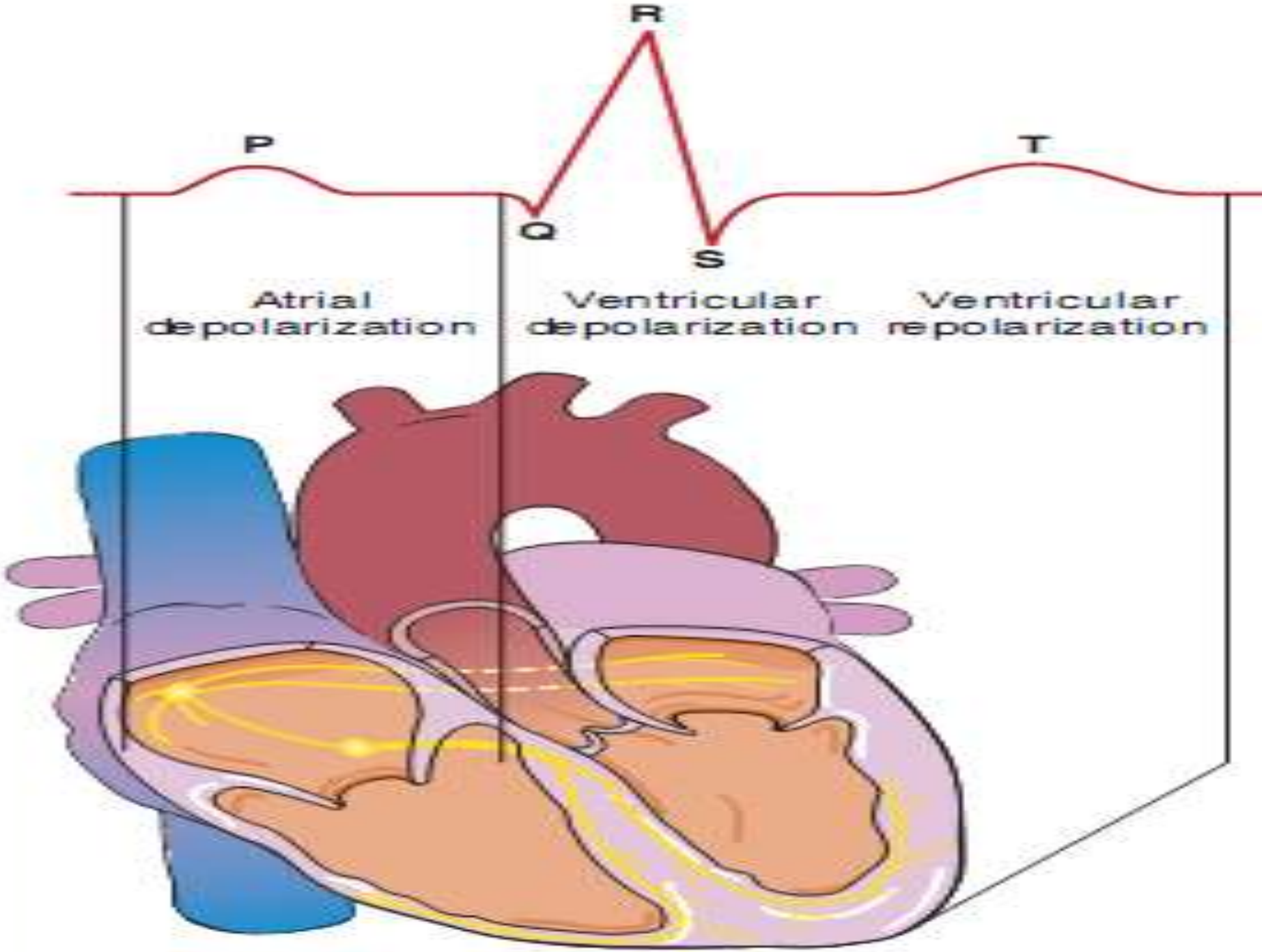
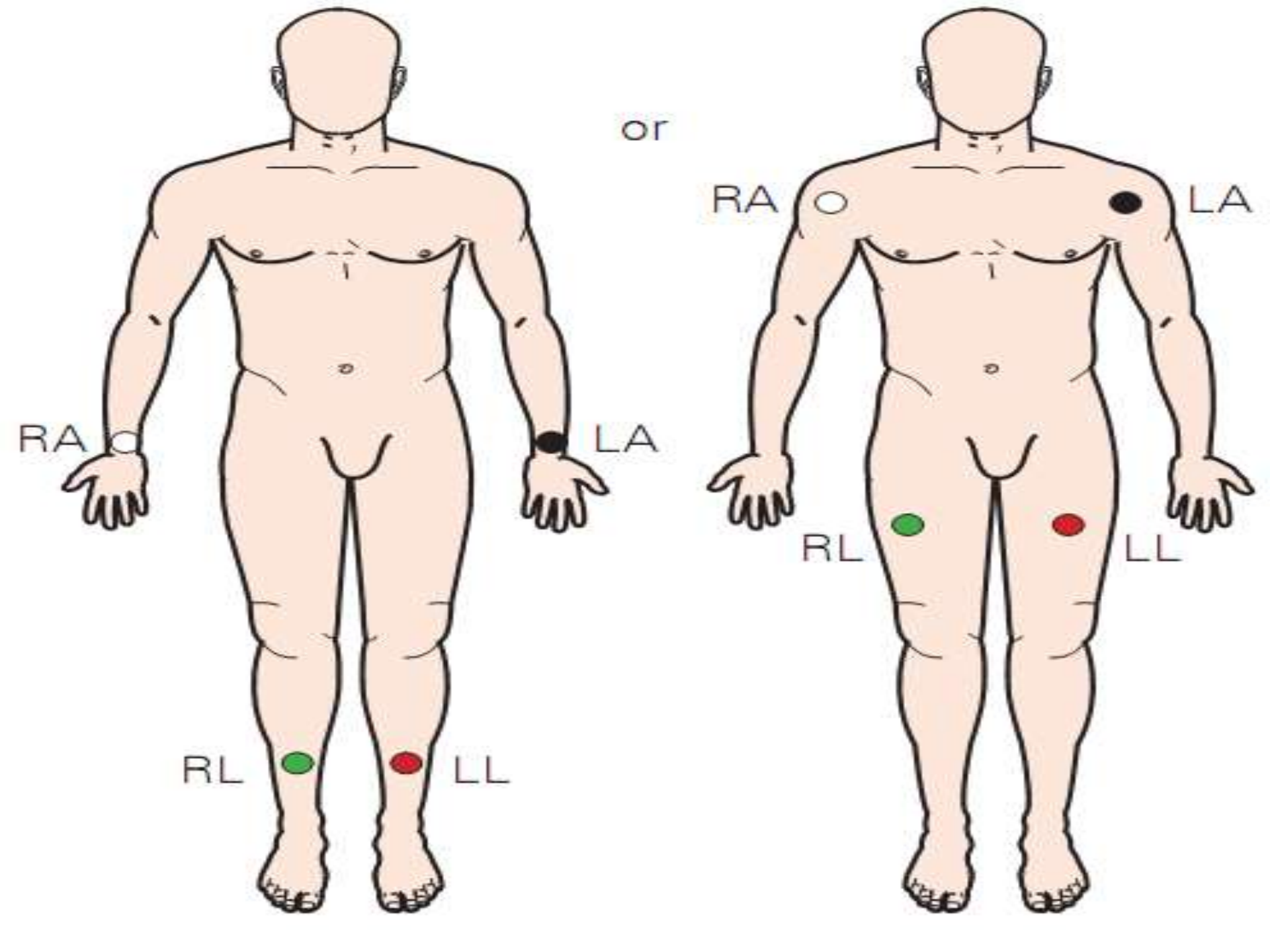
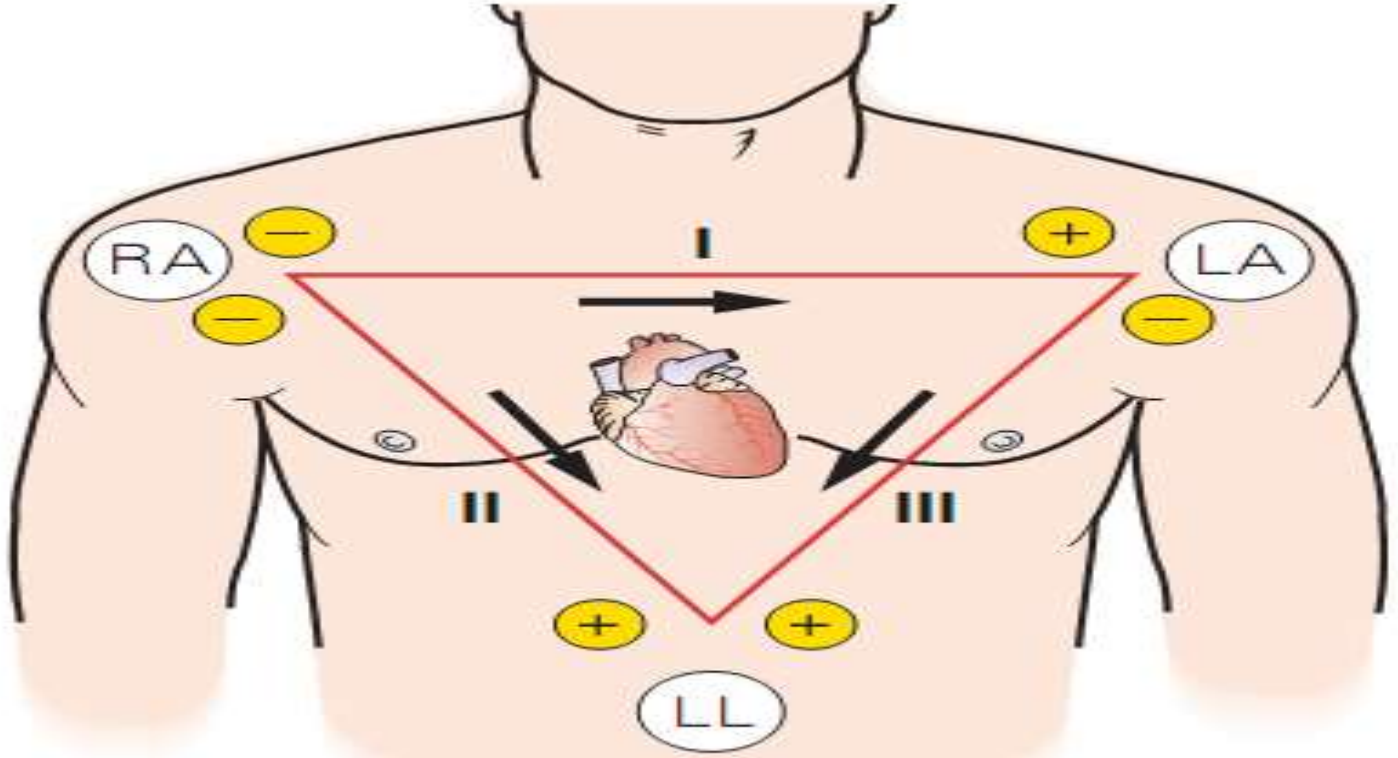
ECG MONITORING


R
P
T
Q
S
Atrial
depolarization
Ventricular
depolarization
Ventricular
repolarization


RA
LA
RL
LL
or
RA
LA
RL
LL

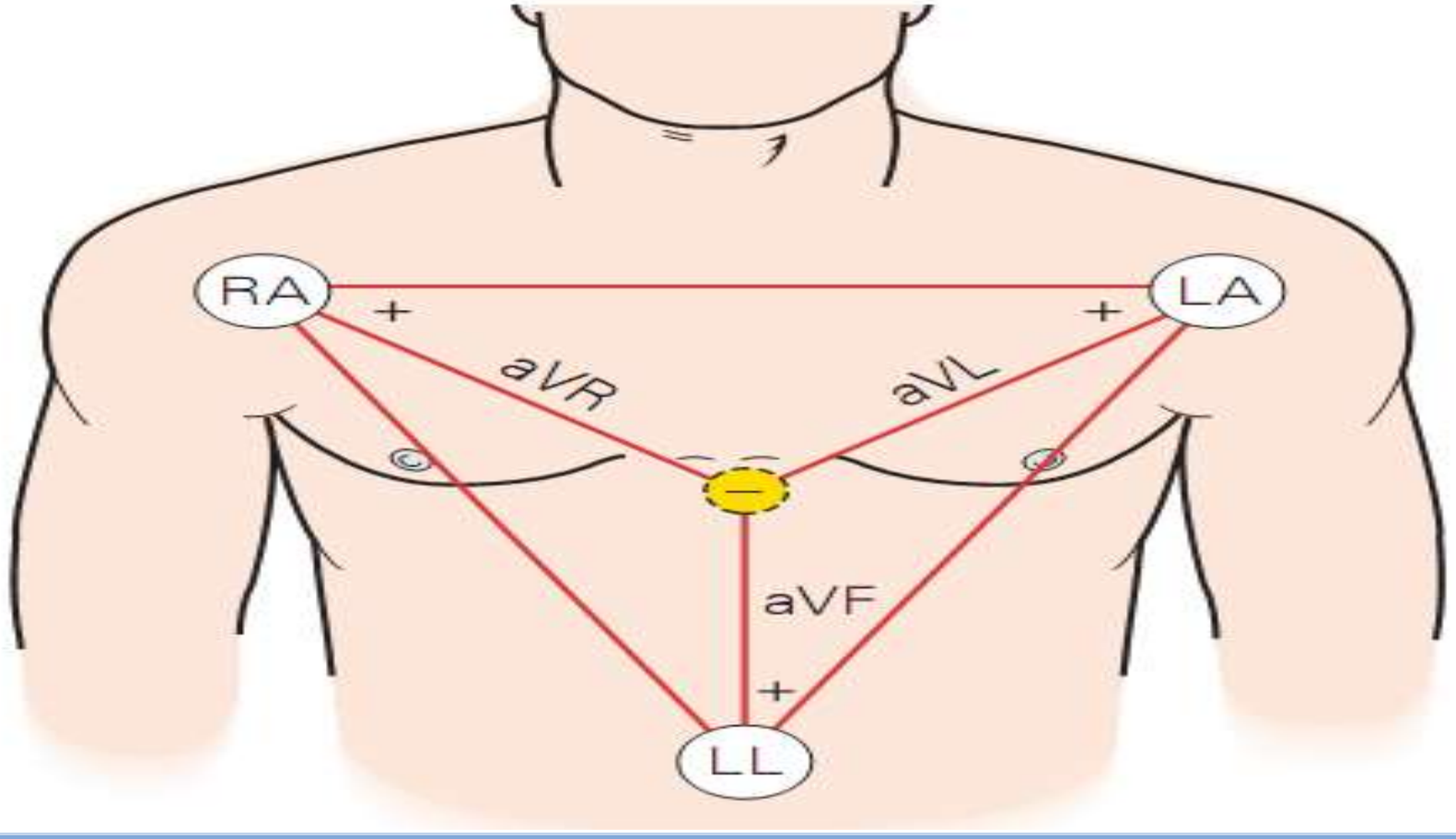
Standard Limb Leads



Elements of Standard Limb Leads

Lead	Positive Electrode	Negative Electrode	View of Heart
I	LA	RA	Lateral
II	LL	RA	Inferior
III	LL	LA	Inferior

Augmented Limb Leads

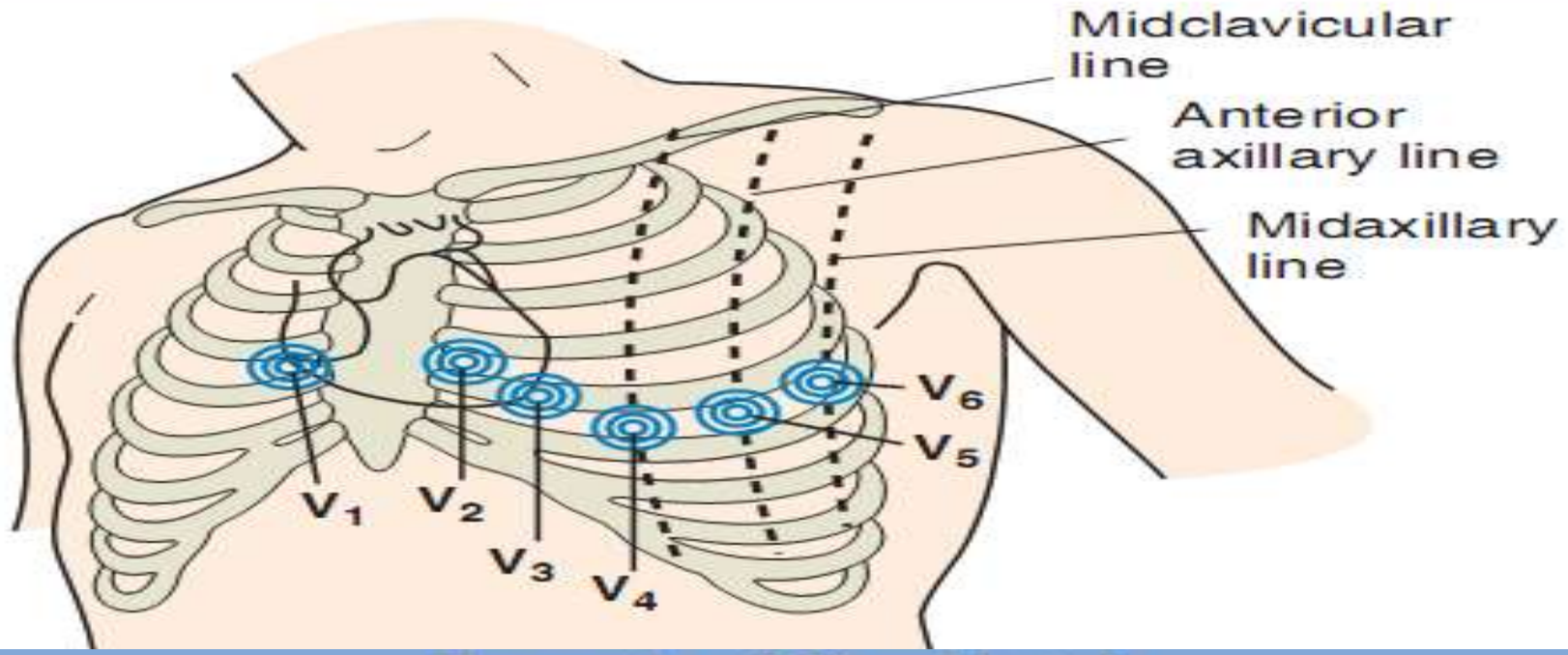


Elements of Augmented Limb Leads

Lead	Positive Electrode	View of Heart
aVR	RA	None
aVL	LA	Lateral
aVF	LL	Inferior

Chest Leads

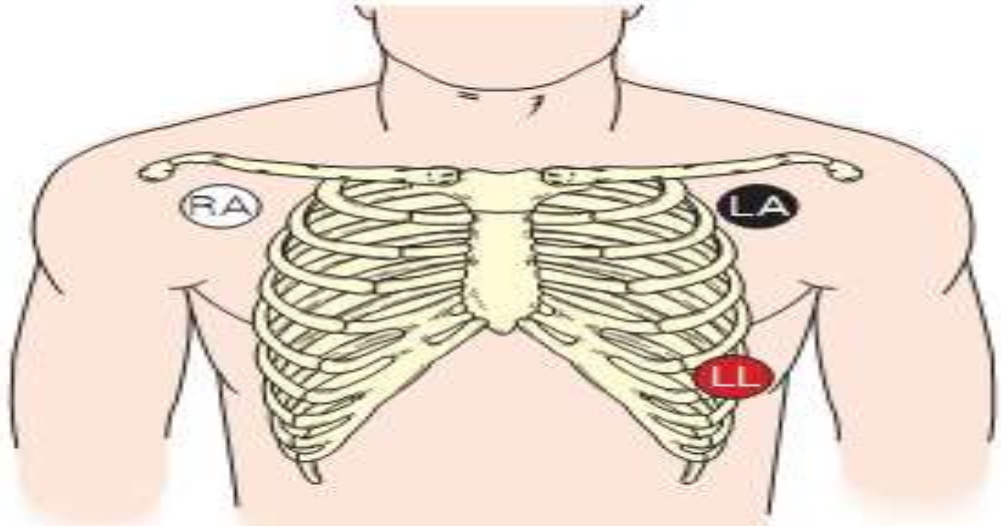
Standard Chest Lead Electrode Placement



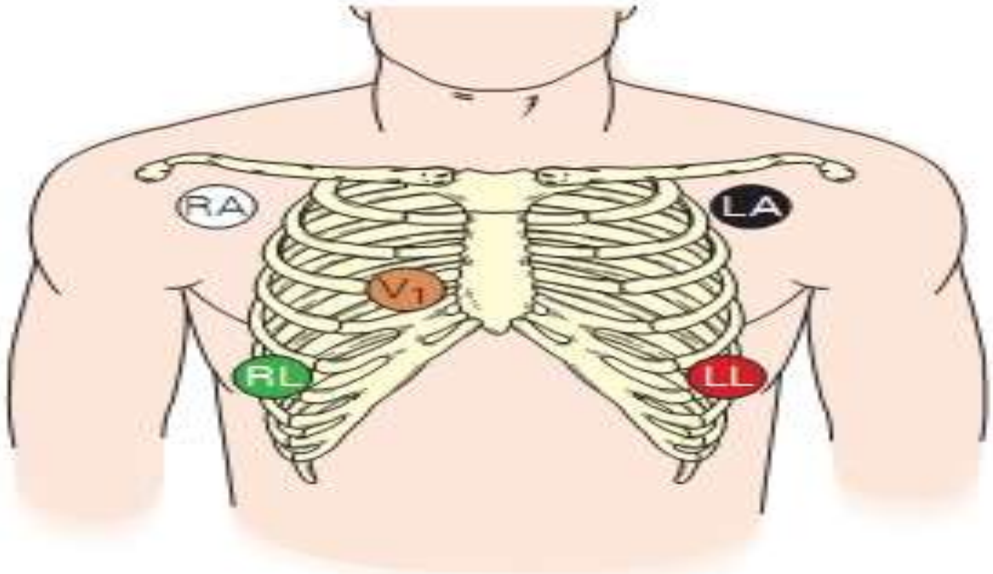
Elements of Chest Leads

Lead	Positive Electrode Placement	View of Heart
V_1	4th Intercostal space to right of sternum	Septum
V_2	4th Intercostal space to left of sternum	Septum
V_3	Directly between V_2 and V_4	Anterior
V_4	5th Intercostal space at left midclavicular line	Anterior
V_5	Level with V_4 at left anterior axillary line	Lateral
V_6	Level with V_5 at left midaxillary line	Lateral

Electrode Placement Using a 3-Wire Cable

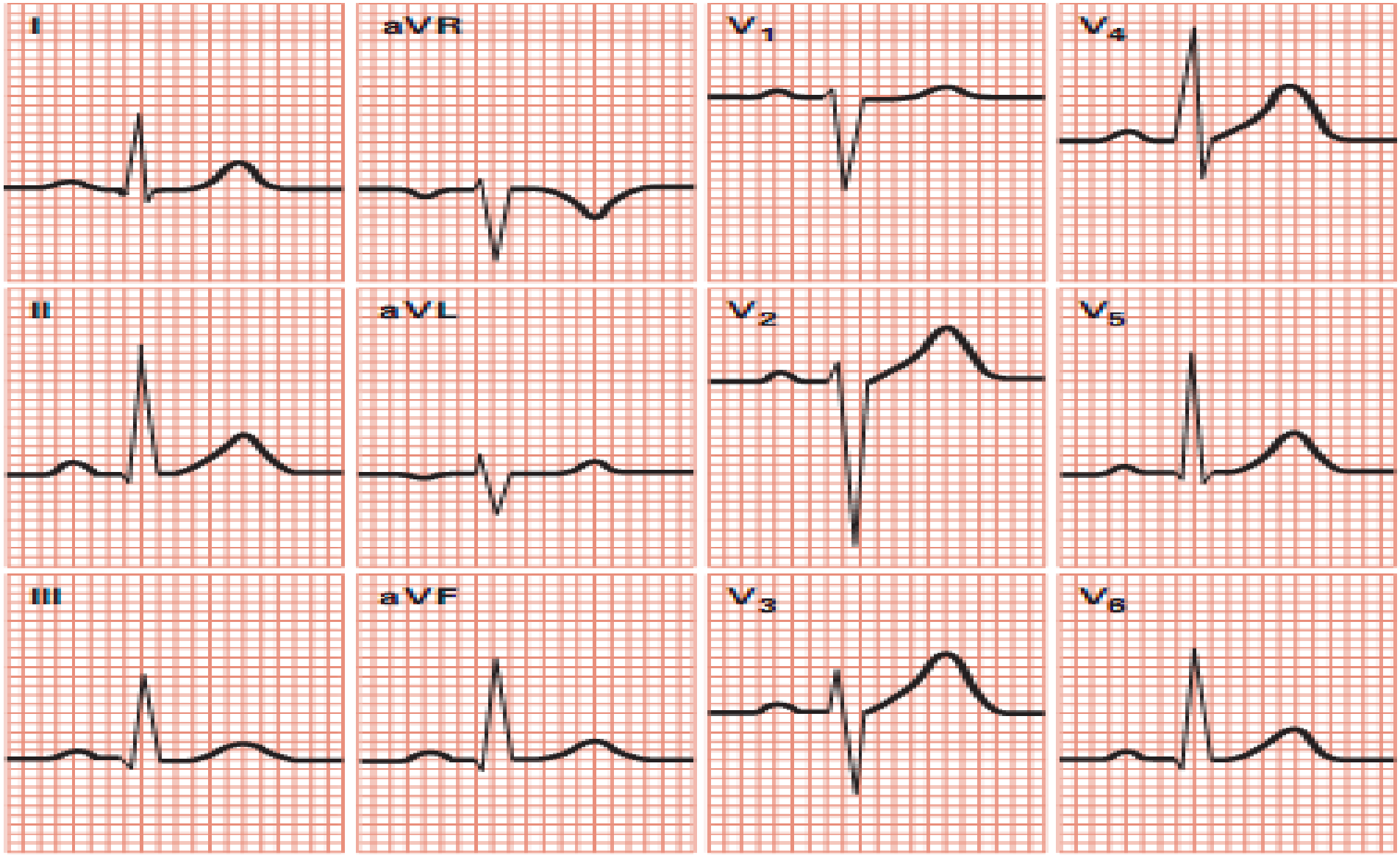


Electrode Placement Using a 5-Wire Cable



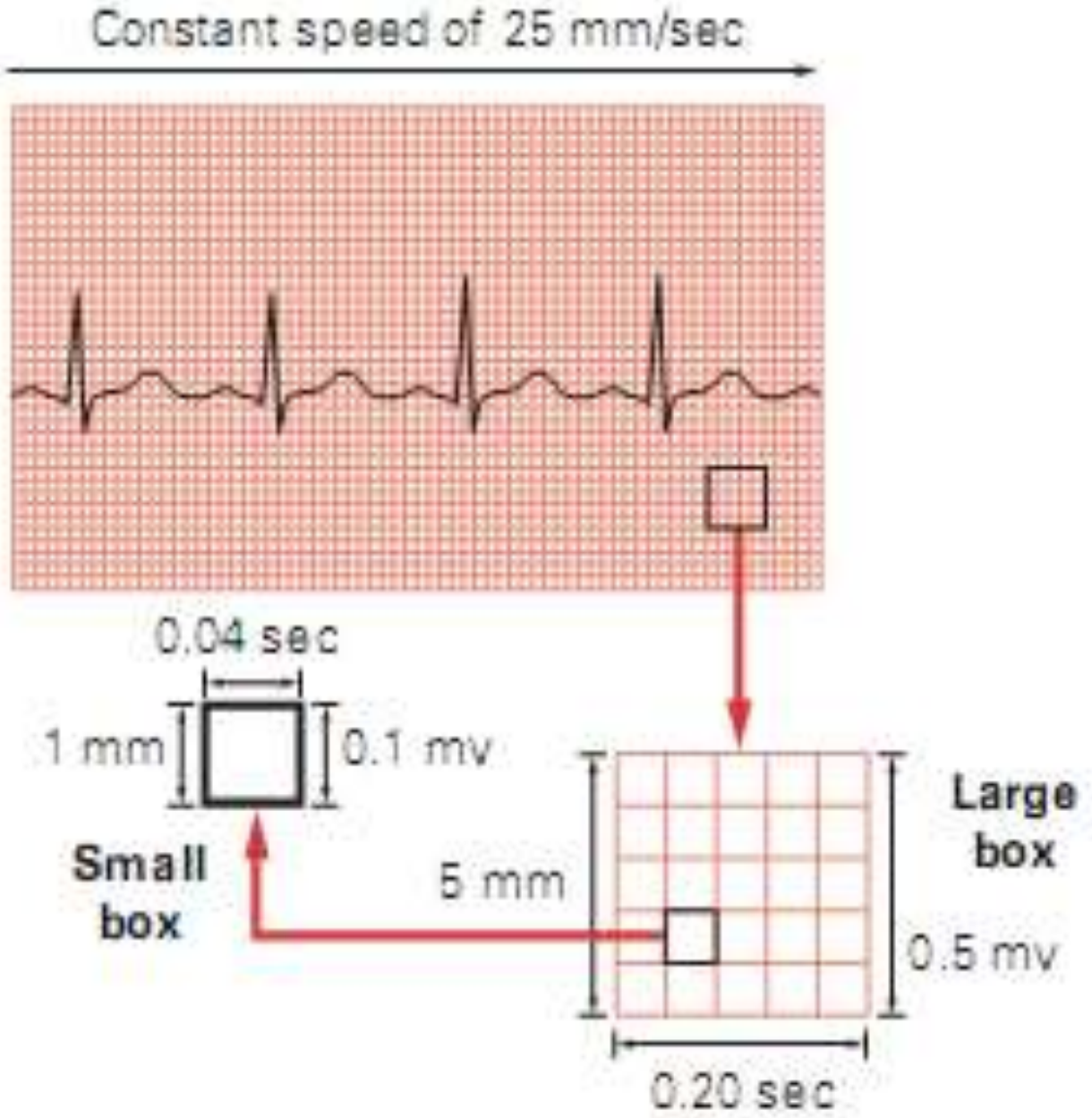
♥ **Clinical Tip:** Five-wire telemetry units are commonly used to monitor leads I, II, III, aVR, aVL, aVF, and V_1 in critical care settings.

Normal 12-Lead ECG

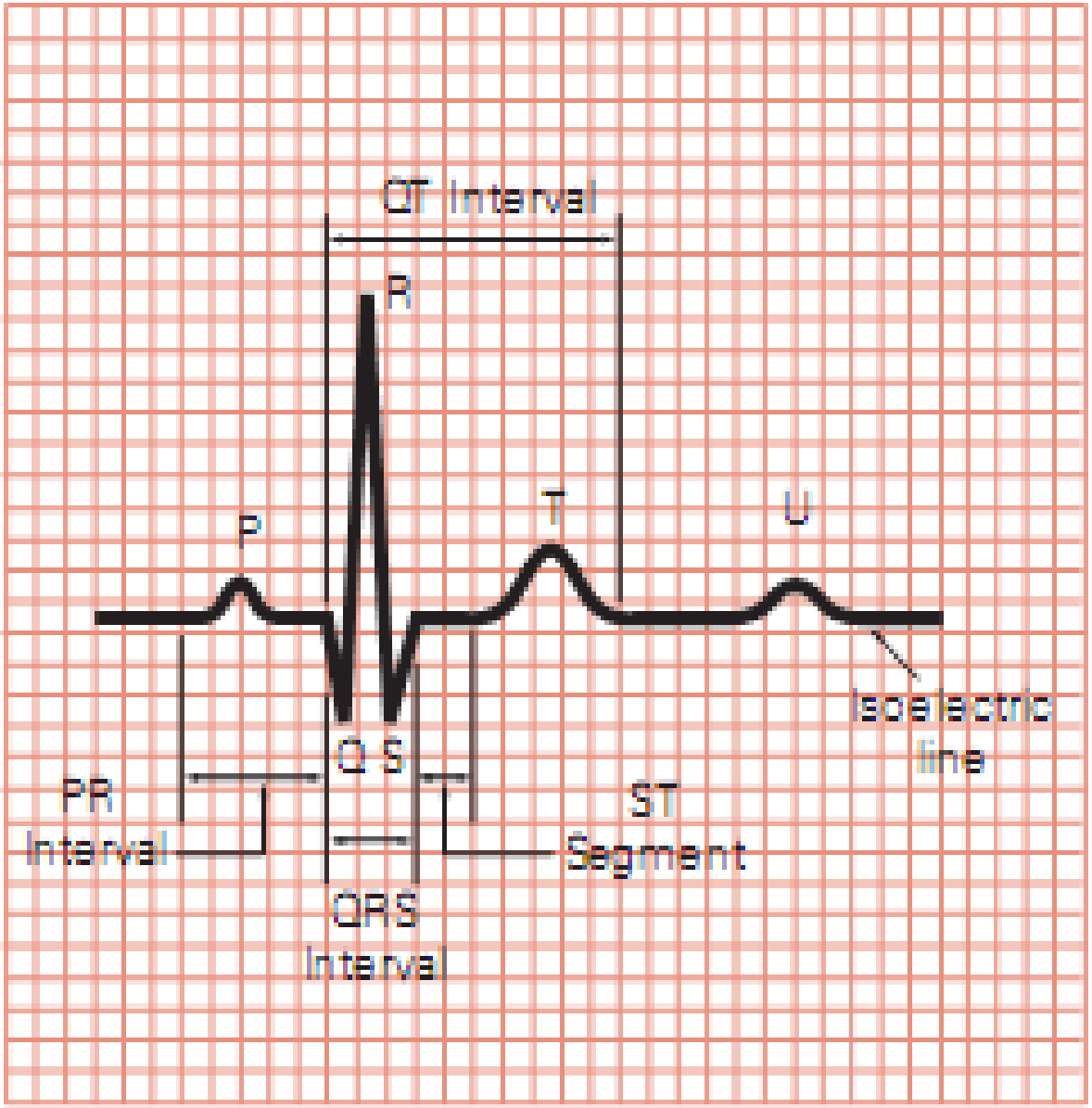


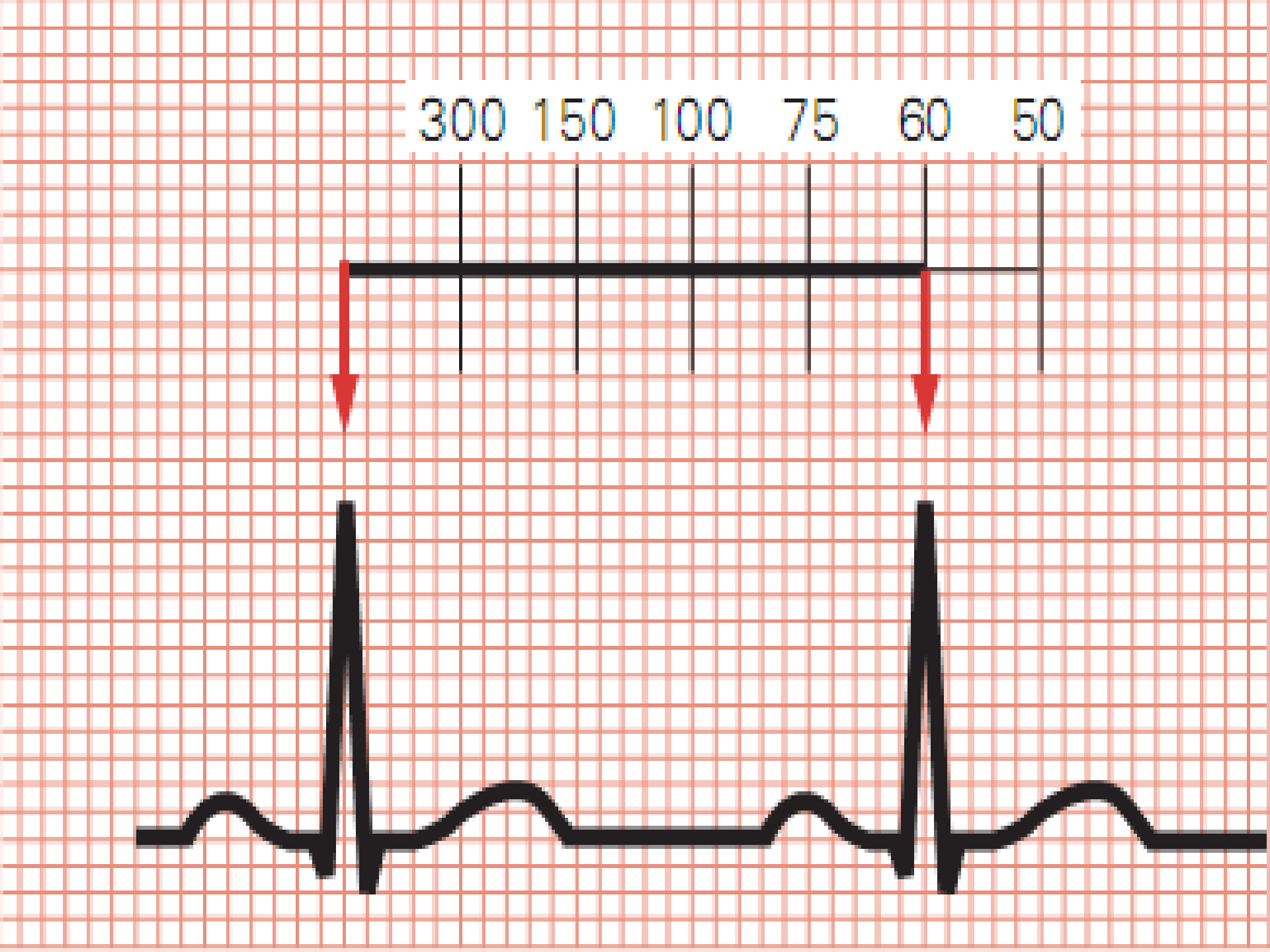
♥ **Clinical Tip:** A normal ECG does not rule out any acute coronary syndrome.

Recording of the ECG



Components of an ECG Tracing




300 150 100 75 60 50

Analyzing a Rhythm

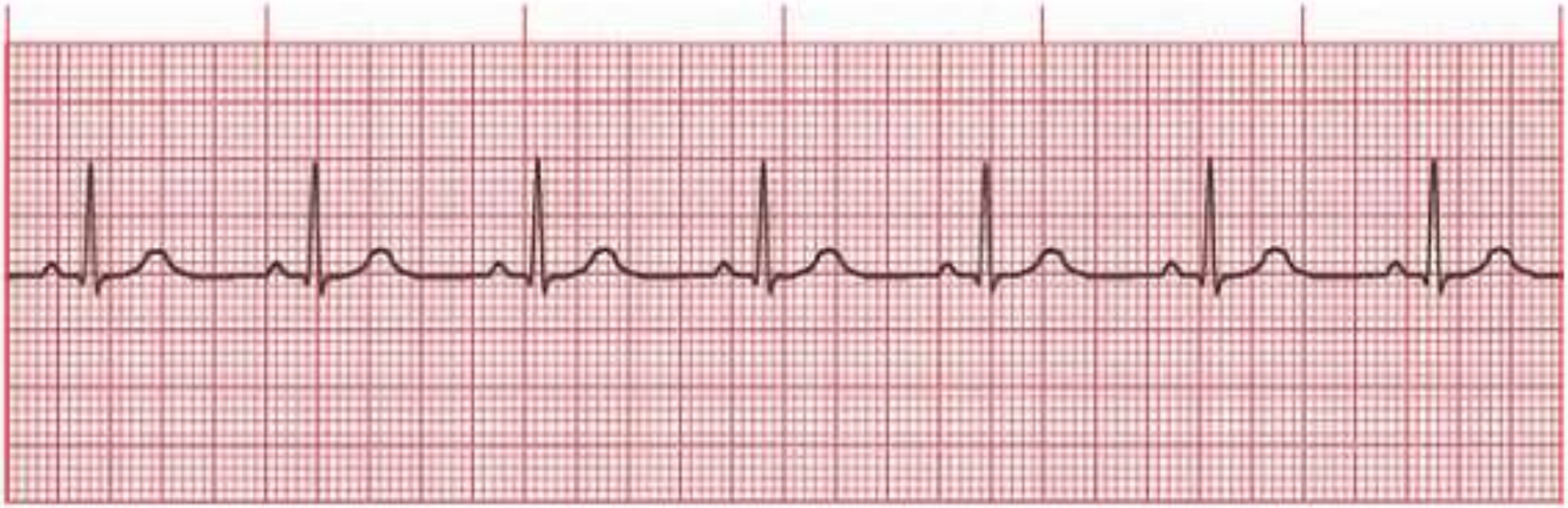
Component	Characteristic
Rate	The bpm is commonly the ventricular rate. If atrial and ventricular rates differ, as in a 3rd-degree block, measure both rates. Normal: 60–100 bpm Slow (bradycardia): <60 bpm Fast (tachycardia): >100 bpm
Regularity	Measure R-R intervals and P-P intervals. Regular: Intervals consistent Regularly irregular: Repeating pattern Irregular: No pattern
P Waves	If present: Same in size, shape, position? Does each QRS have a P wave? Normal: Upright (positive) and uniform Inverted: Negative Notched: P′ None: Rhythm is junctional or ventricular.
PR Interval	Constant: Intervals are the same. Variable: Intervals differ. Normal: 0.12–0.20 sec and constant
QRS Interval	Normal: 0.06–0.10 sec Wide: >0.10 sec None: Absent
QT Interval	Beginning of R wave to end of T wave Varies with HR. Normal: Less than half the R-R interval
Pause	Compensatory: Complete pause following a premature atrial contraction (PAC), premature junctional contraction (PJC), or premature ventricular contraction (PVC) Noncompensatory: Incomplete pause following a PAC, PJC, or PVC
QRS Complex grouping	Bigeminy: Repeating pattern of normal complex followed by a premature complex Trigeminy: Repeating pattern of 2 normal complexes followed by a premature complex Quadrigeminy: Repeating pattern of 3 normal complexes followed by a premature complex Couplets: 2 Consecutive premature complexes Triplets: 3 Consecutive premature complexes

Sinoatrial (SA) Node Arrhythmias

- Upright P waves all look similar.
- PR intervals and QRS complexes are of normal duration.

Note: All ECG strips in this tab were recorded in lead II.

Normal Sinus Rhythm (NSR)

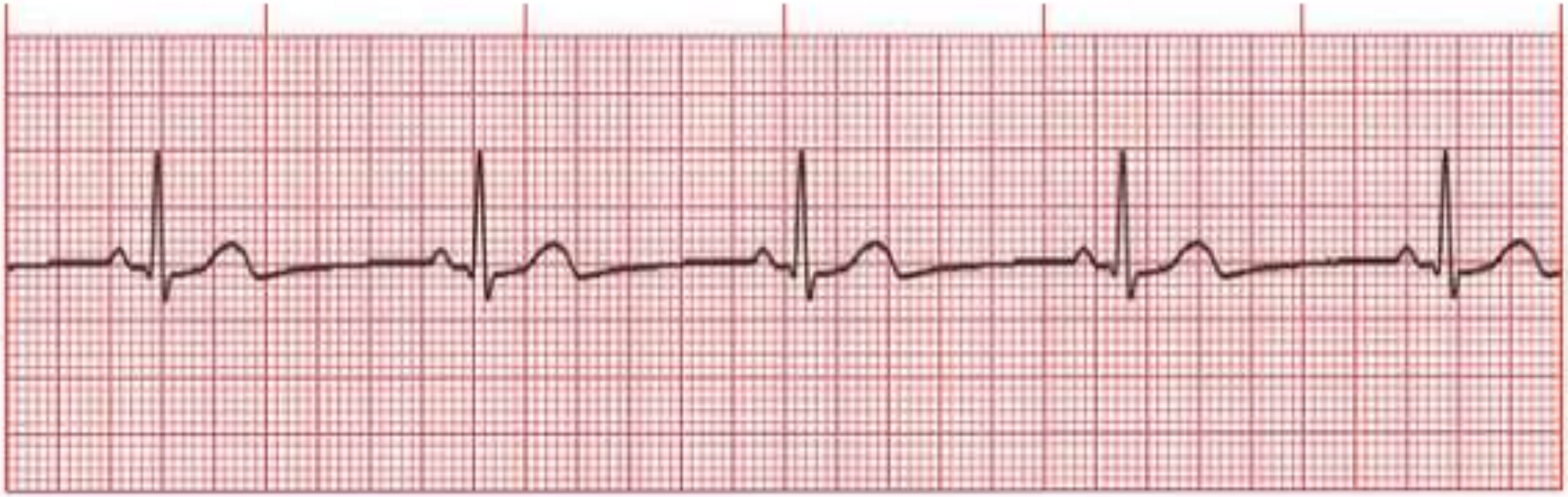


Rate: Normal (60–100 bpm)
Rhythm: Regular
P Waves: Normal (upright and uniform)
PR Interval: Normal (0.12–0.20 sec)
QRS: Normal (0.06–0.10 sec)

♥ **Clinical Tip:** A normal ECG does not exclude heart disease.

Sinus Bradycardia

- Results from slowing of the SA node.

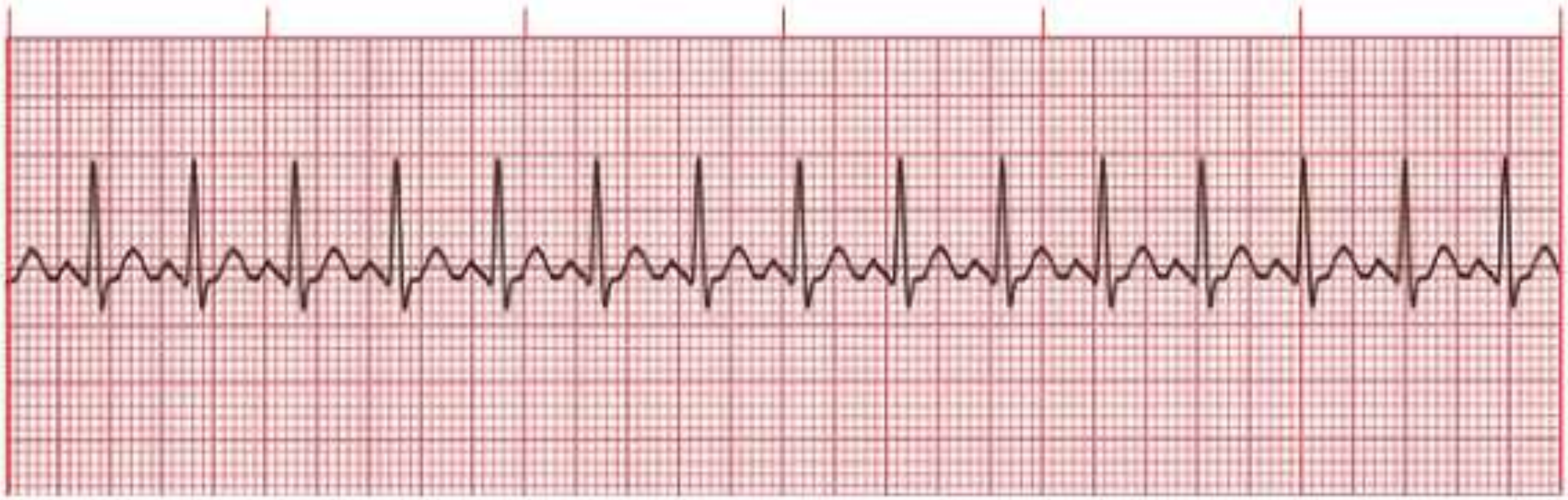


Rate: Slow (<60 bpm)
Rhythm: Regular
P Waves: Normal (upright and uniform)
PR Interval: Normal (0.12–0.20 sec)
QRS: Normal (0.06–0.10 sec)

♥ **Clinical Tip:** Sinus bradycardia is normal in athletes and during sleep. In acute MI, it may be protective and beneficial or the slow rate may compromise cardiac output. Certain medications, such as beta blockers, may also cause sinus bradycardia.

Sinus Tachycardia

- Results from increased SA node discharge.

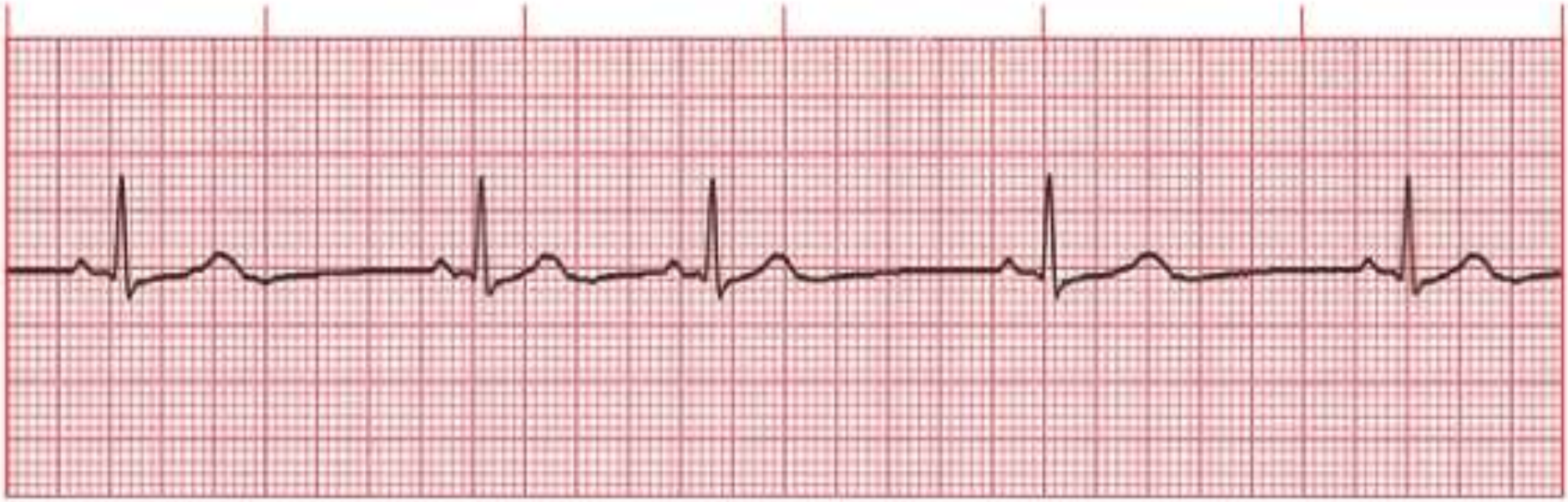


Rate: Fast (>100 bpm)
Rhythm: Regular
P Waves: Normal (upright and uniform)
PR Interval: Normal (0.12–0.20 sec)
QRS: Normal (0.06–0.10 sec)

♥ **Clinical Tip:** Sinus tachycardia may be caused by exercise, anxiety, fever, hypoxemia, hypovolemia, or cardiac failure.

Sinus Arrhythmia

- The SA node discharges irregularly.
- The R-R interval is irregular.

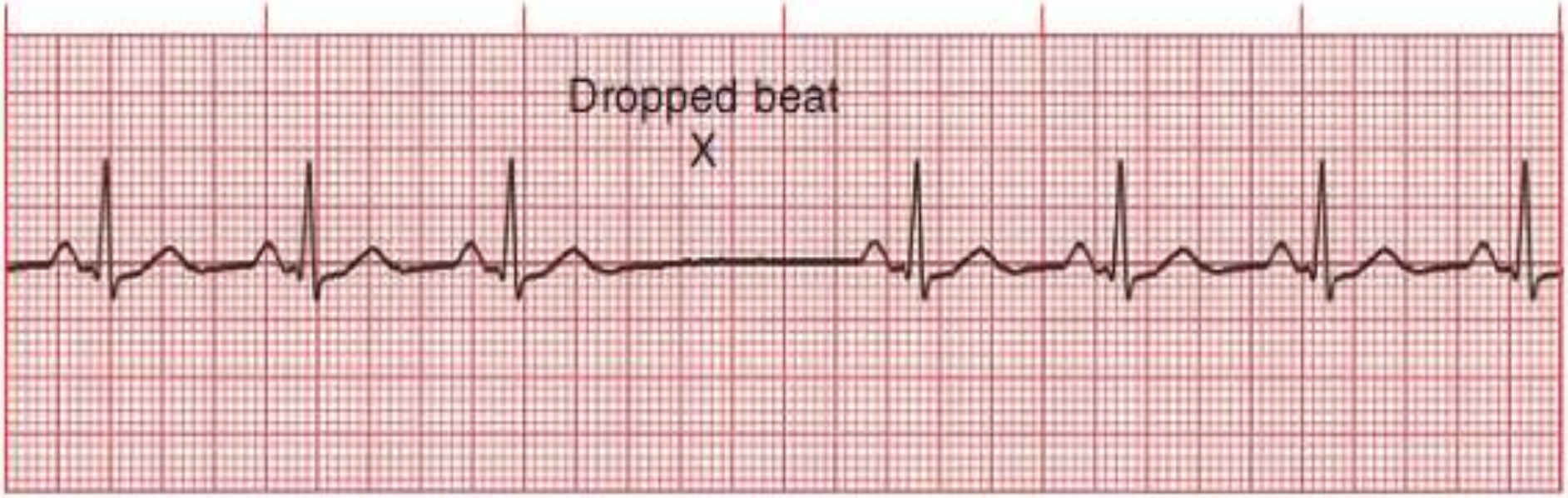


Rate: Usually normal (60–100 bpm); frequently increases with inspiration and decreases with expiration
Rhythm: Irregular; varies with respiration
P Waves: Normal (upright and uniform)
PR Interval: Normal (0.12–0.20 sec)
QRS: Normal (0.06–0.10 sec)

♥ **Clinical Tip:** The pacing rate of the SA node varies with respiration, especially in children and elderly people.

Sinoatrial (SA) Block

- The block occurs in some multiple of the P-P interval.
- After the dropped beat, cycles continue on time.

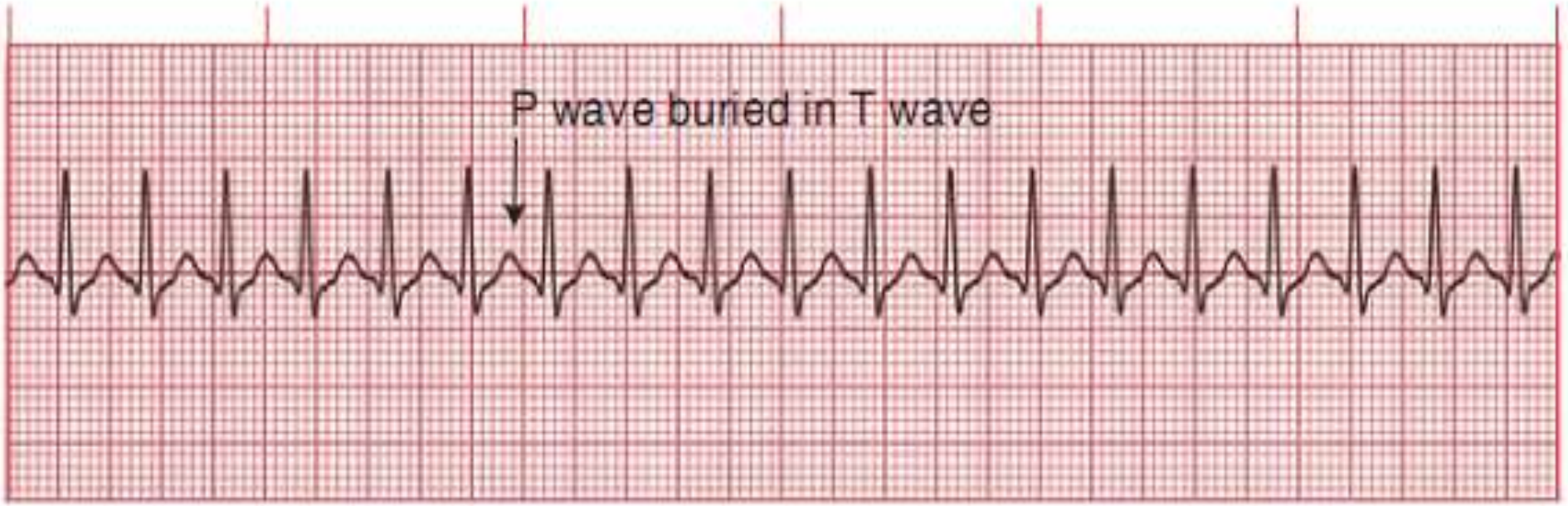


Rate: Normal to slow; determined by duration and frequency of SA block
Rhythm: Irregular whenever an SA block occurs
P Waves: Normal (upright and uniform) except in areas of dropped beats
PR Interval: Normal (0.12–0.20 sec)
QRS: Normal (0.06–0.10 sec)

♥ **Clinical Tip:** Cardiac output may decrease, causing syncope or dizziness.

Supraventricular Tachycardia (SVT)

- This arrhythmia has such a fast rate that the P waves may not be seen.

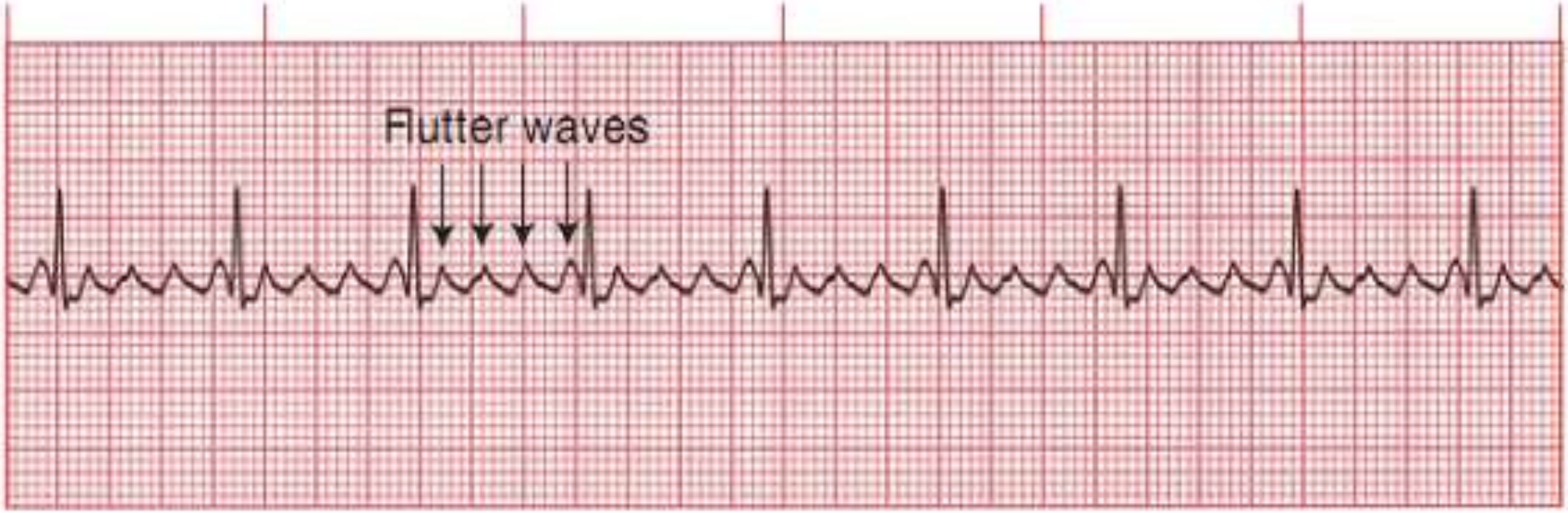


Rate: 150–250 bpm
Rhythm: Regular
P Waves: Frequently buried in preceding T waves and difficult to see
PR Interval: Usually not possible to measure
QRS: Normal (0.06–0.10 sec) but may be wide if abnormally conducted through ventricles

♥ **Clinical Tip:** SVT may be related to caffeine intake, nicotine, stress, or anxiety in healthy adults.

Atrial Flutter (A-flutter)

- AV node conducts impulses to the ventricles at a 2:1, 3:1, 4:1, or greater ratio (rarely 1:1).
- Degree of AV block may be consistent or variable.



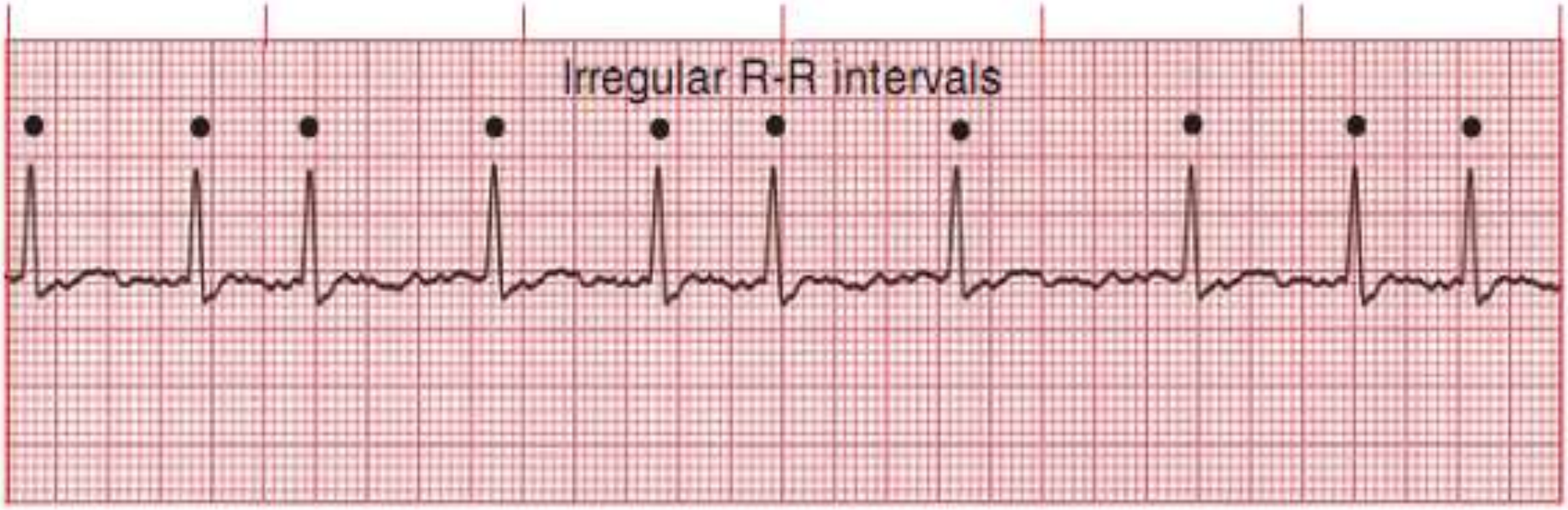
Rate: Atrial: 250–350 bpm; ventricular: slow or fast
Rhythm: Usually regular but may be variable
P Waves: Flutter waves have a saw-toothed appearance
PR Interval: Variable
QRS: Usually normal (0.06–0.10 sec), but may appear widened if flutter waves are buried in QRS

♥ **Clinical Tip:** The presence of A-flutter may be the first indication of cardiac disease.

♥ **Clinical Tip:** Signs and symptoms depend on ventricular response rate.

Atrial Fibrillation (A-fib)

- Rapid, erratic electrical discharge comes from multiple atrial ectopic foci.
- No organized atrial contractions are detectable.



Rate: Atrial: 350 bpm or greater; ventricular: slow or fast
Rhythm: Irregular
P Waves: No true P waves; chaotic atrial activity
PR Interval: None
QRS: Normal (0.06–0.10 sec)

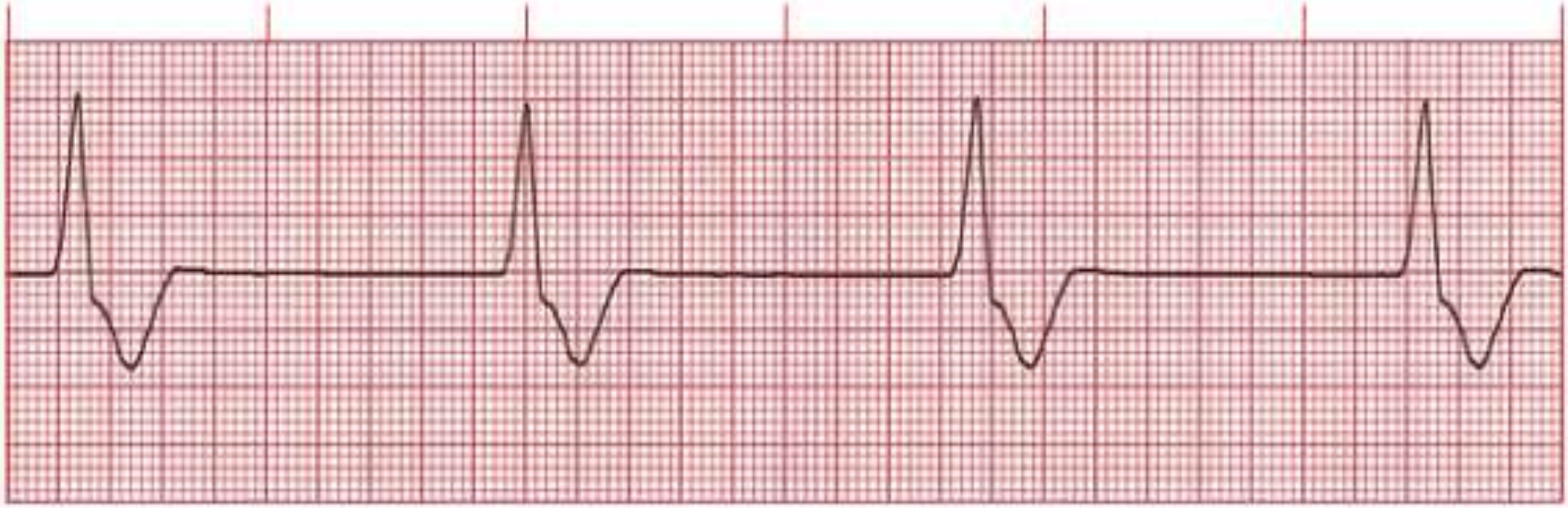
♥ **Clinical Tip:** A-fib is usually a chronic arrhythmia associated with underlying heart disease.

♥ **Clinical Tip:** Signs and symptoms depend on ventricular response rate.

Ventricular Arrhythmias

- QRS complex is >0.10 sec. P Waves are absent or, if visible, have no consistent relationship to the QRS complex.

Idioventricular Rhythm

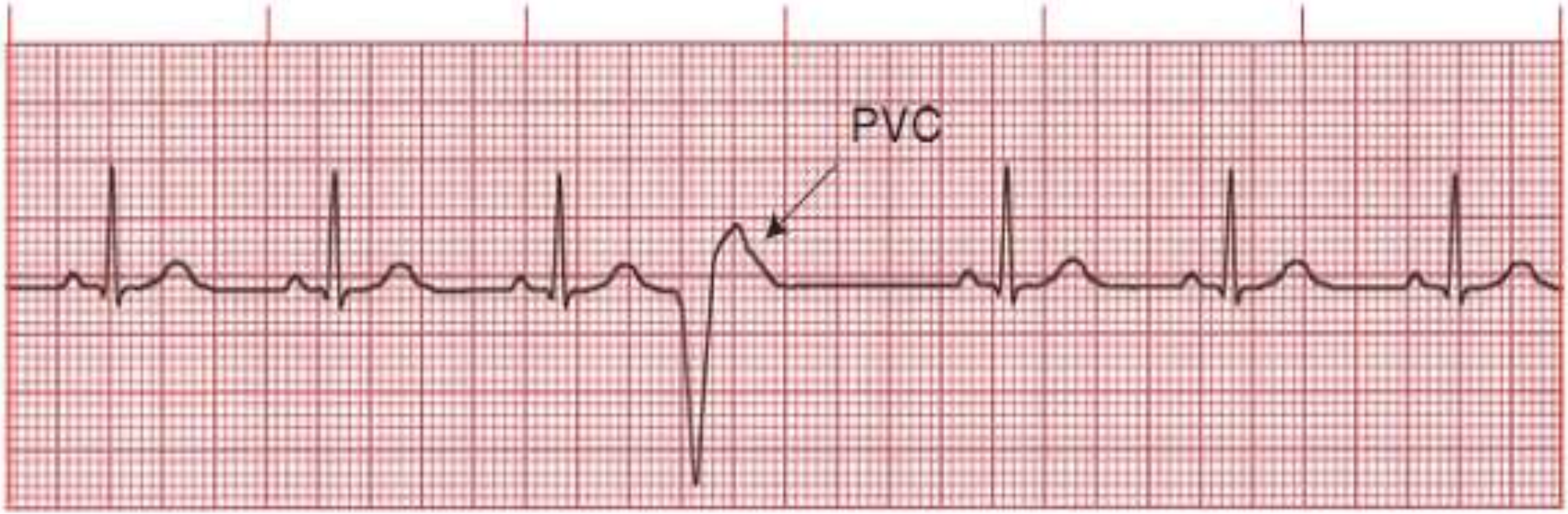


Rate: 20–40 bpm
Rhythm: Regular
P Waves: None
PR Interval: None
QRS: Wide (>0.10 sec), bizarre appearance

♥ **Clinical Tip:** Idioventricular rhythm may also be called agonal rhythm.

Premature Ventricular Contraction (PVC)

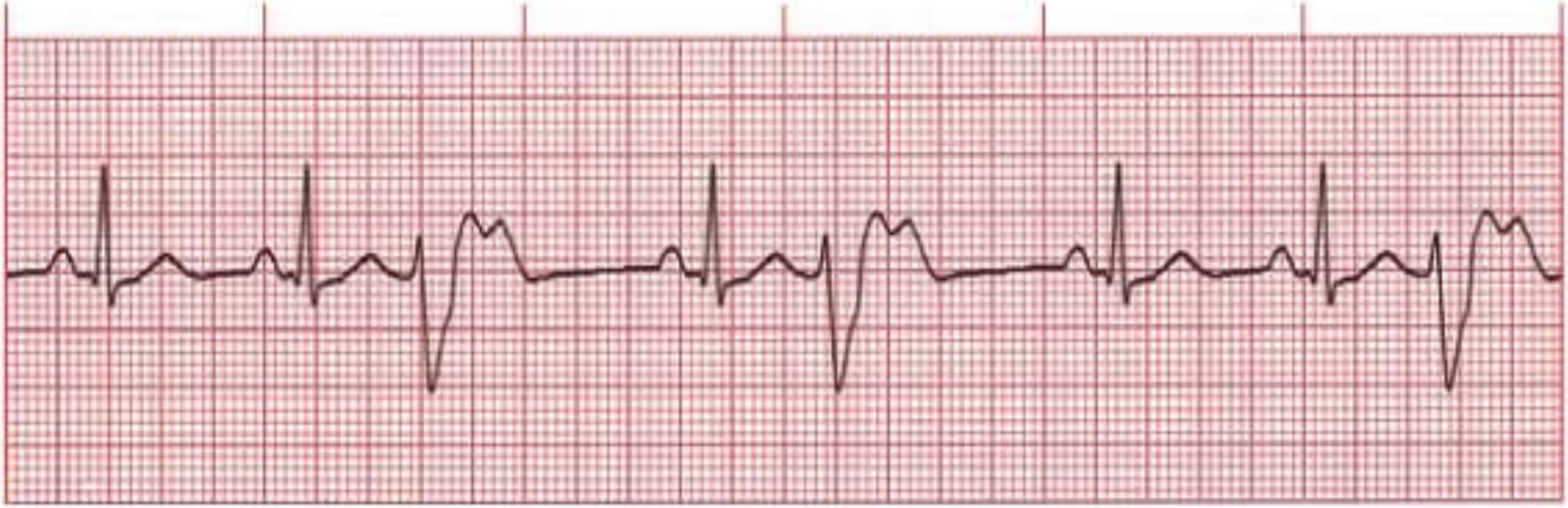
- Usually PVCs result from an irritable ventricular focus.
- PVCs may be uniform (same form) or multiform (different forms).
- The pause following a PVC may be compensatory or noncompensatory.



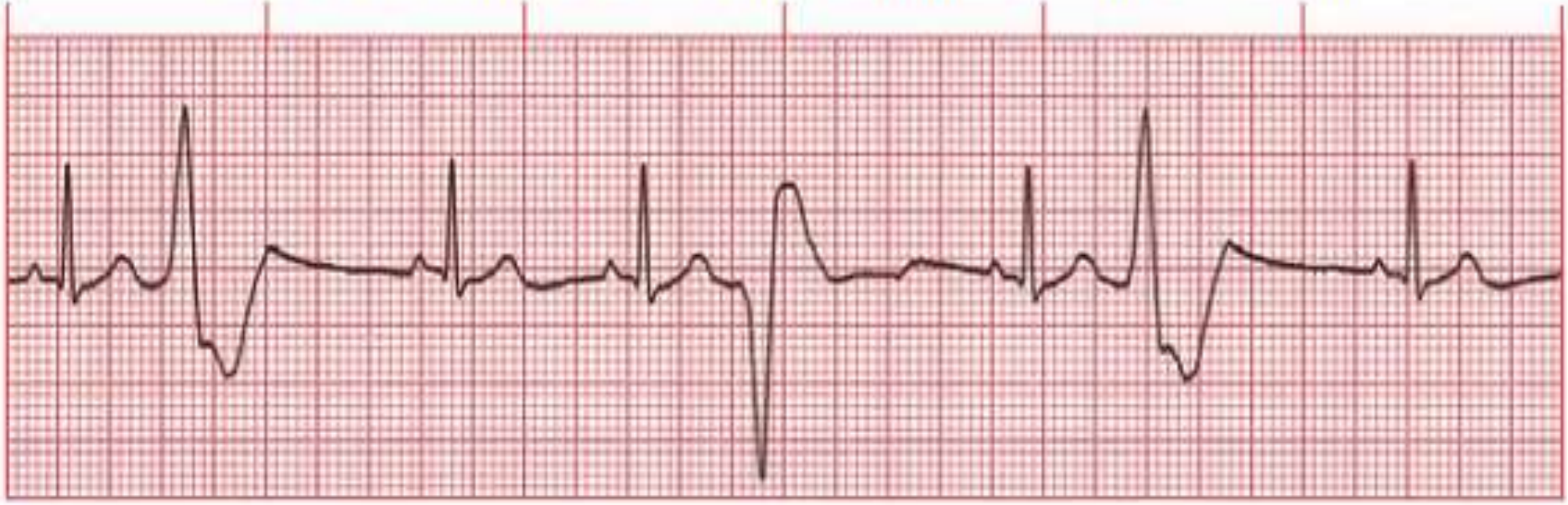
Rate: Depends on rate of underlying rhythm
Rhythm: Irregular whenever a PVC occurs
P Waves: None associated with the PVC
PR Interval: None associated with the PVC
QRS: Wide (>0.10 sec), bizarre appearance

♥ **Clinical Tip:** Patients may sense the occurrence of PVCs as skipped beats. Because the ventricles are only partially filled, the PVC frequently does not generate a pulse.

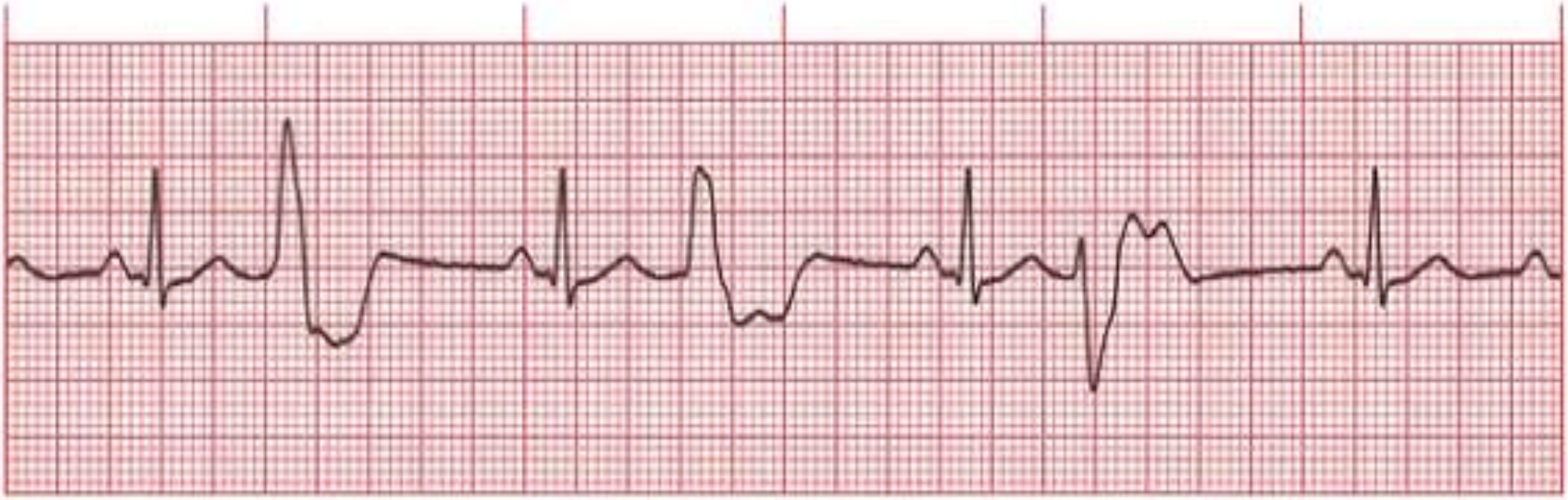
Premature Ventricular Contraction: Uniform (same form)



Premature Ventricular Contraction: Multiform (different forms)



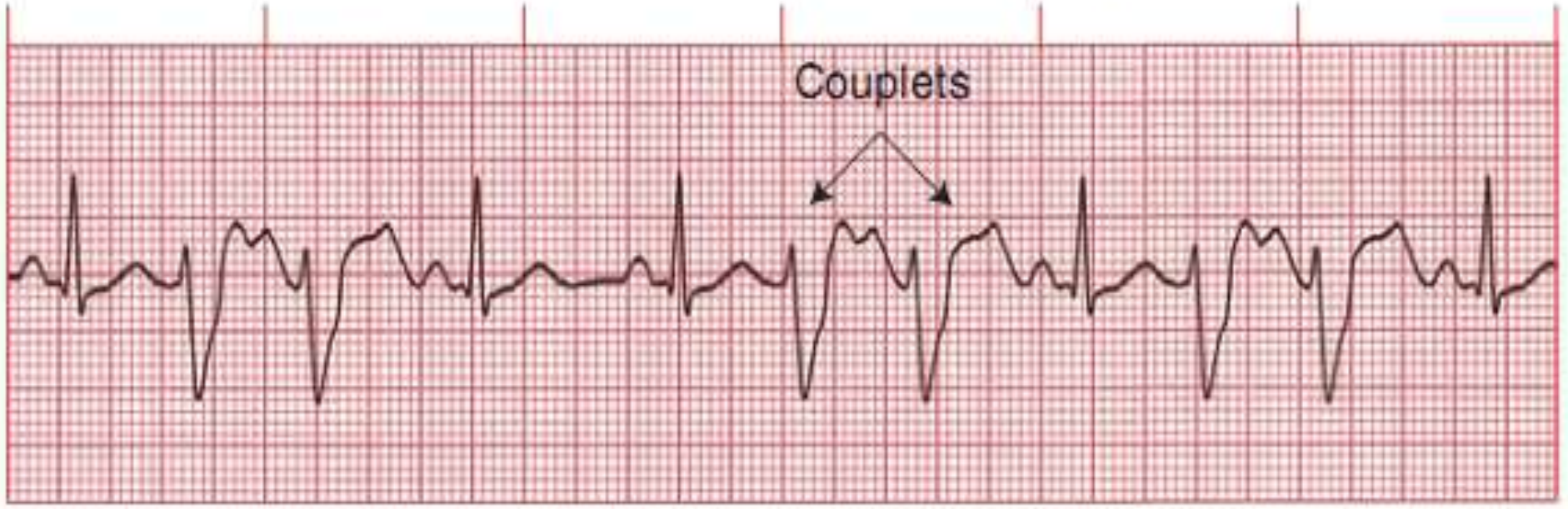
Premature Ventricular Contraction: Ventricular Bigeminy (PVC every other beat)



Premature Ventricular Contraction: Ventricular Trigeminy (PVC every 3rd beat)

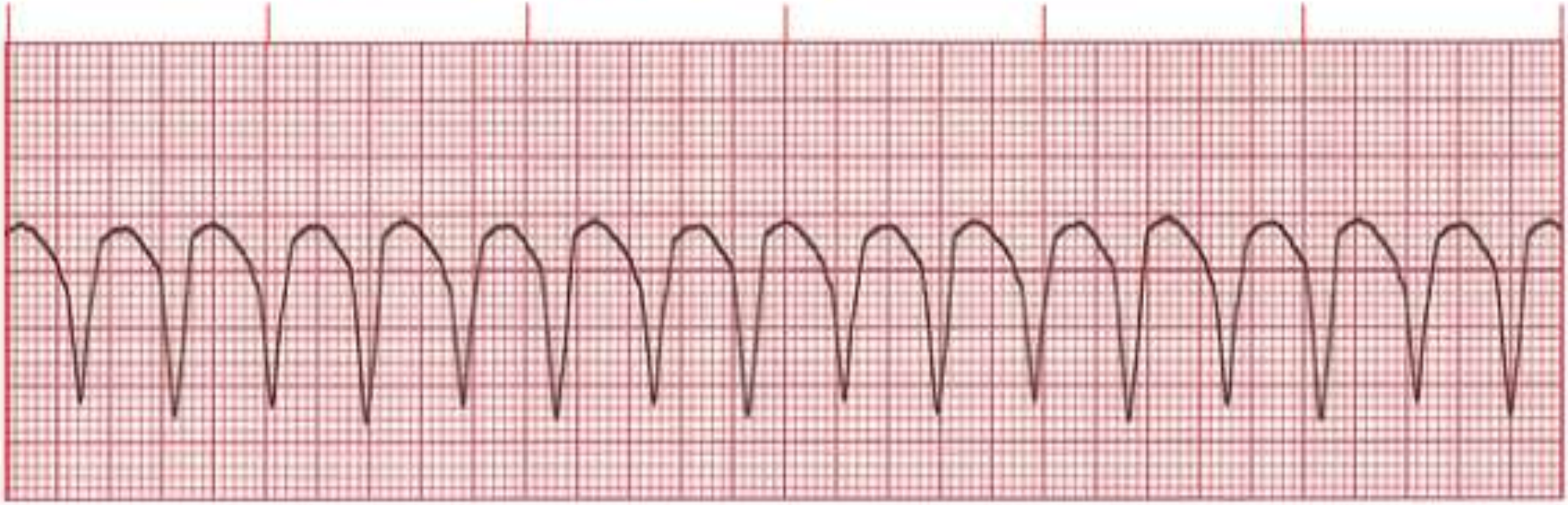
Premature Ventricular Contraction: Ventricular Quadrigeminy (PVC every 4th beat)

Premature Ventricular Contraction: Couplets (paired PVCs)



Ventricular Tachycardia (VT): Monomorphic

- QRS complexes in monomorphic VT have the same shape and amplitude.



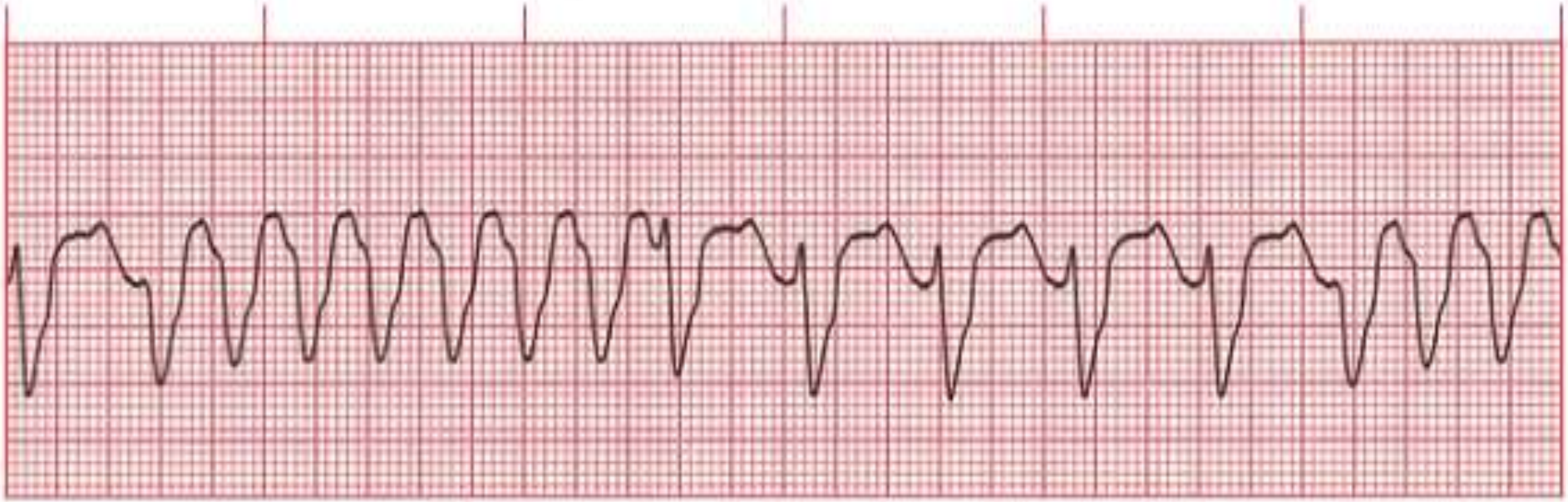
Rate: 100–250 bpm
Rhythm: Regular
P Waves: None or not associated with the QRS
PR Interval: None
QRS: Wide (>0.10 sec), bizarre appearance

♥ **Clinical Tip:** It is important to confirm the presence or absence of pulses because monomorphic VT may be perfusing or nonperfusing.

♥ **Clinical Tip:** Monomorphic VT will probably deteriorate into VF or unstable VT if sustained and not treated.

Ventricular Tachycardia (VT): Polymorphic

- QRS complexes in polymorphic VT vary in shape and amplitude.
- The QT interval is normal or long.



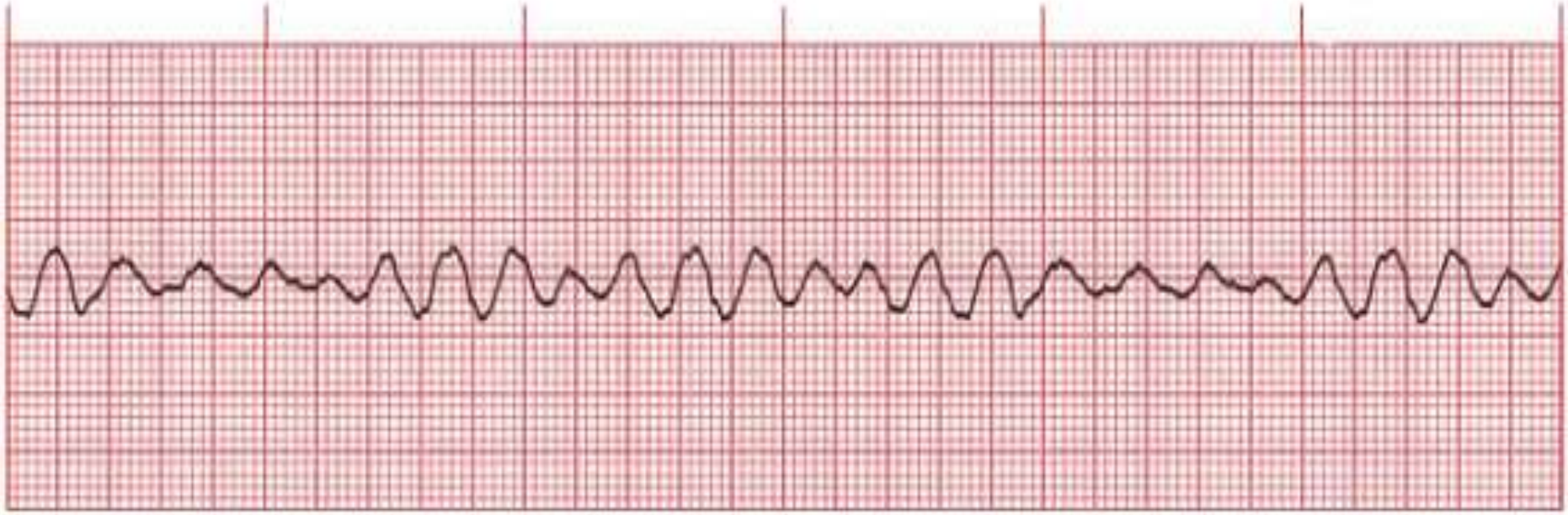
Rate: 100–250 bpm
Rhythm: Regular or irregular
P Waves: None or not associated with the QRS
PR Interval: None
QRS: Wide (>0.10 sec), bizarre appearance

♥ **Clinical Tip:** It is important to confirm the presence or absence of pulses because polymorphic VT may be perfusing or nonperfusing.

♥ **Clinical Tip:** Consider electrolyte abnormalities as a possible etiology.

Ventricular Fibrillation (VF)

- Chaotic electrical activity occurs with no ventricular depolarization or contraction.
- The amplitude and frequency of the fibrillatory activity can be used to define the type of fibrillation as coarse, medium, or fine.



Rate: Indeterminate
Rhythm: Chaotic
P Waves: None
PR Interval: None
QRS: None

♥ **Clinical Tip:** There is no pulse or cardiac output. Rapid intervention is critical. The longer the delay, the less the chance of conversion.

Pulseless Electrical Activity (PEA)

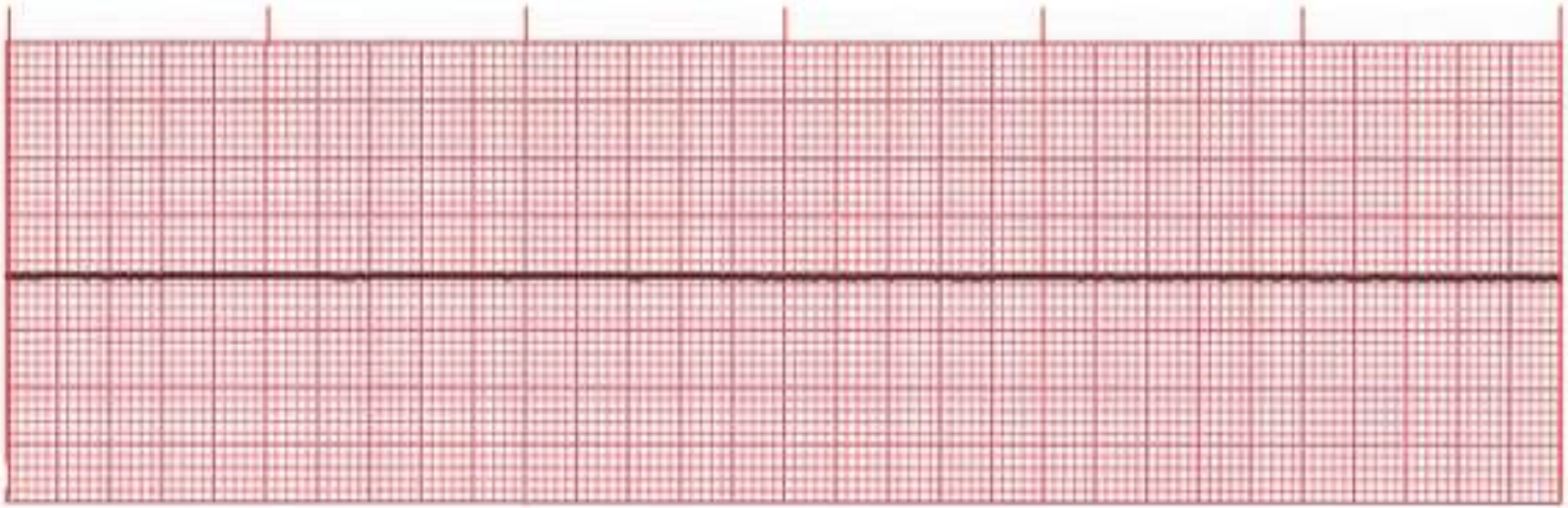
- Monitor shows an identifiable electrical rhythm, but no pulse is detected.
- Rhythm may be sinus, atrial, junctional, or ventricular in origin.
- PEA is also called electromechanical dissociation (EMD).

Rate, rhythm, P waves, P-R interval, and QRS: Reflect underlying rhythm.

♥ **Clinical Tip:** Potential causes of PEA are pulmonary embolism, MI, acidosis, tension pneumothorax, hyper- and hypokalemia, cardiac tamponade, hypovolemia, hypoxia, hypothermia, and drug overdose (i.e., cyclic antidepressants, beta blockers, calcium channel blockers, digoxin).

Asystole

- Electrical activity in the ventricles is completely absent.



Rate: None
Rhythm: None
P Waves: None
PR Interval: None
QRS: None

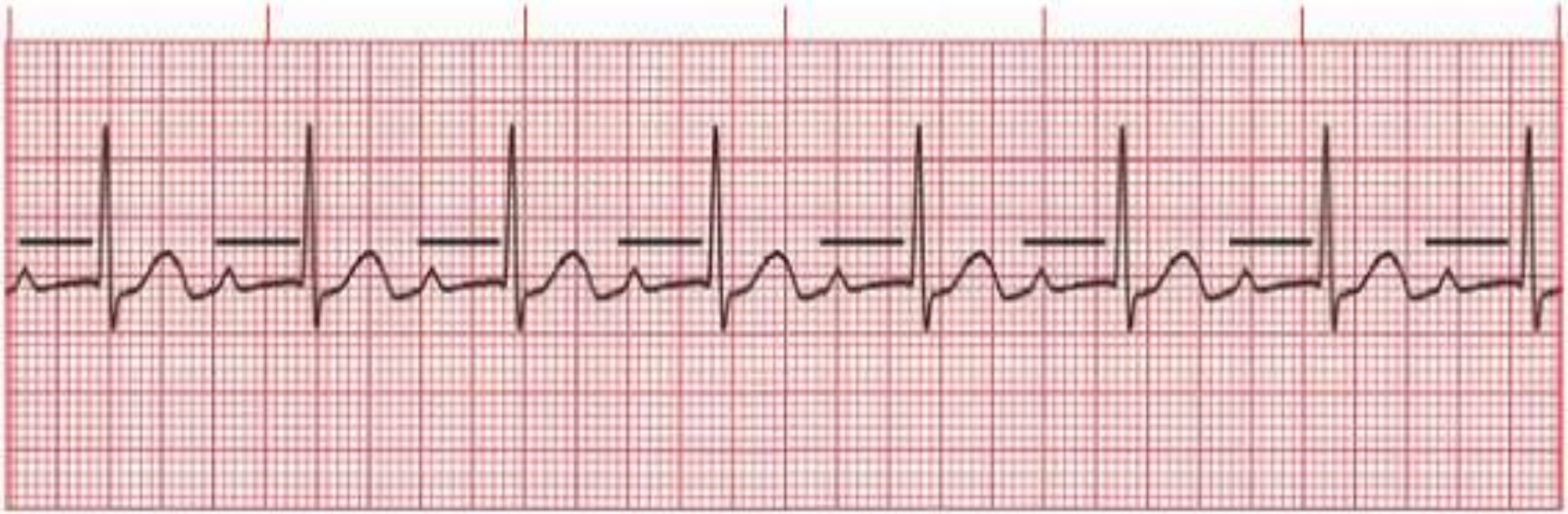
♥ **Clinical Tip:** Always confirm asystole by checking the ECG in two different leads. Also, search to identify underlying ventricular fibrillation.

♥ **Clinical Tip:** Seek to identify the underlying cause as in PEA.

Atrioventricular (AV) Blocks

- AV blocks are divided into three categories: first-, second-, and third-degree.

First-Degree AV Block



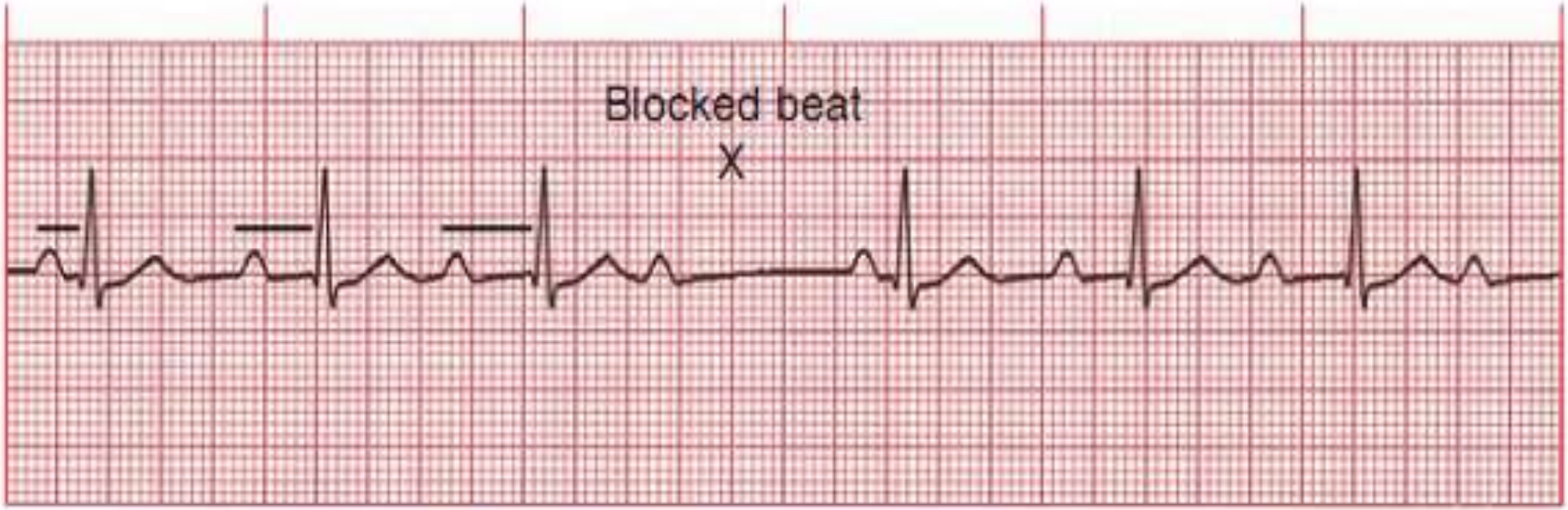
Rate: Depends on rate of underlying rhythm
Rhythm: Regular
P Waves: Normal (upright and uniform)
PR Interval: Prolonged (>0.20 sec)
QRS: Normal (0.06–0.10 sec)

♥ **Clinical Tip:** Usually AV block is benign, but if associated with an acute MI, it may lead to further AV defects.

Second-Degree AV Block

Type I (Mobitz I or Wenckebach)

- P-R intervals become progressively longer until one P wave is totally blocked and produces no QRS. After a pause, during which the AV node recovers, this cycle is repeated.



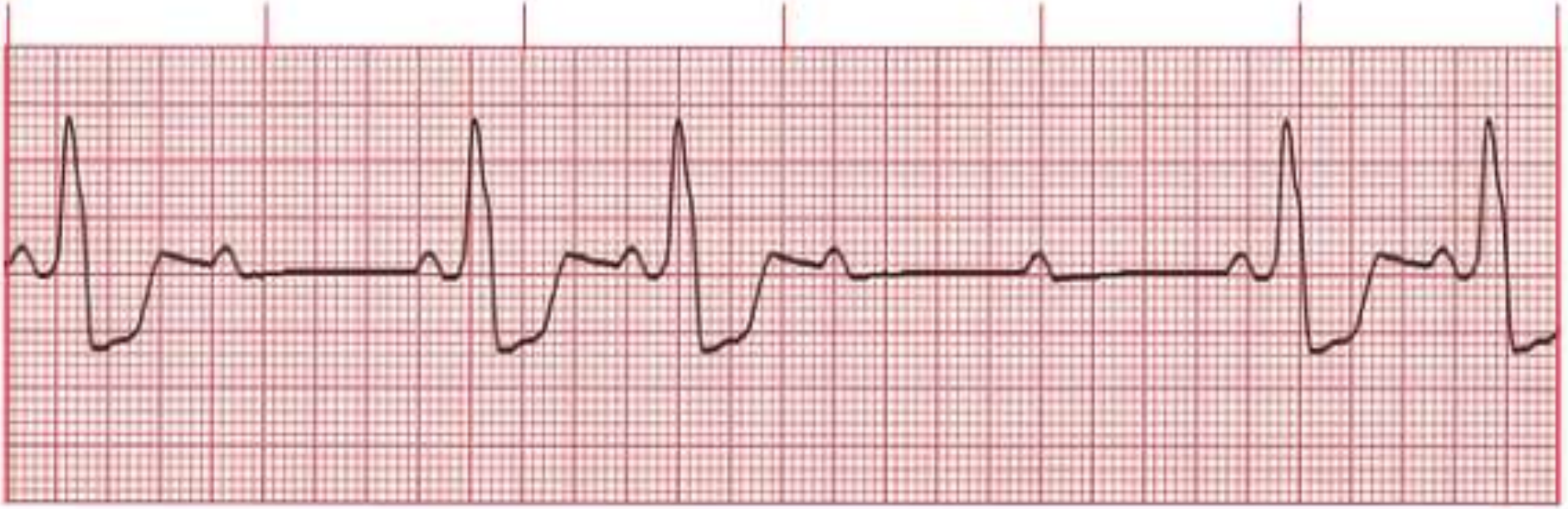
Rate: Depends on rate of underlying rhythm
Rhythm: Irregular
P Waves: Normal (upright and uniform)
PR Interval: Progressively longer until one P wave is blocked and a QRS is dropped
QRS: Normal (0.06–0.10 sec)

♥ **Clinical Tip:** This rhythm may be caused by medication such as beta blockers, digoxin, and calcium channel blockers. Ischemia involving the right coronary artery is another cause.

Second-Degree AV Block

Type II (Mobitz II)

- Conduction ratio (P waves to QRS complexes) is commonly 2:1, 3:1, or 4:1.
- QRS complexes are usually wide because this block usually involves both bundle branches.

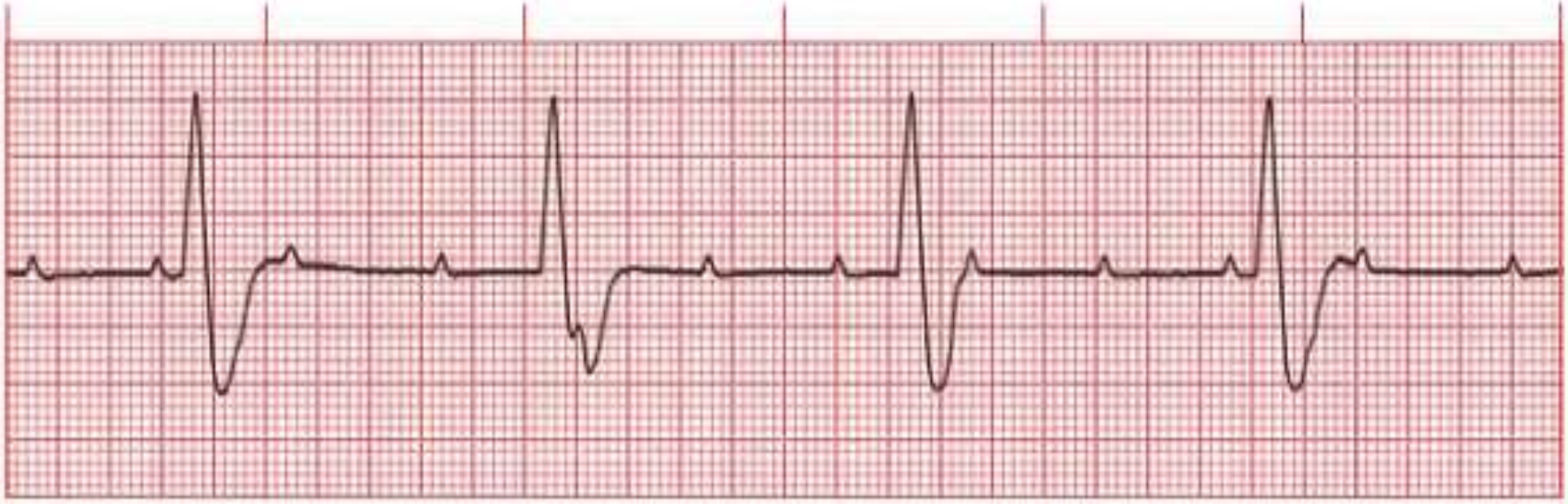


Rate: Atrial rate (usually 60–100 bpm); faster than ventricular rate
Rhythm: Atrial regular and ventricular irregular
P Waves: Normal (upright and uniform); more P waves than QRS complexes
PR Interval: Normal or prolonged but constant
QRS: Usually wide (>0.10 sec)

♥ **Clinical Tip:** Resulting bradycardia can compromise cardiac output and lead to complete AV block. This rhythm often occurs with cardiac ischemia or an MI.

Third-Degree AV Block

- Conduction between atria and ventricles is absent because of electrical block at or below the AV node.
- "Complete heart block" is another name for this rhythm.



Rate: Atrial: 60–100 bpm; ventricular: 40–60 bpm if escape focus is junctional, <40 bpm if escape focus is ventricular

Rhythm: Usually regular, but atria and ventricles act independently

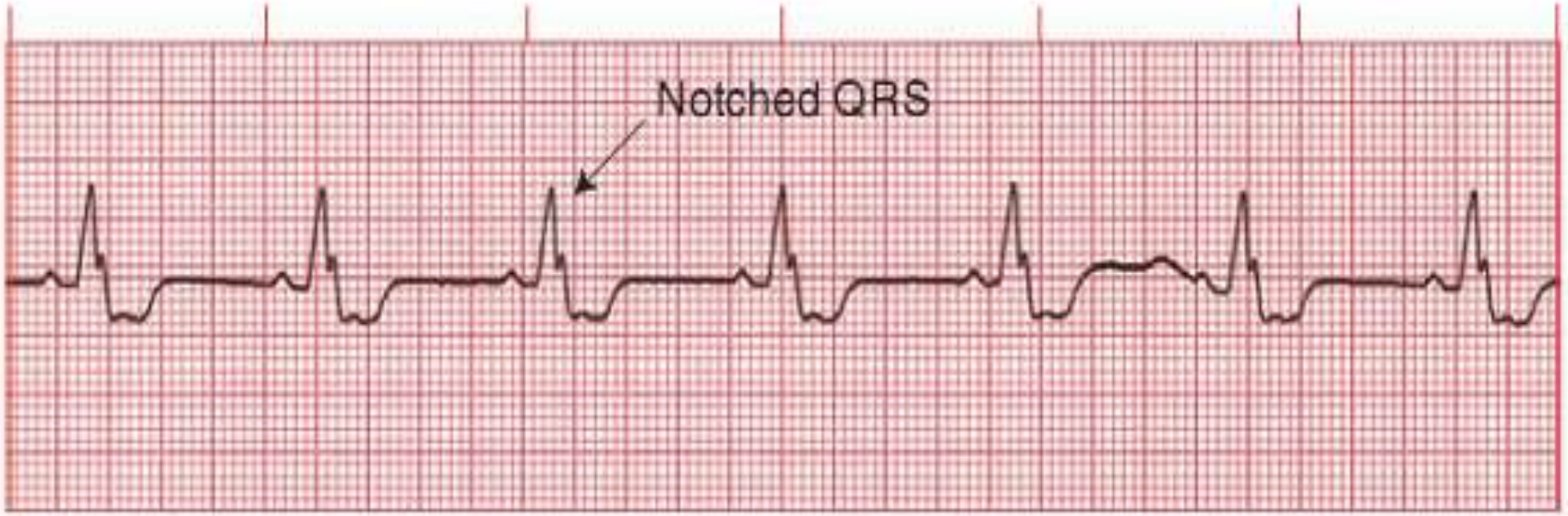
P Waves: Normal (upright and uniform); may be superimposed on QRS complexes or T waves

PR Interval: Varies greatly

QRS: Normal if ventricles are activated by junctional escape focus; wide if escape focus is ventricular

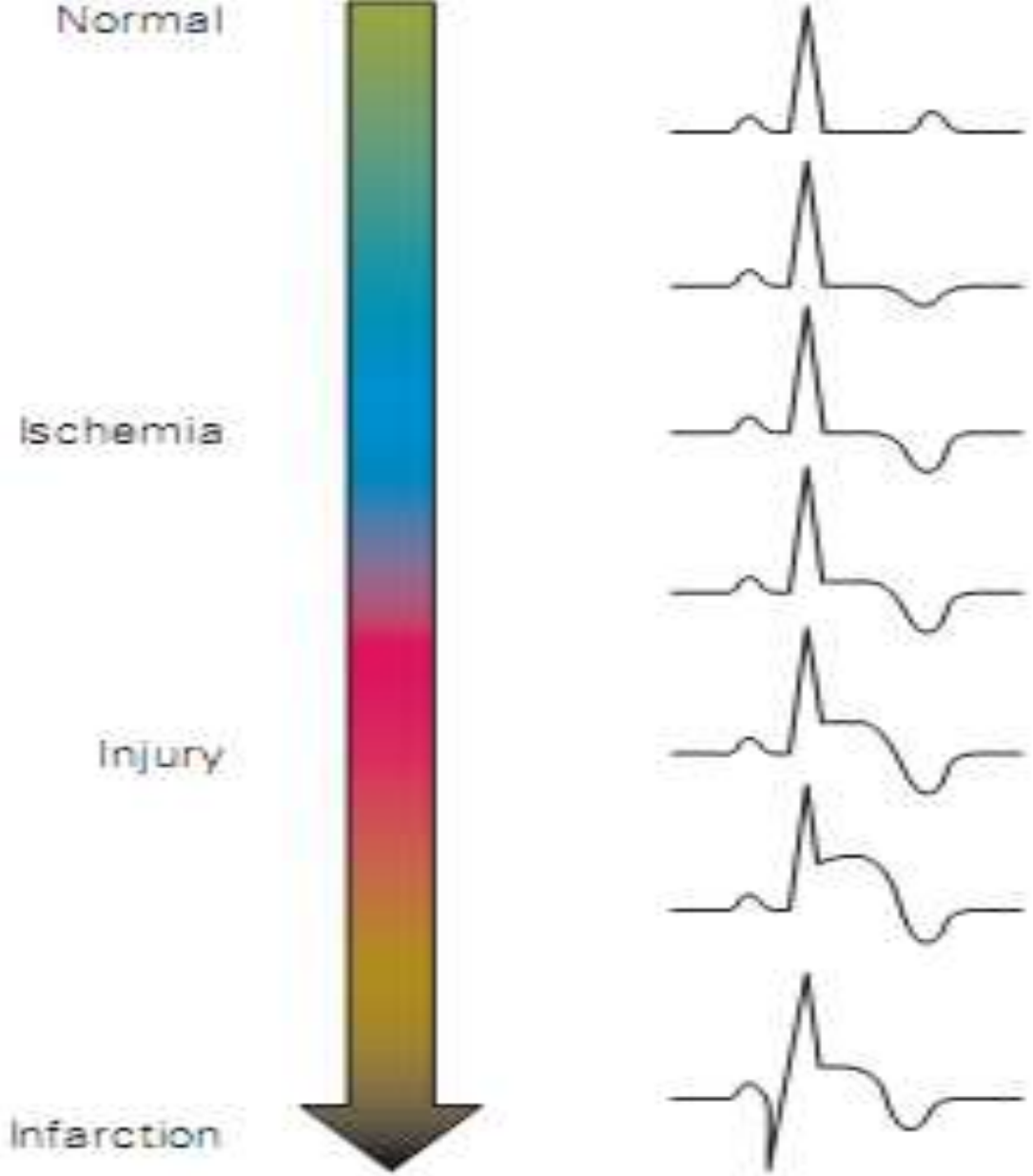
Bundle Branch Block (BBB)

- Either the left or the right ventricle may depolarize late, creating a "notched" QRS complex.



Rate: Depends on rate of underlying rhythm
Rhythm: Regular
P Waves: Normal (upright and uniform)
PR Interval: Normal (0.12–0.20 sec)
QRS: Usually wide (>0.10 sec) with a notched appearance

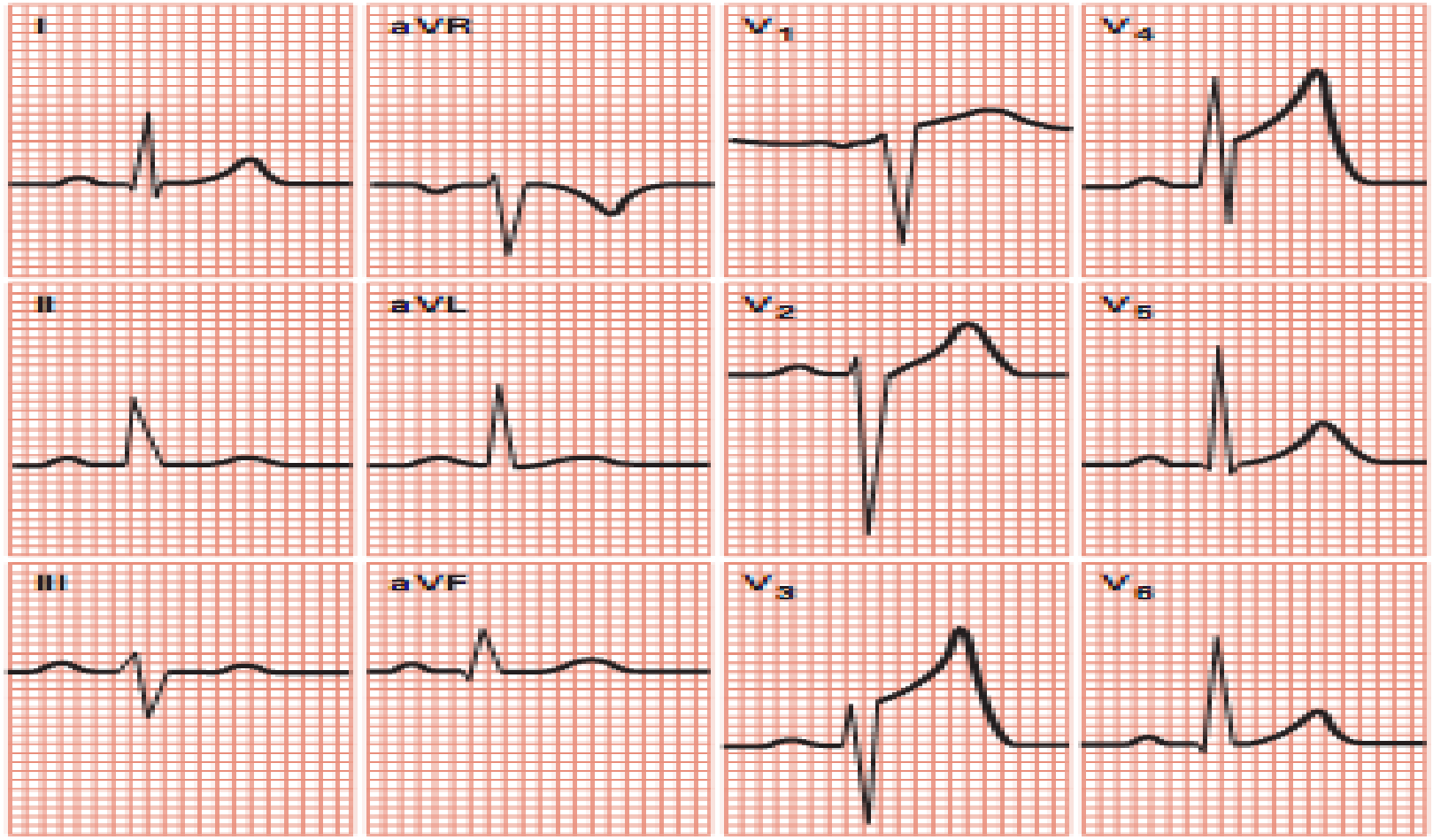
♥ **Clinical Tip:** Commonly, BBB occurs in coronary artery disease.



♥ **Clinical Tip:** Once the acute MI has ended, the ST segment returns to baseline and theT wave becomes upright, but the Q wave remains abnormal because of scar formation.

Anterior Myocardial Infarction

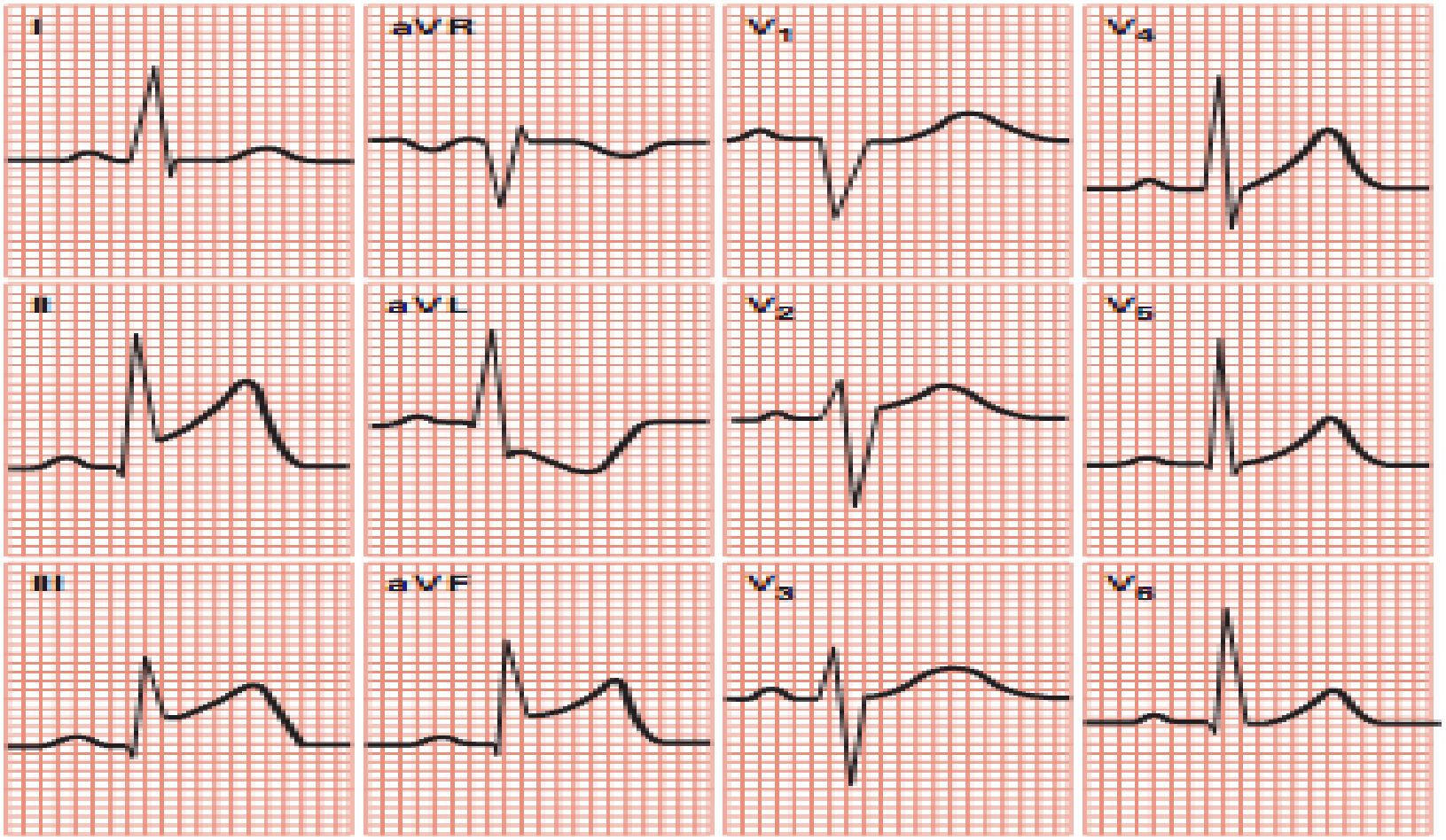
- Occlusion of the left coronary artery—left anterior descending branch
- ECG changes: ST segment elevation with tall T waves and taller-than-normal R waves in leads V_3 and V_4



♥ **Clinical Tip:** Anterior MI frequently involves a large area of the myocardium and can present with cardiogenic shock, second-degree AV block type II, or third-degree AV block.

Inferior Myocardial Infarction

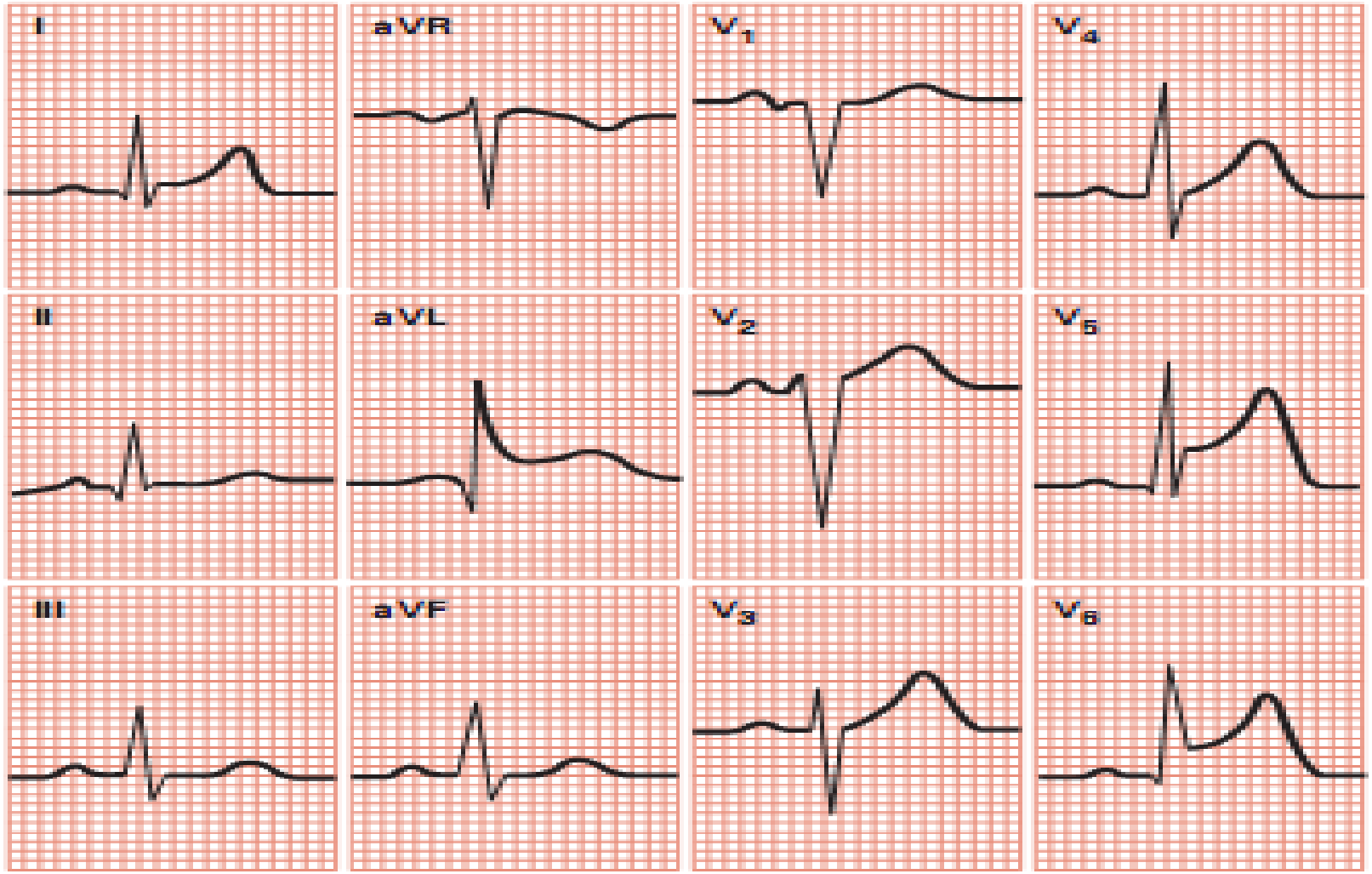
- Occlusion of the right coronary artery—posterior descending branch
- ECG changes: ST segment elevation in leads II, III, and aVF



Clinical Tip: Be alert for symptomatic sinus bradycardia, AV blocks, hypotension, and hypoperfusion.

Lateral Myocardial Infarction

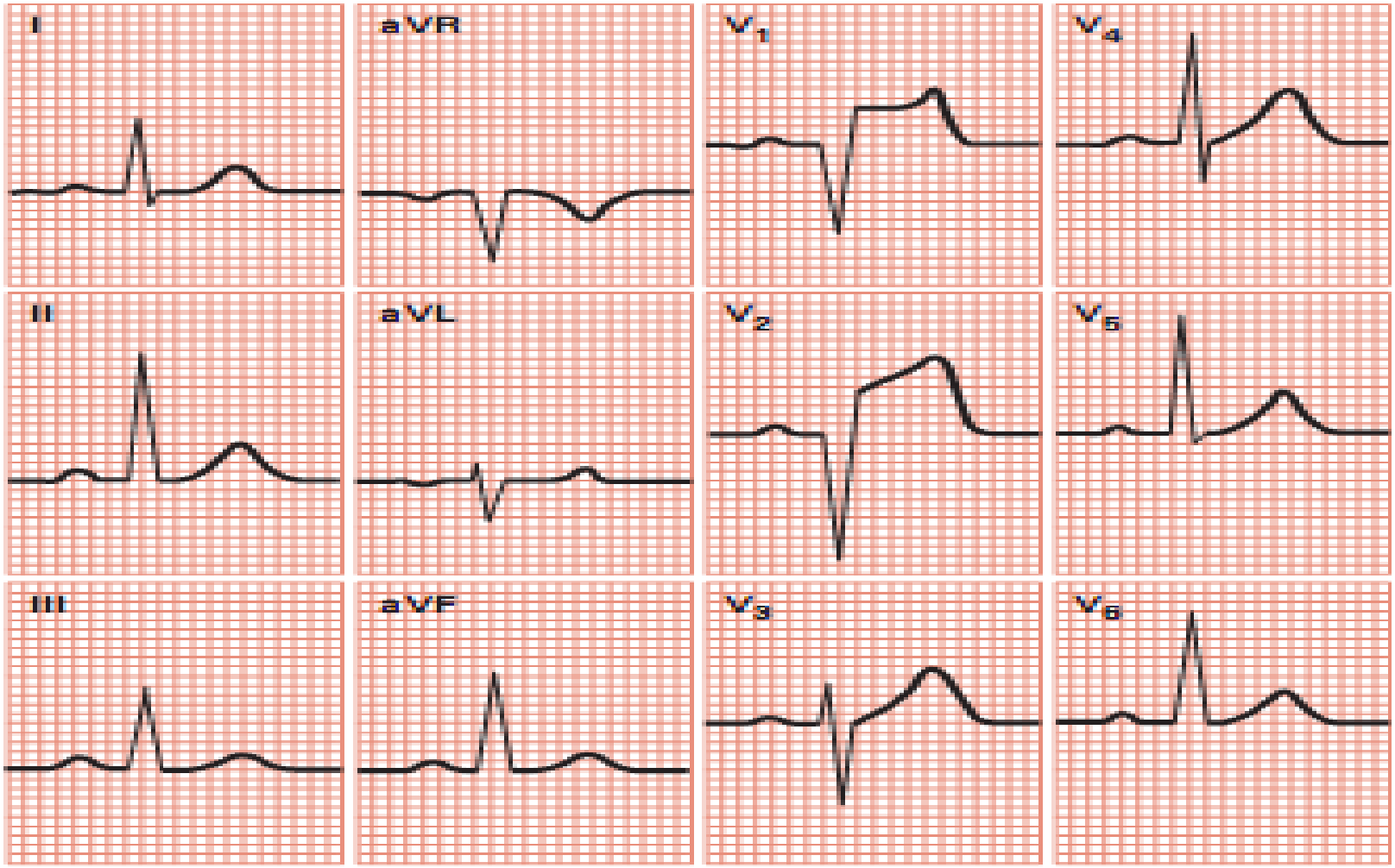
- Occlusion of the left coronary artery—circumflex branch
- ECG changes: ST segment elevation in leads I, aVL, V_5, and V_6



Clinical Tip: Lateral MI is often associated with anterior or inferior wall MI. Be alert for changes that may indicate cardiogenic shock or congestive heart failure.

Septal Myocardial Infarction

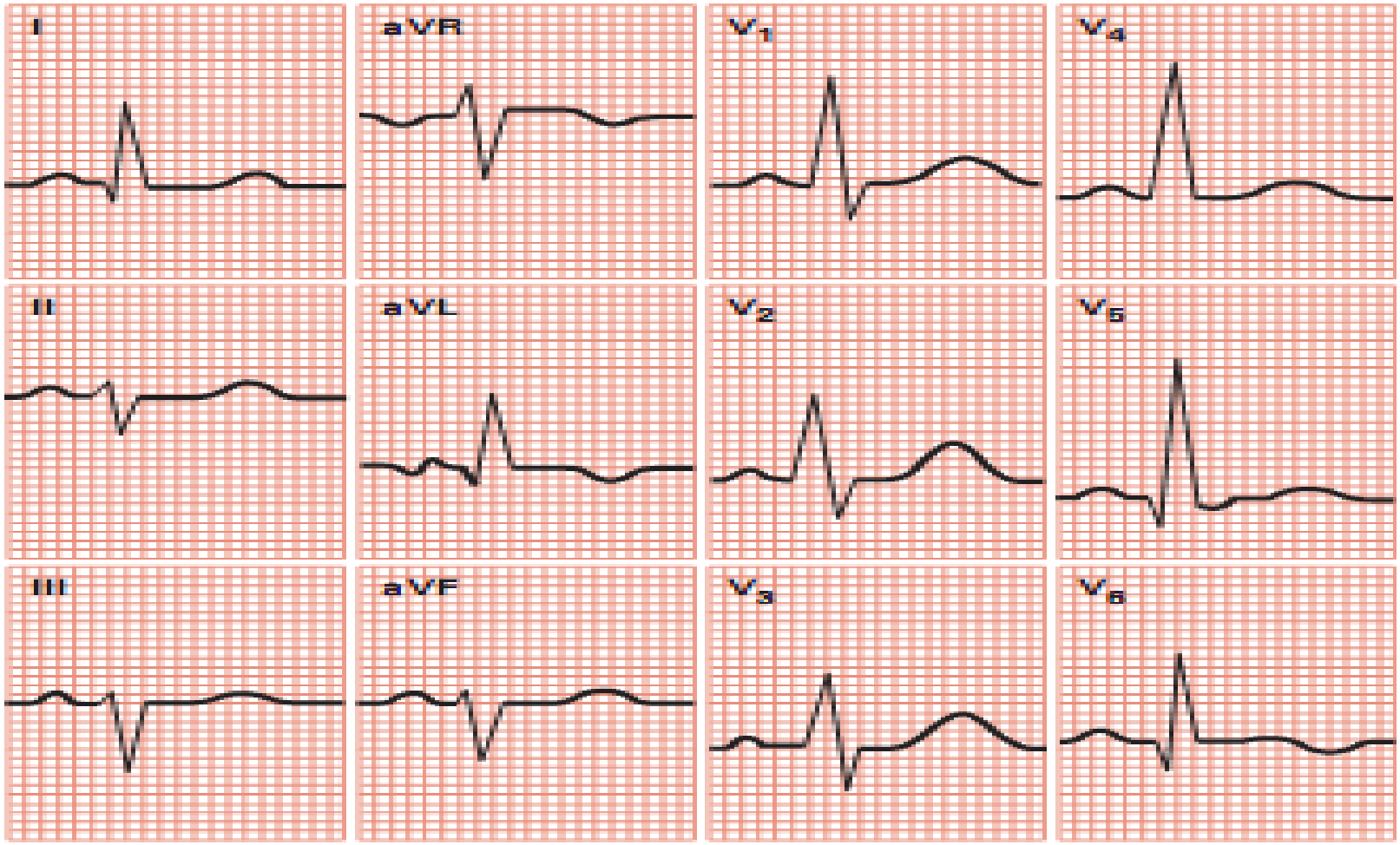
- Occlusion of the left coronary artery—left anterior descending branch
- ECG changes: pathological Q waves; absence of normal R waves in leads V_1 and V_2



Clinical Tip: Septal MI is often associated with an anterior wall MI.

Posterior Myocardial Infarction

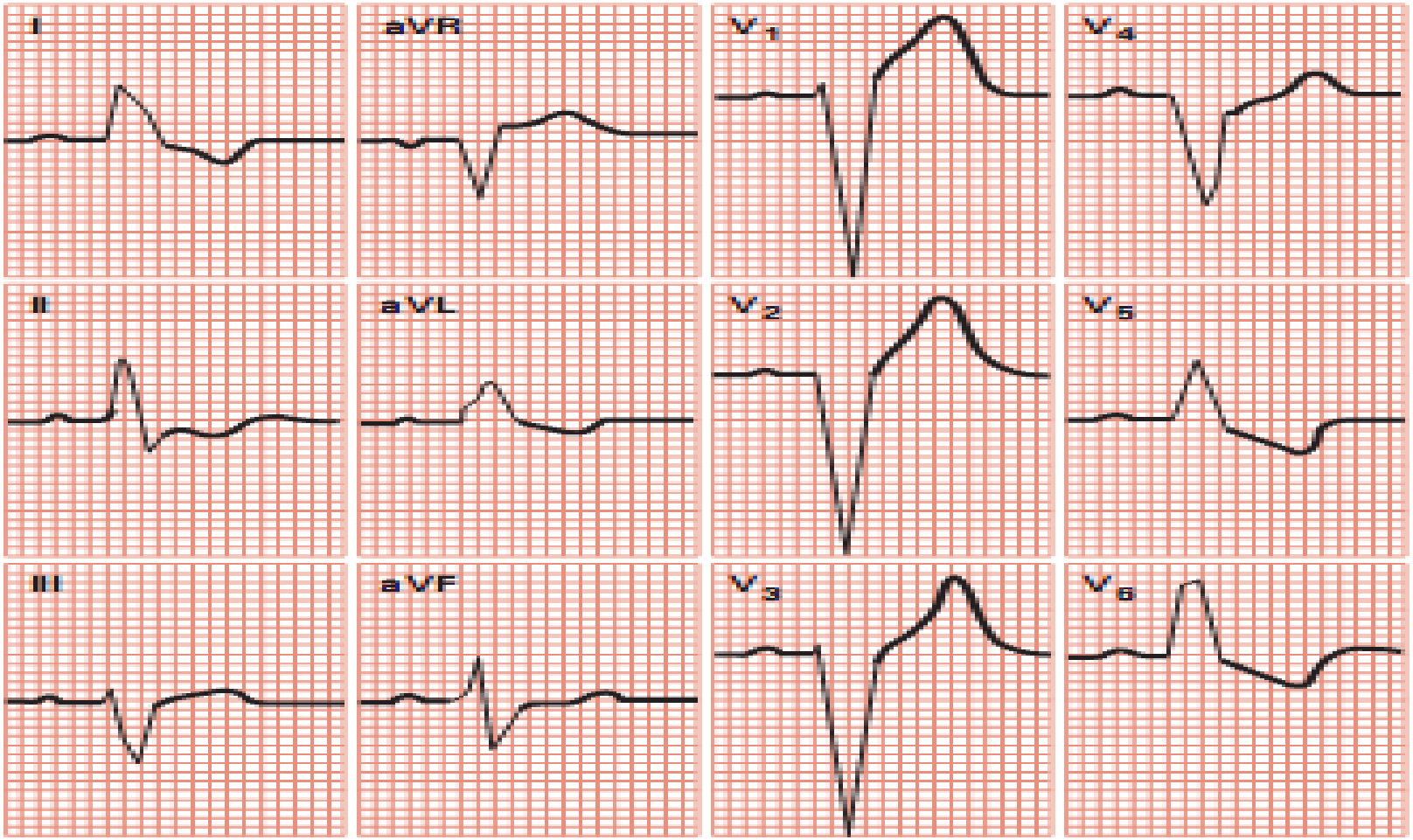
- Occlusion of the right coronary artery (posterior descending branch) or the left circumflex artery
- Tall R waves and ST segment depression possible in leads V_1, V_2, V_3, and V_4
- ST segment elevation in true posterior leads, V_8 and V_9



Clinical Tip: Diagnosis may require a 15-lead ECG because a standard 12-lead does not look directly at the posterior wall.

Left Bundle Branch Block

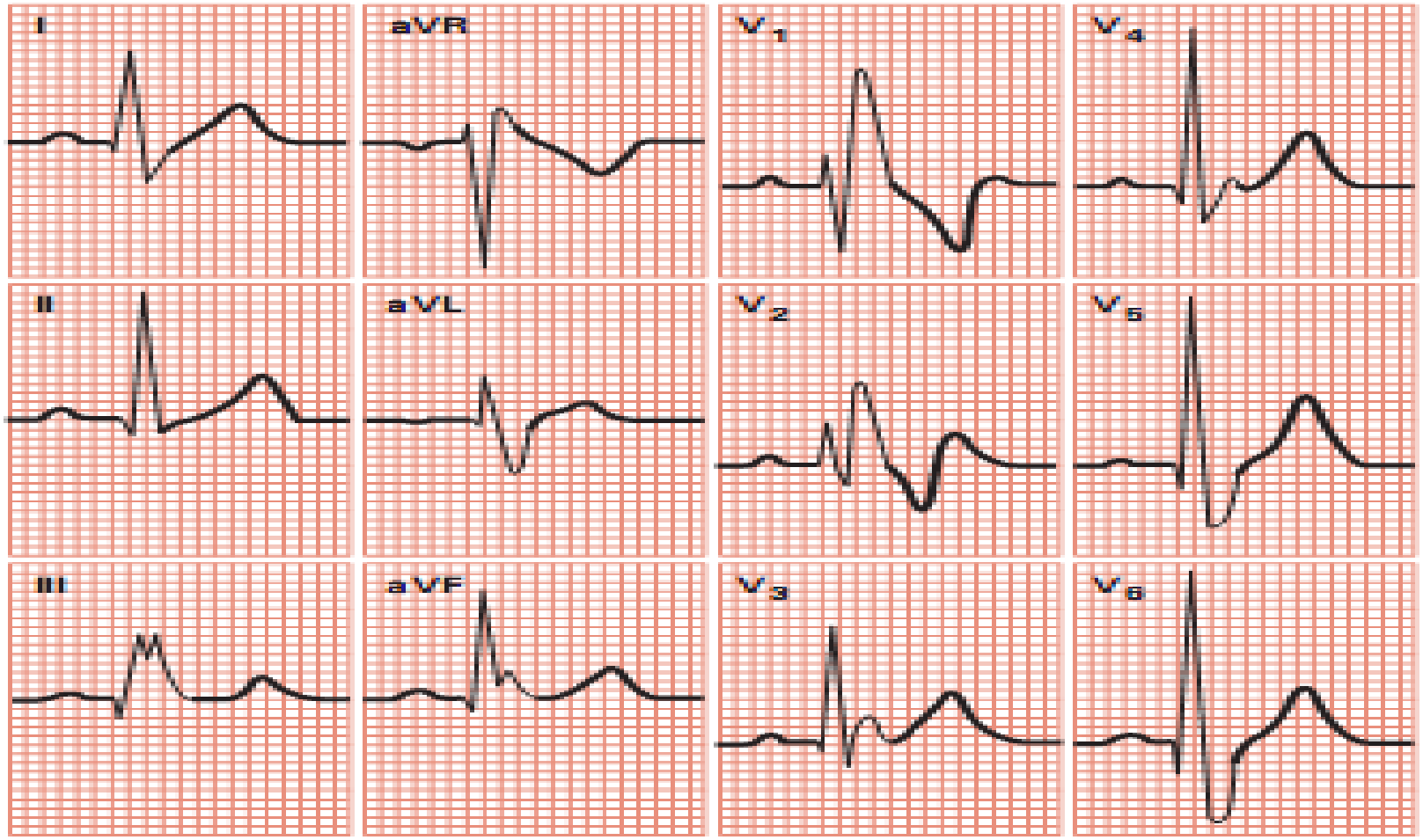
- QRS >0.10 sec
- QRS predominantly negative in leads V_1 and V_2
- QRS predominantly positive in V_5 and V_6 and often notched
- Absence of small, normal Q waves in I, aVL, V_5, and V_6
- Wide monophasic R waves in I, aVL, V_1, V_5, and V_6



Clinical Tip: Patients may have underlying heart disease, including coronary artery disease, hypertension, cardiomyopathy, and ischemia.

Right Bundle Branch Block

- QRS >0.10 sec
- QRS normal or deviated to the right
- Slurred S wave in leads I and V_6
- RSR′ pattern in lead V_1 with R′ taller than R



Clinical Tip: Patients may have underlying right ventricular hypertrophy, pulmonary edema, cardiomyopathy, congenital heart disease, or rheumatic heart disease.

1

BRADYCARDIA
Heart rate <60 bpm and inadequate for clinical condition

2

- Maintain patent **airway;** assist **breathing** as needed
- Give **oxygen**
- Monitor ECG (identify rhythm), blood pressure, oximetry
- Establish IV access

3

Signs or symptoms of poor perfusion caused by the bradycardia?
(eg, acute altered mental status, ongoing chest pain, hypotension or other signs of shock)

Adequate Perfusion

4A

Observe/Monitor

Poor Perfusion

4

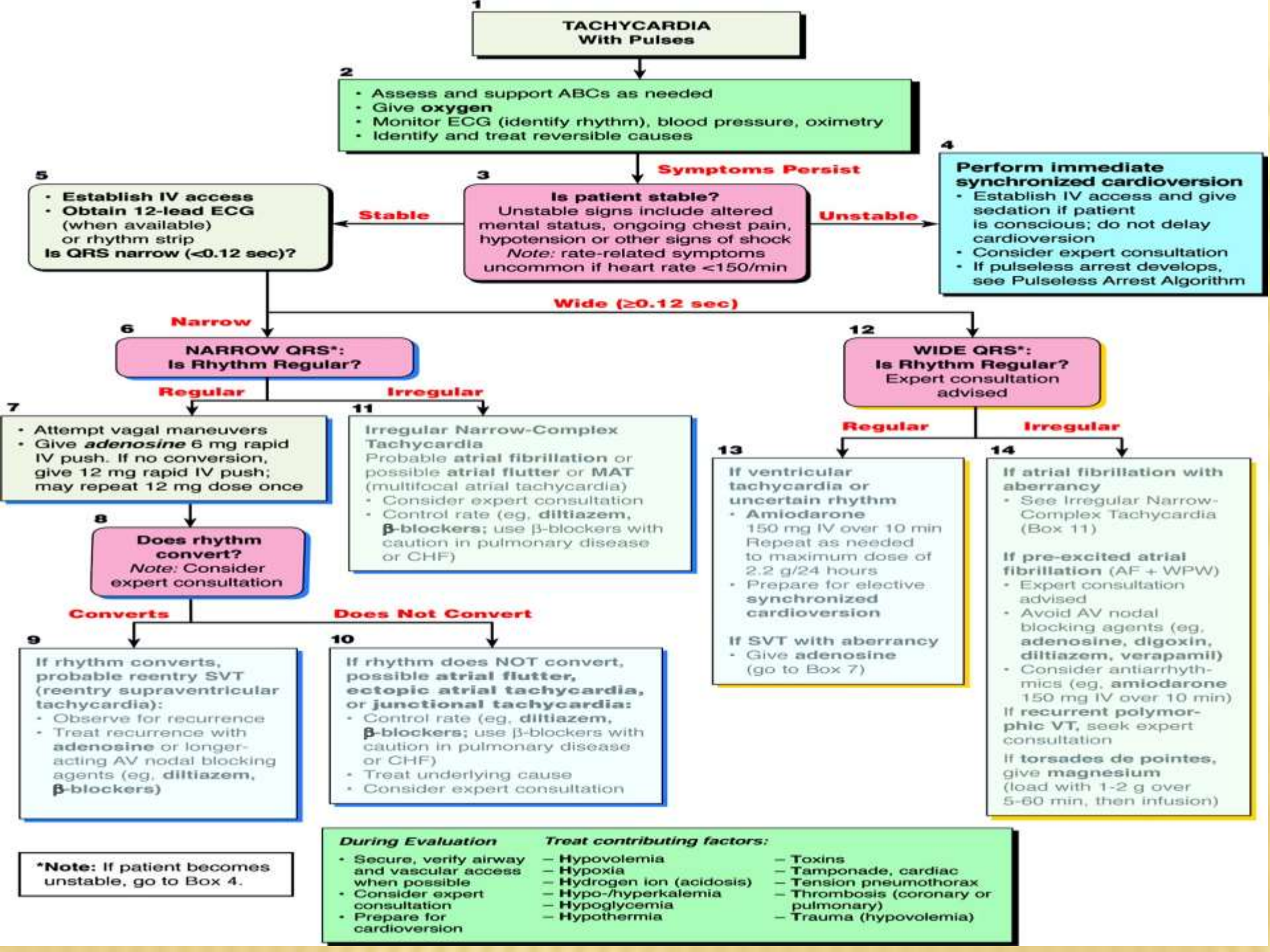
- **Prepare for transcutaneous pacing;** use without delay for high-degree block (type II second-degree block or third-degree AV block)
- Consider **atropine** 0.5 mg IV while awaiting pacer. May repeat to a total dose of 3 mg. If ineffective, begin pacing
- Consider **epinephrine** (2 to 10 µg/min) or **dopamine** (2 to 10 µg/kg per minute) infusion while awaiting pacer or if pacing ineffective

5

- Prepare for **transvenous pacing**
- Treat contributing causes
- Consider expert consultation

Reminders

- If pulseless arrest develops, go to Pulseless Arrest Algorithm
- Search for and treat possible contributing factors:
  - **H**ypovolemia
  - **H**ypoxia
  - **H**ydrogen ion (acidosis)
  - **H**ypo-/hyperkalemia
  - **H**ypoglycemia
  - **H**ypothermia
  - **T**oxins
  - **T**amponade, cardiac
  - **T**ension pneumothorax
  - **T**hrombosis (coronary or pulmonary)
  - **T**rauma (hypovolemia, increased ICP)


1
TACHYCARDIA
With Pulses
2
• Assess and support ABCs as needed
• Give oxygen
• Monitor ECG (identify rhythm), blood pressure, oximetry
• Identify and treat reversible causes
Symptoms Persist
3
Is patient stable?
Unstable signs include altered mental status, ongoing chest pain, hypotension or other signs of shock
Note: rate-related symptoms uncommon if heart rate <150/min
Stable
Unstable
4
Perform immediate synchronized cardioversion
• Establish IV access and give sedation if patient is conscious; do not delay cardioversion
• Consider expert consultation
• If pulseless arrest develops, see Pulseless Arrest Algorithm
5
• Establish IV access
• Obtain 12-lead ECG (when available) or rhythm strip
Is QRS narrow (<0.12 sec)?
Narrow
Wide (≥0.12 sec)
6
NARROW QRS*:
Is Rhythm Regular?
Regular
Irregular
7
• Attempt vagal maneuvers
• Give adenosine 6 mg rapid IV push. If no conversion, give 12 mg rapid IV push; may repeat 12 mg dose once
8
Does rhythm convert?
Note: Consider expert consultation
Converts
Does Not Convert
9
If rhythm converts, probable reentry SVT (reentry supraventricular tachycardia):
• Observe for recurrence
• Treat recurrence with adenosine or longer-acting AV nodal blocking agents (eg, diltiazem, β-blockers)
10
If rhythm does NOT convert, possible atrial flutter, ectopic atrial tachycardia, or junctional tachycardia:
• Control rate (eg, diltiazem, β-blockers; use β-blockers with caution in pulmonary disease or CHF)
• Treat underlying cause
• Consider expert consultation
11
Irregular Narrow-Complex Tachycardia
Probable atrial fibrillation or possible atrial flutter or MAT (multifocal atrial tachycardia)
• Consider expert consultation
• Control rate (eg, diltiazem, β-blockers; use β-blockers with caution in pulmonary disease or CHF)
12
WIDE QRS*:
Is Rhythm Regular?
Expert consultation advised
Regular
Irregular
13
If ventricular tachycardia or uncertain rhythm
• Amiodarone 150 mg IV over 10 min Repeat as needed to maximum dose of 2.2 g/24 hours
• Prepare for elective synchronized cardioversion
If SVT with aberrancy
• Give adenosine (go to Box 7)
14
If atrial fibrillation with aberrancy
• See Irregular Narrow-Complex Tachycardia (Box 11)
If pre-excited atrial fibrillation (AF + WPW)
• Expert consultation advised
• Avoid AV nodal blocking agents (eg, adenosine, digoxin, diltiazem, verapamil)
• Consider antiarrhythmics (eg, amiodarone 150 mg IV over 10 min)
If recurrent polymorphic VT, seek expert consultation
If torsades de pointes, give magnesium (load with 1-2 g over 5-60 min, then infusion)
*Note: If patient becomes unstable, go to Box 4.
During Evaluation
• Secure, verify airway and vascular access when possible
• Consider expert consultation
• Prepare for cardioversion
Treat contributing factors:
– Hypovolemia
– Hypoxia
– Hydrogen ion (acidosis)
– Hypo-/hyperkalemia
– Hypoglycemia
– Hypothermia
– Toxins
– Tamponade, cardiac
– Tension pneumothorax
– Thrombosis (coronary or pulmonary)
– Trauma (hypovolemia)

THANK YOU