

ElectroCardioGram Notes

Normals

P wave (atrial depolarization): 0.06-0.10 sec, < 2.5 mm in height; ↑ - I, II, aVF, aVL, V4, V5, V6 (II should have tallest P wave, therefore, with NSR P wave axis is about +60°); ↓ - aVR; biphasic - III, V1; isoelectric - III, aVL

PR Interval (AV conduction): 0.12 - 0.20 sec (3-5 mm or 3-5 small boxes)

Q wave (interventricular septum [septal] depolarization): initial negative deflection of QRS, normal - I, aVL, V5, V6; small Qs may be seen II, III, aVF, V4

QRS Terminology: Q - initial negative deflection, R - initial positive deflection, r - small R wave, S wave - negative deflection following an R wave, s - small S wave, R' - second positive deflection, r' - small second positive deflection, QS - no positive deflection with QRS complex

QRS (ventricular depolarization): 0.05 - 0.10 sec; ↑ - I, II, V5, V6; ↓ - aVR, V1; transition zone (QRS turns positive) - V3 (normal R wave progression); ↑ or ↓ - aVL, aVF, III; left chest leads height < 27 mm; generally tallest in V5; V1 - rS (R wave generally increases and the S wave generally decreases from V1-V5)

Abnormal Q: ≥ 0.04 sec; > 25% of height of following R; any Q in V1, V2, V3

ST Segment: from conclusion of ventr. depolarization to start of ventr. repolarization

J Point: where end of QRS meets the beginning of the ST interval

T wave (ventricular repolarization): ↑ - I, II, V5, V6; ↓ - aVR; may be inverted - III, aVF, aVL, V1; abnormal ↓ T's: ischemia, subendocardial MI, LVH - V5/V6, LBBB, WPW, PM; T wave axis generally parallels QRS axis

QT Interval (ventr. depolarization and repolarization): 0.34 - 0.42 sec or 40% of RR interval; ↑HR → shorter QT interval (100/min - 0.31 ± .04 sec, 90/min - 0.32 ± .04 sec, 80/min - 0.33 ± .04 sec, 70/min - 0.36 ± .05 sec, 60/min - 0.38 ± .05 sec); QTc = QT (measured) / √RR (sec)

U wave (ventr. repolarization - final phase): small deflection occasionally seen after T wave, generally in same direction as T wave; ↑ - hypokalemia, phenothiazines, quinidine, CVA; ? ↓ - ischemia / LVH

Axis: -30° → +100° (normal)

EKG Paper (25 mm/sec); small box = 0.04 sec = 1 mm; dark large box = 0.20 sec = 5 mm

Rate (✓ RR intervals, ? regular): Tachycardia > 100/min, Bradycardia < 60/min

Large Box or 5 mm Intervals: 1 large box (5 mm) → 300/min (250, 214, 187, 167 - 1mm intervals afterwards); 2 → 150/min (136, 125, 115, 107); 3 → 100/min (94, 88, 83, 79); 4 → 75/min; 5 → 60/min; 6 → 50/min; 7 → 43/min; 8 → 38/min; 9 → 33/min; 10 → 30/min.

Bradycardias = (# of beats per 6 sec/strip x 10) where 6 sec/strip = 2 marked 3 sec cycles, where 3 sec cycles = 15 dark large boxes

Pacemakers: SA or sinus node: 60 - 100/min, Escape rates following sinus arrest: atrial - 60-75/min, junctional (AV junction near AV node): 40 - 60/min, ventricular: 25 - 40/min.

Rhythm (✓ P and QRS locations, ✓ PR interval, ✓ QRS-? wide ? regular)

1. **Normal Sinus Rhythm, NSR** (60 - 100/min): P-P and R-R intervals stable (identical atrial and ventricular rates), similar P before QRS in each lead. Expect positive P in II, and a negative P in aVR with average P axis of +60°.

2. **Sinus Tachycardia, ST** (>100/min, generally < 150-160/min, if rate > 150-160/min may be difficult to distinguish from PSVT [ST has no response to carotid massage or adenosine] or AFlutter with 2:1 block, TC > 160/min is generally not sinus TC): normal P waves / normal PR intervals (PR may be shortened with increasing rate); **DDx** - fever, dehydration, hypovolemia (fluid loss, bleeding, 3rd spacing...), shock, infections, sepsis, hypoxemia, pericarditis, anxiety, pain, thyrotoxicosis, acute pulmonary embolism, CHF, acute MI, anemia, withdrawal (narcotics, benzodiazepines, alcohol...), meds (theophylline, catecholamines, caffeine, cocaine, stress, catecholamines or catecholamine induced physiological response - sympathetic activity [see above], exercise, beta agonists, isoproterenol, atropine, nicotine), pericardial tamponade, LV dysfunction; **Rx** - treat underlying cause, ? beta blockers; prolonged ST may extend myocardial injury with ACS / MI

3. **Sinus Bradycardia, SB** (< 60/min): normal Ps with each QRS / regular rhythm / normal narrow QRS; most common bradyarrhythmia with acute MI (especially inferiorly); **DDx** - athletes, normal young adults (40-60/min), physiologic, vagal stimulation (carotid massage, vomiting, valsalva, diving reflex - face in cold water...), carotid sinus hypersensitivity, meds (beta blockers, calcium channel blockers, digoxin, procainamide, amiodarone, flecanide, sotalol, clonidine, cimetidine), acute MI (esp. inferior wall), hyperkalemia, hypoxemia / respiratory failure - arrest, hypothyroidism, jaundice, hypothermia, increased intracranial pressure, sick sinus syndrome, sleep apnea syndrome; **Rx** - stop appropriate meds / atropine / epinephrine / PM

4. **Sinus Arrhythmia:** similar P's, normal P QRS T waves, variable rhythm, varies with respiration (increases with inspiration / decreases with expiration), not pathological - usually asymptomatic, variable P-P interval (change in P-P interval > 0.16 seconds, i.e. the shortest R-R interval is less than the longest R-R interval by 4 small blocks or less), via vagal activity, generally in children and elderly (may be related to digoxin)

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5. **Sick Sinus Syndrome (SSS)**: degenerative alterations of SA node leading to SA node dysfunction (may be transient); May present with brady - tachyarrhythmias (can be alternating) / sinus arrest / SA block / junctional escape rhythms. AFib may be present. **Symptoms** include syncope / lightheadedness / dizziness / palpitations with tachycardias / altered mental status. **Associated with** elderly, CAD, previous MI, myocarditis, pericarditis, cardiomyopathies (dilated, infiltrative), connective tissue dis., rheumatic heart dis., cardiac surgery, antiarrhythmic meds. May need PM for Rx.
6. **Ectopic Escape Rhythms** (follows sinus pause): atrial, AV nodal, ventricular
7. **Premature Atrial Contraction (PAC or APC) / Atrial Premature Beat (APB, atrial ectopic beat)**: appears early, \pm abnormal P wave, generally normal QRS, not from SA node, very early PACs may be nonconducted and cause a pause, may be superimposed on preceding T wave. Generally interrupts a sinus rhythm. **Associated with** caffeine, alcohol, stress, fatigue, smoking, CAD, MI CHF, COPD, valvular pathology, hyperthyroidism, digoxin, hypokalemia, normal ECG finding, infection / sepsis, enlarged atria (cor pulmonale, MV pathology), or normal finding.
8. **AV Nodal Premature Contraction (AV Node ectopic beat), Junctional Premature Beat (JPB), Junctional Premature Contraction (JPC or PJC)**: generally normal QRS, negative (inverted) or absent P wave. Short PR interval if present. Generally interrupts a sinus rhythm. **Associated with** - see PAC / APCs.
9. **Wandering Atrial Pacemaker (WAP)**: 3 or more different P waves (beat originates from different supraventricular sites), normal narrow QRS complexes, variable PR and RR intervals, atrial rate 60-100 / min; **Associated with** COPD, mitral / tricuspid pathology.
10. **Multifocal Atrial Tachycardia (MAT)**: 3 or more different P waves, normal QRS complexes, variable PR and RR intervals, atrial rate 100-130 / min; **Associated with** COPD, CHF, hypoxia, digoxin or aminophylline toxicity, CAD elderly.
11. **Atrial Flutter, AFlutter**: atrial rate 200 - 350 - 400/min, saw tooth pattern (best seen in leads II, III, aVF - inferior leads), common ventricular rate \rightarrow 150/min (2:1 block with atrial rate 300/min), absent P waves, flutter (F) waves - abnormal atrial depolarization, narrow QRS with normal ventricular conduction, ?stable R-R interval with constant conduction ratio (2:1, 4:1, ...); **Associated with** CAD, MI, hyperthyroidism, pericardial pathology, valvular pathology (MV most common), acute pulmonary embolism, SSS, COPD, congenital heart pathology, organic heart disease, alcoholism; ? Caused by intra-atrial reentry mechanism. 1:1 conduction is not common but may occur with antiarrhythmic Rx without AV nodal blockers.
12. **Atrial Fibrillation, AFib**: highly irregular rhythm (check palpable pulse), irregular R-R intervals, no discernible P waves, normal QRS unless ventricular conduction is pathological, mildly irregular chaotic baseline, underlying atrial rate at 300-600/min with variable ventricular response rate (brady \rightarrow tachycardia [40-200/min]); **Associated with** CAD, S/P MI, CHF, mitral valve pathology (rheumatic, stenosis, regurgitation leading to left atrial enlargement), hypoxemia, pericarditis, acute pulmonary embolism, chronic hypertension, post op cardiac surgery / thoracotomy, organic heart disease, cardiomegaly, cardiomyopathy, alcohol (holiday heart - acute, chronic), thyrotoxicosis, aminophylline / theophylline, catecholamines, pheochromocytoma, increased risk in elderly esp $>$ 80 years (10%), sick sinus syndrome, chronic lung disease; **Presents with** palpitations, hypoperfusion symptoms (exacerbated by rapid ventricular response / significant tachycardia / loss of atrial kick contribution to stroke volume), dizziness, chest pressure / pain / angina, dyspnea / SOB / PND / orthopnea, syncope, systemic embolization secondary to increased risk of atrial thrombi (stroke, focal neuro deficit...); Patients with significant MV pathology and LA enlargement may have difficulty converting to NSR and have significant increased risk of stroke. **Initial work up** includes CBC, PT / aPTT / INR, K, Mg, Ca, Phos, TFTs, CXR, D dimers, 2D ECHO, med levels (digoxin, theophylline, procainamide...)
13. **PAT (Paroxysmal Atrial TC)**: P's identifiable, narrow QRS, 150 - 250/min, intermittent burst of activity, ectopic pacemaker in atria
14. **PSVT (Paroxysmal Supraventricular TC)**: 120 - 250/min; narrow QRS ($<$ 0.10 sec); Wide QRS complex ($>$ 0.10 sec) may exist with pre-existing bundle branch block, tachycardic induced bundle branch block, or with ventricular pre-excitation with tachycardia; \pm P waves - may be hidden in QRS complex. May present with palpitations, chest pain / pressure / angina / CHF, lightheadedness, syncope, weakness. Episodes may be brief or sustained.
- a. **Atrioventricular / AV Nodal Re-entrant TC (AVNRT)**: dual AV nodal pathways; P wave typically buried in QRS. Conduction pathways have varying refractory periods and conduction velocities.
- b. **Atrioventricular / AV Re-entrant TC (AVRT)**: accessory AV pathway
WPW Syndrome: PR $<$ 0.10 - 0.12 sec, delta wave at beginning of QRS, QRS \geq 0.12 sec, ? ST or T wave abnormalities; anterograde conduction via accessory AV pathway.
- c. **Accelerated Junctional TC**: \uparrow automaticity of AV junction; inverted P waves in II, III, aVF (may be antegrade, retrograde, or buried); R/O critical illness, digoxin or theophylline toxicity, thoracic surgery, myocarditis, MI, hypokalemia.
15. **PVC, Premature Ventricular Contraction (ventricular ectopic beat)**: early wide QRS, no P wave, ST and T waves slope opposite to QRS, generally followed by compensatory pause; Note - danger with PVC on T (R on T phenomenon with increased risk of VT or VFib). Originates below AV node. May be asymptomatic or cause palpitations or dizziness. **Associated with** hypokalemia, hypomagnesemia, digoxin toxicity, stress, physical exertion, 2

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caffeine, smoking, myocardial ischemia, CAD, MI, hypoxemia, hypercalcemia, fatigue, anxiety, sympathomimetic meds, valvular pathology, organic heart dis., congenital heart dis., cardiomyopathy, primary cardiac dysfunction, S/P reperfusion, cardiac procedures esp. with catheters contacting endocardium; **Couplet** - 2 consecutive PVCs.

16. **Multifocal or Multiformed PVC's**: different morphology PVC's in same strip, ? ↑ risk.

17. **Bigeminy (coupled beat)**: (Sinus beat → PVC) → (sinus beat → PVC)

18. **Trigeminy**: (Sinus → sinus → PVC) → (sinus → sinus → PVC)

19. **Ventricular TC, VTach, VT**: ≥ 3 PVC's in a row, broad QRS rhythm at rate of 100 - 250/min, no P waves; Increased chance of wide complex TC being VT with capture or fusion beats, AV dissociation, LAD, precordial concordance; QRS ≥ 0.14 - 0.16 sec; V1 with R-S wave or R-S-r'. **Associated with** MI, ischemia, digoxin, hypokalemia, hyperkalemia, hypomagnesemia, organic heart disease, myocarditis, endocardial stimulation via mechanical device, cardiomyopathy (esp dilated), reperfusion, sarcoid

20. **Torsades de Pointes**: twisting of QRS, prolonged QT interval (increased risk - see Special Conditions), may progress to VFib.

21. **Accelerated Idioventricular Rhythm, AIVR**: wide QRS, 50 - 100/min, no conducted P waves; **Associated with** inferior wall MI, reperfusion arrhythmia (spontaneous or with thrombolytics), warm up period, fusion beats; generally not sustained.

22. **Ventricular Fibrillation, VFib**: extremely irreg. baseline, no discernible beats, BP = 0.

Blocks (✓ PR interval, ? QRS with each P, ✓ PP and RR intervals, ? wide QRS, R-R'/R-S-R' in V1, V2 or V6; ✓ axis)

1. **First Degree (1°) AV Block**: PR interval > 0.21 sec, regular R-R interval, all P's associated with QRS

2. **Type I 2° AV Block, Mobitz Type I, Wenckebach**: increasing PR interval until QRS dropped, irregular RR interval, usually benign, usually 3:2 4:3 or 5:4; **Associated with** digoxin, inferior MI / myocardial ischemia, increased vagal tone, myocarditis, athletes, normal

3. **Type II 2° AV Block, Mobitz Type II**: QRS dropped without increasing PR interval (PR interval constant), PP interval regular, block usually below bundle of His, increased clinical risk / progression to complete heart block. **Associated with** acute MI (anterior, inferior), sick sinus syndrome, digoxin, calcium channel blockers, beta blockers. May need PM.

4. **Third Degree AV Block, Complete AV Block (no conduction from atria to ventricles)**: atrial (P's) and ventricular beats (QRS) are independent, stable PP and RR intervals while P and QRS rates are different, width of QRS depends on location of escape PM, usual rate 40 - 60/min. **Associated with** acute MI, med toxicity (digoxin, calcium channel blockers, beta blockers), post cardiac surgery, SSS (conduction degeneration), myocarditis, congenital

5. **RBBB**: RR' / RSR' / rSR' in V1 or V2 ≥ 0.12 sec with possible ST depression and flipped T waves; (incomplete RBBB RR' < 0.12 sec), wide S - I, aVL, V5, V6; may be benign, possible T wave changes.

6. **LBBB**: R-R' (no Q or S) / rSR' in I, aVL, V5 and V6; QRS ≥ 0.12 sec (incomplete LBBB with QRS 0.10-0.12 sec); wide deep S (QS or rS) in V1 - V2; no R-S-R' in V1; possible T wave changes; ± LAD; ST interval and T wave direction opposite to QRS; difficulty diagnosing infarct or ventricular hypertrophy when present.

7. **Left Anterior Hemiblock, Left Anterior Fascicular Block (LAFB)**: LAD, QRS 0.10 - 0.12 sec, small Q / tall R (qR) in I and aVL; small R / deep S (rS) in II, III, and aVF, no infer MI.

8. **Left Posterior Hemiblock, Left Posterior Fascicular Block (LPFB)**: RAD; QRS 0.10 - 0.12 sec; S (rS) in I; qR in II, III and aVF

9. **Bifascicular Block**: RBBB + LAFB, or RBBB + LPFB, RBBB or LBBB + 1° AVB, RBBB alternating with LBBB

Axis (direction of QRS depolarization) - evaluate I, II, III, aVR, aVL, aVF (frontal plane leads)

Normal: -30° → +100°

Left Axis Deviation (LAD): -30 → -90; **Associated with** LVH, LAFB, MI, aging, LBBB, endocardial PM

Right Axis Deviation (RAD): +100 → +180;

Associated with pulmonary HTN, acute pulmonary embolus, COPD (emphysema, chronic bronchitis), RVH, MI (lateral wall of LV), LPFB, epicardial PM, congenital heart disease (tetralogy of Fallot, ASD,...), pulmonic stenosis

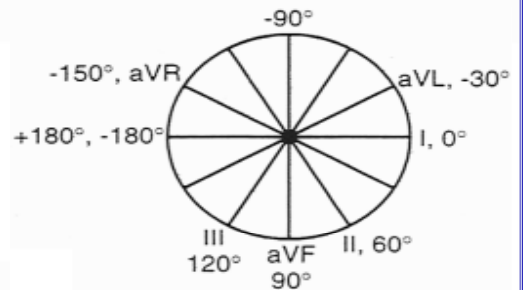
Indeterminate or Extreme Axis Deviation: -90° → -180°

Axis Determination:

1. Evaluate I and aVF for a fast rough estimate of QRS axis: (normal: +I, +aVF; LAD: +I, -aVF; RAD: -I, +aVF; indeterminate / extreme RAD: -I, -aVF).

2. Find isoelectric (biphasic) lead and QRS axis is at 90°, and is directed towards the leads with the tallest positive R waves.

3. The average QRS axis is directed half way between the two equal tallest R waves.



Hypertrophy

1. **Right Atrial Abnormality (RAA)**: tall P > 2.5 mm in height in II (P pulmonale), (may be also in III and aVF); large diphasic P wave with tall initial part in V1, P wave < 0.12 sec (normal width); **Associated with** acute and chronic pulmonary disease, congenital heart disease (ASDs, pulmonic valve stenosis, malformed tricuspid valve - Ebstein's abnormality), RVH

2. **Left Atrial Abnormality (LAA) / Left Atrial Enlargement (LAE)**: biphasic P in V1 with large terminal downward phase; M shaped P (P mitrale) in I, II or aVL; P ≥ 0.12 sec in width; **Associated with** chronic hypertension, CAD, heart valve pathology (AS, AR, MS, MR), cardiomyopathies

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3. **Right Ventricular Hypertrophy (RVH):** RAD; R > S in V1; R > 5 mm in V1 and aVR; decreasing R wave V1 → V4 (reversing of normal R wave progression); ST depression and flipped T's V1 - V2 (RV strain pattern), S > R in V6, ? RAA, ?incomplete RBBB; **Associated with** congenital heart disease (ASD, T of Fallot, PS...), chronic pulmonary disease

4. **Left Ventricular Hypertrophy (LVH):** LAD without LBBB or LAHB; deepest S in V1 or V2 plus largest R in V5 or V6 ≥ 35 mm; tallest R in V1 - V6 ≥ 27 mm; R in aVL ≥ 12 mm; possible ST depression and flipped T waves in I, aVL, or aVF, V5, V6 (LV strain); ? LAA; ?QRS 0.09 - 0.12 sec; **Associated with** hypertension, aortic stenosis, intravascular fluid overload, dilated cardiomyopathy, AR, MR. LVH may increase cardiovascular risk.

Ischemia, Injury, Infarct / MI Location

Ischemia / angina is associated with flat or inverted symmetrical T waves and/or ST depression. Infarct and injury are represented by ST segment elevation (< 48 hours old) or depression (reciprocal leads). Q waves indicate infarction (acute and old), although tiny Q waves (< 0.04 sec) may be normally seen in I, II, aVL, V5 and V6. Days to weeks after MI, ST segment elevation is gone, but T waves may be inverted. Weeks to months to years later, only significant Qs may persist and Ts are upright. LBBB complicates the diagnosis of acute MI.

Anterior (LAD): ↑ ST and Qs (V1-V4), ↓ ST - reciprocal changes (II, III aVF), ?PRWP

Anteroseptal (LAD): ↑ ST and Qs (V1-V2), generally no reciprocal changes

Extensive Anterior / Extensive Anterolateral (LAD or left main): ↑ ST and Qs (V1-V6, I, aVL), ↓ ST - reciprocal changes (II, III aVF)

Inferior (RCA, circumflex): ↑ ST and Qs (II, III, aVF), ↓ ST - reciprocal changes (I, aVL, anterior - V leads), within 1 year after acute MI 50% may lose Q waves

Lateral (circumflex): ↑ ST and Qs (I, aVL, V5, V6), ↓ ST - reciprocal changes (II, III aVF)

Posterior (RCA, circumflex): ↑ ST and Qs (not present - no post. leads), ↓ ST / ↑ T / tall R waves - reciprocal changes (anterior V1-V3, esp. V1), may be signs of inferior or lateral MI

DDx ST elevation — myocardial injury / infarct (MI), pericarditis, ventricular aneurysm, Prinzmetal's angina (coronary artery spasm), LBBB, early repolarization, hypothermia; J point elevation (early repolarization) may be normal with children, black men, or young adults.

DDx ST depression — ischemia / angina, subendocardial MI, digoxin, LVH, RVH, TC's, strain, hypokalemia, hypomagnesemia, WPW, critical anemia, BBB's.

Special Conditions

1. **Amiodarone:** prolonged PR / QRS / QT intervals, bradycardia
2. **Brugada Syndrome:** RBBB pattern with ↑ ST and ↓ Ts in V1-V3, increased risk of sudden cardiac death.
3. **COPD:** RAD (negative Lead I), low voltage, P pulmonale (RAE), ± RBBB, PRWP
4. **CVA:** tall or inverted or wide T waves, Q waves, u waves, prolonged QT
5. **Digoxin Effect:** downward curve of ST segment with ? flat / inverted T waves; short QT
6. **Digoxin Toxicity:** SA Block, AV Blocks, variable TC's, junctional TC's, PVC's, bigeminy, trigeminy, VT, VFib
7. **Hypercalcemia:** short QT
8. **Hyperkalemia:** peaked T's, wide → flat P, wide QRS, prolonged PR absent P, sine waves, arrhythmias, asystole - cardiac arrest
9. **Hyperthyroidism:** sinus TC, enlarged amplitudes with thyrotoxicosis.
10. **Hypocalcemia:** prolonged QT
11. **Hypokalemia:** flat or ↓ T waves, U waves, U > T waves, ST depression, tachyarrhythmias
12. **Hypothermia (<36° C):** prolonged intervals (PR, QRS, ST, QT), Osborn waves
13. **Hypothyroidism:** sinus BC, low voltage, ST depression, flat or inverted T waves.
14. **Low Voltage DDX:** obesity, COPD, pericarditis, hypothyroidism, pleural effusions, pericardial effusion / tamp., extensive MI, myocardial infiltration (fibrosis, amyloidosis), normal
15. **Pericarditis:** flat or concave ST elevation (precordial and ? limb leads), ± low voltage, ± inverted T waves.
16. **Pulmonary Infarct / Embolus:** large S - I, Q - III, RAD, ± RBBB, variable ST or T wave changes, sinus TC
17. **QT - Prolonged DDX:** hypomagnesemia, hypocalcemia, hypokalemia, tricyclic antidepressants, phenothiazines, acute MI, antiarrhythmic agents (amiodarone, sotalol, dofetilide, ibutilide, azimilide, procainamide, quinidine), antifungal azoles, macrolides, congenital, CVA, hypothermia, hypothyroidism
18. **Wide QRS DDX:** BBBs (RBBB, LBBB...), ectopic ventricular beats, WPW, hyperkalemia, procainamide, flecanide, quinidine, tricyclic antidepressants, phenothiazines

Individual patient clinical correlation required. Obtain cardiology consults when appropriate.