Adult Electrocardiogram (ECG) Notes

ECG lead placement

Standard limb leads: RA, LA, RL, LL
Chest leads: V1-4icsRSE, V2-4icsLSE, V3-half way V2-V4, V4-5icsmcl, V5-5icsaal, V6-5iccsmal
Extra leads: V3R-V6R as for V3-V6 but on right side, V7-9 at 5icspal & then spaced at 2cm intervals.
Misplaced: If leg switched with arm lead, the ECG will seem very strange except in the V leads. There may be extreme axis deviation. If the L & R arm leads are reversed → dextrocardia pattern in limb but not chest leads

Identification

- Patient name, date and time of recording.

Quality and calibration

- Should be a square wave calibration to show that 1mV = 1cm in height.
- Speed should be 25mm/sec. 1 large square = 200msec and 1 small square = 40msec.

Rate

- Ideally on the rhythm strip (lead II).
- Rate (6 x No. complexes in 10s strip or 300/[R-R dist in large sq.])
    - Normal: 60-100bpm in adults. (Variable: 60-160 for children.)
    - Bradycardic: <60bpm or Tachycardic: >100bpm
    - Junctional: 40-60bpm (accelerated if 60-100bpm, junctional tachycardia if >100bpm)
    - Idioventricular or escape: 30-40bpm (accelerated if 40-110bpm, VT if >110-120bpm)

Rhythm

- Sinus? – Each P has a QRS following & every QRS has a preceding P with normal axis.
- Irregular? – ectopics, 2nd deg block, irregular brady- & tachycardias (see below)

Axis (QRS)

- Normal: -30 to 90°(some say 0-120°). Use I & aVF to vector QRS axis.
- LAD: LVH, LAFB, inf MI, primum ASD, ventricular ectopy, paced, WPW(B), emphysema, hyperK,
- RAD: RVH, LPFB, lat MI, secundum ASD, ventricular ectopy, paced, WPW(A), PE, COPD, ASD, Na channel blockers, normal in the young or slim adults, dextrocardia.
- Far left/right ("Northwest") axis: Emphysema, hyperK, lead transposition, pacing, VT

P wave

- Normal P axis if upright in I & inf leads
- Inverted in I or inf leads: ectopic atrial focus, junctional rhythm
- Small amp in hyperkalaemia
- Peaked/Pulmonale: >2.5mm in inf leads – COPD
- Bifid/Mitrale: duration>120ms or biphasic/neg term deflection in V_1
- Multiple morphologies: >3 shapes = wandering pacemaker or MAT
- Sawtoothed (esp II, V_1): Atrial flutter rate of ~300, usually with 2:1 or more block
- Retrograde: Common in SVT or a junctional rhythm

PR interval/segment

- Normal: 120-200ms (3-5 small sq.) - depolarisation of atria
- Short: HOCM, accessory pathways – WPW (δ wave), Lown-Ganong-Levine (no δ wave)
- Long: 1st degree block (constant), Mobitz I 2nd degree [Wenckebach] (lengthening)
- Depressed segment: Pericarditis (elevated in aVR), ??infective endocarditis affecting valve ring

QRS

- Normal duration: 80-120ms (2-3 small sq.). 110-120ms in incomplete BBB
- Broadened (>120ms): BBB & other aberrant intraventricular conduction, ventricular ectopy, paced, hyperK, Na channel blockers (e.g. TCA, CCB, venlafaxine, Ia, Ic antiarrhythmics, propanolol).
- Delta wave – pre-excitation in WPW
- Low amplitude (<5mm all chest leads, <10mm all limb leads): pericardial effusion, COPD, obesity, pulm oedema, myxoedema, end-stage cardiomyopathy, constrictive pericarditis, hypoNa

Q

- Pathological: ≥25% R wave or >1mm small square wide & deep – AMI, HOCM. Isolated Q in III: ?normal.

Bundle Branch Blocks

Unifascicular

- RBBB: MaRRoW – Broad/upright QRS, RSR (2^{nd} R higher) or qR in V_1. Wide/slurred S in I & V_6. Normal axis
- LAFB: rS in inf leads + LAD.
- LPFB: rS In ant leads + RAD (without any other cause).

Bifascicular

- Combination of RBBB+LAFB or RBBB+LPFB: the left fascicular QRS axis deviation is dominant.
- LBBB: WiLLiaM – Wide S in V_1. Broad M or pyramid shaped R in I & V_6. Loss of usual small Q-wave in the left-ventricular leads (I, aVL, V5 and V6). May have LAD, RAD, superior or normal axis.

Trifascicular

- Bifascicular block + 1^{st} degree block.

R

- LVH – R_I>15mm, R_{aVL}>11mm, S_{V1}+$R_{V5\ or\ V6}$>35mm, Σ(all R waves)>175mm
- V_1 R>S / R>5mm: RVH, RBBB, PE (RV strain), WPW (A & C), post MI, HOCM, dextrocardia, ectopy
- Electrical alternans: common in tachyarrhythmias. If in SR → ?pericardial effusion.
- Poor R wave progression: R_{V3}<3mm: prev antsep MI, LVH, norm variant, leads placed high

ST

- Elevation:
  - Shape: Convex upwards: AMI, concave: pericarditis
  - Diffuse: Large MI, pericarditis, BER, ventricular aneurysm, coronary vasospasm.
  - V_1: LVH, LBBB, acute antsep MI, acute RV MI, Brugada syndrome, PE
  - Differentiating AMI, BER & pericarditis on ECG:

Feature	AMI	BER	Pericarditis
ST Shape	Convex up	Concave up	Concave up
Lead location of ST↑	Territory	Chest	Limb & chest
Reciprocal ST↓'s	Yes	No	No
Q waves	Yes	No	No
Loss R wave voltage	Yes	No	No
PR depression	No	No	Yes
ST↑/T height ratio in V6	N/A	<0.25	>0.25

- Depression: myocardial ischaemia, most specific if down-sloping, least if up-sloping.
- J or Osborn waves - pos deflection in terminal part of QRS complex: hypothermia, hyperCa, TBI, Brugada

T

- Peaked: acute ischaemia, hyperK, acute pericarditis, LVH, BER, BBB, WPW/LGL
- Flattened: non-specific, but may be ischaemia. hypoK
- Inversion: ?ischaemia, BBB, RV strain, SAH, hypoK, HOCM,LVH, stage III pericarditis. old/new.
- Arrow head: subendocardial MI, ICH
- Reverse tick – down-sloping ST + inverted T: digoxin effect

QT

- QTc: Bazett's formula: QT/(√(R-R)) all in seconds. Normal: 0.35-0.44
- Long: predisposes to torsade de pointes. Causes: congenital, hypoCa, hypoMg, ↑ICP, K^+ channel blockers (antipsychotics, Class IA, IC & III, TCA, antihistamines, citalopram, venlafaxine, bupropion, chloroquine, quinine, macrolides), hypothermia, hypothyroid, ischaemia, HOCM, acute myocarditis

U

- Prominent: HypoK (T-U fusion may appear to give long QT)
- Inverted: HyperK

Specific Conditions

Atrioventricular (AV) Dissociation

- Atria and ventricles beat independently of each other. There is no anterograde or retrograde conduction in complete AV dissoc, but in incomplete, or interference, AV dissoc some conduction does occur.
- The atrial rate may be faster (usually 3^{rd} deg block), equal to (isorhythmic) or slower than ventricular rate.
- Non-AV Block causes: non-paroxysmal junctional tachycardia (e.g. digoxin toxicity, sinus bradycardia with faster escape junctional rhythm or after cardiac surgery - esp valve related), VT, ventricular pacing, sinus node disease, MI, structural heart disease, hyperK, vagal activation, catecholamines, β-blockers, radiofreq ablation.

Bradycardias

Regular: Sinus, regular Mobitz II 2nd and 3rd degree heart blocks, junctional & idioventricular (escape) rhythms
Irregular: Sinus arrhythmia, wandering pacemaker, slow AF, Mobitz I 2nd degree block, sinus arrest, atrial ectopics

Tachycardias

Regular

- Narrow – ST, SVT, Atrial flutter
- Broad – VT, (SVT, ST, or Atrial Flutter) with aberrant conduction

Irregular

- Narrow – AF, Atrial Flutter with variable block, MAT
- Broad – VT, Torsade (polymorphic VT), AF + WPW, (AF, Atrial Flutter with variable block, or MAT) with aberrant conduction e.g. BBB

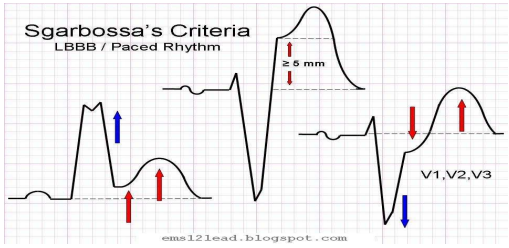
Myocardial infarcts

No LBBB:

- ST↑ ≥1mm in 2 contiguous limb leads or
- ST↑ ≥2mm in 2 contiguous chest leads

LBBB or with a paced rhythm: (Sgarbossa criteria)

- *5pt:* for ST elevation ≥1mm concordant with QRS (any lead)
- *3pt:* for ST depression ≥1mm in leads V1, V2 or V3
- *2pt:* for ST elevation ≥5mm (or ≥0.2xS depth) discordant with QRS
- *Score≥3pt*: 90% specific for AMI (20% sens)



Wall	ST Elevation	Reciprocal ST↓	Suspected Culprit Artery
Septal	V_1, V_2	None	LAD
Anterior	V_3, V_4	None	LAD
Anteroseptal	V_1, V_2, V_3, V_4	None	LAD
Anterolateral	V_3, V_4, V_5, V_6, I, aVL	II, III, aVF	LAD, LCX, or obtuse marginal
Anteroseptal + Lateral extension	V_1,V_2,V_3, V_4, V_5, V_6, I, aVL	II, III, aVF	LCA
Inferior	II, III, aVF	I, aVL	RCA, or LCX
Lateral	I, aVL, V_5, V_6	II, III, aVF	LCX or obtuse marginal
Posterior (true or with inf or lat)	V_7, V_8, V_9	V_1, V_2, V_3, V_4	PDA (RCA branch) or LCX
RV (± assoc with inf)	II<III, aVF, $V_{1±2}$, V_4R	I, aVL, ±V_{2-3}	RCA±LCX **NB: prox RCA if STE$_{V4R}$>1mm**

RCA 'TYPE' LESIONS ±

INFERIOR MI
STE: II, III, aVF
STD: aVL (reciprocal STE)
RCA occlusion distal to RV
58% of MI

Seek and exclude
INFERIOR AND RV MI
STE: II, III, aVF and V1, V4R
RCA occlusion proximal to RV
40% of Inferior MI
Increased mortality risk

INFEROLATERAL MI
STE: II, III, AVF and I, aVL, V5, V6 ± V4R
LAD and LCX occlusion in a L dominant system

INFEROPOSTERIOR MI
STE: II, III, AVF and V7-9
STD: V1, V2 (reciprocal STE)
R:S ≥ 1: V1-2
Tall T: V1-2
RCA and LCX occlusion

LCX LESIONS ±

POSTERIOR MI
STE: V7-9
STD: V1-2 (reciprocal STE)
R:S ≥ 1: V1-2
Tall T: V1-2
RCA and LCX occlusion

Seek and exclude
POSTEROLATERAL MI
STE: V7-9 and I, aVL, V5-6
STD: V1, V2
LAD and LCX occlusion

INFEROPOSTERIOR MI
STE: II, III, AVF and V7-9
STD: V1, V2 (reciprocal STE)
R:S ≥ 1: V1-2
Tall T: V1-2
RCA and LCX occlusion

LAD LESIONS

Combinations of the following

SEPTAL MI
STE: V1-2
LAD occlusion

ANTERIOR MI
STE: V3, V4
LAD occlusion

LATERAL MI
STE: V5, V6, I, aVL
LAD occlusion

Extra leads for Right Ventricular & Posterior AMIs

$V_{3,4±5,6}$ for ?RV MI if ST↑ in inf leads. Clues: hypoBP, ST↑ in V1, ST↑ III > II, ST↑ in V1, ST↓ in V_{2or3} > V_1

V_{7-9} for ?post MI if ST↑ in inf or lat leads & ST↓ V_{1-3} or R/S in V_{1or2}>1. Clues: hyperacute T↓ V_{1or2}, or later T↑ in V_{1or2}

Pulmonary Embolism

- Sinus Tachycardia
- $S_IQ_{III}T_{III}$
- RV strain – RAD, RBBB (may be incomplete), prominent R in aVR, peaked P in II.
- T↓ in V_{1-4} or non-specific ST & T changes.

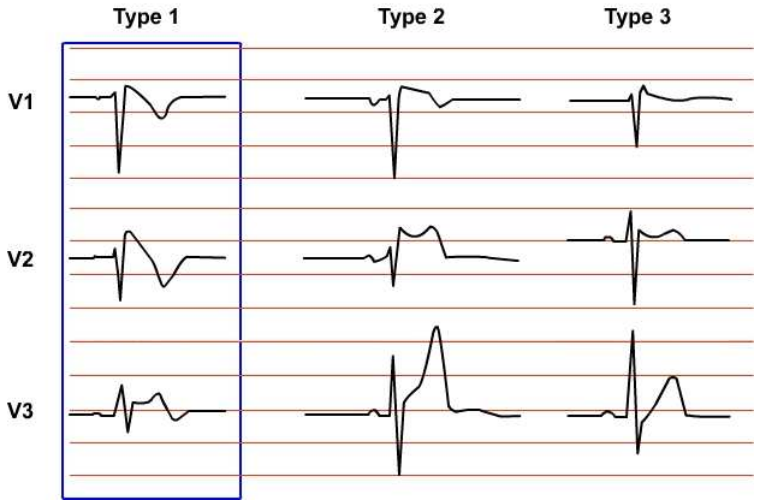
Hypertrophic Obstructive Cardiomyopathy (HOCM)

- Large amplitude QRS (LVH), LAE, deep, narrow ant, lat, inf lead Q's (confusingly called "septal Qs") with assoc upright T's (however giant T↓ may occur V_{5-6} in apical HOCM), tall R in V_{1-2}. May have WPW, AF, VT.

Other ischaemic ST/T patterns

Non-ST elevation (non-Q wave): ST↓ ±T↓ in ≥2 leads. (always check for ST↑ in reciprocal leads)
Coronary vasospasm: Prinzmetal's variant angina → widespread transient ST↑ segment elevations.
Stress-induced cardiomyopathy (tako tsubo): Marked by reversible wall motion abnormalities of the LV apex and mid-ventricle. Typically a post-menopausal woman who presents with chest, ST↑, and ↑Trp/CK mimicking an AMI.
Wellens' syndrome: Deep T↓ ($V_{1-4\pm5-6}$) or biphasic T pattern (usually $V_{2-3\pm1,4-6}$) in pain-free period after ischaemic chest pain ± minimal or no ↑ in Trp/CK or ST. All have >50% LAD stenosis with a high incidence of anterior MI. Inferior Wellens' – upward bowing of inf STs with symmetrically ↓T suggests very tight RCA.
Left main coronary artery occlusion: suggested by widespread ST↓ esp V_{4-6} with T↓, or ST↑ V_{2-6}, I+aVL, or ST↑ in aVR & aVL, or ST↑ aVR>V1
Pseudonormalization of T waves: Paradoxical T normalization in ECG with prev abnormal T↓

Brugada syndrome



- Rare syndrome of life-threatening tachyarrhythmias→sudden cardiac death (25-55yo).
- More common in Asian men.
- Related to cardiac sodium channel mutations on Chr.3 (SCN5A).
- Criteria: VF/polymorphic VT, FamHx sudden cardiac death <45yo, relations with typical ECG pattern, electrophysiologic inducibility of VT, unexplained syncope suggestive of a tachyarrhythmia, or nocturnal agonal respiration AND Brugada ECG pattern
- ECG shows - Pseudo-RBBB (no wide lateral S waves), J-wave≥2mm and persistent ST↑ in leads V_{1-3}.
- 3 patterns of ST have been described:
    - Classic Type 1: ST↑ (≥2 mm) descends with an upward convexity (coved) to a ↓T wave.
    - Types 2 & 3: "saddle back" ST-T wave configuration, ST↑ (≥1mm type 2, <1mm type 3) + upright/biphasic T.
- May be provoked by: pacing, vagal manoeuvres, drugs, incl sodium channel blockers, Li, flecainide, BB, nitrates, nicorandil, SSRIs, EtOH, fever, ↑↓K^+, ↑Ca^{2+}.
- Mx: AICD.
- Prognosis: 20% mortality at 2 yrs unless AICD inserted.

Pericarditis

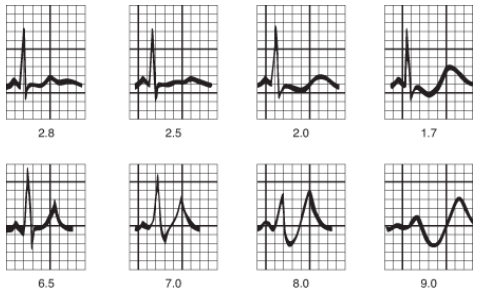
- Classically 4 stages: concave ↑ST in all but aVR & V1 ± PR depression, then transiently normal, followed by T↓ after days/weeks, finally resolution in months.
- May also be sinus tachy, ↓QTc, low amp if effusion & electrical alternans if tamponade.

Hypokalaemia

- Low amp T, prominent U, ST↓, PVCs, apparent long QTc, ventricular dysrhythmias.

Hyperkalaemia

- Peaked T, low amp P, broad QRS → sinusoidal, axis deviation, ↓U



Drug toxicity

- Digoxin:
    - Bradyarrhythmias: any atrioventricular block, slow AF.
    - Tachyarrhythmias: SVT, VEBs, bigeminy, VT
- Na channel blockade: Broad QRS, RAD of terminal QRS (term R_{aVR}>3mm, R_{aVR}/S_{aVR}>0.7), VT, VF, (bradys).
    - TCA, Class $I_{A\&C}$, phenothiazines, carbamazepine, propranolol, quinine, CCB, LA, cocaine, chloroquine

Dextrocardia

- I & aVL: inverted P, negative QRS. III & aVR: upright P & QRS. V_1 tallest R wave.

Paediatric Electrocardiogram (ECG) Notes

ECG lead placement

- Lead positions as for adults. Common to include a V_{3R} or V_{4R} lead if<5y, to detect RVH or RA hypertrophy.

Quality and calibration

- As for adults but occ use half-std gain or 2x paper rate used to clarify large QRS and very fast rates resp.

Rate

- Age-dependent normal ranges for heart rate, decreasing until >10yo. (See table)

Rhythm

- As for adults

Axis (QRS)

- Initial RV dominance is overtaken by LV which develops on exposure to systemic circulation over 1-3mo
- Hence initial RAD in neonate

P wave

- Amplitude<3mm & duration<70ms if ≤1y or <90ms >1y.

PR interval

- Varies with age & heart rate but roughly normal: 80-160ms (2-4 small sq.)
- Short: accessory pathways – WPW (δ wave if anterograde cond), rarely glycogen storage disease
- Long: 1st degree block (constant, hyperK, ASD, Ebstein's), Mobitz I 2nd degree [Wenckebach] (lengthening)

QRS

- Normal duration: see table
- Delta wave – pre-excitation in WPW

Q

- Normal if narrow (<30ms) or seen in inf (≤8mm) & lateral chest (≤5mm) leads
- Deep Q's suggest LVH. Presence of Q in V_1 suggests RVH.

R

- High amplitude (see table): ventricular hypertrophy, ventricular disturbances e.g. BBBs & WPW
  - LVH – LAD, tall R in V_{5-6} + deep S in $V_{1\ \&\ 4R}$. R/S ratio ↓ in V_{1-2}. Q in V_{5-6}. ↓T in I, aVL.
  - RVH – RAD, tall R in V_1, V_{4R} + deep S in V_{5-6}. R/S ratio ↑ in V_{1-2} or <1 in V_6. qR in V_1.↑T in $V_{1\ or\ 4R}$ 7d-7y
- Low amplitude: normal newborns, pericarditis, myocarditis, hypothyroidism

ST

- ST changes ±1mm (±2mm chest leads) is normal.
- J point depression + up sloping ST depression is normal
- BER common in adolescents

T

- 1st wk all chest lead T's upright ,from 7d to ~7y TV_{1-3} inverted (juvenile T-wave pattern) then upright again.
- T wave amp in V_5<11mm in infants, else <14mm. In V_6 these are 7 & 9mm respectively.

QT

- Shortens from <490ms when <6mo to <440ms > 6mo.

Normal Paediatric values:

(Considerable variation in some of these in published normal ranges)

Age	HR bpm	Axis mean (range) °	PR ms	QRS ms	R_{V1} mm	S_{V1} mm	R_{V6} mm	S_{V6} mm
Newborn	100-170	+135 (+60-170)	80-160	<70	<25	<20	<21	<12
1mo	100-170	+110 (+30-160)		<75	<25	<18-20	<20	<7-12
3mo	100-170	+70 (+10-125)		<75	<20	<18	<20	<7
6mo	100-170	+60 (+10-110)	70-150	<75	<20	<16-18	<20	<6
1y	100-160	+60 (+10-110)	70-150	<75	<18	<16-27	<20-24	<6
5y	70-120	+60 (+20-120)	80-160	<80	<18	<30	<24	<5
10y	60-105	+50 (-30-105)	90-170	<85	<16	<26	<24	<4

Arrhythmias

- Sinus arrhythmia common, but VT, VF, AF & A Flutter uncommon
- 90% dysrhythmias are SVT & 25% have CHD.
- Broad complex tachyarrhythmias more likely SVT+ aberrancy or AF+WPW
- 90% of SVT are re-entrant (~30% WPW). Other causes incl sinus tachy, atrial tachy & JET