SGR clinical guides

An approach to interpreting electrocardiograms (ECGs)

How to use this guide: when becoming familiar with a systematic approach to ECGs, it is best to practice and read through a few times with a few ECGs alongside (including some normal ECGs) and follow along as best as you can. A great resource for lots of interesting ECGs can be found here: https://litfl.com/ecg-library/. A great book we recommend reading is ***The ECG Made Easy (9th Ed)* by John Hampton** (especially its introductory chapters), of which much of this guide is adapted from. There are not many shortcuts to ECGs though, and the best way to learn after reading through this and other resources is repetition and practice.

Basics:

Components of the trace: a quick revision of the heart and its conduction pathways is recommended to better understand each part of the trace in better detail. To the right is a labelled trace with the main components of an ECG trace (Image 1.).

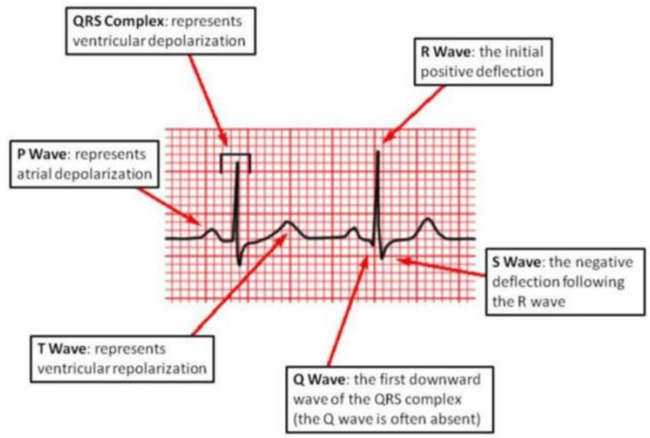


Image 1. The ECG trace and its basic components.

Leads: think of leads on an ECG not as single points in space connected to a wire, but as vectors (having both a direction and magnitude) of electrical activity – the line made between two ECG sticky dots on a person. Chest leads look at the heart in approximately the horizontal plane (Image 2.), while limb leads look at the heart in approximately the vertical plane (Image 3.). The ECG will trace an upwards stroke (positive deflection) in a particular lead if the depolarisation of the cardiomyocytes is moving *towards* that lead and conversely, it will trace a downwards stroke (negative deflection) in a particular lead if the depolarisation is moving *away* from that lead (Image 3.) Knowing these basic principles allows us to practice seeing a complete ECG not as just esoteric squiggles on a page, but as a short 10 second 3D video of the heart's electrical activity… or more simply ECG = heart_3D.*gif*. For the nerds who just want to relive their maths spec vector days, I have included a list of each lead and their component electrodes in Table 1. at the end of this document.

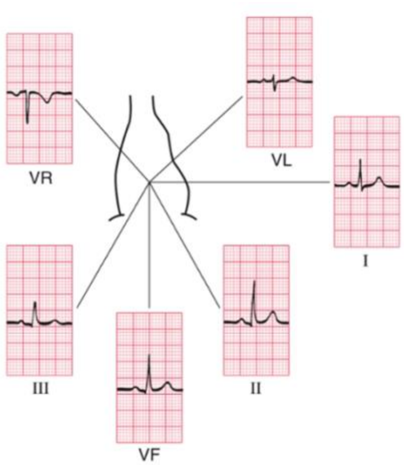


Image 2. Limb leads I,II,III, VR, VL, VF[1]

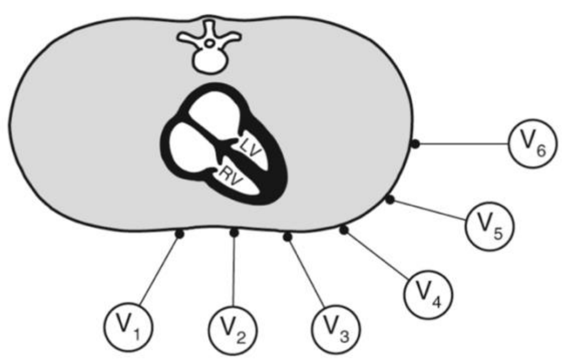


Image 3. Chest leads V_{1-6}[1]

Western Australian Medical Students' Society (WAMSS): Student Grand Rounds (SGR)
Last edited: 07/02/2021

SGR WAMSS
Medical student learning

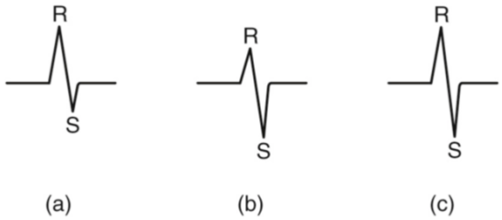


Image 4. Depolarization moving towards the lead, causing a predominantly upward QRS complex (a); depolarisation moving away from the lead, causing a predominantly downward QRS complex (b); and depolarisation moving at right angles to the lead, generating equal R and S waves (c).

Cardiac axis: cardiac axis describes the average direction of ventricular depolarisation in (approximately) the vertical plane. Because axis is concerned with the vertical plane, to estimate axis we can use the limb leads i.e. I, II, III, VR, VL and VF. Axis is technically measured in degrees, but when just eyeballing an ECG it is more practical to say whether the axis is deviated (towards the left or right side of the heart) or normal. A normal axis is approximately between -30° and +90° (Image 5.). A simple way to estimate cardiac axis is called the *quadrant method* by using leads I and VF (Image 6.). Because leads I and VF are vectors at right angles to one another, we look at how positive or negative their QRS complexes are to estimate the cardiac the axis. With this method there are four main scenarios (largely positive and negative deflections) (Table 2.):

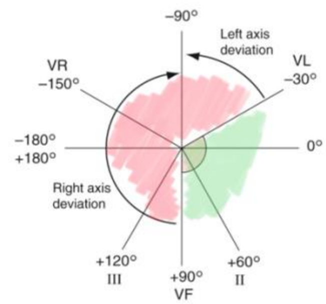


Image 5. Cardiac axis and corresponding limb leads.

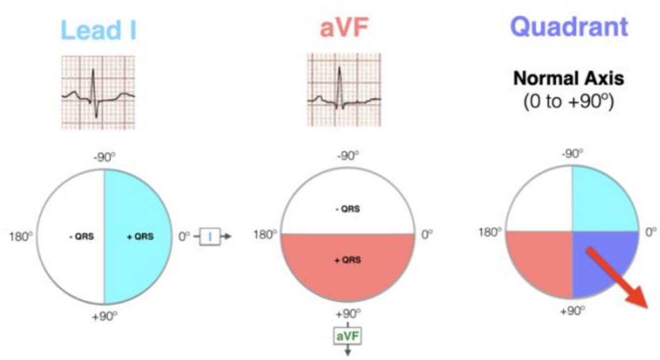


Image 6. *Quadrant method* for estimating cardiac axis

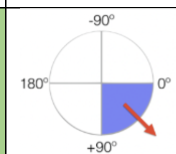
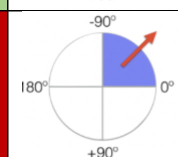
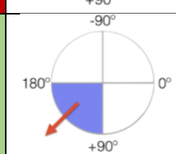
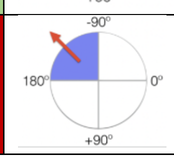
I	VF	Axis	
			Normal
			Possible left-axis deviation
			Right axis deviation
			Right axis deviation

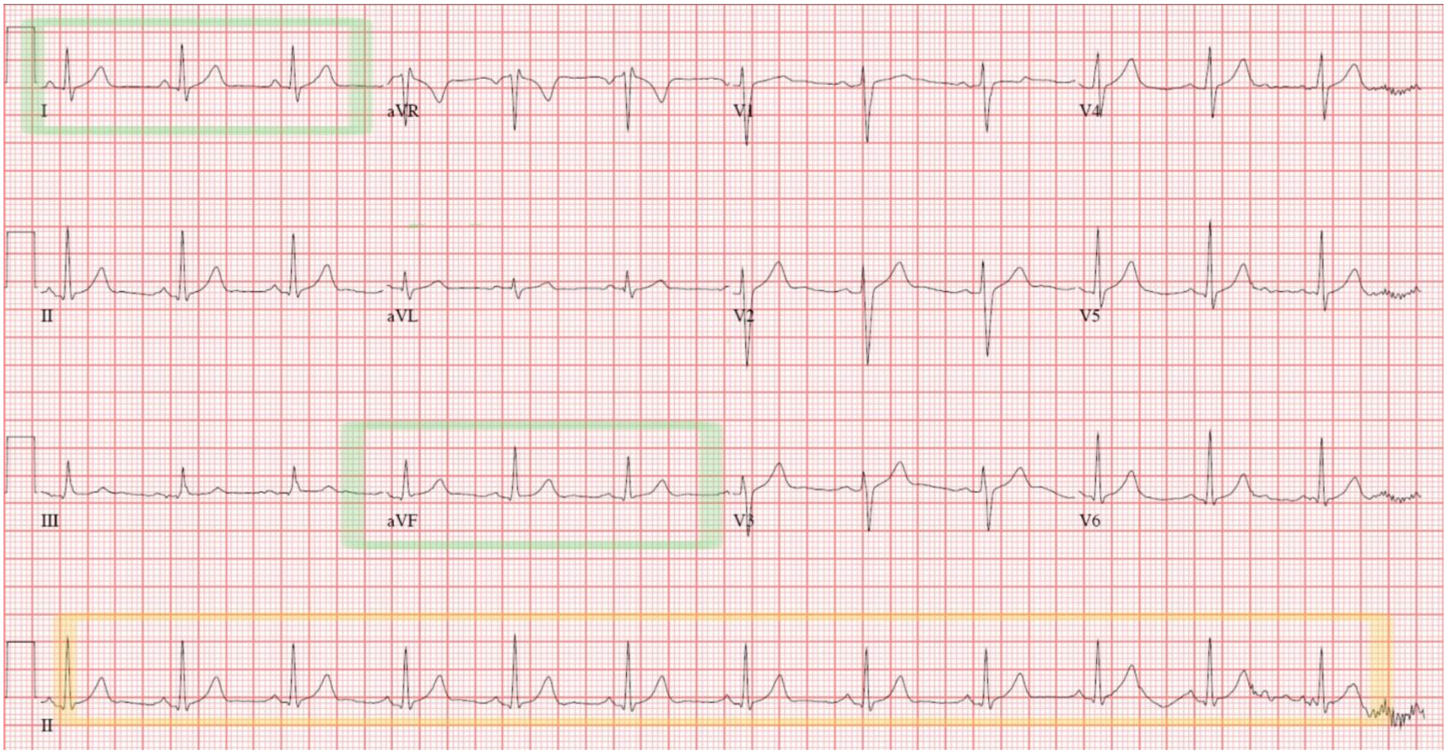
Table 2. Estimating cardiac axis.

There are many reasons cardiac axis is useful to assess. For example, cardiac axis may be deviated towards areas of ventricular hypertrophy or away from areas of ventricular ischemia. Additionally, because various types of heart block affect how the ventricles contract, this can also affect cardiac cardia axis.

Note: this method has its obvious limitations but should be mostly sufficient for use outside of a cardiology placement. For other methods of estimating cardiac axis see recommended readings at the start of this document.

Reading the ECG: you now know theory of how an ECG captures the movement of electricity through the heart to create vectors called leads, that allow use to see the heart's 3D conduction over a short period of time. But now you're handed that off-white bit of paper with pink and scribble all over it; where do you start?

Parts of the ECG:



Rate and rhythm: use the "rhythm strip" (the long lead II at the bottom of the many ECG traces) and count the tops of each R-wave for a set amount of time. Remember that one big square is 0.2s and one small square is 0.04s. i.e. in this normal ECG there are 7 R-waves in 25 big squares → 7 beats in 5 seconds → rate is approximately 84 bpm. Each R-wave is approximately equidistant apart, therefore the rhythm is regular.

Axis: if using the quadrant method discussed earlier look at leads I and aVF. The axis is normal.

For the following, it is easiest to look at each part of the ECG as if you were reading it from left-to-right of a normal trace; starting with the P-wave and finishing at the end of the T-wave.

P-waves: best to look for P-waves first in the rhythm strip, but if unsure look elsewhere. For the above a comment could be "this patient is in sinus rhythm with P-waves present and proceeded by a QRS complex".

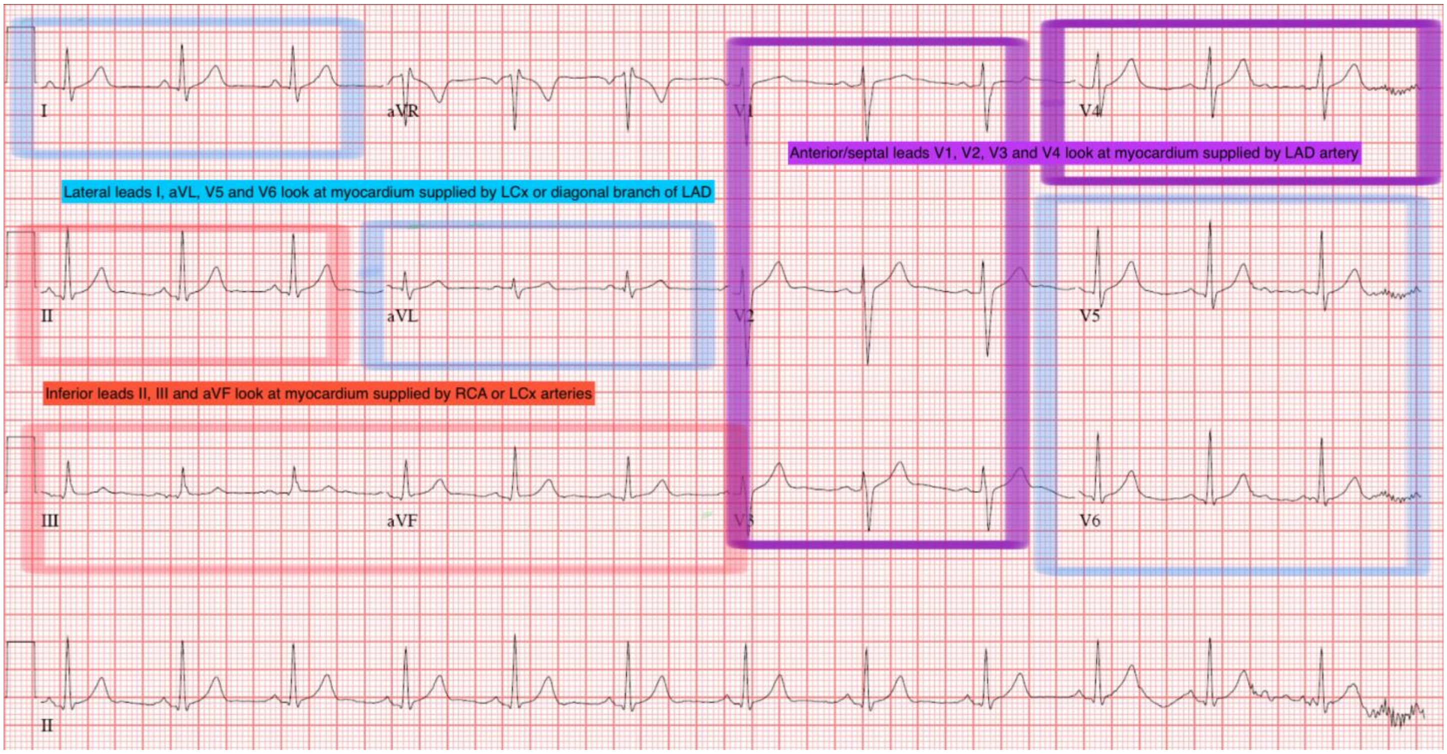
PR interval: normal PR interval is ~120-200ms i.e. 3 to 5 small squares. PR-intervals can be shorted by accessory pathways of conduction e.g. in Wolff-Parkinson-White syndrome or lengthened in various types of heart block. For the above: "PR-intervals are within normal limits".

QRS complex: a normal QRS should be narrow and <120ms (3 small squares). QRS complexes can be wide if conduction through the ventricles is not originating from the sinoatrial node e.g. in ventricular tachycardia. Or the QRS can have strange morphology such as the 'M'-shaped notch of the R-wave in V1 in right-bundle-branch blocks.

Q-waves: Q-waves are a negative deflection seen prior to an R-wave and should be small. If Q-waves are >40ms wide (1 small square), >80ms deep (2 small squares) or seen in V1-3, they are said to be a pathological and could indicate myocardial infarction or other pathologies. It is best to check all leads and assess Q-waves.

ST-segments: is the ST-segment raised or depressed? DO NOT MISS ST-SEGMENT CHANGES and learn the criteria for a STEMI. ST-segment changes could indicate life-threatening ischemia. As changes to ST-segments are often an issue of coronary artery blood flow, it is useful to divide the ECG into its anatomy and blood supply (see below).

T-waves: are the T-waves inverted in anterior or inferior leads? Are the T-waves of different size of shape? Normally T-waves should be smaller than their preceding QRS complex and have a gentle concave shape to them (like above). Like the ST-segments, T-wave morphology is sensitive to ischaemia it is useful to divide the ECG into its anatomy and blood supply (see below).



QT_c/other: the QT interval is normally <440ms (males) and <460ms (females). This can be prolonged in congenital disorders or by many medications (especially in psychiatric drugs). Also look for anything else obvious e.g. extra U-waves that might follow the T-wave.

Impression: strong concluding sentence that summarises your findings. For the above an example might be: "in summary, Mr X's ECG was unremarkable. Mr X was in regular sinus rhythm at 80bpm, featuring normal intervals and QRS morphology. Importantly there were no changes to suggest acute ischemia when compared with his previous ECGs, and as such a cardiac source of his chest pain is less likely. I would recommend a CXR to further explore possible causes of his chest pain."

ECG interpretation summary:

The following is a brief summary of questions you should ask yourself when reading an ECG. It by no means covers everything, but can help get you out of a "caught in the headlights" scenario at 8am on a Monday round.

Demographics & details	Introductory sentence, once again proving your CAN read: *"This is an ECG taken a few moments ago of Mr X, a 40yo male with a 20 pack-year smoking history, who presented with 20min history of non-radiating central chest discomfort."*
Rate & rhythm	• Assess from the rhythm strip (long lead II) • Is the rate normal (~60-100bpm)? • Is it sinus rhythm? (P-waves before every QRS) • Is the rhythm regular? (approximately equidistant R-R intervals throughout rhythm strip)
Axis	• Assess from leads I and aVF (quadrant method) • Is the axis normal or deviated?
P-waves	• Look for P-waves first in the rhythm strip (long lead II) • Is each P-wave followed by a QRS complex? • Is each P-wave normal in shape?
PR interval:	• Normal PR interval is ~120-200ms i.e. 3 to 5 small squares • Are the PR-intervals too short? E.g. in accessory pathways • Are the PR-intervals too long? E.g. in heart block
QRS complex	• QRS should be narrow and <120ms (3 small squares). • Are the QRS complexes wide? E.g. in VT • Do the QRS complexes feature any odd morphology? E.g. in WPW or RBBB
Q-waves	Pathological Q-waves may be: • >40ms wide (1 small square) • >80ms deep (2 small squares) or • In V1-3
ST-segments	• Look at ECG in anatomical coronary artery supply segments • Ss the ST-segment raised or depressed? • DO NOT MISS ST-SEGMENT CHANGES
T-waves:	• Look at ECG in anatomical coronary artery supply segments • T-waves should be smaller than their preceding QRS complex and have a gentle concave shape. • Are the T-waves inverted in anterior or inferior leads? • Are the T-waves of different size of shape?
QT_c/other	• QT interval is normally <440ms (males) and <460ms (females). • Anything else obvious? e.g. extra U-waves that might follow the T-wave.
Impression	Strong concluding sentence that summarises your findings e.g. "In summary, Mr X's ECG was unremarkable. Mr X was in regular sinus rhythm at 80bpm, featuring normal intervals and QRS morphology. Importantly there were no changes to suggest acute ischemia when compared with his previous ECGs, and as such a cardiac source of his chest pain is less likely. I would recommend a CXR to further explore possible causes of his chest pain."

Western Australian Medical Students' Society (WAMSS): Student Grand Rounds (SGR)
Last edited: 07/02/2021

Lead	Comparison of electrical activity
I	LA and RA
II	LL and RA
III	LL and LA
VR	RA and average of (LA + LL)
VL	LA and average of (RA + LL)
VF	LL and average of (LA + RA)
V_1	V_1 and average of (LA + RA + LL)
V_2	V_2 and average of (LA + RA + LL)
V_3	V_3 and average of (LA + RA + LL)
V_4	V_4 and average of (LA + RA + LL)
V_5	V_5 and average of (LA + RA + LL)
V_6	V_6 and average of (LA + RA + LL)
Key: LA, left arm; RA, right arm; LL, left leg.	

Table 1. (Nerd) table of leads represented by their electrode components.