Nursing Standard
CARDIORESPIRATORY

How to record a 12-lead electrocardiogram

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Emma Menzies-Gow
Senior lecturer, **School of Nursing, Faculty of Health, Social Care and Education**, Kingston University and St George's, University of London, London, England

Correspondence
E.Menzies-Gow@sgul.kingston.ac.uk

Conflict of interest
None declared

Peer review

Contributing to the How to series
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Rationale and key points

This article provides a step-wise, practical approach to recording a 12-lead electrocardiogram (ECG) and explores the evidence base that supports the use of this important assessment tool in clinical practice.

- A 12-lead ECG is frequently used in a variety of clinical settings, including emergency care, preoperative and post-operative assessment and primary care. It is used to assess and diagnose patients with suspected hypertension, coronary heart disease or heart failure.
- Correct positioning of the electrodes using anatomical landmarks is essential to ensure an accurate and good-quality ECG recording.

Reflective activity

How to articles can help to update your practice and ensure it remains evidence-based. Apply this article to your practice. Reflect on and write a short account of:

1. How this article might improve your practice when recording a 12-lead ECG. Consider how you prepared the patient for the procedure and how the patient may have felt during the ECG. Did the findings of the ECG influence the patient's care?

2. How you could use this information to educate your patients and colleagues on the appropriate technique for recording a 12-lead ECG.

Keywords
atrial fibrillation, cardiac arrhythmias, cardiology, cardiovascular, electrocardiograms, emergency care, heart diseases, patients, patient assessment

Preparation and equipment

- Before approaching the patient, ensure that you understand why the electrocardiogram (ECG) is being undertaken for the patient, so that you can explain the reason for the procedure to them. Consider any communication barriers that might affect the patient's understanding of the procedure and plan how these could be effectively addressed, for example by providing an interpreter or supplying written information. The patient will be asked to remove some of their clothing during the procedure, therefore they may wish to have a chaperone present (Society for Cardiological Science and Technology (SCST) 2017).
- Ensure that the 12-lead ECG machine is clean and ready for use, in accordance with your local policy, with no evidence of damage such as fractured leads or broken clips. Sufficient ECG graph paper should be loaded and the machine should be charged. If not charged, ensure the machine can be easily connected to a power source while undertaking the procedure.
- Ensure all necessary equipment is available, including:
  - **A 12-lead ECG machine.**
  - **One sheet of ten new, pre-gelled electrodes.**
  - **Alcohol hand gel.**
  - **Soap and water.**
  - **Clinical waste bag**
  - **A paper towel, gauze or abrasive tape.**
  - **Disposable razor or battery-operated razor with a new single use blade.**
  - **Sharps bin.**

Procedure

1. Decontaminate your hands using alcohol hand gel or soap and water, as per local policy.
2. Introduce yourself to the patient. Explain that you intend to record a 12-lead ECG and the reason why (Nicol et al 2012). Explain that the procedure will be painless, but they will be required to lie still for a few minutes during the recording. Ensure the patient has the opportunity to ask any questions and **that** you gain their consent to proceed.
3. Bring the equipment to the patient's bedside. Confirm the identity of the patient using three identifiers: name, date of birth and unique patient identification number (for example NHS number) (Dougherty and Lister 2015). Assist the patient to lie on a bed or couch, **supported with two or three pillows** to position the patient comfortably in a semi-recumbent position at approximately 45 degrees (SCST 2017). If the patient is unable to tolerate this position, the ECG should be performed in a safe, comfortable position for them; for example, sitting upright if they are short of breath or in a wheelchair. This should be noted on the ECG recording printout (Dougherty and Lister 2015).
4. Ensure the patient's comfort and dignity are maintained throughout the procedure. Close the curtains and/or doors. Ask the patient to remove the clothing required to undertake the procedure, usually undressing above the waist, assisting them if necessary. Jewellery or watches **in close proximity to the electrodes should** be removed, (Rowlands and Sargent 2014). Whenever possible, cover the patient with a gown or sheet during the procedure to keep them warm (Dougherty and Lister 2015). Position the bed or couch to a suitable working height and position the ECG machine so that the leads can easily reach the patient.

5. Assess the patient's skin to determine if skin preparation is required before applying the electrodes. The skin should be intact, clean and dry (Crawford and Doherty 2009). If it appears sweaty or has been recently moisturised, clean it with soap and water and dry it thoroughly before applying the electrodes (Grant 2014). If skin **appears to be** damaged in the standard **electrode** positions, apply the electrodes as close as possible to these positions and note any adjustments made on the ECG recording printout(SCST 2017). If necessary, remove dead skin by exfoliation, using a paper towel, gauze or abrasive tape (Crawford and Doherty 2009). Remove any hair from the sites where the electrodes are to be applied using a single-use disposable razor or battery-operated razor with a single-use blade. Dispose of the single-use razor or blade in a sharps bin (Dougherty and Lister 2015).

   Using a sheet of ten new, disposable self-adhesive electrodes for the ECG recording, apply the four limb electrodes (Figure 1). **All four electrodes should be an equal distance away from the heart (Goldberger et al 2017). To achieve this, one electrode should be applied to skin near each wrist and each ankle ideally, although this may not always be suitable particularly if the patient has a significant tremor or has an amputated limb. All four limb electrodes may be repositioned further up each limb, for example at the top of the arms and top of the legs, thereby ensuring the electrodes are equidistant from the heart.**

Figure 1. Two options for positioning the limb electrodes

6. Begin to apply the precordial (chest) electrodes (V1-V6), as indicated in Table 1. V1 and V2 should be placed in the fourth intercostal space, to the right and left of the sternum respectively. To accurately locate the fourth intercostal space, place two fingers at the top of the patient's sternum. Gently slide your fingers down the sternum until you feel a bump, which is at the bottom of the **manubrium** known as the angle of Louis (Figure 2). Slide both fingers to the right of the sternum into the groove of soft tissue between two ribs; this is the second intercostal space. Gently slide your fingers down over the next two ribs to locate the fourth intercostal space and place the V1 electrode in this position.

Table 1. 12-lead electrocardiogram precordial (chest) lead positions

Electrode	Colour	Position
V1	Red	Fourth intercostal space, right sternal edge
V2	Yellow	Fourth intercostal space, left sternal edge
V3	Green	Midway between V2 and V4
V4	Blue	Midclavicular line, fifth intercostal space
V5	Brown	Anterior axillary line, fifth intercostal space
V6	Purple	Midaxillary line, fifth intercostal space

(Society for Cardiological Science and Technology 2017)

Figure 2. Anatomical landmarks for positioning the precordial (chest) electrodes

7. Repeat step 7 on the left side of the patient's sternum to position the V2 electrode in the left fourth intercostal space

8. Position the V4, V5 and V6 electrodes on an imaginary horizontal plane (line) aligned with the fifth intercostal space on the left side of the chest wall (Figure 2). Use anatomical landmarks to identify the exact position for each electrode on this horizontal plane (Table 1). In female patients, place these electrodes underneath the breast tissue (SCST 2017). If

necessary, seek permission from the patient to gently lift their breast or, where possible, ask the patient to do this themselves so that you can precisely locate the fifth intercostal space.

9. Position the V4 electrode in the fifth intercostal space, aligned with the middle of the left clavicle (midclavicular line) (Figure 2).
10. Position the V3 electrode midway between V2 and V4. This electrode may be located on top of the breast tissue (Figure 2).
11. Position the V5 electrode on the same horizontal line as V4, aligned with the anterior axillary line (Figure 2).
12. Position the V6 electrode on the same horizontal line as V4 and V5, aligned with the middle of the left axilla (midaxillary line) (Figure 2). Cover the patient with a blanket or sheet once the electrodes are in place while you prepare to apply the leads.
13. Bring the leads to the patient's bedside, separating the four longer leads that will be connected to the limb electrodes from the six shorter leads that will be connected to the chest electrodes.
14. Connect the **four** limb leads to the electrodes using the clips attached to each lead, as indicated in Table 2. Attach the red (**RA or R [Q or R? yes please]**) lead to the electrode in the right arm position and the yellow (**LA or L [Q or L? Yes]**) lead to the left arm electrode. The green (**LL or F [Q or F Yes?]**) lead should be attached to the left leg electrode and the black (RL or N) lead to the right leg electrode. **You may find the mnemonic 'Ride Your Green Bike' a useful aide-memoire. [Q reviewer 1: suggest removing this sentence – it might be confusing if different colour combinations are used by some manufacturers] This is a widely used mnemonic. It is highly unlikely the colour combinations for the limb leads will vary, although the chest lead colours often do. Happy to remove if you prefer.**

Table 2. 12-lead electrocardiogram limb lead positions

Electrode label	Description	Colour	Position
RA or R	Right arm	Red	Right forearm (wrist area)
LA or L	Left arm	Yellow	Left forearm (wrist area)
LL or F	Left leg or foot	Green	Left leg (ankle area)
RL or N	Right leg or neutral	Black	Right leg (ankle area)

(Society for Cardiological Science and Technology 2017)

15. Connect the precordial leads to the electrodes, as indicated in Table 1. Note that some manufacturers may use different colour combinations; therefore, it is important to check their instructions, which are often printed on the 12-lead ECG machine or on the leads.
16. Turn on the 12-lead ECG machine. If you are unsure how the machine operates, consult the associated documentation or ask an experienced colleague before proceeding. Using the information provided on the display, check the calibration of the equipment by ensuring the paper speed is set to 25mm per second (mm/s) and the voltage (gain) is set at 10mm per millivolt (mm/mV). **Add patient identifiers when requested [Q does this mean inputting this information into the ECG machine itself? Yes, ideally, although often it is handwritten on the printout].** Avoid ~~using~~ **selecting the filter option [Q could it be briefly explained what this is? Is this now clearer?]** on the first recording because this may remove important electrical activity from the recording. However, the filter may be used on subsequent recordings if there is considerable electrical interference (**Holbery and Newcombe 2016 [Q please add to references list Thank you – I have added it]**).
17. Ensure the patient is warm and as relaxed as possible, with their arms resting comfortably by their side. Tension may be evident if the patient has clenched fists, which may interfere with the recording. Reassure the patient throughout the procedure, encouraging them to relax and remain still during the recording, to breathe normally but not to speak (Grant

2014). **[Reviewer 1: can you touch the patient during the recording?] It is not clear in the definitive SCST document whether this causes a problem or not. Would you mind if I don't comment on this?**

18. Press the appropriate button to start the recording, usually 'auto' or 'start'. The 'copy' button should not be used for the recording, because this may reprint a previous recording from a different patient (SCST 2017). Advise the patient when the recording is complete.
19. Once the ECG recording printout has emerged, check the printed paper speed is documented as 25mm/s and the voltage calibration is 10mm/mV (Menzies-Gow and Spiers 2018). This is often indicated at the beginning or end of the recording by a rectangle that should be two large squares (10mm) high (Figure 3) (Rowlands and Sargent 2014).
20. Assess the quality of the trace across all 12 views on the ECG. An undulating baseline or absence of a recording for any of the leads suggests poor electrode contact (Figure 4) (Dougherty and Lister 2015). External electrical interference may cause a fuzzy appearance on the ECG, resulting in a thick black line known as artefact (Figure 5) (Goldberger et al 2017). **[Reviewer 1: suggest mentioning the rhythm strip here – i.e. If the ECG is irregular or abnormal, record a rhythm strip, usually from lead II] Usually, a rhythm strip forms part of the ECG printout so I think adding a statement here may be confusing. I've mentioned this below anyway in the 'Evidence-base' section.**

Figure 3. Example of a 12-lead electrocardiogram recording

Figure 4. Electrocardiogram recording showing wandering baseline [Q artefact?] **caused by poor contact of electrodes with the skin**

Figure 5. Electrocardiogram recording showing artefact caused by external electrical interference

21. Take steps to address poor electrode contact and/or external electrical interference before undertaking a further ECG recording. Reattach loose electrodes or leads, or minimise external electrical interference from nearby equipment by moving it further away, plugging the ECG machine into a different socket or, if safe to do so, switching ~~**the equipment**~~ off **unnecessary equipment** (Goldberger et al 2017). If these are ineffective, the filter can be applied to subsequent ECG recordings **to minimise electrical interference** (SCST 2017). **Use of the filter should be indicated on the ECG printout.**
22. Disconnect the leads. If the patient is acutely unwell, the electrodes may be left in place for a short time to take additional recordings. Remove the electrodes from the patient's skin, because these can be highly irritant if left in place **and dispose them in a clinical waste bag**. **[Q would these be disposed of in the clinical waste bag?] Yes please– thanks!**
23. Advise the patient to dress and provide assistance as necessary. ~~**Discard the electrodes and**~~ **C**lean the ECG leads **and clips**, as per local policy and manufacturer's guidelines, before returning them to the ECG machine. **Decontaminate your hands using soap and water. [Q using alcohol hand gel or soap and water?]** (Dougherty and Lister 2015).
24. The 12-lead ECG must be reviewed by a practitioner who is competent in ECG analysis, who should document their interpretation on the recording (Dougherty and Lister 2015). This should be expedited if the patient is acutely unwell (Menzies-Gow and Spiers 2018). Inform the patient of the outcome of the assessment.

Evidence base

An ECG is a visual record of the electrical activity of the heart that measures the force and direction of electrical current (Grant 2014). A 12-lead ECG is a commonly used clinical tool to aid patient assessment and diagnosis (Rowlands and Sargent 2014). It is a routinely requested test in preoperative and post-operative assessment and for patients with suspected hypertension, coronary heart disease or heart failure.

A 12-lead ECG is especially useful in the assessment of acutely unwell patients presenting with a range of symptoms, including palpitations, dyspnoea, fatigue and **also** angina, ~~**which may**~~ **which may present as pain, an ache or heaviness in the chest, neck, arms or jaw [Q is this referring to the presentation of angina only, or of palpitations, dyspnoea, fatigue and angina? Just angina]** (Menzies-Gow and Spiers 2018). An ECG will be necessary to diagnose arrhythmias, such as atrial fibrillation and complete heart block, and acute coronary syndrome (Rowlands and Sargent 2014). The 12-lead ECG can also identify the presence of cardiac conduction abnormalities, such as bundle branch blocks, pre-excitation, long QT syndrome and Brugada syndrome, and can provide evidence of the structure, size and shape of the heart, which may be altered by a variety of conditions, such as cardiac valve disease and cardiomyopathy (Goldberger et al2017).

Electrical forces generated during the cardiac cycle are conducted through the body and detected at the surface using electrodes placed on the skin (Rowlands and Sargent 2014). The 12-lead ECG uses ten electrodes to record a snapshot of 12 different views of this electrical activity, whereas cardiac monitoring usually provides a continuous trace of the electrical current often from a single perspective (Grant 2014). The electrodes record the magnitude and direction of current, known as vectors (Goldberger et al 2017). If electricity is travelling towards an electrode it will record an upright (or positive) trace on the ECG; if it is travelling away from an electrode, a downwards (or negative) trace will be recorded.

The six precordial leads (V1-V6) are unipolar and view the heart on the horizontal or transverse plane (Goldberger et al 2017). Occasionally, these are recorded as C1-C6 (Sampson and McGrath 2015a). The four limb leads should be placed an equal distance away from the heart to create six views of the electrical current on a frontal, vertical plane (Goldberger et al 2017). Leads I, II and III are standard limb leads that display the difference in electrical current between a positive and a negative electrode; these are referred to as bipolar leads (Rowlands and Sargent 2014). The three augmented vector (aV) limb leads are unipolar, recording electrical current from the electrodes placed on right arm (aVR), left arm (aVL) and left leg (aVF). **The right leg (black) electrode serves as an electrical ground [Q thus helping to remove external interference? Yes please!].**

A standardised approach to 12-lead ECG recording is necessary to enable accurate identification of specific waveforms and measurements (**Houghton and Gray 2014 [Q please add to references list done now -sorry]**). This is achieved through accurate patient positioning, electrode placement and standardised calibration of the equipment to record the patient's cardiac electrical current at a speed of 25mm/s and an amplitude of 10mm/mV (SCST 2017). Misplacement of any of the electrodes can cause subtle changes that may lead to inappropriate diagnosis and treatment (Richley and Winter 2017).

Time, or the duration of activity seen on the trace, is measured on the horizontal axis of the ECG. On special graph paper, the standardised speed of 25mm/s will result in 1mm (small square) representing 40 milliseconds (ms). The amplitude of electrical current is measured on the vertical axis. A voltage calibration of 10mm/mV signifies that 1mm (small square) represents 0.1mV of electrical current (Menzies-Gow and Spiers 2018). The ECG machine usually records cardiac electrical activity seen from each of the 12 leads, or views, for approximately three seconds. Often, the ECG machine provides a further recording of lead II for approximately **12 seconds [Q should this be 10 seconds? I don't think so)]** (rhythm strip), which is useful for accurate identification of sinus rhythm or the presence of arrhythmias (Rowlands and Sargent 2014).

It is essential to ensure that a good-quality ECG recording is achieved using the standardised technique described to enable accurate interpretation of the findings, even in an emergency situation (SCST 2017). Before removing the electrodes, it is advisable to check that the standard paper speed and voltage calibration have been used and to **scan each of the ~~leads~~ views on the recording to ensure there is a good-quality trace from the patient in case a repeat recording is necessary [Q please clarify what is being scanned here – is it the ECG recording printout or the leads themselves?].** Skin impedance, or resistance to electrical flow, may cause electrical interference that negatively affects the quality of the recording (Crawford and Doherty 2009). This results in artefact, seen as an undulating trace (Figure 4), which could be caused by poor electrode contact or electrodes being placed where there is a significant amount of dry or dead skin cells, grease, sweat or hair (Crawford and Doherty 2009). Therefore, skin preparation is an essential part of the procedure.

The presence of a fuzzy or thickened trace (Figure 5) also suggests a poor-quality ECG recording. It is often caused by patient movement or muscle tremor, external electrical interference from equipment such as infusion pumps, or from jewellery in close proximity to the electrodes (Rowlands and Sargent 2014). However, if artefact remains despite taking all measures to eliminate it, the filter may be applied to subsequent recordings and should be documented on the recording (SCST 2017).

Useful resources

Creed F, Spiers C (Eds) (2012) [Q 2010? Yes, sorry.] Care of the Acutely Ill Adult: An Essential Guide for Nurses. Oxford University Press, Oxford

Huff J (2016) ECG Workout: Exercises in Arrhythmia Interpretation. Seventh edition. Wolters Kluwer, Philadelphia PA

Sampson M, McGrath A (2015b) Understanding the ECG part 1: anatomy and physiology. British Journal of Cardiac Nursing. 10, 11, 548-554

Wesley K (2017) Huszar's ECG and 12 Lead Interpretation. Fifth edition. Elsevier, St Louis MO

References

Crawford J, Doherty L (2009) Recording a standard 12-lead ECG: filling in gaps in quality. British Journal of Cardiac Nursing 4, 4, 162-167. [Q should this be 1, 8, 327-334? **http://www.paramedicpractice.com/cgi-bin/go.pl/library/article.cgi?uid=42406;article=pp_1_8_327_334;format=pdf**]

Dougherty L, Lister S (Eds) (2015) The Royal Marsden Manual of Clinical Nursing Procedures. Ninth edition. Wiley Blackwell, Chichester. [Q please specify which chapter was used and the page numbers – was this Chapter 11 Observations? Yes p.504-510]

Goldberger AL, Goldberger ZD, Shvilkin A (2017) Goldberger's Clinical Electrocardiography: A Simplified Approach. Ninth edition. Elsevier, Philadelphia PA.

Grant R (2014) Cardiac assessment. In Olsen K (Ed) Oxford Handbook of Cardiac Nursing. Second edition. Oxford University Press, Oxford. [Q please add the page numbers for this chapter]

Holbery N and Newcombe P (Eds) (2016) Chapter 14 - 12-lead electrocardiogram (ECG). In Holbery N and Newcombe P (Eds) (2016) Emergency Nursing at a Glance Wiley Blackwell, Chichester

Houghton A and Gray D (2014) Making sense of the ECG: a hands-on guide. Fourth edition. Boca Raton Florida: Taylor and Francis Group

Menzies-Gow E, Spiers C (2018) Rapid Cardiac Care. Wiley Blackwell, Chichester.

Nicol M, Bavin C, Cronin P et al (2012) Essential Nursing Skills. Fourth edition. Mosby Elsevier, London.

Richley D, Winter JL (2017) Technical errors in ECG recording and treatment delays. British Journal of Cardiac Nursing. 12, 2, 77-78.

Rowlands A, Sargent A (2014) The ECG Workbook. Third edition. M&K Publishing, Keswick.

Sampson M, McGrath A (2015a) Understanding the ECG part 2: ECG basics. British Journal of Cardiac Nursing. 10, 12, 588-594.

Society for Cardiological Science and Technology (2017) Clinical Guidelines by Consensus: Recording a Standard 12-Lead Electrocardiogram. An Approved Method by the Society for Cardiological Science and Technology. www.scst.org.uk/resources/SCST_ECG_Recording_Guidelines_20171.pdf (Last accessed: 12 March 2018.) I am not certain that this is the correct reference. In the document, the authors have asked that the text be referenced as:

Campbell B, Richley, D, Ross C, Eggett, CJ (2017) Clinical guidelines etc. but Richard Hatchett recommended that it be changed to list SCST as the authors. What do you think?

Figure 1. Two options for positioning the limb electrodes

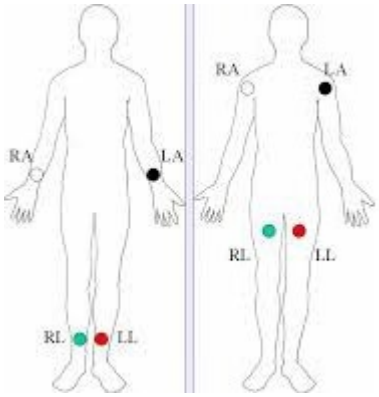

Figure 2. Anatomical landmarks for positioning the precordial (chest) electrodes

A drawing like this would be great, although some amendments would be needed.

- The anterior axillary line is not in the correct position – this should be aligned with V5.
- An additional line could be added to indicate the midaxillary line for V6.
- It would be great to add a horizontal line joining V4, V5 and V6 to illustrate the horizontal plane of the 5th

- **Please remove labels for: suprasternal notch, infraclavicular space**

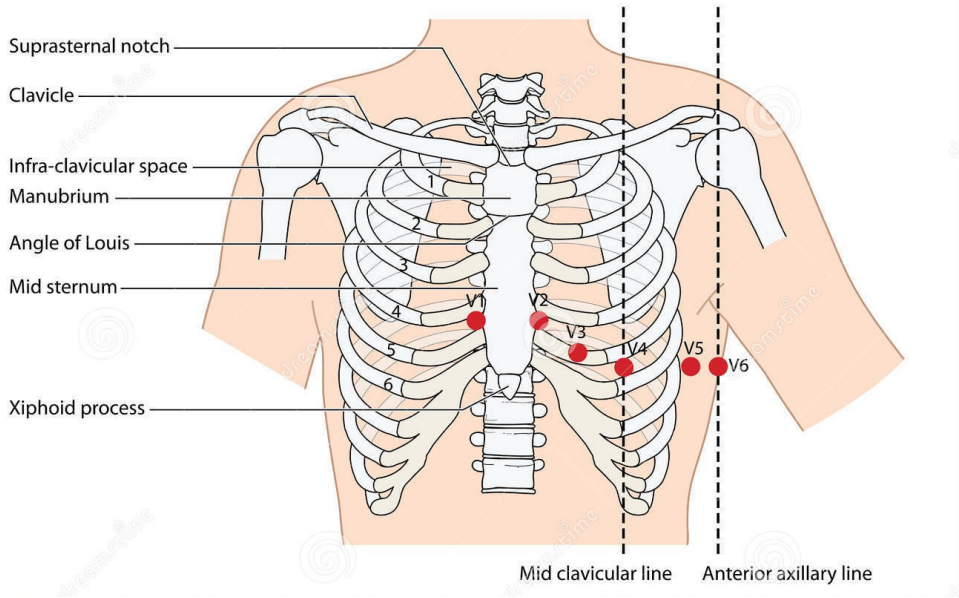

Figure 3. Example of a 12-lead electrocardiogram recording

Please insert an image of an ECG trace – you may have a suitable one, which would allow us to add an example of the necessary unique identifying information and reason for taking the recording e.g. Worsening shortness of breath, respiratory rate 25/min or 'Routine Pre-Op ECG' or similar. You can use this one below but it would require modification i.e. If this ECG image is used, the following information must be removed:

Date, Time 'Age not entered, assumed….etc.' Normal sinus rhythm could possibly be left on there.
Indicate where the paper speed and voltage calibration mark can be found (as shown below)
Remove this information under the blue shaded boxes

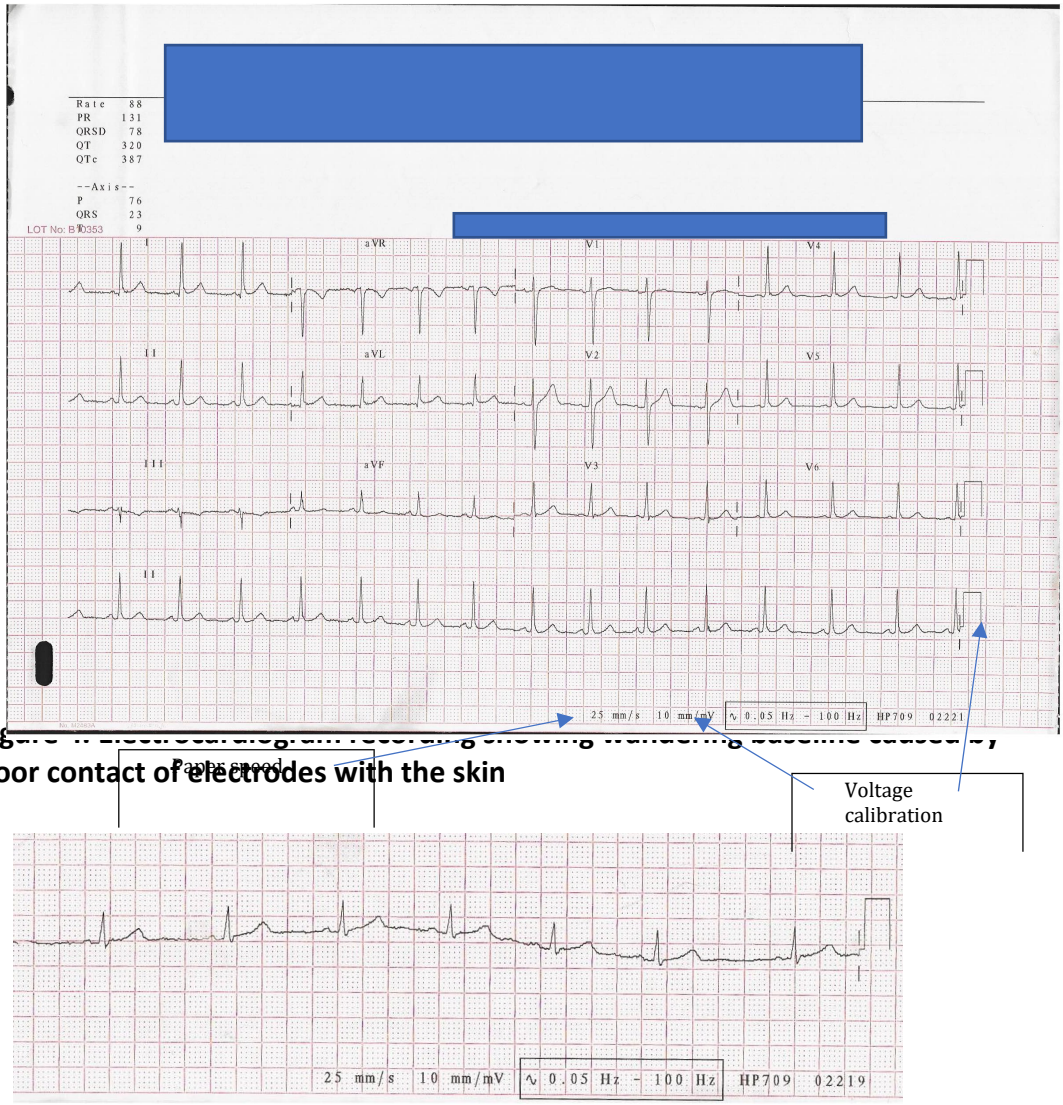

Figure 4. Electrocardiogram recording showing wandering baseline caused by poor contact of electrodes with the skin

Figure 5. Electrocardiogram recording showing artefact caused by external electrical interference