How to record a 12-lead electrocardiogram

Emma Menzies-Gow

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 arrhythmias, hypertension, coronary heart disease or heart failure.

» Correct positioning of the electrodes using anatomical landmarks is essential to ensure an accurate and high-quality ECG recording.

» Skin preparation is essential, since suboptimal electrode contact or electrodes being placed where there is a significant amount of dry or dead skin cells, grease, sweat or hair, can negatively affect the quality of the 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.

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

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Keywords

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Preparation and equipment

» Before approaching the patient, ensure that you understand why the electrocardiogram (ECG) is being undertaken, so that you can explain the reason for the procedure to the individual. 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 (Campbell et al 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 ECG 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.
A 12-lead electrocardiogram (ECG) is a 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 for this (Nicol et al 2012). Explain that the procedure will be painless, but that the patient 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, and support them with pillows if necessary so that they are positioned comfortably in a semi-recumbent position at approximately 45 degrees (Campbell et al 2017). If the patient is unable to tolerate this position, the procedure should be performed in an alternative position that is safe and comfortable for them, for example sitting upright if they are short of breath or in a wheelchair. This position 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 to provide privacy. Ask the patient to remove the clothing necessary for the procedure to be undertaken, usually undressing above the waist, and assist them if required. 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 ensure they remain warm (Dougherty and Lister 2015). Position the bed or couch at 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 patient’s 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 the patient’s skin appears to be damaged in the standard electrode positions, apply the electrodes on healthy and intact skin as close as possible to these positions and note any adjustments made on the ECG recording printout (Campbell et al 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).
6. Using a sheet of ten new, disposable self-adhesive electrodes, apply the four limb electrodes. All four electrodes should be an equal distance away from the heart (Figure 1) (Goldberger et al 2017). Ideally, one electrode should be positioned on each wrist and each ankle, although it may be necessary to position all four electrodes further up each limb, for example if the patient has a significant tremor or an amputated limb (Campbell et al 2017).
7. 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 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.
8. Repeat step 7 on the left side of the patient’s sternum to position the V2 electrode in the left fourth intercostal space.
9. Position the V4, V5 and V6 electrodes using anatomical landmarks on an imaginary horizontal plane (line) aligned with the fifth intercostal space on the left side of the chest wall (Figure 2). In female patients, place these electrodes underneath the breast tissue (Campbell et al 2017). If necessary, request 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.

10. Position the V4 electrode in the fifth intercostal space, aligned with the middle of the left clavicle (mid-clavicular line) (Figure 2).

11. Position the V3 electrode midway between the V2 and V4 electrodes (Figure 2). This electrode may be located on top of the breast tissue.

12. Position the V5 electrode on the same horizontal line as the V4 electrode, aligned with the anterior axillary line (Figure 2).

13. Position the V6 electrode on the same horizontal line as the V4 and V5 electrodes, 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.

14. 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.

15. 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) lead to the electrode in the right arm position and the yellow (LA or L) lead to the left arm electrode. The green (LL or F) 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-mémoire.

16. Connect the precordial leads to the electrodes, as indicated in Table 1. Note that some manufacturers may use different colour combinations for the precordial leads; therefore, it is important to check their instructions, which are often printed on the ECG machine or on the leads.

17. Turn on the ECG machine. If you are unsure about any aspect of how the machine operates, consult the manufacturer’s guidelines 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). Input the patient identifiers into the ECG machine when requested. There will be a filter option on the ECG machine that minimises electrical interference; however, avoid using this on the first recording because this may remove important electrical activity from the recording. The filter may be used on subsequent recordings if there is considerable electrical interference (Holbery and Newcombe 2016).

18. 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, and to breathe normally but not to speak (Grant 2014).

19. 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 (Campbell et al 2017). Advise the patient when the recording is complete.

20. 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).

21. Assess the quality of the trace across all 12 views on the ECG recording. An undulating baseline or absence of a recording for any of the leads indicates suboptimal electrode placement. 

### Table 1. I2-lead electrocardiogram precordial (chest) lead positions

<table>
<thead>
<tr>
<th>Electrode</th>
<th>Colour</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>Red</td>
<td>Fourth intercostal space, right sternal edge</td>
</tr>
<tr>
<td>V2</td>
<td>Yellow</td>
<td>Fourth intercostal space, left sternal edge</td>
</tr>
<tr>
<td>V3</td>
<td>Green</td>
<td>Midway between V2 and V4</td>
</tr>
<tr>
<td>V4</td>
<td>Blue</td>
<td>Midclavicular line, fifth intercostal space</td>
</tr>
<tr>
<td>V5</td>
<td>Brown</td>
<td>Anterior axillary line, fifth intercostal space</td>
</tr>
<tr>
<td>V6</td>
<td>Purple</td>
<td>Midaxillary line, fifth intercostal space</td>
</tr>
</tbody>
</table>

(Adapted from Campbell et al 2017)

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**Figure 1. Two options for positioning the limb electrodes**

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

22. Address suboptimal 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 off unnecessary equipment (Goldberger et al 2017). If these measures are ineffective, the filter may be applied to subsequent ECG recordings and documented on the printout (Campbell et al 2017).

23. Disconnect the leads. If the patient is acutely unwell, the electrodes may be left in place for a short time to undertake additional recordings. Remove the electrodes from the patient’s skin and dispose of them in a clinical waste bag, because these can be highly irritant if left in place.

24. Ask the patient to dress and offer them assistance, if necessary. Clean the ECG leads, as per local policy and manufacturer’s guidelines, before returning them to the ECG machine. Decontaminate your hands using soap and water (Dougherty and Lister 2015).

25. The ECG recording must be reviewed by a practitioner who is competent in ECG analysis, who should document their interpretation on the printout (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 the 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 arrhythmias, hypertension, coronary heart disease or heart failure.

A 12-lead ECG is particularly useful in the assessment of acutely unwell patients presenting with a range of symptoms, including palpitations, dyspnoea and fatigue, as well as angina, which may present as pain, an ache or heaviness in the chest, neck, arms or jaw (Menzies-Gow and Spiers 2018). An ECG will be required 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 al 2017).

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). A 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 the electrical current, known as vectors (Goldberger et al 2017). If electricity is travelling towards an electrode it will record an upright (positive) trace on the ECG; if it is travelling away from an electrode, a downwards (negative) trace will be recorded.

The six precordial leads (V1-V6) are unipolar and view the heart on a horizontal or transverse plane (Goldberger et al 2017). Occasionally, these are recorded as C1-C6 (Sampson and McGrath 2015). The four limb leads should be placed an equal distance away from the heart to produce 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 the electrical current between

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**TABLE 2. 12-lead electrocardiogram limb lead positions**

<table>
<thead>
<tr>
<th>Electrode label</th>
<th>Description</th>
<th>Colour</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA or R</td>
<td>Right arm</td>
<td>Red</td>
<td>Right forearm (wrist area)</td>
</tr>
<tr>
<td>LA or L</td>
<td>Left arm</td>
<td>Yellow</td>
<td>Left forearm (wrist area)</td>
</tr>
<tr>
<td>LL or F</td>
<td>Left leg foot</td>
<td>Green</td>
<td>Left leg (ankle area)</td>
</tr>
<tr>
<td>RL or N</td>
<td>Right leg neutral</td>
<td>Black</td>
<td>Right leg (ankle area)</td>
</tr>
</tbody>
</table>

(Adapted from Campbell et al 2017)

**Figure 3. Example of a 12-lead electrocardiogram recording**

- Normal ECG
- Unconfirmed diagnosis

- Paper speed 10 mm/s
- Graph height 20 mm
- Voltage calibration 10 mV

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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 the electrical current from the electrodes placed on the patient’s right arm (aVR), left arm (aVL) and left leg (aVF). The right leg (black) electrode serves as an electrical ground, thus assisting in removing external interference.

A standardised approach to 12-lead ECG recording is required to enable accurate identification of specific waveforms and measurements (Houghton and Gray 2014). 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 (Campbell et al 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 ECG graph paper, the standardised speed of 25mm/s will result in 1mm (small square) representing 40 milliseconds (ms). The amplitude of the 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 10 seconds (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 high-quality ECG recording is achieved using the standardised technique described to enable accurate interpretation of the findings, even in an emergency (Campbell et al 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 views on the recording to ensure there is a high-quality trace, in case a repeat ECG recording is required.

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 an undulating baseline (Figure 4), which could be caused by suboptimal 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 low-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 or a watch in close proximity to the electrodes (Rowlands and Sargent 2014). However, if artefact remains despite all possible measures being undertaken to eliminate it, the filter option on the ECG machine may be applied to subsequent recordings to minimise electrical interference (Campbell et al 2017).

References


