Recognizing and reducing interference on 12-lead electrocardiograms

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Abstract

The 12-lead electrocardiogram (ECG) is a diagnostic test used in many different clinical settings. Healthcare professionals who record ECGs as part of their role are often unable to recognize interference that disrupts the quality of the ECG recording. This interference can lead to a reduction in diagnostic quality. Nurses who record ECGs should be able to recognize the commonly encountered forms of interference, and be able to take steps to eliminate, or substantially reduce, this interference whenever possible to ensure the highest possible quality of ECG recording.

Key words: Artefact ■ Diagnostic quality ■ Electrocardiogram

The use of the 12-lead electrocardiogram (ECG) has increased over recent years due to a reduction in the cost of electrical technology and an increase in use in non-cardiac specialist areas. The ECG is a cost-effective, easily repeatable, and simple to use test (Payne, 2004). Therefore, most acute hospital wards, GP surgeries and other clinics and departments have access to an ECG machine.

The Resuscitation Council UK (RCUK, 2004) claims that, in addition to other resuscitation equipment, clinical areas should also have access to a 12-lead ECG recording machine (RCUK, 2004). The Department of Health (DH) states that patients presenting with coronary heart disease should receive prompt and appropriate professional assessment (DH, 2000). The ECG forms a pivotal component of this coronary assessment. It is often the case that many staff nurses and other healthcare professionals, including student nurses and auxiliary nurses, lack the essential knowledge and skill required to recognize and identify quality issues pertaining to the recording of diagnostic quality ECGs. This includes the ability to recognize and reduce forms of interference that reduce the diagnostic quality of the ECG.

The nursing profession requires that nurses offer an evidence-based rationale for the skills and tasks they carry out (Nursing and Midwifery Council, 2004); regarding ECGs, a lack of awareness concerning the quality of recording can lead to misdiagnosis and potential mismanagement of a patient.

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The normal 12-lead ECG

The ECG represents electrical changes associated with contraction of the myocardial tissue (Gregory, 2005). The 12-lead ECG displays 12 different views of the heart's electrical activity, and is composed of 12 leads: I, II, III, aVR, aVL, aVF, V1, V2, V3, V4, V5 and V6 (Houghton and Grey, 2003). *Figure 1* shows a normal 12-lead ECG with leads in the standard positions. Electrical activity is represented as a waveform on the ECG, consisting of PQRST waves (see *Figure 2*). On a standard 12-lead ECG, PQRST waves are described as:

- P – Atrial depolarization
- QRS – Ventricular depolarization
- T – Ventricular repolarization.

When reviewing the ECG prior to removing the cables and electrodes from the patient, and passing the ECG to a member of staff qualified in ECG interpretation, the ECG recorder should briefly review the ECG to ensure it meets the criteria of an acceptable recording. To do this the recorder should review several key areas on the ECG recording itself, these are discussed below.

Lead aVR

The augmented vector lead aVR should be checked. PQRST waves in lead aVR are almost always negatively deflected (Khan, 2004). A positive deflection should alert the recorder to the possibility that physical arm leads have been applied the wrong way round. This is known as technical dextrocardia, and can mimic the rare condition of true dextrocardia, a condition whereby the heart is located on the right-hand side of the chest cavity. This can be simulated on an ECG by swapping the arm leads over (Hampton, 2003a). In both technical and true dextrocardia there are inverted P-waves in lead I, and often a right axis deviation (see *Table 1*) and prominent R-waves in lead aVR (Jenkins and Gerred, 2005). The main difference between technical dextrocardia and the true dextrocardia is seen in the R-wave progression in the

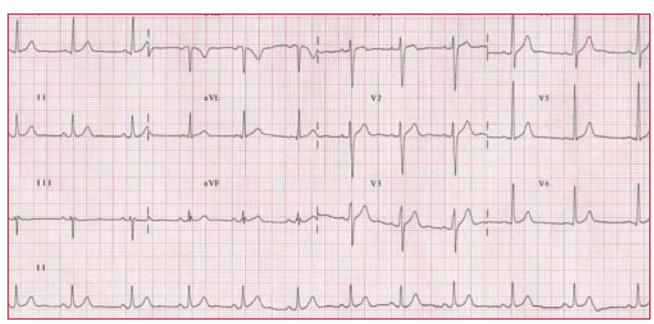


Figure 1. Normal 12-lead electrocardiogram recorded with correct lead positions.

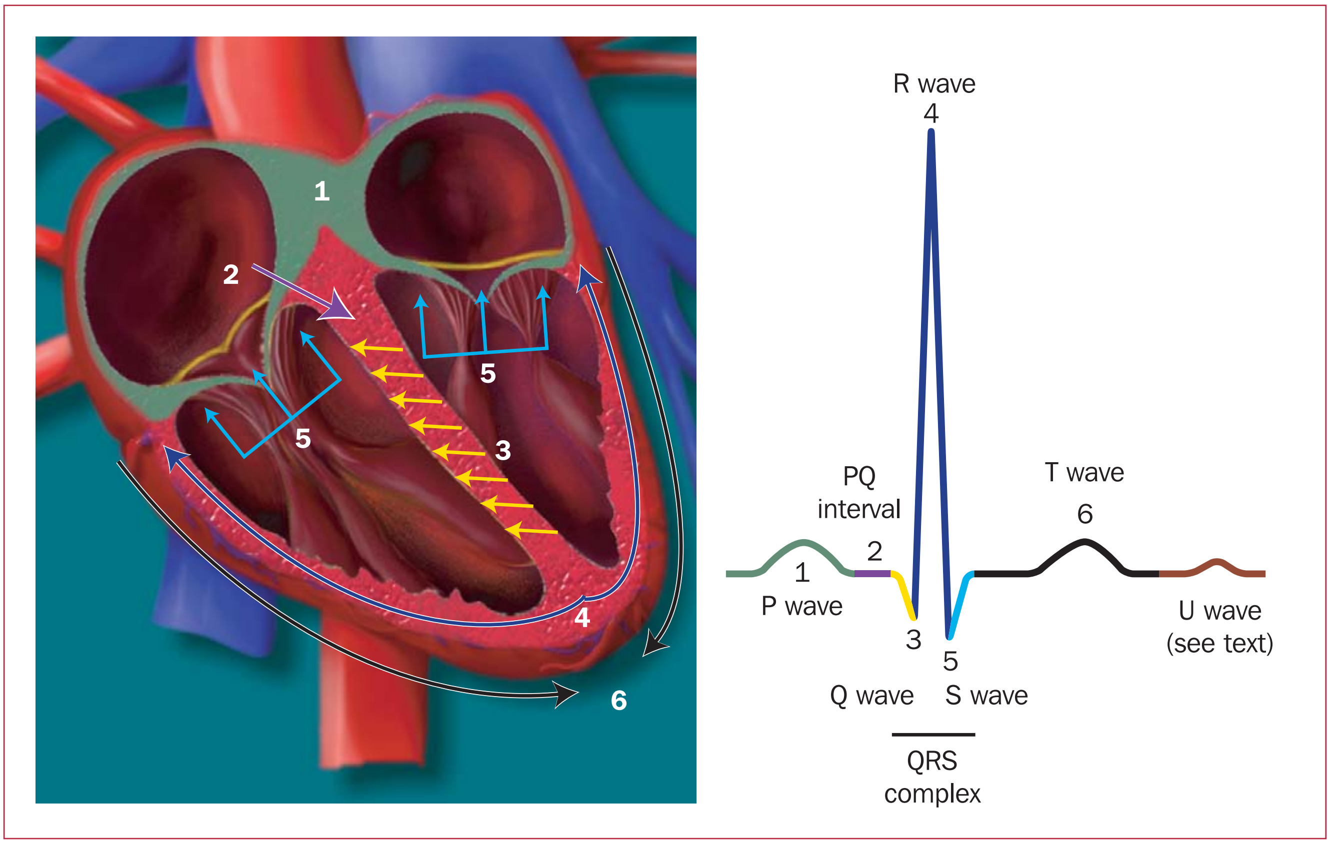


Figure 2. Origin of the PQRST waveform seen on the electrocardiogram (ECG). Events during the cariac cycle are colour-coded to the waveforms seen on the ECG.

chest leads. In technical dextrocardia the R-wave progression is normal (see R-wave progression below). Another good indicator is found by checking the deflection of lead aVR in the patient's previous ECGs. Deflection refers to the direction the waveform takes on the ECG from the isoelectric line. If current is travelling away from a lead a negative deflection is noted; if, however, the current moves towards a lead, a positive deflection is subsequently observed (Khan, 2004) (see *Figure 3*). When confronted with a positively deflected aVR one should check the arm leads are in the correct place and adjust them accordingly. *Figures 1* and *4* show the same ECG, *Figure 1* was recorded with the leads in the normal locations, where as in *Figure 4* the limb leads were swapped over, note the positively deflected aVR lead and negatively deflected leads I and II and the rightward axis shift.

R-wave progression

This refers to the changing form of the R-waves in chest leads V1–V6 (*Figure 5*). V1 is predominantly negatively deflected, and leads V5 and V6 are predominantly positively deflected (Mills, 2005). Abnormalities in R-wave progression are often due to misplaced chest leads (Whitbread, 2006) (*Figure 6*). Poor R-wave progression may be an indicator that the chest leads have been applied in the wrong order. See *Figure 7* for normal lead positions.

Calibration markers

These are usually located at the beginning or end of the ECG recording (See *Figure 8*).

Markers should be 1 cm in height (covering two large boxes as shown in *Figure 8*). This pertains to 1 millivolt (mV) moving the stylus vertically by 1 cm (Hampton, 2003b). This is the standard calibration used for drawing the waveforms on the graph paper. In circumstances such as a presence of large R-waves (exceeding 25 mm in height). It may be necessary to reduce the amplitude to 0.5 cm to increase readability of the ECG. If this is done it should be stated on the printout by the recorder to aid in interpretation (Bowbrick and Borg, 2006).

When recording the ECG the calibration markers should be reviewed to ensure they are set to the standard calibration, usually displayed as text at the bottom of the ECG printout, unless otherwise indicated. *Figure 9* illustrates an ECG recorded on an acute ward; note the strange appearance of

Table 1. Quick guide to electrical axis

Lead I (deflection)	Lead aVF (deflection)	AXIS
+	+	Normal axis
+	–	Left axis
–	+	Right axis
–	–	Extreme right axis

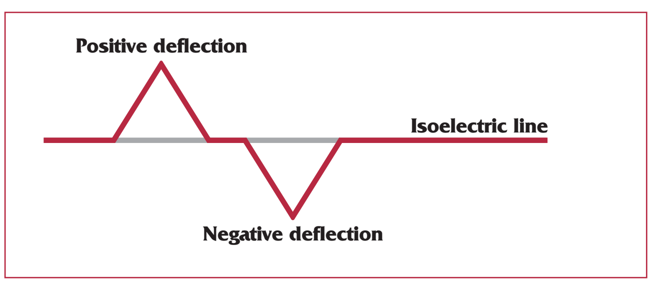


Figure 3. Positive and negative isoelectric deflection.

Figure 4. Electrocardiogram recorded with limb leads swapped over.

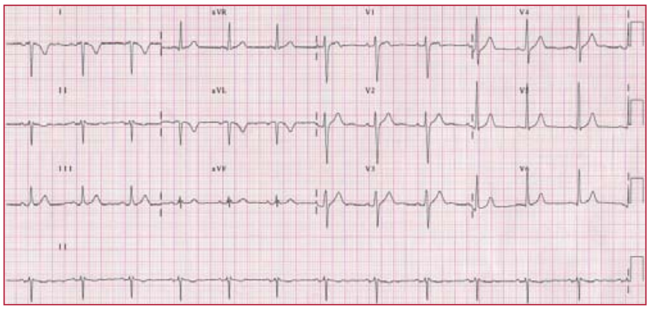


Figure 5. Normal R-wave progression from V1 to V6.

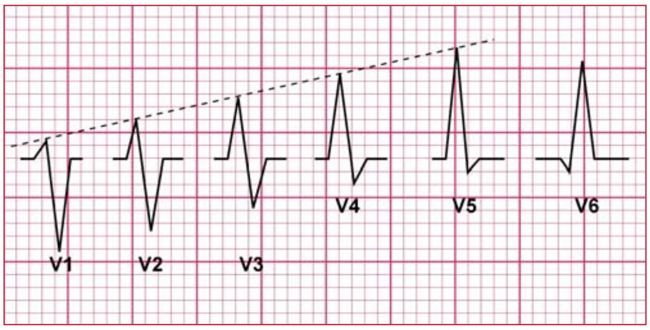
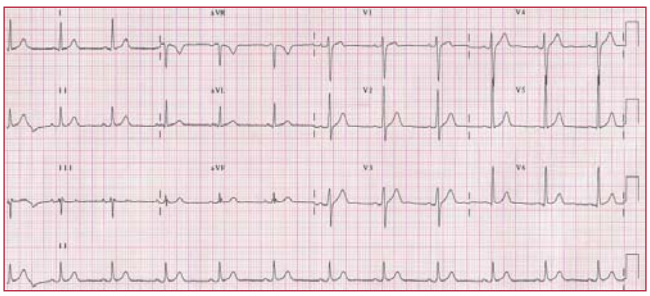


Figure 6. Chest leads misplaced changing R-wave progression.



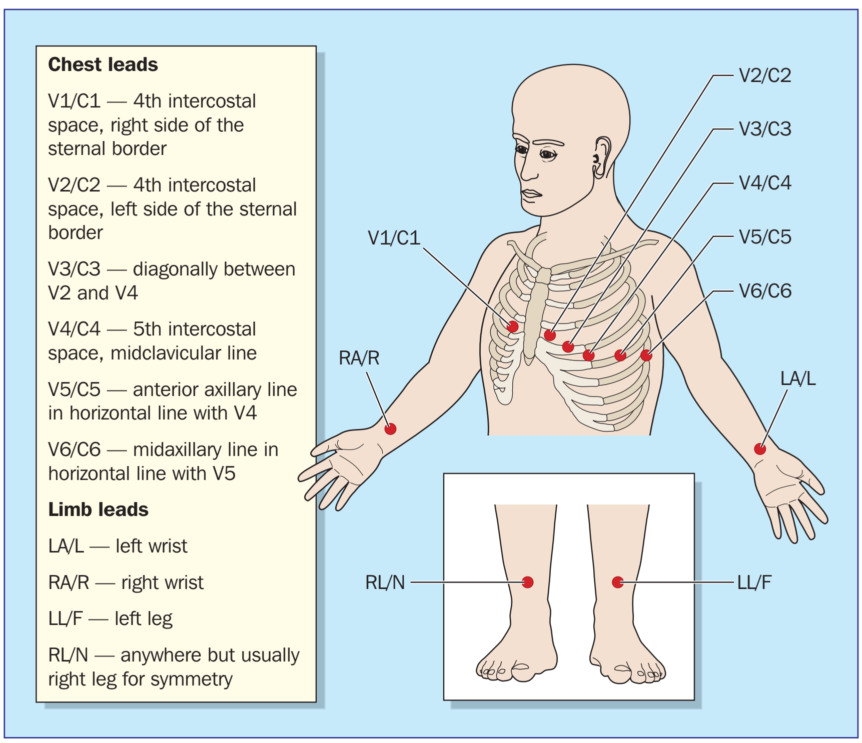


Figure 7. Electrode placement positions.

the calibration marker (over 4 cm). A standard ECG recording machine detects voltage changes in millivolts. The size of each wave on the ECG paper corresponds to the amount of voltage created by the initiating event (Houghton and Grey, 2003). Changing this setting to greater or less than 1 cm can affect the height of the waveforms shown on the ECG trace. The cause for the tracing produced in *Figure 9* was unknown but subsequent re-recording revealed a normal ECG.

Chart speed

The standard chart speed of ECG recording in the UK and USA is 25 mm/s (Hand, 2002). Time is measured via the horizontal plane of the ECG along the X-axis, each of the small 1 mm^2 squares represents a time interval of 0.04 of a second, therefore each large square (five small squares) represents a time interval of 0.2 of a second (Khan, 2004). This only applies, however, when the chart speed is set to the standard 25 mm/s (Conover, 2003). By changing the chart speed the time intervals are also changed. If the chart speed was increased to 50 mm/sec (a setting used in some areas of Europe) the wave forms on the ECG paper would double in width. Increasing the speed will add to the width of waveforms, whereas a decrease will have an opposite effect. If this change was to go unnoticed the intervals on the ECG could be miscalculated leading to an incorrect diagnosis.

Artefact

Artefact has been described by Chernecky et al (2006) as an artificial disturbance affecting the quality of the ECG. There are many different types of artefact (interference) that can present on an ECG recording. The principle types of artefact commonly encountered by ECG recorders are now discussed.

Muscle/somatic tremor artefact

This is a commonly encountered type of artefact, caused by muscular movement; the interference picked up by the ECG machine originates in muscles other than the heart (see *Figure 10*).

Somatic muscle tremor is usually caused by shivering, hiccups, anxiety and various forms of pathological tremor such as Parkinson's disease. The principle problem with this form of artefact is that it can lead to misdiagnosis. For example, a patient whose ECG shows artefact in multiple leads can obscure P-waves and mimic fibrillation waves leading to the misdiagnosis of atrial fibrillation; such false positives can lead to unnecessary treatment (Salerno et al, 2003). Paradoxically, the masking of P-waves can lead to inability to identify the PR interval (distance between start of P-wave and Q-wave, normally 0.12–0.20 seconds) – this is used to detect various forms of heart block, which may then go undiagnosed.

The ECG recorder should take reasonable steps to reduce this form of artefact once detected. In the case of anxiety the patient should be reassured and fully informed of the reason for undertaking the 12-lead ECG and their fears addressed. Where a patient is cold, attempts should be made to increase the temperature of the room to a comfortable level or blankets applied. The patient should only be exposed for as long as necessary to facilitate the recording of the ECG, with dignity maintained throughout.

Where tremors are present due to myoclonics or Parkinson's disease the limb leads can be moved closer to the heart forming a modified ECG (see modified ECGs below). This should be used as a last resort and marked clearly on the ECG that the recording was modified.

Another consequence of excessive movement during ECG recording is artefact that mimics ventricular tachycardia or ventricular fibrillation (see *Figure 11*); this again may result in the patient receiving unnecessary and sometimes dangerous medical interventions (Vereckei, 2004), especially in the case of ventricular tachycardia which has been simulated by Parkinson's tremor. Bhatia and Turner (2005) identified a number of Parkinson's patients who received a false diagnosis of ventricular tachycardia which led to a range of unnecessary medical interventions being carried out, ranging from the precordial thump to the implantation of a cardioverter defibrillator. Bhatia and Turner (2005) recommend increased training and awareness of serious cardiac arrhythmias are essential to reduce such diagnostic errors.

60-cycle interference/AC mains interference

This form of interference is caused by the improper grounding of electrical equipment, and is identified by the presence of 60 small spikes in a 1 second interval on the ECG trace and a thick, bold baseline (see *Figure 12*) (Chernecky et al, 2006).

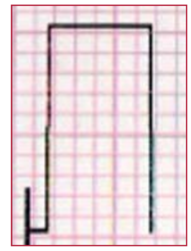
This is often caused by other electrical equipment operating at 50 Hz frequency or greater, such as improperly grounded medical monitors or devices, or alternatively a fractured wire within a cable (Bowbrick and Borg, 2006). Chernecky et al (2006) recommend that when presented with AC mains interference the recorder should attempt to determine the source of the interference and remove it, or in the case of medical equipment, turn off any non-essential devices, such as infusion pumps that may potentially interfere with the quality of the ECG. The bedside area may also contain patients' own electrical equipment such as radios or electric shavers; such equipment should be formally evaluated by the biomedical department to determine any possible cause of interference. Any defective equipment should also be sent to the biomedical department for repair or replacement. If the cause is found to be due to a fractured internal wire inside a cable, the cable should be replaced by appropriately trained personnel (Bowbrick and Borg, 2006).

Baseline wander

This form of artefact is displayed on the ECG as an irregular baseline (see *Figure 13*), increasing the difficulty in interpretation (Payne, 2004).

It can be caused by anxiety, pain, cable movement, patient perspiration, orthopnoea (Bowbrick and Borg, 2006; Chernecky et al, 2006), or respiratory swing seen in patients with chronic obstructive pulmonary disease. Bowbrick and Borg (2006) go on to recommend reducing these potential artefacts by ensuring cable movement is minimized, i.e. not dangling over the edge of the bed. In the case of respiratory swing, the recorder could ask the patient to hold their breath, although this may not be practical in patients with respiratory pathology; alternatively the patient may be placed in a more upright position. To reduce the possibility of baseline wander being caused by perspiration, the patients' skin can be cleansed with an alcohol wipe. Alcohol wipes also remove other debris that can interfere with electrode contact (Mills, 2005). Where religious sensibilities are involved soap and water can be used as a substitute to alcohol wipes. Pain and anxiety should also be considered and reduced or prevented where possible.

Figure 8. Calibration marker.



Modified ECGs

Electrodes can be placed closer to the torso to reduce somatic muscle tremor artefact and thus improve the quality of the ECG. It should, however, be noted clearly on the ECG that it is modified and should only be used when all other methods of reducing artefact have failed. Docherty (2005) emphasizes altering the limb leads' position will affect the appearance of the ECG and, therefore, local policy should be followed.

Healthcare professionals should be aware there are many potential consequences attached to recording a modified ECG which have been known to alter the cardiac axis, show non-existent myocardial infarctions, and misleading clinically important T-wave changes. These changes can lead to abnormal ECG presentation in 'normal' people (Jowett et al, 2005).

Details to be noted on an ECG recording

The recorder should endeavour to document on the ECG where the ECG was recorded, the patient's details, including name, date of birth and unit number. In addition, the recorder should also time, date and sign the ECG, highlighting the clinical reason for the recording (i.e. chest pain). Any deviations from standard should also be noted, including modified lead positions and any changes to chart speed or calibration.

Conclusion

Healthcare professionals whose role incorporates the recording of the 12-Lead ECG should have an awareness of the consequences of their recording technique and level of knowledge when carrying out the procedure of ECG recording. The author believes that staff development in the area of artefact recognition would prepare staff to identify and reduce errors. With the skills and knowledge to recognize artefact and other erroneous causes which reduce the quality

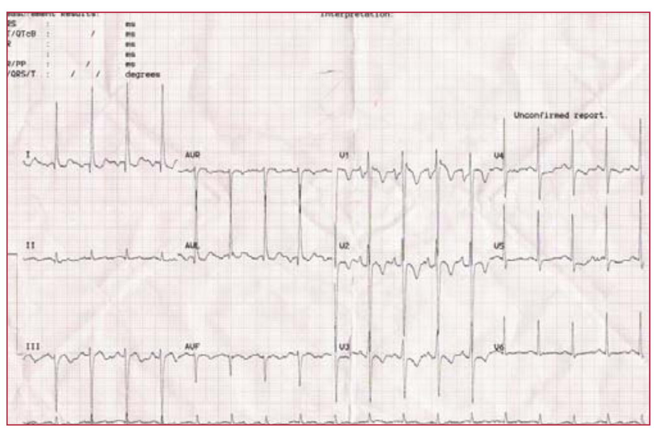


Figure 9. Abnormal calibration setting (no known cause).

Figure 10. Somatic muscle tremor in multiple leads.

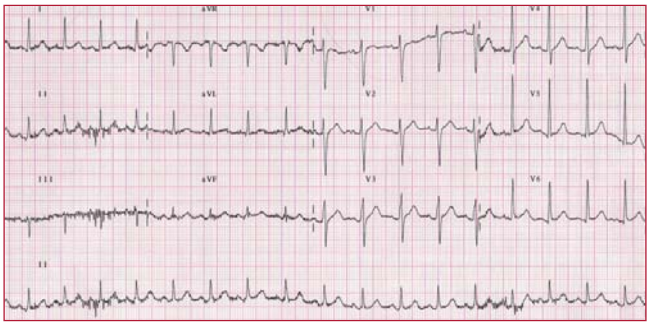


Figure 11. Patient movement simulating ventricular fibrillation.

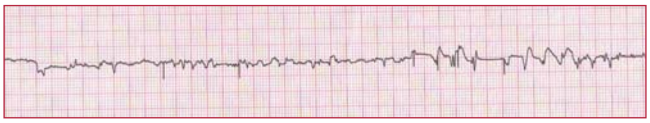


Figure 12. 60-cycle interference/AC mains interference.

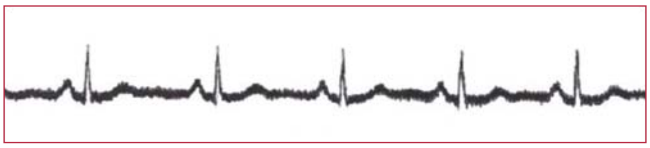
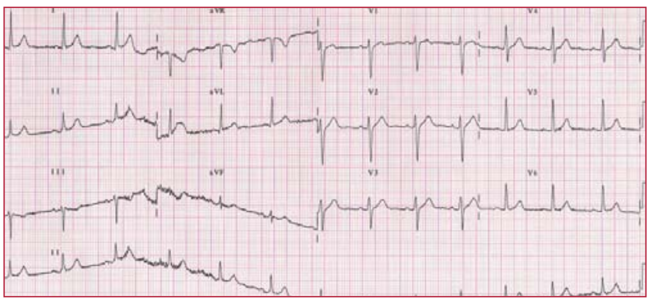


Figure 13. Baseline wander.



of the ECG recording, the healthcare professional should be able to take steps to reduce error and interference.

Producing ECGs with minimal error and interference that are clearly labelled will aid in the correct diagnosis of the 12-lead ECG by a trained interpreter, therefore reducing any potential confusion and possibility of misdiagnosis. The chance of findings being artefactual in origin should always be considered in asymptomatic patients who are otherwise haemodynamically stable (Srikureja et al, 2000). A large portion of potential artefact can be removed or reduced substantially with awareness of its causes and resolutions. By relaxing and reassuring the patient, wiping the skin with an alcohol wipe, correctly positioning the patient, ensuring all unnecessary electrical equipment that may cause potential interference is turned off, and untangling the cables, most of the artefact discussed can be reduced or removed completely before the professional even records the ECG (*Box 1*). Subsequent checks on the areas of the ECG highlighted previously allow the recorder to ensure the recording is of diagnostic quality. This saves time, repetition of procedures, and ensures patients are more likely to receive a correct diagnosis and appropriate treatment. BJN

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Box 1. Tips to reduce error and interference from the ECG prior to recording

- Ensure patient is relaxed
- Place patient in supine position
- Prepare skin with alcohol wipe prior to electrode application
- Shave excess body hair to ensure good electrode contact
- Ensure patient is warm enough to prevent tremor
- Turn off all unnecessary electrical equipment to reduce potential interference
- Untangle cables
- Ensure cables are not dangling over the bed/trolley

KEY POINTS

- The 12-lead electrocardiogram (ECG) is a vital component of cardiac assessment.
- Knowledge of different types of ECG interference and methods of its reduction can increase the quality and diagnostic value of the 12-lead ECG.
- Most of the common forms of artefact can be prevented or reduced prior to recording the ECG.
- Nurses should posses knowledge and evidence-based rationale for their practice when recording a 12-lead ECG.