



THE SOCIETY FOR _____
CARDIOLOGICAL SCIENCE & TECHNOLOGY

Clinical Guidelines by Consensus

Recording a standard 12-lead electrocardiogram

An Approved Methodology



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Introduction

Practice varies across the Health Service predominantly due to historical circumstances, personal preferences and resources. Guidelines aim to reduce such variation by gathering and presenting the evidence for best practice, thereby improving the equity and quality of services.

This guideline has been developed by the Society for Cardiological Science and Technology (SCST) and has been approved by the British Cardiovascular Society. The guideline is based on existing research and on the knowledge and experience of practitioners. Where research based evidence is not yet available consensus decisions have been made. As the research base is constantly growing, SCST will regularly review the guideline to ensure that it continues to reflect current best practice.

Audit is a recognised way of changing and improving practice and will be used to revise, modify or update subsequent guidelines. Appendix C of the guideline contains a useful checklist intended for use as an audit tool. This checklist can be used to assess how well the guideline is being followed. Additionally, the audit checklist may be used to ensure that any local guidelines developed from this consensus document meet the essential requirements.

Acknowledgements

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Guidelines for recording a standard 12-lead electrocardiogram

Equipment

- Electrocardiograph that meets or exceeds the requirements of IEC 60601-2-51 (2003)*.

The device should be pre-programmed in accordance with American Heart Association (AHA) specifications^{1,2}.

- The low-frequency filter should be set no higher than 0.05Hz to avoid distortion of the ST segment**
- The high frequency filter should be set no lower than 100Hz to prevent loss of high frequency information³

Recommended recording bandwidths pre-stored in device set-up

'Auto' mode	0.05Hz – 100Hz or 0.5Hz – 100Hz**
'Manual' or 'real time' mode	0.05Hz – 100Hz only

NB. Mains (50Hz) filter - off

When front panel 'filter' button selected

'Auto' mode	0.5 Hz – 40 Hz
'Manual' or 'real time' mode	0.05 Hz – 40 Hz

- Disposable tab electrodes that meet or exceed the requirements of AAMI EC12-00 (2000)***
- Skin preparation equipment (for example, razor, abrasive tape)

* IEC 60601-2-51 (2003) - *Particular requirements for safety, including essential performance, of recording and analysing single channel and multichannel electrocardiographs*. This document establishes minimum safety and performance requirements for electrocardiographic (ECG) systems that are intended for use in the analysis of rhythm and of detailed morphology of complex cardiac complexes.

** Digital filter design allows for the low-frequency filter to be raised to **0.5Hz** when recording in 'auto' mode. However, ST-segment distortion may occur when this setting is used in 'manual' mode. Fixing the low-frequency setting at **0.05Hz** in the pre-set should prevent this error occurring³.

*** AAMI EC12-00 (2000) - This standard establishes minimum labeling, safety, and performance requirements for disposable electrodes used for diagnostic electrocardiography.

Training

The operator should be competent in both the use of the electrocardiograph and in the recording of an electrocardiogram (ECG). Ideally, this will be in the form of a recognised qualification, awarded by the Society for Cardiological Science & Technology (Certificate or Associate membership) following the successful completion of the appropriate examination. As a minimum, personnel should provide evidence of having undertaken a practical assessment process that has been carried out by a competent practitioner holding the above award. It is essential that competence in the recording of an electrocardiogram is maintained and this should be reviewed on an annual basis.

Procedure

Prior to undertaking the procedure the following should be checked:-

- That electrocardiograph is safe and ready to use (date & time settings are correct).
- The patient area is clean and tidy.
- There is sufficient paper, electrodes, razors and skin preparation equipment.
- The identity of the patient should be confirmed and cross-checked with the request.

Patient Preparation²

Unrestricted access to the skin in the chest area, arms and lower legs is required to allow for correct placement of the electrodes. Once the electrodes are positioned and the connecting wires are appropriately attached, the patient should be covered with a gown to preserve his/her dignity during the procedure. Patients may feel uncomfortable about being touched on their upper torso. The ECG procedure requires sensitivity. Operators must make every effort to respect the sensitivities of patients and minimise their embarrassment. Operators must adhere to the Trust's chaperone policy and ensure that patients are made aware of the policy.

The appearance of the electrocardiogram can vary depending on the position of the body at the time. Therefore, a recumbent position is recommended for the patient. Any variation to this position should be noted on the printed ECG.

The bed or couch should be large enough to support the body and limbs.

In order to achieve clinically accurate recordings with minimal artefact it is essential for patients to be comfortable and relaxed. This may be achieved through optimising the environmental conditions and providing sufficient explanation to the patient and / or carer.

Skin preparation

Skin preparation is often required to help produce an artefact-free and accurate ECG. Various methods are available, all of which are designed to minimise the skin-to-electrode impedance.

For example,

- The removal of chest hair may be required to ensure adequate contact with the skin. Verbal consent should be obtained from the patient and a clean razor used which should be disposed of in a sharps bin immediately afterwards.
- Exfoliation may be required and should be undertaken with very light abrasion using either a paper towel, gauze swab or proprietary abrasive tape designed specifically for this purpose.
- On occasions the skin may require cleansing. A variety of methods exist ranging from washing with mild soap to cleaning with an alcohol wipe. **However, care must be taken in patients with sensitive or broken skin.**

Electrode placement

The following electrode sites should be correctly identified and the placement of the electrodes must conform to AHA recommendations^{1,2}.

(NB. Each lead wire is generally colour coded to aid identification. However, the colour may vary depending on manufacturer. The colours listed are consistent with IEC (European) recommendations).

Limb leads

Evidence exists to demonstrate that moving the limb lead attachments away from the distal limbs alters the appearance of the ECG. This variation can invalidate the use of such recordings for many diagnostic purposes^{4,5}.

To ensure consistency between recordings it is recommended that the electrodes are attached to both arms and legs, slightly proximal to the wrist and ankle. It is imperative that recordings from other sites are labelled accordingly so that the results are not confused with those obtained from standard sites.

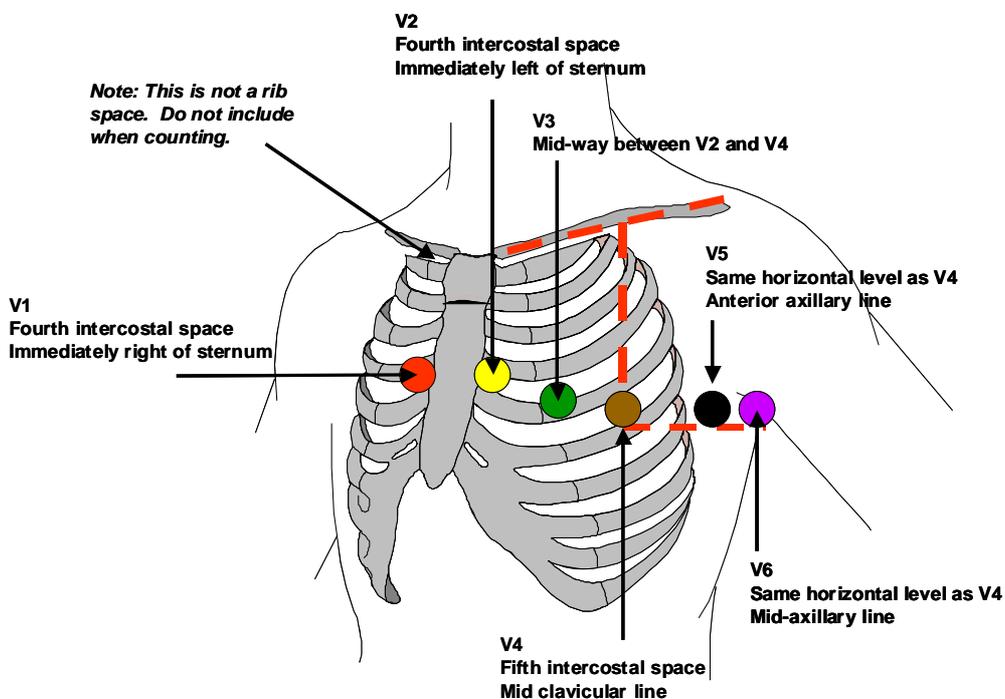
- Right arm limb lead (RA, red) – right forearm, proximal to wrist
- Left arm limb lead (LA, yellow) – left forearm, proximal to wrist
- Left leg limb lead (LL, green) – left lower leg, proximal to ankle
- Right leg limb lead (RL, black) – right lower leg, proximal to ankle

Precordial (chest) leads

Variation in the placement of the precordial electrodes produces diagnostically significant differences in the ECG⁶. **Previous studies have demonstrated that V1 and V2 are frequently placed too high and the left lateral leads too low^{7,8}.**

The correct anatomical positions for placing the precordial leads have been defined^{9,10,11} and should always be used (see figure below). If any deviation from these positions is necessary then this must be clearly labelled on the printed ECG. The centre of the active surface area of the electrode should be aligned with the relevant anatomical landmark.

Electrode	Position
V1 (C1)	Fourth intercostal space at the right sternal edge
V2 (C2)	Fourth intercostal space at the left sternal edge
V3 (C3)	Midway between V2 and V4
V4 (C4)	Fifth intercostal space in the mid-clavicular line
V5 (C5)	Left anterior axillary line at same horizontal* level as V4
V6 (C6)	Left mid-axillary line at same horizontal* level as V4 & V5



Standard ECG chest electrode positions

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* at right angles to the mid-clavicular line

Locating chest electrode positions

- Care should be taken when counting the intercostal spaces down from the clavicle that the small space between the clavicle and the first rib is not mistaken for the first intercostal space.
- In order to avoid this common error the sternal angle (angle of Louis) should be used as the main reference point. This anatomical landmark denotes the position of the sternal angle at the manubriosternal joint.

To locate the sternal angle, a finger should be run down the sternum, from the sternal notch at the top until a bony horizontal ridge, the sternal angle, is met. With the finger on this ridge, sliding down and to the side will locate the second intercostal space. Then count down to the third and fourth space. Locate the very edge of the sternum and place V1 there. Repeat this procedure on the left side to correctly position V2.

- Next the position for V4 should be located. This should be placed in the fifth intercostal space in line with the mid point of the clavicle.
- Once the V4 electrode has been correctly placed then the location for V3 can be identified, directly mid-way between V2 and V4.
- V5 and V6 are then positioned, taking care not to follow the line of the ribs, but to follow a horizontal line from V4. V5 is placed in line with the anterior axilla and V6 in line with the mid-axilla.
- The centre of the active surface area of the electrode should be aligned with the relevant anatomical landmark, i.e. the middle of the V1 electrode should be placed at the right sternal edge.
- When recording an ECG from female patients by convention the lateral chest electrodes (V4, V5 and V6) are placed beneath the left breast. Whilst it is acknowledged that there is emerging evidence to support the positioning of these electrodes over the breast without any attenuation of the signal^{12,13} there are insufficient published data to support alteration of the widely adopted technique of placing V4 to V6 under the left breast.

Recording

- In order to record a good quality ECG the patient must be relaxed and comfortable. If these conditions are not satisfied the ECG will record somatic muscle potentials as well as cardiac activity. Such interference will make the ECG more difficult to interpret. Some patients cannot relax fully because of pain from arthritis or may have a neurological condition such as Parkinson's disease causing tremor. Make them as comfortable as possible and annotate the trace with an appropriate explanation.
- On occasions it may be necessary to adapt the recommended ECG recording techniques. For example, wheelchair bound patients may need to remain in their chair during the recording process. **Any variations to standard recording techniques must be highlighted on the trace**, e.g. "ECG recorded whilst patient in wheelchair".
- Patient details (name and a second unique identifier such as hospital number or date of birth) should be entered into the ECG machine, after it has been checked with the patient directly (or someone speaking on their behalf).
- Before recording the ECG, check that the patient's limbs are still and appear relaxed. If the patient has clenched fists or stiff arms, or is moving his / her fingers, it will not be possible to obtain a high quality ECG.
- Press the appropriate button on the machine to initiate a recording (usually labelled 'start' or 'auto'). A 12-lead ECG and rhythm strip should be recorded at 25mm/s with a gain setting of 10mm/mV^{1,2}.
- The filter button **should not** be selected for this initial recording.

If, despite efforts to relax the patient and make them comfortable, there is somatic muscle interference on the ECG, switch on the filter and repeat the recording. Use of the filter should be clearly identified on the final ECG.

NB. The filter will reduce the interference. However, as it will also distort the ECG³ it should only be used when absolutely necessary (after all attempts to eliminate the interference have failed).

- If the ECG complexes are of high voltage then the gain should be adjusted (5mm/mV) to enable them to be measured accurately. Any alteration in the gain settings should be clearly marked on the tracing.
- If the rhythm is noted to be irregular then an additional rhythm strip (traditionally lead II) should be recorded for a minimum of 10 seconds.
- Any changes on the ECG that might require urgent medical attention should be identified and advice sought from a senior member of staff if necessary. If the patient has any cardiac symptoms at the time of recording, such as chest pain or palpitations then this should be noted on the tracing and brought to the immediate attention of a senior member of staff.
- If the ECG is technically correct and of good quality, ensure that it is fully and correctly labelled (patient identification information, relevant clinical details) then remove all of the electrodes from the patient and dispose as clinical waste.

Appendix A

The recommended approach to recording the 12-lead ECG in the patient with dextrocardia

The term dextrocardia refers to any situation where the heart is located within the right side of the chest rather than the left side. It may be associated with the condition *situs inversus* where all of the patient's organs are in a mirror-image position.

When the P wave in lead I is inverted (P axis $> 90^\circ$) the diagnosis of dextrocardia may be suspected, provided there is no technical error, such as reversal of the right and left arm connections. Poor R wave progression across the chest leads will support this ECG diagnosis.

A second ECG should be recorded with the chest electrodes positioned on the right side of the chest using the same intercostal spacing and anatomical landmarks (right sided).

This approach will provide a 'true' ECG representation. The limb lead complexes will continue to appear inverted, demonstrating the abnormal location of the heart. However, the re-positioned chest leads will now show the appropriate R wave progression.

Clear annotation describing the repositioned electrodes should be handwritten onto the hard-copy (For example, V3R, V4R etc.)

Both of the annotated ECGs should be retained for inclusion in the case notes.

Note

Swapping of the right and left limb leads will 'normalize' the appearance of the limb leads. If this approach is preferred it is imperative that the ECG is very clearly annotated to prevent the possibility of the dextrocardia being overlooked.

Appendix B

Electrocardiography in childhood

A patient and gentle approach is necessary for the recording of an ECG from infants (first year of life), and children, in order that an artefact-free electrocardiogram is obtained. With a few exceptions the recording method is closely similar to that described for adults.

If possible, the recording is made with the subject supine, but the sitting position is allowed if this will prevent restlessness or distress.

The choice of leads to be recorded will sometimes be determined by local preferences.

The four limb leads are attached as previously described.

Where possible, six precordial leads, V4R, V1, V2, V4, V5, and V6 are recorded. V3R and V7 may be recorded, by special request. (V3R and V4R are right sided leads placed in a mirror image position to V3 and V4. V7 is a posterior lead placed in the posterior axillary line at the same horizontal level as V4).

For recording purposes a paper speed of 25mm/s is standard. The younger the child the faster the heart rate; where necessary, for accurate analysis of the electrocardiogram, a paper speed of 50mm/s is recommended.

In terms of voltage, the standard is a vertical deflection on the electrocardiogram of 10mm representing 1mV. When QRS complexes in simultaneously recorded leads would be so large as to overlap, the deflection should be halved so that a deflection of 5mm would represent 1mV.

Normal values for ECG intervals and waves, most divergent from adult values in the very young, gradually converge with physical growth.

When an electrocardiogram is presented for analysis (diagnosis), any variation from the usual recording procedure must be clearly and indelibly stated.

Appendix C: AUDIT CHECKLIST

Filter Settings

1. In 'Auto' mode is the machine preset to a recording bandwidth of either:
0.05Hz – 100Hz or *0.5Hz – 100Hz*?
 Yes No
2. In 'Manual' or 'real time mode' is the machine preset to a recording bandwidth of
0.05Hz – 100Hz?
 Yes No
3. Is the mains filter (50Hz) set to 'off'?
 Yes No

Training

1. Has the person performing the ECG recording been appropriately assessed in this technique?
 Yes No

Electrode placement

1. Has appropriate skin preparation been carried out prior to recording the ECG?
 Yes No
2. Are electrodes positioned as per the guidelines?
 Yes No
3. If electrodes are not positioned as per guidelines is the ECG annotated with an appropriate explanation?
 Yes No N/A

Recording

1. Are the patient details present and correct?
 Yes No
2. Is the ECG free of artefact?
 Yes No
3. If artefact is present has an explanation been written on the ECG?
 Yes No N/A
4. Has the mains filter been used?
 Yes No
5. If the front panel 'filter' has been selected has an explanation been written on the ECG?
 Yes No N/A
6. Have the appropriate gain settings been used?
 Yes No
7. If the rhythm is irregular has an additional rhythm strip been recorded?
 Yes No N/A

References

1. Recommendations for standardization of leads and of specifications for instruments in electrocardiography and vectorcardiography. Kossman CE et al. *Circulation* 1967;35:583-601
2. Recommendations for standardization of leads and of specifications for instruments in electrocardiography and vectorcardiography. Pipberger HV et al. *Circulation* 1975;52;11-31
3. Recommendations for standardization and specifications in automated electrocardiography: Bandwidth and digital signal processing. Bailey et al. *Circulation* 1990;81;730-739
4. Evaluation of changes in standard electrocardiographic QRS waveforms recorded from activity-compatible proximal limb lead positions. Pahlm O et al. *Am J Cardiol* 1992;69:253-257
5. Invalidation of the resting electrocardiogram obtained via exercise electrode sites as a standard 12-lead recording. Sevilla DC et al. *Am J Cardiol* 1989;63:35-39
6. Positional and respiratory changes in precordial lead patterns simulating acute myocardial infarction. August T et al. *Am Heart J* 1958;55:706-714
7. Variability of precordial electrode placement during routine electrocardiography. Wenger W, Kligfield P. *J Electrocardiol* 1996;29:179-184
8. Electrocardiographic poor R wave progression III: the normal variant. Zema MJ et al. *J Electrocardiol* 1980;13:135-142
9. Joint Recommendations of the American Heart Association and the Cardiac Society of Great Britain and Ireland. Standardization of precordial leads. *Am Heart J* 1938;15:107-108
10. Committee of the American Heart Association for the Standardization of precordial leads. Supplementary report. *Am Heart J* 1938;15:235-239
11. Committee of the American Heart Association for the Standardization of precordial leads. Second supplementary report. *J Am Med Assoc* 1943;121:1349-1351
12. False positive ECG reports of anterior myocardial infarction in women. Colaco R et al. *J Electrocardiol* 2000;33;239-244
13. Precordial electrode placement in women. Macfarlane PW et al. *Neth Heart J* 2003;11:118-122