Application note

Improving ECG quality

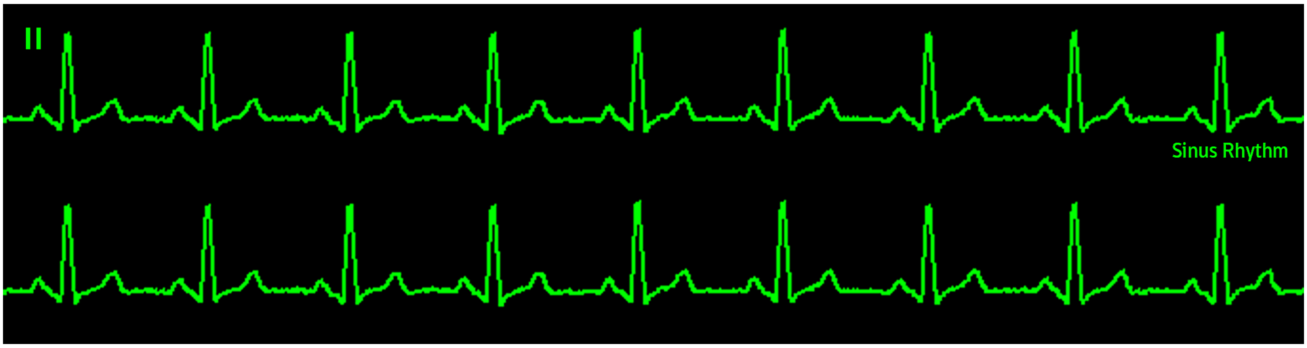
Introduction

Good ECG signal quality—it is something every clinician strives to secure every time they monitor a patient's heart. This application note will look at why ECG signal quality is important and discuss how to improve the stability and quality of the signal as part of cardiac monitoring with electrodes, whether the patient is in an EMS or hospital environment.

Importance of ECG Quality

Acquisition of quality ECG data is critical in providing accurate and timely diagnosis and patient treatment. Poor ECG quality can:

- Result in the monitor's inability to recognize the R-wave, thus affecting arrhythmia analysis and the ability to perform procedures such as synchronized cardioversion and transcutaneous pacing
- Inhibit reading a 12-lead accurately
- Result in false alarms and unnecessary troubleshooting, potentially delaying treatment



ECG quality improvement

Back in 1984, in *Critical Care Nursing*, an article discussing ECG artifact stated: "Improvement in electrode preparation techniques and a better understanding of the sources of artifact can enhance equipment performance, resulting in improved patient assessment, more effective utilization of nursing time, and reduced operating costs."[1] This statement still holds true today despite advancements in monitoring devices. In other words, poor electrode preparation can result in a poor waveform, no matter how advanced the device is.

So, how can you improve ECG quality and subsequently patient assessment and care? It involves:

- Good skin preparation
- Use of quality electrodes
- Proper electrode application
- Good electrode-to-patient contact
- Artifact elimination, and/or
- Proper lead selection.

Let's look at each option more closely.

Skin preparation

Skin is a poor conductor of electricity and may create artifact that distorts the ECG signal. In fact, artifact from the outer layer of the skin (epidermis) is more troublesome than other types of artifact because:

- It is difficult to filter electronically
- Its amplitude is often larger than the ECG signal[2]

Unfortunately, clinical studies have shown that the electrode-skin interface is frequently overlooked as a major source of artifact affecting many electrophysiologic recordings.[3]

Also, in a survey at the 1998 AAMI Annual Meeting and AACN NTI, only 17% of the participants said they had protocols in place that required skin preparation prior to electrode placement on a patient.[3] Although skin preparation can add a little time, the extra effort may reduce the time spent dealing with poor electrode-to-patient contact and ECG artifact.

To prepare the skin for electrode placement, dry, dead epidermal layers of skin must be removed, along with any natural oils and dirt that impede electrical flow and thus create a resistance to signal quality. Though skin preparation should be well known by clinicians involved with ECG monitoring, it is worth reviewing the steps and related benefits.

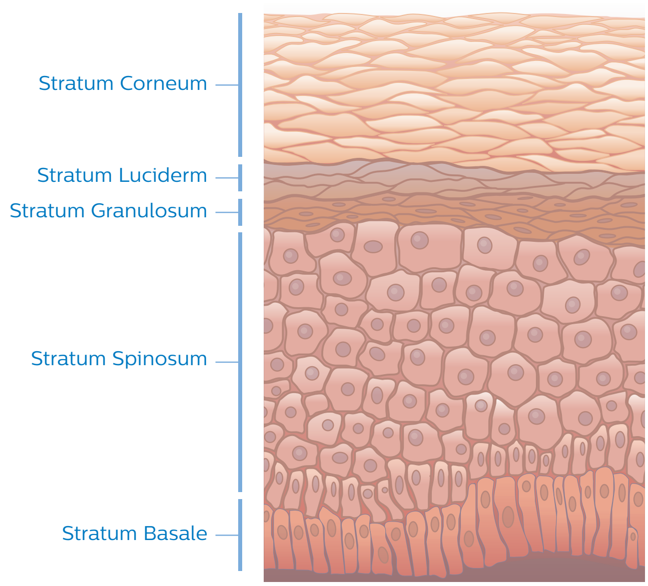


Figure 1: Epidermis Cross Section.

1. Shave or cut hair from electrode sites since excessive hair prevents good electrode contact
2. Clean each site thoroughly with soap and water, a non-alcohol wipe, or 4 x 4 to improve electrical flow
3. Dry the skin vigorously to increase capillary blood flow to the tissues

   NOTE: Though cleaning and drying the skin may be difficult in emergency situations, it can improve electrode adhesion and trace quality. Also, it is recommended not to use alcohol for cleaning purposes because it dries the skin and may diminish electrical flow.
4. Use an ECG skin prep pad or paper (such as Philips' M4606A ECG Skin Prep Paper), with its abrasive fine sandpaper finish, to:
   - Remove part of the **stratum corneum** (epidermis outer layer, see Figure 1 for epidermis cross section) to allow electrical signals to travel to the electrode
   - Scratch the **stratum granulosum** (epidermis middle layer) to reduce motion artifact

Using an abrasive has been documented to reduce skin resistance and artifact (with little probability of skin irritation) by Medina et al.[4] with just one stroke of fine sandpaper. Another study showed a 334 kΩ reduction in average impedance (from 354 to 20 kΩ), in part by using fine sandpaper material.[5] Abrasion also minimizes inertial and relative motion problems in the stratum granulosum, and rids the skin of oils and other debris that impede electrical flow.[6]

Keep in mind that the **stratum corneum** can regenerate itself in as little as 24 hours, thus compromising electrode-to-patient contact. So, repeated skin abrasion should be considered during long-term monitoring.

Though time is critical for the clinician who first treats a patient, a few more seconds of skin preparation using an abrasive can potentially improve ECG analysis and diagnosis, and subsequent treatment.

Quality electrodes

Use of quality electrodes is an important part of the overall monitoring process. When selecting electrodes, keep the following guidelines in mind:

- Electrodes exist in different shapes and sizes, are made up of different materials, and are recommended for different clinical applications (e.g., ambulatory ECG, critical care unit, etc.). Use only electrodes specified by the manufacturer of the monitor/defibrillator you are using. Philips' data sheet entitled "Why buy Philips ECG Electrodes?" can help make the electrode selection task easier
- All electrodes selected should be of the same brand and type to help minimize noise
- Adhere to all instructions for use found on the electrode packaging (e.g., 'Use by' date)
- Electrodes packaged together in large quantities should be used shortly after the packaging is open or the packaging should be tightly re-sealed since extended exposure to air will dry out electrodes prematurely and reduce their adhesive and conductive properties. Consider writing the date and time that packaging is opened to help track electrode quality
- If monitoring for extended periods of time, change electrodes periodically, based on manufacturer's specifications

Electrode application

Proper electrode application can help maximize ECG signal quality. Consider the following steps the next time you apply electrodes:

- When possible and appropriate, explain the electrode application procedure to the patient to decrease anxiety and increase relaxation
- Attach the lead wire to each electrode **before** applying the electrode for patient comfort
- For 3-lead and 5-lead, place electrodes as shown in Figures 2 and 3
- Apply the electrode by pressing around the entire edge of the electrode. Avoid pressing directly on the electrode center since it spreads the gel out and may create air pockets that contribute to noise

NOTE: If you are using multifunction electrode defibrillator pads, you may need to reposition ECG electrodes to allow for correct pad placement to facilitate pacing or defibrillation therapy.

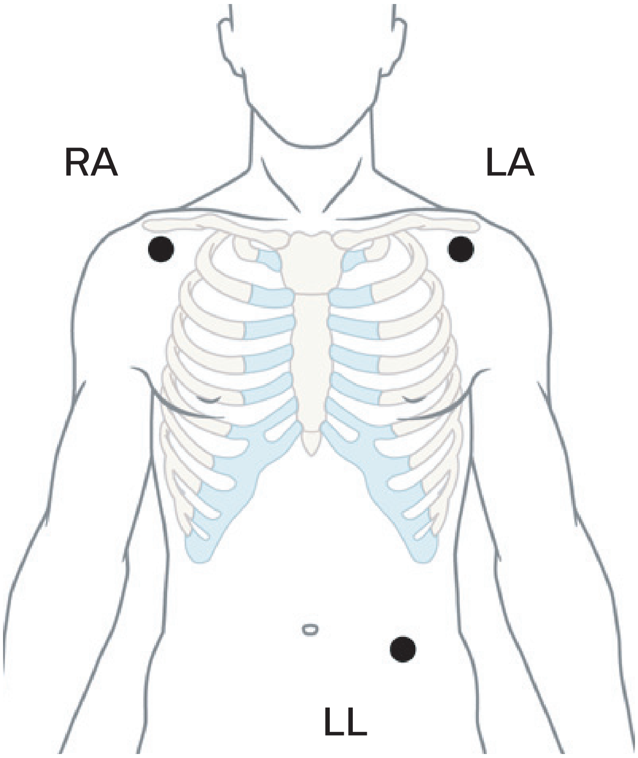


Figure 2: 3-lead electrode placement.

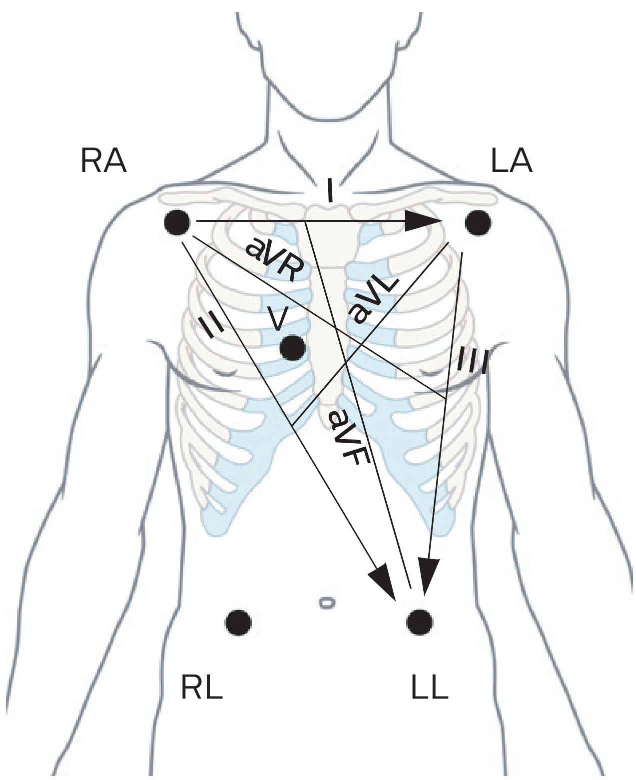


Figure 3: 5-lead electrode placement.

Electrode-to-patient contact

Poor electrode-to-patient contact can result in poor signal quality and relative waveforms, as well as false alarms. Poor contact could result from to poor skin preparation, dried electrode gel, and/or defective ECG cables or lead wires.[1] Keep in mind the following guidelines to ensure good contact:

- Once attached, electrodes should not move in any way
- Check electrodes periodically for firm adhesion and complete contact. If an electrode moves easily, the electrode connection is too loose and may need to be changed
- Tape down the lead wire about 3-4 inches away from the electrode, with slack in the wire to prevent it from pulling on the electrode

Artifact elimination

An artifactual signal is anything on an ECG that is not caused by the electrical currents generated by the heart.[2] This signal can come from sources such as:

- Electrical interference (also known as low frequency noise) originating from the 60Hz current which supplies power to electrical wall outlets, or from a remote device such as a cell phone
- Muscle tremor
- Patient movement
- Loss of electrode contact[7]

It is difficult to deal with electrical interference since it can't be filtered without compromising the ECG complex because of its similarity to the ECG signal frequency, so it is best to monitor away from other equipment, ensuring cable and lead wires do not cross the power cables of other equipment or vent tubing. To reduce muscle tremor and patient movement, attempt to warm a shivering patient or make them more comfortable in a reclined position, if possible, rather than adjust a filter setting.[2] Finally, continually check lead wire-to-electrode connection and electrode-to-patient's skin adhesion to ensure ECG quality and prevent false alarms, as mentioned in the previous section.

Lead selection

It is important to select a suitable lead that shows the largest amplitude and cleanest signal so a QRS complex and R-wave, in particular, can be accurately detected by the monitor. Consider the following lead selection guidelines:

- The QRS complex should be tall and narrow (recommended amplitude > 0.5 mV)
- The R-wave should be above or below the baseline (but not biphasic)
- The P-wave should be smaller than (1/5) R-wave height
- The T-wave should be smaller than (1/3) R-wave height

To prevent detection of P-waves or baseline noises as QRS complexes, the minimum detection level for QRS complexes is set at 0.15 mV, according to AAMI-EC 13 specifications. If the ECG signal is too weak, you may get false alarms for asystole.

In many monitors, increasing the gain (size) of the ECG does not change the signal to the monitor. Therefore, the signal should meet the above criteria without changing the gain to ensure the monitor can accurately analyze the waveform.

Conclusion

Clinicians depend on the monitors they use every day to provide accurate and useful information. When it comes to ECG quality, the electrode type, electrode application, and skin preparation are factors that play an important role in sending a good ECG signal to the monitor for analysis. The goal is to eliminate as much resistance, interference, and/or artifact as possible to ensure stable electrophysiologic recordings for better analysis, diagnosis, and treatment of the patient's condition. The results should be a reduction in:

- **Troubleshooting** ECG quality
- **Time delay** to patient care
- **Frustration** on the part of the clinician

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