Proper Skin Prep Helps Ensure ECG Trace Quality

Clinician survey finds that most are unaware of variations in skin impedance and how easily it can be reduced for artifact-free traces and increased efficiency.

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Most clinicians have experienced unacceptable ECG trace quality when using disposable electrodes. When the monitor alarm goes off, they try everything to fix the problem from adjusting the ECG monitor to replacing all the electrodes, leadwires or cables to calling biomedical engineering for help. All this takes time, increases costs, adds to staff and patient frustration, and may place the patient at risk.

A new survey shows that something as easy and simple as proper skin preparation prior to electrode placement can significantly reduce ECG artifact in most electrode situations by lowering patient skin impedance. Nursing professionals and biomedical engineers attending the 1998 AACN National Teaching Institute™ & Critical Care Exposition (AACN 1998 NTI™) and the 1998 Annual Meeting of the Association for the Advancement of Medical Instrumentation (AAMI) experienced first hand the dramatic difference in traces after a skin preparation agent was performed to their own arms prior to electrode placement.

The skin contributes to the noise or artifact associated with disposable skin electrodes. But clinical studies have shown that the electrode-skin interface is frequently overlooked as a major source of artifact affecting many electrophysiologic recordings.[1] The ideal skin preparation technique for the application of disposable ECG electrodes includes removing part of the stratum corneum to allow electrical signals to travel back to the electrode.[2]

Patient Skin Impedance

Electrocardiography (heart monitoring) measures and records the time sequence of the electronic voltage generated by the heart muscle. The electrocardiogram (ECG, EKG) is the graphical recording of the electrical activity of the heart. A patient's heart and skin, along with the monitor, cable, leadwire, connector, and ECG electrode all play a distinct role in obtaining an electrocardiogram. This paper describes how high patient skin impedance at the electrode placement site is a common reason ECG artifact is seen and how it can be greatly reduced.

There are short-term and long-term monitoring applications for ECG electrodes. Short-term monitoring is also referred to as resting or diagnostic monitoring. Usually the electrocardiogram is produced in a few minutes. Long-term monitoring is generally of the "critical care" type, with patients being monitored for extended periods of time. This may consist of Holter or cardiac event recorders, telemetry transmitters and intensive care or bedside monitoring units.

An electrode basically consists of a sensing element (snap) in contact with an electrolyte (gel). When the electrode is placed on the skin surface, the skin becomes an integral part of the circuitry. Should this circuitry be compromised due to high patient skin impedance, the signal integrity can be adversely affected, causing base line wander, substantial noise (artifact) and even loss of the ECG trace. Other influences beyond high patient skin impedance that can contribute to high patient skin impedance artifact include the environment i.e. electrical field (60 Hz), humidity, temperature, static electricity or the patient's skin condition such as diaphoresis.

The skin is the body's outer covering, which is called the integumentary system. Its function is to protect the body against a multitude of environmental insults. The skin is the most flexible organ of the body. The skin has two distinct layers; the epidermis (the outer most layer), and the dermis, (the inner layer).

Most of the epidermis is stratified squamous epithelium and lacks blood vessels. The cells deeper and closer to the dermis, however, are nourished by dermal blood vessels and can reproduce. As this happens, they push old cells toward the skin's surface. By the time they reach the surface, those cells are dead and flattened. The remaining dead cells contain keratin fibers packed with plasma membranes. This outermost layer is named the stratum corneum. It is tough, shedding millions of skin cells daily. This layer is the source of most problems with ECG trace quality.

How Skin Impedance Affects Trace Quality

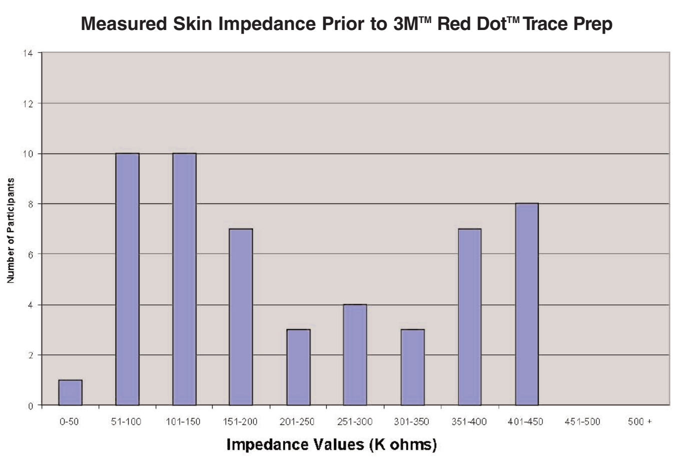
Skin impedance can be defined as the opposition or resistance to the passage of alternating current (AC) electrical signals and is measured as a voltage/current. There is no quick assessment of a patient, other than actual measurement, to determine if he or she has high skin impedance. Factors such as age, sun exposure, skin lotions, relative humidity and ambient temperature can influence skin impedance. Skin impedance plays a critical role in ECG trace quality.

The challenge facing electrode designers is to develop an electrode with reliable electrical characteristics that are gentle to patient's skin, even during long-term monitoring situations. The challenge facing clinicians is to understand the factors that can affect ECG trace quality, beyond the electrode.

Clinician Survey

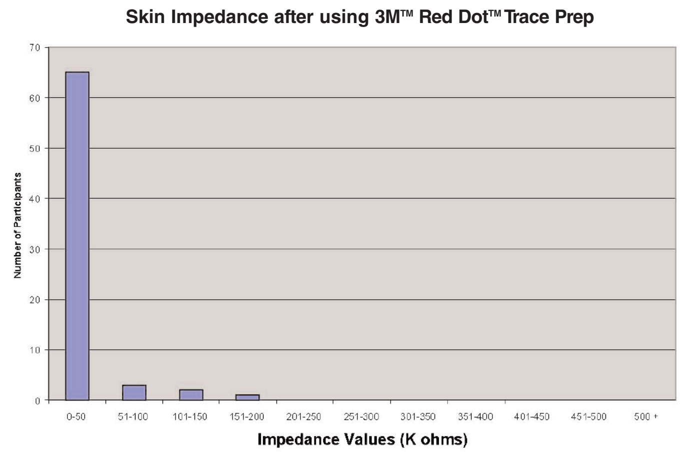
To better understand actual practice for ECG electrode skin preparation, 3M conducted a survey at the 1998 AAMI Annual Meeting and the 1998 AACN National Teaching Institute™ & Critical Care Exposition (AACN 1998 NTI™). Survey participants were primarily biomedical engineers and technicians from AAMI and nursing professionals from AACN 1998 NTI™. The results of the survey were surprising. Most of the nursing professionals were not aware of skin impedance, or how it can affect ECG trace quality. In fact, only 17 percent of the participants said they have a protocol in place that requires skin preparation prior to placing an electrode on a patient. Also, most of the biomedical engineers and technicians were aware of the affect skin impedance has on trace quality, but were not aware of the extreme variability of skin impedance, how it affects ECG trace quality and how easily it can be reduced.

Survey participants had their skin impedance measured by having two 3M™ Red Dot™ Electrodes 2261 and 2259 placed on their forearm with a Prep-Check # 105 electrode impedance meter, made by General Devices, connected to the electrodes. The following histogram describes the measurements taken before any means of electrode site preparation:



The average skin impedance measured in this study was 354 K-ohms.

The skin of each participant was then prepared with mild skin abrasion to the electrode site using 3M™ Red Dot™ Trace Prep 2236 (fine sandpaper material). This mild abrasion technique consisted of holding the participants skin with one hand and gently wiping the skin three times with the trace preparation in the other hand. This technique took a few seconds for each electrode site and was in general, not uncomfortable for the participant. The following histogram describes the measurements taken:



Survey Findings

The average skin impedance measured in this study, after using the trace preparation was 20 K-ohms. This was a 325 K-ohms reduction in the average impedance.

Following the assessment of skin impedance, survey participants were asked if they ever have unacceptable ECG trace quality. Only 14 percent answered that they almost never have unacceptable trace quality. The clear majority of participants stated that they experience occasions of unacceptable trace quality, (52 percent replied "often" and 34 percent replied "occasionally").

Troubleshooting Unacceptable Trace Quality

Troubleshooting trace quality can be time-consuming, costly and risky to the patient. The survey found that 34% of the clinicians most often attempt to resolve the trace quality problem by adjusting the ECG monitor, 30 percent immediately change all of the electrodes and 11 percent immediately change the cable and/or leadwires. When this method of trouble shooting does not work, biomedical engineering is called to assist. Forty-one percent of the survey participants stated that it usually takes biomedical engineering and nursing a total of 15-30 minutes to obtain an acceptable ECG trace. Another 27 percent stated that it takes 60 minutes or more. Many survey participants said, "I eventually pay no attention to monitor alarms!"

Frustrating Delays and Higher Costs

Trouble-shooting ECG trace quality is clearly frustrating for the clinician, may delay treatment for the patient and is costly for a facility. The cost for changing all of the electrodes is approximately $.20 for each electrode. The cost of changing a leadwire is approximately $5 for each leadwire. An average cable costs $60. In a five lead-monitoring scenario, the cost of trouble-shooting may range from $1.00 - $85 for each trouble-shooting event. For a hospital with 100 fully utilized five-lead ECG monitoring systems and an average patient stay of five days, annual trouble-shooting costs could range from a few thousand dollars if only electrodes are changed to many thousand dollars if leadwires and cables are replaced. This cost analysis does not include the cost to the facility for nursing and biomedical time, wasted chart paper, delay in treatment or the risk of missing a life threatening event. It also does not include the discomfort that may be caused to a patient for removal and re-application of electrodes.

Best Recommended Practice for Applying Disposable Electrodes

The stratum corneum of the epidermis has high impedance. Removal of the stratum corneum at the electrode site will dramatically reduce the skin impedance. The following is a technique that can be followed and will reduce skin impedance.

1. Select electrode application sites without bony prominence, avoiding fatty areas and major muscles. This placement method will help reduce motion-related artifact and maximize the ECG signal strength.

2. If the patient has a fair amount of hair at the electrode application site, the hair should be clipped. Shaving is not necessary and may actually cause some skin irritation.

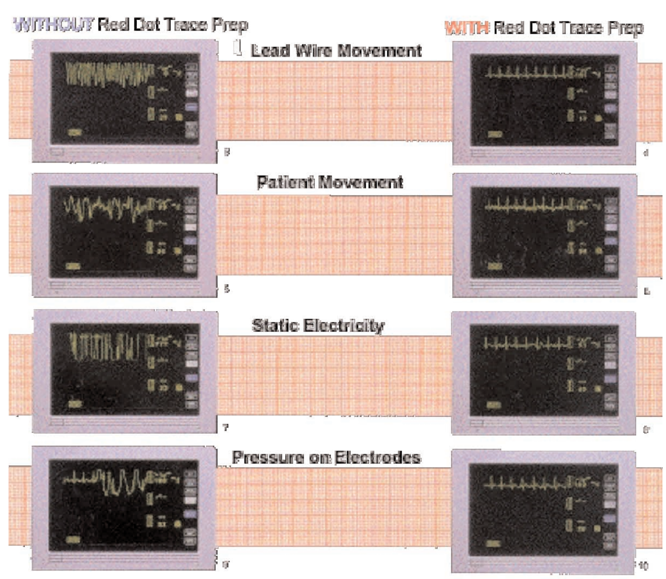
3. The electrode application site should be clean and dry. The preferred method of cleaning is with soap and water plus drying the skin with a dry cloth or gauze. In emergency situations, this may be difficult. However, clean and dry skin does contribute to good electrode adhesion and good trace quality.

4. Cleaning with isopropyl alcohol should be avoided or limited to situations which electrode adhesion is an issue (diaphoresis, excessively oily or lotion-covered skin), since it may dehydrate the skin, thus causing skin impedance to increase. If alcohol is used, allow it to dry prior to the electrode application.

5. Attach the leadwires to the electrode prior to placing the electrode on the patient. This will eliminate the potential for patient discomfort if snap leadwires are pressed onto the electrode, after the electrode has been placed on the patient. Optimum patient comfort can be obtained if squeeze clip or pinch clip leadwires are used.

6. Electrode application sites should be abraded to lower the skin impedance. The Red Dot Trace Prep 2236 used in this clinician survey has proven to be an effective tool for lowering skin impedance.

Dramatic effects of 3M™ Red Dot™ Trace Prep on ECG traces



Note: These photos are intended to show "typical" tracings for the situations indicated. Actual results may vary depending on other factors.

Trace Prep Misunderstandings

Prior to a demonstration of proper skin preparation technique, clinicians often comment that they do not have time to prepare skin; it may be painful for the patient, should only be done as a means of trouble shooting or only with a certain brand of electrodes. After the skin preparation demonstration using the Red Dot Trace Prep, the comments changed to, "that didn't take much time" and "that didn't hurt" or "it feels like a cat's tongue!"

Conclusion

In the clinical setting, artifact can generate false interpretation of recordings and data, induce false alarm conditions, mask true alarm conditions, necessitate frequent electrode replacements and create a time-consuming and frustrating experience for both the patient and caregiver.[3]

The routine use of the appropriate trace preparation has been demonstrated to be an effective tool for lowering patient skin impedance for adults. Trace preparation tends to be thought of – wrongly – as a tool to be used only with certain electrodes or only as a means of trouble-shooting ECG artifact.

The findings of this paper support use of the appropriate skin preparation for all electrode applications. This best practice will eliminate most skin impedance related ECG artifact and produce clearer traces for better diagnosis, lower costs, reduce time and frustration for nursing and biomedical engineering and improve overall comfort for patients.

ABSTRACT
Proper Skin Prep Helps Ensure ECG Trace Quality

Although most clinicians do not realize it, the skin is a major source of ECG artifact. Artifact can lead to unnecessary electrode changes, higher costs, false alarms and frustration for staff and patients. By lowering skin impedance, clearer traces result.

A survey of biomedical engineers, technicians and nursing professionals attending a national conference looked at actual practice for ECG electrode skin preparation and time-consuming troubleshooting activities. Only 17 percent of the respondents said they have a protocol in place that requires skin preparation prior to placing an electrode on a patient. The survey showed that proper skin preparation prior to electrode placement lowers skin impedance and can significantly reduce artifact in all electrode applications.

BIOGRAPHY

Craig Oster is a Mechanical Engineer who has spent his most recent 10 years of his 20 year engineering career with 3M Health Care in product development, manufacturing and currently in technical service.

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