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# Proper Skin Preparation Improves Trace Quality and Reduces ECG Monitoring Alarms

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# Alarm Fatigue is becoming widely recognized as not only a work environment issue, but also a patient safety issue.

Alarm Fatigue is becoming widely recognized as not only a work environment issue, but also a patient safety issue. The Food and Drug Administration (FDA) reported 566 deaths related to monitor alarms from 2005 to 2008.[1] Alarm Fatigue is a condition where caregivers become overloaded and desensitized to the near constant sound of monitoring alarms. Each day, a nurse can be prompted by as many as 700 alarms, of which 80-99% are false or clinically insignificant.[2] Of those false alarms, many are related to ECG monitoring.

Most clinicians have experienced unacceptable ECG trace quality. When the monitor alarm goes off, clinicians will try to troubleshoot the problem. They often start by adjusting the ECG monitor, followed by replacing all the electrodes, replacing the leadwires/cables and finally calling clinical engineering for help. All this takes time, increases costs, adds to staff and patient frustration, and may place the patient at risk.

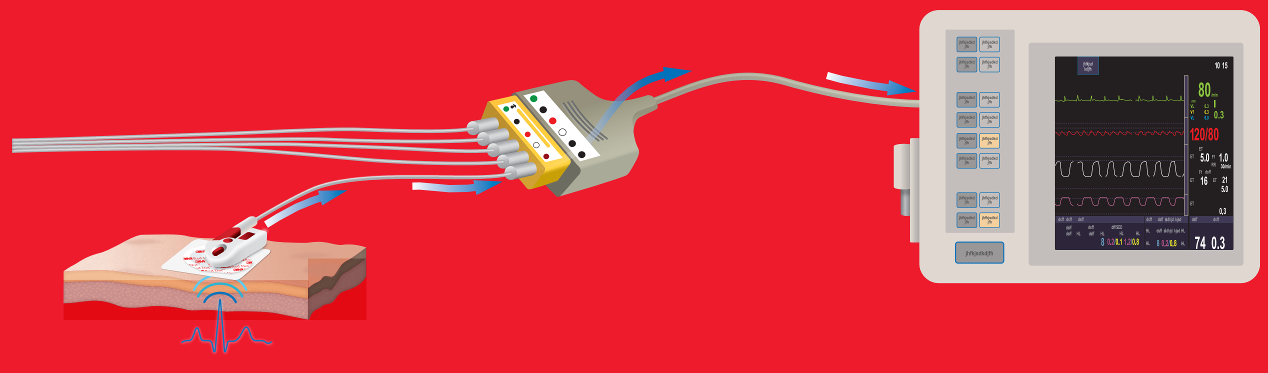
## ECG Monitoring

ECG monitoring is a system of components working together. ECG trace quality can be affected by many factors such as: the monitor filter settings, the condition of the cables and leadwires, the electrodes used, and the conductivity of the patient's skin.

All of these components are part of the path of the ECG signal to the monitor. The ECG signal originates inside a patient's chest, travels through the patient's body, through the patient's skin, through the electrode and along the wires to the monitor (see Figure 1). All of the parts must conduct the ECG signal. High impedance from a broken wire, loose electrode or the patient's skin can act as a barrier to the ECG signal preventing it from easily reaching the monitor.

When in good condition, the electrical path from the electrode to the monitor is very conductive allowing the ECG signal to easily pass along the copper wires. The patient's skin, or skin impedance, is often the biggest hurdle for the ECG signal to overcome.

### Electrical Path from the Heart to the Monitor (Figure 1)



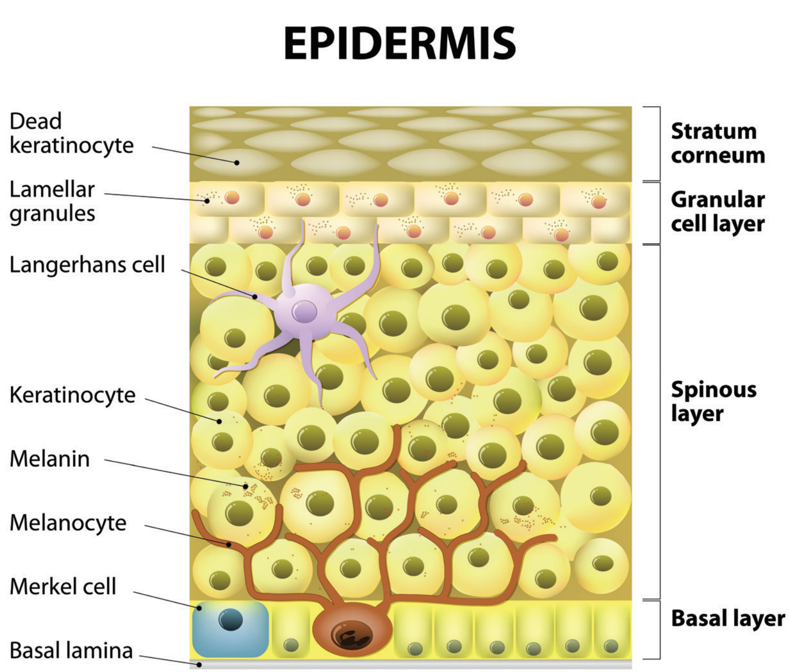
## Skin Impedance

Skin impedance can be defined as the skin's opposition or resistance to electrical signals flowing through it. This resistance of the skin, can impede the transmission of the electrical signal from the heart, to the sensing element in the electrode.

The skin is made up of three distinct layers: the epidermis, which is the outer layer; the dermis, which lies beneath the epidermis; and the subcutaneous fat layer (see Figure 2). The outer layer of the epidermis, or the stratum corneum, is made up of dead skin cells which are not good conductors of the ECG signal. They actually act as a barrier, making it more difficult for the ECG signal to reach the electrodes on the skin's surface. This can create artifact which distorts the ECG trace on the monitor.

There is no quick assessment of a patient, other than actual measurement, that can 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. For good trace quality the ECG signal must easily pass through the patient's skin. In one study, the average ECG electrode skin impedance was found to be 354 K Ohms.[3]

Figure 2 - Skin Layers



## Skin Abrasion Reduces Skin Impedance

Skin impedance can easily be reduced by abrading the skin. Abrading the skin has been consistently shown in the scientific literature to reduce skin impedance by mechanically removing the outer layer of dead skin cells and allowing the electrode gel to come into good contact with the more conductive tissue underneath. The stratum corneum is a microscopically thin layer that is relatively easy to remove using either an abrasive pad or abrasive gel. Abrading the skin is part of proper skin preparation prior to electrode placement.

One 1998 survey at the AAMI Annual Meeting and an AACN National Teaching Institute™ & Critical Care Exposition showed how easily and effectively the skin's impedance can be reduced.[3] The nursing professionals and biomedical engineers experienced, on their own arms, the dramatic difference in skin impedance after proper skin preparation was performed prior to electrode placement.

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

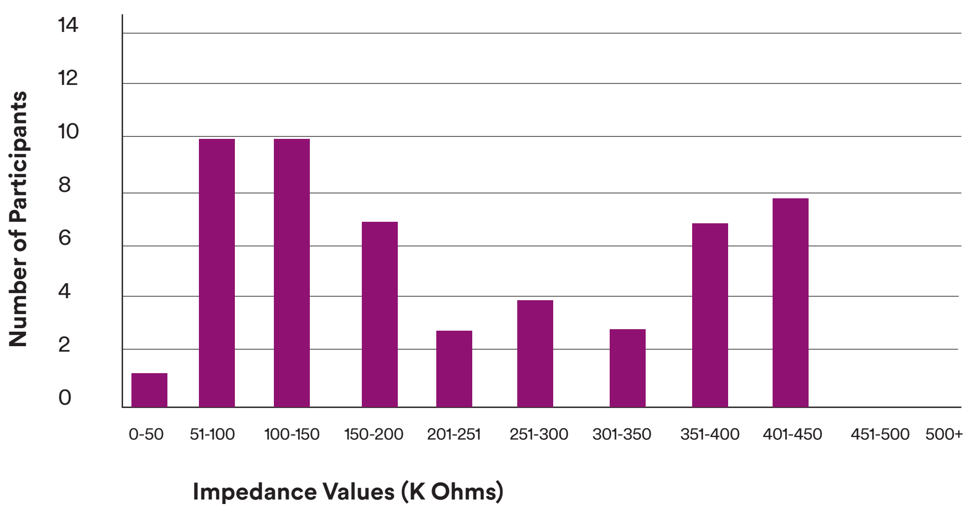



Figure 3 - The average skin impedance measured in this study was 354 K Ohms prior to skin abrasion.

Oster, Craig. Improving ECG trace quality. *Biomedical Instrumentation & Technology* 2000;34(3):219-22.

The skin of each participant was then prepared with mild skin abrasion to the electrode site, using 3M™ Red Dot™ Trace Prep 2236 (which is similar to a fine sandpaper material). The participants' skin was held down with one hand and the skin was gently wiped 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:

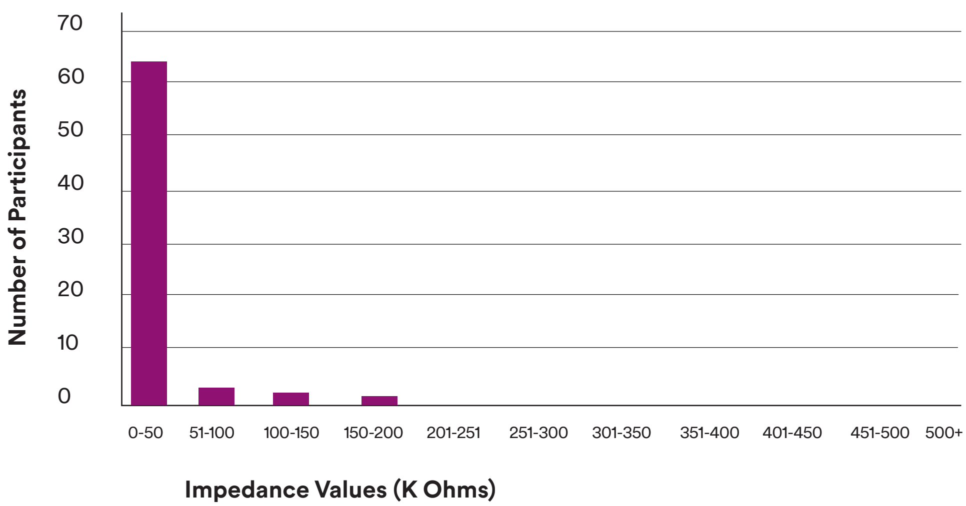



Figure 4 - The average skin impedance after using 3M™ Red Dot™ 2236 Trace Prep measured in this study was 20 K Ohms.

Oster, Craig. Improving ECG trace quality. *Biomedical Instrumentation & Technology* 2000;34(3):219-22.

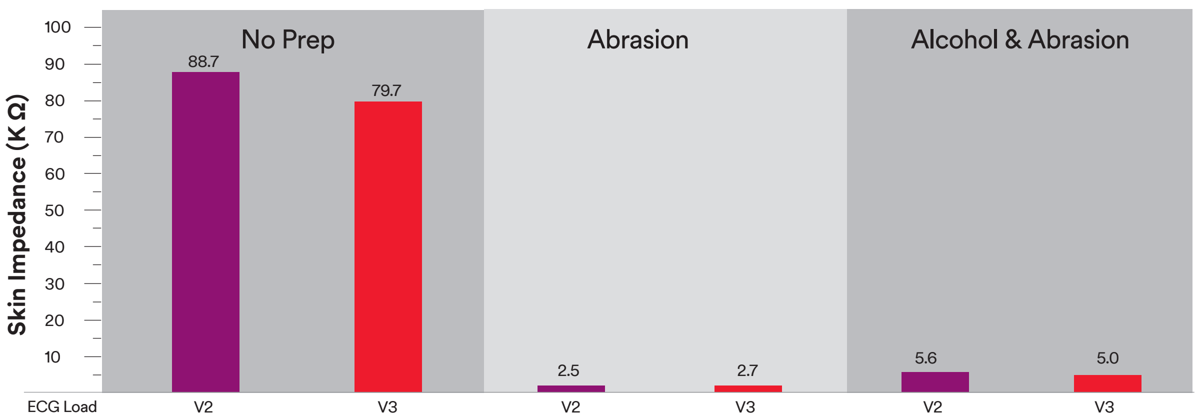
The results of the survey were conclusive. The average skin impedance measured in this study, after using the trace preparation, was 20 K Ohms. This was a 325 K Ohms (94%) reduction in the average impedance.

Following the assessment of skin impedance, survey participants were asked if they ever have unacceptable ECG trace quality. The clear majority of participants stated they experience occasions of unacceptable trace quality, (52% replied "often" and 34% replied "occasionally").

In addition, most of the nursing professionals were not aware of skin impedance, or how it can affect ECG trace quality. In fact, only 17% of the participants said they have a protocol in place that requires skin preparation prior to placing an electrode on a patient. In contrast, most of the biomedical engineers and technicians were aware of the effect 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.

In a study from 2007, involving 22 male subjects, the impact of skin abrasion on reducing skin impedance was also measured. Similar to the previous study, the electrode to skin impedance was measured with and without skin abrasion. In addition to clipping any excess hair, the authors used 400 grain sandpaper to abrade the skin. The figure below shows the impedance values over 24 hours for electrodes with and without skin abrasion.

Skin impedance with no skin preparation, skin abrasion and skin abrasion after alcohol cleaning




Higher skin impedance = larger barrier the ECG signal has to over come to reach the electrode sensor.

Figure 5 - Unprepped leads show significantly higher impedance than those where the skin was abraded.

Jonasson, Linda. *A prospective study on the relevance of skin preparation for noise, impedance and ECG intervals among healthy males.* http://www.essays.se/about/Skin+preparation/

The initial impedance for non-abraded skin was 88.7 and 79.7 K Ohms. When the electrode site was abraded prior to electrode application, the impedance fell to 2.5 K Ohms (97.2% reduction) and 2.7 K Ohms (96.6% reduction).[4] In other words, abrading the skin makes it roughly 97% easier for the ECG signal to pass through the skin to the electrode. Using alcohol is known to dry out the skin and increase skin impedance. The chart also indicates that if the skin is abraded after the alcohol is used, the skin impedance is much lower than the non-abraded skin. According to the paper, the reduced skin impedance also resulted in reduced noise (unwanted artifact on the ECG trace) amplitude.

## Reducing Skin Impedance Improves Trace Quality

The benefits of reducing skin impedance on improving trace quality were published as early as 1987.[5] The paper describes a simple method for reducing skin impedance, which isn't recommended, but it does highlight the trace quality improvement gained by reducing the skin impedance. Without any skin abrasion, and with a skin impedance of 400 K Ohms, the traces appeared very noisy with a thick baseline. After using their method to reduce the skin impedance to 3 K Ohms, the traces appeared artifact free, even when the subject was running in place.[5]

Considering this study was performed a few decades ago, one might expect that monitoring technology has been able to overcome these issues with high skin impedance, but that is not the case.

In 2005, an article was published in *IEEE Transaction on Biomedical Engineering* titled, "Electrocardiographic Motion Artifact Versus Electrode Impedance".[6] The authors asked subjects to move in various ways while having their heart rate monitored. The accuracy of the heart beat counts was then measured. If the monitor either skipped a heartbeat or recorded an extra heartbeat, it was considered an error. According to the authors, "As the impedance is increased, the number of errors also increased".[6]

Another study was published in 2012 in *BI&T*, AAMI's peer-reviewed journal. In "Electrocardiogram Interference: A Thing of the Past?"[7] the authors studied the impact of increased impedance of the left leg (LL) electrode on trace quality. Based on their findings, they instituted a house wide program utilizing proper skin preparation to improve trace quality. One of their examples is shown in Figure 7. The top ECG strip shows ECG traces from a cardiac surgery patient with minimal artifact. The middle strip shows after the heart-lung machine pump was turned on, large amounts of artifact were visible in the ECG tracings. The bottom strip shows that after performing what they describe as remedial skin prep, including an electrode impedance check, the traces have minimal artifact even with the pump running.

The authors state in their conclusion that "Today, with a few years of consistent skin prep and regular use of impedance meters, we have virtually eliminated ECG interference in cardiac surgery (and other areas that follow the necessary procedures)."[7]

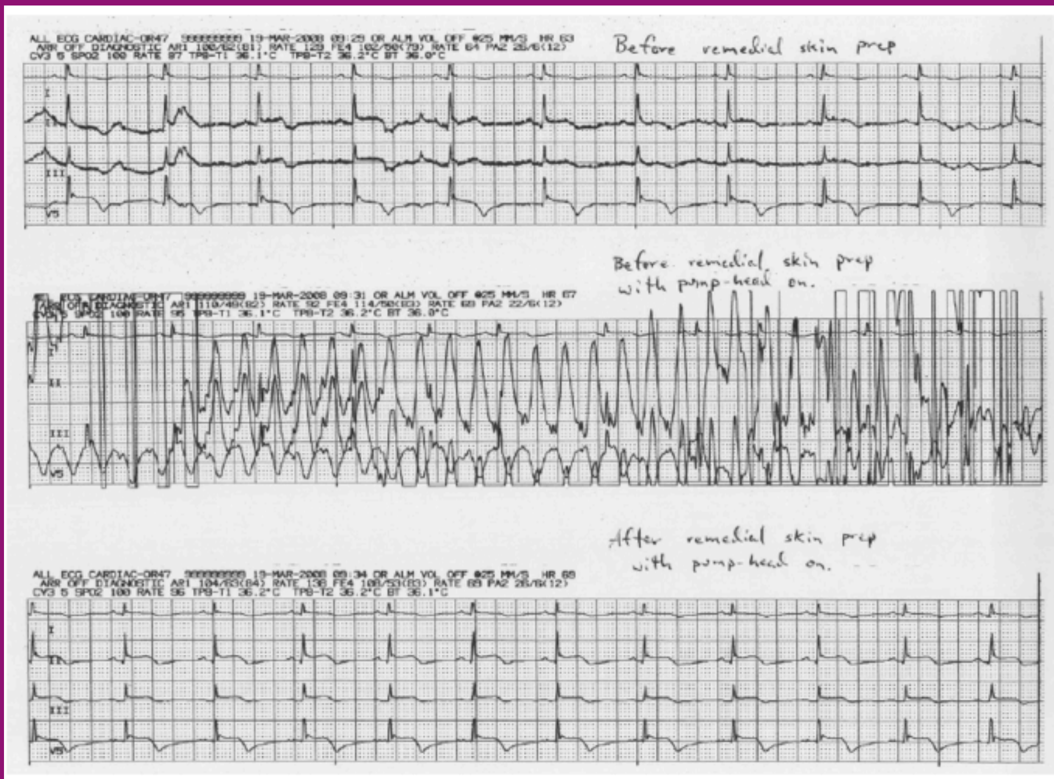



Figure 7 - Top: Sight ECG artifact on stationary patient before remidial skin pre. Middle: Same patient after the heart/lung maching pumpheads have been turned on. Bottom: Sampe patient with pumpheads on after remedial skin prep has been performed.

Melendez L, Pino R, Electrocardiogram Interference: A Thing of the Past?, *Biomedical Instrumentation & Technology*, November/December 2012

## Reduced Impedance Improves Trace Quality and Reduces Clinical Alarms

The goal of proper skin preparation is improved monitoring, which improves patient safety and saves the clinicians time. The AACN recently published a practice alert for alarm management with a list of seven items that clinicians can do to reduce monitoring alarms.[8] The top item in the list, with the greatest level of evidence was "Provide proper skin preparation for ECG electrodes (Level B)." More recently, there have been investigations into the direct link between proper skin preparation and reduced alarms.

In August of 2015, AACN published an educational article where the authors took a bundled approach to reducing alarms.[9] The bundle included disposable leadwires, customized alarm parameters, elimination of duplicate alarms, daily electrode changes and standardized skin preparation. First implemented was the daily electrode changes combined with standardized skin preparation. The skin preparation used was based on the AACN's practice alert for alarm management[8] and included:

**1** Washing the isolated electrode area with soap and water.

**2)** Wiping the electrode area with a rough washcloth or gauze and/or using the sandpaper on the electrode to roughen a small area of the skin.

**3)** Eliminating alcohol for skin preparation to prevent the skin from drying out.

The authors reported an 80-90% reduction in ECG alarms with the bundle overall with an initial 37% decrease from proper skin preparation and daily electrode changes.[9]

In the fall of 2014, the 3M technical team worked with Lancaster General Hospital, to promote proper skin preparation throughout their facility as part of their monitoring alarms reduction initiative. During the baseline alarm data collection it was found that ECG monitoring produced the highest number of alarms. It was believed that proper skin preparation could significantly reduce the number of alarms, and a facility wide change was implemented.

Prior to implementing the new electrode application practices, the number of ECG monitoring alarms were measured. When implementation day arrived, the nurse educators were trained on the technical details of proper skin preparation and its benefits. Then the real work began. Every shift on every unit associated with ECG monitoring was in-serviced over a two-day period to insure that all staff had been educated. Every nurse in every unit was trained on proper electrode application technique. Over the next few days, the Clinical Nurse Specialist continued to drive the improvement by periodically monitoring each unit's adoption of the new policy.

Monitoring alarms continued to be measured and the initiative's impact was impressive. The number of alarms in one of the units that had taken the change to heart, was reduced an astounding 77% in both arrhythmia and parameter alarms and a 67% reduction in technical alarms.[10] Several months later a nurse was working in a different department for a shift where the change wasn't implemented as rigorously. She was amazed by the difference in the number of alarms between the two departments. In the nurse's words, "My pager wouldn't stop going off the entire time. It was constantly going off. I was truly getting really frustrated with the pager. Then I come back home and realize the difference. Thank you."

Sign-up for the 3M Alarm Fatigue Reduction Program

# In Summary

The ECRI Institute recently stated, "Missed Alarms Can Have Fatal Consequences" and Alarm Hazard have been in their top 10 health technology hazards every year since 2008. It's been well known for decades that abrading the skin and reducing skin impedance improves trace quality, but the practice is still rarely used except in diagnostics. Nurses often say they don't have enough time, or they are more worried about other things than the electrodes. The latest studies in alarm management indicate that performing proper skin preparation prior to electrode placement reduces alarms. Following electrode application best practice is well worth the quick time investment. It will also lead to a quieter work and healing environment - promoting patient safety and reducing workplace stress.

1 Weil, K. Alarming monitor problems. Nursing 2014. 2009 Sep 1;39(9):58.

2 Cvach, M. Monitor Alarm Fatigue: An Integrative Review. Biomedical Instrumentation & Technology July/Aug 2012; 268-277.

3 Oster, C. Improving ECG trace quality. Biomedical Instrumentation & Technology 2000; 34(3): 219-22.

4 Jonasson, L. A prospective study on the relevance of skin preparation for noise, impedance and ECG intervals among healthy males. University essay from Högskolan i Halmstad/Sektionen för hälsa och samhälle (HOS). June 2007.

5 Okamoto T, Tsutsumi H, Goto Y, and Andrew P. A simple procedure to attenuate artifacts in surface electrode recordings by painlessly lowering skin impedance. Electromyography and clinical neurophysiology 1987; 27: 173-176.

6 Wiese SR, Anheier P, Connemara RD, et al. Electrocardiographic motion artifact versus electrode impedance. IEEE Transactions on Biomedical Engineering 2005; 52.1: 136-139.

7 Melendez L, Pino R, Electrocardiogram Interference: A Thing of the Past? Biomedical Instrumentation & Technology, 2012; 46.6: 470-477.

8 AACN Practice Alert, Alarm Management, April 2013 available athttp://www.aacn.org/wd/practice/docs/practicealerts/alarm-management-practice-alert.pdf

9 Sendelbach S, Wahl S, Anthony A, Shotts P. Stop the noise: a quality improvement project to decrease electrocardiographic nuisance alarms. Critical care nurse. 2015 Aug 1;35(4):15-22.

10 Haley, Charlene. “Improving Clinical Alarm Management through EBP and Enculturation of Spirit of Clinical Inquiry”, Poster presented at American Nurses Credentialing Center National Magnet Conference, October 2015.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