

Technique

Simplified Solution to Eliminating Electrical Noise During Cardiac Surgery

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ABSTRACT

Electrical noise will be present in the operating room even under ideal circumstances. The addition of the cardiopulmonary bypass machine to the other machinery in the operating room introduces one more source of electrical noise. Identifying and managing this interference may aid in reducing artifactual signals on the electrocardiogram (EKG) monitor.

If electrical interference occurs during the onset of cardiopulmonary bypass, an uninterpretable rhythm pattern on the electrocardiogram monitor may be present.

Adding an extra ground from the main pump head to the heater/cooler helps to reduce noise and, therefore, effectively diminishes pump-generated artifact on the EKG.

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INTRODUCTION

To prevent ischemic damage and to provide a motionless operative field for cardiac surgery, the heart is emptied on cardiopulmonary bypass and arrested with cardioplegia solution. During the period of depolarized arrest, continuous monitoring is required to detect any resumption of electrical activity. This electrophysiological monitoring is accomplished with a surface electrocardiogram (EKG) which should demonstrate a continuous isoelectric baseline pattern. The electrocardiogram tracing is always compromised to some extent by altered electrode placement mandated by the surgical procedure, but other external factors can also adversely affect this important patient monitor (1). Chief among these is the influence of external electrical interference from operating room equipment which can create an irregular or uninterpretable rhythm pattern on the electrocardiogram monitor. This "noise" on the EKG monitor often arises from the cardiopulmonary bypass pump and is referred to as "pump artifact" (2). We describe a simple technique to reduce these problem signals.

MATERIALS AND METHODS

In our facility at the University of Texas Southwestern Medical Center at Dallas, we have applied a grounding system

to reduce electrical interference. We use an EKG electrode and attach it to the metal base of the main pump head, and attach an EKG lead snapped onto the electrode. We attach this lead to the metal outlet or inlet of the heater/cooler where it connects to the oxygenator. It is important to make sure the metal of the outlet or inlet of the heater/cooler has good contact with the metal probe of the EKG lead. Tape or banding holds the lead in place. This can also be accomplished with a single set of wire alligator clips by attaching each clip to a metal point on the main pumphead and to the inlet or outlet of the water/heater connector. Using EKG electrodes and leads is easy and available in every hospital with minimal cost to the patient (Figure 1). If interference is still visible on the EKG monitor, one should switch to a different EKG lead until minimal interference is seen.

RESULTS

This technique establishes a low resistance connection between the grounds of the pump and the heater/cooler and significantly reduces or eliminates the unwanted interference. In the majority of instances, this very simple maneuver minimizes or eliminates the amount of artifact on the electrocardiograph display (Figure 2). This in turn provides better patient information to the physician and perfusionist during the critical portion of the surgical procedure. This technique has been routinely and successfully used at our institution for the past two years.

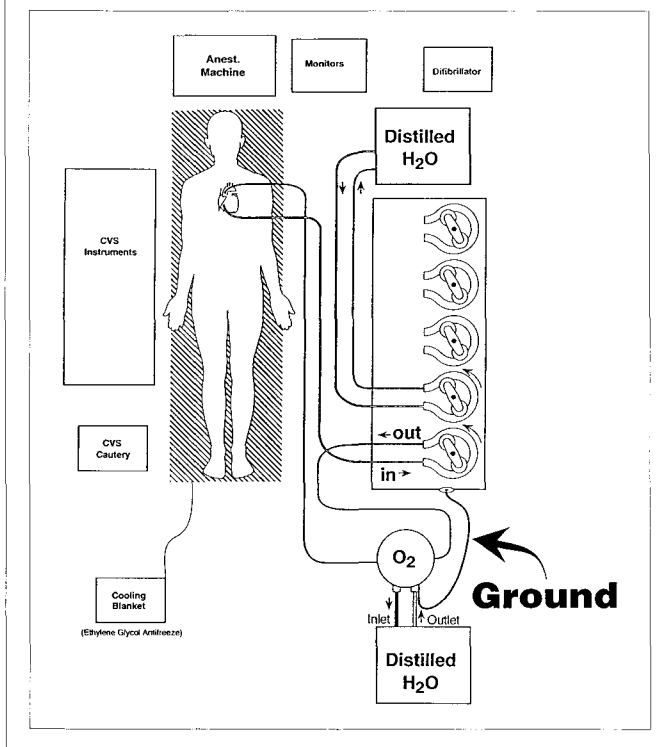
DISCUSSION

CAUSES OF ARTIFACT

Artifact can arise at any location from the point of origin of the biologic signal to the display of the signal (2). During cardiopulmonary bypass, surface electrodes connect the patient to the EKG monitor which processes, amplifies, and displays the cardiac electrical activity. The patient is also directly connected by cannulas to all components of the cardiopulmonary bypass circuit and its associated accessories such as the temperature regulating heater/cooler. Because these components cannot be turned off during the surgical procedure, any electrical interference generated by them must be managed through grounding (3). The cardiopulmonary bypass pump, the heater/cooler and the EKG monitor receive their power supply from different power outlets. In older hospitals, these outlets may have separate grounding points that are not joined to a single connection to the building ground (4). As these machines are also connected to the patient, a second path from one machine to another does exist. These closed current paths between the two grounds are referred to as ground loops (1). Ground loops can introduce artifactual signals on the EKG (2) (Figure 3).

Electrical potentials may be generated across a pair of EKG skin electrodes (offset potential). Also, small potential differences between two grounding sites can cause a common mode voltage on the patient (2). Capacitive electric coupling of the

Figure 1: Establishing a low resistance connection between the grounds of the EKG monitor and the pumps will reduce unwanted interference.



power lines to the pump grounds and magnetic fields generated by the pumps can cause small currents in the ground loop which will be picked up by the high gain amplifier of the electrocardiograph and displayed as noise (1). Additionally, the ground lead of the EKG often runs alongside the signal leads and magnetic fields caused by the current in the grounding circuit form small voltages in the signal lead wires (1).

POTENTIAL SOLUTIONS

The first line of defense against all these artifact voltages is the input differential amplifier of the EKG monitor. Most amplifiers can tolerate 200 mV offset, which should handle artifact potentials generated by skin electrodes (5). Larger noise potentials often require additional measures.

The ideal grounding system would connect all receptacle grounds and conductive surfaces (metal frames on doors, windows etc.) to a single patient-equipment grounding point. Additionally, the patient-equipment grounding point should connect to a reference grounding point that makes one single connection to the building ground (1) (Figure 4A). Thus, an optimal grounding system could be created in the operating room that would avoid any ground loops at all (6) (Figure 4B). In practice, creation of such a system in existing facilities would be prohibitively expensive. An easier and less expensive technique involves attaching a separate ground wire to the cardiopulmonary bypass machine and connecting this wire to a different ground as we have described.

This technique will eliminate noise created by the cardiopulmonary bypass machine and/or the heater/cooler unit. However, potential noise could also arise from other electrical components (cautery, the EKG machine, anesthesia machine and other roller pumps). We have tested the addition of other grounding connections between these components and have not found any incremental benefit from these extra grounds. The moving blood within the cannulae provides a low resistance path to the patient's heart, and is probably responsible for a large portion of the ground loop electrical artifact when the patient is on bypass. This may explain why the artifact disappears or diminishes when the patient is separated from cardiopulmonary bypass but still remains cannulated.

LIMITATIONS OF THIS TECHNIQUE

The technique described offers a simple and effective solution to the problem in the majority of cases. In some instances, electrical noise will persist due to inadequate connections between other components, or at the interface with the patient. Changes in skin temperature, presence of perspiration, or spillover from the surgical field can affect this critical connection to the patient. Occasionally, noise arises

Figure 2: A) The EKG strip (speed=25mm/s) shows a patient's heart rhythm prior to initiating cardiopulmonary bypass. B) The EKG strip shows the same patient's heart rhythm, after cardiopulmonary bypass has started and cardioplegia has been given. Note the artifact on the strip. C) The EKG strip shows the same patient's rhythm after the cardiopulmonary bypass machine has been grounded. An isoelectric pattern is now present.

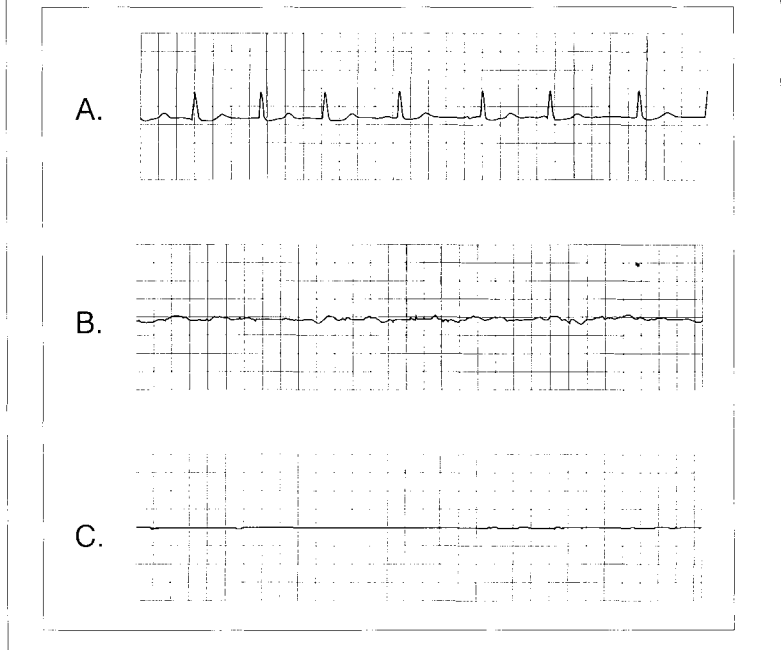


Figure 3: In an ideal grounding system, all the receptacle grounds and conductive surfaces are connected to the patient-equipment grounding point. Each patient-equipment grounding point is connected to the reference grounding point that makes a single connection to the building ground (6). Reprinted by permission of John Wiley & Sons, Inc.

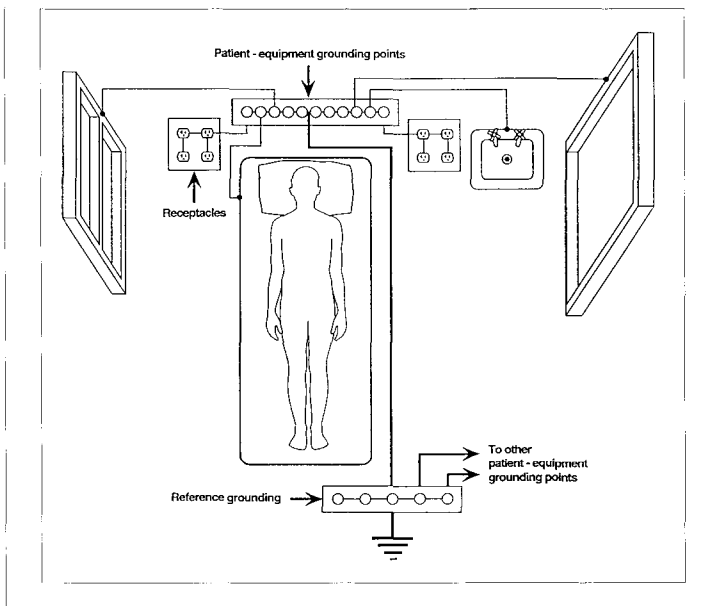
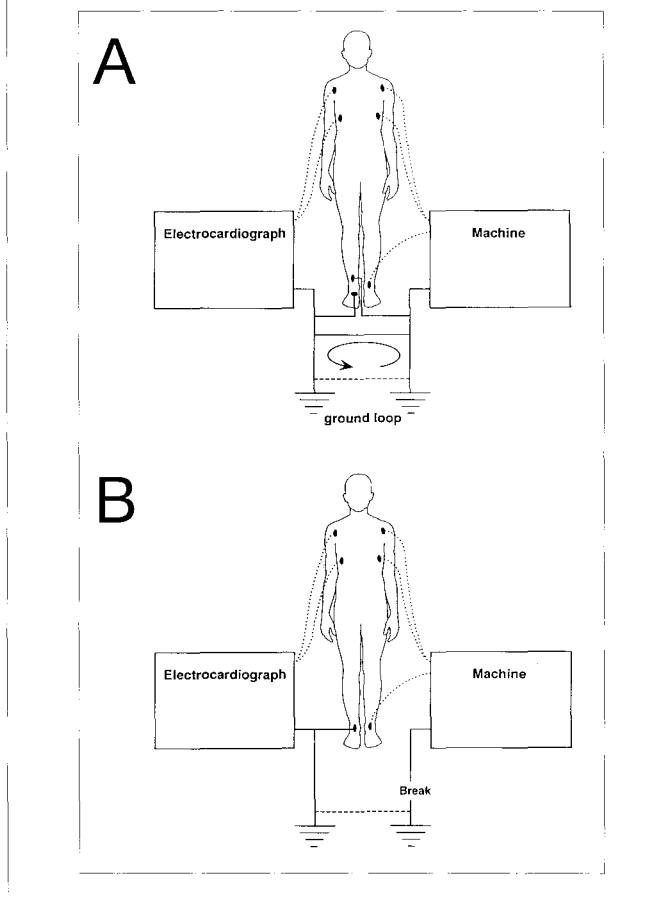


Figure 4: A) Each machine is grounded separately and also connected to the patient, so there is a closed path from the electrocardiograph to the machine. B) Connecting both machines to the same ground eliminates the ground loop (1). Reprinted by permission of John Wiley & Sons, Inc.



from other sources within the operating theater such as cautery devices, anesthetic equipment, or balloon pump consoles, which makes identifying and managing interference from diverse sites challenging.

Even under ideal circumstances, monitoring cardiac electrical activity through a surface electrocardiogram may fail to detect resumption of electrophysiologic events at their earliest stage. Some authors have suggested that use of electrodes placed directly in the heart muscle may provide superior monitoring of myopotentials during cardioplegic arrest (7). Nevertheless, if electrocardiographic monitoring is to be used, efforts should be directed at achieving the best signals possible to help optimize protection of the myocardium during cardiac surgery.

CONCLUSION

Electrical interferences during cardiac surgery can arise from interactions of electrical potentials from multiple sources. A simplified grounding system as described here may offer some

reduction in artifact on monitoring devices to improve electrical surveillance of the patient. This provides better patient information to the physician and perfusionist during the surgical procedure.

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