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Application Note 263 General Strategies for Recording Biopotential and Transducer Data in the MRI and fMRI

This application note lays out some generally recommended methods for recording data from subjects in the MRI or fMRI. BIOPAC Systems, Inc. (BIOPAC) designs systems that can be used to record both biopotential data (such as ECG, EEG and EMG) and transducer data (such as blood pressure, air flow, hand clench strength, finger motion and temperature).

Overview

In most MRI configurations, there is a “dual-room” setup. In these cases, there is a “Chamber” room and a “Control” room. The chamber room houses the actual MRI machine and the control room is where the MRI operator sits to manage the MRI scanning sequences.

BIOPAC MRI-related recording equipment is typically setup with the recording equipment data acquisition system and associated amplifiers in the control room (well-away from MRI). Signals are directed, via a cabling system, from the subject—lying in the MRI—to the recording equipment. The cabling system crafted for this purpose is uniquely suited to performing subject measures, while attached to the subject, when they are being scanned in the MRI. The cabling system, though conductive, does not contain ferromagnetic materials.

The electrodes or transducers attached to the subject in the MRI are plugged into the receiving end of the cabling system. The cabling system then directs the signal data through a “Patch Panel Filter”—which resides between the chamber room and control room—to another portion of the cabling system that directs the data to the input(s) of the appropriate amplifier and then data acquisition system (MP150).

The patch panel filter is very important. The patch panel filters are bidirectional. They prevent radio frequency (RF) energy from getting into the amplifiers. They also prevent control room computer noise from getting back into the chamber room, which might corrupt the MRI imaging process and data quality.

Any electrodes or transducers connected to the subject’s body are connected to the receiving end of the cabling system. This end is typically clipped to a convenient location on the MRI slide-bed. The transmitting end of the cabling system is plugged into the appropriate MRI amplifier (such as ECG100C-MRI, PPG100C-MRI, etc.).

BIOPAC offers a series of electrodes, leads and transducers that can be connected to subjects, while they are being scanned in the MRI.

Electrodes and Leads

Electrodes are the only elements BIOPAC offers that connect electrically to the subject. Electrodes are constructed using conductive carbon attached to a thin layer of Ag/AgCl. The associated electrode leads are constructed from conductive carbon fiber. Typically, the electrode is “pre-gelled.” This means that the electrode is disposable (one-time use) and incorporates a thin layer of conductive gel (EL508) on the surface of the Ag/AgCl disk. This gel should normally be a bit “wet.” If there is no gel observed (EL509), then a thin layer of appropriate gel should be added to the Ag/AgCl disk area. If the electrode is a cavity-type electrode (EL254-RT, EL258-RT), then gel should be carefully added to fill the entire electrode cavity with no bubbles or voids. Use the associated adhesive disks (ADD204 or ADD208) to attach the electrode to the subject’s skin surface.

If in doubt about the best MRI electrode choice, BIOPAC recommends the use of disposable carbon composition electrodes (EL508 and EL509). The added benefit of these disposable MRI electrodes is that they:

- do not incorporate a gel cavity, and are thus less problematic to use
- are simple “peel and stick” electrodes
- have relatively large surface area (10 mm diameter)

Use electrodes with the shortest possible carbon fiber leads (LEAD108 series). Do not coil the leads, but rather route them—in as straight of a line as possible—from the electrode site to the receiving end of the cable set. In some cases, spiral twisting of the two recording leads (Vin+ and Vin-) can help in noisy recording situations; however one can usually obtain acceptable recordings without this added complicated step. BIOPAC advocates the use of a ground lead to compliment the biopotential recording between Vin+ and Vin-, however it may be possible to obtain an acceptable recording without the use of a ground lead. If a ground lead is used, which is recommended, then just one ground lead should be attached to the subject. Do not attach multiple grounds to the subject’s body as this configuration can result in a large conductive loop. Finally, use a thermally insulating barrier between any electrode lead and the subject’s skin surface.

Before applying the electrode to the subject’s skin surface, be certain to abrade the electrode site, using ELPAD. This process will remove dead skin cells and otherwise clean the area to create a solid electrical connection to the subject. Do not use an astringent (such as alcohol) to wipe the skin area prior to electrode attachment. An astringent will dry out the skin surface and create a higher resistance electrical path. Instead, use water to clean any skin area.

Do not apply any electrode gel to the skin surface to improve conductivity. Sufficient gel will migrate from the pre-gelled electrode or electrode cavity to saturate the skin surface after the electrode is attached.

Transducers

BIOPAC transducers designed for use in the MRI do not make any electrical contact to the subject. Transducers will simply convert a subject’s physical processes, such as air flow, blood pressure, temperature changes, hand clench strength or finger motion into a proportional voltage which can then be transmitted to the appropriate amplifier through the cable set.

Transducers do not include any significant amounts of ferromagnetic material. As with electrodes leads, when using transducers with a subject, route the associated cable in a straight line while in or near the MRI bore. Do not coil any transducer leads as the lead runs from the transducer to the cable set receiving end. Use a thermally insulating barrier between any transducer lead and the subject’s skin surface.

General Notes

1. Always check yourself prior to stepping into a MRI chamber room. Be sure to leave any objects, with ferromagnetic parts, outside the chamber room. These may be things like wristwatches, screwdriver, scissors or eyeglasses. If you are in doubt about an object’s composition, do not bring it into the chamber room.

2. Do not run electrically conductive cables from the control room to the chamber room through an open door or window, under a door or through a waveguide. Always route electrical cables through

a patch panel filter. This is very important because the patch panel filter will direct harmful RF energy – going both directions – straight to mains ground. This signal routing condition does present a complication in terms of recording subject data, but it is extremely important, nonetheless.

3. Always insulate electrically conductive cables from the subject's skin surfaces. This is important, because electrode or transducer leads have the potential to heat up when exposed to the MRI RF field. Leads and cables can typically be thermally insulated from the subject's skin surface through the use of layered or folded towels. Also, simple foam insulation (like used for wrapping copper pipes) can be placed around the lead or cable. Generally considered, BIOPAC has not observed noticeable localized heating when using our MRI specified electrodes, leads, transducers and cable systems. However, we are aware of one case where localized heating was observed in a reusable cavity, Ag/AgCl electrode. We suspect the problem resulted from an air bubble in the cavity gel, but we were unable to research the problem more fully. Given this experience, BIOPAC primarily recommends the use of disposable (EL508 and EL509) carbon composition electrodes, as these electrodes do not incorporate a gel cavity.

4. Multiple system aspects help limit any internal heating, however, it's always important to recognize that internal heating can happen in conductive paths placed in an MRI. BIOPAC electrode leads, constructed from carbon fiber, have relatively high internal resistance. BIOPAC transducers for the MRI do not make electrical contact to the skin and their electrically conductive parts are well-thermally isolated from the measurement location. The associated cabling system incorporates internal inductors (at the patch panel) to limit the flow of RF currents. Finally, by strictly limiting electrode or transducer lead coiling, then the conductive lead will be less sensitive to the changing MRI RF field.

5. Watch for the possibility of localized heating of electrode gel. Electrode gel is very conductive and its use must be closely monitored in the MRI recording situations. The best possible electrodes to use in the MRI are disposable carbon composition electrodes. These electrodes come either "wet" or "dry." If wet, they already have a thin layer of conductive gel. If dry, then you will need to add gel to the electrode surface. Be sure to add just a small amount of gel to just the disk area of the electrode. Do not allow the gel to be smeared around the subject's skin surface as a possible "loop of gel" can result in localized heating right on the skin. Wipe off the subject's skin with clean water, if you suspect any gel smearing around or away from directly under the electrode attachment point. If cavity electrodes are used, then be careful to ensure that no voids or bubbles are evident in the electrode gel-filled cavity. This cavity can create a situation where a small loop is created inside the electrode cavity, thus causing localized heating.

6. Keep electrode leads as short as possible. Always use the shortest possible lead (LEAD108 series) to perform the biopotential measurement. Longer leads simply create more possibilities of coupling RF energy from the MRI to the lead. Also, minimize any lead coiling. Any coils in leads enhance the ability of MRI generated RF to couple into the lead, thus increasing measurement artifact.

7. BIOPAC electrodes, leads, transducers, cable systems and amplifiers operate as a complete MRI-compatible recording system. Recording biopotential or transducer data from a subject in the MRI is a complex undertaking. The environment is very noisy and fraught with complexities, such as the very high local magnetic field in the bore, the associated magnetic gradient and radiated RF energy. It's very important to employ a systems-level approach to this recording problem. BIOPAC does not recommend the use of non-BIOPAC specified equipment to be 'mixed and matched' with BIOPAC equipment for MRI recording purposes. Previously unmatched and uncharacterized electrodes, leads, transducers, cabling systems and amplifiers interconnects can have numerous, unforeseen, interactions.