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APPLICATION NOTES

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Application Note 241: EMG Signal Processing During *f*MRI

This application note is concerned with the recording of real-time EMG during an *f*MRI investigation.

Equipment

- MP160WSW or MP150WSW data acquisition system with Acq*Knowledge*®
- MECMRI-BIOP cable/filter set
    - EMG100C-MRI electromyogram Smart Amplifier module
    - LEAD108B or C MR Conditional electrode leads (15 cm or 30 cm)
    - EL508 MR Conditional electrodes

      Condition: Tested 3T to 9T, any scanning sequence, used with LEAD108 carbon composition leads only.
- Insulating barrier—LEAD108B/C are designed for MRI, and are designed to minimize circulating currents, and although they have never been known to get hot (or even warm,) it's always wise to put safety first and assume that they *might* get hot or warm. The insulating barrier should be at least 0.5 cm thick and its principle purpose is to keep the electrode leads from touching the bare surface of the subject's skin. Material options include: simple foam mat, like a thin exercise mat; a small towel folded over a few times; or foam piping insulation, for 1/4" OD copper tubing, to slide around the electrode leads.
- MECMRI-TRANS cable/filter set
    - DA100C general-purpose transducer amplifier
    - TSD114-MRI response/hand force transducer

Setup

1) Prepare the skin surface.
   Remove hair and lightly abrade the skin surface (using ELPAD) to create a good conductive path between electrode and skin surface.
2) Apply EL508 MR Conditional electrodes.
   Place EL508 electrodes on the appropriate part of the subject's body, over the muscle group under investigation. For example, for finger movement or hand-grip strength EMG measures, place electrodes over the appropriate muscle group(s) on the forearm.
3) Connect LEAD108B or C (15 cm or 30 cm) MR Conditional electrode leads to the EL508 electrodes.
   a. Do not twist the electrode leads together or loop them—just run the leads parallel with each other from the MECMRI cable attachment point to the subject electrodes. It's OK to have the leads touch each other, just try to keep the leads all running in the same direction and not looped.
   b. Place an insulating barrier between the electrode lead and skin surface.
4) Connect the leads to the MECMRI-1 cable.
   a. Insert the electrode leads into the receiving end of the MECMRI-1 chamber cable and fix (tape) the cable to the MRI subject slide table or the subject's clothing—do not twist the leads together or loop them.
   b. Insert the other (plastic DSUB-9) end of the MECMRI-1 chamber cable to the respective mating connector on the connector panel between the chamber room and control room.
      - Typically, the exposed connector will be provided by the MRI-RFIF, unless mating 9 pin DSUB connectors are already mounted in the panel.
5) Set the EMG100C-MRI Smart Amplifier module.
   a. Set Gain to 500 and set the band from 1.0 Hz to 500 Hz.
      - Do not use the 100 Hz HPN—the EMG amplifier notch filter will cause an unhelpful ringing and integration of MRI artifact.
6) Set the acquisition sample rate in Acq*Knowledge*.
   EMG source channel: sample rate of 10,000 Hz (10 kHz).
      - Sampling at ≥10 kHz is necessary to properly characterize the MRI artifact generated during EPI.

Recording Guidelines

When the subject is slid into the MRI coil, motion artifacts will be generated. These artifacts result from the superposition of voltages generated from magnetic induction effects and the electromyogram. Mechanical movement of the limb, leads and electrodes, in a magnetic field, will cause the generation of an associated electrical signal. The limb is conductive, in the same fashion as leads and electrodes, because the limb is perfused with blood, a conductive fluid. Ultimately, the movement of any conductor through the magnetic field gradient associated with the MRI will result in an associated potential. This movement artifact potential will be superimposed on the actual EMG. Accordingly, for accurate EMG recordings in the MRI, it's important for the subject to move the limb under investigation as little as possible.

Removing EMG Artifact

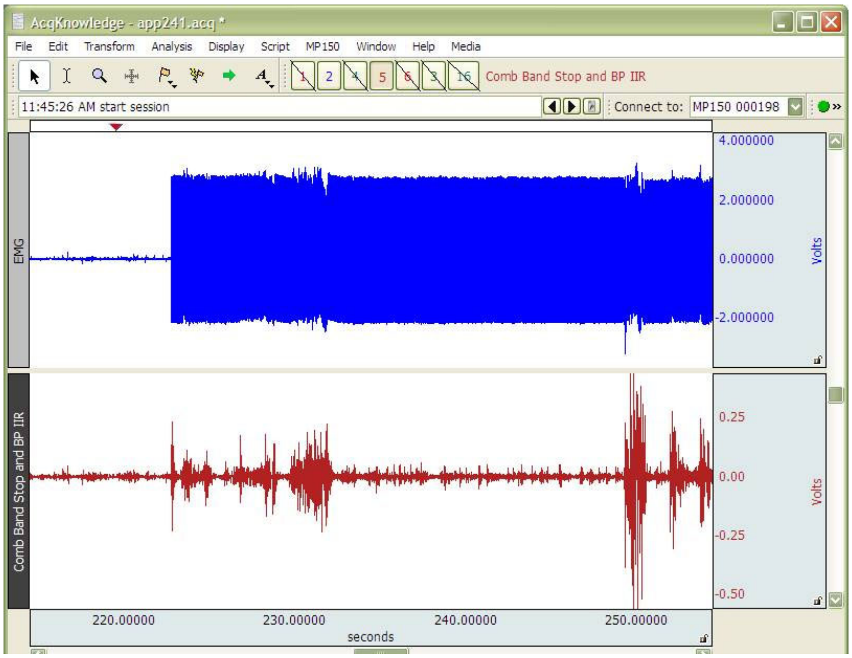
The resulting EMG source data can be processed to remove artifact, either in post-processing or real-time.

1) Determine the interfering frequencies of the artifact.
    a. Perform a FFT on the EMG source data during EPI.
    b. Look for repeating spikes in the spectrum.
2) Run a Comb Band Stop filter on the source data.
    a. Set the start frequency of to the interfering frequency.
    b. Set all harmonics out to Nyquist (5 kHz for a 10 kHz sample rate).

    For example If the Tr (repetition time of the MRI sequence is 2000ms (2 seconds) and the number of slices per repetition is 33, then the interfering frequencies will be located at every (33/2) or 16.5 Hz.
3) Run a Band Pass IIR filter on the filtered data.

    The significant majority of motion artifact can be removed from the EMG data by using a 10 Hz to 500 Hz Band Pass IIR filter; the 10 Hz to 500 Hz band still retains the vast majority of the power spectra associated with surface EMG.

The following graph illustrates the power of this method:



MRI EPI begins roughly half-way into this data graph, as clearly evidenced by the top EMG waveform. The EMG waveform is significantly corrupted by EPI generated artifact.

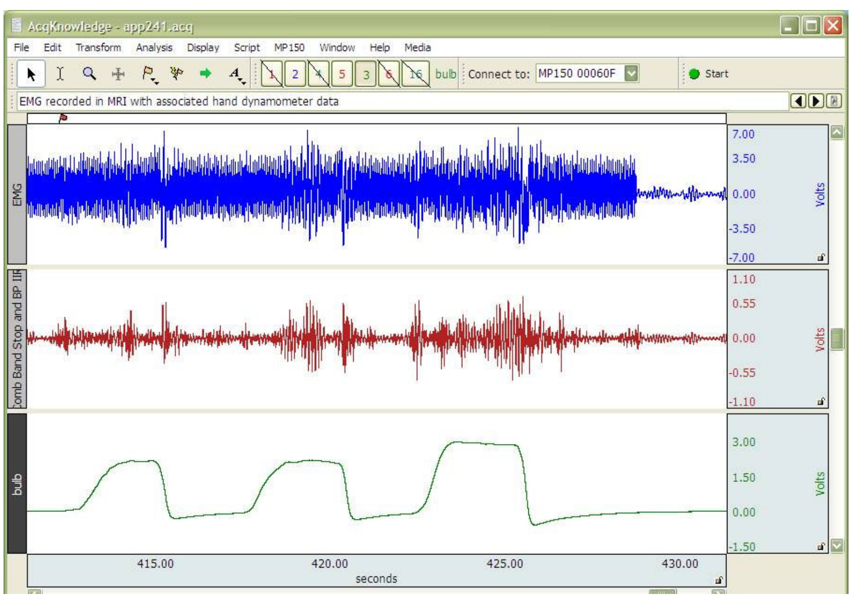
The lower graph is the identical EMG waveform, but processed with a Comb Band Stop filter and a 10 Hz to 500 Hz IIR Band Pass filter with Q=0.707.

- Filters can be performed on the MG data in real time or post-processing.

The scale on the resulting EMG in the lower graph is decreased by a factor of 10 to show more detail in the EMG.

An examination of the modified source data will show that the bulk of artifact on the EMG, during EPI, has been removed.

The following graph shows EMG recorded in the MRI along with associated data from a hand dynamometer:



Grip strength recordings are obtained in units of pressure per unit area, such as kilograms per centimeter squared or pounds per square inch.

The TSD114-MRI transducer used is a "pressure bulb" that effectively integrates applied grip strength to provide a very accurate and repeatable measure of hand-grip or squeezing strength.