Structural MRI Identifies Precise Location of Intramuscular Electrode Recording Site Based on Presence of Micro-hematoma

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IMPROVING the ability of surface EMG to extract information about muscle activation and control at the scale of individual motor units depends critically on the spatial distribution of the surface electrodes with respect to the source of the motor unit action potential (MUAPs) deep inside the muscle [1]. The aim of this paper is to demonstrate that the location of a fine-wire recording site (i.e., a ground-truth source of MUAPs) can be found using structural MRI based on the presence of a micro-hematoma created by the insertion and removal of the needle used to place the electrode. By recording MUAPs at the source with a fine-wire electrode, and knowing its location within the tissues of the forearm, we can maximize the information obtained from surface EMGs [2].

Under a protocol approved by the USC IRB, we recorded fine-wire and surface EMG from the right forearm of a consenting volunteer (male, 28 y.o.) during isometric force generation with the hand and fingers. We placed seven differential surface electrodes (Delsys, Boston, MA) equidistantly around the proximal third of the forearm with a reference electrode on the olecranon. A pair of fine-wire electrodes were inserted using a 26-gauge needle into the belly of the *extensor carpi radialis brevis* (ECRB) muscle between surface electrodes 3 and 4. The target muscle was confirmed using structural landmarks, EMG response, and cross validation with similar scans containing clearly labeled muscle groups.

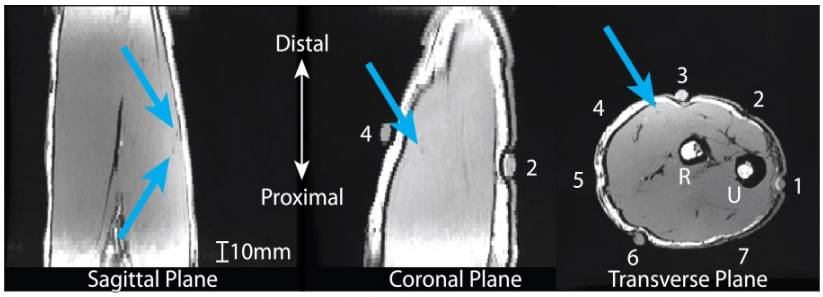

Fig. 1. Structural MR images of forearm indicating a hematoma representing the location of a fine-wire electrode within the *extensor carpi radialis brevis* muscle.

Following these recordings, we obtained structural MR images of the subject's forearm in a clinical 3T scanner (GE Healthcare, Waukesha, WI) in the same palm-down posture. The scanner was configured to acquire fast HD 3D spoiled gradient recalled (SPGR) images. Each surface electrode was replaced by an MRI fiducial marker (vitamin E tablet). The MR images reveal a small hematoma formation that tracks the path of the needle (small dark areas indicated by the blue arrows in Fig. 1). Given the voxel size of the images, the location of the recording site is accurate to within 1.07 mm. Figure 1 shows the sagittal, coronal, and transverse planes that best represent the location of the micro-hematoma. Bright dots around the forearm are the fiducial markers, which match the locations of the surface electrodes. From the images, it can be seen that the electrode pierced into the skin progressing deeper and proximally into the muscle tissue, ultimately reaching a depth of approximately 8 mm into the tissue. The path of the electrode is coplanar with the sagittal plane and appears as two dark hematoma formations extending upwards and to the right. This was consistent with both the estimated depth of the needle and video taken during the electrode placement.

This ability to locate ground-truth MUAPs within the muscle enables the optimization of system identification models, validation of volume conduction models [3], and helps understand signal propagation in biological tissues.

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