J. D. Quartararo and E. A. Clancy, "Preliminary Simulation Results of a Method for Optimizing Spatial Filters in High-Resolution Electromyogram Arrays," *Proceedings of the Sixteenth Congress of the International Society of Electrophysiology and Kinesiology,* Torino, Italy, p. 57, June 29–July 1, 2006.

PRELIMINARY SIMULATION RESULTS OF A METHOD FOR OPTIMIZING SPATIAL FILTERS IN HIGH-RESOLUTION ELECTROMYOGRAM ARRAYS

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AIMS: Decomposition of single motor unit activity in human muscle has typically been accomplished with needle electrodes, which are more spatially selective than conventional surface electrodes and can be situated close to the origin of the electrical activity. However, high resolution surface electrode arrays that can resolve individual action potentials have been demonstrated. These arrays employ spatial filtering to enhance the spatial selectivity of the EMG, limiting the volume of muscle that contributes to the predominant electrical signal. Typically, the normal double differentiating (NDD, or "Laplacian") spatial filter, derived from the field of image processing, is used to reduce the number of superimposed action potentials. In this presentation, we describe a novel optimal EMG spatial filter technique that minimizes the muscle tissue volume whose action potential (AP) firings are prevalent in the resultant spatially filtered signal.

METHODS: Simulations were used to model an AP as a traveling tripole within the muscle, and to calculate the resultant electrical potential induced at an array of monopolar point electrodes positioned at the skin surface. The simulated data were used in conjunction with a map of *desired* spatially filtered output voltages and optimization theory to determine spatial filter weights to achieve the highest spatial selectivity. Two metrics were used to compare spatial selectivity. The first locates the 3 dB drop (from the peak voltage) of the spatially filtered voltage in the skin plane and models this contour as an ellipse. The area of the ellipse is the first metric. The second metric simulates two adjacent APs, one in the region of tissue interest and the other physically offset; the ratio of the peak magnitude from the offset AP with respect to the first is the metric. Smaller values for both metrics imply better spatial selectivity.

RESULTS: The optimal filters were found to be consistently superior to the NDD filter with both selectivity metrics. For example, a 15x15 optimal filter was created for APs at a depth of 7mm, with an interelectrode spacing of 2.5 mm. The center of the array was set as the region of interest. The 3 dB area (first selectivity metric) for the optimal filter was 40% of the NDD filter's area, indicating a noticeable increase in spatial selectivity. For the case of two adjacent APs, the first in the center of the region of selectivity and the second with an offset of 2 mm (second selectivity metric), the optimal filter suppressed the second AP to only 12.1% of the first's peak amplitude, while the NDD filter's attenuation was to 77.9% of the first peak's amplitude. Selectivity was a function of the simulated inter-electrode spacing and the number of electrodes in the array.

CONCLUSIONS: The optimal filters were shown to be superior to the NDD filters. Testing with more realistic simulation models and in human subjects is warranted, based on these initial successful results. The structure of the technique is readily adaptable to more realistic simulators, since the optimal algorithm accepts "black box" simulation data representing the monopolar voltages recorded from an array of electrodes. Thus, more complex models could be used to find a more robust spatial filter for more realistic physiologic conditions.