

THE LIBERTY MYOARRAY™: A DIAGNOSTIC TOOL TO TEST AND TRAIN AMPUTEES TO USE MYOELECTRIC PROSTHESES

William J. Hanson, MS, Matthijs P. Smits, MS, Peter R. Teare
Liberty Technology, 71 Frankland Road, Hopkinton, MA 01748, USA.

INTRODUCTION

When fitting a patient with a myoelectric prosthetic device, a prosthetist or therapist tests the patient to determine the best location on the muscle to place the electrodes. Generally, the optimal location is the one where the myoelectric signal is strongest. Typically, a prosthetist attempts to determine this location through trial-and-error. This is time-consuming and the resulting signals are often inconsistent because each contraction is different.

Others have proposed or utilized multiple electrodes for monitoring muscle activity [1-3] and one research study resulted in a system to facilitate muscle-site identification [4]. These systems however, depend on repetitive or sustained muscle contractions which may introduce another variable, misleading the prosthetist. In addition, these approaches take significantly longer to perform and may tire the patient.

The Liberty MyoArray* has been developed to provide an easy-to-use, portable diagnostic system for quickly measuring myoelectric signals from several locations at once, over a wide muscle area. It increases the likelihood of proper patient fit and control of the prosthesis. For the experienced prosthetists, it speeds the process and it allows the inexperienced prosthetists to succeed with myoelectric technology. It eliminates the possibility of error caused by variation in muscle flexions and facilitates training by providing feedback while the amputee is performing controlled muscle contractions.

DISCUSSION

For people with intact muscles, determining the locations for a strong muscle signals is predictable. However, for amputees or limb-deficient people the muscle remnant may not be intact and may not respond in the usual manner. To determine the best site for placement of myoelectrodes, a prosthetist usually moves a single electrode probe over different portions of the muscle and requests that the patient contract the muscle. This is done repeatedly until the prosthetist concludes that she/he has located the site with the greatest signal strength. This method requires the prosthetist to remember the relative signal strength at each site. It also assumes that the patient performs identical muscle contractions each time – a difficult thing to do. Consequently, the comparisons between locations are not based on identical conditions. If the patient fails to contract the muscle repeatedly with the same force each time, the prosthetist can easily be misled and may identify less than the optimal site for placement of the electrode.

The MyoArray addresses these issues. It consists of an array of electrodes mounted on an easy to install elastic band with a wire harness to form electrode pairs. The electrodes are spaced the same distance apart as Liberty Boston Elbow electrodes. In the longitudinal direction the contacts are mounted on a rigid board, fixing the spacing to ensure proper myoelectric signal detection. In the lateral direction, however, the elastic band stretches causing the spacing to vary. This is acceptable because the MyoArray only measures myoelectric activity using pairs in the longitudinal direction, along the muscle fiber direction.

The MyoArray electrodes are positioned over a muscle. The patient contracts the muscle and the system reads the myoelectric signals from all electrode pairs. These signals are processed, filtered (averaged), and displayed for each electrode pair. The signal processing consists of amplification, rectification and smoothing, as in most myoelectric prosthesis electrode circuits. This is followed by

additional circuitry to determine the strongest signal or group of signals out of the total set of measured signals.

Currently, the system consists of electrode contact pairs, circuitry for one to 15 channels of parallel signal, an interface device, a microprocessor, and a display. The display can be any IBM PC compatible computer or a hand-held read-out device. The computer provides options for more thorough patient assessment through several different analyses.

The present version of the MyoArray has a battery supply and optical isolation for the components. This isolation is utilized to satisfy regulations requiring electrical isolation between the patient and the computer when testing human subjects. Optical isolation provides complete, safe isolation when the computer is powered from an electrical outlet. A lap-top or hand-held computer can be operated without AC power, thus automatically providing isolation when operating on battery.

Early versions of the MyoArray arm band consisted of a variety of electrode pairs and patterns and eventually a 15 electrode band was developed to cover a reasonable muscle area (5 x 10 cm). The circuits evolved from a single channel with a switching device, to a circuit with 15 parallel channels of gain and signal conditioning. This was deemed necessary to allow rapid sampling of all channels. The single channel version required 100 msec sampling per channel (20 msec settling time and 80 msec sampling), resulting in a total sampling time of about 1.5 seconds. Based on experiments, we felt that this was too long for a consistent, sustained contraction. Therefore, we chose to expand the circuit to a full 15 channel device allowing us to sample much more rapidly (total 200 msec) and providing a more responsive display.

The circuitry is comprised of amplifiers, high-pass and low-pass filters, and rectifiers for each channel plus a channel selector switch. The filters attenuate frequencies above 350 Hz and below 100 Hz. The averaging is performed in the converter, so sampling can be done quickly. With this circuitry, the computer does not need to perform the averaging calculations, and thus less computing power is required.

Display

Several display options are available providing instant feedback as a patient assessment tool. The MyoArray can display various combinations of processed myoelectric activity on a computer screen or with a matrix of LEDs. For example, signals can be displayed from all the electrode pairs simultaneously (figure 1), only the electrode pair that shows the strongest signal, or a time history of one or all measured signals.

The bars/balls represent a percentage of maximum output. A maximum of 100% represents the maximum signal which is recorded by the prosthetic device to be fitted. For example, if the maximum input to the device is 1.0 mV, and the gain is 3000, a 100% reading represents 3.0V of output.

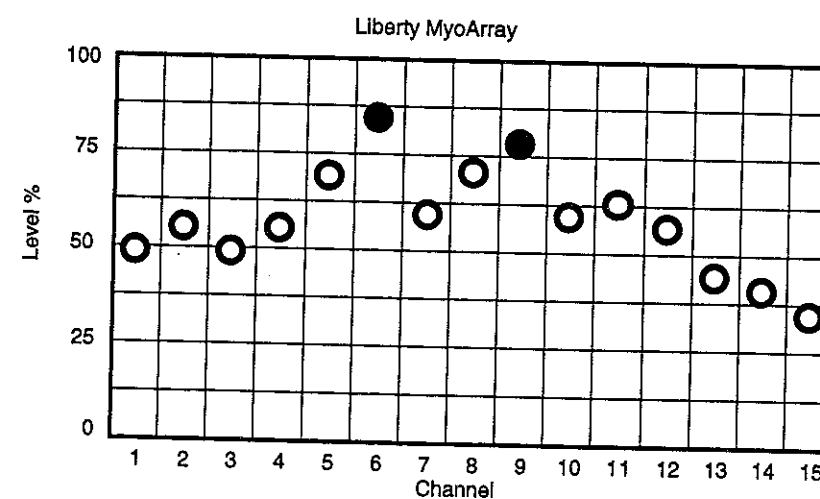


Figure 1. Assessment mode -- multi-channel amplitude display

In addition, the MyoArray can display activity from more than one muscle by replacing the electrode array with two electrodes (figure 2). This provides a training apparatus for the myoelectric prosthesis user, by allowing the amputee to view the signal strength of each muscle as well as the difference in these signals. This difference value corresponds with the direction and speed of the prosthesis, if one were present.

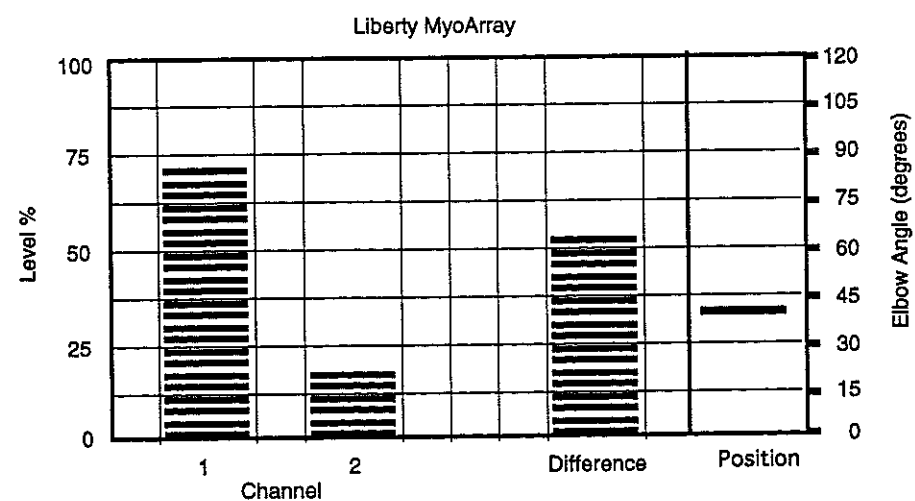


Figure 2. Training mode - two channel display

- A) Multiple channel myoelectric signal amplitude - simultaneously (figure 1):
This display allows the practitioner to view multiple channels dynamically to determine the regions where the strongest signals tend to occur. It also provides information on the signal amplitude trends during a muscle contraction and allows the prosthetist to identify any anomalies. The electrode sampling sequence is used to identify adjacent muscle sites on the graphic display.
- B) Single channel myoelectric signal amplitude:
This display is similar to the multiple channel version, however it monitors a single selected channel and freezes the remaining channels.
- C) Single channel time history:
This display provides a graph of amplitude as a function of time, similar to an oscilloscope. It allows the prosthetist to view the myoelectric activity of a single electrode to evaluate the signal or to diagnose the array.
- D) Two channel, simulated proportional control:
This display is most useful for demonstrating prosthetic function to a patient and for training the patient to control two muscles in a way that will allow him/her to properly control a myoelectric prosthesis such as the Boston Elbow. The relative amplitudes of the two myoelectric signals, plus a third channel which represents the difference between these two signals, results in information which allows the patient and the prosthetist to determine both the direction and speed a proportionally controlled myoelectric prosthesis would be traveling. A patient can perfect these actions by receiving feed-back from the MyoArray without the use of a prosthesis. This provides a better evaluation of the patient, and thus increases the likelihood of a successful fit. In addition, the patient would gain a better understanding of the way these signals control the device.

E) Multiple channel time history:

This display provides a time history of all channels simultaneously, allowing one to observe time variations for the various electrode positions.

Once the patient assessment is complete, the prosthetist removes the array arm-band from the patient. The temporary indentations on the surface of the skin allow him to easily locate the optimum position for placement of the prosthesis electrodes. Knowing the channel or channels of maximum signal strength and the array pattern, the prosthetist quickly determine the optimum site. This assures accurate placement of electrodes.

Several prosthetists have worked with a prototype of the MyoArray and have expressed interest in using the device with patients because of the greater likelihood of locating the optimal electrode sites, and improving the training. In addition, testing and fitting time are significantly reduced, saving time for both the prosthetist and the patient. This is important because a patient who's muscles have remained dormant for several months may fatigue quickly. Patients will learn to use myoelectric prostheses more rapidly and with a greater understanding of the actions that cause various motions.

Training:

The muscle contractions utilized to perform different tasks are not necessarily the same natural contractions that an amputee would have been using to perform those tasks prior to amputation [5]. Therefore, some patients must be "trained" to control the prosthesis. Efficient and effective prosthesis control can eliminate unnecessary muscle contractions or cocontractions which cause patient fatigue. This also allows the patient to position the prosthesis more precisely and more rapidly, thus reducing the amount of power consumed by the electric prosthesis and increasing the use time between charges.

Preferably, the patient contracts each muscle separately, while contracting the other muscle as little as possible to get a better response from the intended contraction. The display (figure 2) has two columns, one for each muscle, e.g., biceps and triceps and the third column showing the difference between the two channels. An additional column shows the position of the arm as an angle relative to a vertically extended position. During training, the patient learns to control the muscles to work independently. For best results, the biceps should be contracted to flex the elbow without contracting the triceps which oppose the biceps. Accordingly, the patient is taught to practice keeping the difference level high while working through the range of motion as shown in the fourth column.

Future

Several versions of the MyoArray have been developed and each provides improved performance and functionality over previous versions. The present 15 channel MyoArray samples rapidly, assessing muscle activity in about 200 msec, thus assuring that all samples are acquired during the same portion of a muscle contraction. In order to produce the device inexpensively, we are investigating the possibility of using two channels of filters/amplifiers and sequentially sampling through the fifteen electrode pairs. This method allows the signal on the second channel to settle while the first channel is being read, and visa-versa, reducing the time period between each sample. If this method introduces any inconsistencies in the resultant data, we will resort to the full fifteen channel version for production.

Our goal is to offer two options;

1. A hand-held processor/display which provides the prosthetist with the essential information to select optimum electrode sites - maximum signal strength as a function of location.
2. A lap-top computer based version which has additional analyses and display modes to thoroughly evaluate, diagnose, and train a patient.

The array size could be increased to accommodate larger muscle sites or possibly even to measure two muscles simultaneously. This would allow the prosthetist to monitor muscle activity and synchronization of an antagonistic muscle pair like the biceps and triceps. At present, we accomplish this with two research electrodes, but a large array or strips of electrodes could simplify the procedure.

We are working on additional enhancements to the MyoArray as well and one that will further improve its usefulness is a new autoscale feature. This will allow the prosthetists to have the system determine the maximum signal from an individual patient and scale the subsequent readings automatically to obtain maximum resolution.

We plan to use the MyoArray system to study myoelectric signals generated in the forearms of intact limbs and to compare them to the signals generated by amputees.

REFERENCES

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- 4 Naumann, Stephen, et.al, *A Portable Muscle-Site Identification System*, The Hugh MacMillan Rehabilitation Centre, Rehabilitation Engineering Department Annual Report 1991
- 5 Smits, Matthijs, *Triphasic Patterns in Above-Elbow Amputees*, Proceedings International Symposium on MyoElectric Control, August 16, 1993

* A patent application entitled *Prosthetics Electrode Array Diagnostic System* was filed on March 19, 1993.