USING PATTERN RECOGNITION TO ENHANCE PROSTHETIC CONTROL IN PATIENTS WITH PROXIMAL AMPUTATIONS WITHOUT TARGETED MUSCLE REINNERVATION: A CASE SERIES

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ABSTRACT

The relatively recent commercialization of pattern recognition has occurred simultaneously with the proliferation of Targeted Muscle Reinnervation (TMR). Reports on applications of pattern recognition have generally been its application on proximal amputation post-TMR procedures or on transradial amputations in the absence of TMR. This case series highlights two successful applications of pattern recognition to patients with high level amputations who had not undergone TMR. In both cases, the users experience enhanced prosthetic control with reduce frustration and cognitive burden of prosthesis use. Pattern recognition appears to be a viable control strategy in high level upper limb amputation without TMR procedures.

INTRODUCTION

Direct control systems have been the traditional standard for myoelectric control of upper limb prostheses. In dual-site direct control a pair of surface electrodes are positioned over a set of antagonistic muscles with distinct EMG signals from these muscles providing threshold-based, proportional control of opposing prosthetic movements. However, the muscular actions of the controlling EMG sites are often physiologically inappropriate and counterintuitive with respect to the desired prosthetic movements [1]. This is more pronounced at high-level amputations where the muscles of the upper arm and shoulder girdle are recruited to control hand prehension and wrist rotation. Further, with direct control systems for high-level amputations the number Of EMG control inputs for prosthetic movements are insufficient, often requiring the user to generate specialized EMG signals to cycle between joint segments of the prosthesis [1].

In contrast to direct control, pattern recognition control reads EMG information from throughout the residual limb. Prosthetic control is provided through the recognition or correct classification of collective muscle patterns obtained from throughout the limb. This allows for direct control of multiple prosthetic movement patterns.

The commercialization of pattern recognition has occurred simultaneously with the proliferation of TMR, an innovative surgical procedure designed to increase the number of independent EMG sites available upon a residual limb. Publications on the application of pattern recognition in prostheses for high-level amputation have generally been confined to individuals who had undergone TMR procedures [2-5]. This cases series will highlight two successful applications of pattern recognition for high-level amputations that have not been revised using TMR techniques. Written informed consent was obtained from both case subjects.

SHOULDER DISARTICULATION CASE

DV presented with a right shoulder disarticulation amputation (Figure 1). He was initially fit with a passive prosthesis to restore an aesthetically acceptable appearance in community activities.

Figure 1: Right Shoulder disarticulation

A year later he was provided with a second prosthesis. The EMG signals on DV’s chest wall were so strong that they effectively drowned out the more modest EMG signals that could be obtained from his upper back. As a result, the control strategy of this first electric prosthesis was a single-site direct control.

More specifically, the EMG signals derived from his chest wall were used to control the sequential movement of his elbow, wrist and hand. EMG signals exceeding the 1st level threshold provided control input to the joint under active control using an alternating strategy in which a brief latency period between contractions allowed control to switch to movement in the opposite direction (I.e., from an elbow flexion to an elbow extension command). Brief spikes exceeding a 2nd level threshold acted as the sequential switching signal between joints.

DV wore this system regularly and became quite adept at its use, but frequently commented on the tedious nature of its control which could become frustrating in the execution of finer motor movements.

Several years later, soft tissue revisions to the limb required the replacement of this prosthesis. At that time pattern recognition was assessed as a possible means of enhancing prosthetic control. During this assessment it was discovered that while the signals were dwarfed by the more powerful signals of the chest wall, discernible EMG signals could be obtained from the infraspinatus, supraspinatus and latissimus dorsi. While these signals were inadequate to exceed the threshold requirements of direct control, and could not be adequately separated from EMG activity of the pectoralis major, they were sufficient to inform the nuanced patterns required in pattern recognition.

A dynamic test socket was constructed with a single pair of anterior electrodes and 3 pairs of posterior electrodes located over the targeted muscle bellies (Figure 2). Over several weeks of use, the DV was able to consistently generate distinct signals for elbow flexion and extension, wrist pronation and supination and hand opening and closing.

Figure 2: Dynamic test socket with 8 electrodes positioned over targeted muscle sites

This control strategy was preserved in the fabrication of the definitive prosthesis, inclusive of an Espire Elbow, Motion Control wrist rotator and BeBionc hand (Figure 3). Passive grip selection using the contralateral hand provided the patient access to 8 distinct grip patterns.

Figure 3: Definitive prosthesis inclusive of pattern recognition control of an Espire Elbow, MC wrist rotator and BeBionic Hand.

While DV continues to prefer his passive prosthesis for much of his community activities, he wears the more advanced arm regularly to accomplish basic ADLs around the house with a specific interest in meal preparation. He is extremely pleased with the enhanced control and reduced frustration in operating the system.

SHORT TRANSHUMERAL CASE

KA presented as a legacy user of a range of upper limb prostheses following his short transhumeral amputation secondary to an IED blast sustained in combat (Figure 4).

Figure 4: Short transhumeral amputation secondary to IED blast injuries

At the time of KA's presentation to our clinic, he was using a hybrid prosthesis with a body-powered elbow, passive control of pronation and supination and dual-site direct control of a BeBionic hand. He presented with ample

EMG signal from his residual triceps, but extremely weak EMG from his residual bicep. He was able to cycle between 3 targeted grips using an “open-open” switching signal, but his ability to consistently close the hand was poor. He expressed frustration with both his consistency of operation and the cognitive burden of prosthetic control.

In response to these deficits, pattern recognition was explored as an alternate means of myoelectric control. Eight electrodes were positioned over the anterior, medial and posterior aspects of the socket (Figure 5). These produced an extensive EMG palate that ultimately generated discrete control of active pronation and supination, hand opening and 3 discrete closing signals for his TASKA hand including general grasp, flexi-tool and a custom grip that allows him to hold his tablet while working as an environmentalist in a mine.

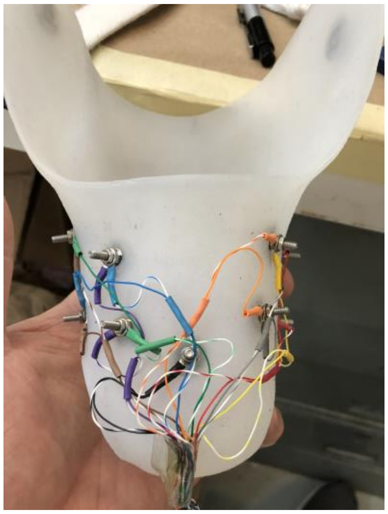

Figure 5: Placement of 4 pairs of electrodes to inform the patient’s pattern recognition control scheme.

The patient’s definitive hybrid prosthesis was inclusive of a suction socket with a body powered hybrid elbow and myoelectric control of a powered wrist rotator and a heavy duty multiarticulate TASK hand (Figure 6). The patient reports daily use of this prosthesis with specific application in his work setting.

Figure 6: Definitive hybrid prosthesis

CONCLUSION

Pattern recognition in the control of prostheses for high level amputations has largely been described in patients who have undergone TMR to expand the strength and availability of EMG control signals. In this case series we describe two high level patients who experienced substantial improvements in their control of their electric prostheses with the introduction of pattern recognition without the benefit of TMR. The ability of pattern recognition to recognize subtle distinctions in EMG patterns at proximal amputation levels appears to be sensitive enough to provide many discrete signal inputs even in the absence of TMR.

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