INTRODUCTION

After several cases utilizing TMR as the foundation for control it becomes apparent that even the most advanced commercially available systems lack all the necessary variability to accommodate a wide array of clinical presentations. Some patients present with multiple sites for control but may want, in addition to a fully myoelectric prosthesis, a hybrid device; giving them the flexibility to use all available types of prostheses. Some patients present with muscle that is hyper-mobile; making the job of securing the prosthesis and providing a good interface for the electrode an extreme challenge. As a result there is a need for further development of components made available so as to provide devices that meet these demands.

HYBRID TMR PROSTHESIS WITH THREE SIMULTANEOUS DEGREES OF FREEDOM

Transhumeral hybrid prostheses have been used successfully by upper extremity amputees for many years to increase function while allowing 2 degrees of simultaneous freedom; controlling the elbow while operating the terminal device. Many patients prefer this prosthetic control strategy to the strict body powered or myoelectric designs. With the advent of recent TMR Targeted Muscle reinnervation surgical techniques, we have been able to increase function of hybrid prostheses.

Targeted Muscle Reinnervation has given Prosthetists additional myoelectric locations to capture EMG signals. With the increase in the number of EMG sites the Prosthetist can increase function for the patient. To date most patients who underwent TMR surgery were fit with purely myoelectric system (myoelectric elbow, wrist and hand or other terminal device). In most cases this gives the user 2 degrees of simultaneous control of the myoelectric prosthesis.

Using existing hybrid transhumeral prosthetic components we are able to increase simultaneous control of the prosthesis from two to three degrees of simultaneous control. This allows the patient the ability to actively control the elbow flexion and extension, wrist pronation and supination, and hand opening and closing simultaneously giving the patient a more natural way of moving the prosthesis in space while doing activities of daily living more closely resembling a natural human arm.

Advantages of the three degrees of simultaneous movement should allow the patient faster response time when manipulating objects, greater wearing time due to the decreased weight of the body powered elbow and increased proprioception and speed of elbow flexion in space through the Bowden cable system.

Extensive Occupational and Physical therapy will need to take place to improve the patient’s control and function with a device that allows the user three simultaneous degrees of freedom.

Overall, patients that have been fit with the Hybrid TMR prosthesis report they prefer to wear this prosthesis over their body powered or TMR myoelectric prosthesis.

Further trials will need to occur to in future TMR patients to gain the understanding of what can be accomplish.

THE SOCKET AND ELECTRODE INTERRELATIONSHIP IN TMR SHOULDER DISARTICULATION CASES

The goal behind TMR surgery is to surgically treat the nerve in a more appropriate manner, to produce more electrode sites and to create sites that are more intuitive resulting in less switching and higher simultaneous control of multiple degrees of freedom. Along with the creation of more electrode sites there are issues that may require the typical approaches to socket design and electrode placement and management to be modified. Sometimes the surgery produces a muscle that is hyper-mobile. This may be caused directly by hyper-reinnervation, surgically removing the origin or insertion of the muscle or by removing the subcutaneous tissue resulting in a more adherent skin to muscle connection. Regardless of the cause, the result is that managing the placement and constant contact between the electrode and the skin can be a challenging problem.

The problems of tissue sliding and pulling away from the socket have been previously reported.1 In Shoulder disarticulation cases this problem of hyper-mobility is more of an issue because frame type socket designs do not encapsulate the musculature and restrict movement as it would in a Transhumeral situation. This gives the skin over the muscle freedom to move and makes the job of keeping...
the electrode in place more of a challenge. If the electrode is held in position in the frame, we typically expect the skin to stay relatively in the same position under the electrode. If any sliding occurs, a motion artifact is produced resulting in unpredictable behavior of the prosthesis. It is common to allow for some flexibility outward with the electrode with flexible mounts but it has not been a problem to control lateral shifting of the musculature by simple socket designs. In these TMR cases, expansion, change in topography and lateral shift of the muscle is very common.

Initially efforts were made to modify the socket for the final resting position of the electrode upon complete contraction. When not contracting, the muscle and the surrounding soft tissue would find a home inside the strangely shaped interior of the frame. This worked well to a point but several side issues arose. The patients would report significant pressure over their electrode sites, they would describe numb feelings in their “transferred” limb sensation and often the muscle would not fire as strong resulting in the need for higher than needed amplification through the electronics. Another problem with having so many electrodes in one area, like over the pectoralis muscle, was that the socket surface had to be quite large to accommodate the electrodes. This made the socket larger, hotter and more susceptible to coming off of the chest when in a seated position from counter pressure to the posterior inferior member of the supporting socket frame. These issues spawned the thought that if we could develop an individual electrode holding appliance and connect it flexibly and remotely to the frame that we could control individually the tension over the site and independent of any other electrodes, keep them separately flexible when each muscle fired.

The first generation of flexible connector involved a spring steel arm and a fixed connector at the electrode that would pivot over the length of the spring steel. Otto Bock suction socket electrodes were utilized to provide the connection point to the fixed connector. If the only need was to accommodate substantial outward movement of the skin, more than a typical flexible electrode mount would accommodate this worked fine. It did not work however in a situation that the topography changed where the angle of the electrode needed to change to maintain contact. Tilting of more than 30 degrees was necessary in this case.

Another generation of device was made with a pivoting attachment over the electrode. It accommodated the necessary tilt of the electrode but lacked the ability to control rotation of the electrode. It was also noted that this design allowed for some accommodation of the shear movement under the electrode by compressing the soft tissue over the muscle as it expanded. This isn’t a perfect solution when the skin is significantly sweaty as there is less coefficient of friction between the electrode and the skin so the tilt would not be enough to stabilize the electrode.

The third generation under development will accommodate the following criteria

1. Spring steel attachment arm for adjustable tension and flexible attaching to the socket frame
2. Rotatable locking electrode holder
3. Pivoting head
4. Gain adjustment access
5. Shear accommodation
6. Protection for electrode wire

With the above listed modifications the device will be able to be used on even the most challenging of TMR presentations and maintain independence of the electrode from the anchor and necessarily stable structure of the socket.

CONCLUSION

TMR surgery has expanded the functional capacity of modern upper limb prosthetic devices and as we explore these cases and try to maximize the potential of each patient it is clear that there is a great need for fine tuning our approaches. As a result there will be a spill-over effect of these techniques incorporated for both the TMR population and non-TMR population to benefit.

REFERENCES