HYBRID TRANSRADIAL PROSTHESIS FOR A COMPLETE BRACHIAL PLEXUS INJURY: A CASE STUDY

Robert D. Lipschutz, CP, BSME
Newington Orthotic & Prosthetic Systems
Newington Certificate Program in Orthotics and Prosthetics

ABSTRACT
The gentleman in this case study presents with the typical etiology of a brachial plexus injury, status post motorcycle accident. The accident occurred several years ago with surgical intervention including a shoulder allograft and arthrodesis as well as a transradial amputation. Because of the presence of a complete brachial plexus injury it is difficult to decipher the rationale behind a transradial amputation. Many of us have fit individuals who had suffered these type of injuries and have opted for transhumeral amputations. Difficulty arises from attempting to accommodate the non-functional articulation, namely the elbow joint. Past prosthetic fittings have been with a conventional, elbow disarticulation style prosthesis with external locking hinges and voluntary opening terminal device. Due to the limited excursion of this gentleman and his wear on the contralateral shoulder for these many years, it was time to consider a different prosthetic design. The design consideration was to utilize some of the components that he presently functions with and to add electronic components which require limited excursion and strength in order to operate.

HISTORY
The gentleman in this study presents with a left, short transradial amputation and shoulder arthrodesis. He suffered a brachial plexus injury approximately twelve years ago which left him with a passive arm distal to the shoulder. After repeated trauma and the increased risk of infection to the hand and forearm, he agreed to a transradial amputation. He has been able to function quite well in the past with the design of his current cable-driven prosthesis that is set up similarly to an elbow disarticulation style prosthesis. It consists of three ply sock fit, modified figure 8 harness with anterior control strap for locking and unlocking of the elbow joints, thermoplastic triceps cuff with metal band, Hosmer Outside Locking Hinge, large sizeTM, laminated socket and forearm, Hosmer FM Quick Change WristTM, and Sierra 2-Load Voluntary Opening HookTM.

DISCUSSION
Due to the limited range of motion (ROM) of the contralateral limb, the figure 8 harness had to be very tight in order for the patient to get enough excursion to control both elbow flexion and terminal device operation. Over the years of wearing this harness so tight, he has developed pain in the sound arm, neck, and back. He desired the greater pinch force of the Sierra 2-Load Voluntary Opening HookTM terminal device. This created higher axillary pressure due to the necessary cable excursion and force. Because of his limited ROM, the routing of the fair-lead cable was never optimum creating friction in the cable and wear on the client’s anatomy.

Myoelectric control was obviously not a possibility due to the complete brachial plexus injury, therefore, switch controlled devices became our considered choice for operation of a terminal device. However, the patient had a voluntary opening, terminal device for so long that we thought a similar style device would be the best choice to replace his existing hook. Possibly we could employ an adult electronic hook terminal
device, switch controlled, with a voluntary opening, automatic close control mode, i.e. cookie-crusher circuit. This did not currently exist, but would be shortly. From the patient’s perspective, the Otto Bock Greifer™ was unacceptable due to its mechanical configuration and the tasks that this gentleman performs at work. This left us with the NU-VA Synergetic Prehensor™, or the Steeper Powered Gripper™. Neither of these were designed to work with a cookie cruser circuit, however the configuration of the NU-VA Synergetic Prehensor™ more closely resembled the Sierra 2-Load Voluntary Opening Hook™ terminal device and had possibilities of being converted into a switch controlled, voluntary opening, automatic closing terminal device. The electronic configuration had to be customized for this terminal device in order to convert its function.

With the aid of Steve Duff, an electronics technician and clinical assistant at the Rehabilitation Institute of Chicago, an electronic configuration was designed to control the NU-VA Synergetic Prehensor™ in the desired voluntary opening, automatic close mode. The definitive prosthesis (Figure-1) consisted of a modified figure 8 harness. The control cable was a fair-lead style which ran through a forearm lift loop and into a pre-flexed forearm terminating with a Hosmer Ball Receiver with sliding cover™. The triceps cuff again was ventilated thermoplastic and the elbow hinges were one Hosmer Outside Locking Hinge, Large, Heavy Duty™ and one Hosmer Flail Arm Hinge, Non-Locking™. On the inside of the forearm, mounted laterally, is an Otto Bock 9x18 Cable Pull Switch™ with a Hosmer Ball Terminal™ attached to it proximally. The output of the pull switch is connected through a battery cable to an Otto Bock On-Off Switch™ and a VASI V26CCB Power Bridge for a Cookie Crusher Circuit™ down to the Hosmer FM100 Wrist Unit™ and finally the NU-VA Synergetic Prehensor™. Medially on the forearm is an Otto Bock 757Z104-2 Battery Receptacle™ where an Otto Bock 757B8 Interchangeable Battery™ is housed.

The same control motions were used in this prosthesis to activate elbow flexion and lock as were used in his existing prosthesis. The patient had some residual motion in his shoulder which would allow his humeral head to project anteriorly. With the lock control strap running across this projection, he was able to lock and unlock the elbow. This was analogous to what he had done with his completely cable driven prosthesis. An electronic alternator switch was initially intended to be in parallel with the outside locking hinge, turning power on and off to the terminal device, so that when the elbow was unlocked the terminal device was not operational. Due to difficulty in finding such a component, the delay in finding such a part, and the fact that the client uses his contralateral hand to preposition the arm in its final few degrees of elbow flexion, we decided to go with an on off switch distally that he could activate with his sound thumb. The heavy duty outside locking hinges were used because the wearer had continuously bent the hinges away from the forearm due to his lifting of heavy items at work. The spring assist in the flail arm hinge was to assist in elbow flexion and the pre-flexed forearm helped compensate for aging eyes.

**PROGRESS**

Problems that have arisen following fitting and delivery have stemmed primarily from the harness. Because of the change in design from the cable driven to electrically driven terminal device requiring much less excursion, the harness needs to be somewhat looser in order to avoid inadvertent opening of the hook. This looseness must then be balanced by a tighter anterior suspension strap in order to maintain optimal suspension of the prosthesis. The harness has been adjusted several times and different materials, such as elastic webbing have been added to the control attachment strap in order to decrease the sensitivity of the electric terminal device. The difficulty with making the elastic too thin or the strap too loose is that the control of elbow flexion becomes compromised. Another problem is that the NU-VA Synergetic Prehensor™ can presently have only two set pinch forces: either a very light pinch force less than two pounds, or full...
force of the terminal device, approximately twenty-five pounds. This is changed by varying the setting on the VASI V26CCB Power Bridge for a Cookie Crusher Circuit™ pot. There is no in between setting for force nor can the user presently adjust these settings himself.

There also exists some speculation that since we have utilized these components for purposes for which they have not been designed, it may cause them to eventually breakdown. Specifically, the use of a switch control to assist in elbow flexion while being pulled on by a cable attachment without activation of an electronic component may lead to mechanical failure. The utilization of a power bridge that was designed to control a pediatric 2-6 size hand being used for an adult electric hook with greater current draw is also of concern. And the daily and total life of the battery being subjected to loads by both the power bridge and the terminal device may impact the life of the batteries.

In spite of these concerns, I believe that this control strategy can be used successfully for many other clients with upper extremity amputations. This design is analogous to what he previously had, specifically his voluntary opening hook terminal device. In order for current users of voluntary opening terminal devices to achieve this type of pinch force when closing, they have to overcome many rubber bands or springs during opening. This new type of design will eliminate both the excursion and force required to perform this task. Hopefully, this can be further investigated and be made adjustable to each user with respect to necessary cable excursion and maximum pinch force.
MANUFACTURERS

Hosmer Dorrance Corporation, 561 Division Street, PO Box 37, Campbell, CA 95008.

Liberty Technology, Prosthetics and Orthotics Group, 71 Frankland Road, Hopkinton, MA 01748.

Otto Bock Orthopedic Industry Inc., USA, 3000 Xenium Lane North, Minneapolis, MN 55441.

Variety Ability Systems, Inc., 3701 Danforth Ave, Scarborough (Toronto), Ontario, Canada M1N262.

ACKNOWLEDGEMENTS

*Special Thanks to Stephen I. Duff, Electronics Technician and Clinical Assistant at the Rehabilitation Institute of Chicago for his assistance in designing of the electronic wiring scheme.

Plympton, Eugene, R.T.(P), Newington Orthotic and Prosthetic Systems, Newington, CT