

APPLICATION OF EXTERNAL POWER IN BRACHIAL PLEXUS INJURY MANAGEMENT: A CASE STUDY

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This paper will describe the process of applying external power technology in the traditionally complex clinical area of brachial plexus injury (BPI) management. The acute and long term management of people who have acquired BPI's often presents the clinical team with many complex management challenges. Simpson [1] concisely summarised the core functional prerequisites that are needed for upper limb function as:

- Proximal stability – shoulder integrity
- Placement in space – ability to position the limb
- Functional grasp – the effectiveness of prehension.

When BPI's are so frequently accompanied by closed head injuries, a further prerequisite is simplicity in design and operation. We intend to illustrate the importance of considering these principles through the presentation of a single case study of a client who we have been working with for the past 7 years.

CLIENT HISTORY

Our client is a 43 year old man who had a motorbike accident in 2001. He sustained a right brachial plexus injury (C6-T1) and surgical repair of the plexus was not deemed possible. As a result he presented with an insensate and flail arm with associated shoulder subluxation. He has also had ongoing problems with severe root avulsion pain. In addition, the client sustained a closed head injury (CHI) at the time of the accident, impacting on his memory, concentration and ability to manage stress. At the time of his injury he was married with a 12 year old daughter, and was working as a maintenance engineer that included using lathes and hand tools, and his leisure activities were hunting, fishing and gardening. He was referred to our service approximately one year post-injury.

ORTHOTIC HISTORY

A standard arm sling was fitted early and continues to be used periodically to position and protect his forearm. He also uses it to transport items such as his wallet and mobile phone.

Design 1

In the first instance, the client was reviewed by our Upper Limb Review Clinic team and expressed three key functional requirements: (1) improved grip to allow bilateral function, (2) stabilisation of his flail arm and (3) reduced subluxation of his right shoulder. In discussion with the clinic team it was agreed that primary shoulder stabilisation by something more than a sling may assist with pain management through relieving traction on the damaged brachial plexus. Traditionally the Stanmore Orthosis has been utilised for people with BPI's and has delivered good results. We fitted the Stanmore Orthosis in October 2002 and this allowed the client to experience increased stability and some restoration of bimanual prehension. He quickly came to realise though that this orthosis did not meet his functional expectations because:

- It had insufficient excursion (due to the inherent design of the Stanmore Orthosis, his body shape/flexibility and limited uniscapular abduction).
- It had low excursion force translating to low prehension force

- There were difficulties maintaining the position of the terminal device during prehensile activity due to instability of both the client's anatomical shoulder joint and an inherent inability to maintain the orthosis in a forward position.

This was compounded by his high expectations of any device given his engineering background, leading to early rejection of the Stanmore Orthosis. Even though this orthosis was unsuccessful, the client's introduction to wearing an orthosis led to his determination to improve the design and he continued to work closely with the team to achieve this end.

Key orthotic design parameters for the next orthosis were:

- Increased prehension force to enable participation in engineering based tasks
- Easier operation of the terminal device – minimising the effort & excursion required
- Sufficient structural rigidity to allow the positioning of a manually locking shoulder joint to allow forward positioning (shoulder flexion) of the orthosis allowing improved positioning of the terminal device
- Simplified donning and doffing.

Design 2

In response, a second design phase was entered into. The second orthosis incorporated:

- A lightweight carbon fibre construction including a padded shoulder saddle and padded forearm section with a modified thoracic strap suspension
- An early version MICA manual locking shoulder joint
- Stanmore manual locking elbow joints
- Switch control external power system including a 9X14 switch, VASI SPM controller and a Lithium Ion power system, and
- A custom fabricated terminal device mounting for the Hosmer 5XA hook.

We felt that external power was the logical solution to the lack of body powered prehension force. The use of the Otto Bock Greifer was discussed at this stage but the client decided that the design of the 5XA hook with its fine tips was suitable for many of his workshop tasks. It was therefore decided that the 5XA hook would be linked to an external power source and control. We researched commercially available components, we sought advice from international colleagues and eventually a VASI linear actuator was fitted to a customised mounting to actuate the hook.

Again there were limitations to this design, specifically a relatively slow open & close speed. In addition, the linear actuator did not apply sufficient force to the terminal device to sustain adequate grip force on the tools and objects that the client wanted to utilise on a daily basis. While the fine tips of the 5XA were deemed useful, other inherent design issues with this terminal device include difficulty holding round objects and lack of surface area diminishing his prehensile ability. Also, the traditional positioning of the terminal device on the medial/distal surface of the forearm and the hook's fixed position restricted pronation/supination leading to significant functional limitations.

The use of the MICA shoulder joint allowed passive positioning of the terminal device but there were concerns about the longevity of the shoulder joint and its use within heavier activities. In addition, given that this shoulder unit incorporates a friction abduction joint the client's upper limb was unable to be maintained in a stable position when force was applied.

As a design revision, the 5XA hook was substituted with an OttoBock Greifer and a 9X50 linear transducer replaced the 9X14 pull switch. These changes increased prehension force and allowed proportional control, but the medial mounting position of the Greifer compromised its function. The client was also restricted in operating controls on his lathe and other machinery due to the close proximity of the hand shell.

During this period three external influences emerged and impacted upon the client's progress:

1. The client underwent unplanned shoulder stabilisation surgery,
2. He experienced marital problems culminating in separation, and
3. He began to self-mutilate his insensate hand leading to infection and subsequent phalangeal loss.

We recognised the need to take a more lateral and realistic approach to designing the orthosis. Through continued discussion with the client our revised design parameters included:

- Increased prehension force beyond what was achievable with the linear actuator,
- Increased stability of his arm to allow more accurate and stable prehension,
- A structural design that would relieve the terminal load of the relatively heavy electric terminal device,
- Better position of the electric terminal device to allow clear line of sight and space to manipulate objects with his sound left hand,
- Protection of his flail hand and arm to minimise self-mutilation,
- Given the client's ongoing cognitive issues, simplification of the cognitive capacity required to operate the prosthesis.

Design 3

These design parameters were achieved in the third design phase through:

- Deleting the shoulder girdle and shoulder joint
- Casting and moulding of the forearm/hand section closely to the body and stabilised by a thoracic strap
- Utilising the existing manual locking elbow joint
- Relocating the terminal device to the lateral aspect of the forearm (see Figure 1.)



Figure 1. BPI Orthosis – Design 3

Through a trial process we found that the client preferred the terminal device to be positioned closer to his left hand. He reported that this was advantageous as it took less time to move into a bimanual prehension position.

The flexible cover over the forearm/hand section was originally designed to provide protection from welding spatter and minimise other mechanical injury. However a

secondary benefit of enclosing the forearm completely was identified. The client's access to his fingers was limited as a result of the cover and therefore opportunity for further self-mutilation was minimised.

SUMMARY

While this paper presents a single case study, many of the issues raised are common to a broad range of clients who have sustained significant brachial plexus injuries, especially those with root avulsion and associated closed head injuries. We recognise that a long recovery period frequently follows brachial plexus injury and there is often reduced motivation to utilise an orthosis. Michael and Nunely [2] state that "it is therefore imperative that the patient be actively involved in all prescription decisions from the outset; without a motivated and cooperative individual, even heroic prosthetic/orthotic interventions are doomed to failure" (p.297). Throughout this process we endeavoured to work within a client centred practice framework and, utilising the team's knowledge and experience, we were able to develop and refine the design to meet the client's primary functional need for a positive grip force on a stable base enabling maximal participation in his everyday activities.

Learning from this process

- Utilising as many commercially available components as possible leads to more predictable outcomes.
- Positioning the flail arm in alternative positions may provide a more stable base for prehension.
- Working with a client over an extended period has its own therapeutic benefits.
- Utilising a functional orthosis allows people to maintain bimanual ability and to establish a wearing pattern that may extend through to future prosthetic use.
- Current research and development into the rehabilitation and orthotic management of these patients remains limited, in particular development of more appropriate componentry appears to be a priority.

1. Simpson, D.C. The hand/arm system. In G. Murdoch (Ed.), "Prosthetics and Orthotic practice". London, United Kingdom: E.Arnold, 1968.

2. Michael, J.W. & Nunely, J.A. Brachial Plexus Injuries: Surgical advances and Orthotic/Prosthetic management. In J.Bowker & J.W. Michael (Eds.), "Atlas of Prosthetics", (pp.293-310), 1989.