A CLINICAL AND ECONOMIC ASSESSMENT OF A MYOELECTRIC ORTHOSIS FOR BRACHIAL PLEXUS INJURY
**Background**

Brachial plexus injuries (BPI) can occur as a result of shoulder trauma, tumors, or inflammation. The brachial plexus is made up of spinal nerves that are part of the peripheral nervous system. It includes sensory and motor nerves that innervate the upper limbs. The brachial plexus includes the last 4 cervical nerves (C5-C8) and the 1st thoracic nerve (T1). Each of those nerves splits into smaller trunks, divisions, and cords. The lateral cord includes the musculocutaneous nerve and lateral branch of the median nerve. The medial cord includes the medial branch of the median nerve and the ulnar nerve. The posterior cord includes the axillary nerve and radial nerve. Injuries to the brachial plexus result from excessive stretching or tearing of the C5-T1 nerve fibers and can be classified as either traumatic or obstetric.

Obstetric injuries may occur from mechanical injury involving shoulder dystocia during difficult childbirth. Traumatic injury may arise from several causes including sports, high-velocity motor vehicle accidents, especially involving motorcycles. Traumatic BPI most commonly affects the supraclavicular zone.

**Traumatic Brachial Plexus Injury Incidence**

Vehicle crashes are the leading cause of BPI. Annual data on such accidents provides a method for estimating TBPI incidence.

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Non-Fatal Accidents</th>
<th>% Resulting in TBPI</th>
<th>Annual TBPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobile/Truck</td>
<td>2.07M</td>
<td>0.67%</td>
<td>13,869</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>88K</td>
<td>4.20%</td>
<td>3,696</td>
</tr>
</tbody>
</table>

Depending upon the severity of the BPI different treatment pathways may be followed. Although in the 1990s it was considered prudent to wait five or six months before indicating surgery, improvements in imaging examinations sometimes change wait times. Today, depending on the severity of the injury, there is a tendency to indicate surgery earlier rather than later since more is now known about earlier nerve regeneration. For those that undergo surgery (procedures include neurolysis, nerve grafting and neurotization), approximately 45% will regain function sufficient enough to perform activities of daily living (ADL) and return to work. This results in an annual incidence of approximately 9,700 individuals who remain disabled due to the injury.
Treatment Options for Surgical Failure with BPI

For those individuals who experience little to no recovery post surgery, upper limb hemiparesis which can include the elbow, wrist and hand has several treatment pathways.

Rehabilitation
Rehabilitation programs that attempt to range the affected arm and possibly reduce muscle atrophy are typically used. They require compliance by the patient and the ability to maintain insurance coverage for therapy. Long term rehabilitation and therapy for the upper limb can become costly, time consuming and often difficult to maintain due to slow recovery and patient frustration.

Amputation with Prosthetic
Transhumeral amputation plus shoulder fusion with prosthesis is sometimes considered for complete and untreatable plexus lesions, although many clinicians have noted that a significant percentage discard their prostheses over time. Advances in available prosthetic componentry have multiplied the options available for amputees with BPI and have increased the percentage of patients who can actuate an active prosthesis. Upper extremity BPI prosthetics arms can be complex to control due to requirements of a series of fine muscle movements.

Flail Arm Static Orthosis
In view of the substantial percentage of BPI amputees who reject prosthetic devices, immobilization of the flail arm is preferred using splints or non-movable orthoses. While management of the flail arm is achieved, muscle atrophy and other comorbidities often result from lack of use.

Myoelectric orthoses
A commercially available myoelectric elbow-wrist-hand orthosis (myoelectric EWHO) is the MyoPro Motion-G from Myomo, Inc. The device is custom fabricated and is designed to be used in the home to increase functional ADLs by providing the user with intention driven, myoelectric elbow and hand movement and manual wrist articulation. Not all hemiparetic individuals with brachial plexus injury are candidates. The general inclusion criteria are:

- Inability to use affected arm(s) functionally, inability to open/close hand
- Minimum of trace MMT (1/5) in Biceps and/or Triceps (i.e. good volitional EMG signal)
- Full passive range of motion in elbow, wrist and fingers
- Intact cognition (mini-mental score > 20)
- Good caregiver/family support
- Highly motivated
- Active shoulder flexion of at least 30-40 degrees or shoulder abduction of at least 20 degree

The MyoPro Myoelectric EWHO can help users perform ADLs and promote independence.
Clinical Considerations

Treatment approaches and outcomes for BPI with disability can be qualitatively assessed across several dimensions including increased independence, a return to work, the ability to perform ADLs, preventing overuse of unaffected side and a reduction in muscle atrophy. These are summarized in Table 2.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Increase Independence</th>
<th>Return to Work</th>
<th>Perform ADLs</th>
<th>Preventing Overuse of Unaffected Side</th>
<th>Reduce Muscle Atrophy</th>
<th>TOTAL SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rehabilitation</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>9</td>
</tr>
<tr>
<td>Amputation w/Prostheses</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>15</td>
</tr>
<tr>
<td>Static Orthosis</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>9</td>
</tr>
<tr>
<td>Myoelectric EWHO</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>23</td>
</tr>
</tbody>
</table>

Scale: • Highly effective (5) • Moderately effective (3) • Not effective (1)

A myoelectric EWHO can be an effective treatment pathway since the device will support the weakened arm and range the elbow, wrist and hand through user intention. Clinically, this enables the performance of goal driven ADLs in the therapy clinic and home and may help to avoid overuse of the unaffected arm while reducing muscle atrophy. This device may also contribute to overall well being by enabling the user to function more independently with the ability to perform functional tasks related to feeding, dressing and hygiene. By providing a numerical value to rate each of the three levels of effectiveness it is possible to quantify an overall clinical value for each treatment type.

Economic Considerations

Brachial plexus injury brings with it non-trivial costs associated with initial treatment and post injury care. For those injuries that require surgical intervention including neurolysis, nerve grafting and neurotization, the total cost (including hospital fees) can range from $20,000 - 40,000 depending upon the complexity of the repair. Published rehabilitation cost data for stroke can be used as a proxy for BPI as the services provided have overlapping similarities. Annual rehabilitation costs average $17,000 annually. Surgical costs associate with amputation can range from $20,000-60,000 ($40,000 avg) while the average cost for a post amputation myoelectric prosthetic arm is $60,000. Static orthoses average $1,200 while a myoelectric EWHO average cost is in line with that of a myoelectric prosthetic.

Figure 2 summarizes average cost associated with BPI over a 5 year period with various treatment strategies. Several treatments are often utilized simultaneously (rehabilitation and therapy is common over a five year period to both a prosthetic and static orthosis while a myoelectric EWHO user does not require long term therapy).

Post Surgical Treatment for BPI
Treatment costs should be considered in the context of the long term benefit they can provide (Table 1). A cost benefit examination shown in Figure 3 indicates that a myoelectric EWHO can offer a lower cost, post surgical treatment solution with greater clinical value than other prescription treatments.

**Conclusion**

Traumatic brachial plexus injury resulting from motor vehicle accidents results in approximately 10,000 cases of hemiparesis annually despite surgical intervention. Post surgical options include amputation with prosthesis, continued rehabilitation, fitting of a static orthosis to control a flailing arm and provision of a myoelectric EWHO to provide functional capability and continuous ranging of the upper limb. A comparison across all treatments which assesses clinical and economic value was performed. This comparison indicated that a myoelectric EWHO can offer significant clinical value as it can help the BPI patient perform functional tasks and other ADLs that the other treatments could only partially provide or not provide at all. From an economic standpoint, the myoelectric EWHO demonstrated an overall lower five year cost than other treatments. The cost/benefit associated with the myoelectric EWHO was substantially lower than that associated with other post surgical treatments for BPI.

A myoelectric EWHO can be an effective treatment pathway as the device will support the weakened arm and range the elbow, wrist and hand through user intention. Clinically, this enables the performance of goal driven ADLs in therapy clinic and home and may help to avoid overuse of the unaffected arm.

Myoelectric Elbow-Wrist-Hand Orthosis
References