CONSIDERATIONS FOR PROSTHETIC MANAGEMENT OF ELECTRIVE UPPER LIMB AMPUTATION FOLLOWING BRACHIAL PLEXOPATHY INJURY WITH AN ILLUSTRATIVE CASE STUDY

Branden Petersen CP LP[1], Phillip M. Stevens Med, CPO[1,2]

[1]*Upper Limb Prosthetics Program, Hanger Clinic, San Antonio TX, USA*

[2]*Department of Clinical and Scientific Affairs, Hanger Clinic, Austin TX, USA*

ABSTRACT

Most major upper limb amputations result from trauma. Occasionally, these traumatic injuries include localized inury to the nerves of the brachial plexus. Patients may seek elective amputation following severe brachial plexus injury (BPI) [1]. The evaluation and development of a prosthetic treatment plan for this cohort often involves surgical considerations prior to prosthetic intervention. This paper will review the types of injuries that can be sustained to the brachial plexus nerve complex as well as surgical options associated with brachial plexopathy cases. A representative case study will document the surgical and prosthetic considerations of an individual that was involved in a motor vehicle accident that left him with a flail upper limb secondary to BPI. For this case presentation long term follow-up, patient perceptions and functionality will be discussed. .

INTRODUCTION

Brachial plexus nerve injuries can have devastating consequences to an individual's overall functionality and quality of life [2]. These significant injuries can lead to the inability to return to premorbid occupations and activities. The deficits associated with BPI may be partial or full and can often require months to years to fully realize the full possibilities of functional return [3,4]. This realization of requires the consideration of critical surgical timeframes which are often unknown or neglected, undermining long term outcomes for those with BPI cohort [5].

Patients may live with their flail limbs for years, at times supported and protected in various bracing systems. Over time, gravitational forces acting on the neurologically impaired shoulder muscles and glenohumeral joint may cause the limb to sublux. In such cases the supporting musculature and ligaments are no longer sufficient to maintain the humeral head in the glenoid fossa. In addition, without protective sensation, this cohort can sustain severe injury to their limb without their immediate awareness. In many cases discussions of elective amputations are driven by continued inadvertent injury to the flail and insensate hand and limb. Elective amputations should not be considered a failure but an opportunity for reconstruction [6,7]. Collective effort from the patient, patient's family, surgeon, rehabilitation physician, prosthetist, occupational and physical therapists will be key in developing the best rehabilitation plan.

BPI TYPE AND SEVERITY

The type and severity of a BPI are a function of the mechanism, extent and location of the injury. *Nerve root avulsion* injuries occur when the nerve root is torn from the spinal cord and cannot be surgically repaired. As the name implies, a *nerve stretch injury* results from a mild stretch of the nerve that may allow some functional return over time. In such injuries it is generally accepted to receive occupational/ physical therapy and allow time for functional return. *Nerve rupture* represent a more forceful nerve stretch injury that may result in partial or full nerve tears. Such ruptures may be repaired surgically depending on the location of the injury.

Depending on the mechanism of injury, various portions of the brachial plexus can result in different palsy presentations. These include upper trunk, lower trunk, and pan nerve injuries, each with specific clinical presentations. *Upper trunk palsy* of the brachial plexus is often the result of the arm being pulled down while the head is forcefully pushed to the opposite side of the arm involved [8]. Such injuries generally results in muscle weakness around the shoulder joint as well as elbow positioning capabilities, with compromise to the deltoid, rotator cuff, and biceps musculature. *Lower trunk palsy* can result from injuries where the arm is forcefully pulled upward. These injuries will generally result in functional loss at the hand of the affected extremity, with claw-like hand deformities commonly occurring. *Pan palsy* is when both upper and lower trunks are injured resulting in complete paralysis of the musculature around the shoulder, elbow and hand. This is often referred to as flail limb.

BPI TREATMENT APPROACHES

There are several treatment approaches that can be considered when the nerves of the brachial plexus nerve are injured. Viable options depend on the where the nerves were injured as well as the extent of the associated nerve damage. They include nerve repairs, nerve grafts, nerve transfers, tendon and muscle transfers, and joint arthrodeses.

Nerve repair can be done to surgically restore the cut ends of nerves. These can assist in stabilizing joints, restoring elbow functionality and a sensible hand following nerve injury [9]. *Nerve grafting* occurs when a healthy nerve from another part of the body is used to replace a missing or damaged nerve. *Nerve transfers* from one muscle to another can occur to provide alternate innervation to a major muscle group when the primary innervation has been injured. *Tendon and muscle transfers* can be performed to address significant functional deficits by restoring key joint movements.

When surgical reconstructive efforts fail to yield a functional hand or elbow, some patients may wish to pursue elective amputation of the flail limb. This is often coupled with glenohumeral arthrodesis, and is performed when there is adequate muscle strength in the trapezius, levator scapulae, rhomboids, and serratus anterior [10,11]. The generally accepted position of the glenohumeral joint is in 30 degrees flexion, 30 degrees abduction, and 30 degrees internal rotation [12,13]. In general, a 4 month postoperative period is required for fusion occur [13].

While there are many different references to these fusion angles discussed the literature, the guiding principles are to pace the residual limb in enough glenohumeral joint abduction to clear the axilla as well as allow the patients to perform axillary hygiene, to place the residual limb in enough forward glenohumeral flexion to bring the arm and terminal device of the prosthesis toward the midline for functional activities and minimize subluxation of the glenohumeral joint

CASE STUDY

Written informed consent was obtained from the patient prior to his inclusion in this paper. In 2012 our case study of a 22 year old male was involved in a snowmobiling accident that left him with nerve avulsion injuries to his the brachial plexus resulting in a flail limb. This individual worked on a family dairy farm and expressed an interest in returning to his family business. He described himself as a “hands on” individual desiring to return to as much functionality as possible. The patient’s contralateral scapular range of motion was with in normal range, and contralateral scapular strength was sufficiently strong to operate cable operated components. The medical team discussed several options with the patient, ultimately choosing shoulder joint arthrodesis coupled with an elective elbow disarticulation as the best option to restore functionality for his lifestyle (Figure 1 and 2).

Figure 1: Initial limb following should fusion in 2012

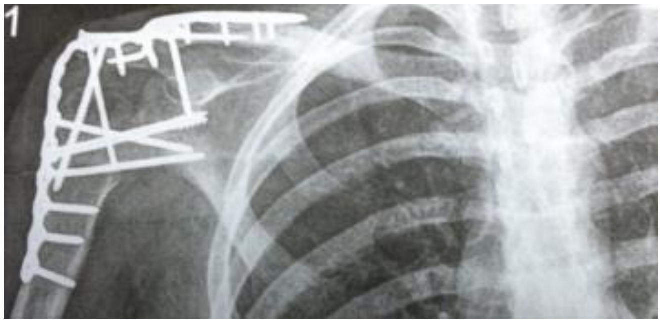

Figure 2: Internal hardware in initial shoulder fusion

Following the elective surgical procedures and prosthetic fitting the patient expressed satisfaction with his ability to move his arm again (Figure 3). He was able to demonstrate full functionality of the prosthesis in both elbow control and terminal device function. He reported regular use of his cable operated device on his family farm daily running equipment, carrying and manipulating objects. Regular clinic visits for frequent repairs to his device support the patient’s reports of sustained regular use of the device for heavy duty activities on his farm.

Figure 3: Initial body powered prosthesis with work hook, external locking elbow joints and chest strap.

At 8 years post injury, our case demonstrated several anatomic characteristics common to sustained severe BPI. (Figure 4). For significant nerve root avulsion injuries these include atrophy of the deltoids, infraspinatus, supraspinatus, biceps, and triceps muscles. Bony anatomy becomes very prominent, including the spine of the scapula, acromion, and coracoid process. The lack of protective sensation, diminished muscular padding, and significant prominence of bony anatomy creates significant design consideration when designing a prosthetic socket for individuals with brachial plexopathies.

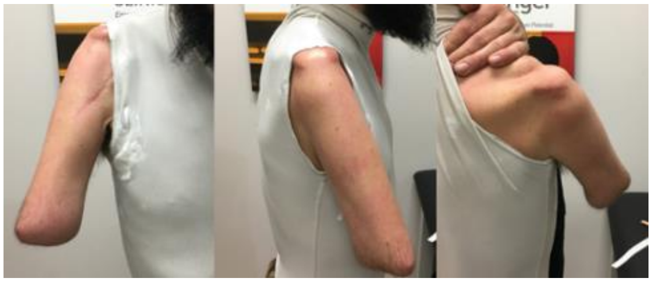

Figure 4: Limb presentation 8 years post injury, elective amputation and shoulder arthrodesis characterized by soft tissue atrophy and significant bony prominence around the shoulder.

In 2018 the internal fixation hardware from the arthrodesis was removed from the patient's limb due to harness pressures and prosthesis usage on his highly atrophied limb (Figure 5). The surgeon evaluated and determined that the glenohumeral joint had fused well enough to remove most of the internal hardware and screws.

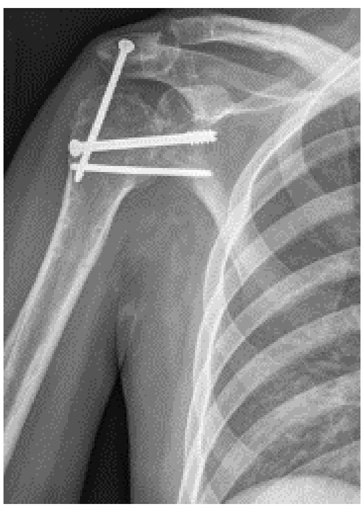

Figure 5: Subsequent removal of most internal fixation hardware with adequate bony fusion

In 2020 the patient continues to work on his family farm as well as running his own business offering handy man services. He is currently married and has children. He continues to wear his prosthesis every day full time for all of his home and work activities (Figure 6). He continues to need repairs to his prosthesis indicating that indeed he uses the device daily and in a heavy duty capacity.

Figure 6: Current body-powered prosthesis

CONCLUSION

The prosthetic management of individuals with brachial plexopathies can be challenging and should involve several medical professional to develop the best treatment plan with optimum outcomes. Brachial plexus surgical interventions can improve the overall functionality when considering prosthetic intervention. In this particular case study the shoulder arthrodesis produced a very functional outcome for almost a decade. The patient actively utilizes his limb and prosthesis for most of his activities.

This case study does not reflect every patient's particular situation. This patient is a young, active male that has excellent scapular strength and range of motion. In some BPI cases patients may not be able to generate the required force and excursion requirements to operate a body powered systems and require externally powered components to create the desired functionality (14). Patients will require individual evaluation to determine their functional capabilities following BPI so that an appropriate prosthetic treatment plan can be created.

These cases present many challenges to the rehabilitation team. Decisive surgical decision making can create a limb that is better reconstructed for improved prosthetic functionality.

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