Challenges in restoring prehension following severe brachial plexus injury.

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Background

Severe brachial plexus injury(BPI) from trauma is an uncommon but devastating injury suffered predominantly by young working-age men involving motor cycles or cars (1,2). The literature on this topic contains many references to other causes of brachial plexus injury, including obstetric and radiation in particular, but I wish to concentrate on the trauma induced variety of severe BPI (i.e. pan-plexus). The Prince of Wales Hospital Rehabilitation Dept, is recognised for its expertise in upper limb amputee management and prosthetic fitting and training, and we have become a referral centre for BPI cases all of whom are treated by the Specialist BPI Reconstructive Surgical Unit in my State of New South Wales (Australia). While Rehabilitation, by its nature, involves an holistic multidisciplinary approach to the wide variety of problems resulting from such a devastating injury, it became clear that our expertise in providing prehension might add significant value to the functional outcomes sought by our Surgical colleagues.

According to 2 large reported series from Brazil and the USA, in those requiring surgical reconstruction, half have panplexus injuries, 30-40% have upper plexus injuries, and a small minority have lower plexus injuries (1,2). Our experience at POWH concurs with these reports.

A myriad of surgical techniques are used to attempt to restore function to the arm - decompression and repair, nerve transfers, free functional muscle transfers, tendon transfers, joint arthrodesis, rotation osteotomy, and more recently, targeted muscle reinnervation (3). The literature is not clear on which technique is superior in any particular case, and the variability of approaches reported makes this hardly surprising. What is clear is that the surgery should only be carried out be experts and the situation in NSW is precisely that.

Rehabilitation is multidisciplinary, person-centred and goal oriented. It seeks to optimise function - physical, functional, psycho-social and vocational. In doing so it seeks to optimise quality of life in persons who have suffered disability from injury (or illness). In treating a patient with BPI this may include: to maintain joint range of motion, protect the flail limb from secondary injury, address pain management, provide psychological support, teach personal care independence, and provide vocational support to return to their existing employment or retrain.

In the early years of my career at another teaching hospital I received occasional referrals of such patients, usually from their General Practitioners, often many years after their original injury and treatment. Typically I found them seeking help with intractable neuropathic pain, carrying a flail upper limb supported via a variety of methods including nothing, hand in pocket, collar and cuff, or triangular sling. Invariably they had severe gleno-humeral subluxation. They had often undergone surgical repair years earlier but seemed to have no understanding of what that had been intended to achieve, and whether it had been successful or not. They had rarely returned to work, and often asked if I could help them to obtain an amputation believing (or at least hoping) it might help their pain. Of course, the surgical options are complex, often requiring multiple procedures, and the recovery times e.g. after nerve transfers, can be much longer than patients anticipate, leading to a loss of engagement, and uncertainty about achievable outcomes. I observed that what rehabilitation had occurred, was generally predominantly physiotherapy delivered by Specialty Hand physiotherapists. The patients seemed not to understand that there was generally no expectation that hand function could be recovered.

Restoring prehension

In the past prehension was addressed through body powered(BP) or externally powered(EP) orthoses or combined gleno-humeral arthrodesis and transhumeral amputation (THA) and BP or

EP prostheses. Many examples are readily found in old textbooks often from Specialty centres in the UK like Roehampton and Stanmore. My 1980s training had taught me that 1. None of these orthoses were used, 2. That THA might be performed for a flail arm which was suffering from repeated trauma but it should never be contemplated early and to beware of the patient believing it would help their pain, and 3. THA prostheses fitted after THA were rarely used as function was so poor. In Australia these approaches have largely fallen out of favour.

Our recent experience confirms that The RNSH BPI surgical unit in Sydney has a reliable expectation of providing a stable shoulder with limited abduction/flexion and good biceps function following nerve and or tendon transfers +/- humeral rotation osteotomy. They explicitly state that they have no ability to restore intrinsic hand function though some finger function via tendon transfers or muscle grafts combined with wrist fusion can restore some grasp. What patients lack is fine prehension. I was inspired by Aszman's innovative work combining TMR and Trans Radial Amputation(TRA).

Current approach to restoring prehension

We have since developed an approach which, following surgical reconstruction, involves a patient centred choice between TRA and prosthetic fitting, or exoskeleton, both of which can be activated by auxiliary switching technology if necessary, in the absence of sEMG signals in the arm. I will present examples of each from cases which we have treated at The Prince of Wales Hospital in Sydney Australia.

Exoskeleton

The exoskeleton is the option for those who do not want amputation. This is the majority of our cohort and tends to be the younger aged. Preserving passive hand function is important in this group. The rigid exoskeleton fitted (Myopro) required a patient who could tolerate a bulky heavy unit suspended from a shoulder saddle resting on their wasted shoulder girdle. The hand module demanded a flexible wrist and hand, with a fully preserved thumb web space or the risk of trauma was significant. The exoskeleton utilised the reinnervated biceps sEMG signal to provide enhanced elbow flexion power. The hand close/open relied upon a single site switching approach using sEMG e.g. rhomboids, or a linear transducer or alternative. The decision was based on a team discussion between patient, Occupational Therapist and Orthotist/Prosthetist, and testing of various options for the most reliable. Fitting was difficult and successful positioning of the electrode could only be achieved by an assistant. The patient could successfully open and close the hand reliably but usage in functional tasks was not achieved.

Trans Radial Amputation (TRA) and prosthetic fitting

In those willing to undergo TRA, a prosthetic socket was fitted and initially supported by attachment to the Wilmer BPI orthosis. A myoelectric TD was added and single site activation via a linear transducer attached to a chest strap was reliably demonstrated. Over time, as the biceps became stronger, the Wilmer support was removed. Reliable holding of an object in the Prosthetic TD supports functional task performance but weak shoulder flexion limits the range of tasks.

Decision pathway

1. Financial options known
2. Pt preferences re amputation understood.
3. Pt beliefs about pain relief recognised and cautioned.
4. Psychological evaluation (esp re amputation)
5. Precluding injuries excluded e.g. severe TBI, skeletal injuries (harness tolerance and motion)
6. Surgical plan for G-H stability & Elbow Flexion reinnervation agreed and/or underway.
7. Shoulder and elbow function achieved.
8. TRA amputation undertaken and prosthesis fitted OR exoskeleton trialled.

Future plans

1. A more suitable exoskeleton is needed. The soft orthotic glove type exoskeleton appeals as a better alternative, although none of the existing commercially available models have proved to be suitable for the needs of this patient group.
2. Alternative activation systems are needed. The limited sEMG signals available suggests that linear transducers will be relied upon despite their own limitations. BCI technology may ultimately solve this problem.

1. Faglioni et al 2013
2. Kaiser et al, Neurosurgical Review, 2020-04, Vol 43(2). P442-453.
3. Hruby et al, J Neurosurgery, Vol 127, issue 5, 2017, p.1163-1171.