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OCCUPATIONAL THERAPY OUTCOMES WITH TARGETED HYPER-REINNERVATION NERVE TRANSFER SURGERY : TWO CASE STUDIES

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INTRODUCTION

The control of prostheses, both externally powered and body powered, increases in complexity with higher levels of amputation. The externally powered prosthesis has a limited number of options for controlling multiple joints myo-electrically. Some method is necessary to switch control between functions (ie: elbow and hand). Targeted hyper-reinnervation nerve transfer surgery has the potential to greatly improve control of the electric prosthesis for the above elbow and shoulder disarticulation subjects by increasing the number of control options available.

When the limb is lost the Brachial Plexus typically remains intact. The nerve supply to the missing limb is viable and connected to the motor cortex, but the motor end points served are gone. In nerve transfer surgery, the peripheral nerve is relocated to an area of denervated muscle tissue in the residual limb –a muscle that no longer moves the missing limb. Hyper-reinnervation occurs resulting in an area of say the Biceps, being controlled by the Median Nerve (in the intact limb, the Median Nerve supplied finger and wrist flexors). A muscle contraction occurs in the graft area of the Biceps when the subject attempts to close his hand. A myo-control site is added if the subject can isolate the contraction from that of the Biceps muscle served by the Musculocutaneous Nerve distribution.

SUBJECT #1

The first experimental surgical procedure was preformed on a gentleman with bilateral shoulder disarticulation. The successful nerve transfers on his non-dominant side included Musculocutaneous, Radial and Median Nerves transferred to denervated areas of the Pectoralis Major muscle. The Ulnar Nerve transfer to the relocated Pectoralis Minor muscle was unsuccessful. The Median Nerve transfer ultimately resulted in two distinct areas of re-innervation which corresponded to "hand close" and "hand open" (probably thumb abduction). The area of Musculocutaneous re-innervation corresponded to elbow flexion and the Radial Nerve distribution corresponded to wrist extension/elbow extension.

The subject had previously been fitted and trained with a body powered prosthesis on his dominant right side and an externally powered hybrid prosthesis using FSR's to control the elbow and hand on the left. Training post-operatively consisted of isolating contractions corresponding to the nerve transfers. Myoelectric testing ultimately revealed the following control sites: elbow flexion (Musculocutaneous Nerve); hand close (Median Nerve 1); hand open (Median Nerve 2); elbow extension (Radial Nerve). The subject quickly learned to control the prosthesis once electrodes were installed in the socket and necessary adjustments were made. He managed simultaneous myoelectric control of his elbow and hand that physiologically corresponded to his intention.

OUTCOMES

The outcome measures used were chosen for their ability to detect the differences between the hybrid control system and the experimental prosthesis.

The Box and Blocks[1]

The Box and Blocks is a grasp and release test requiring lifting 1" wooden blocks from a well on the side of the arm being tested, over a divider, to deposit into another well on the contralateral side. The sequence is: position the terminal device in the same side box (extended elbow), grasp a block, flex elbow, extend elbow, release block, flex elbow, extend elbow, grasp etc. The standardized test measures the number of blocks moved over the barrier in one minute. For our purposes, the subject

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performed the task 3 times and 2 minutes was allowed for each trial. It was anticipated that simultaneous, intuitive control of the elbow and hand would be reflected in the number of blocks moved.

Table 1. Comparison of **Box and Blocks** test for touch pad controlled prosthesis and nerve-muscle graft controlled prosthesis.

	Touch pad control Number of blocks	Myoelectric control Number of blocks
Trial 1	5	10
Trial 2	5	14
Trial 3	7	18
Average	5.7	14

The Clothes Pin Relocaton Task

The Clothes Pin Relocation Task used a standard clothes pin tree commonly found in an occupational therapy clinic for strength and coordination of pinch, forearm rotation and reach. The task was to move three clothes pins from a horizontal bar to a vertical bar. This task required more precise pre-positioning of the terminal device and incorporated wrist rotation, elbow flexion and extension. The task was timed and, as with the Box and Blocks, was repeated three times. Again, it was anticipated that the simultaneous intuitive control of the elbow and hand would enhance pre-positioning, improve the smooth appearance of reach and decrease the amount of time required to perform the task.

Table 2. Comparison of **Clothes Pin Relocation Task** for touch pad controlled prosthesis and nerve-muscle graft controlled prosthesis.

	Touch pad control Time (sec)	Myoelectric control Time (sec)
Trial 1	153	83
Trial 2	137	122
Trial 3	121	99
Average	137	101

Functional Bimanual Tasks

The subject required set up, adaptive equipment, and frequent physical assistance for feeding, upper body dressing, oral/facial hygiene, and telephone communication. He required total assistance for toileting hygiene, lower body dressing (except shoes and boxers) and bathing. He was evaluated and recommended for a foot steering motor vehicle modification. While his ADL status remained unchanged using the experimental prostheses, there was a visible improvement in the quality of movement. He reported that the new experimental arm was much easier to use. He used his prostheses for yard work and during household tasks regularly. The new experimental prosthesis in fact, added some functional advantage. Being easier to use, the subject was more likely to wear it and be engaged in purposeful occupations in and around his home.

SUBJECT #2

The second subject was a gentleman with a unilateral transhumeral amputation on his dominant side. His terminal device of choice was a hand. Prior to the surgery, the subject was independent in all basic and instrumental ADLs using one-handed techniques. The successful nerve transfers

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included the Median Nerve to the denervated Medial Head of the Biceps, and the Distal Radial Nerve to the denervated Brachialis.

The subject had previously been fitted and trained with a myoelectric prosthesis using the Musculocutaneous Nerve (Biceps for elbow flexion and hand close) and the Radial Nerve (Triceps for elbow extension and hand open). Co-contraction of the Biceps and Triceps switched function between the elbow and the terminal device. During the recovery period after surgery, a bump switch was installed to change functions in order to discourage co-contraction and encourage isolating of signals. Myoelectric testing ultimately revealed four control sites that physiologically corresponded to a natural limb for elbow flexion, extension and hand open and close. He was able to simultaneously control both hand and elbow positions. Wrist rotation was via a pull switch mounted in the harness

OUTCOMES

The Box and Blocks and **Clothes Pin Relocation Task**

The outcomes measures used with this subject included those used with the first subject and predictably demonstrated increased speed of performance and improved quality of movement.

Table 3. Comparison of **Box and Block** test for the original myoelectric control prosthesis and nerve-muscle graft controlled prosthesis.

	Original 2 Site Myoelectric Number of blocks	4 Site Myoelectric Control Number of blocks
Trial 1	2	20
Trial 2	4	22
Trial 3	5	35
Average	3.6	25.6

Table 4. Comparison of **Clothes Pin Relocation Task** for the original myoelectric controlled prosthesis and nerve-muscle graft controlled prosthesis

	Original 2 Site Myoelectric Time (sec)	4 Site Myoelectric Control Time (sec)
Trial 1	103	45
Trial 2	110	25
Trial 3	52	32
Average	88.3	34

Bimanual ADL Tasks

In the interest of evaluating the subjects ability to integrate the prosthesis into functional activities, nine bimanual activities were chosen that varied in complexity and allowed the subject to choose how best to use the prosthesis. The tasks were timed, although the subject was not instructed to perform them "as quickly as possible". Each task was performed once during the evaluation.

Table 5. Comparison of the time required to perform bimanual activities

TASK	**Time (sec) (2 Sites)**	**Time (sec) (4 Sites)**
1) Cut food using knife & fork (toast)	90	11

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2) 3 items onto a try & carry (roll of tape, small plastic bowl and a plate)	114	37
3) Put 3 soup cans into a grocery bag with handles	109	35
4) Open a jar of peanut butter (plastic)	14	8
5) Stir with a spoon in a mixing bowl	32	3
6) Open a letter using a tool (letter opener)	21	17
7) Pull on socks	28	28
8) Don and doff and button down LS shirt	116	94
9) Wrap a package	356	97

The first evaluation was administered 7/03 and the second 4/04. It is difficult to assess whether the faster performance is a reflection of nine months experience using an artificial limb or attributable to the experimental procedure and prosthesis.

The Assessment of Motor Process Skills (AMPS)[2,3]

The AMPS is an observational assessment that is used to measure the quality of ADL. Performance is assessed by rating the effort, efficiency, safety and independence of 16 ADL motor and 20 ADL process skill items.

The transhumeral subject scores indicated that there were problems with motor skills that affected the quality or effectiveness of task performance. Though improved at the second evaluation, there continued to be problems. Notable improvement was evidenced in Process Skill scores. At the second evaluation, scoring was above the cutoff, indicating that there were no longer problems in the area of process skills. This was anticipated because of the more direct connection between the motor cortex through the peripheral nerve to produce movement responses in the experimental prosthesis..

The UNB Test of Prosthetic Function[4]

The UNB will be the assessment tool for future research subjects with unilateral amputation. It will replace the ADL Tasks above as a functional assessment. While it is not a timed test, it yields scores for "skill" using the prosthesis and "spontaneity" using the prosthesis. It is anticipated that it will capture the differences between the pre-operative and experimental prosthetic solutions.

CONCLUSION

The targeted hyper-reinnervation nerve transfer surgery has been successful for the 2 subjects discussed here. The functional outcomes for both these experimental prostheses are favorable using the measurements described above, however functional ADL status remains unchanged. Both subjects report that the experimental prosthesis is easier to use than the pre-operative prescription. Further experiments with sensory feedback resulting from cutaneous nerve re-generation is promising. In addition, the development of a six motor artificial arm for the shoulder disarticulation subject has the potential to improve functional ADL status by adding shoulder flexion and humeral rotation giving the subject access to a far larger workspace.

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