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Case Study

Training a Phantom Hand to Move

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Phantom limb pain has been described from different angles for years. Many limb amputees are purported to experience a painful stump, a phantom hand, or phantom pain; all are difficult conditions to treat. The pathophysiology is not completely understood. Sensations in the phantom limb can be described as shooting, cramping, burning and aching and may be intermittent or present all the time. Gender, age of adults, and side of amputation are not recognised as being pertinent. Peripheral, spinal and superspinal mechanisms have been suggested and investigated but without decisive conclusions about the aetiology. A broad range of treatments are offered but without proven results [1].

Keywords: Phantom Limb Pain; Biofeedback; Mirror Therapy; Augmented Reality; Proprioception; Kinesiology.

Characteristics, causes and treatments are described by Flor [2]. Central changes are seen to be a major determinant of phantom limb pain but Flor suggests that peripheral and psychological processes may contribute to it. She writes that many studies show that treatment is ineffective and do not take into account the mechanisms underlying the production of the pain. Listed are 36 pharmacological, surgical, anaesthetic, psychological and other interventions. Recent focus has been on the use of a mirror in a box to superimpose an image of the sound hand onto the stump of the amputated arm. The patient inserts both the sound and amputated arms into the box and is instructed to look at the mirror image of the intact arm which is perceived as an intact image of the amputated hand. Instructions are given to move both hands symmetrically. This procedure allows some participants to regain control over the phantom limb and sometimes to alleviate pain but controlled data is lacking. This visual feedback alters the perception of the amputated limb. Diers [3] calls for more research to identify the causal mechanisms related to mirror treatment, imagined movements or movements of the other hand associated with pain perception.

An alternative treatment has been proposed recently by Catalan [4] who describes the manner in which the muscles in the arm stump send out electrical signals which can be sensed by electrodes on the skin. Complex algorithms translate these electrical signals into arm movements. On a computer screen the patient was shown an arm that is superimposed onto his stump and was able to control the movements of the arm using his own neural commands in real time. This method is called "augmented reality" and differs from mirror therapy because the signals are retrieved from the arm stump, and thus the affected arm is in charge.

Biofeedback techniques use auditory signals to give information about muscle activity and skin temperature that are retrieved from the stump. Schwartz [5] monitored the stump region using feedback to the patient to raise the skin temperature. At the same time he monitored the electromyograph. Temperature increased by 2 degrees and muscle activity was reduced; the phantom fingers opened from being a fist. His rationale for relaxation and thermal biofeedback was that increased blood flow to the amputated limb can reduce the phantom pain.

The work of Schwarz with temperature feedback and of Catalan with electrodes attached to the muscles in the residual stump directs attention more directly to the stump itself. After amputation the surgeon sutures residual muscle ends with the purpose of forming a well-shaped stump on which to fit prosthesis. Muscles are not necessarily aligned anatomically. In the functioning hand muscles work in patterns; put simply

the agonists initiate a joint movement, the antagonists relax to allow this joint movement and the fixators steady the origin of the working muscles. It is probable that sensations within these muscles alter when there is no proprioceptive feedback from the amputated joints that would have separated their actions; now agonists and antagonists may be sutured together.

In a survey with 400 respondents, people with phantom limb pain rated their caregivers' knowledge of phantom limb pain as being lower than their own. A call was made for better information about the pathophysiology and treatment to be made available, not only for the patients, but also for the caregivers [6]

In response, in this paper describes the successful treatment of a person with phantom limb pain, using electromyographic biofeedback to re-train the residual muscles associated with hand movement.

A Single Case Study

Introduction

A man aged 30 had suffered an industrial accident in which a ress had crushed his left hand. His left forearm was amputated surgically six inches distal to the olecranon process. The man appeared to rehabilitate well. The wound healed normally and he mastered quickly the working of prosthesis. He returned to his former job three months after his accident.

However, he was disturbed greatly by the sensation in the phantom, "thumb screws" were pushing though his phantom hand. He was referred to a Pain Clinic and was prescribed pharmaceuticals and from there was referred to physical therapists for transcutaneous nerve stimulation (TENS), to a psychologist for hypnotism and counselling, to an acupuncturist and to various other practitioners. He had no relief from the pain and the "thumb screw" sensation; this was interfering in both his work and his home situations. His referral was for "biofeedback" with no directions.

Clinical Situation

On examination he was a normal young man with prosthesis on his left hand. The stump had healed well, was a good colour and was not painful. The EMG biofeedback equipment was demonstrated to him and both general relaxation training with electrodes recording forehead activity and specific muscle training were explained to him. He understood readily. Once-weekly training sessions started with general relaxation followed by specific muscle training.

This man's wife came with him on two visits. She had not been included in previous treatment situations. She had experienced his distress with the pain and the disappointment that the phantom pain had not been alleviated by other interventions. Both had wondered if a missing hand in pain could be a sign of mental illness. She confronted her husband about his lack of any emotional reaction to the loss of his hand. Her presence was helpful as it sounded bizarre to say that her husband was going to learn to move a hand that was not there! She needed to know what was happening and to be able to trust this treatment situation.

Specific Muscle Training

The neck and shoulder muscles were tight on palpation so electrodes were placed on the trapezii. The man was able to reduce the tone emitted by the biofeedback machine and he reported that his phantom felt warmer.

Electrodes were placed on the biceps/triceps bellies of the left arm. The tone emitted was high and he was instructed to relax and lower the tone. He was lying down in a relaxed position and was instructed to indicate with his healthy right arm the position of his phantom left hand and fingers. Other electrode positions were tried.

Monitoring the flexor tendon only of the left arm gave a "breakthough" result. He showed with his sound hand that he could move the phantom hand sideways and that this loosened the phantom fingers. The man reported at the end of the session that his phantom hand was better than it had ever felt.

Localised monitoring of various forearm muscles continued. Two sessions later the man reported that he could get the phantom hand to where he felt a sensation of "cotton wool" as if it were lying on a lambskin. He said that he repeated this in bed at night and could get a sensation of a phantom hand instead of a phantom pain. He could squeeze his hand but he could not open it. He said that he could move the hand sideways and swivel it. He said that he felt as if he were contracting the residual muscles of his forearm.

In the following session the man reported that both hands were comfortable; then he suddenly recalled the flash of fear at the moment of his injury as the press was dropping. He recalled electrodes being placed on his chest and then waiting for the jolt. He was grey and shaking; this moment of recall and the shock being experienced were unexpected. With a cup of black coffee, a warm blanket and quiet talking he recovered.

For a few weeks depression followed this acute recall. The man was expressing his anger about the whole experience, the loss of his hand and the loss of abilities. His wife's earlier confrontation that he had denied an emotional reaction to his loss had been appropriate. This recall situation seemed to have been cathartic. Also reiterated was his quick adaptation to the hook prosthesis, because he had not wanted anyone to see his stump. Hence, he had not developed any perception of the stump. He was instructed to take the prosthesis off at home to get used to seeing the stump, touching it and finding out what he could do with it, like carrying objects against his chest.

In his twelfth and final session he arrived saying that he was

managing his phantom hand to his own satisfaction. He would take moments at work to release the phantom, in much the same way as typists with overuse syndromes are taught to take micro-pauses when working on their keyboards. He was confident that, with concentration, he could move the phantom hand into the "cotton wool" position in most situations. He took his mind off the pain and concentrated on other things. If there were stabs of pain he did not worry but walked outside for a few minutes. As well he was very happy to say that he had met two leg amputees at his golf club and the three men were practising playing golf together. Discharge was by mutual agreement.

Discussion

This case study indicates the flexibility needed within the clinician, requiring the ability to understand muscle action, movement and body awareness. A relationship, a crisis and depression were encountered. The complexity of clinical situations may need more recognition.

When a person moves a limb, muscles activate to do the actual task; other muscles activate to stabilise the origin of the working muscles. When the task is complete proprioception leads to the relaxation of the working and the fixator muscles. In an amputee the pattern is similar; as the prosthesis it used to grip an object the forearm muscles are activated; however, proprioception is disrupted as there is no real hand to send the message that the task is complete. It seems that the forearm muscles are in a continual state of activation, perhaps spasm, and are fatigued. Schwartz (op cit) showed that increased blood flow in the stump was an effective treatment and, of course, working muscles require an adequate blood supply but muscles in spasm reduce blood flow.

Biofeedback techniques, like skin temperature and muscle action (EMG) are not intrusive. Signals of temperature and muscle activity are received directly from the stump, and are not information received from a surrogate source (the other arm through a reflection). Direct information can be comprehended and assimilated readily. However, the training with visual feedback (mirror or augmented reality) and with auditory biofeedback (skin temperature or electromyograph) have a common property; they are all replacing proprioception which was lost when the wrist and the smaller joints and tendons of the hs and were destroyed.

Proprioception is defined as the sense of the relative position of neighbouring parts of the body and the strength of the effort being employed in movement [7]. In humans it is provided by proprioceptors which are muscle spindles in skeletal striated muscles, the Golgi organ in tendons and from the fibrous capsules of joints. The cerebellum is largely responsible for the coordination of the unconscious aspects of proprioception [8]. The endings of muscle spindles respond to the size of the muscle length change; they contribute both to the sense of limb position and movement. Cutaneous receptors provide information about joint position and movement. A joint position sense, a key component of proprioception, is the ability to perceive the position of a joint without the aid of vision [9].

When a hand is amputated many muscles and tendons are destroyed, some are shortened, and some are sutured to other muscles whose original functions were opposing. There are many joints in the wrist and the hand which have been destroyed. Methods of re-training and supplementing proprioception are essential.

Conclusions

The breadth of the clinician's role has been described. Increased communication between the researcher and the clinician could increase comprehension and resolution through a combination of therapies that develop a focus on the total disability of phantom limb pain.

Proprioception is a key component of the methods of mirror and augmented reality methods using visual feedback, and of the two methods recording biological measures and using auditory feedback. Proprioception is a primary focus for future research that is aiming to ameliorate phantom limb pain.

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