Upper limb electrical stimulation exercises.

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In this article we wish to document some of the electrical stimulation techniques we use for the upper limb, primarily with hemiplegics, in the Salisbury FES clinic. There is a growing body evidence for the effectiveness of the use of electrical stimulation in the upper limb but it is not the intention that it is reviewed here. Instead, we refer you to the excellent recent review articles by John Chae et. al[1, 2] and the comprehensive review in the Rancho Book.[3] The Rancho Book also includes a very useful description of electrical stimulation techniques and treatment regimes.

Electrical stimulation can be used for the following purposes:

- For strengthening weak muscle
  As with any repetitive exercise, muscle bulk and strength will be increased. This will also lead to greater capillary density and therefore improved local blood supply and tissue condition.

- For increasing ROM
  Electrical stimulation can provide regular stretching, similar to passive stretching but performed over a more extended period. Be careful that some joints are not over stretched while trying to increase the range of others. For example it is sometimes useful to use MCP joint extension blocking splint to protect the MCP joints and improve the effectiveness of the action on the PIP and DIP joints. Another example might be the use of wrist flexion blocking splints when exercising finger flexors. Care must be taken that repetitive movement does not lead to skin marking.

- For enhancing the effect of botulinum toxin.
  This can be done in two ways. Firstly, it has been shown that botulinum toxin is more easily taken up by the receptors if the muscle is active. This can be achieved by direct stimulation of the target muscle or by exercise of the antagonist muscle leading to stretch reflexes in the target muscle. Botulinum take up occurs over the first two days following injection. The second method is to use electrical stimulation to enhance relearning of movement in the three month window before spastic tone returns.

- For relaxation of spastic muscles
  When a muscle contracts, activity in the muscle spindles is relayed via inhibitory interneurones to the α motor neurones of the antagonist muscle reducing its activity. This is known as reciprocal inhibition and its effect can be exploited by stimulating the antagonist muscle to the spastic muscle. As the Ia afferents, the nerves that pass from the muscle spindles to the spinal cord and inhibitory interneurones, are of large diameter, they require only a low level of stimulation to excite them so will always be excited even if the stimulation produces only a small contraction. Consequently stimulation will have a direct effect as well as via mechanical changes of tension in the muscle itself. Commonly, after exercising the antagonists to the spastic muscles there is a period of reduced spasticity which can last from minutes to hours. By repetition of these exercises the synaptic connections can be strengthened via long term potentiation and spasticity reduced for an extended time. However, most studies have shown that the treatment needs to be maintained long term for continuing therapeutic benefit.

  Stimulation of the spastic muscles themselves have also been shown to have a relaxing effect. This is thought to be due to antidromic stimulation of the α motor neurones, that is stimulation that course a nerve impulse to travel up the nerve towards the spinal cord, acting upon Renshaw interneurones. The Renshaw interneurones has an inhibitory effect on the α motor neurones, reducing its excitability and therefore reducing the spastic activity. Reciprocal stimulation of agonist and antagonist pairs can be an effective way of reducing spasticity. However, there are some concerns that by strengthening spastic muscles, spasticity may be stronger when it returns. Generally, we restrict stimulation to the antagonist muscles unless strengthening and retraining of the spastic muscle is also a clinical goal.

- For re-education of movement
  When a muscle contraction is produced by electrical stimulation, a whole range of sensory inputs are produced. This includes the direct sensation from the stimulation and the proporeceptive feedback from joints, tendons, muscles and mechanoreceptors. There will also be antidromic stimulation of α and γ motor neurones. All this will cause a significant increase in activity along the remaining pathways to the cortex and other centres, stimulating the production of new synaptic connections. Excitation of the Ia afferents will have the same effect as activating muscle spindles by stretching them, causing excitation of the α motor neurone to cause a muscle contraction. However, this increased level of α motor neurone excitation will also make it easier for weak descending inputs to activate the motor neurone and therefore produce a voluntary contraction. It is good practice to ask the patient to try and assist the action of the stimulator with voluntary movement to enhance this effect. However, this voluntary effort must not be so great that it cause a rise in spasticity and inhibits the desired movement.

- To improve sensory awareness
  As described above, the sensory input will encourage new synaptic connections in the sensory cortex and increase sensory awareness. Many anecdotal comments have been reported of improved sensory ability and this has been illustrated by improvements in 2 point discrimination and reduction of neglect syndrome.

- To reduce pain associated with spasticity or shoulder subluxation.
  By reducing spasticity and improving the resting position of joints, pain can be reduces or eliminated. The stimulation itself will also have an effect similar to TENS, as the stimulation waveforms are similar chiefly differing in only intensity.

To be effective the exercises should be performed on a regular basis, ideally daily or twice daily. As ours is an outpatient clinic, patients take stimulators home. Exercise times commence for only 5 minutes sessions at a time, increasing to up to 30 hour over a period of one month. Regular follow up is required to ensure the exercises are performed correctly. It is not uncommon that electrode positions will need adjusting as patients progress or simply because they have forgotten the correct positions. For this reason, patient and carer education is very important. We supply written instructions, electrode position diagrams or digital photographs and we mark electrode positions with indelible marker pens. To assess their progress we use the Jebsen-Taylor hand function test or the Action Research Arm Function Test. We also record active and passive ROM, Ashworth and 2 point discrimination.

Where spasticity is present it is important that a stimulator with a long rising ramp of at least 2 seconds is used. This is because a sudden contraction will rapidly stretch the antagonist muscle and induce a stretch reflex resulting in a reduced ROM. A long ramp will also be more comfortable which in its self may reduce tone levels. We have not found that the stimulation frequency is very critical in practice but generally 40 Hz produces a smooth and comfortable contraction. All exercises are performed using cyclical stimulation with stimulation on times of 8 –10 seconds followed by a rest period of the same time (Microstim modes 6 or 7). A standard pulse width of 300µs is fine but it is sometimes useful if using the Odstock 4 Channel Exercise Stimulator to reduce the pulse width to 100µs as this allows finer control of the amplitude controls.

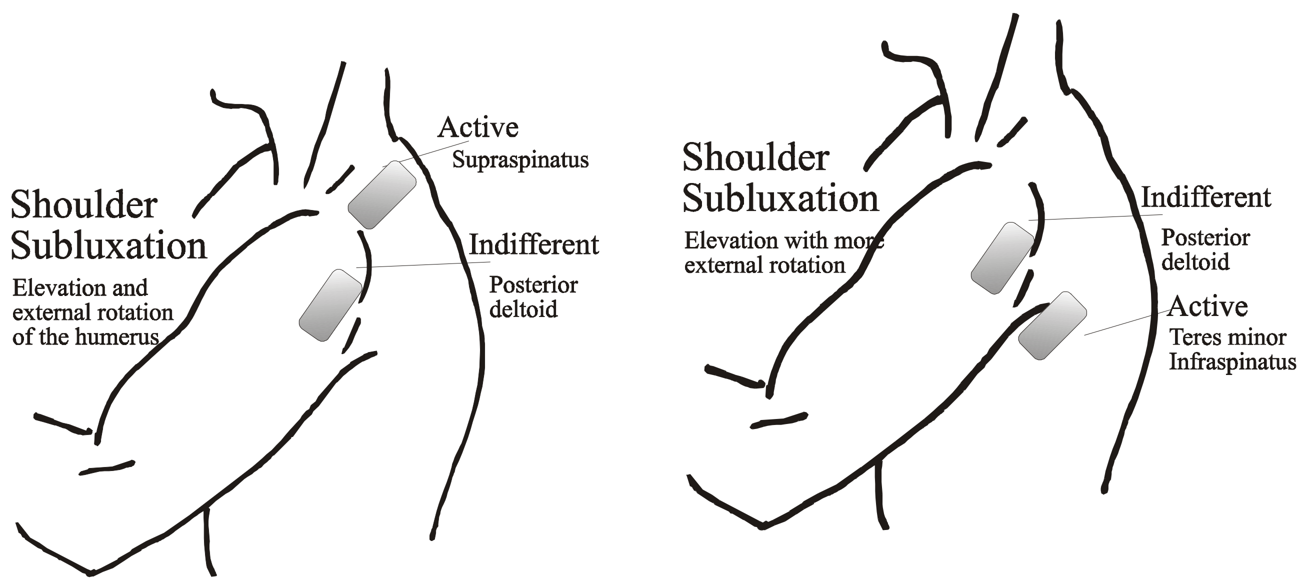
It is our impression that patients have a greater re-education effect if they have some motor ability before treatment begins. As a minimum, it should be possible to take the hand to the mouth. Patients with less ability than this may still benefit from use of stimulation to reduce spasticity for cosmesis, pain reduction or assistance ADL tasks such as dressing. As a general rule, the number of muscle groups exercised should be kept to a minimum. Most patients will find more than 2 muscle groups hard to cope with. Less able patients will need assistance from a carer to perform the exercises. Cardiac demand pace makers are contraindicated. This is because interference from the stimulator may prevent the detection of bradycardia. Poorly controlled epilepsy should also be avoided, as there are some anecdotal incidents of increased symptoms when using electrical stimulation. However, where it is controlled by drugs there should be no problem.

Upper limb FES applications in hemiplegia

Shoulder subluxation

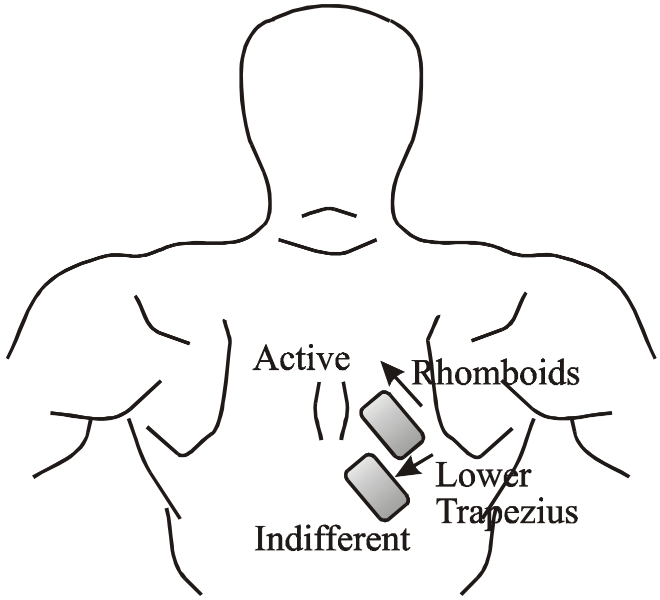
Subluxation occurs when muscle tone around the shoulder is reduced, resulting in a loss of continuity at the gleniol-humeral joint.   Tissues around the socket become stretched and pain is frequently a problem as well as reduced function. Often, when spasticity follows a period of flaccid paralysis, muscle tone will not be balanced and over active pectoral muscles can pull the humerus into internal rotation. The muscles around the shoulder can be divided in to two groups, those such as the supraspinatus or teres minor which principal role is to locate the humerus head in the socket and those such as the deltoid or pectorals, which primarily move the whole limb. The deltoid is easy to stimulate as it is the most superficial muscle but it is useful to target supraspinatus because of its central role in locating the numeral head. If there is no internal rotation, place one electrode over middle deltoid and the second over supraspinatus. Chose which electrode to make the active by which you wish to have the strongest effect. For example if placing the active over the deltoid produces too much abduction, reveres the polarity.

If the arm is internally rotated, place the deltoid electrode over the posterior deltoid. If greater external rotation is required, stimulation of the teres minor and infraspinatus can be tried. Stimulation of the supraspinatus can be difficult to achieve without activation of the trapezius resulting in elevation of the shoulder girdle. If this is the case it is often better to stimulate the middle and posterior deltoid.   Two channels of stimulation can be used, alternating between the electrode positions.



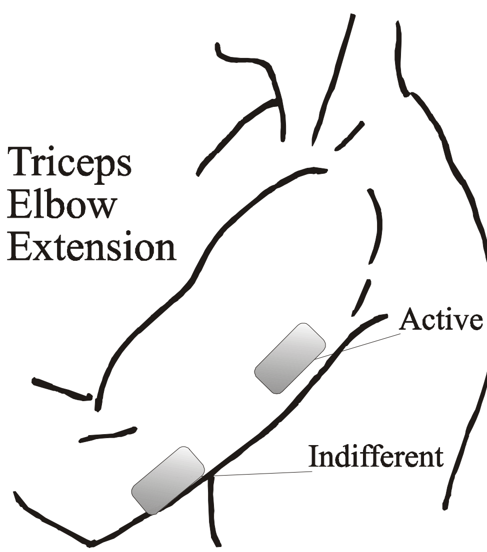
Scapula Stabilisation

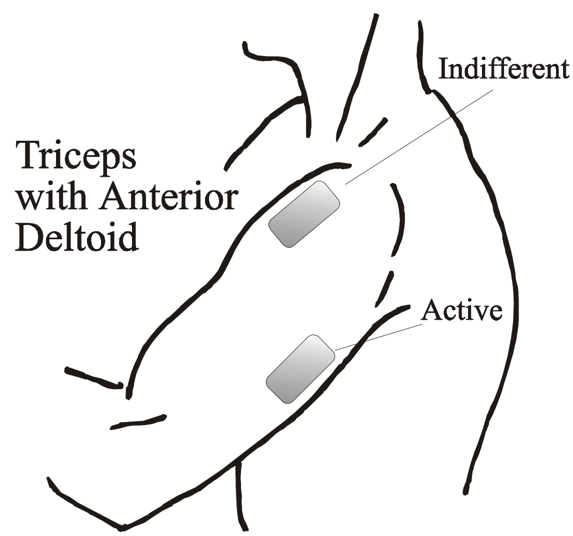
Scapula winging is a common problem following hemiplegia and is due to weakness in muscle such as the trapezius and rhomboids. These muscles can be exercised using electrical stimulation with the electrode positions shown. The rhomboids will retract and elevate the scapula while the more superficial lower trapezius will adduct and depress it. This exercise can be combined with other exercises, for example reaching exercises.



Elbow extension

The triceps is easily stimulated by placing an active electrode over its motor point and the indifferent over the tendon at the elbow. As this is a fairly large muscle, it is sometimes useful to use larger electrodes, 50mm x 50mm for example, which may produce a more effective movement with greater comfort. Patients can be asked to assist with the movement. Practising "table polishing" by sliding the hand over a table using a cloth to reduce friction can be effective. The triceps action can be supplemented by placing the indifferent over the anterior deltoid to assist shoulder flexion. Posterior deltoid can be added in the same way to extend the shoulder and this is sometimes done in the swing phase of gait using an ODFS or O2CHS, controlled using a foot switch. If the biceps are weak, triceps contraction can be alternated with biceps. The active is placed over the belly of the biceps with the indifferent 2 fingerbreadths lower.

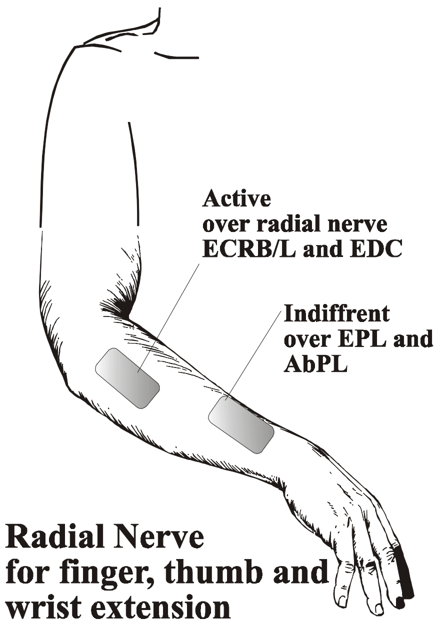


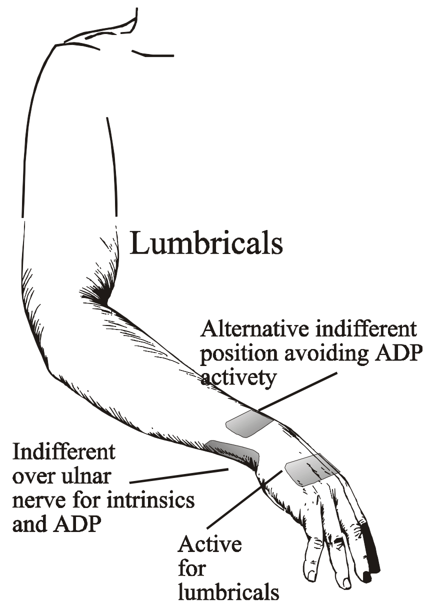


Wrist, finger and thumb extension

This is best achieved by stimulation of the radial nerve, which will produce a general extension pattern. It is often a problem to get good thumb extension so it is good practice to place the indifferent over the motor points of EPL and AbPL, about three fingerbreadth proximal to the wrist. If thumb extension is still not good, make this electrode the active, assuming this does not significantly reduce finger and wrist extension.

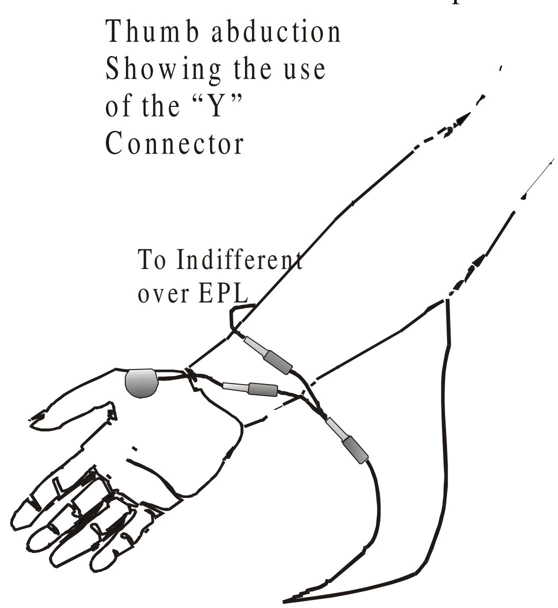
Care should be taken to avoid either radial or ulna deviation of the wrist. If there is excessive ulna deviation move the active electrode towards the extensor carpi radialis brevis on the radial side of the arm. If radial deviation occurs, move the electrode towards the ulna side and the extensor carpi ulnaris. If finger extension is poor, perhaps due to spasticity of the finger flexors, while wrist extension is present, it is some times possible to stimulate the finger extensors alone by placing the active electrode more distally. As the extensor digitorum communis is deeper than the wrist extensors it can be difficult to achieve pure finger extension.





Lumbricals and abductor pollicis

Radial nerve stimulation is often used to reduce the tone of spastic wrist, finger and thumb flexors. However, its effectiveness can sometimes be improved by alternating it with lumbricale stimulation to produce MCP joint flexion with extension of the phalangeal joints, producing a two phase stretch of the finger extensors. This exercise can also be effective at reducing oedema of the hand. The two groups can also be stimulated together, to improve finger extension with wrist and thumb extension. Use a long thin active electrode placed just proximal to the knuckles of the hand. A 30x50mm Pals electrode is sometimes adequate or you can cut down a 70mm round pals electrode using scissors. As the index and middle finger lumbricals are activated by the median nerve, while the others are of the ulna nerve, make sure the electrode is over the index side. The active can be placed over the back of the wrist or often more effectively over the

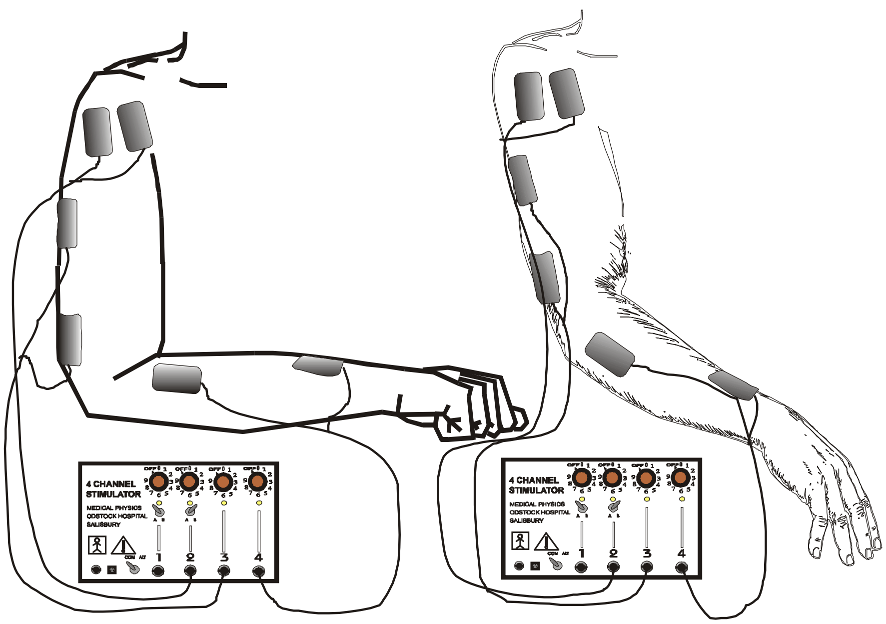


ulna nerve as it enters the wrist. The later placement will bring in the adductor pollicis and other intrinsics, which is often an advantage.

Thumb Abduction and Opposition

Radial nerve stimulation can effective at opening the hand but thumb extension alone can leave the thumb in a less than functional position. Abduction and opposition can be produced by stimulating the thenar eminence. Place the active electrode over the motor point of Abductor pollicis brevis or opponens pollicis and the indifferent over the back of the wrist. To combine this movement with a general extension pattern it can be useful to use a "Y" connector. The diagram shows how the indifferent electrode lead can be shared between two electrodes, one over the extensor pollicis longus (hidden behind the arm) and the other over the abductor pollicis brevis while the common active is over the radial nerve (also hidden). Stronger abduction may be obtained, if required, by sharing the active electrode lead instead of the indifferent. However, be aware of unusual conduction paths using this method as multiple electrodes can lead to unwanted over spill to neighbouring muscles and nerves.

Reaching

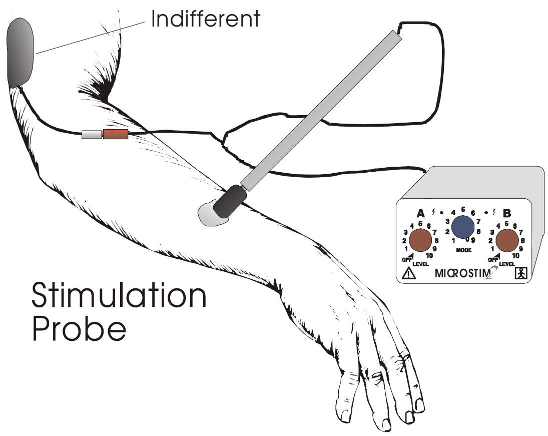


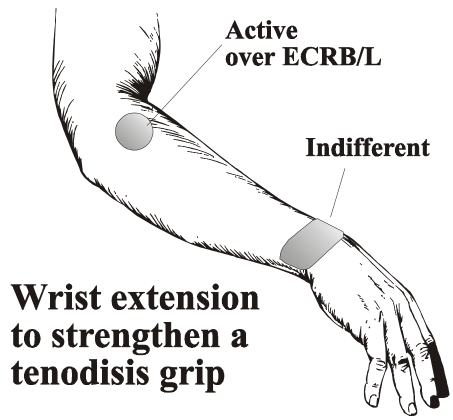
It is often useful to combine muscles to produce a gross pattern of movement, similar to the combination movements used in every day life. In this way it may be possible to more effectively re-train function rather than by practising individual muscle activity. Such a movement is reaching where finger, thumb and wrist extension from radial nerve stimulation are combined with elbow extension and shoulder flexion by stimulation of triceps and anterior deltoid. This can be done using an Odstock 4 Channel Stimulator bringing all channels on together. If scapular stability is a problem, a 4th channel for rhomboids and lower trapezius can be added. Alternatively a 2 channel Microstim can be used combining the stimulation of triceps and anterior deltoid together as previously described.

Applications in tetraplegia

Electrical stimulation can be used to strengthen weak, partially denervated or paralysed muscles using the same electrode positions as above. Additionally it can be useful to stimulate the ulna and median nerves, thereby recruiting all the muscles in the forearm. However, it must always be born in mind that frequently some or many of the muscles may be denervated due to peripheral nerve damage at the site of the spinal lesion. These muscles will not be excitable. The stimulation wand can useful to isolate individual muscles and determine which muscles are denervated. Place the indifferent electrode behind the elbow and place the wand on the target muscles using conductive gel.

It is also possible to strengthen the tenodesis grasp of C6 lesion tetraplegics by exercise of the wrist extensors. Use a small electrode over extensor carpi radialis brevis/longus to avoid over spill to the radial nerve and therefore finger extension. The indifferent can be placed over the back of the wrist or elbow. We have also used electrical stimulation to strengthen and retrain muscles following tendon transfer. For example the posterior deltoid following transfer to the triceps for elbow extension or the brachiolradialis transferred to the extensor carpi radialis/brevis for wrist extension. In all the above cases the patient is asked to assist the effect of the stimulation, thereby re-enforcing the recruitment of the movement.





Conclusion

This article has been a summary of the techniques used in Salisbury. While there is much evidence in the literature to justify there use, more work is required to establish clinical effectiveness. We would be very pleased to hear from you about the methods you use so we can expand our knowledge and pass on ideas to readers of the Salisbury FES Newsletter.

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