Acupuncture and Related Therapies 2 (2014) 14–18

Contents lists available at ScienceDirect

Acupuncture and Related Therapies

journal homepage: www.elsevier.com/locate/arthe

Case report

Electrical current and acupuncture treatment for a paediatric patient with a recurring long thoracic nerve paralysis

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ARTICLE INFO

Keywords:
Long thoracic nerve palsy
Pain
Complex regional pain syndrome
Electrical stimulation
Acupuncture

ABSTRACT

A female paediatric patient aged 9 years presented with right long thoracic nerve palsy for the second time. The first injury that occurred in 2011 was due to a fall and although the patient had a paralysis of the serratus anterior muscle and was unable to elevate the arm, with rehabilitation and conventional physiotherapy, she recovered completely according to the nerve conduction test that was conducted six months post recovery.

The second injury to the long thoracic nerve was due to a ballet movement that occurred in 2012. Besides the nerve palsy that reoccurred there was also a complication of severe pain and evidence of a complex regional pain syndrome (CRPS). The second injury was limited by the inability to participate in rehabilitation exercises and physiotherapy due to pain and hyperaesthesia in the distribution of C5 and C6 dermatome both in the trapezius and shoulder region. The third nerve conduction test deteriorated to those recorded after the first nerve conduction test.

A different physiotherapy approach was then applied – initially to reduce pain and decrease hyperaesthesia and then to attempt to *increase* nerve conduction by the inclusion of an electrical device that simultaneously delivers both a low and a high frequency current. This treatment was *combined* with various pain resolving tactics including acupuncture, individual sub-liminal, low and high frequency electrical currents. Several interventions were applied to tailor the treatment to the patient to achieve maximal improvement in pain and mobility. It is therefore difficult to attribute improvement to one particular modality or even natural resolution of the condition however previous clinical application and experience of activating nerve conduction with the combination current in other conditions implied that improvement could be expected. This particular electrical current is a combination of a low frequency and a magnetic field.

The condition resolved completely with full movement and no pain after 13 treatments over two months – it was evident that *the combination* of treatment had an effect on expediting the healing in the nerve. The patient was able to resume all her normal activities including gymnastics and ballet.

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1. Background

Most patients diagnosed with long thoracic nerve injury with a resulting paralysis of serratus anterior may only recover after two years. The fact that the paediatric patient mentioned in this case history was able to recover within two months was unexpected and seemed remarkable. It has been discovered that a recently developed non-interventional high frequency current has been able to stimulate a nerve root, plexus or branch nearest to a nerve injury with rapidly improving strength occurring in the compromised muscle. This has been illustrated clinically in patients with Bell's palsy. It is noteworthy that faradic current, transcutaneous electrical nerve stimulation (TENS) and galvanic type current cannot be expected to accelerate normal nerve conduction in this type of neuropraxia.

2. Literature review

The first report of the non-interventional pulsed radio frequency device was made by T Goroszeniuk and S Kothari on "External Stimulation: Simplistic Solution to intractable pain?" at the Pain Management Centre, St. Thomas' Hospital, London in 2009. A prototype of the device called the Neurotrace III was used on 35 patients with peripheral neuropathic pain. Three treatments were given once weekly for 5 min per treatment and there were no negative results, with 19 patients achieving 100% improvement. The second report given by a physiotherapist from Pretoria, South Africa by DA Muller in 2010 on a patient with left sided Bell's palsy that had

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http://dx.doi.org/10.1016/j.arthe.2013.11.002

Fig. 1. A left sided Bell's palsy patient, after 6 months with no further recovery.

Fig. 2. The same patient after one month of non-interventional pulsed radiofrequency.

not resolved after six months. The neurologist advised that no further treatment would improve the condition. The physiotherapist commenced normal treatment of ultrasound, laser, electrical stimulation and facial exercises three times weekly from 26 February until 13 May with no change in the left facial muscles. Muller then gave her patient the above-mentioned non-interventional pulsed radiofrequency device to use at home once a day for 5–10 min on the left facial nerve branches. By the end of June, most left facial muscles improved from 0/5 to 3–4/5 on the Oxford Grading Scale, except for orbicularis oculi that only reached 2/5 and the eye could not close completely (Figs. 1 and 2).

Since 1936 according to Ginsberg [1], ultrashort radio waves have been used as a therapeutic agent. Lombardo [2] presented information at the Symposium at the Ginsberg Foundation for Medical Research 1959 on the treatment of decubitus ulcers with radiofrequency. Jeran et al. [3] published their results on the effects of low frequency pulsing electromagnetic fields on skin ulcers of venous origin in humans: a double blind study. Al-Badawi et al. [4] in 2012 recorded the efficacy of pulsed radio frequency energy in temporomandibular joint pain and dysfunction. However all the previous types of non-interventional pulsed radiofrequency treatments did not involve contact with a probe on a nerve root, plexus or branch but rather were either placed adjacent but not on the body area or used electrodes that may have been strapped near the offending area to be treated.

Van Zundert et al. [5] found in a study on a rat model that pulsed and continuous radio frequency adjacent to the dorsal root ganglion induces latent cell activity via the upregulation of c-fos mRNA. This may have implications for nerve stimulation and possible regeneration.

Fig. 3. The appearance of the scapular in this patient on the second occurrence of the long thoracic nerve injury and paralysis, October 2012.

3. Case report

3.1. Presenting history and complaint

A nine years old female was referred on 25 October 2012 to a physiotherapy practice for pain management and rehabilitation after being diagnosed with long thoracic nerve compression with paralysis for the second time and with the added complication of complex regional pain syndrome according to the referring rheumatologist. This second injury was caused by holding hula-hoops during a ballet class while practicing for a concert.

When the condition appeared in the first week of October the patient was referred for conventional physiotherapy that consisted of: biokinetics with exercises, physiotherapy with both active and passive movements plus interferential electrical current stimulation and hydrotherapy.

These treatments increased stress and pain. As pain and hyperaesthesia became a major issue and all attempts to mobilize and strengthen the shoulder became impossible, it was then decided that conventional physiotherapy should cease and that pain management commence, to break the pain cycle. This non-interventional pain management included various electrical currents and acupuncture.

4. Objective examination

Winging of the scapula was evident (Fig. 3).

There was severe pain from the right lateral cervical region from C4/5 referring to the right shoulder both anteriorly and laterally (deltoid region).

The area was hyperaesthetic with a red flare/erythema of discolouration mainly in the neck when touched or even if the patient was distressed by the *thought* of having the shoulder touched or moved.

The patient held her right upper arm close to the chest with the elbow flexed. There was full movement of the right forearm, hand and fingers but nil active movement of the shoulder in all ranges. The scapular winged noticeably, the right upper trapezius muscle was depressed with the cervical spine tilted to the right with 50% limitation of right rotation of the cervical spine.

Assessment of pain at the first consultation 25-10-2012.

Visual analogue scale (VAS): best is 7.5/10, worst 10/10.

Pain was constant, aching, allodynia present with movement, hyperaesthesia to light touch and a sensation of painful cold or freezing pain.

The patient was assessed for neuropathic pain on the Doleur Neuropathique 4 screening tool [6] and had brush allodynia, hyperaesthesia to light touch and painful cold or freezing pain, among her other complaints rating 3/10 on the DNP4 scale for neuropathic pain. On this assessment scale, 4 or more points out of 10 indicates neuropathic pain.

Sleep is disturbed by pain (lying is painful).

The pain is aggravated by lying, moving and writing activities. There was no use of the right arm and all schoolwork was done with the left hand.

Nil eases the pain

Mood – the patient indicated that she was anxious, sad (weeping at times) and the mother, a psychologist, felt that her child was depressed which is not unusual with continuing severe pain.

In assessing the general health – nil except for a mild heart murmur and seasonal rhinitis. This patient presented as a fit and healthy child, highly intelligent and motivated towards getting better.

Medication: trepilene, gabapentin, neurontin – no information on dose was available. According to the mother all medications were abandoned after a few days and none of the medications were used for longer than one week. No difference to pain was detected and the patient felt sleepy on the trepilene. There was also nil response to any analgesic.

At the time of her first consultation she was still participating in hydrotherapy and as this appeared to increase her pain it was decided to stop this activity at that time.

Nerve conduction study: the nerve conduction studies by the neuro-physiologist (17 October 2012) indicated a 70% drop in amplitude of the right motor nerve conduction compared to the left side (0.4 compared with 2.1) with a severely delayed latency (5.1 compared with 3.0). The sensory nerve conduction studies of the ulna and median nerves were normal. These results were similar to the previous nerve conduction studies in August 2011 performed after the first injury and that had returned to normal on re-testing in July 2012 before re-injury in October.

5. Past history

This young patient's first injury occurred in July 2011, due to a fall at school resulting in a subluxation of her right shoulder joint. This injury to the long thoracic nerve created winging of the scapula that recovered fully after 6 months. This original injury was not accompanied with pain but the patient was limited by her inability to elevate her right arm. The subject's normal activities included gymnastics and ballet.

6. Treatment

A combination of treatment was given that has been applied with a selection of the modalities listed below initially to determine best treatment for the patient and the condition but the treatment would often need to change depending on the mental and physical state of the patient at each appointment. A maximum of 4 modalities would be given at each treatment and each treatment was maintained for 45 min.

- Microcurrent/subliminal [7] current sensation 0.5–1 Hz for hypersensitivity – (Alpha-Stim/AS), a sub-liminal current is applied around but not on the sensitive region.

DATE	No of Rx	VAS before	VAS post	Mobility	Touch	Mood
25/10/2012	1	8--10				
26/10/2012	2	Unable to score				
30/11/2012	3	8	7.4			
01/11/2012	4	7				
06/11/2012	5	8	7.5	Using arm		
08/11/2012	6	8	7			
13/11/2012	7	Unable to score		Holding teddy bear		
15/11/2012	8	Unable to score		Using arm		Improved
19/11/2012	9	Not measuring		Using arm		Improved
23/11/2012	10	Not measuring		Using arm	Massage	Improved
27/11/2012	11	Not measuring		Using arm	Massage	Improved
05/12/2012	12	Not measuring		Using arm	Massage	Improved
10/12/2012	13	6		Using arm	Massage	Improved
07/01/2013	14	0		Full ROM	Nil needed	treatment

Fig. 4. Chart shows dates, numbers of treatments, visual analogue scale (VAS) before and after a treatment, mobility, ability to touch the area of pain and mood of the patient.

- Cranial electrotherapy [7] (CES) applied with clips on the ears to give the same treatment as above and is found to produce relaxation and decrease stress.
- Acupuncture [8,9] for:
  relaxation, stress and pain: GV20, LI4, LIV3,
  increasing shoulder mobility: electro-acupuncture (EA) at LI11, LI15,
  improving pain, muscle spasm and mobility in the shoulder: GB34, ST38, GB21.
- NMS/Stimpod is a non-interventional (NI) pulsed radiofrequency at 133,000 Hz superimposed upon a square direct current wave with an intermittent low frequency pulsed at 2 Hz and this device is usually applied at the nerve root (relevant facet joint) or nearest plexus, in this case the brachial plexus (BP) either superior or inferior to the clavicle or even on an area of muscle spasm [10].
- Laser (low level laser) applied for hypersensitivity over but not in contact with the sensitive region (has been found by the author to reduce hyperaesthesia in some patients).
- TENS [11] for home use with a rate of 200 Hz and a width of 80 ms for pain.
- Direct current (APS) for inflammation and swelling [12].
- Transeva/faradism to stimulate the muscles along rhomboids, deltoid, trapezius and serratus anterior.
- High frequency (Panag) current 10,000 Hz [13].
- Explaining pain.
- Visual imagery (colour and size changes) breathing exercises and relaxation.
- Mirror therapy.
- 13 treatments were given (Fig. 4).

7. Outcome

All movements returned between Christmas 2012 and New Year 2013 with complete relief of pain. The patient was discharged on 07-01-2013. On telephonic inquiry in November 2013 the patient's mother assures that her daughter remains pain free and mobile and is able to participate in all her normal activities. She does however have hypermobility in her shoulder joint that may be attributed to her original injury in 2011.

8. Discussion

Initially it was not expected that the nerve damage could repair from a severe loss of conduction within less than six months. Compared with the first attack on the long thoracic nerve which took six months to repair, one can only assume that the combination of the treatments offered has had an influence on restoring nerve conduction. The condition on the second attack was also complicated by severe pain and a diagnosis of CRPS that would also influence the outcome and make it more difficult to treat.

The fact that the area was extremely painful, hyperaesthetic with a red flare/erythema of discolouration mainly in the neck when touched or even if the patient was distressed by the *thought* of having the shoulder touched or moved is often consistent with early CRPS.

CRPS often manifests with allodynia, hyperaesthesia, discolouration, oedema and dysfunction of mobility. Clinical features of CRPS may include a mix of sensory, autonomic, and motor symptoms, particularly intractable pain, limb oedema, blood flow and sudomotor changes, cutaneous trophic irregularities, and movement disorders [14].

As the previous physiotherapy was discontinued pain management with treatment of the peripheral (ascending) and the central (descending) mechanisms commenced. Treating the peripheral (ascending) mechanisms implied treating the local area of pain with modalities that would not increase pain with sub-liminal electrical current that could possibly decrease the cutaneous sensation of pain and inhibit pain. Treating the central (descending) mechanisms implied interacting with the patient to assist in increasing endorphins by the physiotherapist: explaining pain, teaching relaxation, breathing techniques and visualization [15], demonstrating 'mirror therapy' encouraging assisted movements that did not increase pain and giving the patient confidence to cope, control the pain and accept the situation that the nerve would eventually recover. Case studies and anecdotal data are overwhelmingly supportive of mirror therapy, or 'virtual' mirror therapy, in which a virtual reality environment is used instead of a mirror to relieve phantom limb pain, complex regional pain syndrome (CRPS), and for post-surgical rehabilitation [16].

The availability of the non-interventional combination pulsed radio frequency superimposed upon a square wave (NI-PRF/Stimpod) on many neuropathic pain conditions treated over the past three years has demonstrated remarkable effects within 3 treatments. This treatment has also improved patients' with early Bell's palsy within 2–5 treatments in some cases demonstrating that this type of current may facilitate nerve conduction more effectively than galvanic, faradic or with TENS type currents. This may imply that the NI-PRF/Stimpod is able to have an inhibitory effect on pain and improve nerve conduction whether it is due to a neuropraxia or a minimal nerve injury.

When this patient was first assessed it was important to try, as soon as possible, to break the pain cycle and relieve the anxiety and depression. Many patients who have hyperaesthesia and allodynia do not improve if passive or active movements are forced or have increased pressure, ultrasound, TENS applied to the hypersensitive area due to the presence of sensitization. Therefore acupuncture and cranial electrotherapy were used to relieve stress, anxiety and pain, and microcurrent and IRL (both being sub-liminal or having very little sensation) were used to relieve hyperaesthesia. Electro-acupuncture was used to improve the range of the shoulder movement and improve strength. However it was not a simple journey as it was difficult to find the treatment that would not distress the patient and give her confidence that physiotherapy would not increase the pain.

The mainstay of the treatment was the consistent use of NI-PRF/Stimpod in specific positions. The long thoracic nerve is usually formed from three cervical nerve roots – the fifth, sixth and or seventh cervical nerves, but the root from the seventh may be absent [17,18]. The activity of the muscle with the pectoralis minor draws the scapular forwards and is the chief muscle concerned in reaching and pushing movements. The upper part of serratus anterior together with levator scapulae and the upper fibres of trapezius provide a muscular suspension for the scapula, supporting the unloaded arm. The lower fibres of serratus anterior play an important part in raising the arm above the head [17,18].

Injury to the long thoracic nerve causing paralysis or weakness of the serratus anterior muscle, can be disabling. Patients with serratus anterior muscle palsy may present with pain, weakness, limitation of shoulder elevation, and scapular winging with medial translation of the scapula, rotation of the inferior angle towards the midline, and prominence of the vertebral border [19].

Long thoracic nerve dysfunction may result from trauma or may occur without injury. Fortunately, most patients experience a return of serratus anterior function with conservative treatment, *but recovery may take as many as 2 years*. Bracing often is tolerated poorly. Patients with severe symptoms in whom 12 months of conservative treatment has failed may benefit from surgical reconstruction. Although many surgical procedures have been described, the current preferred treatment is transfer of the sternal head of the pectoralis major tendon to the inferior angle of the scapula reinforced with fascia or tendon autograft. Many series have shown good to excellent results, with consistent improvement in function, elimination of winging, and reduction of pain [20].

The target of treatment with NI-PRF/Stimpod therapy in this condition was to treat C5, 6, 7 at the nerve roots as they exit the cervical foramina, the brachial plexus superior and inferior to the clavicle, in the levator scapulae and upper trapezius muscles and along the costal border of the ribs and close to the ventral scapula attachment of the serratus anterior but some of these areas were often inaccessible due to the hyperaesthesia.

The NI-PRF/Stimpod has been in use since 2009 with most promising results specifically but not exclusively in neuropathic pain from different aetiologies. The treatment is an externally applied, non-interventional, pulsed radio frequency (PRF) device that delivers 133 kHz of power via a small probe to a nerve or region such as a joint or muscle that may be involved in either a neuropathic or nociceptive condition or combination of these conditions. The most commonly treated area is the peripheral nerve or even central nerve root (spinal) that supplies the painful region. The probe may be applied to the skin for only 5mins even once weekly for 3 treatments and often, complete resolution of symptoms may occur in certain individuals. The Stimpod/NMS 460 targets the nerve responsible for the pain and it is specifically the neuropathic component of pain where the most demonstrable and profound effects occur.

In addition to pain relief, improvement in mobility and strength also occurs post treatment and this has encouraging effects for continuance of other/normal treatment modalities for nociceptive or other pain conditions and also in the rehabilitation phase of a condition. It is believed that the current applied either to peripheral or central nerves activates pain-blocking mechanisms at the dorsal root ganglion mimicking the effects that may occur at the dorsal root ganglion as in an interventional approach yet without causing any injury or damage to the nerve or overlying tissues.

Since its development NMS 460/Stimpod has been used clinically to treat many patients with varying conditions including headache, post operative wounds, diabetic neuropathy, neuropathic pain from both peripheral and central regions including complex regional pain and lumbar degenerative pain even including a patient experiencing meralgia paraesthetica [21].

In the chart above, it can be seen that the first six treatments did decrease pain by between 10 and 30%. However there were

Fig. 5. A photograph taken on 05 December 2012 where the deformity of the scapular winging had improved and was less visible.

also improvements in mobility, stress and sleep quality and it was thought that it was not positive to emphasize pain relief score but rather mobility therefore after the sixth treatment, the patient was not asked to score the pain but rather to measure her activity. The hyperaesthesia and the discolouration diminished by the tenth treatment and massage and mobilization was then possible indicating that the CRPS/neuropathic component of the condition had settled. Once the severe pain had decreased it was easier to increase exercise and improve strength (Fig. 5).

The main thrust of the treatment was to achieve pain free mobility even if full strength was not obtainable or expected due to the length of time it would normally take to recover from the long thoracic nerve injury. It was also important to get the patient's confidence in the treatment and co-operation with practicing the exercises and increasing activities. Although it was hoped, it was not expected that full strength would be achieved in such an abbreviated period – six months was the previous benchmark for recovery after the first injury in 2011. As the NMS/Stimpod device has contributed to pain relief with neuropathic and other pain conditions, has rapidly improved strength in Bell's palsy and also in many case histories demonstrating loss of activity due to nerve pressure or oedema (minimal nerve injury) over the past three years, it may therefore be possible to assume that this device contributed to the rapid and unexpected recovery in this case history.

As a result of the interesting results demonstrated above the combination of the radio and low frequency current device is now being evaluated in studies on animal rehabilitation, in vivo application during radiofrequency interventions on degenerative spinal conditions and a pilot study on the possible prevention of postoperative pain syndromes among other investigations.

9. Summary

Long thoracic nerve palsy normally improves over a protracted period of time or may require surgery.
A paediatric patient had nil pain and paralysis within 2 months.
Electrical currents and acupuncture relieve pain, increases neural conduction and improves mobility.

Conflict of interests

None.

Acknowledgements

I would like to thank the parents of the patient and this young patient herself for their encouraging enthusiasm of this treatment approach. I would also like to thank them for permitting me to submit this case history for publication.

Patient consent obtained.

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