Case report

Traumatic brachial plexus injury rehabilitation using neuromuscular electrical muscle stimulation in a polytrauma patient

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SUMMARY

We report a 28-year-old man admitted postmotorcycle versus car in September 2017. The patient sustained multiple injuries in both the upper and lower limbs. He sustained a complex brachial plexus injury on his left side and was transferred immediately to Stanmore Hospital to undergo specialist surgery (supraclavicular brachial plexus exploration and neurolysis) to repair his brachial plexus injury. The patient was transferred back to the specialist trauma ward for additional surgeries for his subsequent injuries. Due to the complexity of the injury and surgery the patient was not able to start rehabilitation until six weeks post operation, at which point he was referred to outpatient physiotherapy. Prior to this his left upper limb was in a sling but was instructed to move it as able. The patient commenced his comprehensive physiotherapy programme in January 2018.

BACKGROUND

Traumatic peripheral nerve injuries can occur following road traffic accidents and lead to severe disability and loss of function in the upper and lower limbs.[1] Research suggests these types of injuries occur in a young male population.[1] A large percentage of traumatic peripheral nerve injuries affect the upper limb and specifically the brachial plexus. Post injury common problems include neuropathic pain and loss of muscle function leading to poor quality of life scores.[1] Major advances in emergency care and the development of trauma centres have led to the diagnosis and surgical treatment of brachial plexus injuries being completed in excellent time.[1] However, there is limited research into the rehabilitation of these complex patients.

Brachial plexus injuries often result in impaired sensation and muscle strength of the upper limb. Despite microsurgical repair techniques, there is inevitably a distortion of the profile of neural impulses reaching the sensory and motor cortex.[2] Some regenerating axons will be trapped in the scar interface and will therefore never reach the receptor.[2] Other axons will be misdirected, and some will re-innervate the wrong sensory receptor or re-innervate an irreversibly degenerated receptor.[2] This will result in impaired sensation and loss of muscle strength of the shoulder and upper limb.[2]

Neuromuscular electrical stimulation (NMES) is a rehabilitation tool that has been investigated previously with a specific focus on the regeneration of nerves following traumatic injury.[3] These authors concluded using both NMES and exercises was a promising treatment for peripheral nerve injuries and subsequent functional recovery. However, there has been little investigation into acute traumatic brachial plexus injuries in the polytrauma population. More specifically, younger males with multiple-site trauma requiring extensive multi faceted rehabilitation.

With the expansion of Major Trauma Centres an increasing number of patients with both polytrauma and brachial plexus injuries are requiring rehabilitation outside of specialist peripheral nerve centres. While local guidelines exist, there is an apparent lack of an agreed national rehabilitation pathway for complex brachial plexus injuries in the polytrauma population. This could arguably have a detrimental long-term impact on function and quality of life for this patient group. In order to guide future management of these unique patients, it is important to provide specific examples of where clear rehabilitation goals have been implemented successfully, as evidenced with validated outcome measures, with the use of established treatment adjuncts such as NMES.

CASE PRESENTATION

This patient is a 28-year-old man who works as an accountant and lives with his girlfriend. He had no significant personal or family medical history; he was completely independent prior to his accident. His hobbies included riding motorbikes and pushbikes.

He was involved in motorcycle versus car Road Traffic Accident (RTA) on 17 September 2017 which resulted in:

- Left superior condyle C1 fracture.
- Superior endplates fractures T3–T6, T11, L2–L4.
- Left radial head fracture.
- Left comminuted ulna and radius fracture (figure 1).
- Left neck of femur and mid shaft femur fracture.
- Left pneumothorax.

He sustained a brachial plexus injury on his left side. His neurological assessment when assessed on the ward on 27th October 2017 was documented as follows (table 1):

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Figure 1 Left comminuted ulna and radius fracture.

On assessment he had a positive sulcus tests on his left side.

INVESTIGATIONS

The patient was admitted to a major trauma centre due to his complex life-threatening injuries. He had multiple chest, arm, wrist, pelvis and hip X-rays. He has also had CT scans for neck, arm and hip. See figure 1 for left Ulna and Radius X-ray.

The patient had an open reduction internal fixation (ORIF) on his left forearm on the 19 of September 2017 a dynamic hip screw and retrograde nail on his left femur on the 17th September 2017. His neck was conservatively managed in a hard collar for four months.

The Seddon classification was used to diagnose the nerve injury—'Neuropraxia' was identified (a pre-ganglionic lesion with evidence of conduction block, no degenerative injury seen in operation). The classification of a neuropraxia with conduction block was used to grade the injury alongside myotome and dermatome testing pretreatment and post-treatment. An MRI and exploratory operation took place on the 20th October 2017 postinjury demonstrating a neuropraxia injury to the brachial plexus (lateral and posterior cord).

Table 1 Neurological assessment of patient

Myotomes	Dermatomes
Shoulder elevation 5/5	C4 50%
Shoulder flexion 2/5 to 20 degrees	C5 100%
Shoulder abduction 0/5	C6 80%
Shoulder internal rotation 1/5	C7 80%
Shoulder external rotation 0/5	C8 60%
Elbow flexion 2/5	T1 100%
Elbow supination 1/5	
Elbow pronation 1/5	

TREATMENT

The patient was referred to physiotherapy for musculoskeletal management of his neck, shoulder, elbow, hip and knee injuries. His first appointment was on the 23rd November 2017, two months after his initial accident.

His lower limb rehabilitation progressed well with range and strength returning rapidly. A significant proportion of his physiotherapy therefore focused on his brachial plexus injury for which he completed NMES training. This rehabilitation also included home exercises and a NMES programme for both his elbow and shoulder joints. He was also issued with active-assisted exercises to maintain and progress range around his elbow and shoulder joints. He attended supervised rehabilitation gym session to progress the strength in his lower limbs.

Week 1–4

In this early stage we established a baseline measure of the patient's neurology in terms of muscle activity. We also measured his active and passive range of motions in his hip, elbow and shoulder. Due to his brachial plexus injuries his early stage rehab was to complete active-assisted ranges of motion around these joints to maintain range. Due to him having a positive sulcus on his left shoulder we also focused on protecting this joint with advice on sling use. Due to the more mechanical nature of his lower limb injuries he was started on strength exercises including functional movements such as squats and bridging. However due to more deficits in his upper limbs the majority of our early treatment focused on this area.

Week 4–8

At this stage of his rehab we had progressed his lower limb rehab into the gym where he was doing resistance training as well as cardiovascular work to improve his fitness and strength. At this stage we also started muscle stimulation on his left upper limb focusing on his elbow flexion (starting at 30 Hz). He was also issued his own machine to self-rehabilitate. Manual therapy was also attempted on his elbow at this stage to increase his passive range. The techniques we used included 'muscle energy technique' as well as gentle joint distraction. In addition to this rehabiliation plan the patient particicpated in regular hydrotherapy sessions to increase the strength and range of movement in his upper and lower limb injuires.

Week 8–12

At this stage he was out of the hard collar for his neck injuries but remained stiff and was therefore issued with self-management stretching exercises. His active muscle stimulation was progressing with bicep activation so this was extended to additionally include the deltoid and rotator cuff muscles. The patient was completing active assisted exercises with the muscle stimulation sessions. Due to the limited effect from manual techniques on his elbow a re-referral back to orthopaedics was completed to review any potential articular restrictions at the elbow joint.

Week 12–20

At this stage the patient's lower limb rehabilitation focused on a gradual progression of resistance and the introduction of more advanced functional tasks to challenge balance and strength, such as step up with weights and lunging. Following advice from

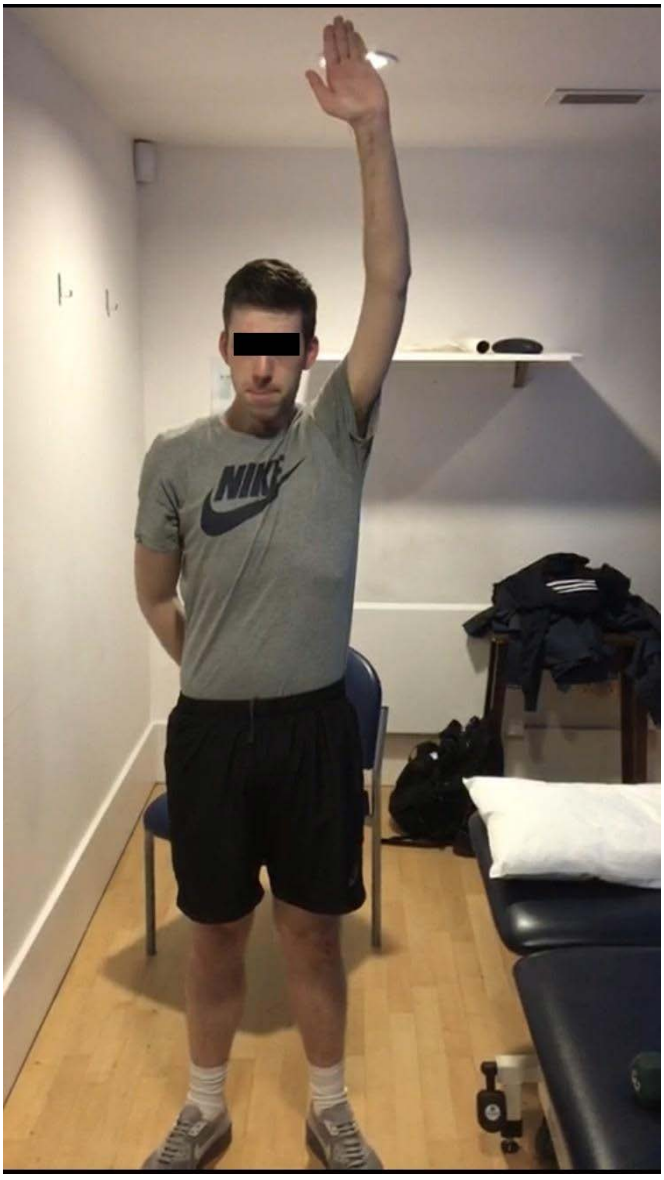

Figure 2 The patient demonstrating shoulder flexion following six months of rehabilitation.

Figure 3 The patient demonstrating shoulder abduction following six months of rehabilitation.

the orthopaedics team, we were advised not to progress onto plyometric exercises for the lower limb at this stage due to the complexity of the femoral fracture. The patient's muscle activation around the upper limb muscles continued to improve, which resulted in a resolved sulcus and weaning off use of the sling. His rehabilitaion is still ongoing where we are monitoring his range in his elbow and shoulder and will likely progress this into manual therapy of the shoulder to increase range. His lower limb rehab will continue to be progressed by increasing his strength, balance and control.

OUTCOME AND FOLLOW-UP

A six month post physiotherapy intervention using specific strengthening exercises and daily NMES the patient presents with:

- Biceps activity has progressed to 4/5 (Oxford grading scale) into available range.
- 4/5 shoulder flexion and abduction throughout range (see figures 2 and 3).
- The patient reports full 100% sensation on his left side and there is increased sensitivity and pins and needles when his C7 dermatome is tested.
- Negative sulcus sign.

The disabilities of the Arm, Shoulder and Hand (DASH) questionnaire is a validated outcome measure for the upper limb. It is a 30-item questionnaire looking at the ability for patients to perform certain upper limb activities and can be used as a measurement of functional recovery of the upper limb; lower DASH scores indicate greater functional independence. The DASH was completed at the start of physiotherapy and six months post physiotherapy. The patient was assessed at the start of physiotherapy intervention and six month post intervention. Results demonstrate:

- A score of 89/100 start of physiotherapy.
- A score of 68/100 six months post physiotherapy.

This patient scored a difference of 21 points between pre and six months post physiotherapy intervention DASH measurements. A change in DASH score exceeding 15 points is required

to show a meaningful clinical difference between significant improvement (or deterioration) in functional ability .

From a functional perspective, the patient has returned to work; he drives an automatic car and is independent with most off his personal care although he still reports intermittent difficulties with some daily motor tasks such as chopping food.

DISCUSSION

Traumatic brachial plexus injuries can occur following road traffic collisions, where they are commonly part of a complex polytrauma presentation. The most commonly associated injuries include fracture dislocation of the glenohumeral joint, and many patients will need surgical intervention.[1] Brachial plexus injuries are complex and require intensive, long-term rehabilitation input. Patients often struggle with activities of daily living and returning to work, especially where the occupation involves manual work.

The focus of this case review was the rehabilitation of a traumatic brachial plexus injury in a young multitrauma patient post road traffic accident. The rehabilitation of a brachial plexus injury in isolation is commonly regarded as a challenging process. However, when considered in combination with further polytrauma injuries, there was an additional complexity to the current case study that is rarely seen outside the scope of Major Trauma Centres. This is reflected by the relative absence of any rehabilitation guidelines to direct the recovery of combined brachial plexus and polytrauma recovery.

While there is little empirical evidence for the rehabilitation of brachial plexus polytrauma patients, there is more support for the diagnostic accuracy of MRI assessment in this patient population. Our findings are in accordance with previous authors[4] who reported the use of MRI imaging correlated highly with diagnostic surgery in preganglionic lesions. These findings gave us confidence that the predictive chances of recovery would be high as the lesion was found to be neurapraxia and not full nerve damage.

The post operative instructions included using a sling for comfort, mobilise the arm as able and consider for rehabilitation at six weeks postsurgery. Interestingly, the medical team did not recommend active physiotherapy rehabilitation until postexploratory surgery. With hindsight, knowing that the nerve injury was a neuropraxia, there may have been a missed opportunity for rehabilitation at an earlier stage. This is one potential negative outcome of awaiting surgery until starting rehabilitation, as opposed to simply relying on the MRI diagnosis. However, this meant that the patient was not even considered for rehabilitation until 10-week post injury, which may have affected his overall recovery.

An alternative argument is that that even if BP rehabilitation was indicated sooner, the complexity of the polytrauma would have made this very challenging. Indeed, a delayed start to rehabilitation may actually have enabled post-traumatic nerve inflammation to settle and ultimately lead to a more successful, and less painful, rehabilitation process.

We are unable to speculate as to whether the patient's recovery would have been enhanced if NMES itself was utilised at an earlier stage and future research be very interesting in this specific patient population. However, from this case study we can confidently say that starting NMES at a later time post operatively appeared to have no negative implications for functional recovery.

One study investigated the outcomes postneuropraxia brachial plexus injury.[5] The authors reported that 69.6% of patients were able to return to work and also scored clinically significance difference in the DASH outcome score, which was in agreement with our case study findings. Interestingly, research reported only 35.3% of their patients who underwent an exploratory procedure demonstrated a good functional outcome.[4] When considered alongside the excellent functional recovery in the present study, these values could be considered rather low. The suggestion is therefore raised that with access to NMES and full gym-based rehabilitation, functional recovery may be improved postneuropraxia exploratory surgery.

NMES provided an effective adjunct to the rehabilitation process and was used daily by the patient as part of strength

Patient's perspective

Polytrauma was not a word I had ever heard of or encountered until I entered the physio department for that first assessment. It was at this point that the road to recovery and the time that it may take truly dawned on me.

The overall combination of injuries I sustained were very complex. At the first physio session I had virtually no movement in my left arm due to the breaks, muscle wastage and nerve damage. I suffered breaks in my leg and hip and I used a crutch to walk. I had broken bones in the base of my neck and wore a neck brace from the day the accident happened until early December.

During the first 1-2-1 physio session we practiced some mobilisation exercises and I was placed on a static bike. A full rotation of the pedals was agony but with great effort it was possible. Over the next few sessions exercises ranged from stretching with a walking stick to climbing a set of stairs. Each session was physically draining however (in hindsight I can see that) progress was being made even if it was only slight. Various exercises and stretches were added to my daily routine. At this time, my days consisted of an abundance of hospital appointments and physio sessions and that was pretty much it. The physiotherapists and the structure of physio exercises gave me a new responsibility and set targets to achieve and I developed the determination to get as fit as possible.

It was approximately 2 months into the physio programme that a muscle stimulator was introduced with the aim of activating what muscle was left in my left upper arm. We used the muscle stim during our 1-2-1 sessions trying different strengths and placements to target my shoulder, back and arm. I was grateful to be able to take the muscle stimulator home and incorporate it in to my daily routine of exercises. I used it three to four times a day following a 'dystrophy' programme, adjusting the strength as required. I feel that a real step-up in my recovery was noticed after it's prolonged and disciplined use, with more sensation and the faintest flicker of muscle twitch where there had previously been none. Physio eventually moved to a more group-based gym therapy session, using the rehab gym and its equipment with the guidance of the physio's. This phase of the treatment helped introduce the exercises into a more conventional setting whilst also giving me the confidence to join a gym local at home and continue my rehabilitation between sessions.

I am sure that without the professionalism, dedication and compassion showed by the physio team I would not have gone on to make such a remarkable recovery. The physio team were (and still are) an enormous factor in my recovery, both physically and mentally. Physiotherapy enables an individual to take an active role in their recovery which is not always possible in medical treatment, with the investment from that individual being effort and time the rewards can be grasped.

Learning points

- Neuromuscular electrical stimulation can be used effectively as a rehabilitation adjunct to promote nerve regeneration following traumatic brachial plexus injury.
- Brachial plexus rehabilitation requires a multifaceted approach including strengthening, manual therapy, gym sessions and hydrotherapy.
- There is need for increased awareness of the management of brachial plexus injuries outside of specialist peripheral nerve centres.
- Physiotherapy intervention can be successful in promoting improvement in strength, range of motion and functional recovery following brachial plexus and polytrauma injuries.

building in the upper limb.[3] Upper limb exercises and hydrotherapy were also vital in the patient's rehabilitation. It is also important to acknowledge the importance of continued physical and emotional support with such a complex rehabilitation programme, as evident by the 6 months of input covered by this case study. To date the patient's upper limb strength, sensation and DASH scores have significantly improved and the patient has achieved their initial long-term goal of returning to work.

Throughout the rehabilitation programme there were a number of limitations that had an impact on the overall recovery times observed. These included neuropathic pain, weight-bearing limitations of the upper limb and additional, complex surgeries. A cause of particular frustration to the patient was the latency of nerve recovery compared with purely orthopaedic injuries. These limitations often affected the patient's motivation and represented a significant challenge throughout the rehabilitation process.

A further limitation to this case study is the absence of strength-duration curves. This approach would have been a useful measure to quantify the achievements following the NMES process. However, this would have been difficult to arrange so soon after trauma on the ward setting due to ongoing medical needs associated with polytrauma. Furthermore, due to the various modalities used, not solely NMES, we felt that it would be very difficult to attribute any changes in the strength-duration curves directly to NMES.

In conclusion, this case study provides encouraging evidence for the use of NMES following brachial plexus injury in a complex polytrauma patient. It provides a rare example of a successful rehabilitation process that encompassed the management of orthopaedic and neurological pathologies where no current national guidelines are available to guide care. Muscle stimulation appeared to be of particular benefit with no reported side effects. These isolated findings would suggest that further research is warranted into the use of NMES in combined brachial plexus injury and polytrauma patients.

Contributors The corresponding author of this manuscript is JAR. Contribution of the authors is mentioned below with their responsibility in the research. AN is senior physiotherapist and TW is advanced physiotherapy practitioner. All authors have been involved in planning, conducting and reporting of this case study. JAR and AN have been involved in the interpretation of data. TW was involved in writing up and discussion of the case report along side JAR and AN. All authors have made a substantial contribution to the conception and design of the case report and the acquisition of the report. Drafting and review of critically important and intellectual content of the manuscript were completed and submitted by all. The manuscript has not been previously published and is not under consideration elsewhere.

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