Threshold Electrical Stimulation (TES) and the TASC Network Model of Recovery from Brachial Plexus Injury (BPI)

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TES in Brachial Plexus Injury

Threshold Electrical Stimulation or TES was first developed as a pediatric protocol for neuromuscular stimulation. There are some key differences between TES and classic Neuromuscular Electrical Stimulation (NMES). Both techniques use an electrical current to affect the muscle, but the method of delivery is not the same. With NMES, there are short periods of relatively high intensity stimulation that causes the muscle to contract. TES delivers the stimulation over a longer period during sleep and at a very low intensity. TES is used at a sub-contraction, sensory threshold. This means that the current does not make the muscle contract. Another difference is that TES treats a different level of muscle weakness than NMES. As a general rule, if the muscle is 3+ or less on the MRC muscle assessment scale, it should be treated with TES first. If the muscle is 3+ or greater, daytime NMES may be added to the treatment program as well as continuing TES at night.

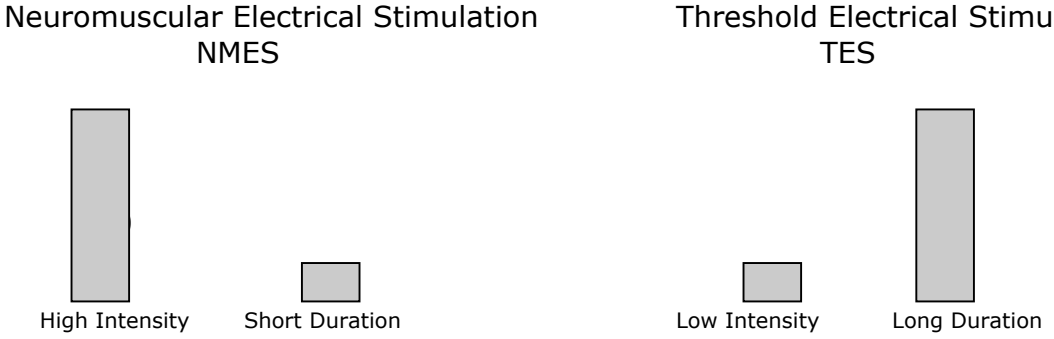

Figure 1

(Caption to Figure 1)
Classical Neuromuscular Stimulation (NMES) is performed above the motor threshold (25–100 mAmps) for 20 minutes to 1 hour, several times a week, for months. Threshold Electrical Stimulation (TES) is done at the sensory threshold (2–10 mAmps) overnight for 8 to 12 hours, 6 nights a week, for years. (end caption)

In the old days, it was accepted medical wisdom that the only way to effectively change the growth pattern or strength of a muscle was to work the muscle. In other

words, the muscle would have to contract. A recent article examines the research evidence for both NMES and TES used in children with Cerebral Palsy. (1) Although much of this research is considered anecdotal, each technique has one "scientifically valid" study that documents change. When we first introduced TES protocols to the health care community, there was a fair amount of skepticism. However, 15 years later, it is accepted that TES, using a low level of stimulation overnight, during sleep, causes growth of muscle.

In the companion article to this piece, Richard Roseboom and his mother, Vanda, relate their experiences after adding TES into a their active exercise program. Richard and his family are very good examples because they have been active for years and are very compliant with their exercise protocol. They had not been sitting idle hoping to get better. However, in spite of all the work, Richard had reached a plateau and his shoulder stability was NOT getting better. With TES and the Model for Recovery coaching, new muscle growth was achievable, even in a teenager, Actually, Richard's exercise program works better because he is a teenager. Puberty is a great stimulus for growth. During puberty, the body is primed and readied to grow.

As well as new muscle growth, many patients have commented that there is an apparent increase in sensory awareness after relatively short periods of time using TES at night. Richard was able to "find" his back muscles, contract them and so strengthen them. This observation is interesting to me as a scientist, as there are excellent animal research studies that relate to this finding. In animals, low-level electrical current has major effects on the re-innervation process. After direct nerve injury, applying a low-level electric field improves not only the speed of the regeneration, but also the quality of regeneration, with an improved number of nerve sprouts. (2-4) There is some interesting information on the actual mechanisms of this change in animal studies but equivalent human studies have yet to be done. I think it is a very interesting area of further research and we can all look forward to more investigation in the coming years.

However, as both Richard and his family will attest, the new growth of muscle, while exciting, is not enough to change function. In order to change function that new muscle has to be strengthened and integrated into daily use. The TASC Model for Recovery was developed to help individuals integrate the available information into a focused plan of action. Making a plan and then taking action is the only way to get a better result.

The Model for Recovery

"How to achieve your child's personal best"

In the Model, we draw on a wide variety of treatments, technologies, medicine and surgery…whatever is needed to get the best possible result. Of course, this type of treatment model makes good researchers want to tear out their hair! One of the problems with doing research in humans compared to animals is that TES, or any other intervention used in Brachial Plexus Injury rehabilitation, is difficult to evaluate by itself. Best possible recovery from BPI requires a multi-disciplinary approach. Many interacting therapies may need to be used at the same time. In contrast, the aim of formal research studies is to isolate the individual variables and then study them one at a time. The investigators work hard to try to isolate the effect of just one therapy. The problem with this approach is that it is like doing great surgery

without any therapy. We all know the results that you would get without therapy are pretty miserable. No matter how skilled the surgeon, therapy pre- and post-surgery will improve the outcome. In Richard's case, TES helped his very atrophic, weak muscles to grow. Then he could learn to activate them. And now, he is working to strengthen them in active movements. All the techniques he has used have helped and no one treatment would produce those results if used alone.

The good news for brachial plexus injury rehabilitation is that there are lots of "neat new things" that are now available to improve the functional results. This is good news for the parents of babies recently born with a Brachial Plexus Injury. And the good news carries through all the way to adults who may not have considered change for many a long year. However, all this good news is sometimes hard to digest. If you spend a day searching the internet, you are almost guaranteed to be totally confused by the wealth of information, competing claims, and lack of a clear path or direction. For this reason, I decided to create a "Model for Recovery" based on what we now know about nerve injury and recovery and the developmental stages of the child.

These developmental stages are important because the child with OBPI is a very different human than the adult with a later occurring traumatic Brachial Plexus Injury. The key difference is that as the child grows, there are serious changes produced in their muscles, bones, joints, tendons and even the very wiring of their brain. The bad news is that this makes the process a little more complicated in children. The good news is that the potential for recovery is greater than it is in adults. The Model for Recovery is my attempt to make sense out of this process and provide guidelines for what techniques are best used, at what time, and in what order.

"Doing the RIGHT thing at the RIGHT time, in the RIGHT order is crucial to achieving the best possible results."

Why Do You Need a Model for Recovery?

Over the last year, while I have been writing this model, I was also in the process of building my "dream house" in Toronto. In the past, I have never been involved in more than a small renovation. Taking on the project of building a house from scratch has been challenging to say the least. But as I have gone back and forth between these two projects, it struck me that building a house could be used as a metaphor for why both parents and professionals need a conceptual Model for Recovery to help guide the rehabilitation process.

Building a house or helping a child reach his or her own "personal best" requires a plan of action. For the house it is architectural plans ready for construction. For personal best, we need a plan or model to direct us the best possible recovery.

The BPI Model for Recovery has four separate but related sections.

1. The Nerve Injury and Recovery

The pathophysiology of peripheral nerve injury has been well understood for many years. This is not new knowledge. We know how to diagnose nerve injury. We know how to repair nerve injury. We know how to graft nerves. We know how to transplant nerves. For quite a few years, we have been able to transplant both muscle and nerve to replace lost function. We know how to diagnose the severity of brachial

plexus injury. We know the timeline for spontaneous recovery. And the criteria for diagnosing delayed recovery are well accepted. All of these issues are within the standard of care in the fields of adult medicine and surgery. Over the last ten to fifteen years, what is new are the major improvements in microscopic surgical techniques and the anesthetic and post-operative management of babies. I am always fascinated by the attitude of some of my colleagues who consider primary surgical intervention as a "radical new technique" in obstetric brachial plexus injury. I think it is important for parents and professionals alike to recognize that these are NOT new techniques. The only new part about them is that they are being applied to a new patient population.

The part of the Model for Recovery that deals with the nerve injury and the recovery from that injury can be compared to the electrical engineering plans created for a new house. The electrical engineer creates the plans. The contract electricians are the ones that will actually install the wiring in the house.

The healthcare equivalent of the electrical engineer and the electricians are those people who contribute directly to the nerve injury and recovery focus. This is the field of the Neurosurgeons, the Plastic Surgeons, Neurologists, PM&R Physicians and Developmental Pediatricians. These are the folks who help with the diagnosis of the injury and recommend the appropriate treatments. The correct management of the nerve injury is the first step in the Model for Recovery.

2. The Bones, the Tendons, and the Joints

After an early brachial plexus injury, the arm movement is absent or limited for a prolonged period of time. During this period, there are important changes that take place in the structure of the upper limb and shoulder. These changes occur in the bones, the tendons and the joints and can lead to significant problems in the biomechanics of movement for life. This part of the Model for Recovery describes the best that we can currently offer with therapy, bracing, splinting, night splints, taping and surgeries. Parents and professionals need a clear understanding of what to expect as the child grows. Truthfully, the results that we are currently achieving are not good enough. The Model for Recovery outlines what new areas need to be developed to improve the outcome. Working together, we should be able to do a better job of preventing the structural complications that happen after a brachial plexus injury

In this area, the Model for Recovery can be compared to the structural engineering plans for the new house. Hopefully, the structural engineer will make sure that the walls are straight and the house does not fall down. When building a house, the structure is the responsibility of the general contractor and sub-contracted trades that actually build it. In BPI, your healthcare experts are Occupational and Physical Therapists, Brace and Splint Manufacturers, as well as Orthopedic and Plastic Surgeons who specialize in upper limb rehabilitation. Our aim for both the child and the house are straight lines.

3. The Muscles

The muscle is a much forgotten tissue of the body. When the muscle is deprived of nerve input for long periods of time, there are significant changes in the muscle. (5) The first change in the muscle, without nerve input and with decreased movements, is that the muscle withers away. It shrinks! Medically this term is called disuse muscle atrophy. A relatively new research finding in animal studies is that if the

muscle is deprived of nerve input for too long, the number of muscle fibers is limited for life. In other words, the muscle is smaller than normal for life. This is one of the reasons that it is so important to have an early surgical evaluation and make sure that if primary nerve surgery is possible for your child, that it be done early enough that there is not a permanent loss of muscle fibers. Our aim for the period of regeneration, with or without surgery, is to preserve what is there and stimulate new muscle growth while waiting for nerve regeneration.

The second major problem, once the nerve has reached the muscle, is to strengthen the muscle and integrate its function into the motor movement as soon as possible. If the muscles are too weak to work, we will not recognize the return of neurologic function. Richard Roseboom had nerves to the muscles on his back that controlled the motion of the scapula. But they were so weak that he could not activate them. TES was able to stimulate enough growth and awareness to allow him to activate them and thus improve function.

Let's go back to the house analogy. This area can be compared to the mechanical engineers who do the heating, cooling, and water systems for the house. If these systems do not work, it is not a nice house to live in. If the muscles don't work, you do not have good performance.

Our healthcare experts for BPI in this area are Occupational and Physical Therapists, Massage Therapists, Sensory Integration Therapists and techniques like TES, NMES, hybrid FES units and more. There are a lot of options to explore that may be used to help preserve muscle function. One approach is some interesting research from overseas. These physicians are using direct muscle stimulation (myostimulation) during the period of absent innervation to help keep the muscle in shape. Strength training, once the muscle is reinnervated, can be done casually and haphazardly or in a focused, organized plan that I call "strength training like a peak performance athlete". You will learn about all these protocols and how they fit into an overall approach at the Model for Recovery workshops.

4. Function and Performance - Brain Wiring

The last part of the BPI Model for Recovery concerns how the arm and hand are actually used in function as the child grows and moves into adult life. Brachial plexus injury is a peripheral nerve injury, but it also has an effect on the developing brain and how it functions. Not much is written about what actually happens to the brain and the child's motor pattern of movement. A few years ago, I was part of a research group that investigated this problem and defined the clinical condition of Developmental Apraxia. (6) This brain "wiring" problem occurs in children after brachial plexus injury.

In the study, the investigators performed detailed neurologic examinations and neurophysiologic testing with children, many years after their brachial plexus injury. All of the children had shown some degree of functional recovery. Their movements were not normal, but they did have movement. When the testing actually measured how much nerve they had, it was a surprise to find that they had the potential for much more function. In other words, the nerve had regenerated enough for normal functional levels, but the child's function was far below normal. The children were not using the nerve that they had!

In the report of the study, we hypothesized that this was because the child did not "know" how to use the arm. They had not been able to move the arm during the

time when the brain "wires up" the motor area. Years later, when the nerve and muscle reconnected, the child did not know how to use the newly restored nerve function. This is another key difference between children and adults. Children do not "know" what is normal. After an injury, children develop their own movement patterns. As the child with a brachial plexus injury grows, they will use whatever they have to cope. They compensate and by doing this, they create abnormal movement patterns that become their habit, their normal. What is "normal" for the child recovering from brachial plexus injury is not what we consider normal. Their habitual movement pattern is what is normal for them.

The new understanding taught in the Model for Recovery is that these habits can actually hide recovery. In the first picture you see a young man with a right brachial plexus injury. He has been asked to lift his arm up. He lifts it to the limit of his voluntary movement. Then he is asked to do jumping jacks. In this test, he can easily lift the arm above the head. The nerve function sufficient to allow normal movement is present. When asked to do the movement, he uses his HABIT. When challenged with a different movement pattern, jumping jacks, he uses all that is available and low and behold, he can lift up his arm.

Figure 2a (left)
(Caption) Respond to the request "Raise both your arms over your head." Note limited reach on right and compensatory movements of his trunk. (end Caption)

Figure 2b (below)
(Caption) Note range of right arm movement during "jumping jacks", a non-habitual movement pattern. (end Caption)

The Model for Recovery teaches you how to separate habit from nerve recovery. If the child can ever do the movement, then the nerve is there and the potential function is there. The fact that they fall back into their habitual movement pattern just means that you have a challenge in front of you. We need to inhibit, or knock out, the old habits and then re-teach new movement patterns.

At this point, the house comparison would be how you, as a family, chose to live in the brand new home. How you turn that house into your home. In the healthcare field, there are your physicians, physical and occupational therapists, and the techniques of EMG Biofeedback, FES, EMG-FES, Kineso-Taping, Constraint Therapy, Brain Substitution Therapy, Sports Therapy, Music Therapy and more. One of the most interesting mew techniques is called EMG/NMES or EMG/FES. (7) In this technique, the EMG signal from the recovering nerve is used to "turn on" a neuromuscular stimulator to complete the movement. As the performance improves, the therapist can change the settings to bring in more and more of the patient's own neuromotor system. All of these approaches and techniques can be used to access the "hidden" nerve recovery underlying your child's habitual movements. This work is based on the concept of activity induced neuroplasticity - now applied to BPI. (8)

One of the most exciting areas of development in this part of the Model for Recovery is the use of Botulinum injections (BOTOX, MYOBLOC) to temporarily inhibit habitual movement and allow a retraining of new movement patterns. (9) Part of changing habitual function is learning that it takes a lot of repetitions to change a habit. We as adults know how hard it is to break some of our bad habits. Even professional athletes, with perfect neuro-motor systems, need 5000 to 10,000 repetitions to change a motor movement. It is near to impossible to change habits working only once or twice a week in therapy. The Model for Recovery teaches new and innovative technologies that can be used to produce the number of repetitions needed to rewire the brain and improve function.

Good Enough or Best Possible?

I think the benefit of the Model for Recovery for professionals is pretty obvious. In one short course, they can get up to date information and understand the options now available at the beginning of the 21st century. I was surprised to find that some parents were not sure why they should attend. They asked me, “Why do I have to go to this? Why can't the professionals do this? I am a parent. I am not a doctor etc. etc. etc.” Well, the truth of the matter is that the parent is the holder of the child's vision until the child is old enough to create their own vision. The house building analogy lets parents understand why they have to be the head coach of their child's recovery. My architect/designer could not build my house unless I told him what I wanted in the house. What are your goals for your child's recovery? Are you willing to settle for “good enough” or are you going to go for "best possible" recovery?

I am not a very political person and in Canada, we do not have Presidential Elections. Maybe it is because we do not have such spectacles, that I enjoy watching the conventions. President Bush made a very interesting statement in his recent nomination acceptance speech. He said that one of his goals was to challenge the "soft bigotry of low expectations". He was referring to the reality that some people do not have high educational expectations of children born in poverty. It struck me that within pediatric rehabilitation, we may also suffer from the "soft bigotry of low expectations”. People who dismiss or minimize the impact of OBPI by saying "It is only the arm." or "Aren't you lucky it isn't worse." are expressing a low expectation for recovery.

A last word or two about communication between all your heath care professionals. In the process of house building, each expert has their own area of training and expertise. Each can explain their work and what they have to offer to the overall process of building a house. But each expert in house building can only speak from their area of training and expertise. No one expert, no matter how good, is going to have all the answers. You would not ask an electrician to solve a plumbing problem.

In brachial plexus rehabilitation, each health professional speaks to you from the perspective of their own training and expertise. As a parent or an adult survivor of brachial plexus injury, you need to integrate all the available information into a plan that is workable for you, your child with BPI and your family as a whole. The Model for Recovery is not rocket science. It is a simple, easy to understand framework for action. From this base, you can learn to choose intelligently from all the wonderful treatments, surgeries, and technologies that are now available to help the child and adult with brachial plexus injury.

"The Future is Not What It Used To Be."

Please visit www.tascnetwork.net for more information on the Model for Recovery from OBPI.

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