Neuromodulation Therapies for Lower Urinary Tract Symptoms

Neuromodulation has been introduced as a new and effective treatment for selected patients with refractory forms of lower urinary tract dysfunction. Neuromodulation is a non-traditional therapy and as physicians, we are typically slow to adopt new practice patterns until the scientific basis for the therapy is defined and familiar. This article will discuss some of the common factors that provoke lower urinary tract symptoms and it will provide a rationale for using neuromodulation for patients who have failed conventional therapies.

The Urologist is the physician of last resort for patients with persistent lower urinary tract symptoms. Many conditions are clear. The diagnosis can be made with confidence by appropriate history taking and targeted physical examination. For some the diagnosis will be confirmed by objective tests such as urinalysis, cystoscopy or imaging studies and effective treatment will resolve the symptoms. For others, the diagnosis is less clear and traditional treatments seem to offer little relief.

Our tradition is to look for the cause of symptoms or evidence of disease - within the urethra, prostate or bladder. It is now clear that some of the clinical problems that we see in patients with lower urinary tract and pelvic symptoms are due to abnormal patterns of muscle activity in the pelvic floor. For these patients the traditional evaluation of the lower urinary tract may be unremarkable, but the symptoms are moderate or severe and recurrent or persistent. The lower urinary tract rests upon and is contained within the pelvic floor. Disorders of pelvic floor muscle will produce lower urinary tract symptoms.

Muscles are comprised of populations of similar motor units. Each motor unit is an oscillator – that is to say that at any moment in time, each unit is in one of two states – contraction or relaxation. The duration of contraction is constant for each motor unit, but the interval of relaxation between contractions is variable. In the pelvic floor, there are muscle groups on the
right side and on the left. The two sides may be similar or dissimilar just as feet may be symmetrical or asymmetrical.

There is a natural resonance of activity in all muscle systems and there are factors that lead to aberrant activity rather than normal firing patterns. Coupling of motor unit firing would provoke symptoms. When the units all relax at the same time, there will be urinary incontinence. When the units are all cycling in activity the muscle will be “locked on” to produce urinary retention. Asymmetrical states would produce symptoms of urinary urgency and frequency with or without incontinence. Neuromodulation is the use of technology to modify the rate and patterns of neuromuscular activity in order to relieve or resolve lower urinary tract symptoms.

**Pelvic floor muscle function**

The pattern of design for all muscles is broadly similar – a composite of a number of similar anatomical and functional elements. Each element is called a motor unit and consists of a single motor neuron, its axon with motor end plates and the respective muscle fibers. For muscles of the eye there are only very few muscle cells in each motor unit, but for anti-gravity muscles and muscles of posture such as quadriceps there may be hundreds of muscle cells in each motor unit.

The activity of the motor units is not static. (Fig.1) It is dynamic and changing. The changing patterns of activity are reflected by the sounds of electromyography (EMG). The sounds of the urethral sphincter EMG will range from complete silence during the act of voiding by volition, through quiet sounds at rest with an empty bladder. With bladder filling EMG activity increases with louder sounds and finally crescendos of activity will occur with coughing or straining. The steady increase in activity that occurs during the filling phase of cystometry is called recruitment. Computer analysis of motor unit action potentials (MUAP) of urethral sphincter during cystometry provides an accurate measure of recruitment. (Fig.2)

If we consider the muscles of the pelvic floor, there is a possible contribution of nerve impulses from the left and from the right. Just as in the muscles of the face - innervation will be from one side or the other. There is no population of motor neurons in the absolute mid-line of the nervous system - all are either on the left or the right.
More about Firing Patterns

In the resting state, only a small fraction of the total number of motor units will be firing and the great majority of units will be at rest – available to be added as needed when the demand is increased. With an increase in activity, there might be an increase in the rate of firing of the low threshold units (these are the first of the hierarchy and are usually the smaller units). With an increase in activity, there might also be recruitment of medium sized and higher threshold motor units (midsize and large). As the number of units firing increases, the number of inactive units will decrease and the population of uncommitted (available) units will decrease.

Each muscle cell can be active for a time and then there must be an obligatory interval of recovery. It would be reasonable to liken the muscle cell(s) of the motor unit to a matchstick that needs a certain stimulus of striking to ignite (an all or nothing response). The match will burn for an interval according to its characteristics small or large, paper or wood (fast twitch or slow twitch fibers). When the energy source is exhausted the match-flame will be extinguished (end of contraction). In the muscle fiber, the energy source is rechargeable and after an obligatory interval of recovery (latent period), the cells will effectively become available and able to contract again when the next stimulus arrives.

In the muscles of the pelvic floor, we are dealing with a population of units not a solitary one. It might be helpful to think of this more as a division of infantrymen each with a single shot musket. After firing each must reload before firing again. The active elements would be those that are firing and the inactive would be those who are ready to fire. At a slow rate there would be an intermittent pattern of firing that might be regular. As more men fire, there will be fewer available in reserve. As the firing rate is increased further, there will come a time when there is no reserve and the reloading is not finished before it is time to fire again. These individuals would be unable to maintain the pattern of firing. To the observer there would be an audible change and irregularities in the sound as the firing pattern is disturbed.

It is clear that there are predictable factors that would influence the behavior of a group of oscillators whether infantrymen or motor units. The number of elements in the group would determine the range of activity. The greater the number of elements, the greater or more versatile would be the range of activity. The rate of firing would determine the stress/strain/pressure in the
system. The slow firing rate would be easy to maintain and the faster rates
would be more difficult.

The nervous system is organized in networks that are called central pattern
generators (CPG). These neural networks determine the pattern, the order
and frequency of firing for each motor unit. For familiar movement patterns
like walking there is integration of many independent oscillators that serve
to coordinate the activity of sequential muscle groups for the right and the
left. The nervous system will link together huge circuits of oscillators at
different levels in the spinal cord segments, which interact with one and
other to create complex movement patterns.

These neural networks have been studied exhaustively in animal movement
patterns. Investigation of these networks has helped to explain how it is that
a horse can transition from a pattern of slow walking to a trot, then a canter
or a gallop according to the rates and pattern of firing. In these more
complex movements, the firing patterns are working alternately for right and
left and in phase or out of phase for synergistic muscle groups and their
antagonists. It is the CPG that directs which motor units are activated and in
what order.

Patterns of recruitment and Lower Urinary Tract Symptoms

In the course of an activity such as walking, there is a dominant rhythm or
resonance in the pattern of CPG activity. As that activity is sustained in the
primary muscles of locomotion there will be effects on the adjacent muscle
groups also. In walking, there will be phasic oscillation of activity in the
long flexors and extensors of the hip and also the gluteals and in the short
muscles around the hip joint (pyriformis, and short rotator muscles) and in
the pelvic floor muscles. This walking rhythm will be the dominant
influence and the alternate left and right firing patterns will be reflected in
the activity of the pelvic floor muscles so long as the walking movement is
sustained.

In the act of walking, there is an obligatory firing pattern for the muscles of
the pelvic floor. At any one moment in time, the resonance of the firing
pattern of the motor units of the pelvic floor will be dictated by the wider
activity of the adjacent major muscle groups. It is clear that the locomotor
pattern is dominant, because so long as the activity is sustained there can be
no relaxation of the pelvic floor. This is in contrast to the movement patterns
associated with activity such as skip rope jumping or bouncing on a trampoline. In these activities there is simultaneous activity of the right and left sides acting together. It is these movements that are most likely to result in urinary leakage, because the right and the left pelvic floor muscles are working together at the same moment and must relax together - instead of in an alternating pattern.

We should emphasize that in order to initiate the act of voiding there must first be relaxation of the pelvic floor muscles - both the right and the left. It would follow that if relaxation was blocked by alternating activity of right / left / right / left, it would be more difficult to initiate the act of voiding. In clinical observations this appears to be true. It is impossible to empty the bladder while continuing to swim with the lower limbs. For the marathon swimmers, it is necessary to stop kicking with the legs in order to initiate and sustain the urinary flow. In the swimming pool, it is the child who is standing still in the water that may be passing urine rather than the ones that are actively playing or swimming.

**Symptoms of urge incontinence**

Consider “key in the door” incontinence. The patient has been away from home and returns with a nearly full bladder. The pelvic floor muscles are active due to reflex up-regulation by the bladder filling. Activity is also increased by the standing position and the burden of a loaded shopping bag. Symptoms may not be prominent during walking, but at the door the patient stops and stands still. The CPG of walking movement is stopped and motor units revert to a default pattern of activity.

Already the muscle is moderately active and there may be a sense of pressure or urgency, but it is still manageable. In an effort to prevent leakage, the patient grips with the pelvic floor and drives the uncommitted / resting motor units to become active. This activity will drive the pelvic floor muscles towards all units being active and this is followed by obligatory relaxation. Relaxation will effectively open the urethra and there will be a flood of leakage.

To avoid leakage, we should encourage the patient to adopt an alternating pattern of muscle activity that uses the right and then the left. Instead of stopping at the threshold encourage walking on the spot and instead of gripping with the pelvic floor, try to avoid contracting the muscles. It is
critical not to grip or “hold on tight” because it is the very act of gripping that will increase muscle activity and drive the motor units further into synchrony. Patients should be encouraged to concentrate on creating and sustaining an alternating pattern of muscle activity between the right and the left. In that way you will recreate the resonance of a sustained rhythm in the CPGs and urgency will pass and leakage will be avoided.

Neuromodulation – How does it work for urge incontinence?

Neuromodulation can modify nerve function and motor unit firing patterns for the relief of symptoms. Imagine the effects of an obligatory electrical stimulus on the activity of the pelvic floor muscles. The axons closest to the electrode would be most influenced by the electrical discharge and most likely to depolarize creating propagating impulses that would pass both distally to the motor end plates and also back to the spinal cord. This would create some level of activity in the muscle. With repeated stimulation there would be repeated contractions of that population of motor units.

The effect of an obligatory stimulus would create a pattern of repeated contractions, such that there would be no absolute relaxation. This might be similar to the firing pattern that would have been created by CPG activity such as walking or swimming. The result would be to maintain a low level of activity in the muscle and thus resist the possibility of urinary leakage.

The success of neuromodulation for urge incontinence is easier to understand when the mechanism of action is clear. The effect is most clearly seen when we observe the electrical activity of the pelvic floor muscles. The clinical benefits of neuromodulation for urge incontinence are usually evident soon after test stimulation. Many patients report relief of symptoms in the first hours and certainly in the first days after placement of test leads.

In urological practice, neuromodulation has been applied with equal success for symptoms of urgency, urinary frequency and even for urinary retention. It is difficult to imagine how it is that a therapy that will stop urge incontinence will also promote effective bladder emptying. We must look more closely at the mechanisms of urinary retention to understand why this might be so.

Symptoms of voiding difficulty and urinary retention
The activity of the neural networks generates and controls the firing patterns. The CPG determines the activity of muscle groups and the rate of firing at any moment in time. The rate of firing is increased by reflex activity (bladder filling) and postural changes (supine, sitting and standing). (fig 1) Further the patient can increase or decrease muscle activity by volition. (fig. 2) In health, at times of rest, the system will slow down and the firing rate will default to a random asynchronous pattern.

We are familiar with synaptic transmission. This is the normal mechanism to induce muscle fiber contraction. The motor nerve is depolarized and the action potential is transmitted down the axon to the motor end plates. At the nerve terminal there is release of a chemical transmitter (acetylcholine) from storage vesicles and it diffuses across the narrow cleft to the muscle cell to induce a chemical cascade of events in which the interlocking linear proteins of actin and myosin move to create the physical changes of shortening – muscle contraction.

Synaptic transmission is the normal nerve to muscle mechanism that will induce muscle contraction, but there are also abnormal mechanisms. (ref) Ephaptic transmission is activity that spreads directly from muscle cell to muscle cell. In ephaptic transmission, the electrical events in one muscle cell can “spill over” to an adjacent cell territory and provoke or facilitate depolarization. In this abnormal situation, instead of depolarization coming only from nerve axon to motor end plates to muscle cell, there are also interactions between adjacent motor units. Depolarization of one muscle cell can trigger depolarization of its neighbors.

These mechanisms provide opportunities to disturb the firing pattern. Ephaptic transmission may occur that can influence activity to promote or inhibit adjacent motor units. Urethral sphincter EMG is changed dramatically by ephaptic transmission. The sounds have been called repetitive high frequency discharges and sound like a racing motorcycle or dive bomber that is accelerating towards you and then away and back again in repetitive cycles of activity. (ref)

To explore the effects of ephaptic transmission, consider the crowd in a sports stadium. Under most conditions, activity in the crowd is random and asynchronous. Individuals or small groups might stand and cheer at different times. At other times, there might be a propagating “wave” that makes its way around the arena. The wave occurs as one large group stands together at
the same time. The neighboring spectators at the edge of the group will then stand also. As the first group sits down, the spectators that were sitting at the progressing edge of the standing group move to stand. In this way, there is a wave of activity that will often travel round and round the stadium.

In this example, each spectator is an oscillator – in one of two states either sitting or standing. As the system becomes excited, the behavior can change. As the activity of adjacent oscillators becomes coupled, they will tend to act together and there is a tendency to propagate a new state or create a new behavior. In the stadium, you can observe the events that might tend to create or extinguish the wave. A home run might bring many to their feet all at once, before the advancing wave arrives and the wave will become weaker or may dissipate.

In the pelvic floor and sphincters, we have small circular muscles that are not unlike the stadium. Ephaptic transmission of depolarization could spread like a wave around the muscle. After contraction there would be obligatory relaxation for each muscle cell, but the interval to recovery would be passed before the advancing wave returns. In the pelvic floor, this activity could be self-sustaining and persist for extended intervals.

The impact on function would be predictable. If there were a perpetuating wave of activity traveling round and round the muscle, there would be no opportunity for coordinated relaxation. Ephaptic transmission interferes with normal voiding. It is associated with voiding dysfunction, incomplete emptying or urinary retention. Fowler has described the urethral sphincter EMG in young women with unexplained urinary retention. These abnormal patterns are not rare and have been recognized and reported men with urinary retention. (ref)

**How does neuromodulation work for retention?**

Neuromodulation provides obligatory repetitive stimuli that provoke contraction in some motor units out of synchrony with the wave. Those cells that have been active in the moments before the advancing wave will not be able to contract again with the ephaptic depolarization because of the latent interval that must occur between each contraction. Over time with persistent neuromodulation, the abnormal “wave” will tend to be extinguished and the muscle might be unlocked and accessible to respond to synaptic influences.
When the abnormal activity is eliminated, the sphincter will be released and more normal function will be restored.

In practice, it is the patient with urinary retention who tends to be slower to gain benefit from test stimulation. It might take two or three weeks of neuromodulation before improvement is noticed. This is to be expected because it might take a longer interval of stimulation to dampen and extinguish an established wave of ephaptic transmission.

It would be unreasonable to make too many assumptions about these mechanisms, because the complexity of cell-cell interactions is great and as we move to consider neural networks and CPGs the interactions become formidable. It is possible that coupling of motor unit activity might occur at higher levels within a spinal segment or between adjacent spinal segments. It is possible that afferent fibers from the lower urinary tract have an influence. Neural activity from adjacent organ systems such as the anus and rectum or uterus and vagina might also contribute to activity in the neural pathways.

When we look for causes for lower urinary tract symptoms, we have a narrow perspective focused on the bladder and we might assume the integrity of the innervation unless there are obvious external signs of a neurogenic deficit. When the structures appear to be normal, the urologist might consider psychological or behavioral causes, but fail to consider a defect of the neurological structures.

**Innervation of pelvic floor muscles**

The traditional view of the physician conducting a physical examination is to start at the head of the patient and extend to the feet. Examination proceeds in an orderly way from above and ends at the feet. The physician’s view is not at all the same as the nervous system’s view of the body. The spinal cord is organized in a highly ordered stepwise pattern and all of the segments of the body are represented by corresponding segments of the spinal cord. (fig. 3) When the physician stops at the feet, the most caudal segments of the nervous system are excluded. This traditional perspective has failed to include the whole patient. Just as the familiar view of a ship extends downwards to the water line, but excludes those parts that are concealed by the water. (fig. 4) The innervation of the pelvic floor is from the terminal sacral segments of the spinal cord – S 3,4 and 5. If we are to recognize
neurological deficits in the most distal segments— we must include these areas in the examination.

There is remarkable variation in the distal human spinal cord and variation in the caudal structures, such as the sacrum. There is a wide range of neuromuscular structures in the pelvic floor and a corresponding range of function from one patient to another. The perfect muscles have a full complement of nerve and muscle structures and possess a full and versatile range of function. Patients with a perfect complement of structure do not have symptoms. It is those who have less than the perfect complement that lack full versatile, coordinated function, muscle strength and endurance. Lower urinary tract symptoms will be prominent in those who lack an adequate complement of neuromuscular structure. Sacral neurological deficits are both congenital and acquired. This means that the impact of an acquired deficit will be felt differently for different individuals.

A deficit could be symmetrical or asymmetrical and could have a clinical effect that was only on the right or the left. The contra-lateral structures could be complete or deficient. Perfect symmetry is not to be expected in Nature, but structures should be broadly similar between the right and the left, just as one hand is broadly similar to the other. The pelvic floor is innervated from the left and the right and the two sides should be similar. Many patients have marked asymmetry in the size and shape of the feet that is reflected in similar asymmetry of the pelvic floor structures. The spectrum of deficit in nerve structures would determine the range of function that could be expected. The clinical symptoms and signs will be determined by the complement of structure on the right and the complement on the left working together. An adequate complement on one side might provide protection against leakage, but the lack on the other side might produce symptoms of frequency, urgency and voiding difficulty.

**Symptoms of urinary frequency and urgency**

The work of a muscle is shared between the motor units. Some are contracting while others are not, passing the load and sharing the work. When the activity of the muscle increases with recruitment, the number of active motor units will become larger and the number of inactive or resting units will become smaller. At any moment the reserve of available units will be the population of resting motor units. As we look for the causes of urinary frequency and urgency, we should include the pelvic floor muscles as a
possible source for symptoms. Muscle is a potent source of symptoms. How could striated muscles cause urgency?

Consider this exercise. Hold your arm out straight in a constant outstretched position and hold it steady. At first it is easy and feels effortless, but as you hold the same position, the arm begins to feel heavier and there is a sensation of pressure. With time, the pressure feeling will continue to build. After a little while, there will be a strong feeling that you cannot hold on, that you must let go! This feeling is very similar to the urinary urgency described by patients who will often state that they feel pressure and later that they just cannot hold on and must let go!

How do you avoid the feeling of pressure in the outstretched arm? You do it by changing position or creating a rhythmic pattern of movement. This will restore an on/off pattern of activity such as swinging the arm. This will have the effect of resting some motor units and using others to create a resonance of activity that can be sustained for an indefinite interval without stress. Changing position is key. For the muscles of the pelvic floor there is less opportunity for movement and the factors that increase muscle activity are more related to position, activity and visceral reflexes. In the lower urinary tract, the striated muscles of the urethral sphincter and pelvic floor might have a potent role in provoking symptoms of urgency that would in turn lead to urinary frequency. It is possible that increasing activity in the urethral sphincter might create a sensation of needing to go - a sensation that one cannot hold on any longer.

For each individual, the range of muscle function will vary according to the number and size of the motor units that are present and available to be recruited. The completeness of nerve and muscle structures in the lower urinary tract and pelvic floor will determine the number of motor units and in turn dictate whether the sphincter has a full versatile range of activity or a more limited range. In essence the muscle cells are divided up between the nerve fibers so that one muscle fiber receives an innervation from just one axon, but one axon might supply one or more muscle fibers. Each motor unit is capable of contraction, independent of the others. If the full complement of nerve fibers is present, the muscle will be divided into a large number of separate units of function. Methods have been developed to measure the number of motor units using EMG analysis. (ref)
The full complement of structure will provide the full versatile range of function. There will be the possibility of fine regulation of muscle activity with the addition or subtraction of just one motor unit. Each motor unit would contribute only a tiny increment of variation. Further it would be expected that the central regulation and modulation of motor function would be influenced by the complement of motor units. A larger number of neurons in the spinal segment would support a larger number of synapses for transmission of modulating impulses from the higher centers.

These quantitative differences between individuals may help to explain some of the variation in bladder function that we observe in children. It is in the early years when the complement of neurological structures will be incomplete that full versatile function will be lacking. As maturation occurs and the maximum number of motor units is reached there will be a plateau in function. For those who are blessed with the best of structure, full function will be assured and will come early. For others who might lack some number of nerve elements “maturation” will be slower. For some who might have more than a subtle deficit, the range of function will always be rather less.

It is not coincidental that the most common urinary symptoms of childhood are just the same as we are discussing - urinary frequency, urgency, leaking episodes and voiding dysfunction. These are also the most common symptoms of the aged who will have been losing some of the nerve cell complement as a result of natural attrition or disease.

**How does Neuromodulation work for Frequency and Urgency?**

Neuromodulation will not change the absolute number of motor units, but it will change firing patterns. We have considered some of the abnormal firing patterns. The most common aberrant behavior in any system of oscillators is called coupling. Coupling is the tendency of adjacent units to act together rather than independently of one another. Just as on a piano keyboard, when the keys may begin to stick together and as one note is played, more than one note is sounded.

Coupling is a universal feature of all oscillators and has been studied in various biological and medical systems. In the heart, it is coupling of adjacent cardiac muscle that leads to common and sometimes fatal dysrythmia. In the brain, it is coupling that can initiate involuntary
movements and epileptic seizures. In skeletal muscle, it is coupling that will provoke involuntary movements or painful muscle cramps.

In the pelvic floor, coupling of two or more adjacent motor units would mean that with activation of one of the units – all of the group would act together. The effects of coupling would be to reduce the number of independent motor units in the muscle and to increase the functional size of motor units. This would convert a more versatile muscle into a less versatile one. The range of function that might have been within normal limits will be reduced in the presence of coupling. The behavior of the muscle will now be different from before, but this change might be temporary and reversible.

This view of the pelvic floor as a population of motor units with firing patterns could help to explain why a single episode of urinary tract infection might provoke symptoms of urinary urgency and frequency that persist after resolution of the infection. The trigger event has increased motor unit activity and provoked coupling of adjacent elements that might persist even after the infection has resolved. These episodes are common. In children, sudden onset of symptoms can occur without evidence of a significant trigger event. In women, sexual activity or vaginal infection can be a trigger. In the elderly fecal impaction or urinary retention could be a trigger event. Instrumentation of the urinary tract or passage of a urinary calculus through the distal ureter could be the trigger event for some patients.

There may be predictable outcomes that are determined at least in part by quantitative features of the oscillator system. For the muscle, it would be expected that the larger the number of motor units, the greater the trend would be to default towards a random firing pattern – the normal state. In the same way, it would be predictable that some diversity in the size of the individual motor units would provide resistance to abnormal firing patterns. If the firing rate of the muscle is slower the firing pattern will tend to default towards the normal state of asynchrony.

Conversely, with a smaller number of motor units and less diversity in the size of the units, the firing pattern might tend towards synchrony. That would mean that instead of just a few units firing at any one time, the motor units would tend to become active together and then they would relax together. The act of gripping or squeezing with the muscles would commit more of the units to be active and would drive the activity towards greater
synchrony. Coupled units could be locked in phase with other coupled units forming larger clumps.

This muscle would have far fewer functional motor units and the size of each unit would be much larger because each coupled unit includes more than one motor unit. This would provide a range of function that would be much less versatile because although there would be a range of activity, the individual increments would be fewer and the size of the increments would be larger. The smallest increment of change would be the addition or subtraction of coupled motor units. The severity of the dysfunction would be proportional to the absolute number of coupled motor units.

A change in firing rate could be one factor that would drive the system towards coupling. Symptoms may be exacerbated by voluntary or by involuntary events. The impact of “stress” and endocrine stimulation such as adrenaline or hyperthyroidism could serve to up-regulate these mechanisms. Ingested agents such as spicy foods, sodas and caffeine might have their effects on threshold potentials thus increasing the firing rate and amplifying the symptoms.

Neuromodulation would provide an obligatory motor stimulation that might work to combat inhibit or reverse coupling. This is analogous to the use of pacemaker technology to combat arrhythmia and restore effective cardiac output. It seems likely that neuromodulation may help to uncouple the motor units and restore a larger number of functional motor units.

Neuromodulation can modify nerve function and motor unit firing patterns for the relief of symptoms. The early work was in spinal cord injury by Brindley in England and Nashold in US. The Brindley-Fiengold technology is in clinical use for spinal cord injured patients. In general urological practice, neuromodulation has been applied to problems of incontinence, urgency, frequency and incomplete bladder emptying. The current methods use implantable electrodes and internal pulse generator. (Medtronic Interstim) Peripheral nerve stimulation has been used. (Sans) With the development of electromagnetic systems, it is now possible to modulate nerve and muscle activity of the pelvic floor using a non-invasive magnetic field flux -Extracorporeal Magnetic Innervation (ExMI). These technologies are distinct, but complimentary.

Interstim Sacral Nerve Stimulation
Interstim therapy is attractive, not only because it offers an effective solution to some patients who have been resistant to all other treatments, but also because success is predictable by pre-operative percutaneous testing. Surgical implant is only appropriate when the preliminary test interval produces significant relief of symptoms. If the symptoms are resolved using a quadripolar electrode and an external stimulator, placement of the internal pulse generator (IPG) will always be successful.

Optimal placement of the test electrode is marked by three factors. These are the motor reflex, the sensory distribution and the thresholds for sensation and muscle contraction. An effective “bellows” contraction of the pelvic floor should be demonstrated with stimulation. This motor reflex is usually best elicited by access through the third sacral foramen.

A strong pelvic floor muscle contraction will draw up the anus and perineal body and there will typically be some contraction of the small muscles of the feet or flexion of the toes with increased stimulation. Without a bellows type pelvic floor muscle contraction, stimulation is unlikely to result in a satisfactory clinical response. This would support the suggestion that the pelvic floor muscles might be a primary cause of some “bladder” symptoms, rather than the urinary bladder itself.

With stimulation, the patient should feel a sensation in the anterior perineum, scrotum, vagina or urethra. If the sensation is limited to the posterior perineum, anus or buttock the placement is likely to be too distal (S4 rather than S3). Use of fluoroscopy facilitates optimal electrode placement. The threshold for the motor reflex and sensory awareness of stimulation should be low. This would suggest that the energy needed for chronic stimulation will be small and the life of the IPG battery will be longer - greater than 10 years. The surgical implant has been simplified by improved electrode design and anchoring mechanism. There is no need to dissect for electrode placement and most patients tolerate the procedure using only local anesthetic.

Stoller Afferent Nerve Stimulator (SANS)

This minimally invasive therapy uses electrical stimulation of the posterior tibial nerve at the ankle for relief of bladder symptoms. A needle is placed at the medial aspect of the ankle and stimulation is done in the clinic for
intervals of 30 minutes and may be repeated at weekly intervals for 12 weeks. There is no special training and no complex equipment is needed. Published reports suggest short-term benefit in as many as 71%. (ref) Long-term results are not known.

Extracorporeal Magnetic Innervation (ExMI)

ExMI uses a pulsed magnetic field within the seat of a chair for pelvic floor therapy. Neotonus Inc. The first application of ExMI was for stress incontinence.(ref) Randomized study against sham treatment has demonstrated improved outcome for ExMI for those who failed pelvic floor muscle exercise (ref). Pulsed magnetic stimulation has been demonstrated to improve symptoms of urinary frequency, urgency and urge incontinence. (ref) The benefits for urge incontinence and frequency have been confirmed in placebo controlled trial.(ref)

ExMI is attractive for patients because it is non-invasive painless and easy to use. The patient sits fully clothed on the chair for treatment and sessions are less than 30 minutes. The use of on-screen interactive video tools provides an opportunity for teaching the patient about fluids, timed voiding, diet and bowel care during therapy. Patients can be taught comprehensive strategies for continence care including muscle exercises and strategies to prevent leakage. ExMI therapy is safe and well accepted by patients and physicians.

For patients who have mild to moderate incontinence and have failed initial management with Kegel exercises, ExMI may be an effective treatment. (ref) If the dysfunctional activity can be uncoupled by non-invasive therapy, there will be relief of symptoms. Those who prefer electrical stimulation may use Sans. For persistent or severely disabling symptoms, that have failed traditional therapies, a permanent implant for chronic stimulation may be necessary (Interstim).

In health there is a wide range of neuromuscular structures in the sacral segments of the spinal cord and a corresponding range of function between individuals. The perfect muscle has a full complement of nerve and muscle structure and possesses a full and versatile range of function. It is a challenge to understand more about neuromodulation and how to apply these technologies for optimal effect. It seems likely that some problems lie with our incomplete understanding about the neurobiology of the lower urinary tract and pelvic floor.
It is early days, but these technologies have already changed our clinical practice and improved the outlook for many patients. Neuromodulation is not a panacea for all lower urinary tract problems. Some patients will respond with rapid relief and others will be resistant, but the technology is safe and easy to use. Test stimulation is without risk. These therapies are well tolerated by patients. The skill set is well within the reach of the practicing Urologist and reimbursement is available from Medicare and most major carriers. It is likely that neuromodulation therapies will grow to have an established role in urological care and the management of lower urinary tract and pelvic floor symptoms.

Legends for Figures

Fig. 1 Cystometry of male patient with concentric needle EMG recording of urethral sphincter during filling

Fig. 2 Analysis of upper centile amplitudes of EMG demonstrating changing activity with volitional contraction with bladder full and empty

Fig. 3 Diagram of spinal cord and corresponding body segments. L2/3 moves hip, L4/5 knee, S1 ankle, S2 long flexors of toes, S3 intrinsic muscles of feet and S3/4/5 moves pelvic floor and sphincters

Fig. 4 Our familiar view of patient and ship excludes the lowermost elements

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