**Review Article**

**Neuromodulation for the treatment of urinary incontinence**

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**Abstract:** Neuromodulation has been reported to be effective for the treatment of stress and urgency urinary incontinence. The cure and improvement rates of pelvic floor neuromodulation in urinary incontinence are 30–50% and 60–90%, respectively. In clinical practice, vaginal, anal and surface electrodes are used for external, short-term stimulation, and sacral nerve stimulation for internal, chronic (long-term) stimulation. The effectiveness of neuromodulation has been verified in a randomized, placebo-controlled study. However, the superiority to other conservative treatments, such as pelvic floor muscle training has not been confirmed. A long-term effect has also been reported. In conclusion, pelvic floor exercise with adjunctive neuromodulation is the mainstay of conservative management for the treatment of stress incontinence. For urgency and mixed stress plus urgency incontinence, neuromodulation may therefore be the treatment of choice as an alternative to drug therapy.

**Key words:** electrical, magnetic, neuromodulation, overactive bladder, therapy, urinary incontinence.

**Introduction**

In the 3rd International Consultation on Incontinence held June 26–29 2004, Committee 16 reported that neuromodulation may consist of the use of nerve stimulation and injectable therapy (Botulinum A toxin). However, such neuromodulation usually includes nerve stimulation therapy. Therefore, we herein review exclusively the use of electrical or magnetic nerve stimulation therapy for the treatment of urinary incontinence.

Since Caldwell first used implantable electrodes for electrical stimulation to treat urinary incontinence, electrical stimulation has been recognized to be effective for urinary incontinence. Neuromodulation has been reported to be effective for the treatment of both urgency urinary incontinence (UUI) and stress urinary incontinence (SUI). However, neuromodulation has not been widely accepted as a first-line treatment for urinary incontinence because little physiological and technical information has yet become available, and it also tends to be used when other methods have failed.

For the treatment of UUI, the treatment of choice has been drug therapy using anticholinergics. However, these drugs are sometimes associated with adverse events, such as dry mouth, dyspepsia, nausea and constipation. The cure rate of bladder training varies from 25% to 97%, possibly depending on the patient’s cognitive ability or motivation. Neuromodulation may be an effective alternative to drug therapy for urgency incontinence. For the treatment of SUI, pelvic floor muscle training (PFMT) has been widely accepted as a first choice of treatment. The improvement rates of SUI by PFMT have been reported to be 50–70%, but the cure rates are no more than 15–30%, and a low patient compliance (dropout rate of 39%) has also been reported. If patients can contract their pelvic floor muscle (PFM) sufficiently, then voluntary contraction may be more effective than electrical stimulation. However, more than 30% of women with SUI have been shown to be unable to contract the PFM on their first attempt. Electrical stimulation is effective in patients who are initially unable to identify and contract the correct PFM. Clenbuterol, a β2-adrenoceptor agonist, has been reported to be effective for SUI. However, the effect of this drug is limited to mild–moderate SUI. Biofeedback training is effective for controlling the correct contraction of the PFM and in visualizing the strength and duration of any contraction, however, it is time-consuming and the patient’s motivation is essential for this treatment to be successful. Surgical procedures have been used for severe SUI. The success rate in pubovaginal sling or tension-free vaginal tape or trans-obturator tape has been reported to be 80–90% at follow-up of 6–51 months. However, these surgical procedures sometimes cause complications, such as bleeding, pelvic pain, voiding difficulties, and de novo or persistent UUI. Neuromodulation can be an alternative to these conservative therapies or surgeries for SUI. A combination of PFMT and neuromodulation can be more effective than monotherapy, and it can reduce the duration of the neuromodulation.

In this article, we review the current published reports on the effectiveness of neuromodulation and evaluate its effectiveness for the management of urinary incontinence.

**Mechanisms of action**

The mechanism of neuromodulation for SUI is the contraction of the PFM through an effect on the muscle fibers as well as through the stimulation of the pudendal nerves. The mechanism for the treatment of the overactive bladder, including UUI, has been reported to be the reflex inhibition of detrusor contraction by the activation ofafferent fibers within the pudendal nerve by three actions, in effect, the activation of the hypogastric nerve, the direct inhibition of the pelvic nerve fibers within the sacral cord, and the supraspinal inhibition of the detrusor reflex. Usually the pudendal nerve is stimulated either directly or through the skin of the perineal area, intravaginally or intrarectally, but the stimulation of the thigh muscle is also effective for bladder inhibition.

The electrodes for electrical stimulation are divided into two types: external (non-implantable) and internal (implantable) electrodes, and there are two methods of stimulation: chronic (long-term, continuous) and short-term stimulation. The implantation of electrodes directly in the PFM was used in the first clinical trial. The next step was external long-term treatment with an anal or vaginal electrode. The chronic (long-term) electrical stimulation is characterized by low-intensity electrical stimulation that is carried out for several hours a day for some months. By increasing the stimulation intensity level, intermittent, short-term stimulation (maximal electrical stimulation: MES) has been
developed. Currently, pelvic floor electrical stimulation is the most widely used neuromodulation for the treatment of urinary incontinence. Short-term electrical stimulators for home use are now available. For severe or refractory urgency incontinence, sacral nerve stimulation (SNS) using an implantable electrode has also been reported to be effective.\textsuperscript{27,28}

**Short-term electrical stimulation**

Short-term electrical stimulation has been widely used since Moore and Schofield first reported its effects.\textsuperscript{29} Short-term treatments have emerged with the concept relying on the carry-over effect, that is, the desired therapeutic effects have outlasted the actual stimulation, to make the external stimulation techniques more effective.\textsuperscript{4,21,23,30} For short-term electrical stimulation, external stimulation devices, such as anal and vaginal electrodes are usually used. The short-term electrical stimulation devices for home use are popular nowadays.

**Frequency and duration of stimulation**

Since a wide range of values has been successful, the optimum condition has not yet been determined.\textsuperscript{3,31} For the treatment of SUI, frequencies ranging from 20 Hz to 50 Hz, with a pulse duration of 1–5 ms have been reported to be effective for urethral closure and pelvic floor muscle contraction.\textsuperscript{25,32–34} However, there are several other protocols including stimulation at 12.5 Hz and 50 Hz, 0–100 Hz.\textsuperscript{3,30} Intermittent stimulation has also been recommended because muscle fatigue may be avoided, especially during high frequency stimulation. The on/off duty cycle used during stimulation varies; 1:2–1:3,\textsuperscript{3,35,36} 2:1\textsuperscript{37} and 1:1.\textsuperscript{34}

For the treatment of UI, frequencies between 5 to 20 Hz have been reported to be optimal for reflex detrusor inhibition, but low frequencies such as 5 Hz may cause irritation.\textsuperscript{22,33,34} Therefore, frequencies ranging from 10 Hz to 20 Hz are mostly used.\textsuperscript{25,38} However, there are several other protocols including stimulation at a combination of 12.5 Hz and 50 Hz, 150 Hz, and a random frequency of 4–10 Hz have been used depending on the investigators.\textsuperscript{3,39,40} The pulse durations varied from 0.1 ms,\textsuperscript{30} 0.2 ms,\textsuperscript{30} 0.3 ms\textsuperscript{30} and 1 ms.\textsuperscript{35}

The frequency and period of stimulation vary, according to investigators, from twice daily to once weekly, for 15 to 30 min each, and from a month to 6 weeks, or 3–5 months.\textsuperscript{21,30,36,44–47} Although the majority of studies use daily exercise programs,\textsuperscript{21,36,48} evidence from other reports suggests an optimal frequency of three to five sessions a week for muscle strengthening.\textsuperscript{25} Richardson et al.\textsuperscript{45} have reported no significant differences with regard to the efficacy between the electrical stimulation of daily and every-other-day therapy.

The optimal number of sessions needed is unknown. At least 10 treatments are recommended before the clinical effect is evaluated.\textsuperscript{3,35,36} and a session of 4–6 weeks is usually used.\textsuperscript{25,36,49} Miller et al.\textsuperscript{51} have reported that 14 weeks of stimulation is necessary before significant objective improvements are seen.

Regarding the intensity of electrical stimulation, the stronger the contraction, the better the results.\textsuperscript{52} Therefore the intensity of stimulation is usually set at the maximum tolerable limit.\textsuperscript{21,25,30,36,52}

**Pelvic floor electrical stimulation**

Vaginal, anal, and surface electrodes are used for pelvic floor electrical stimulation. The vaginal electrode is most popular for women and it is usually cylinder-shaped, and the anal electrode, which is bullet-, or hourglass-shaped, is usually used for men which fits into the anal canal and the PFM.\textsuperscript{21,22,25}

Because the intravaginal and anal plug electrodes are intolerable for some patients due to pain, discomfort or mucosal injury,\textsuperscript{21,22,23} surface electrodes stimulating the dorsal nerve of the penis or clitoris (transcutaneous electrical neurostimulation [TENS]) has been used as a less invasive electrical-stimulation therapy for bladder overactivity.\textsuperscript{18,40} The electrodes were usually positioned at the S2-4 dermatome (peri-anal region), so that detrusor-mediated voiding is most influenced.\textsuperscript{13} However, electrical-stimulation applied to the quadriceps and hamstring muscles,\textsuperscript{26} abdomen and inside thighs,\textsuperscript{35} suprapubic region and the skin directly over the third sacral foramina has been reported to inhibit detrusor overactivity.\textsuperscript{40,55} Peripheral tibial nerve stimulation (SANS), in which the electric needle is inserted directly on the tibial nerve, has also been reported to be effective for detrusor inhibition.\textsuperscript{54,55}

**Interferential therapy**

Interferential therapy produces a low-frequency stimulating current within the body while avoiding the problems of skin resistance.\textsuperscript{38,56–60} Two different medium-frequency currents of around 4000 Hz are applied to the body from different directions using four surface electrodes, so that an interferential wave can be generated by the crossing of these two currents in the bladder or the pelvic floor. The frequency of the thus generated interferential waves can be controlled from 0 to 100 Hz.\textsuperscript{38,56–60} McQuire et al.\textsuperscript{56} carried out an interferential therapy and reported that 16 of the 24 patients with stress incontinence or urinary frequency demonstrated a dramatic improvement. Yasuda et al.\textsuperscript{38} reported the superiority of interferential therapy over sham stimulation in a double-blind crossover trial in 76 Japanese patients with pollakiuria, urinary urgency and urinary incontinence. The results are summarized in Table 1. The long-term efficacy of interferential therapy with a mean follow-up of 6.7 ± 3.9 months in 16 patients with pollakiuria, urinary urgency, and urinary incontinence has also been reported with improvement occurring in 71.4% of patients.\textsuperscript{60} Currently, only

<table>
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<tr>
<th>Table 1</th>
<th>Effects of interferential therapy for 68 patients (male 27, female 41, mean age 62.7 years old) with neurogenic detrusor overactivity, idiopathic overactive bladder (OAB) and psychogenic pollakiuria (Yasuda et al.\textsuperscript{38})</th>
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<td></td>
<td><strong>Active</strong></td>
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<td>Overall improvement</td>
<td>52%</td>
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<td>Patient’s impression (&gt;good)</td>
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<td>Improvement in pollakiuria</td>
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<td>Improvement in urgency</td>
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<td>Improvement in incontinence</td>
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<td>Improvement in 1-h pad test</td>
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<td>SUI only (n = 17)</td>
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<td>Safety</td>
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<td>Improvement rates [%] on stratified analysis</td>
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<tr>
<td>Neurogenic bladder (n = 32)</td>
<td>59%</td>
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<tr>
<td>Idiopathic OAB (n = 8)</td>
<td>25%</td>
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<tr>
<td>Psychogenic pollakiuria (n = 11)</td>
<td>27%</td>
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<tr>
<td>Urodynamic SUI (n = 17)</td>
<td>65%</td>
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SUI, stress urinary incontinence.
interferential therapy using the Uromaster is approved for use in the treatment of urinary incontinence in Japan.

**Efficacies of pelvic floor electrical stimulation**

**For stress urinary incontinence**

The cure and improvement rates in SUI have been reported to be 30–50% and 60–90%, respectively. The effectiveness of neuromodulation should be verified by randomized controlled trials (RCT). However, the controlled study of physical treatments is very difficult to achieve because the use of a non-functioning stimulator as a control is too easy for the patient to perceive.

Berghmans et al. reviewed the published randomized studies, and they reported that electrical stimulation alone is no more effective than PFMT alone and that electrical stimulation plus PFMT is no more effective than PFMT alone. Bo compiled nine controlled studies from 1980 to 1996, and reported that in six controlled studies comparing electrical stimulation with PFMT, only one showed a significant improvement in interferential therapy over PFMT. The remaining five reports showed no significant improvements, but none of them were sufficient with regard to the mode of stimulation and the number of patients studied in each group.

There have been seven placebo (sham)-controlled studies for stress incontinence, of which five showed significant superiority to placebo and two did not. Yamanishi et al. compared active electrical stimulation with sham stimulation in men with post-prostatectomy incontinence and women with urodynamic SUI and they reported a significant superiority of active electrical stimulation in comparison to the sham device; the cure and improvement rates being 45% and 60%, respectively, in the active group, and 8% and 15%, respectively, in the sham group. Significant improvements in the number of leakage episodes, number of pad changes, disturbance in activities of daily living, self report of improvement and the pad test were noted in the active stimulation group, but not in the sham group. Sand et al. found that the active group had significantly improved subjective measures and significantly greater changes in the number of leakage episodes in 24 h, number of pads used, amount of leakage on pad test, and PFMT activity (perineometry) than the placebo group. In contrast, Luber and Wolde-Tsadik did not find any statistically significant differences between the active and placebo stimulation groups in terms of the rates of self-reported cure or improvement, negative stress test during urodynamics or valsalva leak point pressure, or number of incontinence episodes in 24 h. Blowman et al. compared active electrical stimulation plus PFMT versus sham stimulation plus PFMT, and found a significant decrease in the number of leakage episodes in the active stimulation group. Jeyaseelan et al. carried out a randomized, double-blind, controlled trial in 27 patients with urodynamic SUI and reported that no significant between-group differences were highlighted in the pad test or bladder diaries, but a significant change in favor of the electrical stimulation group was noted in quality of life score (Urogenital Distress Inventory: $P = 0.01$).

Brubaker et al. compared active with placebo stimulation in 121 women with urodynamic stress incontinence, detrusor overactivity, or mixed incontinence, and reported no statistically significant difference between the two groups in urodynamic SUI. Smith compared intravaginal electrical-stimulation or Kegel exercise in 18 women with SUI, and concluded that the improvement rate of electrical-stimulation (68%) was not statistically significant when compared with Kegel exercise. Moore et al. compared standard treatment (verbal and written instructions about PFMT), versus intensive PFMT versus intensive PFMT plus rectal electrical stimulation (twice a week) in 63 men with urinary incontinence 8 weeks after radical prostatectomy. Incontinence improved greatly in all three groups, but no differences were noted among the three groups in terms of the amount of urine loss at 16 and 24 weeks, or the quality of life (QOL) scores with IQ-7 or QLQ C30. Wille et al. randomized 139 patients who underwent a radical prostatectomy into three groups: those who received PFMT alone ($n = 47$), those who received PFMT plus electrical stimulation ($n = 46$) and those with PFMT plus electrical stimulation plus biofeedback ($n = 46$). The overall subjective continence percentage (questionnaire) was 21.4% immediately after catheter removal, 59.2% after 3 months and 85.9% after 12 months, and there was no significant difference between the groups. The overall objective continence percentage (pad test) was 32.9% immediately after catheter removal, 65% after 3 months and 83% after 12 months without any significant difference between the groups. Opsomer et al. compared intensive PFMT plus electrical stimulation once a week plus biofeedback training ($n = 22$), with simple PFMT ($n = 22$). No statistically significant difference was found between the two groups in terms of cure.

**For urgency urinary incontinence**

The cure and improvement rates of electrical-stimulation have been reported to be 20–45% and 55–91%, respectively. Geirsson and Fall have reported the limitations and pitfalls of the technique in a routine outpatient, the improvement rate in a 4-year routine outpatient procedure being 54%, but the cure rate being only 5%.

There have been eight controlled studies including four placebo-controlled studies. All of the placebo-controlled studies have demonstrated significant improvements in preference for the active group. Brubaker et al. compared active stimulation with placebo stimulation in a group of women with urodynamic stress incontinence, detrusor overactivity or both, and conducted a subgroup analysis on the basis of diagnosis and found that detrusor overactivity became stable in 49% of the active group, but not in the sham group. Bower et al. studied urodynamic effects immediately after an active and sham stimulation delivered both to the suprapubic and third sacral skin in women with detrusor overactivity and those with urgency. For women with detrusor overactivity both stimulation groups (10 Hz, sacral electrodes and 150 Hz, symphysis pubis electrodes) showed a significant increase in first desire to void and a reduction in the maximum detrusor pressure, in comparison to the placebo stimulation group. For women with urgency, a significant increase in the first desire to void in the 150 Hz group, and a significant increase in the maximum cystometric capacity in the placebo group were noted. Yamanishi et al. investigated a placebo-controlled randomized study for 4 weeks in men and women with UI, and have reported the significant superiority of active electrical-stimulation to the sham device, the cure and improvement rates being 22% and 81%, respectively, in the active group, and 4% and 32%, respectively, in the sham group. There were significantly greater improvements in terms of nocturia, number of leakage episodes, number of pad changes, quality of life score and urodynamic evidence of improvement in detrusor overactivity in the active stimulation group in comparison to the sham stimulation group. Abel et al. compared the effect of active stimulation with placebo stimulation (no current) for 20 min once a week for 12 weeks in 28 women with UI, and demonstrated a significant improvement in the subjective parameters (VAS), but not in the objective measurements (24 h pad test and incontinence episodes per day). Wang et al. compared the effects of PFMT, electromyography biofeedback and electrical stimulation for 103 patients with overactive bladder (OAB) and thus concluded that electrical stimulation had the greatest subjective reduction rate of OAB and was...
the most effective of the three treatments. McClurg et al. compared the effects of active or placebo electrical stimulation in combination with PFMT+ biofeedback in 74 patients with multiple sclerosis and concluded that the active electrical stimulation group demonstrated superior benefits in number of incontinence episodes than the placebo group (85% vs 47%). Soomro et al. compared the effects of TENS over the peri-anal region with oxybutynin in 43 patients (13 men, 30 women) with detrusor overactivity, and reported that both treatments improved their subjective parameters but that only oxybutynin showed significant improvements in the objective urodynamic parameters such as bladder volume at first desire to void and at first overactive detrusor contraction. Smith reported that the improvement rates of intravaginal electrical-stimulation (72%) were not statistically significant in comparison to the use of anticholinergics in 38 patients with detrusor overactivity.

**Post-stimulation effects**

The post-stimulation effect or re-education effect, which means that the effect can last several weeks to 3 months or even for several years after finishing the treatment, has been reported. Kulseng-Hanssen et al. reported that no significant difference was found in any of the objective outcome measures 3 months after 5 weeks of maximal electrical stimulation, and only 33% of patients found their UI less troublesome 9 months after stimulation. Bratt et al. conducted a questionnaire survey on the long-term effect 10 years after electric stimulation on the pelvic floor in women with urinary incontinence and reported that a residual effect was noted in 22% of patients with UI and 30% of those with SUI. They also reported that, among 27 women who had been treated with maximal stimulation because of detrusor overactivity 9–13 years earlier, 78% still had UI, which was, however, a minor problem among a third of them. Sixty per cent of their patients were satisfied with maximal stimulation and 78% of patients would have recommended maximal stimulation to a friend today. Scott and Hsueh have reported that the maximal effects are observed within a month or two and long term treatment is unnecessary. However, some other reports doubted this effect. Walsh et al. reported that the urinary symptoms had returned to pre-treatment levels after 2 week of TENS. However, if incontinence relapses, then re-stimulation can be periodically carried out. The long-term effects may be augmented in conjunction with PFMT. Caputo et al. used weekly 30-min maximal stimulation in conjunction with PFMT and reported improvement in 89% of patients. Sussen et al. underwent biofeedback and vaginal electrical stimulation in the treatment of stress incontinence twice a week for 6 weeks and reported an overall success rate of 64%.

**Magnetic stimulation**

Magnetic stimulation has been considered to be a technique for stimulating the nervous system noninvasively and it has been used for experimental and clinical testing on the central and peripheral nervous systems. This method was studied for the purpose of activating the striated urethral sphincters and for the acute suppression of neurogenic and idiopathic detrusor activity. Conventionally, magnetic stimulation has been used in a single-pulse way or in repetitive manner, because the coil soon overheated. Recently, a continuous magnetic stimulator assuring long-time stimulation has been developed.

The mechanism of action of the magnetic stimulation is considered to be the same as that of the electrical stimulation. Magnetic stimulation is useful for activating deep proximal nerves that are difficult to activate with electrical stimulation, and it can activate deep proximal nerves with little pain. The electrical current produced by direct electrical stimulation falls off as a function of the impedance of the tissue between the stimulating electrodes and the neural tissue. Skin, bone, and subcutaneous tissue have high impedance. Hence, to deliver a sufficient electric current to neural tissue, it is necessary to deliver a much higher electric current to the skin, thereby activating pain receptors. A magnetic field, however, penetrates all body tissues without alteration, falling off in magnitude only as the inverse square of the distance. Thus, for the same current generated at the level of the neural tissue, the current generated at the skin will be less than that used for electrical stimulation. Furthermore, patients need not undress because the magnetic field passes through clothing. Magnetic stimulation can be applied both at the sacral root and peripherally at the peri-anal region. However, the former is difficult to fix the coil to for a long time, thus the commercially available stimulator is usually a chair type and stimulates the peri-anal region including the pelvic floor muscles.

The increase in the intra-urethral pressure and the inhibition of bladder contraction have been reported in an animal study, and in healthy volunteers. Using the continuous magnetic stimulator, reductions in the frequency of leakage and urodynamic improvement including maximum bladder capacity in urgency incontinence and increase in maximum urethral closure pressure in stress incontinence have been reported. Consequently, magnetic stimulation can be used as a safe and non-invasive intervention for stress and urgency incontinence. The cure and improvement rates have been reported to be 29–53% and 86–94% of patients with stress incontinence, and 20–25% and 50–85%, respectively, in patients with UI. However, Bradshaw et al. reported no consistent change in the overactive bladder symptoms, although the acute effects in ambulatory urodynamics such as a significant increase in cystometric capacity and a decrease in the amplitude of the detrusor contraction were observed. Voorham-van der Zalm also reported no significant differences in the voiding diary, pad test, quality of life score and urodynamic parameters (no details were reported), although the subjects included a mixture of stress, urge and mixed incontinence and urgency/frequency.

There have been five randomized control trials. Fujishiro et al. carried out a 30-min single stimulation in their active and sham groups and reported a significant improvement in UI and SUI at 1 week after the active stimulation. Yamamishi et al. carried out a randomized comparative study for investigating the urodynamic effects of magnetic stimulation and electrical stimulation on the inhibition of detrusor overactivity in 32 patients (15 males, 17 females; aged 62.3 ± 16.6 years). Although the bladder capacity at first desire to void and the maximum cystometric capacity increased significantly in both groups, the increase in maximum cystometric capacity was significantly greater in the magnetic stimulation group (105.5 ± 130.4% increase in comparison to the pretreatment level) than that in the electrical stimulation group (16.3 ± 33.9% increase). But et al. compared the effects of a portable magnetic stimulator and placebo stimulator in 39 women with mixed incontinence twice daily for 2 months, and reported that significant decreases in voiding frequency, nocturia and pad use as well as urodynamic parameters such as first sensation and maximum cystometric capacity only in the active group. The average success rate was 41.9% and 22.9%, respectively, in the active and placebo group (P = 0.021). Suzuki et al. investigated a randomized, double-blind, sham-controlled, crossover evaluation of the effect of functional continuous magnetic stimulation in 39 patients with UI. They reported that, at the initial half (at 10 weeks) of the treatment, the number of leaks/week, the total score of the International Consultation on Incontinence-Questionnaire Short Form and the maximum
cystometric capacity were significantly improved ($P < 0.001, P < 0.001$ and $P = 0.003$, respectively) in the active stimulation group, but not in the sham group. Four (20.0%) patients were cured in the active group, whereas no patient was cured in the sham group. At the end of the cross-over schedule, significant improvements were demonstrated in the sham-active group as compared with the initial values. At the end of the crossover-schedule in the active-sham group, the effect of the active treatment was still maintained at a significantly improved level, as compared with the initial level. Yokoyama et al. treated 36 men with post-prostatectomy incontinence and randomly allocated them into electrical-stimulation, magnetic stimulation, and PFMT groups (12 men in each group). They found that the leakage weight during the 24 h after removing the catheter was 684 g, 698 g, and 664 g for the electrical-stimulation, magnetic stimulation, and PFMT groups, respectively. At 1 month, it was 72 g, 83 g, and 175 g (electrical-stimulation vs PFMT, $P < 0.05$), and at 2 months was 54 g, 18 g, and 92 g (magnetic stimulation vs PFMT $P < 0.05$), respectively. Finally, 6 months later, the average 24-hour leakage weight was less than 10 g in all groups. No complications were noted in any of the groups. They concluded that both magnetic and electrical stimulation offered earlier success. At the end of the cross-over schedule, significant improvements were demonstrated in the sham group. Four (20.0%) patients were cured in the active group, without any additional therapy. On the other hand, Almeida et al. reported that their continent status was still maintained 9.7 months) responded that their continent status was still maintained 9.7 months) responded that their continent status was still maintained in 36 patients with urgency incontinence, urgency-frequency syndrome and urinary retention.94–97 The most rewarding group was found to be PFMT with neuromodulation (electrical or magnetic stimulation). The combination of PFMT with neuromodulation (electrical or magnetic stimulation) can be the mainstay of conservative management for the treatment of stress incontinence. For UUI and mixed SUI plus UUI, neuromodulation can be the treatment alternative to drug therapy. SNS may be effective for the treatment of refractory UUI.

Sacral nerve stimulation

SNS is an implant type of neuromodulation, that uses mild electrical pulses to continuously stimulate the sacral nerves that innervate the lower urinary tract.24,27,28,39,44 SNS induces modulation for both excitatory and inhibitory effects on the bladder, and thus the SNS has been indicated for various types of lower urinary tract dysfunction refractory to conservative treatment, such as urgency incontinence, pelvic pain and urinary retention.44–47 The most rewarding group was found to be patients with refractory urgency incontinence.24

A percutaneous nerve evaluation (PNE) of the S3 roots is recommended as a temporary screening test to determine the response to neuromodulation, and satisfactory responders are implanted with a permanent (chronic) system.93,96 Recently, a minimally invasive approach to percutaneous placement of the tined lead electrode into the foramen requiring no incisions and no additional fascial anchoring has been developed. This tined lead can be used in the first stage of the SNS procedure, thus offering the possibility of a longer screening duration and no need to change a lead in the second stage.25,98 The permanent placement of the SNS was changed from the abdomen to the buttock because buttock placement resulted in less pain and fewer infections postoperatively and also a reduced operating time.17,99

The long-term efficacy of SNS has been reported. Shaker and Hassouna95 reported that eight of 18 patients became dry and four had average leakage episodes of one or less daily after an average follow-up of 18.8 months. Weil et al.28 reported success rate of 52.8% in 36 patients with urgency incontinence, urgency-frequency syndrome and urinary retention after an average follow-up period of 37.8 months. Van Kerrebroek et al.23 reported that, at 5 years after implantation in 152 patients, 68% of patients with urgency incontinence, 56% with urgency-frequency and 71% with retention had successful outcomes.

The unilateral SNS may fail due to malposition of the electrode and local fibrosis. Hohenfellner et al.100 modified SNS to allow direct and bilateral stimulation of the sacral spinal nerves. Recently, with the new technique using a tined lead electrode, screening was successful in 70 (74%) of 94 patients with urgency incontinence, urinary retention and others, all of whom underwent the second stage of the procedure receiving the pulse generator, and the improvement sustained for up to 6 weeks. At 6 months follow-up, lead migrations occurred in 10% in the tined lead technique.28 Complications included infection (2%), cerebrospinal fluid leakage (3%), superficial wound dehiscence (10%), erosion of the extension cable towards the skin (1%), pain (10%) and lead problems (38%).24,39,100 Recently, Van Kerrebroek et al.23 reported adverse events to occur in 67% at 5-year follow-up, the most frequent event being new pain or undesirable change in stimulation (27%), followed by pain at PNE or the implant site (19.7%), device problems (5.3%) and lead migration (3.3%). Adverse events requiring surgical intervention were noted in 39.5%, including device exchange as the most common intervention (23.7%).

Conclusions

The combination of PFMT with neuromodulation (electrical or magnetic stimulation) can be the mainstay of conservative management for the treatment of stress incontinence. For UUI and mixed SUI plus UUI, neuromodulation can be the treatment alternative to drug therapy. SNS may be effective for the treatment of refractory UUI.

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