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Review Article

TENS: A Treatment Option for Bladder Dysfunction

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Abstract: To ascertain the mode of action and benefits of transcutaneous electrical nerve stimulation (TENS) in detrusor overactivity, stress incontinence and interstitial cystitis, an English-language literature search using Medline (1984–1995) was undertaken with detrusor instability, incontinence, interstitial cystitis, neuromodulation, transcutaneous electrical nerve stimulation and urodynamics as keywords and the material so identified was reviewed. The mode of action of TENS and optimal stimulation parameters in bladder dysfunction remain unclear. Lack of strict selection criteria and deficient reporting of subjective and objective outcomes precluded full assessment of therapeutic efficacy. A beneficial effect was evident in some studies of detrusor overactivity and interstitial cystitis. A trial of TENS in detrusor overactivity and interstitial cystitis refractory to conventional therapy would seem justified. Continued experimental research and further clinical studies will lead to refinement of the treatment modality.

Keywords: Detrusor instability; Incontinence; Interstitial cystitis; Neuromodulation; Transcutaneous electrical nerve stimulation; Urodynamics

Introduction

Electrical stimulation can modulate the neural behavior of the urinary bladder [1]. Intravesical electrical stimulation [2–4], pudendal nerve stimulation using either anal and vaginal plug electrodes [5,6] or percutaneous electrodes [7,8], and sacral anterior root stimulation [6,9–13] have all been reported to modify detrusor function. Neuromodulation using transcutaneous electrical nerve stimulation (TENS) has been described for the treatment of detrusor overactivity, stress incontinence and interstitial cystitis (IC) and provides the basis of this review (Table 1). Material for the text was identified by performing a literature search using Medline between 1984 and 1995 with detrusor instability, incontinence, interstitial cystitis, neuromodulation, transcutaneous electrical nerve stimulation and urodynamics as the keywords.

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Mode of Action of TENS

Various types of transcutaneous electrical stimulation have been shown to be of benefit in the treatment of a variety of bladder disorders, as indicated in Table 2, and there is no consensus on the stimulation parameters used in any particular diagnostic category. Although there are a number of theories concerning the relief of pain by TENS [14], the mechanisms behind the beneficial effect of TENS in the treatment of bladder dysfunction remain unclear. TENS has been shown to increase levels of cerebrospinal endorphins at various stimulus frequencies [15]. Opioid blockade in both cats and humans causes increased detrusor activity [15], from which it might be proposed that elevation of endorphins in the central nervous system would inhibit detrusor activity. An experimental study of intravaginal stimulation in cats has shown that inhibition of detrusor contraction is due to afferent pudendal stimulation (S2–S4), which in turn results in reflex activation of hypogastric efferents and inhibition of pelvic efferents [16]. The same authors report that maximal inhibition of the bladder via the sympathetic route was obtained at about 5 Hz of intravaginal stimulation, whereas the central

Table 1. Summary of publications of TENS for treatment of bladder dysfunction

Author	Year	No. patients	Mean age/ age range	Sex	History	Pre-UDS	Post-UDS	Subjective outcome[1]	Objective outcome[1]
Hasan	1994	20	52	8 M 12 F	IDI	Y	Y	Y no. NS	Y no. NS
Hasan	1996	71	48	30 M 41 F	IDI	Y	Y	Y no. NS	Y no. NS
Madersbacher	1995	25	44 4–96	12 M 13 F	11 IDI 14 DH	Y	Y	NS	Y no. NS
McGuire	1983	16	NS	NS	Detrusor overactivity	Y	Y	NS	15±1
Nakamura	1984	22	7–72	22 M	Non-specific irritative	Y	Y	4	11
Nakamura	1984	10	NS	10 F	NS	Y	Y	NS	1
Nakamura	1986	25	NS	13 M 12 F	Non-specific irritative	Y	Y	9	8
Vodusek	1986	10	25 13–39	8 M 2 F	DH	Y	Y	NS	10
Webb	1992	24	19–72	8 M 16 F	IDI	Y	Y	Y no. NS	Y no. NS
Wheeler	1992	6	36	6 M	DH	Y	Y	NS	6
Krauss	1981	8	68 59–81	8 M	SI	Y	Y	6	NS
Fall	1980	9	59 47–80	9 F	IC	Y	Y	9	9
Fall	1987	35	54 27–80	2 M 33 F	20[a] 15[b]	N	N	16[a] 2[b]	Y no. NS
Fall	1994	60	56[a]	4 M 29 F	33[a]	N	N	27[a]	N
			37[b]	1 M 26 F	27[b]			12[b]	N
Geirsson	1993	8	22–80	8 F	IC	N	N	0	0
McGuire	1983	5	NS	NS	IC	NS	NS	4	N

UDS refers to urodynamic studies. NS = not stated. SI = subjective stress incontinence
[1] Numbers for subjective and objective outcomes are given for those who were considered to show an improvement with TENS
[a] Classic IC
[b] Non-ulcerated IC

inhibitory pathway was optimally activated at 5–10 Hz [17]. In non-human primates with spinal cord injury, TENS of the common peroneal or posterior tibial nerves (S2 ± S3) has been observed to inhibit reflex detrusor activity [18]. It is possible, then, that low-frequency TENS may activate endorphin pathways in the spinal cord when applied at sites with the same spinal root values as the bladder, and so effect detrusor inhibition.

Other mechanisms of action may exist. Direct stimulation of sacral roots appears to activate the external urethral sphincter, which in turn inhibits detrusor activity by means of reflex inhibition [19]. It was suggested that such stimulation could induce hypertrophy of the rhabdosphincter and histochemical evidence of change in fiber subtypes associated with increased fatigue resistance. Whether the application of TENS to sacral dermatomes has a mode of action similar to direct sacral root stimulation is at present unknown. Perianal TENS has been used to good effect in the treatment of stress incontinence following prostatectomy, the authors reporting an increase in sphincter electrical activity in some patients, although it is of interest that there was no significant change in the urethral pressure profile measured during stimulation [20].

By contrast, high-frequency TENS may take effect through blockade of sensory input [15]. This mode of stimulation is particularly useful in the treatment of IC, the reduction of pain during filling allowing the patient to postpone voluntary voiding [21]. These workers have suggested that healing of bladder lesions during prolonged therapy might also result from changes in the pattern of nerve activity to the bladder.

Transcutaneous Electrical Nerve Stimulators

Commercially available devices for delivering TENS are lightweight, readily portable and relatively inexpensive. The device presently used in our unit (COM-TENS, Voltastar Ltd, Northampton, UK) measures 9 × 6 × 2 cm and weighs 125 g, including the PP3 alkaline battery. Most devices are dual-channel models and have two essential parts: the pulse generator with amplifier and the electrodes. A control panel allows pulses of widths between 0.06 ms and 0.25 ms to be delivered. A timer control permits continuous stimulation or stimulation for periods of either 30 or 60 minutes. One of three modes of stimulation may be selected: the normal mode allows adjustable pulse width and frequency, with constant

Table 2. Sites of TENS and stimulation parameters employed in bladder dysfunction

Author	Year	History	Site	Amplitude	Duration (ms)	Frequency (Hz)	Mode	Daily treatment	Treatment period
Hasan	1994	IDI	Sacral	Patient controlled	0.2	50	NS	NS	3 weeks
Hasan	1996	IDI	Sacral	Patient controlled	0.2	50	NS	NS	3±1 weeks
Madersbacher	1995	IDI/DH	Penile/clitoral	15 mA	0.2	5–10	Continuous	20 min bd	NS
McGuire	1983	Detrusor overactivity	Posterior tibial/ common peroneal	NS	NS	NS	NS	NS	NS
Nakamura	1984	Non-specific irritative	Penile	5–50 mV	0.5	10 or 20	Continuous	NS	NS
Nakamura	1984	NS	Clitoral	NS	NS	NS	Continous	NS	NS
Nakamura	1986	Non-specific irritative	Perianal	10–100 V	0.5	20 or 100	NS	NS	10–20 min
Vodusek	1986	DH	Penile/clitoral	7–16 mA	0.2–0.5	1–10	NS	NS	NS
Webb	1992	IDI	Sacral	NS	NS	NS	NS	NS	1 week
Wheeler	1992	DH	Penile	25–70 mA	0.35	5	NS	NS	NS
Krauss	1981	SI	Perianal	Patient controlled	0.08–0.13	3–10	NS	NS	6–21 days
Fall	1980	IC	Suprapubic	Patient controlled	0.2	50	NS	15–120 min bd*	6–24 months
Fall	1987	IC	Suprapubic	Patient controlled	0.2	2–50	NS	120 min bd*	up to 10 years
Fall	1994	IC	Suprapubic	NS	NS	2–50	NS	30–120 min bd*	up to 17 years
Geirsson	1993	IC	Tibial	Patient controlled	0.2	1	NS	30 min od	4 weeks
McGuire	1983	IC	Posterior tibial/ common peroneal	NS	NS	NS	NS	NS	NS

NS = not stated
SI = subjective stress incontinence
* refers to initial prescription. Daily treatment varied by patient once response obtained

repetition of pulses; burst mode results in two bursts of stimulation per second, seven pulses per burst, with 100 Hz rate and only the pulse width remains adjustable. Modulation mode contains a gradual pulse rise time and fall time, cycling on 5 seconds, with adjustable pulse width and frequency. Pulse frequency may be set between 2 Hz and 150 Hz. As indicated earlier in this review, a consensus does not exist on the stimulation parameters to be used in any particular diagnostic category, nor is there a consensus regarding the optimal duration of treatment (Table 2). We prescribe normal mode, continuous stimulation at a pulse width of 0.2 ms and frequency of 50 Hz for patients with detrusor instability and have not so far treated patients with IC. The current amplitude is controlled by the patient to produce a tingling sensation beneath the electrodes using a graduated dial on the uppermost aspect of the device. Daily duration of treatment and the total treatment period have rarely been stated in publications to date. On empirical grounds, we recommend that patients discontinue stimulation only for the purpose of bathing/showering. Arrangements are made for review after a minimum treatment period of 3 weeks.

In our unit two electrodes, each 5.0 × 4.5 cm, are used, although it is of note that four electrodes are almost universally employed in obstetric practice. As electrode size influences stimulation parameters and comfort [22], it would seem appropriate for authors to state the electrode size to allow fair comparison of published data to be made. Electrodes were initially made of silver [23] but are now made of carbon rubber. The latter require attachment using adhesive tape and it has been observed that a proportion of patients (31%) develop local allergic reactions during treatment [13]. Self-adhesive hypoallergenic electrodes are particularly suitable for this subgroup, but their expense precludes use in all patients. To ensure that good contact is made, the rubber electrodes are applied over the area to be stimulated with a layer of water-soluble electrode gel. We recommend that the gel is renewed every 4–6 hours to prevent both discomfort and partial loss of contact which occur if the gel is allowed to dry.

Clear instructions relating to handling and use of the device are imperative prior to the onset of treatment. The site of electrode application affects the outcome of stimulation [24–26] and it is our practice not only to teach patients to locate the correct site by feel of relevant bony landmarks, but also to mark the correct spot so that they can be certain of satisfactory application at home. Patients are made aware both of the sensation of strong stimulation and of the interval that may occur between commencement of therapy and symptomatic benefit, often 7–10 days for detrusor overactivity. All patients have telephone access to a named member of staff during normal working hours in the event of difficulty.

Potential Applications of TENS

Detrusor Overactivity

Incontinence secondary to detrusor overactivity is common but far more difficult to treat than genuine stress incontinence (GSI). Medical treatment with anticholinergic agents provides useful initial management [27]. The relief of symptoms is rarely optimal and pronounced side effects are frequent. Surgical procedures such as cystodistension [27], nerve transection [28–32], enterocystoplasty [33–35], detrusor myomectomy and urinary diversion are reserved for those with intractable symptoms and carry significant morbidity. Therefore, there is a continuing search for alternative treatment modalities. The successful use of TENS in the treatment of detrusor overactivity has been described when used at various anatomical sites.

Common Peroneal and Posterior Tibial Nerve TENS: TENS applied to the common peroneal or posterior tibial nerve with a ground electrode placed over the contralateral common peroneal or posterior tibial nerve resulted in an absence of urgency, together with urodynamic evidence of reduction or abolition of detrusor instability and incontinence in 15 of 16 patients with a variety of neural lesions, a possible improvement being found in the remaining patient [18].

Penile and Clitoral TENS: Stimulation of the pudendal nerve using external or percutaneous devices has been mentioned earlier in this review. The dorsal nerve of the penis and the clitoral nerve, both branches of the pudendal nerve, run close to the skin surface and are accessible for TENS. There are indeed several reports of the effect of TENS applied at these sites [36–39]. The first study reported the urodynamic outcome of penile TENS applied to 22 males who complained of frequency, nocturia, urgency and urge incontinence resulting from causes as diverse as prostatic hypertrophy, Parkinson's disease and idiopathic conditions. Uninhibited detrusor contractions were found in 10 patients prior to treatment and in 3 patients following stimulation. The volume at first desire to void, maximum cystometric capacity and compliance increased in 11, 8 and 11 of the 22 patients respectively, but no data were provided regarding the effect of treatment on incontinence. In the same publication, the authors reported suppression of detrusor overactivity following electrical stimulation of the clitoris in 1 of 3 patients and an increase in cystometric capacity in 1 of 10. They proposed that the increased effect of penile stimulation may be due to the greater pudendal nerve supply to the penis.

The reports of TENS discussed thus far have included patients with a wide range of diagnoses and despite having irritative symptoms, not all have had detrusor overactivity on pre-treatment urodynamics. In addition, control studies have not been undertaken to exclude a purely placebo effect. A further study relating to penile TENS described an absence of detrusor activity and an increase of bladder capacity following treatment of men with detrusor hyper-reflexia (DH) secondary to suprasacral spinal cord injury [37]. Hyper-reflexic contractions have also been reported to be inhibited by penile or clitoral TENS in a similar group of patients [38]. In a more recent report of penile and clitoral TENS in patients with either idiopathic detrusor instability (IDI) or DH, the mean maximum cystometric capacity increased and mean maximum detrusor pressure decreased, although only values obtained in those with DH were significant [39].

Sacral TENS: The application of TENS to the sacral dermatomes 1–2 cm from the anus has been described in both adults and children, all of whom presented with frequency, urgency or incontinence although detrusor overactivity was found in only 8 of 25 on cystometry [40]. Suppression of the overactivity occurred in 4 of 8 and an increase in maximum cystometric capacity of at least 50 ml was recorded in 5 of 25 although the number who were incontinent prior to and following treatment was not stated. It is of note that clinical improvement was evident for between 2 days and 2 months following stimulation in 9 of the 12 patients who were followed up in this study, a phenomenon now referred to as the 'carry-over effect'. None of the other articles relating TENS to the treatment of detrusor overactivity reviewed here have referred to this effect.

The effect of TENS on the third sacral dermatome (S3) in patients with IDI has been further investigated in our unit [13,24,26]. Webb and Powell [24] reported on 24 patients with evidence of IDI on medium-fill cystometry, in whom anticholinergic medication and repeated bladder overdistension had been of minimal benefit. All were incontinent prior to TENS and all underwent treatment in three configurations: no TENS; with TENS active on S3; and with TENS active on T12. Although 1 patient was stable with stimulation on T12, TENS on S3 abolished instability in 11 (46%), and in those with persistent evidence of instability there was a significantly greater volume at first contraction compared to either no TENS or TENS on T12. Cystometric capacity was significantly greater with TENS on S3 than with the other configurations. In addition, urinary frequency, episodes of urgency and urge incontinence were reduced with TENS on S3 but not with TENS on T12. Thirteen patients (54%) were rendered continent with S3 stimulation. Voided volumes were higher with TENS on S3. The subsequent findings of Hasan et al. in a further group of 71 patients with IDI support those of Webb and Powell [13].

A placebo effect of TENS is unlikely to account for the above observations, and it is important to note that the favorable changes in cystometry were accompanied by significant improvement in symptoms. Clearly, a mode of treatment which produces an objective response in the absence of a subjective response would be of little benefit.

Stress Incontinence

The use of TENS in men with stress incontinence following simple or radical prostatectomy has been described with 75% having some improvement in continence [20]. The benefit persisted for 7 months after discontinuation of stimulation in 1 of the men. Cystometrograms were undertaken prior to treatment but those with abnormal traces were excluded from the study. The cases referred to could not, therefore, have had urodynamically proven GSI. We are unaware of any report of TENS in the treatment of GSI. However, its treatment using intravaginal electrical stimulation has been described and the outcome was found to be inferior to operative treatment [5]. If TENS were to have an effect in GSI, it would be useful in those patients who were either unwilling to consider surgery or who were surgically unfit. As detrusor overactivity is a major risk factor for poor outcome after colposuspension and its incidence is increased following continence surgery [41,42], it may be that TENS would render those patients with urodynamic evidence of both GSI and detrusor overactivity better candidates for operative treatment of their GSI.

Interstitial Cystitis

The cause and pathophysiology of interstitial cystitis remain uncertain. The cystoscopic appearances may be characteristic [21] and the histological findings are usually supportive rather than diagnostic [23].

TENS was first reported to have beneficial effects in patients with IC by Fall et al. [21]. All 9 women who underwent suprapubic stimulation were found to have substantial reductions in pain and in voiding frequency. In 4, the number and size of bladder lesions were found to have decreased on post-treatment cystoscopy. In 1 patient, lesions disappeared totally after 18 months of therapy. The effect of TENS persisted after stimulation was discontinued, providing evidence of the 'carry-over effect' in IC. The effect has been observed in other studies of IC [23,43], and may last for up to 7 years [23]. The effect on classic IC exceeded the placebo effects observed in drug studies of IC [23]. It is not therefore only in detrusor overactivity that TENS therapy has an effect above that expected from placebo alone. A separate report of a positive response to common peroneal or posterior tibial TENS in IC has been published [18]. The authors also used stimulation at an identical site in 1 patient with radiation cystitis to little avail.

Less favorable data have, however, been reported in IC [25]. In this study, voiding frequency, maximum and mean voided volumes and symptom scores failed to change significantly following 4 weeks of TENS. However, the majority of patients had non-ulcerated IC, a subgroup shown by Fall to have less benefit from TENS than those with classic IC [23]. In the light of the finding of previous authors [21], it might also be reasoned that treatment duration was rather short in this small study.

Conclusions and Future Applications

The effects of TENS in the treatment of bladder dysfunction are promising with improvements in bladder control and sensory symptoms having been reported. The devices are non-invasive and simple to use, and morbidity is minimal. Continued experimental research and further clinical studies will lead to refinement of the technique. Controlled clinical trials are needed to determine the efficacy and cost-effectiveness of TENS compared to standard treatments. Given that there is no obvious placebo equivalent to therapeutic stimulation, such trials may have to involve 'sham' stimulation at an anatomical site disparate from the site of interest. The optimal stimulation parameters need to be defined, and clarification of the minimal daily treatment duration is required. The results of long-term follow-up will be of particular interest. Prior to undertaking major surgical procedures, we would recommend a trial of neuromodulation using TENS, particularly in patients with detrusor overactivity or interstitial cystitis refractory to conventional methods of conservative treatment.

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