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Improving clinical outcomes for women with overactive bladder or urinary retention symptoms: a comparison of motor response voltages (1–9 V) during Stage 1 sacral neuromodulation

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Objective

To assess whether the utilisation of a motor response of <3 V during Stage 1 sacral neuromodulation (SNM) results in better clinical outcomes compared to >4 V in patients with overactive bladder (OAB) or urinary retention symptoms.

Patients and Methods

An observational, retrospective, double cohort review was conducted of 339 female patients who had experienced medically recalcitrant OAB or urinary retention symptoms. Between September 2001 and September 2014, both cohorts underwent successful Stage 1 to Stage 2 SNM placement. Group A, included 174 women with a motor response at ≤3 V; and Group B, evaluated 110 women with a motor response at ≥4 V for medically recalcitrant OAB. Group C, compared 33 women with a motor response at ≤3 V; and Group D, documented 22 women with a motor response at ≥4 V for non-obstructive urinary retention. Patients completed 3-day voiding diaries, the Urogenital Distress Inventory-6 (UDI-6), Incontinence Impact Questionnaire-7 (IIQ-7), and Patient Global Impression of Improvement Questionnaire.

Results

The mean (SD) follow-up was 116.3 (30.3) months in Group A and 112 (34.6) months in Group B ($P < 0.354$); 150.5 (20.4) months in Group C and 145.8 (17.2) months in Group D ($P < 0.38$). Successful conversion of Stage 1 to Stage 2 showed statistically significant improvement for both <3-V groups (Groups A and C). Group A had a 93.5% (174/186) conversion rate vs 72.3% (110/152) in Group B for OAB symptoms ($P < 0.001$). Group C had a 94% (34/36) conversion rate vs 70% (21/30) in Group D ($P < 0.017$). Defined as a ≥50% reduction in frequency, urgency, urgency incontinence and nocturia, and UDI-6 and IIQ-7 scores, the success rate for Group A was 82.1% (143/174) and for Group B was 63% (69/110) ($P < 0.001$). The mean battery life improved in both <3-V cohorts ($P < 0.001$). Annual reprogramming sessions were reduced in Group A and Group C ($P < 0.001$). Subset analysis of variance showed no statistical improvement in most patient outcomes when 1-V subjects were compared to 2- and 3-V cohorts. However, 32% of 1-V patients ($P < 0.001$) noted the onset of severe pelvic/perirectal pain and big toe plantar flexion movement with small increments in voltage (0.1–0.2 V) during reprogramming. Only 7% of 2-V and 1% of 3-V patients experienced this complication.

Conclusions

Significant improvement was noted (up to 40%) in most clinical voiding parameters in the <3-V patients for both OAB and urinary retention. While <3 V will still statistically improve patient outcomes, a voltage <2 V may elicit self-reprogramming pain with severe bellows and plantar flexion movement, which may discourage patients from therapy adjustments. We recommend randomised, controlled trials to confirm these results.

Keywords

sacral neuromodulation, 3-volt motor response, pelvic/perirectal pain, big toe plantar flexion, #OAB

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Introduction

Sacral neuromodulation (SNM) is a well-studied, minimally invasive, third-tier surgical therapy for women with medically recalcitrant overactive bladder (OAB) or urinary retention symptoms [1]. A panoramic view of the procedure's evolution reveals significant technological improvements in hardware and surgical implantation. In early procedures, the lead was secured to the lumbodorsal fascia but was replaced with a self-retaining model in 2002 [2]. A two-staged approach featuring placement of the permanent lead with an external, portable impulse generator was another improvement over percutaneous testing, with a temporary, office-placed, 2–3 day lead [3]. In 2006, the InterStim® II (Medtronic Inc., Minneapolis, MN, USA) implantable pulse generator (IPG) model 3058 was introduced, with a 37% decrease in displaced volume and 50% reduction in weight (22 vs 42 g), when compared to the original InterStim I footprint (model 3023). Product lifespan for the InterStim II was unfortunately reduced to 3–5 years from the original model's 5–7 years, but new software upgrades now allow for data tracking and patient self-reprogramming options [4]. Further improvements in the InterStim II include Federal Drug Administration (FDA) approval for 1.5-T MRI head imaging (see Medtronic MRI guidelines). The self-contained tined lead is now available in a longer 43-cm length, for application in larger-frame patients and for non-FDA approved pudendal neuromodulation [5,6]. Improvements are not limited to software/hardware innovations. An alteration in Stage 1 SNM approach and technique was brought to light during a review of the fundamentals of electrophysiological theory, namely that the lower the amount of voltage used to stimulate a motor response, the higher the potential for improved stimulation of the intended muscle unit [7,8]. The Medtronic Corporation has never heralded any recommendations about the amount of voltage for a motor response, and this element of adjustment has not been explored in the SNM literature [1–5]. However, we have an extensive 15-year experience utilising our method of a <3-V motor response in women with OAB symptoms and urinary retention that is described in the present study.

Patients and Methods

An observational, retrospective, double cohort review was conducted of 339 female patients who had experienced medically recalcitrant OAB symptoms or non-obstructive urinary retention. Between September 2001 and September 2014, four cohorts underwent successful Stage 1 to Stage 2 SNM placement. Group A included 174 women who underwent differential quadripolar tined lead motor response (bellows and plantar flexion) with one or more leads at ≤3 V, and Group B evaluated 110 women who underwent the same protocol with all lead motor response ≥4 V for medically recalcitrant OAB symptoms (frequency, urgency, urgency incontinence, nocturia, or urinary retention). Group C comprised 33 women with one or more motor response at ≤3 V, and Group D identified 22 women treated with a motor response at ≥4 V for non-obstructive urinary retention symptoms. Stage 1 and Stage 2 surgeries were performed between January 2002 and January 2013 under a general anaesthetic, with a motor response void of all patient verbal sensory input.

All 339 patients underwent similar perioperative diagnostic evaluations including: a complete history and physical examination, urine analysis, urine culture and cytology (as indicated), 3-day voiding diary (preoperative and at 2016 follow-up), multichannel video-urodynamics (including uroflowmetry), office flexible cystoscopy, post-void residual urine (PVR) via straight catheterisation or ultrasonographically determined, Urogenital Distress Inventory-6 (UDI-6; score range 0–100), Incontinence Impact Questionnaire-7 (IIQ-7; score range 0–100), and Patient Global Impression of Improvement Questionnaire (PGI-I; score range 1–7) [9], all pre- and postoperatively, and at the 2016 follow-up as clinically indicated. The numerical voltage values for all four lead electrodes 0, 1, 2, 3 at surgery and adverse events were tracked. Internal Review Board permission for this study was both requested and received in 2016. No funding was requested or received from any source. Successful lead placement was determined by having two or more leads presenting with S_3 bellows (levator ani contraction) and ipsilateral big toe plantar flexion. 3-day voiding diaries were used to objectively assess patient success (defined as a 50% reduction in mean frequency, urgency, urgency incontinence and nocturia; or a return to normal voiding frequency of <8 voids/24 h day/night cycle). Patients with urinary retention needed to have consistent PVRs either through straight catheterisation or ultrasonographically determined values of <100 mL. Preoperative and follow-up maximum urinary flow rate (Q_{max}) was also determined as an accessory qualitative measure.

All adverse events were included during each of the four cohorts' ongoing evaluations. These included events related to either Stage 1 or 2 surgery, therapy, device, or implant site. Battery acquiescence and replacement are a necessary part of this therapy and were not included as an adverse event. Follow-up examinations were performed by independent, board certified physicians with experience in SNM and its programming. For inclusion in the study, patients needed a minimum of 3 years' follow-up.

Data were analysed using the IBM Statistical Package for the Social Sciences (SPSS®) version 19 (SPSS Inc., IBM Corp., Armonk, NY, USA). Categorical data were analysed using Fisher's exact test and Pearson's chi-squared. Continuous data were analysed using Student's independent samples *t*-test and

Mann–Whitney *U*-test for non-normal data. Comparisons of pre-and post-measures were conducted using repeated measures ANOVA. The data were analysed using a multivariate ANOVA (MANOVA), in which the differences between voltage groups (1, 2, and 3 V), as well as the change from pre- and post- measures (time) were compared. A voltage by time interaction was also examined. Paired comparisons to examine differences between groups and times were also conducted. For all factors a $P \leq 0.05$ was deemed statistically significant (Video S1).

Surgical Procedure

The patient was brought to the operating room after surgical antibiotic prophylaxis and placed onto a Jackson orthopaedic table. We do not embrace the sensory means of motor response and positional lead placement, so the patient was given a general endotracheal anaesthetic without paralysing agents and turned 180° to the prone position. The Jackson table has no centre 'I beam', so table obstruction during fluoroscopy is obviated. We used a two-staged approach instead of an initial percutaneous nerve evaluation technique. With a surgical marking pen and radio-opaque 30.5-cm (12-inch) ruler guidance, the C-arm outlined the sacrospinous processes in the midline sacrum down to the coccyx. A vertical line was drawn, connecting both right and left pelvic brim sciatic notches. Next, both S_3 foramina (medial side) had a tangential line drawn away from the midline sacrospinous line. This line segment connoted the aspired positions of both sides of the S_3 nerve. A 12.7-cm (5-inch) bored needle with an attached white test stimulation cable was set at 3 V in Groups A and C, and at 6 V in Groups B and D. We used an electrically active needle to immediately discern a successful motor response of the levator ani (bellows) and ipsilateral big toe (plantar flexion), confirming S_3 placement. Once both were obtained, the procedure was completed by bringing the end of the tined lead and external connection through the ipsilateral buttock pocket to the counter-lateral posterior superior iliac crest area, as per Medtronic recommendations. We used 2-0 nylon suture with an air knot to secure the external connecting wire to the external impulse generator.

Results

The mean (SD) follow-up in months was: 116.3 (30.3) in Group A and 112 (34.6) in Group B ($P < 0.354$); 150.5 (20.4) in Group C and 145.8 (17.2) in Group D ($P < 0.38$). Successful conversion of Stage 1 to Stage 2 (Table 1) showed statistically significant improvement for both <3-V groups (Group A and C). Group A had a 93.5% (174/186) conversion rate vs 72.3% (110/152) in Group B for OAB symptoms ($P < 0.001$). Group C had a 94% (34/36) conversion rate compared to 70% (21/30) in Group D for urinary retention ($P < 0.017$). The success rate, with a definition of ≥50% reduction in frequency, urgency, urgency incontinence, nocturia, and UDI-6 and IIQ-7, for Group A was 82.1% (143/174) vs 63% (69/110) for Group B ($P < 0.001$). The success rate for urinary retention was not significantly improved from Group C at 85% (28/33) compared to Group D at 72.9% (16/22) ($P = 0.32$). However, the study enrolment number (n) needed to achieve statistical significance (notwithstanding Group C's 12.1% improvement over Group D) would have been $n = 99$ for Group C and $n = 66$ for Group D, or a total of 165 participants. The mean (SD) PGI-I scores were significantly different between Group A, at 2.34 (0.76) and Group B at 1.8 (4.8) ($P < 0.001$), but not for Group C 2.46 (0.67) and Group D 2.05 (0.85) ($P = 0.09$). The mean (SD) postoperative urinary frequency improvement was statistically improved for Group A, improved from 19.28 (3.18) to 7.72 (2.58) voids/24 h, compared to Group B, improved from 17.96 (3.09) to 8.7 (2.26) voids/24 h ($P < 0.001$). The mean (SD) pre-and postoperative urinary urgency episodes were reduced in Group A, from 3.33 (1.41) to 1.01 (0.8) episodes/24 h, while Group B showed a reduction from 3.3 (1.16) to 1.35 (0.7) episodes/24 h ($P <0.001$). The mean (SD) pre- and postoperative urgency incontinence episodes reduced in Group A from 1.91 (1.35) to 0.639 (1.01) episodes/24 h and in Group B, from 1.81 (1.19) to 0.751 (0.69) episodes/24 h ($P < 0.03$). The mean (SD) pre-and postoperative nocturia improvement favoured Group A, at 3.42 (1.05) to 1.19 (0.55) compared to Group B, at 3.78 (1.22) to 1.44 (0.64) voids/night ($P < 0.001$). The mean (SD) improvement in pre- and postoperative UDI-6 scores indicated significance for Group A, at 18.08 (2.34) to 7.96 (2.8) when compared to Group B, at 18.45 (1.91) to 9.35 (2.25) ($P < 0.001$). The mean (SD) pre- and postoperative IIQ-7 scores also improved in Group A's favour from 18.79 (2.72) to 8.2 (2.96), and in Group B from 20.04 (2.4) to 9.78 (2.47) ($P < 0.001$). First battery life improved in Group A compared to Group B, at a mean (SD) of 71.79 (6.39) vs 58.6 (5.52) months ($P < 0.001$); while Group C also demonstrated a significantly longer activity time than Group D, at 78.21 (10.2) vs to 57.18 (6.67) months, respectively ($P < 0.001$). Battery duration measurements were taken from the InterStim II IPG exclusively. All InterStim I IPGs' historical data were excluded, so as not to confuse battery duration amongst the two types of IPGs, as the latter has not been available since 2008. Annual reprogramming sessions were reduced in Group A by a mean (SD) of 1.13 (0.81) compared to Group B at 1.86 (1.24) ($P < 0.001$). Tables 2 and 3 show the percentage improvement in multiple voiding parameters in which the ≤3-V Groups A and C outperformed their comparison group. Table 4 outlines the mean tine lead voltages for all four cohorts. Complications noted in Table 1, but not specifically identified, include lead migration associated with trauma such as falls, bicycle or motor vehicle accidents, or infected IPGs (often related to infected

Table 1 Clinical results for the patient cohorts.

Characteristics	OAB		P	Urinary retention		P
	Group A (≤3 V)	Group B (≥4 V)		Group C (≤3 V)	Group D (≥4 V)	
Number of patients	174	110		33	22	
Stage 1 to Stage 2 conversion, %	93.5	72.3	0.001	94	70	0.017
Success rate, %	82.1	63	0.001	85	72.9	0.32
Complications, %	12	15	0.477	24	18	0.528
Mean (SD)						
Follow-up, months	116.3 (30.3)	112.7 (34.6)	0.354	150.5 (20.4)	145.8 (17.2)	0.38
PGI-I score	2.34 (0.76)	1.8 (4.69)	0.001	2.46 (0.67)	2.05 (0.85)	0.09
PVR, mL	39.24 (29.4)	43.4 (24.7)	0.154	75.85 (118.6)	144.5 (167.2)	0.06
Postoperative Q_{max}, mL/s	22.16 (4.27)	22.84 (4.61)	0.203	19.48 (6.81)	15.25 (9.76)	0.01
Frequency: preoperative, episodes/24 h	19.28 (3.18)	17.96 (3.09)	0.001			
Frequency: postoperative, episodes/24 h	7.72 (2.58)	8.7 (2.26)	0.001			
Urgency: preoperative, episodes/24 h	3.33 (1.41)	3.3 (1.16)	0.895			
Urgency: postoperative, episodes/24 h	1.01 (0.8)	1.35 (0.71)	0.001			
Urgency incontinence: preoperative, episodes/24 h	1.91 (1.35)	1.81 (1.19)	0.651			
Urgency incontinence: postoperative, episodes/24 h	0.639 (1.01)	0.741 (0.69)	0.31			
Nocturia: preoperative, voids/night	3.42 (1.05)	3.78 (1.22)	0.008			
Nocturia: postoperative, voids/night	1.19 (0.55)	1.44 (0.64)	0.001			
UDI-6: preoperative score	18.08 (2.34)	18.45 (1.91)	0.165			
UDI-6: postoperative score	7.96 (2.8)	9.35 (2.25)	0.001			
IIQ-7: preoperative score	18.79 (2.72)	20.04 (2.4)	0.001			
IIQ-7: postoperative score	8.20 (2.96)	9.78 (2.47)	0.001			
Battery life, months	71.79 (6.39)	58.6 (5.52)	0.001	78.21 (10.2)	57.18 (6.67)	0.001
Annual reprogramming, *n*	1.13 (0.81)	1.86 (1.24)	0.001	NA	NA	
Operative time, min	18.76 (6.73)	18.92 (4.83)	0.833	35.3 (14.86)	25.14 (15.13)	0.017

Table 2 Percentage improvement in patients with OAB.

Variable	Group A (<3 V)	Group B (>4 V)	% Improvement	P
Stage 1 to Stage 2 conversion rate, %	93.5	72.3	29.3	<0.001
Success rate at follow-up, %	82.1	63	30.32	<0.001
PGI-I score	2.34	1.80	30	<0.001
Frequency: postoperative, episodes/24 h	7.72	8.70	11.26	<0.001
Urgency: postoperative, episodes/24 h	1.01	1.35	25.19	<0.001
Nocturia: postoperative, voids/night	1.19	1.44	17.36	<0.001
UDI-6: postoperative score	7.96	9.35	14.87	<0.001
IIQ-7: postoperative score	8.20	9.78	16.16	<0.001
Battery life, months	71.8	58.6	22.53	<0.001
Annual reprogramming, *n*	1.13	1.86	39.25	<0.001

haematomas secondary to accidents). There were no significant differences between the four cohorts for body mass index, anaesthetic risk factors, postoperative PVR, postoperative Q_{max}, or duration of follow-up. Our power for the MANOVA was 0.80, indicating adequate sample size to show a significant multivariate voltage effect if there were such an effect. There was an overall significant time difference between pre- and post-measures when using MANOVA (Wilks' Lambda = 636.3, d.f. = 7, $P < 0.001$). The interaction MANOVA for voltage by time was not significant ($P = 0.573$).

A multivariate comparison was performed to see if either the 1-V, vs 2-V and 3-V patients (combined) in Group A outperformed the other with regard to all data points discussed in Table 1. To ascertain these results, a MANOVA analysis was performed (Fig. 1). The overall MANOVA for the voltage effect was not significant (Wilks' Lambda = 1.34, d.f. = 14, $P = 0.180$). The univariate ANOVA analysis indicated that there were three significant differences between the motor response voltage subgroups with levels of 1-V compared to both 2- and 3-V with the complex of outcome variables as statistically depicted in Table 5. The measures that showed the most statistically significant effects were for the 1-V cohort pertaining to PVR ($P < 0.032$) and postoperative nocturia ($P < 0.043$). However, Table 5 notes during patient self-reprogramming increased pelvic/perirectal pain and big toe movement with small incremental voltage increments of 0.1–0.2 V: 32% (23/73) in the 1-V cohort, 7% in 2-V patients, and 1% in 3-V patients ($P < 0.001$).

Table 6 is a comparison of our data with three selected study results from important multi-institutional SNM studies for OAB symptoms [10–12] . Parameters include follow-up

Table 3 Percentage improvement in patients with urinary retention.

Variable	Group C (<3 V)	Group D (>4 V)	% Improvement	*P*
Stage 1 to Stage 2 conversion rate, %	94	70	34.29	0.017
Q_{max} postoperatively, mL/s	19.5	15.3	27.35	0.01
Battery life, months	78.2	57.2	36.95	0.001

Table 4 Mean tined lead (0–3 V) during SNM Stage 1.

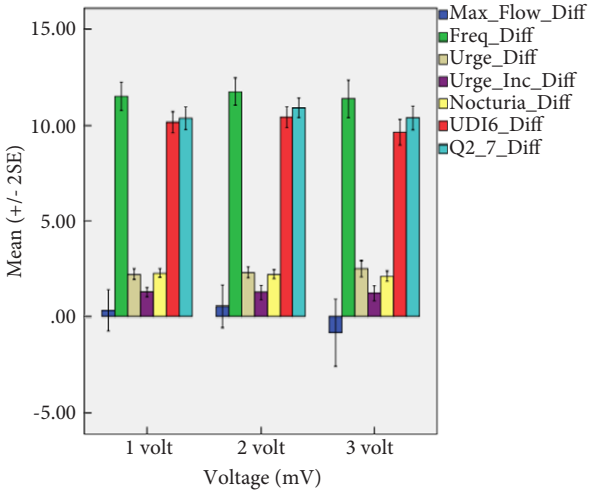
Cohort	Voltage, mean (SD)			
	Lead 0	Lead 1	Lead 2	Lead 3
Group A	3.89 (1.95)	3.31 (1.63)	2.47 (1.12)	2.42 (1.37)
Group B	5.85 (1.43)	5.47 (1.19)	5.32 (1.24)	5.47 (1.49)
Group C	3.52 (2.04)	2.79 (2.04)	2.45 (1.55)	3.80 (2.53)
Group D	5.47 (1.22)	5.47 (1.22)	5.35 (1.09)	5.24 (1.38)

(months), Stage 1 to Stage 2 conversion rates (%), success rates (%), pre- to postoperative frequency, pre- to postoperative urgency, adverse events (%), and explant rate (%). Quality of life measurements (PGI-I) and voiding questionnaires were not used, not comparable, and not included in the analysis. All similar data were compared between the studies, with percentage improvement the determining factor or raw data taken at face value.

Discussion

During my physician training for SNM therapy in 2001, Medtronic Inc. did not recommend any specific analogue voltage levels for attainment of an S_3 motor response. A Medtronic representative was present at every Stage 1 SNM procedure. He or she would apply an arbitrary voltage between 6 and 8 V to stimulate the bellows (levator ani contraction) and elicit brisk plantar flexion of the big toe, demonstrating the criteria for tined lead activation. This method may promptly identify the S_3 nerve and may even minimise operative time and the patient's anaesthetic. However, between 2001 and 2015, there was no conjecture that a particular voltage would affect improved patient outcomes during a Stage 1 SNM motor response trial [7,8]. It is of paramount importance to understand that every Stage 1 SNM is an electromyography (EMG) study in which a specific voltage is applied through a needle to the S_3 nerve to stimulate a motor contractile response. All EMGs should attempt motor stimulation response at the lowest possible voltage, as this may help locate a needle/tined lead position inherently closer in proximity to the nerve to be studied, theoretically with more congruent surface area between the nerve and tined lead, whilst optimising utilisation and elongating battery life (*private communication* with Dr John E. Hall, PhD, editor of *Guyton and Hall Medical Physiology*, 2015). We speculated that a successful lower voltage motor response at 3, 2 or 1 V may impart statistically significant improvements. Our statistical analysis may encourage practitioners to employ this straightforward technical modification during Stage 1 SNM. In our present study of >330 patients with either OAB or urinary retention, most voiding parameters improved ($P < 0.05$) by up to 40% when motor response was performed at ≤3 V. Stage 1 to Stage 2 conversion rates for both OAB and urinary retention were 94% (Table 1), a marked improvement over recent studies reporting a 35.4%, 49.1%, and 63.2% conversion rate [10,13–17]. Success rates are defined as a ≥50% improvement in voiding parameters for Medicare recipients and serve as an international standard. Peeters et al. [10] relate a success rate of 70% (Table 6) in their 2014 study of patients with OAB and urinary retention, with 217 patients and 4-year follow-up. In a multicentre 2018 study, Siegel et al. [11] report a 67% success rate, while Kerrebroeck et al. [12] report a 71% success rate. Two important voiding parameters are frequency and urgency. Table 6 juxtapositions our present 60% improvement in frequency vs Siegel et al. [11] at 35% and Kerrebroeck et al. [12] at 34%. We found a 70% reduction (improvement) in urgency vs both previous groups' 33% and 9% reduction (improvement scores). Adverse events were also a critical comparison. In my practice and the literature [17], adverse events commonly occur after falls or direct impact injuries, which lead to tine lead migration/displacement or independent equipment failure and subsequent outpatient care or operative revisional surgery. While the three study groups ranged from 40% to 50%, we incurred a 12–24% rate of traditional adverse events. We theorise that, in our low-voltage placement of the tined lead, the functional proximity to the S_3 nerve may impart a more serviceable lead space, and the lead may migrate several more millimetres from the nerve before its function becomes clinically worsened, compared to leads placed at a higher voltage. For example, if proximity to the nerve is improved with a lower voltage motor response and the patient falls causing a tined lead migration of 2–10 mm, this small movement of the tined lead may still be functional. However, if the higher voltage response lead is 5–10 mm away, an additional 2–10 mm lead migration may cause a logarithmic decrease in the conductivity of the lead. The essential factors to entertain with our technique is that it is time efficient [Table 1, mean (SD) operative time 18.7 (6.73) min, $P < 0.83$] and likely cost effective without requiring additional training or equipment supplementation/purchase. This is a straightforward approach with statistically significant gains achieved

Fig. 1 Multivariate analysis comparison showing the mean difference (±2 SE) from pre- to post-treatment. The overall MANOVA for the comparison of voltage groups 1, 2 and 3 V indicate no significant difference between the groups on the complex of outcome variables. Univariate ANOVAS on each measure are also non-significant ($P < 0.05$).



in all voiding parameters, validated voiding questionnaires and PGI-I scores.

Another investigative question is whether statistically significant improvements are achieved in patients' objective outcomes when the voltage to elicit a motor response is decreased from 3 to 2 to 1 V? Our MANOVA analysis (Fig. 1 and Table 5) shows that once a motor response of 3-V is achieved compared to 2- or 1-V, there is no additional statistical improvement in most outcome measures ($P < 0.19$).

Three patient outcomes (Table 5, each marked in bold print) were better in the 1-V cohorts vs either the 2- or 3-V groups; however, two of the three have nominal clinical importance. The PVR was better in the 1-V cohort with a mean improvement of 10 mL ($P > 0.032$). Nocturia improved by 0.17 voids/night ($P < 0.04$), but this is not clinically relevant. The third parameter appears to hold special significance, in that patients with a 1-V motor response after Stage 1 implant had a 32% (23/73) ($P < 0.001$) chance of experiencing severe pelvic pain/perirectal pain and big toe movement with small voltage adjustments during patient self-reprogramming (0.1–0.2 V). These untraditional adverse effects seem to improve over time and last between 2 and 6 months (mean 4.2 months) before the S_3 nerve adjusts, but the pain can recur at a later date. Patients report that this becomes a limiting factor in self-reprogramming, contributing to life with potentially suboptimal outcomes. When we examine these patients' 3-day voiding diaries, we find normal frequency (5–8 voids/24 h and one at night) and no urgency or urge incontinence in ~42% of patients. When asked why they reprogrammed themselves if the voiding diary accurately represented their normal urination habits, they appeared confounded and offered no explanation. Was anxiety to

Table 5 Comparison of all voiding of parameters between Group A (lowest voltage of 1 V) and Group B (lowest voltage of 2 or 3 V).

Patient characteristics	Group A (1 V)	Group B (2–3 V)	*P*
Number of patients	73	100	
Patient age, years, mean (SD)	56.2 (9.4)	56.0 (10.4)	0.157
Stage 1 to Stage 2 conversion rate, % (*n*/*N*)	78.1 (57/73)	82.0 (82/100)	0.564
Success rate, % (*n*/*N*)	80.8 (59/73)	83 (83/100)	0.532
Complications, % (*n*/*N*)	12.3 (9/73)	12.0 (12/100)	1.000
Mean (SD)			
Follow-up, months	120.4 (31.1)	113.3 (29.4)	0.126
PGI-I score	2.36 (0.79)	2.32 (0.75)	0.760
PVR, mL	33.6 (31.0)	43.3 (27.6)	0.032*
Postoperative Q_{max}, mL/s	22.4 (3.8)	22.0 (4.0)	0.285
Frequency: preoperative, episodes/24 h	19.4 (3.2)	19.2 (3.2)	0.704
Frequency: postoperative, episodes/24 h	7.89 (3.27)	7.60 (1.94)	0.464
Urgency: preoperative, episodes/24 h	3.24 (1.40)	3.40 (1.42)	0.164
Urgency: postoperative, episodes/24 h	1.02 (0.89)	1.01 (0.75)	0.104
Urgency incontinence: preoperative, episodes/24 h	1.82 (1.40)	1.98 (1.31)	0.451
Urgency Incontinence: postoperative, episodes/24 h	0.53 (0.87)	0.72 (1.20)	0.229
Nocturia: preoperative, voids/night	3.38 (1.06)	3.45 (1.06)	0.677
Nocturia: postoperative, voids/night	1.10 (0.60)	1.27 (0.51)	0.043*
UDI-6: preoperative score	17.89 (2.35)	18.23 (2.34)	0.328
UDI-6: postoperative score	7.73 (3.19)	8.13 (2.49)	0.350
IIQ-7: preoperative score	18.48 (2.71)	19.02 (2.73)	0.199
IIQ-7: postoperative score	8.12 (3.14)	8.33 (2.49)	0.652
Battery life, months	71.92 (5.97)	71.70 (6.72)	0.827
Annual reprogramming, *n*	1.14 (0.77)	1.12 (0.85)	0.843
Operative time, min	18.14 (5.59)	19.22 (7.45)	0.297
Pelvic pain with reprogramming, % (*n*/*N*)	32 (23/73)	8 (8/100)	0.001*

Group A, 1-V patients were only improved in two categories: PVR and nocturia both ($P < 0.05$). However, painful bellows spasm and big toe plantar flexion movement were statistically worse ($P < 0.001$) in the 1-V group taking from 6 to 12 months (mean 8.3 months) for appeasement after surgery.

Table 6 Comparison of lower-voltage vs higher-voltage motor response in clinical studies of SNM for OAB symptoms.*

Study data	Present study (2018)	Siegel et al. [11] (2016)	Kerrebroeck et al. [12] (2007)	Peeters et al. [10] (2014)
Number of patients	174	272	129	187
Age, years, mean (SD)	52.0 (14.6)	57.0 (14.2)	44.7 (11.2)	50.3
Follow-up, months, mean (SD)	116.3 (30.3)	60; −48%	49.3 (15.9); −57%	46.8, −58%
Stage 1 to 2 conversion rate, %	94	80; −14%	80; −14%	61.3; −33%
Success rate, %	82.1	67; −15%	71; −11%	70; −12%
Frequency: preoperative, episodes/24 h, mean (SD)	19.3 (3.2)	12.6 (4.5)	19.3 (7)	NA
Frequency: postoperative, episodes/24 h, mean (SD)	7.7 (2.6); +60%	8.2 (4.4.); +35%	13.0 (7.9); +33%	NA
Urgency: preoperative, episodes/24 h, mean (SD)	3.3 (1.4)	3.0 (0.8)	2.3 (0.6)	NA
Urgency: postoperative, episodes/24 h, mean (SD)	1.01 (0.8); +70%	2.0 (2.2); +33%	2.1 (0.7); +9%	NA
Adverse events, %	12	50; +38%	40; +28%	41; +29%
Explant rate, %	2.0	19.1; +17%	7; +5%	18; +16%

**The red percentages in upper half of the chart denote the percentage difference in follow-up, conversion rate, and success rate compared to our present study's baseline. The percentages in the bottom half of the chart represent improvement in post- vs preoperative frequency and urgency. Finally, the red percentages in adverse events and explant rates are compared to our present study's baseline. *Light blue scores represent the better statistical results for each of the 11 patient data categories. Comparisons reveal significant improvement with ≤3-V motor provocation vs the traditional ≥6 V as likely utilized by these three investigator groups.*

blame? I have no clear-cut answer, but it is important for practitioners to understand the potential pitfalls of this technique.

Since 2017, Medtronic has been advocating the use of a lower voltage technique of ≤2 V, but as of March 2018, no evidence-based papers are available on Medline or PubMed, suggesting that this recommendation is opinion-based opposed to evidence-based. We contacted a Medtronic representative and requested information about the recommendation and were told that the <2-V recommendation is the opinion of their urology SNM consultant team.

We do not endorse this recommendation because of the >30% incidence of severe pelvic/perirectal pain and big toe movement, leaving patients hesitant to self-reprogram. With the above described ANOVA of the results, we show that once 3 V is achieved, no significant clinical improvements are attained by going lower with the motor response voltage – with the caveat that as you approach 1 V, the opportunity exists for severe pelvic pain and big toe movement with patient or physician reprogramming. Thus, 3 V is the safe, watershed moment for this low motor response technique, not 2 or 1 V.

Recently, our described technical concept may have encouraged Medtronic to sponsor a basic science study using lower voltages of 3, 2, and 1 V for motor responses in awake/anaesthetised sheep [18]. We encourage both basic science and clinical research studies with lower voltage motor response for neuromodulation to other nerves to see whether a 30–40% improvement can also be attained with this simple technical adjustment. Could clinical improvements be attained for gastric paresis, lower back pain, pelvic pain, migraine headaches, and movement disorders? We can only speculate that this technique will offer clinical improvements in other conditions, as well.

Conclusion

Our observational, double cohort study of patients with OAB symptoms and urinary retention advocates the use of ≤3-V motor response in Stage 1 SNM. The ≤3-V technique has shown statistically significant improvements ($P \leq 0.05$) in conversion rate, success rate, most voiding parameters, PGI-I, UDI-6, IIQ-7 questionnaires, adverse events, battery life, and annual reprogramming sessions with a mean follow-up approaching 10 years. We recommend a threshold of 3-V for motor response attainment to avoid potential problematic bellows and ipsilateral plantar flexion with small increments in voltage adjustments and because lower voltage imparts no statistically significant improvement in objective voiding parameters. Further randomised controlled trials must be conducted to verify our outcomes.

Conflicts of Interest

None.

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This paper dedicated to my mentor,

Stuart L. Stanton, MBBS

Professor Emeritus of Urogynecology/Female Reconstructive Surgery

St George's School of Medicine

Tooting, UK,

You taught me how to organize my thoughts and habits for a successful career in Female Reconstructive Surgery. I will always vividly recall our clinic and operating room days at St George's, Greater Portland and Lister Hospitals. I often reminisce our sage laden conversations every Friday morning while in route to Greater Portland Hospital and in between our cases while dining on their splendid Smoked Salmon sandwiches and Turkish Figs. I will always cherish the time I spent under your tutelage. As Alexander the Great is quoted "I am indebted to my father for living, but to my teacher for living well". Happy 80th birthday.

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Abbreviations: EMG, electromyography; FDA, Federal Drug Administration; IIQ-7, Incontinence Impact Questionnaire-7; IPG, implantable pulse generator; MANOVA, multivariate ANOVA; OAB, overactive bladder; PGI-I, Patient Global Impression of Improvement Questionnaire; PVR, post-void residual urine; Q_{max}, maximum urinary flow rate; SNM, sacral neuromodulation; UDI-6, Urogenital Distress Inventory-6.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Video S1. Utilizing a 3-Volt motor respone during Stage 1 Sacral Neuromodulation Improves All Voiding Parameters over Traditional 6 Volt or more motor response and with Fewer Complications.