Clinical Research

Urodynamic parameters as predictors of percutaneous tibial nerve stimulation outcomes in overactive bladder patients

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ABSTRACT

BACKGROUND Percutaneous tibial nerve stimulation (PTNS) is an emerging overactive bladder (OAB) treatment. However, some patient characteristics can affect its effectiveness. Urodynamic studies help diagnose OAB by evaluating bladder function. This study aimed to identify prognostic factors for PTNS treatment based on urodynamic parameters.

METHODS A retrospective study was performed on 108 patients with OAB who underwent PTNS at Persahabatan Hospital, Jakarta, Indonesia, between January 2022 and January 2023. Patients with primary OAB received an 8-week PTNS regimen and were grouped into success and failure. Pre-treatment urodynamic parameters were extracted and compared between groups. Additional multivariate Cox regression analysis was performed to identify risk factors associated with PTNS failure.

RESULTS Of 108 patients (mean age: 51.69 [17.5]), 77 (73.1%) responded favorably to PTNS treatment. Three significant covariates of PTNS failure were identified: initial sensation volume (hazard ratio [HR]: 6.312; 95% confidence interval [CI]: 1.94–20.49), detrusor overactivity (DO) (HR: 8.476; 95% CI: 1.89–38.095), and infravesical obstruction (IVO) (HR: 5.213; 95% CI: 1.40–19.41).

CONCLUSIONS Urodynamic predictors including abnormal first sensation volume, DO, and IVO were observed as risk factors for PTNS failure. These findings can help medical professionals personalize PTNS treatment, enhancing patient outcomes and satisfaction.

KEYWORDS overactive bladder, percutaneous nerve stimulation, tibial nerve, urodynamic

Overactive bladder (OAB) is a common, debilitating urological condition affecting millions of people worldwide, which significantly affects the quality of life (QoL) and inflicts significant healthcare costs.[1] OAB is characterized by urinary urgency, with or without urge incontinence, usually accompanied by increased frequency and nocturia.[2] Although various pharmacological and non-pharmacological treatments, including antimuscarinic drugs, beta 3-adrenoceptor agonists, and neuromodulation therapies, have been developed, patient responses vary.[3]

Percutaneous tibial nerve stimulation (PTNS) is a minimally invasive neuromodulation therapy that targets the sacral nerve plexus by stimulating the posterior tibial nerves. PTNS has demonstrated promising results in reducing OAB symptoms and improving patient QoL.[4] Consequently, this therapy is recommended for patients unresponsive to pelvic floor

exercise, behavioral therapy, or pharmacotherapy.[5] A recent randomized controlled trial (RCT) showed that combining PTNS with standard bladder training significantly improved incontinence severity, voiding frequency, and patient satisfaction, reinforcing its utility in multimodal management strategies for OAB.[6] Although OAB can be diagnosed and evaluated through history taking, urodynamics studies are nevertheless valuable for bladder function assessment.[6,7] Indeed, one prior study suggested that symptomatic diagnosis alone tended to understate the degree of patients' detrusor inability, with nearly 50% of patients with OAB lacking detrusor instability, indicating the existence of alternative etiologies.[7,8]

Identifying the predictive factors for treatment responses can help clinicians in customize therapies, maximize outcomes, and minimize adverse effects. Therefore, this study aimed to explore the urodynamic predictors of successful PTNS regimens in patients with OAB and future research directions. As urodynamic results represent bladder function, abnormalities indicating more severe bladder dysfunction may predict a higher risk of PTNS failure.

METHODS

Patient enrollment and management

This retrospective case-control study enrolled 108 patients with OAB who underwent PTNS at Persahabatan Hospital, Jakarta, Indonesia, between January 2022 and January 2023. The inclusion criteria were patients with primary OAB who completed eight cycles of the PTNS regimen. Each treatment cycle comprised 30 min PTNS sessions conducted once weekly for eight consecutive weeks. PTNS was conducted using a 34-gauge needle inserted 4–5 cephalad into the medial malleolus to stimulate the posterior tibial nerve. Proper electrode placement was confirmed based on large toe flexion or movement. The electrical current was set at 200 µs and 20 Hz, with the intensity adjusted to match patient tolerance. Treatment success was determined using the OAB symptom score (OABSS), a self-reported symptom questionnaire completed before and after PTNS regimens, with a minimum of three points after eight sessions.[9]

Patients receiving PTNS for non-OAB, those with other neurological conditions, or those who did not complete eight cycles of PTNS were excluded. Informed consent was obtained from all eligible patients. Demographic and clinical information extracted from the medical records included age, sex, body mass index, and comorbidities (e.g., diabetes, hypertension, and anxiety disorders), as well as baseline urodynamic findings and subjective outcomes. The baseline urodynamic parameters assessed included the first sensation, strong sensation, bladder compliance, detrusor overactivity (DO), DO with incontinence, bladder outlet obstruction (BOO), detrusor underactivity (DU), and electromyography (EMG) activation.

Definitions

The definitions of key terms were as follows: first sensation, the bladder no longer empties fully; strong sensation, experiencing a repeated urge to urinate without incontinence or leakage; bladder compliance, classified as low or normal and calculated as the volume change divided by detrusor pressure (Pdet; 40 ml/cm H_2O or less); and BOO during voiding phase, identified using elevated Pdet levels and insufficient urine flow. The BOO index (BOOI) was calculated using the following formula: PdetQmax – 2Qmax. The results were classified as follows: BOOI >40 indicated an infravesical obstruction (IVO), 20–40 equivocal, and <20 unobstructed.[4] In women, BOO was defined by Pdet at Qmax >20 cm H_2O and Qmax <12 ml/s, whereas the bladder contractility index (BCI) to diagnose DU was calculated as PdetQmax + 5Qmax. For both men and women, DU was defined as Qmax <12 ml/s, Pdet at Qmax <10 cm H_2O, with a BCI score of 100.[10] EMG was defined as any increased or inappropriate pelvic floor muscle activity during bladder filling or voiding, indicating a possible dysfunction of the bladder-sphincter coordination.[11]

Data and statistical analysis

Patients were categorized as either successful or failed PTNS responders, with success defined as an OABSS reduction of more than two points at the end of the baseline.[8,9] Demographic characteristics at baseline were presented descriptively, whereas pretreatment urodynamic parameters measured were extracted and compared between the two groups. Overall, 13 urodynamic parameters were assessed.

Non-responders and responders were compared using chi-square (categorical variables), Student's *t*- (numerical variables), and Mann–Whitney tests

(ordinal variables). An additional comparative analysis of the OABSS before and after PTNS was conducted to determine the significance of the 8-week PTNS regimen for all patients. Statistical significance was set at $p<0.05$. Both univariate and multivariable Cox regression models were conducted to identify predisposing risk factors for PTNS failure. The interpretation of the Cox regression analysis assumed no significant changes in the proportional hazard of chronic conditions, while linearity was maintained for the Cox regression analysis involving urodynamic parameters, as these parameters directly reflect bladder function. This study was approved by the Ethics Committee of the Faculty of Medicine, universitas Indonesia – Cipto Mangunkusumo Hospital (No: KET-956/UN2.F1/ETIK/PPM.00.02/2023) and complied with the Declaration of Helsinki.

RESULTS

Patients

Of 108 patients with OAB who underwent PTNS with a mean age of 51.69 (17.5) years, 77 (71.3%) underwent successful PTNS treatment. The baseline characteristics were similar between groups (Table 1). Diagnoses were confirmed using urodynamic tests prior to PTNS. Overall, patients had an average Qmax lower than that of the normal values (9.36 [4.37] ml/s), whereas the mean post-void residual volume was slightly higher (51.68 [53.6] ml). The mean detrusor pressure at Qmax was 26.8 (11.9) cm H_2O, whereas the mean bladder pressure was 211.18 (109.95) ml. Overall, 45 (41.7%), 41 (38.0%), and 25 (23.1%) patients had DO, DO accompanied by incontinence, and abnormal bladder compliance, respectively.

Table 1. Baseline characteristics

Baseline characteristics	Failed PTNS, (N = 31)	Successful PTNS, (N = 77)
Age (years), mean (SD)	50.09 (17.63)	52.632 (17.52)
Male sex, n (%)	17 (55)	38 (49)
BMI (kg/m^2), mean (SD)	23.87 (4.43)	23.82 (4.36)
Diabetes, n (%) (n = 98)	11 (38)	18 (26)
Hypertension, n (%) (n = 106)	13 (45)	35 (45)
Anxiety disorder, n (%) (n = 106)	6 (21)	14 (18)

BMI=body mass index; PTNS=percutaneous tibial nerve stimulation; SD=standard deviation

Comparison of urodynamic results

The urodynamic results were compared between the successful and failed PTNS responder groups (Table 2). Failed PTNS responders had a significantly higher Pdet at Qmax, along with greater incidences of DO and abnormal bladder compliance. In contrast, successful PTNS resulted in a significantly higher bladder volume during the filling phase and a greater proportion of normal first sensation volumes. Additionally, DU and IVO were significantly lower among successful cases. No significant differences were observed in the other urodynamic parameters, including DO with incontinence and EMG activation of the bladder.

Predisposing factors

The severity of patients' symptoms before and after PTNS was evaluated using the OABSS for quantitative comparison. The average total OABSS decreased from 5.02 (1.8) before treatment to 2.42 (1.8) after treatment, with a statistically significant mean difference of 2.59 (1.8) ($p<0.001$), indicating symptom improvement. Univariate and multivariate regression analyses were conducted to identify statistically significant factors associated with treatment success/failure (Table 3). Only DO with urinary incontinence and DU were insignificant in the univariate Cox regression. However, multivariate analysis revealed only three statistically significant factors for PTNS failure: first sensation volume (hazard ratio [HR]: 6.312; 95% confidence interval [CI]: 1.94–20.49), DO (HR: 8.476; 95% CI: 1.89–38.095), and IVO (HR: 5.213; 95% CI: 1.40–19.41).

DISCUSSION

This study identified significant differences in several urodynamic parameters between patients in whom PTNS regimens were classified as a failure or success. Key factors influencing treatment success included bladder volume, first urination sensation, bladder compliance, DO (with or without urinary incontinence), IVO, and DU. Multiple studies have highlighted the efficacy of PTNS in significantly improving the clinical and urodynamic outcomes. Sonmez et al[6] further found that PTNS and transcutaneous tibial nerve stimulation (TTNS) combined with bladder training significantly improved OAB outcomes compared to training alone. TTNS and PTNS had similar efficacy, but TTNS was associated with higher patient satisfaction, less discomfort, and a

Table 2. Baseline urodynamic parameters of study participants

Urodynamic parameters	Failed PTNS	Successful PTNS	*p*
Qmax uroflowmetry (ml/s), mean (SD)	9.01 (4.43)	9.49 (4.36)	0.599
Voided volume uroflowmetry (ml), mean (SD)	141.99 (91.61)	133.89 (103.36)	0.705
PVR uroflowmetry (ml), mean (SD)	50.62 (44.97)	52.11 (56.91)	0.897
Filling phase			
Bladder volume (ml), mean (SD)	139.84 (112.31)	210.42 (114.97)	**0.004**
First sensation, mean (SD)	105.59 (33.57)	125.87 (64.49)	**0.037**
Strong sensation (ml), mean (SD)	208.24 (99.06)	207.28 (104.12)	0.966
DO, n (%)			**<0.001**
Yes	20 (69)	25 (32)	
No	9 (31)	54 (68)	
DO with incontinence, n (%)			0.143
Yes	15 (52)	26 (33)	
No	14 (48)	53 (67)	
Bladder compliance, n (%)			**<0.001**
Normal	16 (52)	67 (87)	
Abnormal	15 (48)	10 (13)	
Voiding phase			
IVO, n (%)			**0.002**
Yes	14 (48)	15 (19)	
No	15 (52)	64 (81)	
DU, n (%)			**<0.001**
Yes	19 (66)	17 (22)	
No	10 (34)	62 (78)	
EMG activation, n (%)			0.523
Yes	3 (10)	12 (15)	
No	26 (90)	67 (85)	

DO=detrusor overactivity; DU=detrusor underactivity; EMG=electromyography; IVO=infravesical obstruction; PTNS=percutaneous tibial nerve stimulation; PVR=post-void residual volume; SD=standard deviation

Table 3. Univariate and multivariable Cox regression analyses factors predicting the failed PTNS treatment

Variables	Univariate		Multivariable	
	HR (95% CI)	*p*	HR (95% CI)	*p*
Bladder volume	0.994 (0.99–0.998)	**0.005**	0.998 (0.99–1.004)	0.998
First sensation	7.018 (2.74–17.98)	**<0.001**	6.312 (1.94–20.49)	**0.002**
Bladder compliance	7.393 (2.76–19.79)	**<0.001**	4.465 (1.15–17.32)	**0.031**
DO	4.800 (1.92–12.03)	**0.001**	8.476 (1.89–38.095)	**0.005**
DO with urinary incontinence	1.903 (0.80–4.53)	0.146	0.488 (0.12–2.07)	0.331
IVO	3.982 (1.59–9.99)	**0.003**	5.213 (1.40–19.41)	**0.014**
DU	1.64 (0.63–4.25)	0.308	2.354 (0.64–8.73)	0.200

CI=confidence interval; DO=detrusor overactivity; DU=detrusor underactivity; HR=hazard ratio; IVO=infravesical obstruction; PTNS=percutaneous tibial nerve stimulation

shorter preparation time, supporting its use as a more tolerable alternative.[6] Similarly, in a study lasting 9 years, Iyer et al[12] observed >50% symptom improvement in 61.5% of patients following a 12-week PTNS regimen, with significant reductions in incontinence, nocturia, and urinary frequency. Another study by Tudor et al[13] found that at the end of a 12-week regimen, 66% of patients reported symptom improvement they deemed sufficiently significant to warrant continued maintenance treatment, supporting the long-term benefit of PTNS in managing OAB symptoms. Previous RCTs have reported notable improvements in bladder symptoms, including frequency, nocturia, urgency, and incontinence, among patients treated with PTNS compared to a placebo group.[4,6] These findings are in agreement with the present study, which found a significant reduction in OABSS after PTNS, confirming PTNS as an effective treatment for patients with OAB. However, the existing evidence indicates that PTNS is not universally effective, with some patients experiencing minimal to no benefit. Identifying significant predictors of treatment success is imperative to improve healthcare efficiency, particularly in developing countries where access to specialized urological care, advanced diagnostic tools, and long-term treatment options may be limited. Overall, the present study found that patients with a higher bladder volume, normal first sensation volume, no DO, normal bladder compliance, no IVO, and no DU were significantly more likely to achieve successful PTNS outcomes. These characteristics could therefore be considered as positive predictors of PTNS success, reinforcing the findings of previous studies.

Among patients with successful PTNS, a higher bladder volume emerged as a positive predictor compared to the PTNS failure group. This finding aligns with the understanding that PTNS modulates sacral nerve plexus activity and influences detrusor behavior. As noted by Wibisono and Rahardjo,[14] DO is often driven by neurogenic, myogenic, or afferent hypersensitivity mechanisms that may reduce the efficacy of PTNS in patients with significant DO. Furthermore, PTNS has shown better outcomes in patients without DO or in those with preserved bladder compliance. Additionally, another study linked DO to a greater probability of PTNS failure, further showing that higher detrusor pressure exacerbates the likelihood of failed PTNS.[15] This finding aligns with the present study, in which DO was found to be significantly more common among PTNS failures (69.0% *versus* 31.6%, $p<0.001$). Univariate regression analysis further revealed that patients with DO were 4.8 times more likely to have failed PTNS, whereas the multivariate analysis showed an 8.5 times higher risk. This may be due to underlying comorbidities, such as neurological disorders, which influence the effectiveness of PTNS.[6,16]

To date, no prior studies have identified the first sensation, bladder compliance, DU, or IVO as predictors of PTNS outcomes. The proposed mechanism of PTNS involves peripheral stimulation of the posterior tibial nerve, which modulates the micturition reflex by activating large-diameter somatic afferent fibers. These fibers converge at the L4–S3 spinal segments—a region integral to both motor and sensory control of bladder function—making it a common target for sacral neuromodulation therapies.[17] One animal study by Theisen et al[18] showed that 5 Hz tibial nerve stimulation significantly increased bladder capacity to 85.2 ± 8.2% of controls and inhibited bladder overactivity, whereas lower frequencies (0.5–3 Hz) induced large-amplitude, sustained bladder contractions. As both the first sensation and bladder compliance reflect neural bladder function, a healthier neural pathway may enhance the efficacy of peripheral stimulation. Furthermore, IVO is associated with OAB symptoms, indicating that better baseline urodynamic parameters reflect milder dysfunction, thereby requiring less neuromodulation to achieve symptomatic relief.[19]

This study has several limitations. First, the short 1-year duration of the study limited the sample size. Second, all data were collected from a single hospital in Jakarta, Indonesia, potentially introducing a regional bias. Third, this study assessed only an 8-week PTNS regimen, even though longer durations (>8 weeks) have previously shown better outcomes. Thus, although no optimal duration has been established, the findings apply especially to an 8-week regimen and may differ with extended treatment. Finally, the study was susceptible to sparse data bias due to the uneven distribution of successful and failed PTNS cases, with more patients in the successful group.

In conclusion, the results of this study show that PTNS is an effective management strategy for patients with OAB, and significantly reduces the OABSS. Further, we found several negative predictors of treatment success, including low bladder volume, abnormal first sensation volume, abnormal bladder compliance, DO, and IVO. Among these, abnormal first sensation

volume, DO, and IVO were classified as independent risk factors. Further research is needed to confirm these findings and to identify additional predictors to help clinicians personalize PTNS therapy for individual patients, potentially improving patient outcomes and satisfaction.

Conflict of Interest

Harrina Erlianti Rahardjo is the editorial board member but was not involved in the review or decision-making process of the article.

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