The short-term effects of posterior tibial nerve stimulation on anorectal physiology in patients with faecal incontinence: a single centre experience

Nick A. Heywood, James S. Pearson, James E. Nicholson, Clare Molyneux, Abhiram Sharma, Edward S. Kiff, Peter J. Whorwell and Karen J. Telford

Abstract
Background: Posterior tibial nerve stimulation (PTNS) is a novel treatment for patients with faecal incontinence (FI) and may be effective in selected patients; however, its mechanism of action is unknown. We sought to determine the effects of PTNS on anorectal physiological parameters.

Methods: Fifty patients with FI underwent 30 min of PTNS treatment, weekly for 12 weeks. High-resolution anorectal manometry, bowel diaries and Vaizey questionnaires were performed before and after treatment. Successful treatment was determined as a greater than 50% reduction in FI episodes.

Results: Fifty patients with FI were studied; 39 women, median age 62 years (range 30–82). Compared with pretreatment, there were reductions in episodes of urgency (16.0 versus 11.4, \(p = 0.006\)), overall FI (14.5 versus 9.1, \(p = 0.001\)), urge FI (5.4 versus 3.2, \(p = 0.016\)) and passive FI (9.1 versus 5.9, \(p = 0.008\)). Vaizey score was reduced (16.1 versus 14.5, \(p = 0.002\)). Rectal sensory volumes (ml) decreased (onset 40.3 versus 32.6, \(p = 0.014\), call 75.7 versus 57.5, \(p < 0.001\), urge 104.1 versus 87.4, \(p = 0.004\)). There was no significant change in anal canal pressures (mmHg) (maximum resting pressure 41.4 versus 44.2, \(p = 0.39\), maximum squeeze pressure, 78.7 versus 88.2, \(p = 0.15\), incremental squeeze pressure 37.2 versus 44.1, \(p = 0.22\)).

Reduction in FI episodes did not correlate with changes in physiological parameters \((p > 0.05)\). Treatment success of 44% was independent of changes in manometric parameters \((p > 0.05)\).

Conclusions: PTNS has a measurable physiological effect on rectal sensory volumes without an effect on anal canal pressures. It also reduces FI episodes; however, this effect is independent of changing physiology, suggesting that PTNS has a complex mechanism of action.

Keywords: Faecal, faecal incontinence, incontinence, neuromodulation, PTNS, stimulation

Introduction
Faecal incontinence (FI) is a common problem with a prevalence of between 0.4% and 18% of the adult population,\(^1,2\) depending on how incontinence is defined in studies. It carries with it significant physical and psychological comorbidity.\(^3\) Bowel diaries and scoring systems are commonly used to determine the severity of faecal incontinence and the response to treatment\(^4,5\) and high-resolution anal manometry (HRAM) has become the preferred investigation of choice for patients with FI. However, there is considerable overlap of manometric measurements when comparing continent and incontinent individuals and anorectal manometry is an unreliable predictor of outcomes after intervention.\(^6–8\)
Posterior tibial nerve stimulation (PTNS) is a form of neuromodulation used in the treatment of urinary incontinence and FI, safely performed in an outpatient setting. A number of studies report symptom improvement of FI after PTNS, however most published studies are uncontrolled and many use wide varieties of scoring systems and outcome reporting to define success.

Neither the exact mechanism of action of PTNS nor its effect on physiology is fully understood. PTNS is proposed to act by direct modification of the peripheral nerve roots which share the same spinal roots as the neuronal innervation to the pelvic floor (L4–S3), or by central stimulation of cortical pontine activity. Few studies in the published literature report these effects specifically. Aside from the randomized controlled trial by Knowles and colleagues comparing treatment success of PTNS with sham electrical stimulation, only one recent study has measured HRAM before and after PTNS treatment, which included relatively small numbers. It found a significant correlation between increased maximum squeeze pressures and reduced Wexner score, but the effect on other physiological parameters was unclear. Consequently, we sought to determine the effects of PTNS on physiological parameters in a larger cohort of patients.

**Materials and methods**

Patients referred to our institution with faecal incontinence were seen by a coloproctologist who obtained a full history and performed clinical examination. Specialist assessment included ano-rectal physiology. Patients who had failed conservative management, including lifestyle modification, pharmacological or biofeedback treatment, were considered for PTNS. All patients were discussed at a specialist pelvic floor multidisciplinary team meeting and suitable patients were counselled by a pelvic floor physiotherapist and informed written consent was obtained. Pretreatment HRAM was performed and patients were asked to complete bowel diaries and the Vaizey incontinence score for 2 weeks prior to treatment. Data acquisition, visualization and signal processing were performed using a commercially available manometry system (Solar GI v9.3; Medical Measurements Systems, Enschede, The Netherlands).

**Posterior tibial nerve stimulation**

Patients were positioned in a sitting position with their right foot resting on a stool. The needle electrode was percutaneously sited 5 cm cephalad to the medial malleolus and 2 cm posterior to the tibia with the tip of the needle approximately 2 cm deep to the skin. A surface electrode was placed near the medial aspect of the calcaneus of the ipsilateral limb and both were connected to the stimulator. Correct placement of the needle was identified by running the test programme and eliciting a motor (toe flex, dorsiflexion) or sensory (tingling sensation travelling to the heel, arch or toes) response through incrementally increasing the amplitude of the stimulus. In the case of non-response, the needle was repositioned and placement rechecked until a response was obtained. Once a tolerable response was confirmed, stimulation was delivered for 30 min.

**Equipment**

HRAM was performed using a standard water perfused catheter with a nonlatex balloon attached to the end. It incorporates 10 circumferential sensors at 0.8 cm intervals and has an external diameter of 14 Fr (customized single-use ano-rectal 10ch catheter, S7-R10-1003; Mui Scientific, Mississauga, Canada; balloon #BS6, volume = 400 ml max; Mui Scientific). Prior to the investigation, sensors were zeroed to atmospheric pressure at the level of the anal verge. Data acquisition, visualization and signal processing were performed using a commercially available manometry system (Solar GI v9.3; Medical Measurements Systems, Enschede, The Netherlands).

**Protocol**

HRAM was performed in the left-lateral position following informed written consent. Prior to catheter insertion, a digital rectal examination was performed with subjects asked to ‘squeeze’ and ‘push’ in order to confirm their understanding of these instructions.
The procedure was performed using a modified London HRAM protocol as described by Carrington et al. Briefly, the catheter was inserted into the anorectum with the most distal two pressure transducers being located outside the anal verge. Following a 3 min run-in familiarization phase, subjects underwent a 1 min rest phase and two 5 s ‘squeeze’ phases with a 30 s recovery phase between them. Rectal sensory volumes were examined by balloon insufflation and subjects were asked to indicate their first sensation (onset), desire to defecate (call), and maximum tolerated volume (urge) in ml. Mean resting pressure (MRP), maximum squeeze pressure (MSP) and incremental squeeze pressure (ISP) were recorded in mmHg.

Statistical analysis
Demographic and clinical data were collected and prospectively maintained on an electronic database for clinical audit purposes and analysed using SPSS Statistics version 22 (IBM, Chicago, IL, USA), with statistical support from a medical statistician. HRAM parameters, bowel diaries and Vaizey scores were compared using the paired t test. Comparisons between groups were performed using the independent samples t test and relationships between variables were tested using Pearson correlations. Significance was assumed at the p less than 0.05% level. As an evaluation of a new service, no sample size calculation was performed.

Ethical permissions
Our study was designed and conducted to audit a new service against the UK National Institute of Health and Care Excellence guidance and, after appraisal against the Health Research Authority decision tool, was not subject to ethical review.

Results

Demographics
A total of 50 patients completed the course of PTNS; 39 women and 11 men. The median age was 62 years (range 30–82). Twenty-two (44%) patients had urge, 22 (44%) had mixed and 6 (12%) had passive faecal incontinence. All 50 underwent HRAM before and after treatment and all returned completed bowel diaries. The parameter of ‘urgency episodes’ was added to the questionnaire after the first nine patients had undergone treatment, however it was still included for analysis. One patient’s post-treatment Vaizey score was unavailable for analysis.

Bowel diaries
Compared with pre-treatment there was no significant difference in the mean total number of bowel movements after PTNS. There was a significant reduction in the number of urgency episodes (16.0 versus 11.4, p = 0.006), total FI episodes (14.5 versus 9.1, p = 0.001), urge FI episodes (5.4 versus 3.2, p = 0.016) and passive FI episodes (9.1 versus 5.9, p = 0.008) as shown in Table 1.

Overall, 33 patients had reduction in total FI episodes, 12 patients had an increase and in 5 there was no change. Using the definition of ‘greater than 50% reduction in incontinence episodes’, PTNS was successful in 44% (22/50) of patients.

### Table 1. Comparison of bowel diaries in the 2 weeks before and after treatment with posterior tibial nerve stimulation performed using the paired t test, significance at the 0.05 level.

| Parameter                                      | Mean number pretreatment (SD) | Mean number post treatment (SD) | Mean percentage reduction | p value |
|------------------------------------------------|-------------------------------|---------------------------------|---------------------------|---------|
| Total bowel movements in 2 weeks [n = 50]      | 42.2 [22.0]                   | 39.3 [21.7]                     | 6.9                       | 0.278   |
| Urge episodes [n = 41]                         | 16.0 [16.7]                   | 11.4 [11.5]                     | 28.8                      | 0.006   |
| Urge FI episodes [n = 50]                      | 5.4 [7.5]                     | 3.2 [5.3]                       | 40.7                      | 0.016   |
| Passive FI episodes [n = 50]                   | 9.1 [10.6]                    | 5.9 [8.5]                       | 35.2                      | 0.008   |
| Total FI episodes [n = 50]                     | 14.5 [14.6]                   | 9.1 [11.4]                      | 37.2                      | 0.001   |

FI, faecal incontinence; SD, standard deviation.
When comparing patient groups of success versus failure using this definition, there was no difference in age (58.2 versus 59.8, \( p = 0.68 \)), baseline Vaizey score (16.07 versus 16.18, \( p = 0.93 \)) or number of incontinence episodes listed in Table 1 (\( p > 0.05 \)).

A comparison of pre-PTNS and post-PTNS Vaizey scores and bowel diaries was performed. There was no correlation between the change in Vaizey score and change in total FI episodes, urgency episodes or urge FI episodes. However, a significant positive correlation was found between the change in Vaizey score and the change in total number of bowel movements (0.378, \( p = 0.007 \)) and the change in passive FI episodes (0.309, \( p = 0.031 \)) (Table 2).

Table 2. Pearson correlation between the change in Vaizey score with frequency of defecatory and FI episodes. Significance is at the 0.05 level.

| Parameter                        | Change in total frequency | Change in total FI episodes | Change in urge episodes \( n = 41 \) | Change in urge FI episodes | Change in passive FI episodes |
|----------------------------------|---------------------------|----------------------------|--------------------------------------|---------------------------|------------------------------|
| Change in Vaizey score \( n = 49 \) | 0.378                     | 0.295                      | 0.189                                | 0.27                      | 0.309                        |
| \( p \) value                    | 0.007                     | 0.064                      | 0.193                                | 0.06                      | 0.031                        |

FI, faecal incontinence.

Table 3. Comparison of HRAM parameters before and after treatment with PTNS performed using the paired t test, significance at the 0.05 level.

| Anorectal physiology parameter          | Pretreatment mean (SD) | Post-treatment mean (SD) | Percentage change (%) | \( p \) value |
|-----------------------------------------|------------------------|--------------------------|-----------------------|--------------|
| Onset [ml] Normal range [20–40 ml] \( n = 50 \) | 40.3 (18.8)            | 32.6 (12.3)              | −19.1                 | 0.014        |
| Call [ml] Normal range [40–75 ml] \( n = 50 \) | 75.7 (26.6)            | 57.5 (20.5)              | −24.0                 | <0.001       |
| Urge [ml] Normal range [60–120 ml] \( n = 50 \) | 104.1 (39.6)           | 87.4 (35.4)              | −16.0                 | 0.004        |
| MRP [mmHg] Normal range [33–114 mmHg] \( n = 50 \) | 41.4 (20.3)            | 44.2 (21.5)              | 6.8%                  | 0.368        |
| MSP [mmHg] \( n = 50 \)                  | 78.7 (49.0)            | 88.2 (47.7)              | 12.1%                 | 0.146        |
| ISP [mmHg] Normal range [29–366 mmHg] \( n = 50 \) | 37.3 (45.1)            | 44.1 (37.8)              | 18.2%                 | 0.217        |
| Vaizey score \( n = 49 \)               | 16.1 (4.6)             | 14.5 (5.2)               | −9.9%                 | 0.002        |

HRAM, high-resolution anal manometry; ISP, incremental squeeze pressure; MRP, mean resting pressure; MSP, maximum squeeze pressure; PTNS, posterior tibial nerve stimulation; SD, standard deviation.

High-resolution anal manometry parameters

When comparing patient groups of success versus failure using this definition, there was no difference in age (58.2 versus 59.8, \( p = 0.68 \)), baseline Vaizey score (16.07 versus 16.18, \( p = 0.93 \)) or number of incontinence episodes listed in Table 1 \( (p > 0.05) \).

A comparison of pre-PTNS and post-PTNS Vaizey scores and bowel diaries was performed. There was no correlation between the change in Vaizey score and change in total FI episodes, urgency episodes or urge FI episodes. However, a significant positive correlation was found between the change in Vaizey score and the change in total number of bowel movements (0.378, \( p = 0.007 \)) and the change in passive FI episodes (0.309, \( p = 0.031 \)) (Table 2).
also an increase in MRP (6.8%), MSP (12.1%) and ISP (18.2%), however these changes were not statistically significant (Table 3).

Table 4 explores the differences between patients with or without a successful outcome; that is, those with a reduction in total FI episodes of 50% or more and those without. When the changes in HRAM parameters were compared between these two groups, no significant difference was found. The decrease in Vaizey score, however, is significantly greater in those with a successful outcome ($p = 0.009$).

A correlation analysis was performed to explore the relationship between the change in HRAM parameters and the change in the frequency of FI episodes recorded in the bowel diaries. We found no significant correlation between the reduction in FI episodes and the decrease in rectal sensory volume. There was also no correlation with anal sphincter pressure ($p > 0.05$ for all parameters).

The relationship between HRAM parameters and bowel diaries and Vaizey score

There was a significant negative correlation between the change in MRP with the mean call to stool ($-0.298$, $p = 0.035$) and urgency to defecate ($-0.336$, $p = 0.017$). No other correlation between HRAM parameters was identified. There was no correlation between the change in Vaizey and the change in HRAM parameters (Table 5).

Discussion and conclusion

This study shows that PTNS has a demonstrable effect on rectal sensation with reduction in volume for onset, call to stool and urgency. Furthermore, it also appears to offer significant benefit in some patients with FI with reduction in urgency and number of FI episodes.
A reduction in rectal sensory volumes of up to 24% was reported across all patients compared with pretreatment. There was a strong clinical impression that these patients reported earlier notice of an awareness to defecate post treatment. Higher volumes are considered to represent rectal hyposensitivity (RH) and are associated with both constipation and FI. Burgell and Scott suggest that RH may lead to constipation through faecal retention and rectal evacuatory dysfunction, and incontinence through association with functional constipation and impairment of reflexive or conscious contraction of the anal sphincters.19 Diamant and colleagues’ review of anorectal testing techniques discusses the perception of rectal distension as a requirement for continence, and that improved ability to detect rectal distension is needed for biofeedback treatment for FI.20 Our physiological findings would support the fact that a reduction in rectal sensory volumes may result in patients having earlier sensation of the presence of stool prior to reaching a threshold at which defaecation can no longer be delayed. Consequently, this increased awareness of stool in the rectum would make all the difference for patients reaching the bathroom in sufficient time to avoid an episode of FI. This subtle but significant delay in the need to defecate might make all the difference to the way a patient manages their FI and is not adequately captured in current FI severity instruments.

When adjusted for success (>50% reduction in FI episodes) we found no significant difference in the reduction in volumes between those who had treatment success, and those who did not; only Vaizey score was significantly different. The change in Vaizey score correlated with change in passive FI, however the significance of the correlation of Vaizey score with total bowel movements is not known. The changes in anorectal physiology did not correlate with reduction in FI episodes or Vaizey score, suggesting a physiological effect on patients independent of outcome. This objective change may suggest that the PTNS mechanism of action is through modification of sensory pathways, which is partly supported by our finding of a change in sensory thresholds, and may suggest a more complex action with other effects that we are currently unable to measure with HRAM or rectal sensory volumes alone.

In a recent double-blind, multicentre, pragmatic, parallel-group, randomized controlled trial, Knowles and colleagues16 found that PTNS conveyed no significant clinical benefit over sham electrical stimulation. They found it may confer benefit in certain patient subgroups, where they found a reduction in urge FI episodes. However, it was undertaken on an unselected group of patients with FI and the authors concluded that further studies would be required to determine any potential predictors of response to treatment. In our study, we found PTNS to be successful in 44% of patients, which is somewhat higher than the 38% reported by Knowles and colleagues using the same measure of success. Although our study was uncontrolled, it is interesting to note that the response rate in the control group in the Knowles study was 31%, suggesting that our success rate of 44% may be more than just a placebo effect. Indeed, a post hoc analysis of the CONFIDeNT study has shown a significant clinical effect of PTNS compared with sham when excluding patients with obstructive defaecation.21 The response rate of 48.9% is more comparable to the findings in our study and initial differences in success are likely to be explained by improved patient selection. Our view is also supported by the fact that from the bowel diary assessment, we found a significant reduction in mean urgency.

### Table 5. Pearson correlation between the changes in Vaizey score with HRAM parameters. Significance is at the 0.05 level.

| Parameter Change in onset | Change in call | Change in urge | Change in MRP | Change in MSP | Change in ISP |
|--------------------------|----------------|----------------|---------------|---------------|--------------|
| Change in Vaizey score (∗n = 49) | 0.101 | −0.01 | −0.226 | 0.231 | 0.059 | −0.57 |
| p value                  | 0.492 | 0.946 | 0.119 | 0.111 | 0.685 | 0.699 |

HRAM, high-resolution anal manometry; ISP, incremental squeeze pressure; MRP, mean resting pressure; MSP, maximum squeeze pressure.
total FI and both mean passive and mean urge FI episodes without a reduction in the total number of defecatory episodes, suggesting that PtNS is an effective treatment for FI.

There are few studies evaluating the direct physiological effects of PTNS, and although it is thought to reflexly neuromodulate the rectum and anal sphincters, its exact mechanism of action is not fully understood. Most studies utilize pretreatment anorectal physiology in the absence of a post-treatment comparison, correlating clinical outcomes with the pretreatment findings without examining the physiological effects of PTNS. In one such study of 88 patients with FI, Hotouras and colleagues evaluated the impact of sphincter morphology and rectal sensation on clinical outcome. They found improvements in patients with normal sensation, that clinical outcomes were independent of damage to the anal sphincter complex and they had statistically significant improvement in clinical parameters. In patients with abnormal rectal sensations, they found improvements only in the ability to defer defaecation. However, this used pretreatment definitions of median maximum tolerable volumes to classify hypo-, normo- and hypersensate rectal sensations without post-treatment measurements.

To our knowledge, our study is the largest study in the literature evaluating anal manometry before and after PTNS treatment. A similar study by Lopez-Delgado and colleagues described results in less than half the number of patients studied in our present study. They showed that, in 24 patients with FI, MRP and MSP were increased after treatment. These changes in pressure for all patients were not statistically significant. Although on further analysis, they found a significant increase in manometry pressures in those patients who showed improvement after PTNS, their definitions of successful outcomes were unclear. At 6 months (and after six top-up treatments), they found manometric improvement was more evident and there was a significant negative correlation seen between MRP/MSP and Wexner incontinence score. The outcomes of this self-selected group may suggest a role for top-up treatments, however due to the shorter follow-up period in our study, we cannot corroborate these findings. As with our study, there is also a considerable lack of long-term data on the effects of PTNS. Further follow-up would clarify the role of PTNS in the longer term. Several studies have shown it to have similar efficacy to SNS in the short term (6–12 months). PTNS, however, is much less invasive and can be performed in the outpatient setting, and in the short term, is a less expensive alternative.

Repeated attendances to clinic for PTNS may have a potential placebo effect and we are not able to report the degree of change that may have occurred over this period without intervention. Previous work also suggests that FI symptom severity scores may vary considerably over time in untreated patients. In a study of 45 patients undergoing biofeedback therapy for FI, Boselli and colleagues found reduced rectal sensitivity thresholds after treatment without statistically significant change in manometry variables or correlation with clinical outcome. Considering this, it is difficult to conclude at this time that PTNS alone is responsible for our findings, and it remains possible that there is a placebo effect.

PTNS appears to have a measurable physiological action on rectal sensory volume without effect on anal canal pressures. This change in sensory threshold might confer a benefit, which is not identified by current instruments, such as a delay between sensation and the need to defecate. Additional studies will need to combine manometric and anatomical parameters with more detailed baseline profiles such as the presence or absence of irritable bowel syndrome. Furthermore, there is a need for better selection of patients and use of patient-reported outcomes that identify factors that affect how patients manage FI and its effects on quality of life. Further analysis of increasing numbers of patients undergoing PTNS may be able to identify subgroups who may benefit.

Acknowledgements
We would like to acknowledge Phil Foden for his statistical support and Sharon Archbold, Jane Wych, Margaret Hastings, Sam Treadway and Domini Mullins for their contributions to clinical investigation and treatment. No additional funding was sourced for this study and patients were undergoing routine investigation and treatment for their symptoms. Part of this data were presented as a poster at ESCP, Milan, Italy, September 2016. NH, JP and JN contributed equally to all areas of the study. CM contributed to data collection, analysis of data and writing of the manuscript. AE, EK, PW and KT analysed data and contributed to the writing of the manuscript. The datasets generated
and analysed during the current study are not publicly available due to patients being under the care of the NHS, but are available from the corresponding author on reasonable request.

**Funding**

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

**Conflict of interest statement**

PW has acted as a consultant for, or received research grant support from, the following pharmaceutical companies in the last 5 years: Almirall Pharma, Boehringer–Ingelheim, Chr. Hansen, Danone Research, Ironwood Pharmaceuticals, Salix, Shire UK, Sucampo Pharmaceuticals and Allergan. PW is an associate editor for Therapeutic Advances in Gastroenterology. No other authors report any conflicts of interest.

**ORCID iD**

Nick A. Heywood https://orcid.org/0000-00 02-1852-9426

**References**

1. Jorge JM and Wexner SD. Etiology and management of fecal incontinence. *Dis Colon Rectum* 1993; 36: 77–97.

2. Macmillan AK, Merrie AE, Marshall RJ, et al. The prevalence of fecal incontinence in community-dwelling adults: a systematic review of the literature. *Dis Colon Rectum* 2004; 47: 1341–1349.

3. Perry S, Shaw C, McGrother C, et al. Prevalence of faecal incontinence in adults aged 40 years or more living in the community. *Gut* 2002; 50: 480–484.

4. Rockwood TH, Church JM, Fleshman JW, et al. Patient and surgeon ranking of the severity of symptoms associated with fecal incontinence: the fecal incontinence severity index. *Dis Colon Rectum* 1999; 42: 1525–1531.

5. Vaizey CJ, Carapeti E, Cahill JA, et al. Prospective comparison of faecal incontinence grading systems. *Gut* 1999; 44: 77–80.

6. Quezada Y, Whiteside JL, Rice T, et al. Does preoperative anal physiology testing or ultrasonography predict clinical outcome with sacral neuromodulation for fecal incontinence? *Int Urogynecol J* 2015; 26: 1613–1617.

7. Rieger NA, Sweeney JL, Hoffmann DC, et al. Investigation of fecal incontinence with endoanal ultrasound. *Dis Colon Rectum* 1996; 39: 860–864.

8. Lam TJ, Kuik DJ and Felt-Bersma RJ. Anorectal function evaluation and predictive factors for faecal incontinence in 600 patients. *Colorectal Dis* 2012; 14: 214–223.

9. Staskin DR, Peters KM, MacDiarmid S, et al. Percutaneous tibial nerve stimulation: a clinically and cost effective addition to the overactive bladder algorithm of care. *Curr Urol Rep* 2012; 13: 327–334.

10. Govaert P, Pares D, Delgado-Aros S, et al. A prospective multicentre study to investigate percutaneous tibial nerve stimulation for the treatment of faecal incontinence. *Colorectal Dis* 2010; 12: 1236–1241.

11. Findlay JM, Yeung JM, Robinson R, et al. Peripheral neuromodulation via posterior tibial nerve stimulation - a potential treatment for faecal incontinence? *Ann R Coll Surg Engl* 2010; 92: 385–390.

12. Hotouras A, Thaha MA, Boyle DJ, et al. Short-term outcome following percutaneous tibial nerve stimulation (PTNS) for faecal incontinence: a single-centre prospective study. *Colorectal Dis* 2012; 14: 1101–1105.

13. Shafik A, Ahmed I, El-Sibai O, et al. Percutaneous peripheral neuromodulation in the treatment of fecal incontinence. *Eur Surg Res* 2003; 35: 103–107.

14. Vandoninck V, van Balken MR, Finazzi Agrò E, et al. Percutaneous tibial nerve stimulation in the treatment of overactive bladder: urodynamic data. *Neurolour Urodyn* 2003; 22: 227–232.

15. Wexner SD. Percutaneous tibial nerve stimulation in faecal incontinence. *Lancet* 2015; 386: 1605–1606.

16. Knowles CH, Horrocks EJ, Bremner SA, et al. Percutaneous tibial nerve stimulation versus sham electrical stimulation for the treatment of faecal incontinence in adults (CONFIDeNT): a double-blind, multicentre, pragmatic, parallel-group, randomised controlled trial. *Lancet* 2015; 386: 1640–1648.

17. López-Delgado A, Arroyo A, Ruiz-Tovar J, et al. Effect on anal pressure of percutaneous posterior tibial nerve stimulation for faecal incontinence. *Colorectal Dis* 2014; 16: 533–537.

18. Carrington EV, Brokjaer A, Craven H, et al. Traditional measures of normal anal sphincter function using high-resolution anorectal
manometry (HRAM) in 115 healthy volunteers. *J Neurogastroenterol Motil* 2014; 26: 625–635.

19. Burgell RE and Scott SM. Rectal hyposensitivity. *J Neurogastroenterol Motil* 2012; 18: 373.

20. Diamant NE, Kamm MA, Wald A, *et al.* AGA technical review on anorectal testing techniques. *Gastroenterology* 1999; 116: 735–760.

21. Horrocks EJ, Chadi SA, Stevens NJ, *et al.* Factors associated with efficacy of percutaneous tibial nerve stimulation for fecal incontinence, based on post-hoc analysis of data from a randomized trial. *Clin Gastroenterol Hepatol* 2017; 15: 1915–1921.

22. Queralto M, Portier G, Cabarrot PH, *et al.* Preliminary results of peripheral transcutaneous neuromodulation in the treatment of idiopathic fecal incontinence. *Int J Colorectal Dis* 2006; 21: 670–672.

23. Hotouras A, Thaha MA, Allison ME, *et al.* Percutaneous tibial nerve stimulation (PTNS) in females with fecal incontinence: the impact of sphincter morphology and rectal sensation on the clinical outcome. *Int J Colorectal Dis* 2012; 27: 927–930.

24. Hotouras A, Murphy J, Allison M, *et al.* Prospective clinical audit of two neuromodulatory treatments for fecal incontinence: sacral nerve stimulation (SNS) and percutaneous tibial nerve stimulation (PTNS). *Surg Today* 2014; 44: 2124–2130.

25. Al Asari S, Meurette G, Mantoo S, *et al.* Percutaneous tibial nerve stimulation vs sacral nerve stimulation for faecal incontinence: a comparative case-matched study. *Colorectal Dis* 2014; 16: 0393–0399.

26. Thin NN1, Taylor SJ, Bremner SA, *et al.* Randomized clinical trial of sacral versus percutaneous tibial nerve stimulation in patients with faecal incontinence. *Br J Surg* 2015; 102: 349–358.

27. Cattle K and Kiff E. Faecal incontinence symptom severity scores fluctuate over time without treatment. *International Continence Society*, 2009. [Online]. Available: https://www.ics.org/Abstracts/Publish/47/000649.pdf.

28. Boselli AS, Pinna F, Cecchini S, *et al.* Biofeedback therapy plus anal electrostimulation for fecal incontinence: Prognostic factors and effects on anorectal physiology. *World J Surg* 2010; 34: 815–821.