High-resolution and 3D anorectal manometric parameters based on the London Protocol as a useful tool in the evaluation and follow-up of incontinent women patients undergoing biofeedback therapy

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Abstract

Background/Aim Fecal incontinence (FI) has a multifactorial pathophysiology with a potentially devastating impact on quality of life. The landmark development of high-resolution manometry (HRM) has allowed accurate assessment of anorectal function. Biofeedback (BF) has been recommended as a minimally invasive non-surgical therapeutic tool. This study aims to evaluate high-resolution and 3D manometric parameters based on the London Protocol (LP) for the diagnosis of incontinence compared to healthy volunteers, as well as the manometric repercussions of incontinent patients undergoing the BF protocol and its effectiveness.

Methods Twenty-four female incontinent patients underwent water-perfused 36-channel HRM were compared to 25 healthy female volunteers. Incontinent were submitted to an 8-week BF protocol and their manometric parameters and fecal incontinence scores were compared to pre-BF, 3 and 6 months (m) after BF completion. All manometric data (post-BF, 3 and 6m period) were compared with healthy individuals.

Results Incontinent pre-BF vs healthy: resting- lower pressure (mean maximum, mean,3D), shorter functional anal canal length (FACL), higher asymmetry to highest and lowest pressure; short squeeze-lower pressure (maximum incremental,absolute,mean,3D), higher asymmetry to highest and lowest pressure; endurance- lower 3D pressure (1/3, 2/3, 3/3), lower values (fatigue rate index); cough- lower pressure (anal canal, 3D, anorectal gradient), higher asymmetry to highest pressure (anal canal) and rectal sensory- higher volume (first sensation, desire to defecate, maximum tolerated). After BF (post vs pre): resting-higher pressure (3D,mean), longer FACL; short squeeze-higher pressure (maximum incremental, absolute, mean,3D), long squeeze- higher 3D pressure (1/3, 2/3,3/3); cough- higher anal canal pressure (maximum,3D) and rectum pressure; rectal sensory- higher maximum tolerated volume; (3 and 6m post-BF vs pre): resting- longer FAC (3m>pre); short squeeze- higher pressure (maximum incremental, absolute, mean) and 3D (3m>pre; 6m>pre); long squeeze- higher 3D (1/3, 2/3, 3/3): (3m>pre; 6m>pre); cough - higher anal canal pressure (maximum,3D) and rectum pressure (3m>pre; 6m>pre) and rectal sensory- higher maximum tolerated volume (3m>pre; 6m>pre). Fecal incontinence scores: lower values (post, 3 and 6m < pre-BF).

Conclusions High-resolution and 3D parameters can refine FI diagnosis and provide a robust basis for personalized biofeedback therapy and follow up in selected cases, leading to enhanced outcomes.

Key Points

- Fecal incontinence is a chronic debilitating disorder involving complex multifactorial interactions with a significant impact on quality of life.
- Novel 3D and HRM parameters can be useful tools for accurate diagnosis in incontinence and clustering into patient phenotypes.

- The effectiveness of biofeedback therapy depends on in-depth manometric analysis for tailored referral, guidance and follow-up.

1. Introduction

Fecal incontinence (FI) is a chronic disorder involving diverse etiologies (idiopathic, neurogenic, inflammatory, iatrogenic), often associated with multifactorial interconnections in its pathophysiology[1]. It has a critical impact on quality of life, with broad psychosocial repercussions immersed in family, economic and work contexts. Additionally, the increased incidence of synchronous sexual dysfunctions contributes to high scores on anxiety and depression scales[2,3]. The global pooled prevalence of FI has been estimated at 8.0%, being higher in women (9.1%), increasing with age, and reaching its highest prevalence in individuals over 60 years (9.3%)[4].

The milestone set by high-resolution manometry (HRM) ushered in a new era in the detailed and precise assessment of anorectal function and paved the way for the search for new metrics, phenotypes groups within pelvic floor disorders, as well as potential manometric markers[1,5]. In parallel, anorectal manometry, as the most widely used tool, allows in incontinent patients to assess anal sphincter function and abnormal rectal sensitivity, obstetric injuries after traumatic birth, guide biofeedback training as well as distinguishes passive FI (lower resting pressure) from urgency FI. In addition, HRM has been shown to be more accurate in detecting hypocontractility in incontinent women[6,7].

Biofeedback (BF) has been described as a safe, side-effect-free and minimally invasive therapeutic option for non-responders to conservative treatment in mild to moderate fecal incontinence. Based on training of the pelvic floor muscles, it can generate increased contractile strength, muscular endurance, proprioception and sensitivity of the anal canal in patients with adequate cognitive capacity and motivation[8,9].

The first aim of this study was to evaluate 24 female incontinent according to the London Protocol (LP)[6] under water-perfused 36-channel HRM, comparing the high-resolution and 3D manometric findings with 25 healthy female volunteers from our previous study[10]. The second and main goal was to compare the incontinent group's manometric parameters and fecal incontinence scores, before and after undergoing an 8-week BF protocol (HRM, endoanal electrostimulation and home exercises), as well as at 3 and 6 months (m) after the end of BF (maintaining only guided home exercises). Additionally, all manometric data (post-BF, 3 and 6m period) were also compared with those of the healthy group.

2. Materials and Methods

2.1 Subjects

Twenty-four female incontinent volunteers were consecutively recruited at the Center of Physiology of Piracicaba (São Paulo, Brazil) from April 2021 to March 2023. The mean age was 65.17 ± 13.58 years (age range: 28-81 years) and the mean body mass index (BMI) was 26.93 ± 3.45. Type 2 diabetes was found in 16.67%. The obstetric history showed that 87.50% were multipara, 8.33% primipara, and 4.67% nulliparous. Among them, 62.50% underwent vaginal delivery (45.83% fetal macrosomia, 37.50% reported the need forceps with extended episiotomy) and 37.50% had a cesarean section. Regarding previous anal surgery, 29.17% had undergone hemorrhoidectomy, and 4.17% sphincterotomy.

Inclusion criteria included women from 18 years old with fecal incontinence according to Rome IV criteria[13]. Exclusion criteria were: (1) previous anorectal tumors or incontinence associated with current oncological treatment (radiation and/or chemotherapy); (2) spinal cord injury and congenital abnormalities such as meningomyelocele; (3) dementia syndrome and (4) failure to adhere to the proposed 8-week research protocol.

2.2 Ethics

The study protocol was approved by the Research Ethics Committee of State University of Campinas (UNICAMP- São Paulo, Brazil). Informed consent was obtained of all participants and no identifiable data present. There is no conflict of interest. All authors contributed sufficiently to be named as authors and are responsible for the manuscript. No professional or ghostwriter was hired.

2.3 Equipment

All patients underwent 36-channel water-perfused HRM (Multiplex Alacer Biomédica, São Paulo, Brazil), with a constant flow rate of 0.3ml per minute (min) of sterile water and channels arranged radially spanning 6cm. The topographic color plot pressure data, 3D vectors, and respective pressure volumes (PV) were acquired via the dedicated commercial software (Alacer Biomédica, São Paulo, Brazil).

Endoanal electrostimulation was performed using Dualpex 961 (Quark Medical, São Paulo, Brazil).

2.4 Study protocol

All incontinent volunteers were initially evaluated by anorectal manometry and fecal incontinence scores. Prior to each examination, the subjects were informed about all the steps recommended in the London Protocol (LP), from which we excluded only the pushing maneuver and its analysis. Afterwards, they were referred to 8 consecutive weekly biofeedback sessions (2 months) and promptly reevaluated by manometry and fecal incontinence scores as well as 3 and 6 months after the end of BF, which maintain only guided home exercises once a day. All volunteers performed anorectal preparation the night before each manometry and BF session with a 4.0 g glycerin suppository. The patients were studied in a quiet room, in the left lateral position with knees and hips flexed at 90°. All sequence and manometric parameters (LP, complementary and 3D) evaluated were described in detail in our previous study[10].

2.4.1 Anorectal biofeedback

As a preliminary approach, we recommend dietary restrictions to patients if a possible clinical relationship with food intolerance (lactose, fructose, etc) associated with diarrhea episodes was identified, aiming to avoid Bristol Stool Form Scale type 6 to 7.

All BF therapy was physician-led, the stages illustrated in Figure 1, and included:

- **First stage** (20 minutes): Instructions and reaffirmation of anatomical reference points of the pelvic floor for fecal continence. In addition, training and guided exercises focused on the pelvic floor muscle-sphincter component using the HRM probe, with simultaneous two-dimensional visual interaction with the patient. The guided exercises began with short squeeze 10 repetitions of 5 seconds (s), with a 15-second rest period between them. They were followed by 3 repetitions of long squeeze, with 30s of rest between them, starting at 10s and progressing over the weeks depending on the patient's contractile capacity up to 25 to 30s. The objective was to increase contractile strength, endurance and proprioception and sensitivity of the anal canal (weekly frequency, carried out at the Clinic).
- **Second stage** (20 minutes): Endoanal electrostimulation protocol to provide passive increase in contractile strength and muscular resistance, proprioception activation and improvement of anal canal sensitivity. Active stimulation was 35 Hz with a 2.0 second ramped pulse, 15s (first session) to 25-30s (eighth session) on, 5.0 second ramp down, and one corresponding off-duty cycle, add up to 20 min per session (after exercises with HRM support, weekly frequency, carried out at the Clinic).
- **Third stage** (30 minutes each period): Guided pelvic floor exercise protocol, twice a day to increase contractile strength and muscular endurance as follow: 3 sets of 10 repetitions of short contraction of 5s, with a rest period of 15s between them, with 1minute of rest between each set, totaling 30 times per period per day. They were followed by 8 repetitions of long contraction, of 10s up to 25 to 30s, depending on the patient and their contractile capacity, with rest between each endurance exercise of 1minute, totaling 16 repetitions per day (in addition to therapy at the Clinic within 8 weeks, carried out at home).
- **Fourth stage** (30 minutes per day): Guided pelvic floor exercise protocol described above, once daily to mantain contractile strength and muscular endurance for 6 months (after 8 weeks therapy at the Clinic, carried out at home).

2.4.2 Protocol stages

The research stages followed the following steps:

1. Pre-BF therapy protocol (24 volunteers)

- Assessment of fecal incontinence scores, Cleveland Clinic Fecal Incontinence Severity Scoring System (CCFIS)[11] and St. Mark's Incontinence Score (SMIC)[12], and anorectal HRM evaluation according to the London Protocol (LP)[6].

2. After 8 weekly sessions of BF therapy protocol (24 volunteers)

- Reassessment of fecal incontinence scores (CCFIS and SMIC) and anorectal HRM.

3. After 3m and 6m of post-BF completion - only home exercises once a day (22 volunteers)

- Reassessment of fecal incontinence scores (CCFIS and SMIC) and anorectal HRM.

91.7% of 24 volunteers remained until the final evaluation 6 months post-BF, with 2 patients excluded after 8-week protocol due to lack of complete exercise adherence.

The comparison manometric parameters (LP, complementary and 3D parameters) are depicted in Tables and Supplementary Tables (ST) as follows: resting, short and long squeeze, cough, rectal sensory threshold parameters and recto-anal inhibitory reflex (RAIR).

2.5 Statistical analysis

The Shapiro-Wilk method was used to assess the normal distribution of the data. The unpaired t-test was applied to the difference between normally distributed parameters, and the Mann-Whitney U test was used in univariate analysis for non-normal data. Variables are expressed as mean (standard deviation) and median (interquartile range). The entire normality study database, also including range, minimum (min), maximum (max), 95% confidence interval (95% CI), and 5th and 95th percentiles, is presented in the Supplementary Tables (ST). All p-values<0.05 were considered significant. Statistical analyses were performed using R software version 4.2.2.

3. Results

3.1 Incontinent vs healthy volunteers

High-resolution manometric findings of 24 female incontinent patients (pre and post-BF, 3 and 6m post-BF completion) were compared with 25 healthy female volunteers from our previous study[10] based on the London Protocol (LP)[6].

3.1.1 Resting manometric parameters

Resting manometric analysis showed a statistically significant difference between healthy volunteers vs incontinent (Table 1 and ST1). Mean maximum pressure and resting PV (10^4mmHg^2.cm) were lower in incontinent ($p<0.01$ in all comparisons) as well as mean pressure ($p<0.01$ comparing pre-BF, 3 and 6m, and $p<0.05$, post-BF).

Functional anal canal length (FACL) shown shorter centimeters (cm) in incontinent pre-BF ($p<0.01$) and 3 and 6m ($p<0.05$), however, with no differences compared to post-BF.

Evaluating the asymmetry of the functional anal canal to the highest and lowest pressure based on 3D analyses, we found higher values for incontinent (pre, post, 3 and 6m) compared with healthy. Regarding the highest pressure asymmetry: pre ($p<0.05$) and post, 3 and 6 ($p<0.01$) and for the lowest pressure asymmetry; pre, post, 6m ($p<0.05$) and 3m ($p<0.01$).

3.1.2 Squeeze manometric parameters

Squeeze manometric parameters (Table 2 and ST2) showed lower pressure in incontinent (pre, post, 3 and 6m) comparing with healthy group analyzing maximum incremental, mean and maximum absolute squeeze pressure as well as the 3D parameters ($10^4 mmHg^2.cm$), short and long squeeze PV (1/3, 2/3 and 3/3), with all $p<0.01$.

Analyzing the symmetry (short squeeze) in relation to healthy volunteers: the highest pressure asymmetry was higher in incontinent (pre, post,3 and 6m) with $p<0.01$; and for the lowest pressure, it was higher in incontinent (pre, post) with $p<0.05$ and 3m ($p<0.01$), with no difference evaluating 6m post-BF.

Concerning complementary parameters of endurance analyses, fatigue rate index (FRI), fatigue rate (FR) and capacity to sustain (CS), statistical significance was observed to FRI with lower values only to incontinent (pre) vs healthy ($p<0.05$). FR findings were lower in incontinent (pre, post, 3 and 6m) however with less pressure loss compared to healthy control ($p<0.01$). CS was higher in incontinent (6m) with $p<0.05$ and no difference was observed between incontinent (pre, post and 3m) vs healthy.

3.1.3 Cough manometric parameters

Evaluating cough parameters (Table 3 and ST3), the pressure was lower in incontinent (pre, post, 3 and 6m) compared to healthy group analyzing the anal canal maximum pressure, the corresponding 3D parameter and the complementary parameter (anorectal gradient pressure), with all $p<0.01$, however no difference to maximum pressure of the rectum in all comparison groups. Regarding the highest pressure asymmetry of anal canal, it was higher in incontinent (pre) with $p<0.05$ and 3 and 6m ($p<0.01$) comparing with healthy group and no difference to post-BF vs healthy control. Evaluating the lowest pressure asymmetry did not show differences in all comparison groups.

3.1.4 Rectal sensory threshold parameters and RAIR

Rectal sensory threshold parameters and RAIR were depicted in Table 4 and ST4. The volume found was higher in relation to healthy control in incontinent (pre) to first sensation ($p<0.05$), desire to defecate and maximum tolerated volume ($p<0.01$) as well as to incontinent (post) with $p<0.05$. No statistical difference was observed for the sensory parameters evaluating incontinent individuals (post,3 and 6m) for first sensation and maximum tolerated volume as well as for desire to defecate (3 and 6m). The anal canal relaxation (%) did not show differences between incontinent (pre, post, 3 and 6m) vs healthy.

3.2 Incontinent volunteers under biofeedback therapy

High-resolution manometric findings and fecal incontinence scores (FIS) from 24 incontinent women volunteers (pre and post-BF) and the 22 patients who remained in the study protocol (3 and 6m post-BF completion) were compared across all analyses periods (pre vs post-BF, 3 and 6m; post-BF vs 3 and 6m; and 3m vs 6m).

3.2.1 Fecal incontinence scores

FIS showed a statistically significant difference for the incontinent analyses periods (Table 5 and ST5) as follows: CCFIS and SMIC showed lower values in post, 3 and 6m compared to pre incontinent ($p<0.01$), as well as 3m and 6m compared to post-BF, respectively $p<0.05$ and $p<0.01$. No difference was observed when comparing 3 to 6m.

3.2.2 Resting manometric parameters

Resting manometric pressure analyses (Table 6 and ST6), showed no statistical difference evaluating mean maximum pressure in all comparisons. However, mean pressure and resting PV (10^4mmHg^2.cm) was higher in post-BF compared to pre ($p<0.01$ and $p<0.05$, respectively) as well as mean pressure analyses post-BF > 6m ($p<0.05$).

FACL was longer in post vs pre ($p<0.05$) and 3m vs pre ($p<0.05$) with no differences in other comparisons. Evaluating the highest and lowest pressure asymmetry of the functional anal canal, we found no statistical significance for all comparisons.

3.2.3 Squeeze manometric parameters

Squeeze manometric parameters (Table 7 and ST7) showed higher pressure (post vs pre, 3m vs pre, 6m vs pre) analyzing: maximum incremental and maximum absolute squeeze pressure (all $p<0.01$), as well as mean pressure and 3D parameters short and long squeeze PV (1/3, 2/3 and 3/3) with $p<0.01$ (post and 3m vs pre) and $p<0.05$ (6m vs pre). We found no difference for the other analyses times (post vs 3 and 6m, and 3 vs 6m) related to the manometric parameters described above.

Regarding the symmetry (short squeeze), the highest and lowest pressure asymmetry was lower 6m vs 3m ($p<0.05$) and also evaluating post vs 3m ($p< 0.05$) for lowest asymmetry analyses.

Evaluating complementary parameters of endurance, no statistical significance was observed to FRI in all inter-group analyses. FR findings showed greater pressure loss post vs pre ($p<0.05$) as well as 3m vs pre and 3m vs 6m (both $p<0.01$). CS was higher 6m vs 3m ($p<0.05$) and there was no difference for the other time comparisons.

3.2.4 Cough manometric parameters

Cough parameters analyses (Table 8 and ST8) showed that the maximum pressure in the anal canal was higher (post>pre, 3m>pre, 6m>pre), all $p<0.01$, as well as the corresponding 3D parameter with $p<0.05$ (post vs pre) and $p<0.01$ (3m>pre, 6m> pre). Rectum maximum pressure finding was also higher (post>pre, 3m>pre, 6m>pre), with all p<0.05. Regarding the anorectal gradient pressure, we observed a statistical difference only in the analyses of 3m vs pre with a higher value (p<0.05).

Evaluating the highest and lowest pressure asymmetry of the functional anal canal, we found no statistical significance for all comparisons.

3.2.5 Rectal sensory threshold parameters and RAIR

Rectal sensory threshold parameters and RAIR were depicted in Table 9 and ST9. Regarding the first sensation and desire to defecate findings, no statistical significance was observed in all inter-group analyses. However, the maximum tolerated volume was higher (post >pre, 3m>pre, 6m> pre), with all p<0.01 with no difference for the other analyses times. The anal canal relaxation (%) did not show differences for all comparisons.

4. Discussion

The present study demonstrates and ratifies the differences in high-resolution manometry and 3D findings based on London Protocol between incontinent and healthy volunteers. In addition, it highlights the importance of HRM in the diagnostic approach to fecal incontinence, refining the referral for BF therapy, as well as for better outcomes based on tailored follow-up.

Furthermore, 3D HRM can provide a functional anorectal image[14] based on accurate spatial pressure recording in circumferential and axial directions, deepening the sphincter component analyses, the functional length, the area and asymmetry of the anal canal[15] and making the pathophysiological relevance clearer[16]. Additionally, expanding the diagnosis beyond sphincter defects and including pelvic floor disorders such as internal rectal prolapse and perineal descent[14], it can constitute a detailed screening method in incontinent for referral in selected cases for 3D endoanal ultrasound as well as pelvic floor magnetic resonance imaging (MRI).

4.1 Biofeedback therapy

Anorectal biofeedback is a consolidated treatment for incontinent patients and recommended by several consensus groups[17]. In the context of minimally invasive therapies for fecal incontinence, the use of BF within a broader concept of coordinated interconnection of the 3 useful tools from the therapeutic arsenal: training of the pelvic muscles and anal floor; visual and verbal feedback techniques using a manometry system or electromyography probe and anorectal electrical stimulation, all together can enhance the effectiveness of the results.

A randomized controlled trial showed BF combined with pelvic floor anal sphincter muscle training can be twice as effective as pelvic floor exercises alone. In addition, another randomized study demonstrated clear improvement of BF therapy in fecal incontinence severity in 86% of patients with 20% fully continence[8]. Furthermore, low-frequency endoanal stimulation for fecal incontinence can improve manometric values, continence scores and increase quality of life by activating dormant axons and thus increasing the efficacy of neuromuscular transmission and the rate of pudendal nerve conduction[18]. Corroborating this, the superiority of BF plus electrical stimulation (EMG) over monotherapy has been shown in several trials[19,20] .

In parallel, treatment success based on 50% reduction in weekly fecal incontinence episodes has not been used in clinical trials for comparisons[8], however established scores such as CCFIS, SMIC and quality of life have stood out. Incontinent volunteers undergoing our proposed BF protocol showed ≥50% clinical improvement in 95.4% of their individual baseline scores 6m after BF completion. Initial CCFIs was >10 in 77.3% of patients in which >15 in 31.8%, although an unsatisfactory response to BF was reported in another paper with FI scores greater than 10 as well as poor sustained squeezing pressure[21]. A sustained statistical significance was observed in the CCFIS and SMIC scores for 6 months after completion of BF protocol compared with the period before BF therapy, with the scores remaining unchanged at the 3- to 6-month assessments where patients maintained only home-based guided exercises.

4.2 HRM and 3D parameters

Some manometry differences in the assessment of anorectal function comparing incontinent with controls have been described demonstrating lower anal resting pressure and squeeze pressure increment[22,23]as well as anal sphincter asymmetry at rest and during squeeze effort[24]. In addition, a shorter FACL has been observed in female with fecal incontinence which 97% had associated reduced resting or squeeze pressures compared to normal FACL[1].

We found in the present study high-resolution and 3D manometric findings that differentiated incontinent from healthy volunteers with statistical significance as follow (pre vs healthy): lower pressure - resting (mean maximum, mean and 3D), short squeeze (maximum incremental, absolute, mean and 3D), long squeeze (3D 1/3, 2/3, 3/3) and cough (maximum anal canal and 3D; anorectal gradient); higher asymmetry (to highest pressure) - resting, short squeeze and cough (anal canal); higher asymmetry (to lowest pressure) - resting, short squeeze; higher volume (first sensation, desire to defecate and maximum tolerated). In addition, shorter FACL (resting) and lower endurance value (FRI). The statical differences described above were maintained even post-BF, 3 and 6m after BF completion with the exception of the analyses: FRI, first sensation and maximum tolerated volume.

Biofeedback therapy for incontinent has demonstrated a positive impact on quality of life improving pelvic floor muscles strength and the ability to tolerate larger rectal distention[8] as well as optimizing manometric findings by increasing resting, maximal squeeze pressure and endurance using office support or home device compared to controls[20]. Corroborating this cenarium, we present the effect on manometric parameters after the proposed BF protocol (post vs pre) with statistical significance as follows: longer FACL (resting); higher pressure- resting pressure (mean and 3D), short squeeze (maximum incremental, mean, maximum absolute and 3D), long squeeze (3D 1/3, 2/3, 3/3); cough (maximum anal canal, corresponding 3D and rectum) and higher volume (maximum tolerated).

Some manometric parameters maintained statistical difference even after BF completion, where incontinent patients continued to perform only guided home exercises once a day (3 and 6m post-BF vs pre): longer FACL (3m>pre); higher pressure (3m>pre; 6m>pre) - short squeeze (maximum incremental, mean, maximum absolute and 3D), long squeeze - 3D (1/3, 2/3, 3/3), cough- rectum and anal canal (maximum and corresponding 3D) and higher maximum tolerated volume (3m>pre; 6m>pre). In addition, evaluating 3 and 6m vs post-BF, we didn't find differences regarding the parameters above, with the exception of mean pressure (resting): 6m< post($p<0.05$). These intragroup assessment findings support the feasibility of maintaining prolonged daily home training after the BT protocol along with stabilization of low fecal incontinence scores.

Our results highlighted 3D analyses as a contributing parameter both in the differentiation of incontinent patients from healthy ones and for the detailed evaluation and follow up of patients undergoing the BF therapy protocol. We demonstrated significant differences in the resting, short squeeze, endurance and cough analyses based on 3D and highlighting the long squeeze 3D (1/3, 2/3 and 3/3) as the only parameter that stood out in all time analyses when evaluating intergroup (incontinent vs healthy) and intragroup (incontinent pre vs post, 3m and 6m).

Further studies and validation could provide an additional anorectal manometric parameter of sphincter contractile reserve, similar to esophageal studies in ineffective esophageal motility[25], which may be a predictor of therapeutic response to biofeedback and potential reversibility of fecal incontinence.

This study has some limitations, such as the relatively small sample size, to a certain extent due to the COVID-19 pandemic social contact restrictions at the beginning of the research, the lack of stratification of analyzes by age group, parity, or body mass index and only included female participants.

5. Conclusion

High-resolution and 3D parameters based on the London Protocol may be relevant tool for accurate diagnosis, anorectal functional mapping as well as monitoring of incontinent patients undergoing BF protocols, contributing to tailored therapies and better sustained success rates. Further comparative studies in the search for manometric parameters that predict therapeutic response to BF may enhance results in selected patients.

Declarations

Author's contribution: Alexandre Anefalos: conceptualized and designed the research, recruited volunteers, performed the exams, interpreted the data, and wrote the manuscript; Carlos Augusto Real Martinez: reviewed the research design and the manuscript and Claudio Saddy Rodrigues Coy: reviewed the research design and the manuscript.

Data availability: All data are provided in the manuscript and data files, with corresponding figures and tables attached, as well as in supplementary information (supplementary figures and tables) attached.

Declarations Ethics approval and consent to participate. Informed consent was obtained of all participants.

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References

1. Vollebregt PF, Rasijeff AMP, Pares D, Grossi U, Carrington EV, Knowles CH, Scott SM. Functional anal canal length measurement using high-resolution anorectal manometry to investigate anal sphincter dysfunction in patients with fecal incontinence or constipation. Neurogastroenterol Motil. 2019 Mar;31(3):e13532. doi: 10.1111/nmo.13532. Epub 2019 Jan 13. PMID: 30637863.
2. Imhoff LR, Brown JS, Creasman JM, Subak LL, Van den Eeden SK, Thom DH, Varma MG, Huang AJ. Fecal incontinence decreases sexual quality of life, but does not prevent sexual activity in women. Dis Colon Rectum. 2012 Oct;55(10):1059-65. doi: 10.1097/DCR.0b013e318265795d. PMID: 22965405; PMCID: PMC3720983
3. Heymen S. Psychological and cognitive variables affecting treatment outcomes for urinary and fecal incontinence. Gastroenterology. 2004 Jan;126(1 Suppl 1): S146-51. doi: 10.1053/j.gastro.2003.10.040. PMID: 14978652.
4. Mack I, Hahn H, Gödel C, Enck P, Bharucha AE. Global Prevalence of Fecal Incontinence in Community-Dwelling Adults: A Systematic Review and Meta-analysis. Clin Gastroenterol Hepatol. 2024 Apr;22(4):712-731.e8. doi: 10.1016/j.cgh.2023.09.004. Epub 2023 Sep 19. PMID: 37734583; PMCID: PMC10948379.
5. Carrington EV, Heinrich H, Knowles CH, Rao SS, Fox M, Scott SM; International Anorectal Physiology Working Party Group (IAPWG). Methods of anorectal manometry vary widely in clinical practice: Results from an international survey. Neurogastroenterol Motil. 2017 Aug;29(8):e13016. doi: 10.1111/nmo.13016. Epub 2017 Jan 18. PMID: 28101937.
6. Carrington EV, Heinrich H, Knowles CH, Fox M, Rao S, Altomare DF, Bharucha AE, Burgell R, Chey WD, Chiarioni G, Dinning P, Emmanuel A, Farouk R, Felt-Bersma RJF, Jung KW, Lembo A, Malcolm A, Mittal RK, Mion F, Myung SJ, O'Connell PR, Pehl C, Remes-Troche JM, Reveille RM, Vaizey CJ, Vitton V, Whitehead WE, Wong RK, Scott SM; All members of the International Anorectal Physiology Working Group. The international anorectal physiology working group (IAPWG) recommendations: Standardized testing protocol and the London classification for disorders of anorectal function. Neurogastroenterol Motil. 2020 Jan;32(1):e13679. doi: 10.1111/nmo.13679. Epub 2019 Aug 12. PMID: 31407463; PMCID: PMC6923590.

7. Carrington EV, Knowles CH, Grossi U, Scott SM. High-resolution Anorectal Manometry Measures Are More Accurate Than Conventional Measures in Detecting Anal Hypocontractility in Women With Fecal Incontinence. Clin Gastroenterol Hepatol. 2019 Feb;17(3):477-485.e9. doi: 10.1016/j.cgh.2018.06.037. Epub 2018 Jun 30. PMID: 29966707.
8. Rao SS, Benninga MA, Bharucha AE, Chiarioni G, Di Lorenzo C, Whitehead WE. ANMS-ESNM position paper and consensus guidelines on biofeedback therapy for anorectal disorders. Neurogastroenterol Motil. 2015 May;27(5):594-609. doi: 10.1111/nmo.12520. Epub 2015 Apr 1. PMID: 25828100; PMCID: PMC4409469.
9. Bartlett L, Sloots K, Nowak M, Ho YH. Biofeedback for fecal incontinence: a randomized study comparing exercise regimens. Dis Colon Rectum. 2011 Jul;54(7):846-56. doi: 10.1007/DCR.0b013e3182148fef. PMID: 21654252
10. Anefalos A, Martinez CAR, Coy CSR. London Protocol under water-perfused HRM in a healthy population, towards novel 3D manometric parameters in an evaluation of anorectal functional disorders. BMC Gastroenterol. 2024 Apr 4;24(1):127. doi: 10.1186/s12876-024-03207-w. Erratum in: BMC Gastroenterol. 2024 Jul 27;24(1):236. doi: 10.1186/s12876-024-03327-3. PMID: 38575859; PMCID: PMC10996243.
11. Jorge JM, Wexner SD. Etiology and management of fecal incontinence. Dis Colon Rectum. 1993 Jan;36(1):77-97. doi: 10.1007/BF02050307. PMID: 8416784.
12. Vaizey CJ, Carapeti E, Cahill JA, Kamm MA. Prospective comparison of faecal incontinence grading systems. Gut. 1999 Jan;44(1):77-80. doi: 10.1136/gut.44.1.77. PMID: 9862829; PMCID: PMC1760067.
13. Whitehead WE, Simren M, Busby-Whitehead J, Heymen S, van Tilburg MAL, Sperber AD, Palsson OS. Fecal Incontinence Diagnosed by the Rome IV Criteria in the United States, Canada, and the United Kingdom. Clin Gastroenterol Hepatol. 2020 Feb;18(2):385-391. doi: 10.1016/j.cgh.2019.05.040. Epub 2019 May 30. PMID: 31154029
14. Andrianjafy C, Luciano L, Loundou A, Bouvier M, Vitton V. Three-dimensional high-resolution anorectal manometry can predict response to biofeedback therapy in defecation disorders. Int J Colorectal Dis. 2019 Jun;34(6):1131-1140. doi: 10.1007/s00384-019-03297-z. Epub 2019 May 1. PMID: 31044283.
15. Rezaie A, Iriana S, Pimentel M, Murrell Z, Fleshner P, Zaghiyan K. Can three-dimensional high-resolution anorectal manometry detect anal sphincter defects in patients with faecal incontinence? Colorectal Dis. 2017 May;19(5):468-475. doi: 10.1111/codi.13530. PMID: 27657739.
16. Zifan A, Ledgerwood-Lee M, Mittal RK. A Predictive Model to Identify Patients With Fecal Incontinence Based on High-Definition Anorectal Manometry. Clin Gastroenterol Hepatol. 2016 Dec;14(12):1788-1796.e2. doi: 10.1016/j.cgh.2016.07.021. Epub 2016 Jul 25. PMID: 27464594; PMCID: PMC5108671.
17. Mazor Y, Prott G, Jones M, Ejova A, Kellow J, Malcom A. Factors Associated With Response to Anorectal Biofeedback Therapy in Patients With Fecal Incontinence. Clin Gastroenterol Hepatol.

2021 Mar;19(3):492-502.e5. doi: 10.1016/j.cgh.2020.03.050. Epub 2020 Apr 3. PMID: 32251788.

18. Healy CF, Brannigan AE, Connolly EM, Eng M, O'Sullivan MJ, McNamara DA, Cusack C, Deasy JM. The effects of low-frequency endo-anal electrical stimulation on faecal incontinence: a prospective study. Int J Colorectal Dis. 2006 Dec;21(8):802-6. doi: 10.1007/s00384-006-0102-0. Epub 2006 Mar 17. PMID: 16544149.
19. Vonthein R, Heimerl T, Schwandner T, Ziegler A. Electrical stimulation and biofeedback for the treatment of fecal incontinence: a systematic review. Int J Colorectal Dis. 2013 Nov;28(11):1567-77. doi: 10.1007/s00384-013-1739-0. Epub 2013 Jul 31. PMID: 23900652; PMCID: PMC3824723.
20. Xiang X, Sharma A, Patcharatrakul T, Yan Y, Karunaratne T, Parr R, Ayyala DN, Hall P, Rao SSC. Randomized controlled trial of home biofeedback therapy versus office biofeedback therapy for fecal incontinence. Neurogastroenterol Motil. 2021 Nov;33(11):e14168. doi: 10.1111/nmo.14168. Epub 2021 May 29. PMID: 34051120.
21. Murad-Regadas SM, Regadas FSP, Regadas Filho FSP, Mendonça Filho JJ, Andrade Filho RS, Vilarinho ADS. Predictors of unsuccessful of treatment for fecal incontinence biofeedback for fecal incontinence in female Arq Gastroenterol. 2019 May 20;56(1):61-65. doi: 10.1590/S0004-2803.201900000-17. PMID: 31141067.
22. Prichard DO, Lee T, Parthasarathy G, Fletcher JG, Zinsmeister AR, Bharucha AE. High-resolution Anorectal Manometry for Identifying Defecatory Disorders and Rectal Structural Abnormalities in Women. Clin Gastroenterol Hepatol. 2017 Mar;15(3):412-420. doi: 10.1016/j.cgh.2016.09.154. Epub 2016 Oct 5. PMID: 27720913; PMCID: PMC5316318.
23. Swartz JL, Zifan A, Tuttle LJ, Sheean G, Tam RM, Mittal RK. Fecal incontinence patients categorized based on anal pressure and electromyography: Anal sphincter damage and clinical symptoms. Neurogastroenterol Motil. 2024 Jul;36(7):e14810. doi: 10.1111/nmo.14810. Epub 2024 Apr 30. PMID: 38689439.
24. Williams N, Barlow J, Hobson A, Scott N, Irving M. Manometric asymmetry in the anal canal in controls and patients with fecal incontinence. Dis Colon Rectum. 1995 Dec;38(12):1275-80. doi: 10.1007/BF02049152. PMID: 7497839.
25. Yadlapati R, Kahrilas PJ, Fox MR, Bredenoord AJ, Prakash Gyawali C, Roman S, Babaei A, Mittal RK, Rommel N, Savarino E, Sifrim D, Smout A, Vaezi MF, Zerbib F, Akiyama J, Bhatia S, Bor S, Carlson DA, Chen JW, Cisternas D, Cock C, Coss-Adame E, de Bortoli N, Defilippi C, Fass R, Ghoshal UC, Gonlachanvit S, Hani A, Hebbard GS, Wook Jung K, Katz P, Katzka DA, Khan A, Kohn GP, Lazarescu A, Lengliner J, Mittal SK, Omari T, Park MI, Penagini R, Pohl D, Richter JE, Serra J, Sweis R, Tack J, Tatum RP, Tutuian R, Vela MF, Wong RK, Wu JC, Xiao Y, Pandolfino JE. Esophageal motility disorders on high-resolution manometry: Chicago classification version 4.0©. Neurogastroenterol Motil. 2021 Jan;33(1):e14058. doi: 10.1111/nmo.14058. Erratum in: Neurogastroenterol Motil. 2024 Feb;36(2):e14179. doi: 10.1111/nmo.14179. PMID: 33373111; PMCID: PMC8034247.

Tables

Tables 1 to 9 are available in the Supplementary Files section.

Figures

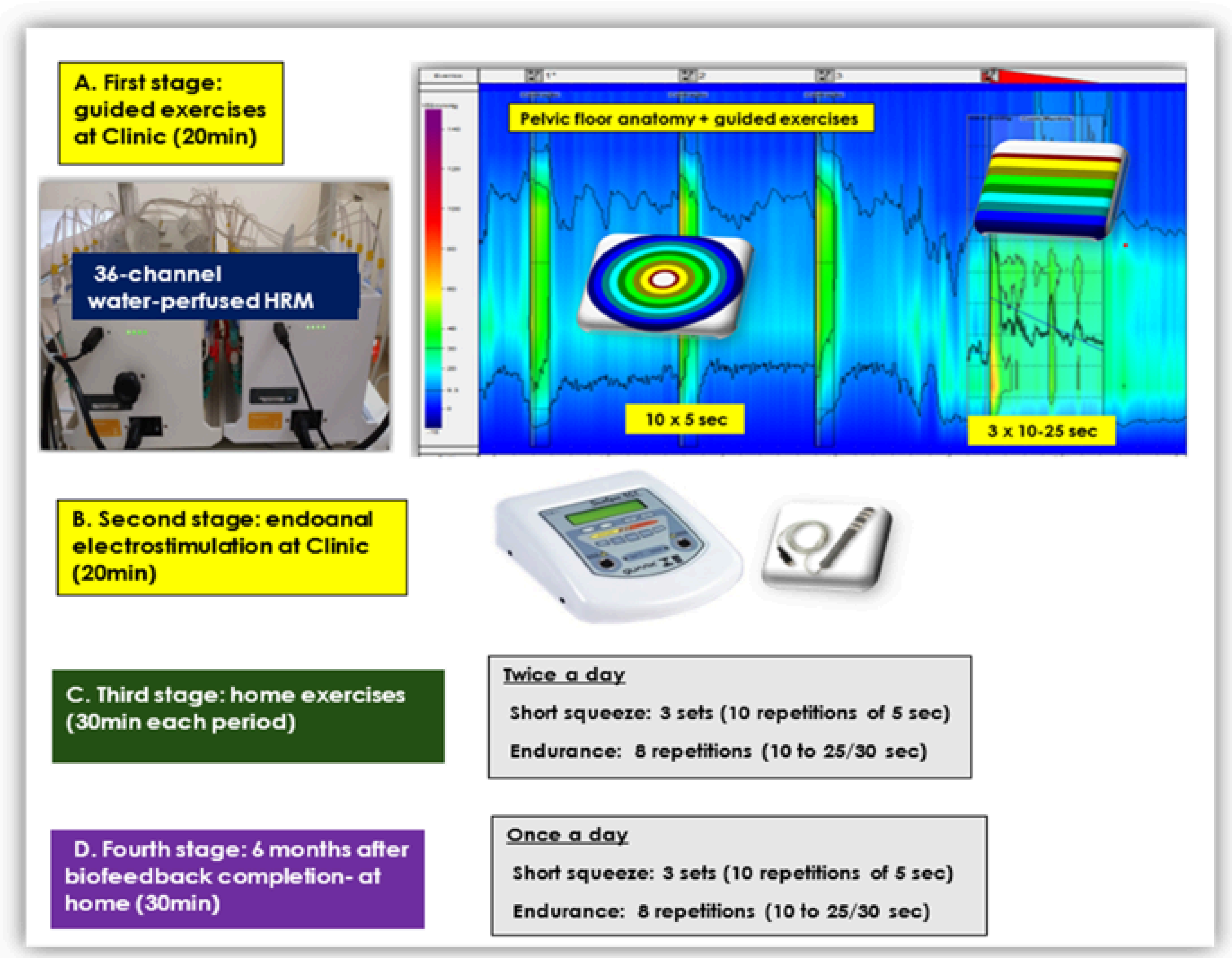

Figure 1

BF therapy protocol. The first and second stages **(A and B)** were performed once a week using 36-channel HRM and endoanal electrostimulation (at the Clinic), together with guided home exercises twice a day **(C)**. After 8 weeks BF protocol, incontinent patients continued only home exercises once a day for 6 months **(D)**.

Supplementary Files

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- Tables.pdf

- Supplementarytables.pdf