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ORIGINAL ARTICLE

Anorectal biofeedback for neurogenic bowel dysfunction in incomplete spinal cord injury

Y Mazor[1], M Jones[2], A Andrews[1], JE Kellow[1] and A Malcolm[1]

Study design: A case–control study of prospectively collected data was performed.
Objectives: To compare anorectal biofeedback (BF) outcomes in patients with incomplete motor spinal cord injury (SCI) and neurogenic bowel dysfunction (NBD) with a group of functional anorectal disorder-matched control patients.
Setting: Neurogastroenterology Unit affiliated with a Spinal Injury Unit in a tertiary referral centre in Sydney, Australia.
Methods: All consecutive patients with SCI and NBD referred for anorectal manometry and BF were matched in a 1:2 ratio with age, gender, parity and functional anorectal disorder-matched control patients. Instrumented BF was performed in six nurse-guided weekly visits. Outcomes included changes in anorectal physiology measures, symptom scores and quality-of-life measures.
Results: Twenty-one patients were included. These were matched with 42 patient controls. Following BF, symptom scores improved significantly in both groups, as did effect of bowel disorder on quality of life. Improvement in these measures did not differ between the groups. Patients with SCI and NBD showed improvement in their sensory and motor anorectal function, including lowering of first sensation threshold and more effective balloon expulsion.
Conclusions: Patients with incomplete motor SCI responded as well to anorectal BF as functional anorectal disorder-matched controls. Spinal cord-injured patients also showed improvement in anorectal sensorimotor dysfunction and balloon expulsion. These novel findings indicate that clinicians should not be dissuaded from considering behaviour-based therapeutic interventions such as anorectal BF in selected spinal cord-injured patients.
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INTRODUCTION

Bowel dysfunction, especially constipation and faecal incontinence (FI), is highly prevalent in patients with spinal cord injury (SCI), with estimates ranging up to 75% in various studies.[1,2] Lack of bowel and bladder autonomy at the first hospitalisation after SCI is a strong predictor for mortality, occurrence of complications, and re-admission and hospitalisation rates.[3] Conservative treatment for patients with SCI and neurogenic bowel dysfunction (NBD) details a multifaceted programme that includes dietary recommendations, anorectal stimulation and a variety of pharmacological agents,[4] benefiting an estimated two-thirds of patients.[5] When conservative management fails, a variety of surgical options can be offered but are utilised by less than 10% of patients.[6,7] Despite these treatment options, NBD has been shown to cause enormous long-term detriment to patient quality of life,[6] limiting social interactions[1] and increasing psychological burden.[8]

NBD due to SCI has been traditionally categorised according to the neurologic level of injury, with implications for bowel symptoms,[9] pathophysiology[10,11] and approach to management.[12,13] Injury to the cauda equina and resulting bowel dysfunction is also common.[14] Although NBD is more likely to develop in patients with complete SCI,[15] it is also highly prevalent in incomplete SCI, with a substantial effect on the patient's lifestyle, medication use and quality of life.[1,16,17] Despite the high prevalence of incomplete SCI,[18] relatively little data are available on the pathophysiology and treatment of NBD in these patients.[17,19]

Anorectal biofeedback (BF) is a well-recognised treatment for non-SCI patients with symptoms of constipation and FI.[20] In particular, there have been three randomised controlled trials in constipation showing that it is the instrumented element of BF therapy that is effective, not just pelvic floor exercises, medications or placebo.[21–23] BF has also been shown to be effective for treatment of NBD arising from multiple sclerosis,[24,25] myelomeningocele in children[26] and spina bifida.[27] Surprisingly, although mentioned in reviews and guidelines for treatment of NBD in SCI,[13,28] no study to date has examined the efficacy of BF for treating adult patients with various degrees of SCI.[29] In clinical practice, these patients are not often offered BF, presumably because of concerns about efficacy and feasibility in this group.

We hypothesised that selected patients with irreversible but motor incomplete SCI with NBD could benefit from BF treatment. The aims of the current study were (1) to report the results of extensive anorectal function studies in patients with incomplete motor SCI and associated NBD undergoing BF and (2) to compare BF outcomes in a selected group of incomplete motor SCI patients with a group of functional anorectal disorder-matched patient controls.

[1]Neurogastroenterology Unit, Royal North Shore Hospital, University of Sydney, Sydney, NSW, Australia and [2]Psychology Department, Macquarie University, Sydney, NSW, Australia
Correspondence: Dr Y Mazor, Neurogastroenterology Unit, Royal North Shore Hospital, Reserve Road, St Leonards, Sydney, 2065 NSW, Australia.
E-mail: Yoav.Mazor@health.nsw.gov.au
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MATERIALS AND METHODS

Patient selection

A case–control study of prospectively collected data was performed in a Neurogastroenterology Unit affiliated with a Spinal Injury Unit in a tertiary referral centre. All consecutive patients with SCI and constipation, FI or both, referred for anorectal BF, and who satisfied the inclusion criteria, were studied. Patients were referred by gastroenterologists after comprehensive investigation and failure of conservative treatment. Inclusion criteria were age over 18 years, completion of baseline anorectal physiological testing, documented motor incomplete SCI or cauda equina lesion, and a minimum time of 12 months since documented spinal cord insult. Patients with a co-existent neurological disorder such as Parkinson's disease and multiple sclerosis were excluded, as well as patients with inadequate documentation of their neurological status. All cases were independently reviewed by two authors (YM and AM) to secure the diagnosis of NBD and to secure the classification as incomplete motor SCI using the motor component of the American Spinal Injury Association (ASIA) impairment Scale.[30] The included SCI patients were matched in a 1:2 ratio with age, gender and functional anorectal disorder-matched patient controls (Rome III).[31] These latter functional anorectal disorder patient controls had no organic cause, including SCI, identified as causing their defecatory symptoms. Female patients were matched for parity. The protocol was approved by the Human Research Ethics Committee of the Royal North Shore Hospital.

Baseline assessment

On initial evaluation, all patients completed the Rome Integrative Questionnaire[31] and the Hospital Anxiety and Depression scale.[32] Medication use, past surgery, concurrent medical conditions and bowel pattern were recorded using a structured questionnaire. The term 'multiple therapeutic interventions used to facilitate bowel movements' was defined as using two or more of the following: fibre supplements, oral laxatives, enemas/suppositories or digital anorectal stimulation or evacuation. Patients completed a 7-day food record diary and stool diary, an abbreviated SF-36 quality of life questionnaire,[33] and underwent a physician's assessment. Stool diaries were maintained throughout the length of the BF programme.

The Knowles Constipation Questionnaire[34] and the Faecal Incontinence Severity Index[35] were calculated before and after treatment for constipated and FI patients, respectively. A 10cm visual analogue scale was also used before and after treatment for (i) impact of bowel dysfunction on quality of life (score anchors: 0 = no impact; 10 = most impact), (ii) patient satisfaction with bowel movement (score anchors: 0 = very dissatisfied; 10 = very satisfied) and (iii) feeling of control over bowel function (score anchors: 0 = no control; 10 = complete control). Another physician assessment was performed at the end of the BF programme, with physician-assessed change in bowel dysfunction rated as major, moderate or minor improvement, no improvement or worsening of bowel dysfunction. Finally, follow-up questionnaires including bowel symptom assessment (improved, stabilised or worsened since BF) were sent to all SCI patients at a mean follow-up of 4 years from completing the BF programme (range 1–9 years).

Anorectal function studies

After clinical assessment, all patients underwent comprehensive anorectal function studies, as previously described in detail.[36] A 7-lumen water-perfused manometry catheter with 5 mm spaced sideholes and a compliant balloon was used (Dentsleeve International, Mississauga, ON, Canada). Data from the pressure transducers were displayed in the digital form on a computer using data conversion software (Neomedix, Sydney Australia). Each individual study comprised assessments of the following parameters: resting and squeeze anal sphincter pressure, cough pressure, sustained squeeze, straining rectal pressure, concomitant anal relaxation or paradoxical contraction, perineal descent, rectal sensitivity thresholds up to 300 ml and the balloon expulsion test (time taken to expel a rectal balloon inflated with 50 ml of warm water while the patient was seated on a toilet). A balloon expulsion time >60 s, a rectal pressure on strain <45 mm Hg and a sustained anal squeeze <20 s were considered abnormal.[37,38]

Anorectal BF

In the Neurogastroenterology Unit a discrete, physician-led course of anorectal BF therapy, including motor and sensory retraining, was performed. The BF training consisted of a 30–60 min session, every week for 6 weeks, with a nurse specialist. The protocol comprised (1) education regarding the anatomy of normal defecation, (2) advice on correct toilet positioning, (3) diaphragmatic breathing, with manometric feedback, to achieve adequate rectal pressure, (4) manometry-based BF to allow anal relaxation to be synchronised with strain, (5) balloon expulsion retraining, (6) rectal sensory retraining and (7) anal squeeze pressure exercises aimed at improving the strength and duration of squeeze, when appropriate.

Statistical analysis

Quantitative measures are reported as mean and standard deviation (s.d.) with sample size available, whereas qualitative measures are reported as percentages and count. Matched SCI and patient controls groups are compared via linear regression with statistical inference via nonparametric bootstrap due to non-normal distributions of some measures and with variances adjusted using the linearisation approach due to matching of cases and controls. Differences between group means are reported with 95% confidence interval and *P*-value. The groups are compared with respect to qualitative (binary) measures using unconditional logistic regression and variances are also adjusted using the linearisation approach due to matching of cases and controls. Within-patient changes in quantitative scores have been evaluated using the Wilcoxon signed ranks test due to non-normal distributions of some measures and reported as within-group mean changes with 95% confidence interval and *P*-value. We performed a correlation analysis (Pearson's correlation coefficient) between the changes in symptom scores, quality-of-life measures or physician assessment at the end of BF and anorectal physiology.

Given the sample size is fixed, power estimation has been retrospective. For the comparison of SCI ($n=21$) and controls ($n=42$) with respect to BF outcome, the available sample size provides statistical power of >0.8 at the 0.05 level of statistical significance (two-tailed) for Cohen's d effect size of 0.76. For qualitative measures under the same conditions but for an odds ratio of 2.0 power is less than desirable at <0.3.

RESULTS

Patients

Twenty-one patients with incomplete motor SCI and NBD underwent BF. The level of injury was lumbosacral, thoracic, cervical and cauda equina in 10, 4, 2 and 3 patients, respectively. Thirteen patients were grade D on the ASIA impairment scale, three patients were grade C and three had cauda equina syndrome. In two patients, one with autonomic gangliopathy and the other with decompression injury, the exact level or completeness of injury could not be definitely determined. Seventeen patients had traumatic SCI, and transverse myelitis and sacral neuropraxia each accounted for a single case of NBD. Eight lesions were classified as upper motor neuron and 13 as lower motor neuron. Ten patients reported urinary symptoms including urgency and leakage, and three patients had a formal diagnosis of neurogenic bladder dysfunction requiring intermittent self-catheterisation. Median time from SCI to referral to BF was 3.5 years (range 1–24).

SCI patients undergoing BF were matched with 42 functional anorectal disorder-matched patient controls who underwent BF. None of these patient controls had an organic cause for their bowel dysfunction.

Baseline characteristics of patients with SCI and functional controls

Table 1 shows the baseline anorectal physiology of patients with incomplete SCI and NBD compared with functional anorectal disorder-matched patient controls who underwent BF. Patients with SCI and NBD displayed lower anal squeeze pressures and had a lower

Table 1 Baseline physiology: incomplete motor spinal cord injury (SCI) patients with neurogenic bowel dysfunction (NBD) compared with functional anorectal disorder-matched patient controls

	SCI with NBD (n = *21*)	*Patient controls* (n = *42*)	*Difference or odds ratio (OR)*[a] *(95% CI)*	P-*value*
Maximal anal resting pressure; mm Hg, mean (s.d.)	62 (19)	62 (23)	−0.2 (–10 to 10)	NS
Maximal anal squeeze pressure; mm Hg, mean (s.d.)	123 (42)	142 (51)	−19 (–38 to 0.01)	0.05
Duration of sustained anal squeeze; seconds, mean (s.d.)	24 (8)	23 (9)	1 (–3 to 6)	NS
Unable to hold sustained squeeze >20 s; *n* (%)	7 (33%)	16 (38%)	OR 1.2 (0.35 to 4.5)	NS
Rectal pressure on strain; mmHg, mean (s.d.)	58 (39)	60 (32)	−1.3 (–17 to 14)	NS
Inadequate (<45 mm Hg) rectal pressure on strain; *n* (%)	9 (43%)	15 (36%)	OR 1.5 (0.06 to 35)	NS
Anal relaxation on strain present; *n* (%)	1 (5%)	4 (10%)	OR 0.6 (0.07 to 3.3)	NS
Perineal descent; cm, mean (s.d.)	0.9 (0.6)	1.2 (0.6)	−0.32 (–0.68 to 0.04)	0.076
Successful (<60 s) balloon expulsion; *n* (%)[b]	11 (55%)	34 (83%)	OR 0.25 (0.07 to 0.86)	0.03
Mean time to balloon expulsion; seconds, mean (s.d.)[b]	83 (84)	37 (56)	45 (7 to 84)	0.02
First sensation threshold; ml, mean (s.d.)	75 (53)	58 (41)	17 (–11 to 44)	NS
Defecation urge threshold; ml, mean (s.d.)	171 (90)	133 (68)	38 (–5 to 80)	NS
Maximal tolerated threshold; ml, mean (s.d.)	225 (69)	201 (66)	24 (–11 to 58)	NS

Abbreviation: NS, nonsignificant.
[a]Using patient control group as a reference.
[b]One patient with SCI and NBD and one control patient did not perform the balloon expulsion test.

Table 2a Baseline clinical features: incomplete motor spinal cord injury (SCI) with neurogenic bowel dysfunction (NBD) patients compared with functional anorectal disorder-matched patient controls

	SCI with NBD (n = *21*)	*Patient controls* (n = *42*)	*Difference or odds ratio (OR)*[a] *(95% CI)*	P-*value*
Age; years, mean (s.d.)	50 (17)	51 (17)	−0.3 (–3 to 2)	NS
Gender; females; *n* (%)	17 (81%)	34 (81%)	OR 1	NS
Multiparous; *n* (%)	11 (65%)	23 (68%)	OR 1.1 (0.9–1.5)	NS
Constipated; *n* (%)	15 (71%)	29 (69%)	OR 0.9 (0.3–2.7)	NS
Duration of bowel symptoms; years, mean (s.d.)	6 (7)	9 (11)	−2.9 (–7.7 to 1.9)	NS
Use of oral laxatives; *n* (%)	13 (62%)	23 (55%)	OR 0.7 (0.3–8)	NS
Use of enemas/suppositories; *n* (%)	11 (52%)	4 (10%)	OR 0.09 (0.03–0.3)	0.001
Digital anorectal stimulation or evacuation; *n* (%)	9 (43%)	10 (24%)	OR 0.4 (0.1–1.5)	NS
Use of fibre supplements; *n* (%)	11 (52%)	16 (38%)	OR 0.6 (0.2–1.5)	NS
Use of antimotility drugs; *n* (%)	3 (14%)	2 (5%)	OR 0.3 (0.03–2.55)	NS
Multiple therapeutic interventions; *n* (%)	16 (76%)	19 (45%)	OR 3.9 (1.1–13.1)	0.032
Daily dietary fibre consumption; g per day, mean (s.d.)	17 (6)	18 (8)	−1 (–5 to 3)	NS
Faecal Incontinence Severity Index; mean (s.d.)	24 (13)	21 (8)	2.3 (–5.6 to 10.2)	NS
Constipation Questionnaire score; mean (s.d.)	19 (4)	16 (5)	3.8 (0.3–7.3)	0.035

Abbreviation: NS, nonsignificant.
[a]Using patient control group as a reference.

success rate in balloon expulsion compared with patient controls. Tables 2a and b display the baseline clinical characteristics of the two patient groups. The baseline number of FI episodes per week did not differ between the groups (2.8 vs 2.5 in the SCI and patient controls, respectively; $P>0.05$).

BF results

Completion rate of BF was 86% in SCI patients with NBD compared with 93% in patient controls (OR 0.46, 95% CI 0.09–2.28, $P=$NS). Symptom scores for both FI and constipation improved significantly in both groups following BF (Figures 1a and b). SCI patients with NBD actually had a larger improvement in the constipation score compared with the improvement of patient controls (40% vs 27%, respectively, $P=0.04$). Reduction in weekly FI episodes was similar in the two groups (24% and 32% in SCI and patient controls, respectively, $P>0.05$).

Effect of bowel disorder on quality of life and patient satisfaction with bowel movement (Figures 1c and d) improved significantly after BF in both SCI patients with NBD and patient controls. Improvement in patients' control over bowel function was also significant in both groups (+398 and +170%, SCI and patient controls, respectively, $P<0.05$ for both groups). No differences were seen when comparing the improvements in these parameters between the two groups ($P>0.05$ for all comparisons). Physician assessment at the end of treatment showed moderate or significant improvement in a similar percentage of patients in both groups (71% vs 72%, SCI compared with patient controls, respectively, $P>0.05$).

Table 3 shows the anorectal physiology parameters before and after BF treatment in SCI patients with NBD compared with patient controls. Patients with SCI and NBD exhibited a reduction in their first sensation threshold and in the time taken to expel the balloon over the toilet after BF compared with before. Patient controls could

Table 2b Baseline quality of life and psychological measures: incomplete motor spinal cord injury (SCI) patients with neurogenic bowel dysfunction (NBD) compared with functional anorectal disorder-matched patient controls

	SCI with NBD (n = *21*)	*Patient controls* (n = *42*)	*Difference*[a] *(95% CI)*	P-*value*
	Mean (s.d.)			
Effect of bowel dysfunction on quality of life	7.2 (2.4)	7.1 (2.4)	0.09 (–1.2 to 1.4)	NS
Patients satisfaction with bowel movements	2.8 (2.2)	3.4 (2.1)	–0.6 (–1.8 to 0.5)	NS
Control over bowel movements	2.8 (1.9)	3.3 (2.5)	–0.5 (–1.8 to 0.8)	NS
Willingness to complete anorectal biofeedback	9.8 (0.7)	9.8 (0.8)	–0.06 (–0.5 to 0.4)	NS
SF-36 PHYSICAL FUNCTIONING (0–100)	45 (33)	79 (21)	–33 (–50 to –16)	0.001
SF-36 ROLE-PHYSICAL (0–100)	37 (44)	68 (43)	–29 (–57 to –0.5)	0.046
SF-36 PAIN INDEX (0–100)	50 (28)	63 (24)	–13 (–31 to 4)	NS
SF-36 VITALITY (0–100)	38 (22)	49 (22)	–11 (–23 to 1)	NS
SF-36 ROLE-EMOTIONAL (0–100)	77 (40)	83 (35)	–7 (–32 to 18)	NS
SF-36 MENTAL HEALTH INDEX (0–100)	66 (16)	72 (18)	–7 (–17 to 2)	NS
HAD anxiety score	8 (4)	5 (3)	3 (0.7–4.7)	0.011
HAD depression score	9 (5)	6 (4)	3 (1.5–5.6)	0.002

Abbreviations: HAD, Hospital Anxiety and Depression; NS, nonsignificant.
[a]Using patient control group as a reference.

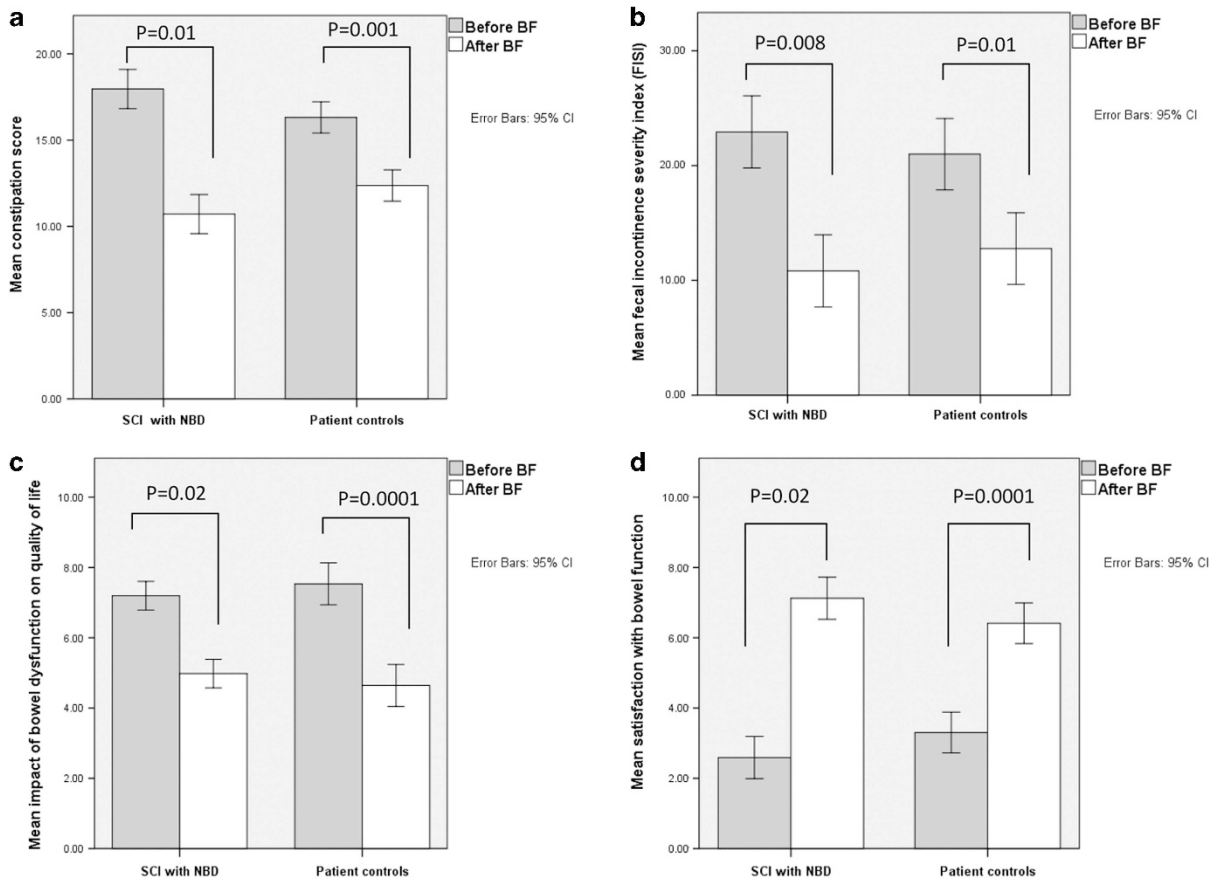

Figure 1 Severity indexes and quality-of-life measures before and after biofeedback (BF) in patients with spinal cord injury (SCI) and neurogenic bowel disorder (NBD) compared with functional anorectal disorder-matched patient controls. (**a**) Constipation score, (**b**) faecal incontinence severity index, (**c**) impact of bowel dysfunction on quality of life and (**d**) patient satisfaction with bowel movements.

hold their sustained anal squeeze for a longer duration following the programme. No differences were seen in the changes in physiology parameters between the groups. No differences were detected in the percentage of patients who were unable to expel the balloon in under 60 s before BF but were able to after treatment (4/6 SCI vs 4/7 controls; OR 1.5, 95% CI 0.06–35), who were initially unable to relax on strain but could do so at the end of BF (11/13 SCI vs 19/31 controls; OR 3.5, 95% CI 0.4–38) or who could sustain maximal anal

Table 3 Changes in anorectal parameters during biofeedback (BF): incomplete motor spinal cord injury (SCI) patients with neurogenic bowel dysfunction (NBD) compared with functional anorectal disorder-matched patient controls

	SCI with NBD				*Patient controls*			
	Before BF (n = 21)	*After BF (n = 18)*	*Percentage change before vs after BF*	P-*value*	*Before BF (n = 42)*	*After BF (n = 39)*	*Percentage change before vs after BF*	P-*value*
	Mean (s.d.)				*Mean (s.d.)*			
Maximal anal resting pressure; mm Hg	62 (19)	53 (21)	−15% (25)	0.04	62 (23)	60 (19)	+4% (31)	NS
Maximal anal squeeze pressure; mm Hg	123 (42)	132 (47)	+2% (31)	NS	142 (51)	145 (48)	+7.3% (27)	NS
Sustained squeeze duration; s	24 (8)	33 (15)	+43% (94)	NS	23 (9)	31 (14)	+62% (92)	0.0008
Rectal pressure on strain; mm Hg	58 (39)	48 (15)	−13% (90)	NS	60 (31)	54 (12)	+15% (79)	NS
Perineal descent; cm	0.9 (0.6)	1.3 (0.3)	+36% (72)	NS	1.2 (0.6)	1.3 (0.2)	+14% (53)	NS
Mean time to balloon expulsion; s	83 (84)	30 (33)	−59% (39)	0.057	37 (56)	19 (20)	+13% (156)	NS
First sensation threshold; ml	75 (53)	64 (65)	−32% (22)	0.005	58 (41)	43 (15)	−9% (48)	NS
Defecation urge threshold; ml	171 (90)	146 (67)	−8% (61)	NS	133 (68)	132 (50)	+1.9% (34)	NS
Maximal tolerated threshold; ml	225 (69)	216 (64)	+1% (19)	NS	201 (66)	200 (51)	+0.3% (23)	NS

Abbreviation: NS, nonsignificant.

squeeze for over 20 s at the end of treatment, while failing to do so before (3/3 SCI vs 11/14 controls; OR 1).

Improvement in balloon expulsion time strongly correlated with improvement in both Faecal Incontinence Severity Index and constipation scores ($r=0.91$ and 0.90, respectively, $P<0.05$). Improvement in the Faecal Incontinence Severity Index score, but not constipation score, correlated with improvement in the feeling of control of bowel movements ($r=0.64$, $P=0.003$) (full data not shown).

Eleven out of the 21 patients with SCI and NBD who underwent BF were available for long-term follow-up. Ten out of the 11 patients reported that their bowel symptoms had either improved or stabilised since BF. None of the patients had required any surgical intervention for their bowel problems.

DISCUSSION

In the current study, for the first time, we demonstrate that anorectal BF is feasible and effective for patients with incomplete motor SCI and NBD. This is shown on the background of information that instrumented BF is more effective than laxatives, exercises or sham BF in three randomised controlled studies in constipation.[21–23] Compared with functional anorectal disorder-matched patient controls, patients with SCI and NBD did not differ, after BF, in their improvements of Faecal Incontinence Severity Index, effect of bowel dysfunction on quality of life, patient satisfaction or control over bowel movements. Moreover, SCI patients with NBD showed a greater improvement in the constipation score compared with patient controls. Importantly, not only symptoms and quality of life improved following BF, but also patients with SCI showed improvement in their sensory and motor anorectal function, including lowering of first sensation threshold and more effective balloon expulsion.

Patients with SCI and NBD in our cohort had more severe bowel dysfunction compared with functional anorectal disorder-matched patient controls: SCI patients with NBD scored higher on the constipation score, and more patients needed multiple interventions to facilitate their bowel movements. As expected, SCI patients with NBD scored lower than patient controls in the physical domains of the SF-36, but no difference was seen between the groups in the emotional domains of the SF-36. These findings provide a novel insight into NBD in patients with SCI, as studies assessing the impact of NBD on quality of life have consistently shown its prevalence and severity,[1,3,7] but have not compared these domains with a group of matched functional anorectal disorder patients. Our data suggest that, although having more severe bowel dysfunction than patients with functional anorectal disorders, the impact of this bowel dysfunction on the quality of life in both groups does not differ. Taken together with the reduction in the impact of bowel dysfunction on their quality of life following BF, our data make a strong case for not discounting selected SCI patients with NBD from BF treatment.

In previous studies using anorectal manometry, resting anal pressure has been shown to be preserved in SCI, and, most, but not all, SCI patients have intact voluntary contraction of the external anal sphincter, although achieving lower squeeze pressures compared with healthy controls.[17,39] We have replicated these findings in a subset of SCI patients with incomplete motor injury compared with patient controls. As previously demonstrated,[17] we show that dyssynergic defecation is common in SCI, with only a minority of patients with incomplete motor SCI being able to achieve anal sphincter relaxation on strain. In addition, we have shown the novel finding of prolonged balloon expulsion time in SCI. It has been shown that patients with motor incomplete SCI have some degree of rectal perception as compared with motor complete SCI, but some patients with incomplete SCI have no intact rectal sensation.[17,39] All but one of our incomplete SCI patients had some preservation of rectal perception (albeit lower than patient controls).

The role of baseline anorectal physiology in selecting patients for BF is controversial. Some studies have shown that BF is more successful in constipated patients with manometric evidence of dyssynergic defaecation, including the inability to expel a balloon, the inability to relax the anal sphincter and inadequate rectal pressure on strain.[22,40,41] With regard to bowel dysfunction secondary to neurological disease, however, clinical intuition and existing data would suggest otherwise—that is, the group with a more intact sensorimotor function would be expected to have more potential to improve with BF.[24] In our correlation analysis, reduction in balloon expulsion time was associated with improvement in symptom scores in both SCI patients with NBD and patient controls. This suggests that balloon expulsion is an important parameter for

assessing suitability for BF in spinal cord-injured patients, both constipation and incontinent, in a similar manner to functional patients. Refinement of the SCI patient selection might lead to an even better outcome than we hereby report. Future studies could more specifically address the optimum selection of SCI patients based on clinical criteria and/or physiology and could also evaluate the relative roles of the individual components of BF such as sensory retraining, motor retraining and balloon expulsion retraining.

This study has some limitations. Although data were collected prospectively, no randomisation of patients to BF treatment was performed. We attempted to overcome this by carefully matching patient controls while accounting for baseline confounders such as age, gender and parity. Although our patient numbers are relatively modest, SCI patients with NBD can be difficult to recruit, and our power analysis suggested that the sample size was adequate to detect clinically significant differences between the groups. Finally, SCI patients are typically a heterogeneous group with a variety of aetiologies and levels of injury, making it difficult to present a more homogeneous group for study.

In summary, incomplete motor SCI patients had more abnormal anorectal physiology, but responded as well to BF, in terms of both symptoms and improvement in anorectal physiology, as functional anorectal disorder-matched patient controls. These novel findings indicate that clinicians should not be dissuaded from considering behaviour-based therapeutic interventions such as BF in SCI patients. Given the enormous impact of anorectal symptoms in SCI patients, anorectal BF treatment should be considered and offered in selected patients.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

YM, AM and JEK planned the study. YM and AA collected all data, MJ and YM conducted all statistical analysis and YM, MJ, AM and JEK interpreted the data and jointly drafted the manuscript. All authors reviewed and approved the final draft submitted.

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