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Original Article

Biofeedback magnetic stimulation improves postoperative bowel dysfunction after rectal cancer surgery

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Abstract: Objective: To evaluate the clinical efficacy of biofeedback magnetic stimulation (BFMS) in the management of postoperative bowel dysfunction (PBD) after rectal cancer surgery and to identify independent predictors of treatment outcomes. Methods: A retrospective cohort study was conducted involving 158 patients who underwent low anterior resection between 2018 and 2023. Patients were divided into two groups: the observation group, consisting of 83 individuals, received BFMS; whereas the control group, comprising 75 individuals, underwent conventional rehabilitation. Defecation function, anorectal manometric parameters - including resting and pressure (RAP), maximum squeeze pressure (MSP), and maximum tolerated volume (MTV) - as well as Wexner scores and QLQ-CR29 quality-of-life scores were assessed at 1, 2, and 3 months postoperatively. Results: At 2 and 3 months postoperatively, the observation group showed significantly greater improvement in defecation function, anorectal pressure metrics, and quality of life scores compared to controls ($P<0.05$). The incidence of adverse reactions was comparable between groups (14.46% vs. 6.67%, $P>0.05$). Multivariate analysis revealed that anastomotic leakage, ultra-low rectal cancer, interspinous diameter, and treatment method were independent predictors of postoperative outcomes ($P<0.05$). Conclusion: BFMS is a safe and effective therapeutic approach for improving bowel function and quality of life in patients with PBD after rectal cancer surgery. Anatomical and surgical variables may serve as important predictors of treatment response.

Keywords: Rectal cancer, postoperative bowel dysfunction, biofeedback magnetic stimulation, influencing factors

Introduction

Rectal cancer is among the most common malignant tumors worldwide, ranking ninth in incidence, with 872,983 new cases and an age-standardized incidence rate of 7.1/100,000 [1]. Advances in early screening and surgical techniques have significantly improved survival rates. However, postoperative complications - particularly bowel dysfunction - remain a major concern, markedly compromising patients' quality of life [2, 3]. Postoperative bowel dysfunction (PBD) includes a spectrum of symptoms, such as constipation, diarrhea, and difficulty in defecation. These symptoms can severely disrupt daily functioning and are associated with long-term consequences such as social withdrawal, depression, and deterioration of physical health.

The development of PBD is multifactorial. Surgical resection, particularly low anterior resection, often affects the integrity of pelvic floor muscles, the anal sphincter complex, and associated neural pathways, leading to impaired defecatory control [4]. In addition, adjuvant therapies such as radiotherapy and chemotherapy may further contribute to intestinal dysfunction [5]. Relevant studies have shown that in Europe and North America, up to 90% of rectal cancer patients experience some degree of bowel dysfunction after surgery [6].

Currently, the management of PBD after rectal cancer surgery mainly relies on pharmacological therapy, dietary adjustment, and intestinal or pelvic floor training exercises [7]. However, these conventional approaches have certain limitations. Although medications may provide

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temporary relief from symptoms such as constipation or diarrhea, they are often associated with the risk of drug dependence and side effects, and they do not address the underlying dysfunction in bowel control [8]. Similarly, intestinal and pelvic floor muscle training require long-term adherence and demonstrates variable efficacy across individuals [9].

In recent years, biofeedback magnetic stimulation (BFMS) has emerged as a promising non-invasive therapeutic modality that integrates biofeedback and magnetic stimulation technologies. BFMS delivers electromagnetic stimulation to target neural pathways and muscle groups, thereby improving neuromuscular coordination and improving bowel function [10]. By continuously monitoring physiological signals in real-time and providing feedback, BFMS facilitates patients' awareness and voluntary regulation of defecation-related muscle activity. It has been widely applied in neurological rehabilitation and the treatment of pelvic floor dysfunction, and has shown potential in improving bowel dysfunction [11]. BFMS can effectively relieve symptoms such as constipation and diarrhea by promoting pelvic floor muscle coordination, improving intestinal motility, and restoring bowel control, with a favorable safety and tolerability profile.

This study aimed to explore the clinical effect of BFMS in managing PBD after rectal cancer surgery, identify key factors influencing treatment outcomes, and to evaluate the therapeutic value of BFMS in postoperative bowel dysfunction.

Methods

Clinical data

This retrospective study analyzed the medical records of 158 patients with rectal cancer who underwent low anterior resection at Baoji Traditional Chinese Medicine Hospital from January 2018 to December 2023. Of these, 83 patients who received BFMS were assigned to the observation group, while 75 patients who underwent conventional rehabilitation served as the control group. This study was approved by the Medical Ethics Committee of Baoji Traditional Chinese Medicine Hospital.

Inclusion and exclusion criteria

Inclusion criteria were as follows: Pathologically confirmed diagnosis of rectal cancer [12]; underwent low anterior resection of the rectum; completed neoadjuvant chemotherapy at least 6 weeks prior to surgery; no evidence of distant metastasis; a minimum postoperative follow-up duration of 3 months; complete and accessible medical records and follow-up data.

Exclusion criteria: Patients were excluded if they met any of the following conditions: Presence of other malignant tumors or organ failure; history of pelvic radiotherapy; intolerance to the assigned treatment method; contraindications to BFMS or conventional rehabilitation therapy, such as the presence of metal implants interfering with magnetic stimulation; pregnancy or lactation; the presence of mental illness or cognitive impairment.

Intervention methods

Patients in the control group received conventional rehabilitation treatment, which included pelvic floor muscle exercises (10-15 repetitions per session, with each contraction maintained for 5-10 seconds), abdominal breathing exercises (10 minutes per session), defecation posture training using a footstool to optimize anorectal angle, and dietary adjustment to increase fiber intake and ensure adequate hydration.

Patients in the observation group received BFMS. Each session lasted 20-30 minutes, administered 3 times per week for a duration of 8-12 weeks. A specialized biofeedback device with an integrated magnetic stimulation function was used. Stimulation parameters were set at a pulse frequency of 40-80 Hz, a pulse duration of 1-2 seconds, and an inter-pulse rest interval of 2-3 seconds. During the treatment, patients were guided to perform voluntary pelvic floor muscle contractions in synchrony with real-time biofeedback cues to enhance anorectal coordination and sensory responsiveness.

Each treatment cycle lasted 15 days, and both groups completed two consecutive treatment cycles.

Defecation function assessment criteria

Excellent: The patient demonstrates effective control of defecation, with normal stool consistency, no nocturnal incontinence, accurate recognition of the urge to defecate and pass flatus, and a normal stool frequency of 1-2 times per day.

Good: The patient occasionally experiences minor leakage of loose stool during flatus or at night, but incontinence is infrequent. The urge to pass flatus and defecate can still be accurately perceived, with stool frequency ranging from 3-4 times per day.

Poor: The patient is unable to control defecation, experiences frequent episodes of incontinence, and is unable to distinguish between the urge to pass flatus and defecate.

Observation indicators

Primary observation indicators: (1) Defecation function: Defecation function was assessed in the two groups at 1, 2, and 3 months after surgery. (2) Quality of life and anal incontinence: Quality of life and the severity of anal incontinence were evaluated preoperatively and at 1, 2, and 3 months after surgery using the QLQ-CR29 scale and Wexner scoring systems, respectively. The QLQ-CR29 scale [13] consists of 6 basic dimensions: defecation problems, fecal incontinence, urinary symptoms, abdominal and pelvic pain, anxiety, and body image. Additionally, it includes 11 single-item measures, covering 4 items related to sexual function and 7 other symptoms such as abdominal distension, dry mouth, alopecia, taste problems, skin issues, stoma-related embarrassment, and rectal stoma problems. Each item is rated on a 4-point scale: 1 = "none", 2 = "a little", 3 = "quite", and 4 = "very". Patients completed the scale according to their actual experience. The total score reflects overall quality of life, with lower scores indicating better function and quality of life. The Wexner score [14] evaluates the severity of anal incontinence across five dimensions: frequency of incontinence for solid stool, liquid stool, and gas; use of protective pads; and lifestyle changes. Each item is scored from 0 to 4, resulting in a total score ranging from 0 to 20. Higher scores denote more severe incontinence.

Secondary observation indicators: (1) Anorectal function: To evaluate anorectal function, three key physiological parameters were assessed using anorectal manometry and a balloon distension test: resting anal pressure (RAP), maximum squeeze pressure (MSP), and maximum tolerated volume (MTV). These measurements were conducted preoperatively and at 1, 2, and 3 months after surgery. RAP reflects the basal tone of the anal sphincter at rest; MSP evaluates the voluntary contractile strength of the external anal sphincter; and MTV indicates the maximum volume of rectal balloon inflation tolerated before significant discomfort or an uncontrollable urge to defecate. (2) Adverse events: Adverse events during the treatment process were recorded in both groups, including skin irritation, muscle soreness, nausea, and abdominal pain. (3) Risk factor analysis: Univariate and multivariate logistics regression analyses were used to identify independent factors influencing postoperative defecation function at 1, 2, and 3 months after surgery.

Statistical methods

Data analysis was performed using SPSS 23.0 statistical software. Quantitative data that conformed to a normal distribution were expressed as mean ± standard deviation. Comparisons between groups were performed using an independent t-test. Count data were expressed as counts and percentages (%), and group differences were evaluated using a chi-square test. The comparison of ranked data was performed using a rank sum test. For repeated measurements across different time points, repeated measures analysis of variance (ANOVA) was performed, followed by the Bonferroni post-hoc test for multiple comparisons. Univariate analyses of baseline data were initially conducted. Variables with a significance level of $P<0.05$ in univariate analyses were used as independent variables for logistic regression analysis to analyze the independent influencing factors of patients at 1, 2, and 3 months after surgery. The predictive performance of these independent factors was analyzed using receiver operating characteristic (ROC) curve analysis. $P<0.05$ was considered statistically significant.

Results

Baseline data

Comparison of baseline data between the two groups showed no statistically significant differences in age, gender, BMI, tumor diameter, T stage, N stage, preoperative chemotherapy, anastomosis method, presence of anastomotic leakage, interspinous diameter of the ischium, or presence of anal sphincter injury ($P>0.05$) (**Table 1**).

Table 1. Baseline data

Variable	Observation group (n = 83)	Control group (n = 75)	χ^2	P
Age (years)				
<60/≥60	40/43	39/36	0.228	0.633
Gender				
Male/Female	54/29	53/22	0.567	0.452
BMI (kg/m^2)				
≤24/>24	62/21	53/23	0.488	0.485
Tumor diameter (cm)				
<3/≥3	34/49	36/39	0.790	0.374
T stage				
T1-2/T3	40/43	32/43	0.485	0.486
N stage				
N0/N1-2	50/33	49/26	0.437	0.509
Preoperative chemotherapy				
No/Yes	39/44	39/36	0.396	0.529
Anastomosis method				
Hand-sewn/Stapler	20/63	15/60	0.383	0.536
Anastomotic leakage				
No/Yes	76/7	70/5	0.175	0.675
Ultra-low rectal cancer				
Yes/No	37/46	30/45	0.338	0.561
Interspinous diameter of the ischium (cm)				
<10/≥10	33/50	34/41	0.501	0.479
Anal sphincter injury				
No/Yes	71/12	62/13	0.245	0.621

Note: BMI: Body mass index, T stage: Tumor stage, N stage: Node stage.

Comparison of postoperative defecation

Assessment of defecation function at 1, 2, and 3 months after treatment revealed no significant difference between the two groups at 1 month (P>0.05). However, at 2 and 3 months after treatment, the observation group exhibited significantly improved defecation function compared to the control group (P<0.05) (**Figure 1**).

Changes in anorectal pressure

Baseline measurements of RAP, MSP, and MTV did not differ significantly between the two groups before treatment (P>0.05). At 1 month after treatment, MSP and MTV were significantly higher in the observation group than in the control group (P<0.05). At 2 and 3 months after treatment, the observation group demonstrated significantly greater improvements in RAP, MSP, and MTV relative to the control group (P<0.05) (**Figure 2**).

Changes in anal incontinence severity and quality of life

Anal incontinence severity was assessed using the Wexner score, while patient quality of life was evaluated with the QLQ-CR29 scale. Baseline comparisons showed no significant differences between the two groups in either Wexner or QLQ-CR29 scores (P>0.05). At 1 month after treatment, the Wexner score of the control group was significantly higher than that of the observation group (P<0.05); however, no significant difference was observed in QLQ-CR29 scores at this time point (P>0.05). At 2 and 3 months after treatment, both Wexner and QLQ-CR29 scores in the observation group improved significantly compared to the control group (P<0.05) (**Figure 3**).

Relationship between anal incontinence and quality of life

Pearson correlation analysis was performed to explore the relationship between anal inconti-

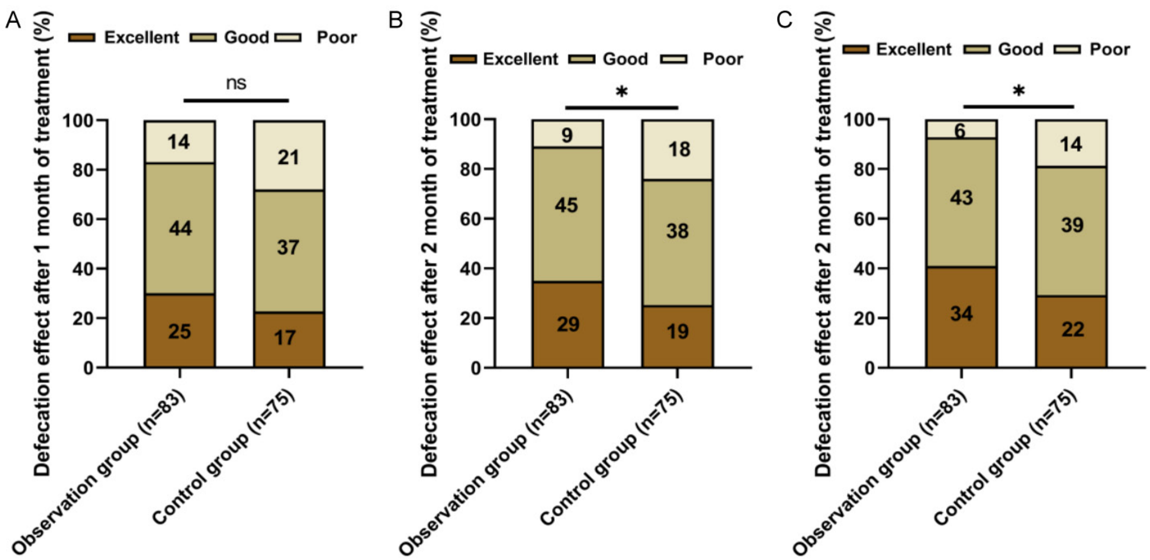

Figure 1. Comparison of defecation outcomes between the two groups after treatment. A. Defecation outcomes at 1 month post-treatment. B. Defecation outcomes at 2 months post-treatment. C. Defecation outcomes at 3 months post-treatment. Note: na indicates P>0.05 compared with the control group, * indicates P<0.05 compared with the control group.

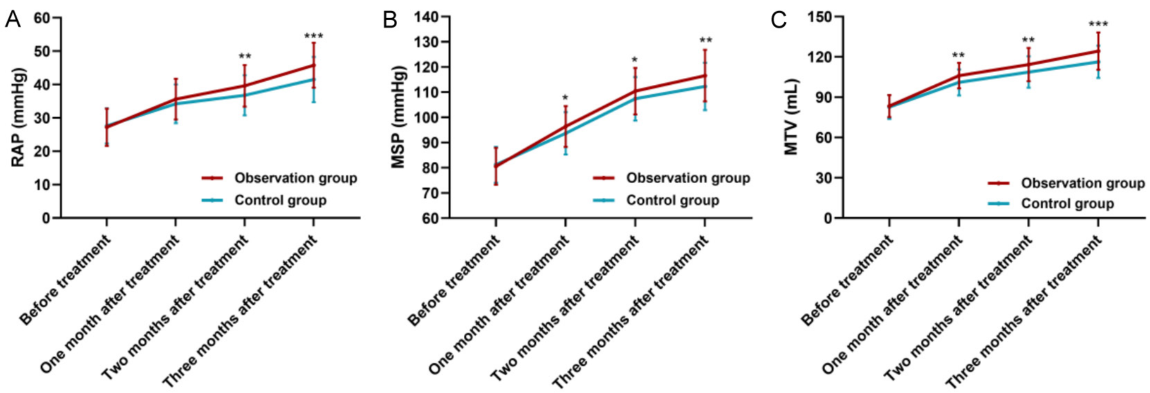

Figure 2. Changes in anorectal pressure of the two groups. A. RAP before treatment and within 3 months of treatment. B. MSP before treatment and within 3 months of treatment. C. MTV before treatment and within 3 months of treatment. Note: * indicates P<0.05 compared with the control group, ** indicates P<0.01 compared with the control group, *** indicates P<0.001 compared with the control group. RAP: Resting anal pressure, MSP: maximum contraction pressure, MTV: maximum rectal tolerance volume.

nence severity and quality of life after surgery. A positive correlation was observed between Wexner scores and the QLQ-CR29 scores at 1, 2, and 3 months after surgery in both groups (**Figure 4**).

Comparison of adverse reaction incidence

The incidence of adverse reactions was compared between the two groups. The observation group experienced skin irritation, muscle soreness, nausea, and abdominal pain, whereas the control group reported muscle soreness, nausea, and abdominal pain. The total incidence of adverse reactions in the observation group was 14.46% (12/83), slightly higher than 6.67% (5/75) in the control group; however, this difference was not statistically significant (P>0.05) (**Figure 5**).

Analysis of factors influencing defecation function after treatment

Univariate analysis identified several factors associated with poor defecation function at different postoperative time points. At 1 month

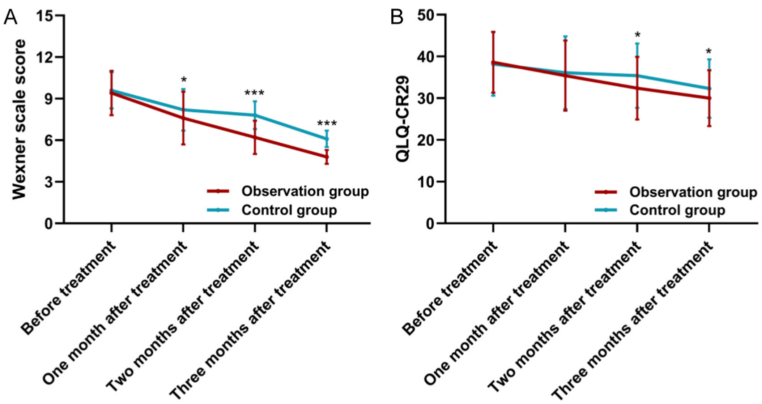

Figure 3. Changes in anal incontinence severity and quality of life of the two groups. A. Wexner scores before treatment and within 3 months of treatment. B. QLQ-CR29 scale scores before treatment and within 3 months of treatment. Note: * indicates P<0.05 compared with the control group, *** indicates P<0.001 compared with the control group.

post-treatment, T stage, presence of anastomotic leakage, ultra-low rectal cancer, and interspinous diameter of the ischium were significant predictors (P<0.05). At 2 months, age, presence of anastomotic leakage, ultra-low rectal cancer, interspinous diameter of the ischium, and treatment method emerged as significant factors (P<0.05). At 3 months, the presence of anastomotic leakage, ultra-low rectal cancer, interspinous diameter of the ischium, and treatment method remained significant (P<0.05) (**Table 2**).

Multivariate analysis of postoperative defecation function

Multivariate logistic regression analysis was conducted to identify independent factors influencing defecation function at 1, 2, and 3 months after surgery. At 1 month, T stage (P = 0.029), the presence of anastomotic leakage (P = 0.035), ultra-low rectal cancer (P = 0.008), and interspinous diameter (P = 0.010) were identified as independent predictors of defecation function. At 2 months, the presence of anastomotic leakage (P = 0.002), ultra-low rectal cancer (P = 0.033), interspinous diameter (P = 0.031), and treatment method (P = 0.012) remained significant, while age (P = 0.121) was not an independent factor. At 3 months, presence of anastomotic leakage (P = 0.007), interspinous diameter (P = 0.039), and treatment method (P = 0.015) continued to independently influence defecation function, whereas ultra-low rectal cancer (P = 0.053) did not reach statistical significance (**Figure 6**).

Predictive value of independent factors for postoperative defecation function

The predictive performance of each independent influencing factor on postoperative defecation function was assessed using receiver operating characteristic (ROC) curve analysis. At 1 month after surgery, the area under the curve (AUC) values were as follows: T stage, 0.585; presence of anastomotic leakage, 0.562; ultra-low rectal cancer, 0.629; and interspinous diameter, 0.643. At 2 months, the AUC values were: the presence of anastomotic leakage, 0.581; ultra-low rectal cancer, 0.609; interspinous diameter, 0.658; and treatment method, 0.608. At three months, the AUC values were: the presence of anastomotic leakage, 0.577; treatment method, 0.606; and interspinous diameter, 0.639. These results indicate moderate predictive accuracy of these factors for poor postoperative defecation function (**Figure 7**).

Discussion

This study aimed to evaluate the effect of BFMS in alleviating postoperative bowel dysfunction following rectal cancer surgery and to analyze factors influencing treatment outcomes. Postoperative bowel dysfunction is a common complication that substantially impairs patients' quality of life. Its etiology is multifactorial, including the extent of surgical resection, methods of intestinal reconstruction, and nerve injury. As a non-invasive therapeutic modality, BFMS provides an innovative approach to rehabilitation by regulating neuromuscular function. Our findings demonstrate that BFMS significantly improves defecation function and quality of life in postoperative patients, with a favorable safety profile. These results provide new scientific evidence and valuable clinical guidance for the rehabilitation management of bowel dysfunction after rectal cancer surgery.

The results show that at 2 and 3 months of post-treatment, patients in the observation group receiving BFMS exhibited significantly

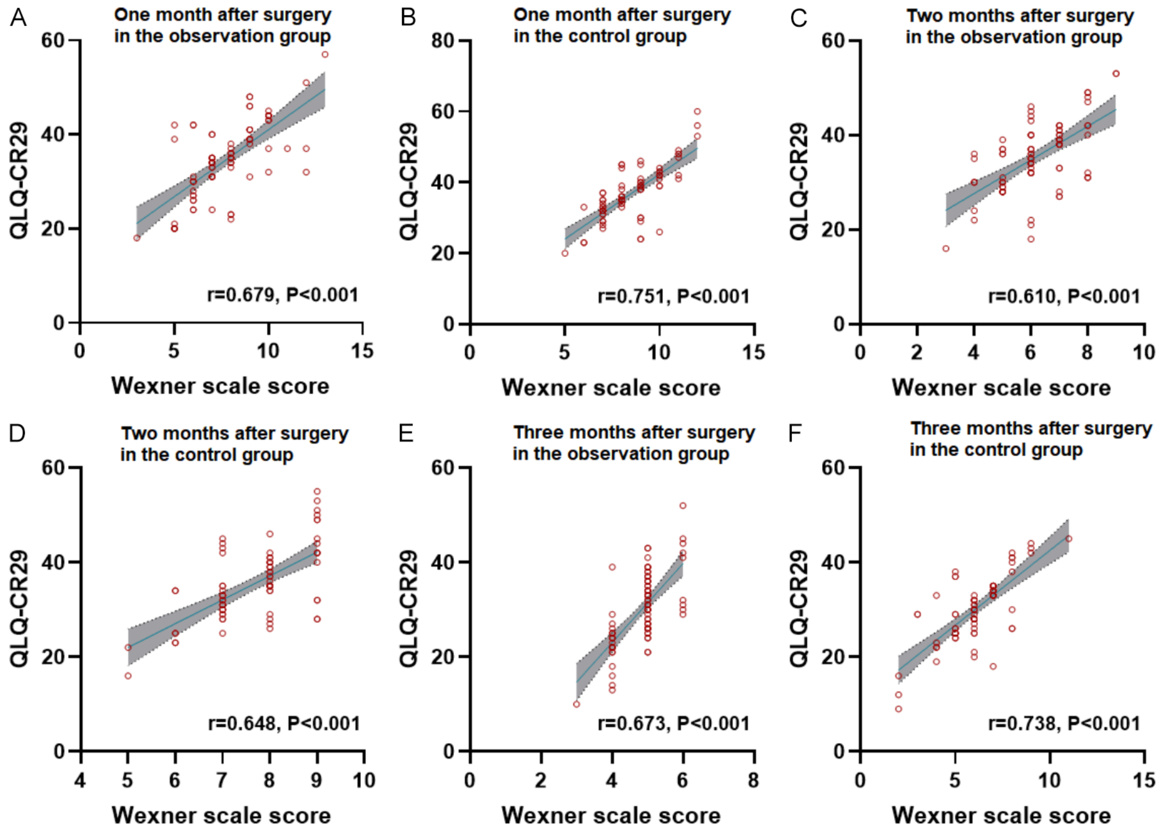

Figure 4. Relationship between anal incontinence severity and quality of life in the Two Groups after Surgery. A. Observation group at 1 month after surgery: positive correlation between Wexner and QLQ-CR29 scale scores (r = 0.679, P<0.001). B. Control group at 1 month after surgery: positive correlation between Wexner and QLQ-CR29 scale scores (r = 0.751, P<0.001). C. Observation group at 2 months after surgery: positive correlation between Wexner and QLQ-CR29 scale scores (r = 0.610, P<0.001). D. Control group at 2 months after surgery: positive correlation between Wexner and QLQ-CR29 scale scores (r = 0.648, P<0.001). E. Observation group at 3 months after surgery: positive correlation between Wexner and QLQ-CR29 scale scores (r = 0.673, P<0.001). F. Control group at 3 months after surgery: positive correlation between Wexner and QLQ-CR29 scale scores (r = 0.738, P<0.001).

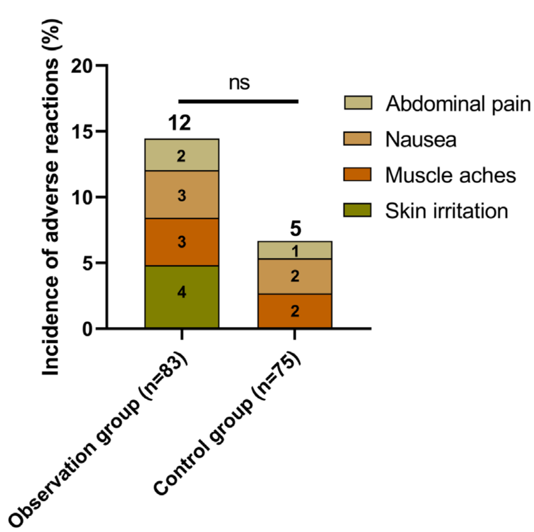

Figure 5. Comparison of adverse reaction incidence.

greater improvements in defecation function, anorectal function, and quality of life compared to the control group. BFMS likely ameliorates bowel dysfunction through mechanisms involving neural regulation and muscle strengthening. Specifically, magnetic stimulation can enhance the strength and coordination of the anal sphincter and pelvic floor muscles, thereby increasing anal canal pressure and rectal capacity [15, 16]. Additionally, its regulatory effects on the autonomic nervous system can promote intestinal motility and evacuation, relieving postoperative defecation difficulties [17]. Notably, improvements in MSP, RAP and MTV were significantly greater in the observation group than in controls, further validating the effectiveness and mechanistic rationale of BFMS. Moreover, a positive correlation was ob-

Table 2. Univariate analysis of factors influencing defecation function at different time points after treatment

Variable	1 month after treatment				2 months after treatment				3 months after treatment			
	Poor bowel function (n = 50)	Non-Poor bowel function (n = 108)	χ^2	P	Poor bowel function (n = 41)	Non-Poor bowel function (n = 117)	χ^2	P	Poor bowel function (n = 36)	Non-Poor bowel function (n = 122)	χ^2	P
Age (years)												
<60/≥60	29/21	50/58	1.873	0.171	26/15	53/64	3.985	0.046	22/14	57/65	2.302	0.129
Gender												
Male/Female	37/13	70/38	1.319	0.251	28/13	79/38	0.008	0.928	24/12	83/39	0.024	0.878
BMI (kg/m^2)												
≤24/>24	35/15	80/28	0.286	0.593	27/14	88/29	1.343	0.247	27/9	88/34	0.115	0.734
Tumor diameter (cm)												
<3/≥3	17/33	53/55	3.147	0.076	13/28	57/60	3.56	0.059	11/25	59/63	3.571	0.059
T stage												
T1-2/T3	17/33	55/53	3.948	0.047	15/26	57/60	1.802	0.179	13/23	59/63	1.682	0.195
N stage												
N0/N1-2	29/21	70/38	0.678	0.410	24/17	75/42	0.402	0.526	23/13	76/46	0.03	0.862
Preoperative chemotherapy												
No/Yes	20/30	58/50	2.568	0.109	16/25	62/55	2.369	0.124	14/22	64/58	2.048	0.152
Anastomosis method												
Hand-sewn anastomosis/Stapler	9/41	26/82	0.731	0.392	5/36	30/87	3.183	0.074	5/31	30/92	1.846	0.174
Anastomotic leakage												
No/Yes	42/8	104/4	7.363	0.007	33/8	113/4	11.204	<0.001	29/7	117/5	9.328	0.002
Ultra-low rectal cancer												
Yes/No	30/20	37/71	9.272	0.002	24/17	43/74	5.899	0.015	21/15	46/76	4.843	0.028
Interspinous diameter of the ischium (cm)												
<10/≥10	31/19	36/72	11.5	<0.001	27/14	40/77	12.465	<0.001	23/13	44/78	8.811	0.003
Anal sphincter injury												
No/Yes	39/11	94/14	2.096	0.148	32/9	101/16	1.561	0.211	27/9	106/16	2.948	0.086
Treatment method												
Biofeedback magnetic stimulation treatment/Conventional rehabilitation treatment	22/28	61/47	2.135	0.144	15/26	68/49	5.646	0.017	13/23	70/52	5.041	0.025

Note: BMI: Body mass index, T stage: Tumor stage, N stage: Node stage.

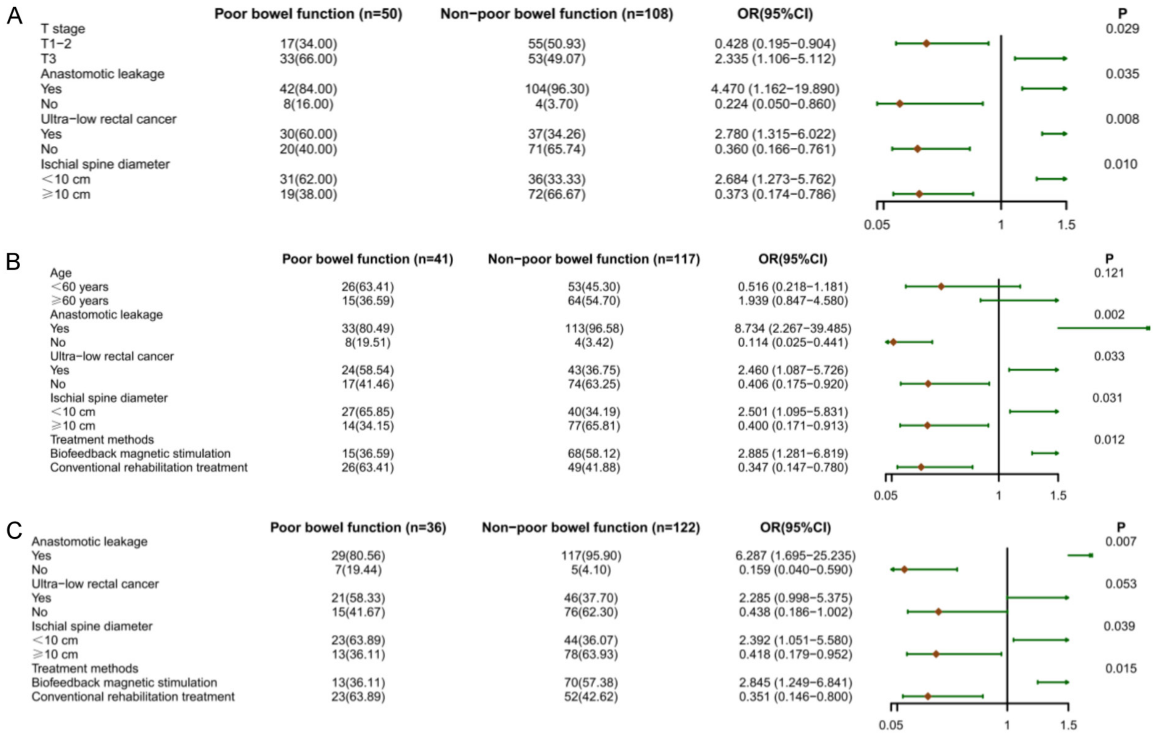

Figure 6. Multivariate forest plot of factors influencing defecation function after treatment. A. Multivariate analysis of factors affecting defecation function at one month after treatment. B. Multivariate analysis of factors affecting defecation function at two months after treatment. C. Multivariate analysis of factors affecting defecation function at three months after treatment.

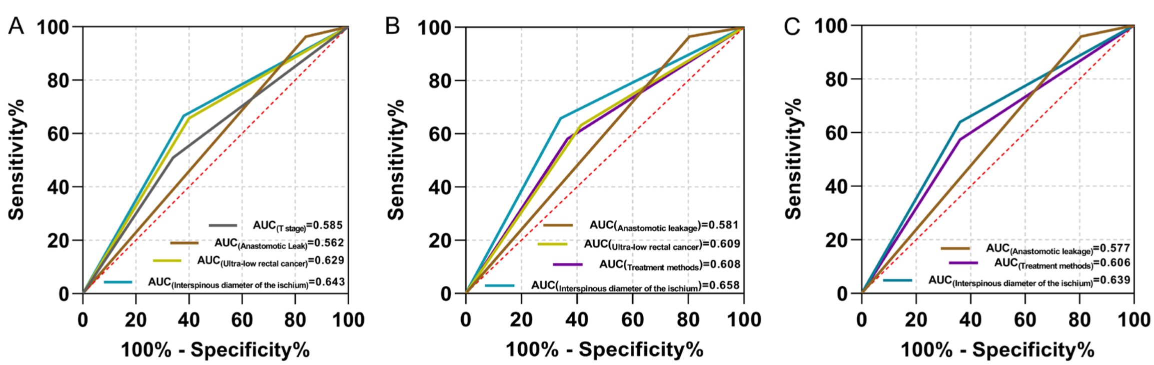

Figure 7. Predictive Value of Independent Factors for Postoperative Defecation Function. A. ROC curves of independent factors predicting poor defecation function at one month after surgery. B. ROC curves of independent factors predicting poor defecation function at two months after surgery. C. ROC curves of independent factors predicting poor defecation function at three months after surgery.

served between Wexner scores and QLQ-CR29 quality of life scores in both groups after surgery, underscoring the critical impact of continence status on overall quality of life. The more severe the incontinence, the lower the quality of life, highlighting the importance of improving incontinence function to enhance patient quality of life.

Notably, this study also explored factors influencing the treatment effect. The analysis identified T stage, anastomotic leakage, ultra-low rectal cancer, and interspinous diameter of the ischium as key variables affecting postoperative rehabilitation. The T stage reflects the extent of local tumor invasion; patients with advanced stages typically require more extensive surgical resection, which may cause irreversible damage to the anal sphincter and related nerves, thereby impairing postoperative recovery. Wu et al. [18] reported that a higher T stage is associated with increased risks of urinary incontinence and erectile dysfunction after prostate cancer surgery. Anastomotic leakage, a common postoperative complication, can induce local inflammation, fibrosis and impaired intestinal motility, consequently delaying functional recovery [19]. In patients with ultra-low rectal cancer, the surgical procedure often involves low rectal resection and anal reconstruction, which substantially compromises sphincter function and prolongs the rehabilitation period [20].

Moreover, the anatomical characteristics of the interspinous diameter of the ischium may affect the structural integrity and functional capacity of the pelvic floor muscles. A narrower interspinous diameter could restrict the pelvic floor muscles' ability to recover, thereby limiting patients' potential for functional improvement in defecation after rehabilitation [21]. Therefore, postoperative rehabilitation strategies should account for individual anatomical variability and be tailored accordingly to optimize treatment outcomes. The results of this study further highlight that the treatment method itself is a critical modifiable factor. BFMS demonstrated superior efficacy compared to conventional rehabilitation, underscoring its importance as an integral component of postoperative management in patients with rectal cancer.

Compared with the existing literature, this study further verified the role of BFMS in ameliorating postoperative bowel dysfunction, while expanding its applicable patient population and clinical indications. Previous studies have predominantly focused on the effects of BFMS on pelvic floor disorders such as urinary incontinence and constipation. For instance, Alouini et al. reported that the combination of biofeedback magnetic stimulation can significantly improve pelvic floor muscle contraction and significantly reduce urinary incontinence [22]. Our study provides direct evidence for its benefit in addressing postoperative dysfunction after rectal cancer surgery, supported by a rigorous research design and comprehensive multi-parameter evaluation. Compared with traditional rehabilitation methods, BFMS shows significant advantages in improving defecation function, especially in terms of the speed of recovery and patient compliance.

This study does have some limitations. First, as a single-center study with a relatively small sample size, selection bias cannot be excluded, which may limit the generalizability of our findings. Second, the follow-up duration was relatively short, precluding a thorough assessment of the long-term efficacy of BFMS and its sustained impact on patients' quality of life. In addition, the evaluation mainly relied on subjective scoring scales; future studies should incorporate imaging techniques or other objective measures to enhance the robustness and credibility of the results.

Future studies should focus on expanding the sample size and adopting multi-center randomized controlled trials to verify the efficacy and safety of BFMS. Meanwhile, in-depth investigations into its underlying mechanisms are warranted, integrating neuroelectrophysiological assessments and advanced imaging techniques to elucidate the precise pathways through which it facilitates neuromuscular functional recovery. Furthermore, for high-risk or special populations, such as patients with ultra-low rectal cancer, more individualized treatment plans should be developed. These may incorporate multimodal approaches, including pharmacological therapy, exercise-based rehabilitation, and psychological interventions, aiming to further optimize postoperative functional outcomes and overall rehabilitation effect.

In conclusion, this study shows that BFMS is a safe and effective rehabilitative intervention following rectal cancer surgery. It significantly improves defecation function, anorectal function, and patients' quality of life. Tailoring treatment plans to individual patient characteristics may further optimize therapeutic outcomes. BFMS holds promise as a vital component of postoperative rehabilitation for rectal cancer, providing novel therapeutic avenues and a solid clinical foundation to improve patients' postoperative quality of life.

Disclosure of conflict of interest

None.

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