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Research on the Mechanism of Bionic Physical Microenvironment Combined with Plant-derived Signaling Molecules in Remodeling the Female Reproductive Tract Microbiota

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Abstract: *Objective*: To explore the remodeling effect of a bionic physical microenvironment combined with plant-derived signaling molecules on the female reproductive tract microbiota. *Methods*: A total of 63 patients with female reproductive tract inflammation admitted to our hospital from June 2021 to June 2024 were selected and divided into an experimental group (32 patients, treated with bionic physical microenvironment combined with plant-derived signaling molecules) and a control group (31 patients, treated with Western medicine). The therapeutic effects of the two groups were compared. *Results*: After treatment, the clinical effectiveness rate, clinical symptom score, and quality of life score in the experimental group were significantly higher than those in the control group, while the incidence of adverse reactions between the two groups showed no significant difference. *Conclusion*: The treatment of female reproductive tract inflammatory diseases using a bionic physical microenvironment combined with plant-derived signaling molecules is highly effective, effectively alleviates related symptoms, improves patients' future quality of life, and exhibits relatively high safety.

Keywords: Bionic physical microenvironment; Plant-derived signaling molecules; Female reproductive tract inflammation; Remodeling of female reproductive tract microbiota

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1. Introduction

Female reproductive tract inflammation is a common disease that affects women of different ages and has a high recurrence rate. The bionic physical microenvironment can deliver antibiotics to the posterior vaginal fornix through perfusion, improving drug concentration in the pelvic region and optimizing local anti-infective effects [1,2]. This method can disrupt the blood-pelvic barrier, allowing antibiotics to directly target

the lesion area, thereby rapidly relieving disease symptoms and eliminating pelvic adhesions and pelvic effusion. The bionic physical microenvironment can physically stimulate pelvic tissues, improving blood supply to the lesion through thermal effects and clearing inflammatory mediators in the pelvic cavity, thus achieving pelvic tissue repair. It can effectively relax pelvic floor muscles, alleviating discomfort such as pelvic pain. Additionally, the bionic physical microenvironment can reduce inflammatory exudation and promote effective absorption of pelvic effusion. Plant-derived signaling molecules are therapeutic agents extracted from natural Chinese herbal medicines, primarily Fuke Qianjin Capsules, which have strong heat-clearing, detoxifying, blood-nourishing, and dampness-resolving effects. Therefore, 63 patients with female reproductive tract inflammation were selected to investigate the effects of a bionic physical microenvironment combined with plant-derived signaling molecules.

2. Materials and methods

2.1. General information

A total of 63 patients with female reproductive tract inflammation admitted to our hospital from June 2021 to June 2024 were selected and divided into an experimental group and a control group by lottery. Their relevant data are shown in **Table 1**.

Table 1. Clinical data of the two groups

Group	Mean age (years)	Mean disease duration (months)
Experimental group (n=32)	37.52 ± 2.96	8.95 ± 1.26
Control group (n=31)	37.48 ± 3.01	9.01 ± 1.17
P value	> 0.05	> 0.05

2.2. Methods

The control group was treated with Western medicine, selecting cefotaxime sodium at a dosage of 2g mixed into 100ml of physiological saline and administered via intravenous drip twice daily. Additionally, levofloxacin was administered orally at a dosage of 500 mg once daily for one week.

The experimental group received a bionic physical microenvironment + plant-derived signaling molecules: 200 mL of tinidazole and 300 mL of ofloxacin were heated to 30–40°C, and 4000U of chymotrypsin and 5mg of dexamethasone were added. Puncture was performed at McBurney's point, located one-third of the way along the line connecting the umbilicus and the anterior superior iliac spine on the lateral side, and a trocar was inserted. When a sense of loss was felt, the needle core was removed, and the aforementioned drug solution was quickly poured in. The entire course of treatment was seven days, consisting of three courses. After the perfusion therapy, the patient was asked to lie flat, and bionic physical microenvironment treatment was initiated. The multifunctional pelvic physiotherapy instrument was connected to the circuit, the power was turned on, and the instrument's status was checked before appropriately adjusting the treatment temperature. The patient's lower abdominal skin was thoroughly cleaned, electrodes were attached, and bandages were securely fastened with appropriate tightness adjustments. The patient's external genitalia were disinfected, and an electrode sheath was placed over the intracavitary electrode rod. A small amount of paraffin oil was applied to the outside of the sheath, and it was then placed in the posterior vaginal fornix. The confirmation key was pressed to start the physiotherapy

process. A warm sensation in the vagina and abdomen was considered appropriate, with each physiotherapy session lasting between 30 and 60 minutes, once daily, for a total of ten days per course, and two consecutive courses were administered. For the selection of plant-derived signaling molecules, Fuke Qianjin Capsules were used, with a dosage of two capsules three times daily for one week.

2.3. Evaluation criteria

The clinical effective rate (marked effectiveness refers to the absence of disease symptoms, normal results from blood tests and vaginal secretion examinations, and imaging examinations showing two-thirds absorption of pelvic effusion; effectiveness refers to the presence of mild symptoms, slightly abnormal results from blood tests and vaginal secretion examinations, and imaging examinations showing one-third absorption of pelvic effusion; ineffectiveness refers to the presence of severe symptoms, abnormal results from blood tests and vaginal secretion examinations, and almost no absorption of pelvic effusion), clinical symptom scores (a 4-grade scoring system based on clinical symptoms such as lower abdominal pain or lumbosacral pain and fatigue, with 0-3 points indicating mild symptoms and higher scores indicating severe symptoms), and laboratory indicators (CRP test values, ηb values, ESR test values, FBG test values, and other hemorheological-related indicators) were compared between the two groups.

2.4. Statistical methods

The data from the study were analyzed using SPSS 23.0 software. For measurement data mean ± standard deviation [SD), a t-test was used, while for count data (%), a chi-square (χ^2) test was employed. A significant difference was indicated when $P < 0.05$.

3. Results

3.1. Comparison results of clinical effective rate between the two groups

As shown in **Table 2**, the clinical effective rate in the experimental group was higher than that in the control group ($P < 0.05$).

Table 2. Comparison results of clinical effective rates between the two groups (n/%)

Group	Number of markedly effective cases	Number of effective cases	Number of ineffective cases	Total effective
Experimental group (n = 32)	21	9	2	30 (93.8)
Control group (n = 31)	15	8	8	23 (74.2)
χ^2 value				4.509
P value				0.033

3.2. Comparison results of clinical symptom scores between the two groups

As shown in **Table 3**, after treatment, the clinical symptom scores of patients in the experimental group were significantly lower than those in the control group, with statistical significance ($P < 0.05$).

Table 3. Comparison results of clinical symptom scores between the two groups (mean ± SD)

Group	Lower abdominal and lumbosacral pain		Fatigue		Abnormal vaginal discharge		Menstrual abdominal pain	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
Experimental group (n=32)	2.28 ± 0.41	0.84 ± 0.12	2.17 ± 0.33	0.75 ± 0.13	2.25 ± 0.36	0.69 ± 0.08	2.08 ± 0.41	0.75 ± 0.11
Control group (n=31)	2.32 ± 0.36	1.59 ± 0.36	2.24 ± 0.31	1.36 ± 0.44	2.19 ± 0.38	1.02 ± 0.31	2.12 ± 0.43	1.29 ± 0.35
t value	0.411	11.165	0.867	7.513	0.644	5.826	0.378	8.316
P value	0.683	0.000	0.389	0.000	0.522	0.000	0.707	0.000

3.3. Comparison results of quality of life scores between the two groups

As shown in **Table 4**, after treatment, the quality of life scores in the experimental group were higher than those in the control group ($P < 0.05$).

Table 4. Comparison results of laboratory indicators between the two groups (mean ± SD)

Group	CRP (mg/L)		ηb (mPa·s)		ESR (mm/h)		FBG (g/L)	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
Experimental group (n=32)	8.71±1.59	5.11±0.72	2.55±0.42	1.60±0.38	39.46±3.74	18.26±2.81	4.66±0.59	3.10±0.50
Control group (n=31)	8.75±1.60	6.27±0.83	2.57±0.44	2.02±0.43	39.51±3.77	25.93±2.94	4.69±0.55	4.18±0.51
t value	0.100	5.931	0.185	4.111	0.053	10.587	0.209	8.487
P value	0.921	0.000	0.854	0.000	0.958	0.000	0.835	0.000

3.4. Comparison results of the incidence of adverse reactions between the two groups

During the treatment process, neither group experienced severe intolerable adverse reactions, and there was no significant difference between the two groups ($P > 0.05$).

4. Discussion

The study revealed statistically significant differences between the bionic physical microenvironment combined with plant-derived signaling molecules and conventional Western medicine in terms of clinical efficacy, improvement of clinical symptoms, normalization of important laboratory indicators, and enhancement of quality of life in the treatment of female reproductive tract inflammation. In the experimental group, the overall clinical effectiveness rate after treatment was 93.8% (30 cases out of a total of 32 cases), while in the control group, it was 74.2% (23 cases out of a total of 31 cases). The chi-square value between the two groups was 4.509, with a *P*-value of 0.033. Regarding clinical symptom scores, there was a significant separation between the two groups after treatment. These data clearly indicate that the combined therapy has definite and extensive advantages in alleviating patients' suffering. The changes in experimental indicators also provide physiological evidence for the above effects. After treatment, the experimental indicators in the experimental group were better than those in the control group ($P < 0.001$). The significant improvement in these parameters not only reflects the potent inhibition of systemic and local inflammatory

responses but also indicates the restoration of pelvic and reproductive tract microcirculation. Additionally, no severe adverse reactions were recorded in either group during the treatment process, and no statistically significant difference in the incidence of adverse events was observed, suggesting that the safety of the combined therapy is comparable to that of conventional Western medicine. Based on all the collected data, the combined therapy exhibits characteristics of "high efficacy, strong improvement, and low risk", providing a solid database for future research.

The remarkable efficacy observed in this study is fundamentally attributed to the multi-target, multi-level synergistic effects of the bionic physical microenvironment and plant-derived signaling molecules in altering the reproductive tract microbiota and restoring local homeostasis [3]. The therapeutic effect of the bionic physical microenvironment is first manifested in the disruption and reconstruction of pathological physical barriers. Percutaneous drug perfusion delivers a mixture of tinidazole, ofloxacin, chymotrypsin, and dexamethasone, preheated to 30-40°C, into the pelvic lesion area, effectively bypassing the blood-pelvic barrier. This targeted drug delivery method results in significantly higher drug concentrations in the pelvic region compared to conventional intravenous administration, facilitating the rapid elimination of pathogenic microorganisms and suppression of inflammatory cascades, achieving an efficient "first-round attack" [4]. Subsequently, multifunctional pelvic physiotherapy is employed, utilizing physical energy (such as thermal effects or specific frequencies of electromagnetic/vibrational stimulation) to intervene in tissue. The intracavitary electrode of the physiotherapy device is placed in the posterior vaginal fornix, while the abdominal electrode is positioned on the lower abdomen, creating an energy field environment that covers the lesion area. Thermal effects significantly dilate local blood vessels, optimizing blood supply to the lesion area, enhancing the delivery of oxygen and nutrients, and accelerating the clearance of metabolic waste and inflammatory mediators. This improvement in blood flow and substance exchange serves as the physical basis for the effective absorption of pelvic effusion and the resolution of tissue edema. Physical stimulation also adjusts the pelvic floor muscles and nerves, promoting the relaxation of spastic muscles and alleviating pelvic pain and a sensation of heaviness [5]. More importantly, this bionic, mild physical microenvironment can influence the activity and function of local immune cells, potentially promoting the secretion of anti-inflammatory cytokines and inhibiting the release of pro-inflammatory factors, creating a microenvironment conducive to tissue repair in terms of immunity [6]. The addition of the plant-derived signaling molecule, Fuke Qianjin Capsule, introduces precise "biochemical-level" interventions to this repair process. The various phytochemicals in Fuke Qianjin Capsule, which are natural signaling molecules, extend beyond simple antibacterial and anti-inflammatory effects. They can regulate the gut-vagina axis or directly influence the vaginal mucosal immune system, thereby affecting the differentiation and function of immune cells. These signaling molecules may act like prebiotics, selectively stimulating the growth and colonization of beneficial bacteria such as Lactobacillus [7]. They may also influence the expression of tight junction proteins in vaginal epithelial cells to improve mucosal barrier function, reducing the adhesion and invasion opportunities of pathogenic bacteria. Additionally, they can regulate local pH, compete with pathogenic bacteria, and even interfere with the expression of virulence factors and biofilm formation in pathogenic bacteria through quorum-sensing quenching. Thus, the bionic physical microenvironment creates an "external improved field" conducive to drug penetration, inflammation elimination, blood circulation, and tissue repair, while plant-derived signaling molecules exert effects from an "internal regulatory network" involving immune modulation, microbiota guidance, and barrier healing [8].

The combination of the two forms a complete intervention process from "physical clearance" to "chemical adjustment" and finally to "life reconstruction", which is likely the fundamental reason for its superior efficacy compared to the antimicrobial drug control group alone. The remodeling effect of the combined therapy on the female reproductive tract microbiota is a crucial step in achieving long-term efficacy and reducing the risk of recurrence. It involves key aspects such as regulating microbiota structure, adjusting microbiota function, and modulating microbiota-host interactions. Conventional Western medicine antimicrobial therapy can rapidly kill sensitive pathogenic bacteria, but its broad-spectrum antibacterial properties often indiscriminately attack beneficial bacteria in the vagina, leading to dysbiosis and disrupting microecological balance. This is one of the reasons why the control group showed less improvement in some indicators compared to the experimental group, and in the long term, this treatment approach may even increase the risk of recurrence [9]. In contrast, the combined therapy demonstrates a more "intelligent" regulatory effect on the microbiota. The bionic physical microenvironment improves local blood circulation, oxygenation, and pH, creating favorable physicochemical conditions for the recovery and colonization of beneficial bacteria such as Lactobacillus. The plant-derived signaling molecule, Fuke Qianjin Capsule, contains numerous active ingredients such as flavonoids, polysaccharides, and alkaloids, which exhibit certain antibacterial and anti-biofilm activities. More importantly, they function like "prebiotics" and "quorum sensing regulators", selectively stimulating the growth of beneficial bacteria without promoting or inhibiting the proliferation of conditional pathogens. Crucially, studies have shown that these plant signaling molecules can influence quorum sensing systems to interfere with the expression of virulence genes and biofilm formation in pathogenic bacteria, thereby weakening their pathogenicity without necessarily eradicating them. This approach facilitates the rapid formation of a healthy microbiota after the clearance of major pathogens, either by preserving or guiding the original microbiota.

5. Conclusion

In conclusion, the bionic physical microenvironment combined with plant-derived signaling molecules represents an effective and safe method for treating female reproductive tract inflammatory diseases. Its mechanism involves the combined effects of physical energy improving the local internal environment, targeted drugs directly exerting anti-inflammatory and antibacterial effects, and plant signals systematically regulating immunity and the microbiota. This combined therapy represents a paradigm shift from "antimicrobial to probiotic (promoting beneficial bacteria)" and from "anti-inflammatory to restoring homeostasis", providing new insights for clinical practice. Subsequent research should focus on increasing the sample size for validation, extending the follow-up observation period, exploring more details of the microbiome-host interactions, and refining treatment parameters to promote the more precise and widespread application of this combined strategy.

Disclosure statement

The authors declare no conflict of interest.

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