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Original Article

Effect of percutaneous auricular vagus nerve stimulation on postoperative recovery quality in patients undergoing gynecologic laparoscopic surgery

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Abstract: Objective: To explore the effect of percutaneous auricular vagus nerve stimulation on postoperative recovery quality in patients undergoing gynecologic laparoscopic surgery. Methods: A total of 104 patients undergoing laparoscopic gynecologic benign tumor resection in our hospital were prospectively enrolled and divided into either a percutaneous auricular vagus nerve stimulation group (T group) or a sham stimulation group (F group) using a random number table method, with 52 cases in each group. Patients in the T group received one 30-minute session of percutaneous auricular vagus nerve stimulation. followed by 30 min in the post-anesthesia care unit, while patients in the F group received sham stimulation for the same duration. The postoperative gastrointestinal recovery time, gastrointestinal symptom score, and postoperative feeding-nausea-vomiting-examination-symptom duration score (I-FEED) were recorded and compared between the two groups. Additionally, postoperative pain score and sleep status (sleep score and incidence of sleep disorders), the incidence of postoperative adverse reactions, postoperative hospitalization time, and quality of life score were compared between the two groups. Results: Compared to the F group, the recovery time of gastrointestinal function in the T group was shorter, and the I-FEED and gastrointestinal symptom scores on the 1st, 2nd and 3rd day after operation were significantly lower. The incidence of postoperative gastrointestinal intolerance and postoperative gastrointestinal dysfunction in the T group was lower (all $P < 0.05$). At the same time, the NRS of patients in the T group decreased on the 1st and 3rd day after operation, the sleep quality was better than that in the F group, and the incidence of sleep disorders was lower than that of the F group (all $P < 0.05$). Finally, the incidence of postoperative nausea, vomiting and dizziness in group T was lower than that in the F group; however, there was no significant difference in the incidence of bradycardia, hypotension or postoperative hospital stay between the two groups ($P > 0.05$). In addition, the quality of life of patients in group T was better than that of group F ($P = 0.043$). Conclusion: Percutaneous auricular vagus nerve stimulation can promote the recovery of gastrointestinal function, reduce the score of postoperative gastrointestinal symptoms, relieve postoperative pain, and improve the score of sleep and postoperative quality of life in patients undergoing laparoscopic gynecologic benign resection.

Keywords: Transcutaneous electrical nerve stimulation, laparoscopic examination, gynecological surgery, postoperative gastrointestinal function, adverse reaction

Introduction

Gynecologic benign tumor, including ovarian cysts and uterine fibroids, are common disorders of the female reproductive system [1, 2]. Currently, the main treatment for benign gynecologic tumors is surgical resection [3, 4]. Due to the shortcomings of large trauma, obvious postoperative pain, and slow recovery, a traditional open surgical approach has been gradually replaced by laparoscopy. However, some patients still experience gastrointestinal dysfunction after laparoscopic surgery [5].

Postoperative gastrointestinal dysfunction is mainly manifested as impaired postoperative feeding function and gastrointestinal reactions, such as nausea, vomiting, and delayed exhaust and defecation [6, 7]. Studies indicate that the incidence of gastrointestinal dysfunction after gynecologic laparoscopic surgery is about 20%, second only to gastrointestinal surgery. On one

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Figure 1. Preoperative tVANS. The stimulation electrode was accurately attached to the patient's auricular cavity, a region predominantly innervated by the auricular branch of the vagus nerve, so as to achieve intraoperative neuromodulation.

hand, it impedes postoperative recovery process; on the other hand, this increases both the economic and psychological burden on patients [8]. Therefore, reducing the incidence of postoperative gastrointestinal dysfunction is of great significance for patient rehabilitation. Recent studies have shown that transcutaneous auricular vagus nerve stimulation (taVNS) can promote postoperative recovery by regulating gastrointestinal function, while also demonstrating its predictive value for postoperative intestinal obstruction. However, research on postoperative recovery after laparoscopic tumor surgery remains limited [9]. Based on this, this study aimed to explore the effects of taVNS on gastrointestinal function recovery following laparoscopic surgery, thereby providing additional medical evidence for improving the overall rehabilitation outcome of benign gynecologic tumor surgeries.

Patients and methods

Patient information

A total of 104 patients undergoing laparoscopic resection of benign gynecologic tumors at Huai'an First Hospital Affiliated to Nanjing Medical University were prospectively selected and divided into a percutaneous auricular vagus nerve stimulation group (T group, **Figure 1**) and a sham stimulation group (F group) according to a random number table method, with 52 cases in each group. This study was approved by the Medical Ethics Committee of Huai'an First Hospital Affiliated to Nanjing Medical University (KY-2024-346-01), with informed consent obtained from patients or their family members. Clinical Registration Number: ChiCTR2400092521.

Inclusion criteria: 1. Age 18-70 years; 2. Patients with benign gynecologic tumors confirmed by preoperative pathology; 3. Anesthesia ASA grade I-II; 4. Initial surgical treatment for a gynecologic tumor.

Preoperative exclusion criteria: 1. Implanted cardiac pacemaker or defibrillator; 2. Preoperative arrhythmia; 3. Preoperative respiratory dysfunction, including asthma and chronic obstructive ventilation dysfunction; 4. Infection at the site for vagus nerve stimulation; 5. History of gastrointestinal dysfunction; 6. Hepatic or renal insufficiency; 7. Lactation; 8. Previous auditory or speech dysfunction.

Intraoperative and post-enrollment exclusion criteria: 1. Intraoperatively confirmed to be malignant tumor; 2. Intraoperative conversion to laparotomy; 3. Withdrawal from the trial.

Methods

Anesthesia method: Patients underwent routine preoperative fasting and fluid restriction. After entering the operating room, oxygen was inhaled via face mask, and peripheral venous access was established. Blood pressure, electrocardiogram, pulse oximetry (SpO_2), and end-tidal carbon dioxide partial pressure ($PETCO_2$) were monitored using an electrocardiographic monitor. Both groups received standardized general anesthesia. Anesthesia induction involved intravenous administration of midazolam (0.05 mg/kg), sufentanil (0.5 μg/kg), propofol (1.5 mg/kg), and rocuronium (0.8 mg/kg). Tracheal intubation was performed after loss of consciousness and adequate muscle relaxation. The patient was connected to a ventilator for volume-controlled ventilation. Tidal volume was set at 6-8 mL/kg, respiratory rate at 12-18 times/min, and end-tidal carbon dioxide partial pressure ($PETCO_2$) at 35-45 mmHg (1 mmHg≈0.133 kPa). Dexamethasone (5 mg) was intravenously administered before skin incision to prevent postoperative nausea and vomiting. Anesthesia was maintained with a combined intravenous and inhalation regimens: continuous infusion of propofol (3-6 mg·kg-1·h-1), remifentanil (0.05-0.15 μg·kg-1·min-1), and rocuronium (30-50 mg/h), alongside inhalation of 1.0% sevoflurane. The pneumoperitoneum pressure was maintained at 14 mmHg during the operation. Doses of propofol, remifentanil, and sevoflurane were dynamically adjusted according to surgical stimulation intensity and the changes in blood pressure and heart rate. The bispectral index was maintained between 40 and 60, mean arterial pressure fluctuations were limited to within 20% of baseline value, and heart rate was maintained between 50 and 100 beats/min. Sufentanil (0.1 μg/kg) was added 15 minutes before the end of surgery for prophylactic analgesia [10].

Intervention program: Patients in the T group received 30 minutes of taVNS before surgery followed by a 30 min stay in the anesthesia recovery room. Stimulation was performed using a certified taVNS device with the following parameters: frequency 20 Hz, pulse width 500 μs, current intensity adjusted individually from the sensory threshold to the tolerance threshold (typically 0.5-2.0 mA). A dense waveform pattern was applied. Patients in the F group received sham stimulation using the same device, with the electrode attached to the earlobe (an area not innervated by the vagus nerve). The device interface appeared identical to that used for real stimulation. However, the output current was set at 0 mA, generating only an initial contact sensation without continuous electrical stimulation. All stimulations were performed by the same research assistant, who was not involved in the grouping or outcome assessment.

Postoperative analgesia methods: After the operation, patients were transferred to the anesthesia recovery room with continuous monitoring of blood pressure, heart rate, and arterial oxygen saturation. An ultrasound-guided transversus abdominal plane block was performed, injecting 20 mL of 0.375% ropivacaine. Once the patient regained consciousness and achieved stable spontaneous breathing, the tracheal tube was removed, and the patient was returned to the ward upon meeting ward criteria. If the patient's numerical rating scale (NRS) exceeded 3 points or active analgesia was required after surgery, flurbiprofen axetil (50 mg) was injected intravenously for remedial analgesia. If vomiting occurred > 2 times or antiemesis was required, metoclopramide (10 mg) was intramuscularly administrated. All patients commenced ambulation the next day after surgery.

Observational outcome

Primary outcomes: Gastrointestinal recovery indicators: The first flatus time and the first defecation time after operation were recorded. Standardized daily visits by full-time research nurses not involved in patient grouping and intervention were conducted at fixed times (8:00 AM, 4:00 PM, and 10:00 PM) to inquire about the occurrence of the above events, and the exact time was recorded in the electronic case report form (eCRF). The time to first flatus is defined as the interval from the completion of surgery to the first passage of gas per rectum; The time to first defecation is defined as the interval from the completion of surgery to the first passage of formed or semi-formed stool.

Intake-Feeling nauseated-Emesis-physical Examination-Duration of symptoms (I-FEED) score: The first four components (intake, nausea, vomiting, abdominal distension) was each scored as 0, 1 or 3 according to symptom severity, and duration was scored from 0 to 2, with total score ranging from 0 to 14. Total points of 0-2 indicate normal, 3-5 points is postoperative gastrointestinal intolerance (POGI), and ≥ 6 points is postoperative gastrointestinal dysfunction (POGD) [11].

Quality of life assessment: Patients' quality of life was assessed using the Chinese version of the Short Form Health Survey (SF-36) on the 1st day before surgery (as baseline) and the 3rd day after surgery. The questionnaire was completed independently by the patient in a quiet environment.

Gastrointestinal Symptom Rating Scale (GSRS) [12]: The GSRS was used to evaluate the recovery of postoperative gastrointestinal function. The scale contains a total of 15 items, covering five core symptom dimensions of reflux, abdominal pain, dyspepsia, diarrhea, and constipation. Each item was scored using a 7-point Likert scale (1: asymptomatic; 7: severe). The total score ranged from 15 to 105 points, with higher scores indicating a heavier gastrointestinal symptom burden. In this study, a face-to-face interview was conducted by a uniformly trained research nurse on the third postoperative day, scoring based on patient descriptions to ensure consistency of evaluation criteria.

Sleep status (sleep score and incidence of sleep disorders): The Athens Insomnia Scale (AIS) [13] was used to evaluate patients' pre- and postoperative sleep status. This 8-item scale measures: sleep duration, nighttime awakenings, early morning awakening, total sleep time, sleep quality, daytime mood, daytime physical functioning, and daytime sleepiness. Each item was scored on a 0-3 scale (0: no problem; 3: severe problem). The total score ranged from 0 to 24, with score ≥ 6 indicating insomnia. To ensure the consistency of assessments, all scales were completed by the same professional research assistant who was not involved in patient grouping and treatment, giving one-on-one guidance to patients in a quiet ward. After explaining the meaning of each item, the patient filled it out on his own.

Secondary outcomes: Postoperative pain was assessed using the Numerical Rating Scale (NRS) on postoperative days 1 and 2, and the use of postoperative remedial analgesics was recorded [14]. The incidence of postoperative adverse reactions, including nausea, vomiting, dizziness, bradycardia, and hypotension, was documented during the postoperative hospitalization period.

Statistical methods

Statistical analysis was performed using SPSS software (version 23.0). Categorical data were presented as number (percentage) [n (%)]. For continuous data, normality was first assessed using the Shapiro-Wilk test. Normally distributed data were expressed as mean ± standard deviation (Mean ± SD) and compared between groups using the independent-samples t-test, while non-normally distributed data were expressed as median (interquartile range) [M (IQR)] and compared using the Mann-Whitney U test (Wilcoxon rank-sum test).

For baseline characteristics, unordered categorical variables (e.g., sex, ASA classification) were compared between groups using the Chi-square (χ^2) test or Fisher's exact test, as appropriate. Ordinal categorical variables (e.g., postoperative gastrointestinal function status: Normal/POGI/POGD) were compared using the Mann-Whitney U test (Wilcoxon rank-sum test).

Sample size estimation was performed with reference to the primary outcome indicator, namely the I-FEED score measured on the 3rd postoperative day. Since no previous research has directly examined the impact of taVNS on I-FEED scores in this particular patient cohort, the anticipated effect size was established based on a clinically significant difference consensus among the research team. A mean I-FEED score difference of 2.5 points was regarded as the minimum clinically meaningful variation, while the combined standard deviation was approximated at 3.5 points, drawing on the variability observed in our clinical practice and preliminary data. Using a two-tailed alpha level of 0.05 and a statistical power (1-β) of 0.80, the calculation revealed that a minimum of 43 patients per group was required. To account for an expected dropout rate of around 20%, the final planned sample size was set at 52 patients per group, resulting in a total of 104 participants.

All tests were two-sided, and a *P*-value < 0.05 was considered significant.

Results

Comparison of baseline data between the two groups

No significant differences were observed in baseline data, including age, height, weight, prevalence of hypertension and diabetes, fertility history, abortion history, menarche age, abdominal surgery history, and disease type (uterine fibroids/ovarian cysts) between the two groups (P > 0.05; **Table 1**), indicating that the two groups were comparable.

Comparison of intraoperative use of anesthetics between the two groups

As shown in **Table 2**, there were no significant differences in operation time, total intraoperative consumption of propofol or sufentanil between the two groups (all P > 0.05), indicating comparable surgical complexity and anesthetic exposure between groups.

Comparison of postoperative gastrointestinal function recovery between the two groups

As shown in **Table 3**, the first postoperative exhaust time, the first defecation time and the first ambulation time in the T group were signifi-

Table 1. Comparison of baseline data between the two groups of patients

Item	T group (n = 52)	F group (n = 52)	Statistics	*P* value
Age (years)	45.3 ± 6.8	46.1 ± 7.2	0.579	0.564
Height (cm)	162.4 ± 5.3	161.9 ± 5.7	0.468	0.641
Body weight (kg)	63.7 ± 8.4	64.2 ± 9.1	0.294	0.769
Hypertension	15 (28.8)	13 (25.0)	0.198	0.656
Diabetes	8 (15.4)	6 (11.5)	0.373	0.542
Fertility history (times)	1.8 ± 0.9	1.7 ± 1.0	0.538	0.592
History of abortion (times)	0.9 ± 0.7	1.0 ± 0.8	0.692	0.491
Age of menarche (years)	13.2 ± 1.4	13.0 ± 1.5	0.713	0.478
History of abdominal surgery	11 (21.2)	14 (26.9)	0.500	0.480
Type of disease			0.078	0.780
Uterine fibroids	28 (53.8)	30 (57.7)		
Ovarian cysts	24 (46.2)	22 (42.3)		

Table 2. Comparison of intraoperative conditions between the two groups of patients

Item	T group (n = 52)	F group (n = 52)	Statistics	*P* value
Operation time (min)	120.5 ± 25.3	118.2 ± 27.1	0.441	0.660
Propofol dosage (mg)	850.6 ± 185.4	865.3 ± 192.7	0.394	0.694
Sufentanil dosage (mg)	0.35 ± 0.08	0.34 ± 0.09	0.608	0.545

Table 3. Comparison of postoperative recovery between the two groups (hours)

Item	T group (n = 52)	F group (n = 52)	Statistics	*P* value
Time to first exhaust	28.5 ± 6.2	38.4 ± 8.1	7.185	< 0.001
Time to first defecation	48.3 ± 10.5	65.7 ± 12.8	7.696	< 0.001
Time to first ambulation	20.1 ± 4.8	30.5 ± 6.9	8.983	< 0.001

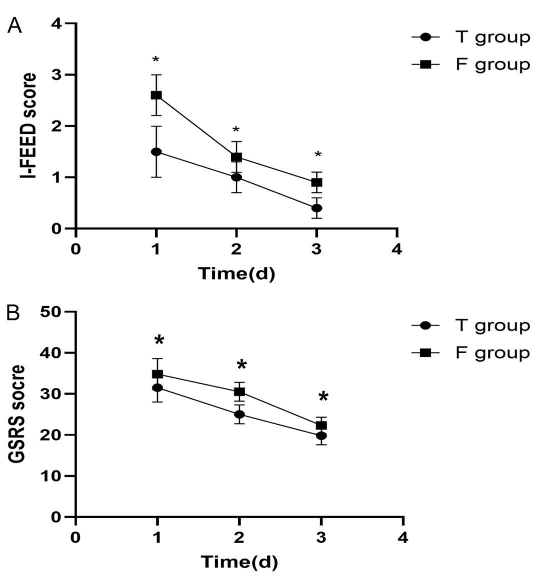

Figure 2. Comparison of postoperative gastrointestinal function scores between the two groups of patients. A: I-FEED score; B: GSRS score. Notes: I-FEED, Intake-Feeling nauseated-Emesis-physical Examination-Duration; GSRS, Gastrointestinal Symptom Rating Scale. *: indicate significant differences between the T group and the F group at the corresponding time points (P < 0.05).

cantly earlier than those of the F group (P < 0.001).

Comparison of postoperative gastrointestinal symptom scores between the two groups

Compared to the F group, the I-FEED scores and GSRS scores in the T group were significantly lower on postoperative day 1, 2, and 3 (all P < 0.05; **Figure 2**). Although the average I-FEED score on postoperative day 3 in the T group was slightly higher than the normal range due to a few patients recovering more slowly, 71.2% (37/52) of the patients in this group had their scores restored to the normal level (**Table 4**), which was significantly higher than that of the F group (34.6%).

Table 4. Comparison of gastrointestinal functional status between the two groups at different time points after surgery [n (%)]

Assessment Time	Functional Status	T Group (n = 52)	F Group (n = 52)	Z Value	*P* Value
Postoperative Day 1	POGI	15 (28.8)	28 (53.8)	-2.741	0.006
	POGD	20 (38.5)	18 (34.6)		
	Normal	17 (32.7)	6 (11.5)		
Postoperative Day 2	POGI	8 (15.4)	22 (42.3)	-3.212	0.001
	POGD	18 (34.6)	20 (38.5)		
	Normal	26 (50.0)	10 (19.2)		
Postoperative Day 3	POGI	5 (9.6)	15 (28.8)	-3.821	< 0.001
	POGD	10 (19.2)	19 (36.5)		
	Normal	37 (71.2)	18 (34.6)		

Note: POGI, Postoperative Gastrointestinal Impairment; POGD, Postoperative Gastrointestinal Disorder. The ordinal variable (functional status: Normal > POGI > POGD) was compared between groups using the Mann-Whitney U test (Wilcoxon rank-sum test).

Table 5. Comparison of postoperative pain between the two groups

Item	T group (n = 52)	F group (n = 52)	Statistic	*P* value
NRS score (points)				
The first day after operation	3.2 ± 1.1	4.5 ± 1.3	5.496	< 0.001
The second day after operation	2.0 ± 0.9	3.1 ± 1.2	5.291	< 0.001
Remedy analgesia rate [n (%)]	8 (15.4)	18 (34.6)	5.141	0.023

Note: NRS, Numerical Rating Scale.

Table 6. Comparison of postoperative sleep quality between the two groups

Item	T group (n = 52)	F group (n = 52)	Statistic	*P* value
AIS score (points)	5.2 ± 2.1	8.6 ± 3.0	6.784	< 0.001
Sleep disorders [n (%)]	10 (19.2)	24 (46.2)	8.547	0.003

Note: AIS, Athens Insomnia Scale.

Comparison of postoperative gastrointestinal function between the two groups

As shown in **Table 4**, on postoperative days 1, 2 and 3, the incidence of postoperative gastrointestinal function inhibition (POGI) in the T group was significantly lower than that of the F group, while the proportion of patients with normal gastrointestinal function recovery was significantly higher than that in group F (all P < 0.05).

Comparison of postoperative pain scores between the two groups

As shown in **Table 5**, the NRS scores on postoperative days 1 and 2 were significantly lower in the T group than those in the F group (P < 0.05). However, the F group demonstrated significantly lower remedial analgesic use rate than the T group (P < 0.05).

Comparison of sleep quality between the two groups

As shown in **Table 6**, the AIS score in the T group was significantly lower than that of the F group, along with significantly lower incidence of sleep disorders (all P < 0.05).

Comparison of SF-36 scores between the two groups

As shown in **Table 7**, the total SF-36 score and scores across each dimension on postoperative day 3 were significantly higher in the T group than those in the F group (all P < 0.05).

Comparison of postoperative complications and hospitalization time between the two groups

As shown in **Table 8**, the incidences of postoperative nausea, vomiting, and dizziness in the T group were significantly lower than those of the F group (all P < 0.05). However, the incidence of postoperative bradycardia and hypotension as well as postoperative hospital stay showed no significant inter-group differences (P > 0.05).

Table 7. Comparison of postoperative quality of life (SF-36) scores between the two groups (points)

Domain	Time Point	T Group (n = 52) Mean ± SD	F Group (n = 52) Mean ± SD	t value	*P* value
Physical Functioning (PF)	Preoperative	88.5 ± 7.2	87.9 ± 6.8	0.451	0.653
	Postop Day 3	85.2 ± 8.4	72.6 ± 10.1	6.965	< 0.001
Role-Physical (RP)	Preoperative	84.1 ± 10.5	83.6 ± 11.2	0.237	0.813
	Postop Day 3	80.5 ± 12.3	65.8 ± 15.7	5.321	< 0.001
Bodily Pain (BP)	Preoperative	86.3 ± 8.1	85.7 ± 8.9	0.365	0.716
	Postop Day 3	82.1 ± 9.7	70.3 ± 11.5	5.689	< 0.001
General Health (GH)	Preoperative	81.2 ± 9.8	80.5 ± 10.3	0.358	0.721
	Postop Day 3	78.4 ± 10.2	66.9 ± 12.8	5.043	< 0.001
Vitality (VT)	Preoperative	80.1 ± 10.4	79.4 ± 11.0	0.336	0.738
	Postop Day 3	75.6 ± 11.5	62.4 ± 13.6	5.255	< 0.001
Social Functioning (SF)	Preoperative	84.6 ± 8.9	83.8 ± 9.5	0.446	0.656
	Postop Day 3	81.3 ± 9.8	69.5 ± 14.2	4.910	< 0.001
Role-Emotional (RE)	Preoperative	85.8 ± 9.2	85.0 ± 10.1	0.425	0.672
	Postop Day 3	83.7 ± 10.6	71.2 ± 16.3	4.576	< 0.001
Mental Health (MH)	Preoperative	82.4 ± 10.0	81.7 ± 10.8	0.343	0.732
	Postop Day 3	79.8 ± 11.1	68.1 ± 13.9	4.763	< 0.001
Total Score	Preoperative	84.4 ± 6.5	83.7 ± 7.1	0.525	0.601
	Postop Day 3	80.9 ± 7.3	68.4 ± 9.5	7.572	< 0.001

Note: SF-36, 36-Item Short Form Health Survey.

Table 8. Comparison of the incidence of postoperative complications and hospitalization time between the two groups

Item	T group (n = 52)	F group (n = 52)	Statistics	*P* value
Postoperative complications [n (%)]				
Nausea	8 (15.4)	20 (38.5)	7.143	0.008
Vomiting	5 (9.6)	15 (28.8)	6.133	0.013
Dizziness	6 (11.5)	16 (30.8)	5.547	0.019
Bradycardia	4 (7.7)	7 (13.5)	0.873	0.350
Hypotension	9 (17.3)	13 (25.0)	0.913	0.339
Postoperative hospital stay (days)	5.2 ± 1.3	5.5 ± 1.6	1.040	0.301

Discussion

Gastrointestinal dysfunction is the most common complication following gynecological surgery. It is primarily manifested as delayed flatus and defecation, abdominal distension, nausea, and vomiting, adversely affecting patients' postoperative recovery. In severe cases, it increases the risk of intestinal infection, leading to long-term complications such as intestinal obstruction [15, 16]. With the gradual application of the Enhanced Recovery After Surgery (ERAS) concept, promoting the rapid recovery of gastrointestinal function after laparoscopic surgery is of great significance for improving patient recovery [17, 18].

The results of this study showed that preoperative taVNS significantly reduced postoperative I-FEED and GSRS scores and accelerated first flatus and defecation in patients undergoing gynecologic surgery. This is consistent with the conclusions of previous studies. For example, a study on colorectal surgery indicated that intraoperative vagus nerve stimulation accelerated the recovery of gastrointestinal motility, a mechanism attributed to the modulation of autonomic nervous system homeostasis [19]. Unlike most previous studies that applied stimulation intraoperatively or postoperatively [19, 20], this study innovatively advanced the stimulation timing to the preoperative period. This "prehabilitation" strategy may establish a protective internal environment by pre-activating parasympathetic tone and anti-inflammatory pathways, thereby mitigating the inhibitory effects of postoperative sympathetic over-excitation and excessive inflammatory responses on gastrointestinal function, which partially explains the more pronounced improvements observed in this study [21].

Postoperative pain is another critical factor affecting patient recovery. This study confirmed that taVNS significantly reduced postoperative pain, as evidenced by significantly lower NRS scores. This finding aligns with the "cholinergic anti-inflammatory pathway" theory proposed by Breit et al. [22, 23], in which vagus nerve activation inhibits the release of pro-inflammatory cytokines (e.g., TNF-α, IL-1β) from immune organ like the spleen through acetylcholine release, reducing neuroinflammation and peripheral sensitization. It is worth noting that the analgesic effect observed in this study may not stem only from direct anti-inflammatory and central inhibition. While previous research has largely focused on taVNS's regulation of inflammatory mediators [23, 24], our study, combined with the significant improvement in gastrointestinal symptoms, suggests that alleviating visceral referred pain caused by gastrointestinal dysfunction might be an additional and significant contributing mechanism. This provides a more comprehensive explanatory model for the analgesic effect of taVNS in abdominal surgery.

Furthermore, the significant improvement in postoperative sleep scores and reduction in the incidence of sleep disorder observed in this study may be attributed to taVNS's regulatory effect on the hypothalamic-pituitary-adrenal (HPA) axis and central neurotransmitters [25, 26]. Our results further support the findings of Zhao et al., who reported that taVNS improved sleep quality in patients with insomnia by modulating serum cortisol levels and 5-hydroxytryptamine metabolism [27]. Notably, the improvement in sleep quality may also be indirectly related to the mitigation of sleep disturbances caused by postoperative abdominal discomfort and pain - a multidimensional benefit rarely discussed in previous single-outcome studies.

Finally, the improvement in SF-36 scores is likely the result of the combined effects mentioned above: alleviated physical discomfort, improved psychological state due to pain reduction and better sleep, and enhanced early mobility. This holistic outcome is consistent with the comprehensive benefits of vagus nerve stimulation reported in other clinical fields [28, 29].

Inevitably, this study has some limitations. First, this was a single-center study with a relatively small sample size. Future large-scale, multi-center studies are needed to further consolidate these conclusions. Second, numerous factors influence postoperative gastrointestinal function, and control for these variables needs further refinement in subsequent research. Third, this study did not include serological testing. Fourth, as an exploratory trial focusing on clinical efficacy, our mechanistic inferences were mainly theory-based, inferring that taVNS exerts its effects through cholinergic anti-inflammatory pathway and modulation of autonomic nerve balance; however, relevant molecular markers (e.g., TNF-α, IL-1β, acetylcholine, and cortisol) were not assessed to provide direct evidence. In addition, there is still a lack of direct data supporting the proposed synergistic mechanism between gastrointestinal function and pain relief (e.g., whether and how improved gastrointestinal function may indirectly alleviate visceral pain). Future research needs to integrate multi-omics and physiologic monitoring to verify these mechanistic hypotheses.

Conclusion

Preoperative percutaneous auricular vagus nerve stimulation is a non-invasive intervention that can promote the recovery of postoperative gastrointestinal function, reduce gastrointestinal symptom scores, alleviate postoperative pain, and improve sleep quality and overall quality of life in patients undergoing laparoscopic gynecological surgery for benign lesions.

Disclosure of conflict of interest

None.

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