Journal of Pain Research

Dovepress
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ORIGINAL RESEARCH

Effects of Transcutaneous Electrical Acupoint Stimulation on Postoperative Acute Visceral, Incisional, and Low Back Pain and Recovery in Patients Undergoing Laparoscopic Hysterectomy: A Randomized Controlled Trial

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Purpose: Laparoscopic hysterectomy(LH) is often associated with multimodal postoperative pain, which impedes patient recovery. This study aimed to evaluate the effect of transcutaneous electrical acupoint stimulation (TEAS) on postoperative acute visceral, incisional, and low back pain (LBP) and recovery in patients undergoing LH.

Patients and Methods: Patients scheduled for elective LH at the First Affiliated Hospital of Wenzhou Medical University (February 2024–2025) were randomly divided (1:1 ratio) into a TEAS and control group. TEAS involved bilateral stimulation at Hegu–Neiguan, and Sanyinjiao–Zusanli 30 min before anesthesia induction and throughout surgery, while the control involved electrodes placed identically for sham stimulation. Pain intensity (visceral, incisional, and LBP) was evaluated using numerical rating scale on postoperative days (PODs) 0 (day of surgery), 1, and 2. Secondary outcomes comprised postoperative serum cytokine profiles, opioid consumption, rescue analgesia demands on POD 1, adverse events, and standardized recovery metrics.

Results: The TEAS group (n=45) demonstrated superior pain control compared to the control group (n=48), with significantly lower visceral pain scores (POD 0–1), decreased LBP scores (POD 0–2), and reduced incidence of moderate-to-severe visceral pain (POD 0–2) and LBP (POD 0) (all $P < 0.017$). TEAS resulted in lower interleukin-6 levels, total sufentanil consumption, and rescue analgesia demands on POD 1(all $P < 0.05$). TEAS was associated with a shorter time to pelvic drain removal, decreased postoperative hospitalization, earlier ambulation, and lower incidence of postoperative nausea and vomiting (all $P < 0.05$). No significant improvement in incisional pain was observed with TEAS intervention.

Conclusion: TEAS provided differential postoperative analgesia, effectively alleviating visceral and LBP but not incisional pain. This primary benefit, coupled with reduced inflammation, opioid use, and adverse events, facilitated recovery in LH patients. These findings support the incorporation of TEAS as an effective non-pharmacological adjuvant within multimodal analgesia and ERAS protocols.

Keywords: transcutaneous electrical acupoint stimulation, laparoscopic hysterectomy, visceral pain, incisional pain, low back pain, postoperative recovery

Introduction

Laparoscopic hysterectomy (LH) is characterized by minimal incisions, low risk of complications, and accelerated recovery, which often leads to postoperative pain underestimation. Beyond incisional pain, LH can provoke heterogeneous pain phenotypes, including visceral pain, low back pain (LBP), and incisional pain. These pains are primarily

Received: 15 July 2025
Accepted: 15 November 2025
Published: 4 December 2025

attributed to traction caused by pneumoperitoneum, surgical trauma, neuroinflammation, and peritoneal irritation, among other factors.[1,2] Previous studies reported that >70% of patients undergoing LH experience moderate-to-severe pain, predominantly visceral and LBP.[3] Uncontrolled postoperative pain triggers sympathetic hyperactivity and restrictive ventilation, potentially precipitating myocardial ischemia, arrhythmia, and atelectasis.[4,5] Opioids (the most potent analgesics) inhibit nociceptive transmission by binding to opioid receptors in the central and peripheral nervous systems. However, high-dose opioid therapy paradoxically fails to adequately alleviate pain and increases the risk of opioid-related adverse events such as nausea/vomiting, ileus, and pruritus.[6]

Transcutaneous electrical acupoint stimulation (TEAS) offers a non-invasive alternative that synthesizes acupoint theory with transcutaneous electrical nerve stimulation (TENS).[7] In contrast to TENS, TEAS is safer, better tolerated, and promotes higher patient adherence. Evidence indicates that TEAS mediates analgesia through a multimodal mechanism. The 2/100 Hz frequency stimulation activates the cerebral endogenous opioid system, consequently triggering the release of enkephalins and endorphins,[8] and key innate analgesic compounds to mediate analgesia.[9] Concurrently, TEAS induces serotonin and norepinephrine release within the spinal cord, leading to inhibition of dorsal horn neuronal excitability.[10] Moreover, it regulates local and systemic concentrations of inflammatory mediators (eg, TNF-α, IL-6),[9] attenuating neural sensitization and pain memory.[11] These mechanisms collectively underpin a synergistic, multi-level analgesic strategy.[12]

Recent randomized controlled trials (RCTs) in gynecological surgeries have established TEAS as a promising intervention for postoperative pain, associated with diminished pain scores, reduced opioid requirements,[13] and accelerated recovery.[14] Although considerable research has investigated TEAS for general postoperative pain, it has largely overlooked its effects on distinct acute phenotypes like visceral, incisional, and low back pain. Furthermore, the conventional use of short-term follow-ups limits insights into the intervention's long-term influence on recovery. Based on the multi-modal analgesic mechanisms of TEAS, we hypothesize that it exerts preferential efficacy against visceral pain following LH. Therefore, we designed an RCT to systematically evaluate its effects on visceral, incisional, and LBP intensities at multiple time points and overall quality of recovery.

Materials and Methods

Study Design and Participants

This study was approved by the Ethics Committee of The First Affiliated Hospital of Wenzhou Medical University on 23 February 2024 (Approval No.: KY2024-019) and registered in the Chinese Clinical Trial Registry (Registration No.: ChiCTR2400093634). This study strictly adhered to the guidelines established by the Consolidated Standards of Reporting Trials (CONSORT) and Helsinki declaration.Written informed consent was obtained from all participants prior to study initiation. In total, 108 patients scheduled to undergo elective LH at the First Affiliated Hospital of Wenzhou Medical University between March 2024 and April 2025 were enrolled.

The inclusion criteria were age 18–65 years, American Society of Anesthesiologists (ASA) I–II, planned patient-controlled intravenous analgesia (PCIA), and independent comprehension and completion of questionnaires. The exclusion criteria included dermatological conditions (infection, lesions, or scarring) at the electrode placement sites, allergy to TEAS electrodes, intraoperative conversion to open surgery, comorbid psychiatric illness, pregnancy or lactation, severe cardiopulmonary disease, severe hepatic or renal dysfunction, preoperative opioid abuse, history of illicit drug use, and withdrawal of consent.

Randomization and Blinding

Randomization was performed using Stata 15.0 software to generate random sequences in a 1:1 ratio. The random allocation sequences were placed in sealed opaque envelopes. After obtaining written informed consent, the research assistant opened the next consecutively numbered envelope to assign the participants to their corresponding groups. Anesthesiologists, outcome assessors, and patients were blinded to the group allocation. The outcome assessors received standardized training, had no involvement in intraoperative anesthetic management, and remained unaware of the treatment assignments. The anesthesiologists did not participate in data collection, entry, or analysis.

Interventions

The TEAS procedure was administered by anesthesiologists who had completed a standardized training program, including at least one week of specialized instruction and a consistency assessment. Prior to electrode placement, the skin was cleaned with 75% alcohol and allowed to dry completely. To prevent interference, the surgical electrocautery return electrode was positioned at a site separate from the TEAS electrodes. All participants were informed that they might perceive slight tingling, mild vibration, or no sensation during the procedure.

TEAS (HANS-200F, Nanjing Jisheng Medical Technology Co., Ltd.) was applied bilaterally to the Hegu (LI4)–Neiguan (PC6) and Sanyinjiao (SP6)–Zusanli (ST36) acupoints (Figure 1). Stimulation commenced 30 min prior to anesthesia and continued throughout the surgery. Stimulation was delivered at 2/100 Hz in the dense-disperse wave mode with the intensity set at 1 mA below the patient's maximum tolerance threshold.

The control group had electrodes placed identically for sham stimulation, which was administered in the 2/100 Hz dense-disperse mode, 1 mA below the sensory threshold. To maintain blinding integrity, the TEAS intervention and outcome assessments were conducted by separate personnel at distinct time points.

Primary Outcome

The primary outcome was the maximum pain score for different types of acute postoperative pains (visceral, LBP, and incisional pain) assessed on postoperative days (PODs) 0 (day of surgery), 1, and 2.[15] Postoperative pain intensity was evaluated using a numerical rating scale (NRS), where 0 represents no pain, 1–3 represent mild pain, 4–6 represent moderate pain, and 7–10 represent severe pain. Pain scores on POD 0 were recorded within the first 6 h postoperatively.

Visceral pain was defined as a deep poorly localized pain originating within the abdominal cavity. Incisional pain was defined as sharp superficial pain localized to the surgical incision site or abdominal wall surface. LBP was defined as pain located between the 12th rib and gluteal region, with or without associated leg pain. Shoulder pain was defined as the pain perceived in the shoulder region.[3]

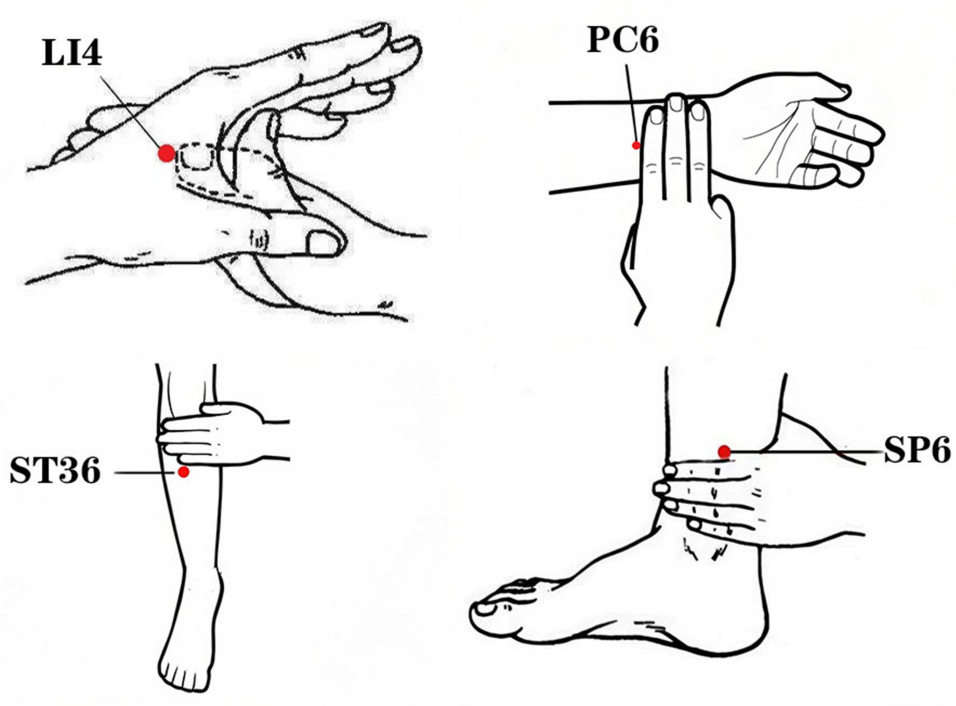

Figure 1 Location of acupoints.

https://doi.org/10.2147/JPR.S553932

Secondary Outcomes

Secondary outcomes included (1) serum concentrations of IL-2, IL-4, IL-6, and TNF-α on POD 1; (2) total sufentanil consumption, number of PCIA bolus demands, and rescue analgesia demands on POD 1; (3) postoperative adverse events [postoperative nausea and vomiting (PONV)], sleep disturbances, dizziness, surgical site infection, fever, cough, allergic reaction, abdominal distension, and other documented complications; and (4) postoperative recovery parameters encompassing time to first ambulation, time to first oral liquid intake, time to first solid food tolerance, time to pelvic drain removal, time to first postoperative flatus, and time to postoperative discharge.

Anesthesia and Analgesia Management

Upon arrival in the operating room, patients underwent continuous monitoring of non-invasive blood pressure, electrocardiography (ECG), pulse oximetry (SpO_2), bispectral index (BIS), and core body temperature. General anesthesia was induced intravenously with sufentanil (0.4 μg/kg), propofol (2 mg/kg), and rocuronium (0.6 mg/kg). Tracheal intubation was performed by an anesthesiologist (>3 years of experience) 1 min after induction. Anesthesia was maintained with a continuous infusion of propofol (4–12 mg/kg/h) and remifentanil (0.1–0.2 μg/kg/min), supplemented with sevoflurane (1–2% end-tidal concentration). Neuromuscular blockade was maintained with supplemental rocuronium boluses (0.1–0.2 mg/kg) as clinically indicated. Ventilation parameters were adjusted to maintain the end-tidal CO_2 ($EtCO_2$) between 30–40 mmHg. The bispectral index was maintained at 40–60 throughout the procedure. Active warming strategies were used when necessary.

Intravenous intravenous palonosetron (0.25 mg) and flurbiprofen axetil (100 mg) were administered 30 min before the anticipated surgical completion. Following skin closure, local anesthetic infiltration was performed at the surgical incision site using 10 mL 0.75% ropivacaine hydrochloride.

All patients received postoperative analgesia via PCIA, with a solution containing 100 μg sufentanil diluted to 100 mL with 0.9% normal saline. The PCIA settings included a background infusion of 2 mL/h, bolus dose of 2 mL, and lockout interval of 10 min. In the post-anesthesia care unit (PACU), rescue analgesia was administered by an anesthesiologist if the patient NRS was ≥4. Sufentanil was administered intravenously until adequate analgesia (NRS < 4) was achieved. After 1 h in the PACU, patients were transferred to the ward, where a rectal indomethacin suppository (50 mg) was administered as rescue analgesia if the NRS was ≥4.

Surgical Technique

All surgical procedures were performed by experienced surgeons according to a standardized protocol. Following the establishment of a pneumoperitoneum using one 10-mm and two or three 5-mm laparoscopic trocars, the uterus was removed transvaginally after sequential division of the round ligament, broad ligament, and uterine artery. The intra-abdominal pressure was maintained below 12 mmHg throughout the procedure. Upon completion of the surgery, CO_2 was evacuated by applying manual compression to the abdomen while opening the laparoscopic trocars.

Statistical Analysis

Statistical analyses were performed using Stata 15 SE software (StataCorp, College Station, TX, USA). Based on preliminary trial results, the maximum visceral pain NRS on POD 1 was 2.53 ± 0.96 in the TEAS group versus 3.40 ± 1.11 in the control group. A sample size of 43 participants per group was estimated ($\alpha = 0.05$, $1\text{-}\beta = 0.8$), which was adjusted to 54, accounting for an anticipated dropout rate of 20% during follow-up. Continuous variables were assessed for normality using the Shapiro–Wilk test. Normally distributed data with homogeneous variance are presented as mean ± standard deviation (SD) and compared using the independent-sample *t*-test. Non-normally distributed continuous data are reported as median (interquartile range) [M(IQR)] and analyzed using the Wilcoxon rank-sum test. Categorical variables are expressed as numbers (percentages) [n(%)] and compared using the chi-square or Fisher's exact test, as appropriate. Postoperative pain outcomes, including NRS scores and the incidence of moderate-to-severe pain, were analyzed using Generalized Estimating Equations (GEE). The model included group, time point, and their interaction term as fixed effects to evaluate differential trends over time, while controlling for the covariates of age, BMI, educational level, and previous abdominal surgery. A significant group-by-time interaction prompted post-hoc comparisons, for which the

Bonferroni method was applied to control the family-wise error rate, with a corrected significance threshold of $P < 0.017$. All statistical tests were two-sided, and $P < 0.05$ was considered statistically significant.

Results

Flowchart and Patient Characteristics

We assessed 120 eligible patients. Five patients declined participation and three failed to meet the inclusion criteria, resulting in 108 enrolled participants. We excluded nine TEAS group (five for surgical protocol modifications and four for consent withdrawals) and six control group patients (for surgical protocol modifications). Finally, 93 patients (TEAS, n = 45; controls, n = 48) were included in the statistical analyses (Figure 2).

Comparison of Baseline Characteristics Between the Two Groups

The two groups were similar in age, BMI, and educational level. There were no differences in the history of hypertension, diabetes, previous abdominal surgery, dysmenorrhea, surgical duration, or anesthesia duration between the groups ($P > 0.05$, Table 1).

Maximum Pain Scores and Incidence of Moderate-to-Severe Pain for Different Types of Acute Postoperative Pain

After adjusting for age, BMI, educational level, and previous abdominal surgery, the GEE models revealed significant main effects of the group on both maximum acute visceral pain score (Wald $\chi^2 = 7.35$, p =0.007) and maximum acute LBP score (Wald $\chi^2 = 6.37$, p =0.012) (Table 2). The adjusted post-hoc analyses showed that, compared to the control group, the TEAS group had significantly lower visceral pain scores on POD 0 (adjusted $\beta = 0.72$, 95% CI [0.20, 1.25], p=0.007) and POD 1 (adjusted $\beta = 0.96$, 95% CI [1.67, 2.65], p=0.009). The incidence of moderate-to-severe visceral pain was also reduced in the TEAS group on POD 0, POD 1, and POD 2 ($p < 0.017$).

For LBP, the TEAS group showed significantly reduced maximum scores on POD 0 (adjusted β =0.65, 95% CI [0.14, 1.16], p =0.012), POD 1 (adjusted $\beta = 1.06$, 95% CI [0.20, 1.91], p =0.016), and POD 2 (adjusted β =0.71, 95% CI

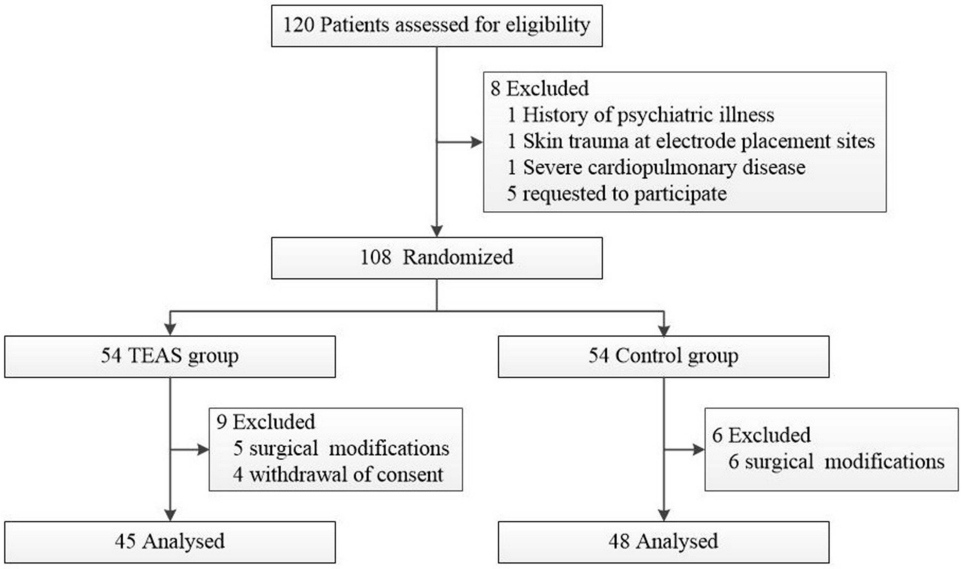

Figure 2 Flowchart of participants in the trail.

https://doi.org/10.2147/JPR.S553932

Table 1 Comparison of Baseline Characteristics Between the Two Groups

Variables	TEAS Group (n=45)	Control Group (n=48)	P
Age (years)	51.91±7.37	50.31±6.46	0.27
BMI (kg/m^2)	23.63±2.72	24.52±3.09	0.14
Education level			0.25
Primary school or below	10(22.22)	5(10.42)	
Junior high school	18(40.00)	16(33.33)	
Senior high school or equivalent	13(28.89)	22(45.83)	
College degree or above	4(8.89)	5(10.42)	
Hypertension	14(31.11)	10(20.83)	0.26
Diabetes	3(6.67)	3(6.25)	0.93
Previous abdominal surgery	17(37.78)	10(20.83)	0.07
Dysmenorrhea	12(26.67)	14(29.17)	0.79
Anesthesia duration (min)	91.66±36.56	95.58±28.62	0.58
Surgical duration (min)	73.34±33.12	84.13±25.84	0.09

Note: Values are presented as the mean ±SD, n (%).
Abbreviations: BMI, bodymass index; TEAS group, transcutaneous electrical acupoint stimulation group.

Table 2 Generalized Estimating Equation (GEE) Analysis of Postoperative Pain Outcomes Over Time

Variables	Unadjusted			Adjusted		
	Estimate	Wald	P	Estimate	Wald	P
Visceral pain						
Group TEAS	−0.694	6.48	0.011	−0.723	7.35	0.007
TimePOD1	0.813	4.95	0.026	0.813	5.05	0.025
TimePOD2	−0.708	7.37	0.007	−0.701	7.60	0.006
GroupTEAS:TimePOD1	−0.235	0.27	0.605	−0.235	0.27	0.602
GroupTEAS:TimePOD2	0.619	3.74	0.053	0.619	3.86	0.049
LBP						
Group TEAS	−0.624	5.91	0.015	−0.651	6.37	0.012
TimePOD1	0.917	5.21	0.022	0.917	5.34	0.021
TimePOD2	−0.688	6.45	0.011	−0.687	6.62	0.010
GroupTEAS:TimePOD1	−0.406	0.64	0.425	−0.406	0.65	0.421
GroupTEAS:TimePOD2	−0.068	0.04	0.847	−0.068	0.04	0.847

(*Continued*)

Table 2 (Continued).

Variables	Unadjusted			Adjusted		
	Estimate	Wald	P	Estimate	Wald	P
Incision pain						
Group TEAS	−0.243	1.17	0.28	−0.281	1.60	0.210
TimePOD1	0.375	2.60	0.11	0.375	2.66	0.100
TimePOD2	0.104	0.26	0.61	0.104	0.26	0.611
GroupTEAS:TimePOD1	−0.175	0.29	0.59	−0.175	0.29	0.590
GroupTEAS:TimePOD2	0.407	1.83	0.18	0.407	1.82	0.180

Abbreviations: TEAS, transcutaneous electrical acupoint stimulation; POD, postoperative day; LBP, Low back pain; The model included group, time point, and their interaction term as fixed effects. All models were adjusted for the covariates of age, BMI, educational level, and previous abdominal surgery.

[0.24,1.2], p =0.003), along with a lower incidence of moderate-to-severe pain on POD 0 ($p < 0.017$). No differences were observed between the two groups in either the maximum acute incisional pain score or incidence of moderate-to-severe incisional pain during the postoperative period (all $p > 0.017$) (Figure 3).

Plasma Cytokine Levels Between the Two Groups on POD1

Plasma IL-6 levels were lower in the TEAS group than in the control group on POD 1 (mean differece= −21.96, 95% CI [−31.48, −12.44], $P < 0.001$), whereas no differences were observed in the plasma levels of IL-2, IL-4, or TNF-α ($P > 0.05$, Table 3).

Postoperative Analgesia Between the Two Groups on POD1

Compared with the control group, patients in the TEAS group exhibited significantly reduced total sufentanil consumption (mean differece= −3.26, 95% CI [−5.25, −1.27], P=0.002), total PCIA bolus demands (mean differece= −1.75, 95% CI [−2.96, −0.53], P<0.001), and rescue analgesia administrations (RR=0.70, 95% CI [0.44, 1.10], P=0.002) on POD 1 ($P < 0.05$, Table 4).

Postoperative Recovery of Patients Between the Two Groups

Compared to the control group, patients in the TEAS group exhibited shorter times to pelvic drain removal (mean differece= −9.15, 95% CI [−15.43, −2.88], P=0.005), first postoperative ambulation (mean differece= −8.39, 95% CI [−14.27, −2.51], P=0.006), and postoperative discharge (mean differece= −2.05, 95% CI [−4.80, −0.71], P=0.004), whereas no difference was observed in the time to first flatus, oral liquid intake, and solid food tolerance ($P > 0.05$). The total hospitalization costs were higher in the TEAS group than in the control group (mean differece= −1361, 95% CI [−1951, −770], P=0.004) (Table 5).

Postoperative Complications Between the Two Groups

Compared to the control group, the TEAS group demonstrated a lower incidence of PONV (RR=0.60, 95% CI [0.36,0.99], P=0.04). No significant differences were observed regarding the other complications between the groups (Table 6).

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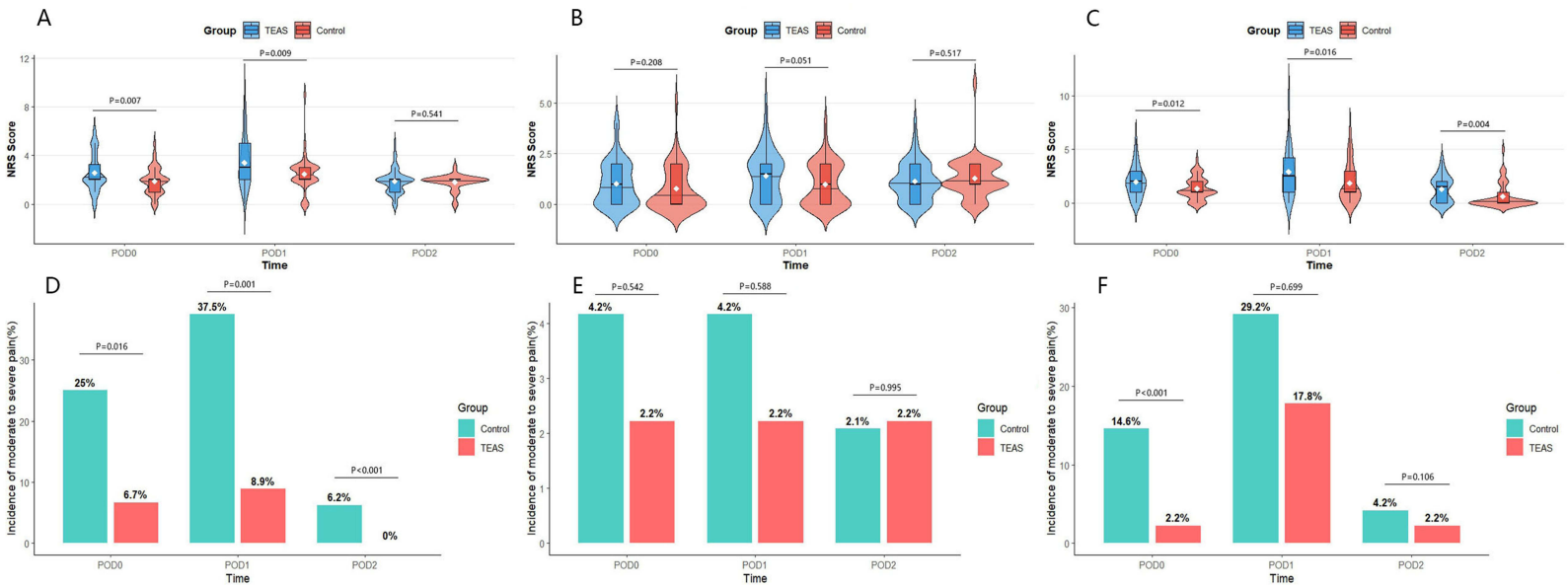

Figure 3 Maximum pain scores and incidence of moderate-to-severe pain for different types of acute postoperative pain Maximum pain scores (**A–C**) and incidence of moderate-to-severe pain (**D–F**) across visceral, incisional, and low back pain.

Table 3 Plasma Cytokine Levels Between the Two Groups on POD1

Variables	TEAS Group (n=45)	Control Group (n=48)	Mean Difference (95% CI)	P
IL-2	2.58±0.29	2.61±0.45	−0.03(−0.12 to 0.19)	0.67
IL-4	2.88±1.20	3.17±1.45	−0.29(−0.84 to 0.26)	0.30
IL-6	16.63±13.85	38.59±29.22	−21.96(−31.48 to −12.44)	<0.001
TNF-α	2.87±1.37	2.57±0.28	0.30(−0.10 to 0.70)	0.14

Note: Values are presented as the mean ± SD.
Abbreviations: IL-2, interleukin-2; IL-4, interleukin-4; IL-6, interleukin-6; TNF-α, tumor necrosis factor-alpha;95% CI, 95% Confidence Interval.

Table 4 Postoperative Analgesia Between the Two Groups on POD1

Variables	TEAS Group (n=45)	Control Group (n=48)	Estimated Effect (95% CI)	P
Total sufentanil consumption (μg)	50.53±4.46	53.79±5.14	MD:-3.26(−5.25 to −1.27)	0.002
Total PCIA bolus demands	0(0,2)	2(1,4)	MD:-1.75(−2.96 to −0.53)	<0.001
Rescue analgesia demands	14(31.11)	29(60.42)	RR:0.70(0.44 to 1.10)	0.005

Note: Values are presented as the mean ± SD, median (interquartile range) or n (%).
Abbreviations: TEAS group, transcutaneous electrical acupoint stimulation group; PCIA, patient-controlled intravenous analgesia; MD, mean difference; RR, relative risk; 95% CI, 95% Confidence Interval.

Table 5 Postoperative Recovery of Patients Between the Two Groups

Variables	TEAS Group (n=45)	Control Group (n=48)	Mean Difference (95% CI)	P
Time to pelvic drain removal(h)	19.95±7.89	29.10±17.51	−9.15(−15.42 to −2.88)	0.005
Time to first postoperative ambulation(h)	19.91±5.88	28.31±19.01	−8.39(−14.27 to −2.51)	0.006
Time to postoperative discharge(d)	4.07±1.68	6.06±4.28	−2.05(−4.32 to 0.23)	0.004
Time to first postoperative flatus(h)	13.14±10.53	16.60±10.36	−3.46(−7.77 to 0.84)	0.110
Time to first oral liquid intake(h)	7.11±5.66	9.16±5.39	−2.05(−4.80 to 0.71)	0.077
Time to first solid food tolerance(h)	13.11±7.53	15.16±5.79	−2.00(−3.35 to −0.64)	0.140
Total hospitalization costs(¥)	14,542±158	15,903± 15,245	−1361(−1951 to −770)	<0.001

Note: Values are presented as the mean ± SD, median (interquartile range) or n (%).
Abbreviations: TEAS group, transcutaneous electrical acupoint stimulation group; PCIA, patient-controlled intravenous analgesia; 95% CI, 95% Confidence Interval.

Table 6 Postoperative Complications Between the Two Groups

Variables	TEAS Group (n=45)	Control Group (n=48)	RR (95% CI)	P
Shoulder pain	1(2.22)	2(4.17)	0.53(0.05 to 5.82)	0.99
PONV	14(31.11)	25(52.08)	0.60(0.36 to 0.99)	0.04
Sleep disturbances	8(17.78)	6(12.50)	1.42(0.54 to 3.78)	0.48
Dizziness	5(11.11)	6(12.50)	0.89(0.29 to 2.71)	0.84
Surgical site infection	0(0.00)	1(2.08)	NA	0.33

(*Continued*)

Table 6 (Continued).

Variables	TEAS Group (n=45)	Control Group (n=48)	RR (95% CI)	P
Fever	12(26.67)	8(16.67)	1.60(0.72 to 3.55)	0.24
Cough	7(15.56)	12(25.00)	0.62(0.69 to 1.44)	0.26
Allergic reaction	0(0.00)	1(2.08)	NA	0.33
Abdominal distension	5(11.11)	6(12.50)	0.89(0.29 to 2.71)	0.84
Intermuscular venous thrombosis	0(0.00)	1(2.08)	NA	0.33

Note: Values are presented as the n (%).
Abbreviations: TEAS group, transcutaneous electrical acupoint stimulation group; PONV, postoperative nausea and vomiting; 95% CI, 95% Confidence Interval.

Discussion

Acute postoperative pain, which is the most prevalent yet inadequately managed clinical challenge, primarily originates from surgical trauma and inflammatory responses. Its management requires substantial healthcare resources. Patients undergoing LH frequently experience visceral, incisional, low back, and shoulder pains. This RCT evaluated the efficacy of TEAS in alleviating different types of acute postoperative pain (visceral, LBP, and incisional pain) following LH. The TEAS group (n=45) demonstrated superior pain control compared to the control group (n=48), with significantly lower visceral pain scores (POD 0–1), decreased LBP scores (POD 0–2), and reduced incidence of moderate-to-severe visceral pain (POD 0–2) and LBP (POD 0) (all $P < 0.017$). TEAS resulted in lower interleukin-6 levels, total sufentanil consumption, and rescue analgesia demands on POD 1(all $P < 0.05$). TEAS was associated with a shorter time to pelvic drain removal, decreased postoperative hospitalization, earlier ambulation, and lower incidence of postoperative nausea and vomiting (all $P < 0.05$). No significant improvement in incisional pain was observed with TEAS intervention.

Visceral pain was defined as poorly localized deep abdominal pain accompanied by autonomic responses (nausea, vomiting, and sweating).[16] Its pathophysiology involves complex mechanisms, including surgical manipulation, peritoneal inflammation, visceral ischemia, and peripheral/central sensitization-induced visceral hypersensitivity. Such pain frequently evokes negative emotions due to dual autonomic innervation with central projections to limbic emotional centers. Despite multimodal analgesia combining opioids and non-steroidal anti-inflammatory drugs, suboptimal visceral pain control persists after LH.[17] Consistent with previous evidence,[18] our study demonstrated that TEAS significantly reduced visceral pain scores (POD 0–1), and the incidence of moderate-to-severe visceral pain (POD 0–2).

LBP is a common musculoskeletal disorder characterized by pain, soreness, muscle tension, and stiffness in the lumbosacral region.[19] In this study, 14 patients (29.17%) in the control group developed moderate-to-severe LBP postoperatively, with two patients reporting a pain score of 10. The high incidence of postoperative LBP may be attributed to the general anesthesia coupled with the lithotomy position and prolonged maintenance in the steep Trendelenburg position during surgery. This posture causes the lumbar region to sustain biomechanical stress, and predisposes patients to acute postoperative LBP. According to the clinical practice guidelines issued by the American College of Physicians, nonpharmacological and noninvasive treatments are recommended as first-line therapies for LBP.[20] These therapies produce biological effects through physical modalities such as sound, light, electricity, and thermal energy.[21] TEAS can thus be conceptualized as a targeted physical intervention mediated by well-defined electrical parameters.In this study, TEAS significantly reduced the intensity of acute postoperative LBP on PODs 0–2. These results indicate that TEAS can safely and effectively reduce postoperative LBP, warranting wider clinical adoption as a non-invasive therapeutic modality.

This study revealed a divergent analgesic profile of TEAS following LH: while it significantly alleviated visceral and LBP, it demonstrated no appreciable effect on incisional pain. This differential response may be attributed to distinct neural mechanisms underlying different pain types and their interactions with perioperative analgesic strategies.

Although both visceral and incisional pain typically peak on the day of surgery,[22] all patients in this trial received ropivacaine wound infiltration, which likely created a "ceiling effect" that masked any incremental benefit of TEAS at the incision site. In contrast, the absence of comparable preemptive analgesia for visceral and LBP allowed persistent nociceptive signaling, thereby establishing a therapeutic window in which TEAS could exert its modulatory effects.

Post-laparoscopic shoulder pain (PLSP) is another common complication, primarily caused by diaphragmatic irritation following CO_2 pneumoperitoneum;[2] thus, the evacuation of residual CO_2 is a primary preventive measure. To enhance the evacuation of residual intra-abdominal CO_2, surgeons at our institution delayed the removal of the largest trocar until complete closure of the other incisions. This approach may explain the lower incidence of PLSP in our cohort than in previous cohorts. Although the low incidence of PLSP in this cohort prevented a focused evaluation of the direct impact of TEAS intervention as originally planned, its potential benefits warrant further investigation. Future studies could target specific high-risk populations, such as patients undergoing laparoscopic cholecystectomy, to further validate the effect of TEAS on PLSP.

The analgesic effects of TEAS involve several mechanisms. To further validate these mechanisms, blood samples were collected to measure immune cytokines on POD 1. IL-6, a pro-inflammatory cytokine, elicits inflammatory and stress responses.[23] Plasma IL-6 levels are correlated with the severity of surgical trauma. In this study, the plasma IL-6 levels on POD 1 were significantly lower in the TEAS group than in the control group, suggesting that TEAS alleviates inflammatory pain by attenuating IL-6 levels. Conversely, Jiang et al reported that TEAS treatment elevates serum IL-2 levels and reduces IL-4 secretion, facilitating a rapid return to preoperative levels.[24] However, no significant differences were observed in IL-2, IL-4, or TNF-α levels between the two groups on POD 1, likely because of our limited sample size and lack of serial cytokine measurements at multiple time points. Further investigations are warranted to clarify these findings.

The pain associated with PONV, one of the most common postoperative complications, may be treatable by TEAS at PC6, which likely functions through the modulation of the neuroendocrine system, including endogenous opioid release, and adrenergic and noradrenergic pathway activation, thereby modulating serotonin levels. Consistent with previous findings, we demonstrated that TEAS significantly reduced the incidence of PONV.[25] Furthermore, compared to the control group, patients receiving TEAS exhibited significantly shorter times to pelvic drain removal, first ambulation, and hospital discharge. These recovery outcomes may be attributed to the ability of TEAS to mitigate oxidative stress and reduce postoperative adverse events.[26]

In this study, bilateral stimulation was simultaneously applied to the PC6, LI4, ST36, and SP6 acupoints. Stimulation at LI4 and PC6 primarily mediates central regulatory effects; LI4 activation is known to engage the endogenous opioid system, promoting the release of neurotransmitters such as endorphins and enkephalins for central analgesia,[8,9] while PC6 modulation contributes to sedative and anti-emetic outcomes, effectively reducing anxiety and preventing postoperative nausea and vomiting[10] (PONV). Conversely, stimulation at SP6 and ST36 exerts targeted peripheral effects. SP6, a pivotal point for gynecological conditions, helps alleviate deep visceral pain by modulating pelvic blood flow and organ function.[14] Simultaneously, ST36 enhances gastrointestinal recovery by promoting motility, reducing abdominal distension, and significantly shortening the time to first flatus and defecation.[27]

This study has some limitations. First, as a single-center clinical trial with a limited sample size, the findings of this study may not be generalisable to a broader population; future multicenter controlled trials are warranted. Second, chronic postoperative pain was not assessed. Extending the follow-up duration to assess the potential of TEAS in preventing the transition from acute to chronic post-surgical pain represents a critical direction for future research. Third, the control group received sham TEAS stimulation rather than no treatment. Finally, only IL-2, IL-4, IL-6, and TNF-α were analyzed on POD 1. Future studies should include a longitudinal assessment of all relevant cytokines at multiple time points.

Conclusion

TEAS provided differential postoperative analgesia, effectively alleviating visceral and LBP but not incisional pain. This primary benefit, coupled with reduced inflammation, opioid use, and adverse events, facilitated recovery in LH patients.

These findings support the incorporation of TEAS as an effective non-pharmacological adjuvant within multimodal analgesia and ERAS protocols.

Abbreviations

LBP, low back pain; LH, laparoscopic hysterectomy; LI4,Hegu; PC6,Neiguan; SP6,Sanyinjiao; ST36,Zusanli; PODs, postoperative days; TENS,transcutaneous electrical nerve stimulation; RCT,randomized control trial; ASA,American Society of Anesthesiologists; PCIA,patient-controlled intravenous analgesia; PONV,postoperative nausea and vomiting; ECG,electrocardiography; SpO_2,pulse oximetry; BIS, bispectral index; $EtCO_2$,end-tidal CO_2; PACU,post-anesthesia care unit; SD,standard deviation; M(IQR), median (interquartile range).

Data Sharing Statement

We all agree to share individual deidentified participant data. The data used to support the findings of this study are available from the corresponding author (Wenwen Du) on reasonable request.

Acknowledgments

This work is financially supported by Zhejiang Traditional Chinese Medicine Administration Project (grant No. 2023ZL086), National Natural Science Foundation of China (grant No.82104622), Wenzhou Science and Technology Bureau(grant No.Y20210787), and Zhejiang Natural Science Foundation(grant No.LQ24H310013).

Disclosure

The authors declare that they have no competing interests.

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