Research Square

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Perioperative Transcutaneous Electrical Acupoint Stimulation for Improving Postoperative Gastrointestinal Function in Patients Undergoing Laparoscopic Colorectal Tumour Resection: A Randomized Controlled Trial

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Abstract

Background

Postoperative gastrointestinal dysfunction (POGD) is a common complication in postoperative patients. Transcutaneous electrical acupoint stimulation (TEAS) may facilitate the recovery of patients with POGD. However, no consensus has been reached regarding the selection of acupoint compatibility. To our knowledge, this is the first trial in which upper abdominal acupoints combined with lower limb acupoints have been used to prevent POGD.

Methods

In this two-arm, parallel, single-blinded randomized controlled trial, we enrolled 184 patients scheduled for laparoscopic colorectal cancer resection. After exclusions, 162 in the the modified intention-to-treat analysis (TEAS group, n = 81) and (Control group, n = 81), one control patient withdrew before anaesthesia, leaving 81 and 80 patients, respectively. The primary outcome was time to first flatus; Secondary outcomes: time to first bowel motion and defecation, QoR-15 questionnaire scores, and postoperative hospital stay.

Results

Compared with those in the control group, patients in the TEAS group had shorter durations to first flatus (55.51 ± 16.14 hours vs. 70.89 ± 10.89 hours; mean difference: -15.39; 95% confidence interval (CI): -19.67 to -11.10; $P < 0.001$), first-time bowel sound recovery (16.78 ± 3.63 hours vs. 24.76 ± 5.04 hours; mean difference: -7.98; 95% CI: -9.35 to -6.61; $P < 0.001$), first-time defecation (96.81 ± 18.41 hours vs. 109.33 ± 14.62 hours; mean difference: -12.52; 95% CI: -17.69 to -7.74; $P < 0.001$), and shorter postoperative hospital stays (7.94 ± 1.72 days vs. 10.85 ± 4.08 days; mean difference: -2.91; 95% CI: -3.88 to -1.94; $P < 0.001$). Compared with control patients, patients in the TEAS group had higher QoR-15 scores on postoperative day 3 (108.33 ± 11.34 vs. 103.90 ± 14.69; mean difference: 4.43; 95% CI: 0.35 to 8.52; $P = 0.034$). With no multiple comparison correction performed, exploratory QoR-15 analyses yielded marginally significant trends suggesting that perioperative TEAS may improve postoperative appetite, sleep quality, pain and postoperative nausea and vomiting (PONV). The other secondary outcomes did not differ between the groups. There were no severe adverse events.

Conclusions

Perioperative TEAS at CV12 and bilateral ST36, ST37, and ST39 shortened the time to first flatus and may facilitate early recovery of gastrointestinal function after laparoscopic colorectal tumour resection.

Trial registration:

Chinese Clinical Trial Registry (https://www.chictr.org.cn, ChiCTR2400090939), registered on October 16th, 2024.

Introduction

Postoperative gastrointestinal dysfunction (POGD) refers to temporary gastrointestinal motility inhibition caused by nonmechanical factors after surgery and is among the most common complications following laparoscopic colorectal tumour resection[1, 2]. It is characterized by delayed recovery of flatus and defecation, abdominal distension, inability to eat, postoperative nausea and vomiting (PONV), and prolonged postoperative ileus (PPOI), with an incidence rate of approximately 10–30%. This leads to decreased quality of life for patients, prolonged hospital stays, and increased treatment costs.

Colorectal cancer is the third most common cancer by incidence and the second leading cause of cancer-related death worldwide[3]. Laparoscopic surgery remains the primary therapeutic modality for treating colorectal cancer, whereas postoperative complications occur frequently in patients. The incidence of postoperative ileus following elective colorectal surgery ranges from 10% to 30%. POGD is prevalent among patients undergoing gastrointestinal surgery, which is attributed to the increased incidence of perioperative risk factors, including intestinal manipulation and a prolonged duration of anaesthesia.

The unsatisfactory efficacy of standard treatment regimens and potential adverse effects associated with pharmacotherapy have prompted patients to seek complementary and alternative medicine (CAM), including acupuncture[4]. Traditional Chinese medicine (TCM), which originated from ancient China, has been practiced in China for thousands of years[5]. Currently, it serves as an important CAM therapy. As a representative TCM therapy, acupuncture[6] has attracted global attention in recent decades because of its analgesic effect; moreover, studies have shown that it is effective at regulating gastrointestinal function and treating digestive system diseases[7, 8].

TEAS is an emerging therapeutic modality that integrates the dual advantages of transcutaneous electrical nerve stimulation and acupoint stimulation[9, 10]. TEAS activates and enhances the inherent homeostatic regulatory functions of the human body, thereby restoring physical homeostasis[11]. As a nonpharmacological and noninvasive intervention, it exerts therapeutic effects by delivering low-frequency electrical pulses to acupoints on the skin surface. This technique has broad application prospects in perioperative multimodal therapy, enhanced postoperative recovery, and vital organ protection, including perioperative analgesia and the prevention of postoperative nausea and vomiting.

The most commonly adopted acupoints for the treatment of gastrointestinal disorders include Hegu (LI4), Zusanli (ST36), Shangjuxu (ST37), Xiajuxu (ST39), Tianshu (ST25), Pishu (BL20), Weishu (BL21), Dachangshu (BL25), Xiaochangshu (BL27), Neiguan (PC6), Sanyinjiao (SP6), Gongsun (SP4), Daheng (SP15), Taichong (LR3), and Zhongwan (CV12)[12–16]. Among these acupoints, ST36, ST37, ST39 and

CV12 are preferentially selected owing to their anatomical proximity to the surgical region and convenient operability. ST36, ST37 and ST39 are located along the stomach meridian, whereas CV12 pertains to the conception vessel. To the best of our knowledge, this is the first study to investigate the combined stimulation of upper abdominal acupoints and lower limb acupoints for the prevention of POGD. This study aims to provide a theoretical basis and practical reference for clinically accelerating recovery from POGD.

Methods

This randomized controlled trial was reported in compliance with the Consolidated Standards of Reporting Trials (CONSORT) guidelines, and a completed CONSORT checklist is provided as a supplementary file.

Participants

A total of 161 patients who underwent laparoscopic colorectal tumor resection under general anesthesia between October 2024 and July 2025 were enrolled, based on sample size calculation using PASS software.The enrollment of the first patient took place on October 21, 2024.

Eligibility criteria

The inclusion criteria were as follows: (1) aged 18–75 years; (2) underwent laparoscopic colorectal cancer resection with primary anastomosis under general anaesthesia; and (3) voluntarily participated and signed the informed consent form.

The exclusion criteria were as follows: (1) local skin infection at acupoints; (2) intolerance to TEAS; (3) enterostomy or other abdominal organ resection; (4) lower limb nerve injury; (5) drug or alcohol abuse; (6) chronic constipation or diarrhea; (7) preoperative chemoradiotherapy; (8) uncontrolled diabetes, severe cardiac, central nervous, or psychiatric disorders, or coagulopathy; (9) implantation of cardiac pacemakers or other electrical stimulation devices; and (10) participation in other clinical trials.

Withdrawal and termination criteria: Participants could withdraw if they requested, experienced serious adverse events (SAEs), experienced severe complications requiring emergency measures, violated the protocol, or were withdrawn by the investigator. Withdrawn participants' data were processed per protocol, and those with SAEs were followed until symptom resolution or stabilization. The trial was terminated if TEAS-related refractory SAEs occurred or severe intraoperative/postoperative complications (e.g., reoperation, unplanned ICU transfer) developed.

Sample Size Calculation

On the basis of the findings of the pilot study and published literature, the time to first flatus was 71.3 ± 22.7 hours in patients who underwent laparoscopic colorectal surgery, whereas it was shortened to 62.2 ± 15.3 hours in those who underwent TEAS. According to the method of comparing the sample means of two independent groups, the ratio between groups was 1:1, assuming a statistical efficiency of 0.8. According to a bilateral test, α = 0.05, the proportion of shedding was 10%, and the total sample size of the study was 162 cases. The results are calculated via PASS 2021 (NCSS) software.

Randomization and Blinding

Eligible participants were randomized into two groups, Group T and Group C, using a stratified block randomization design (block size = 4). The random sequence was generated by an independent statistician using SAS 9.3, and allocation was concealed via opaque sealed envelopes prepared by a third party not involved in the trial. Single-blinding was implemented: the acupuncturists and clinical research coordinators were unblinded to group allocation, while the participants, outcome assessors, data managers, statisticians, and study monitors remained blinded. TEAS devices were housed in a sealed box to conceal stimulation intensity, maintaining blinding until analysis completion.

Blinding integrity was assessed at the end of the last intervention session by asking participants to guess their allocated group. The success of blinding was evaluated by calculating the proportion of correct guesses; a correct guess rate close to 0.5 indicated successful blinding. As shown in Table 3, among the 161 patients included in the per-protocol analysis, 45 (55.56%) patients in Group T and 38 (47.50%) patients in Group C correctly guessed their intervention. The overall correct guess rate was 51.55%, which was close to the 50% chance level, confirming that blinding was successful and well maintained throughout the trial. No significant difference in the distribution of guesses was observed between groups ($P > 0.05$; Table 1), suggesting that participants could not reliably distinguish active TEAS from sham TEAS, thus ensuring the validity of the trial results.

Primary outcome

Under the enhanced recovery after surgery protocol, the primary outcome, time to first flatus, was significantly shorter in Group T than in Group C (55.51 ± 16.14 hours vs. 70.89 ± 10.89 hours; mean difference: -15.39; 95% confidence interval (CI): -19.67 to -11.10; $P < 0.001$; Table 4). These results demonstrated that TEAS effectively accelerated the recovery of gastrointestinal function in patients who underwent laparoscopic colorectal tumour resection.

Secondary outcomes

With respect to the secondary outcomes related to gastrointestinal function recovery (Table 4), the time to first bowel sound recovery was significantly shorter in Group T than in Group C (16.78 ± 3.63 hours vs. 24.76 ± 5.04 hours; mean difference: -7.98; 95% CI: -9.35 to -6.61; $P < 0.001$). Similarly, the time to first defecation was significantly shorter in Group T (96.81 ± 18.41 hours vs. 109.33 ± 14.62 hours; mean difference: -12.52; 95% CI: -17.69 to -7.74; $P < 0.001$). Additionally, the mean length of postoperative

hospital stay was significantly shorter in Group T than in Group C (7.94 ± 1.72 days vs. 10.85 ± 4.08 days; mean difference: 2.91; 95% CI: -3.88 to -1.94; $P < 0.001$).

With respect to postoperative recovery assessed by the QoR-15 questionnaire (Table 4), there was no significant difference in the total QoR-15 score between the two groups on postoperative days 1 and 2 ($P = 0.066$ and $P = 0.651$, respectively). However, on postoperative day 3, the total QoR-15 score was significantly greater in Group T than in Group C (108.33 ± 11.34 vs. 103.90 ± 14.69; mean difference: 4.43; 95% CI: 0.35 to 8.52; $P = 0.034$), indicating better overall postoperative recovery in Group T.

Analyses of individual items of the QoR-15 scale were performed for exploratory purposes (Table 5), and no correction for multiple comparisons was applied. Statistically significant differences between the two groups were identified for five items at postoperative days 1, 2 and 3. Specifically, the score for “being able to enjoy food” was significantly higher in Group T than in Group C on postoperative days 1 and 3 ($P = 0.011$ and $P = 0.006$, respectively). The score for “have had good sleep” was significantly greater in Group T on postoperative days 1, 2, and 3 ($P = 0.002$, $P = 0.024$ and $P = 0.002$, respectively). On postoperative day 3, the score for “moderate pain” was significantly greater in Group T ($P < 0.001$). Additionally, the “severe pain” score was significantly greater in Group T on postoperative days 2 and 3 ($P = 0.035$ and $P = 0.013$, respectively), whereas the “nausea or vomiting” score was significantly greater in Group T on postoperative days 2 and 3 ($P = 0.003$ and $P < 0.001$, respectively). No significant differences were observed in the other QoR-15 items between the two groups at any time point (all $P > 0.05$).

Standardized Anaesthesia Procedure

No premedication was administered. Standard anaesthesia monitoring (electrocardiography, pulse oximetry, bispectral index, noninvasive/intra-arterial pressure) was performed every 5 min. Anaesthesia was induced with midazolam (0.04–0.06 mg/kg), propofol (1.5–2.5 mg/kg), and sufentanil (0.2–0.4 μg/kg), with muscle relaxation achieved via rocuronium (0.6–0.9 mg/kg) and 100% oxygen (6 L/min). Tracheal intubation was performed after induction, with additional monitoring of end-tidal carbon dioxide, central venous pressure, and urine output.

Anaesthesia was maintained with propofol and remifentanil and was adjusted to maintain the bispectral index at 40–60 and vital signs within 20% of baseline. Intraoperative analgesia was supplemented with sufentanil (0.05–0.1 μg/kg) or uraladil (5 mg IV for refractory hypertension) and rocuronium (0.1–0.2 mg/kg) for muscle relaxation. Wound infiltration with 0.5% ropivacaine (0.3 ml/kg) and ondansetron (0.06 mg/kg IV) was administered for postoperative analgesia and antiemesis, respectively. Postoperatively, patient-controlled intravenous analgesia with sufentanil (1 μg/ml) was provided, and postanaesthesia care unit stay and related adverse events were recorded.

Intervention

All acupuncture-related interventions were reported in accordance with the STRICTA 2010 (Standards for Reporting Interventions in Clinical Trials of Acupuncture) guidelines (Appendix 1). Patients in Group T received transcutaneous electrical acupoint stimulation at bilateral Zusanli (ST36), Shangjuxu (ST37), Xiajuxu (ST39), and Zhongwan (CV12) using an SDZ-V electric stimulator (Fig. 1). The stimulation was delivered with disperse-dense waves (2/100 Hz, sparse wave: 10 s, dense wave: 15 s), and the intensity was adjusted to the maximum tolerable “de qi” sensation (13.0–15.0 mA). Each session lasted 30 minutes and was administered once 30 minutes before anaesthesia induction and once daily on postoperative days 1, 2, and 3. All procedures were performed by qualified and standardized trained clinical staff. Patients in Group C received identical electrode placement, frequency, waveform, and treatment duration, but the stimulation intensity was set to 0 mA to ensure successful blinding of participants and outcome assessors. No other adjunctive acupuncture-related therapies were applied in either group. The detailed intervention measures are shown in Fig. 2. Written informed consent for publication of the clinical image was obtained from the patient shown in Fig. 2.

Outcome Measures

The preoperative general status and surgical parameters, including demographic details, comorbidities, surgical history, intraoperative fluid administration, anaesthesia and surgical duration, were continuously monitored and recorded. Postoperative data were collected by a masked observer.

Primary outcome: Time to first flatus (reported by patients or caregivers).

Secondary outcomes included time to first bowel motion and defecation, QoR-15 questionnaire scores (assessed at 15:00 on postoperative days 1–3), and postoperative hospital stay. The QoR-15 (0–150 points, higher scores = better recovery) evaluates 5 domains: pain, physical comfort, physical independence, psychological support, and emotional state.

Statistical Analysis

Continuous variables were tested for normality via the Shapiro–Wilk test: Normally distributed data are presented as the mean ± SD (independent samples t-test), and nonnormally distributed data are presented as the median (Mann–Whitney U test). Categorical variables are presented as n (%) and were analysed via the chi-square test with continuity correction or Fisher’s exact test, as appropriate. Two-sided $P < 0.05$ was considered to indicate statistical significance. Statistical analyses were conducted using IBM SPSS 21.0 by an independent statistician. Data quality and compliance were monitored by the Capital Medical University Clinical Research Institute, with review by its Institutional Review Board.

Risk assessment.

TEAS is a non-invasive, low-risk intervention. Stimulation intensity was titrated to a comfortable level, stimulation sites were monitored for skin irritation or discomfort, and all serious adverse events were

reported to the institutional ethics committee. The expected benefits were considered to outweigh the minimal risks.

Results

Study population

A total of 184 patients were assessed for eligibility. Of these, 16 patients were excluded: 2 with changed or cancelled surgery, 2 with a history of drug abuse, 4 with uncontrolled diabetes, hypertension or coronary disease, 2 who refused to participate, 1 with severe dementia or communication barrier, 1 receiving renal replacement therapies, 2 unsuitable for acupoint stimulation, and 2 for unspecified reasons. The remaining 168 patients met the eligibility criteria. Six patients were further excluded before randomization: 2 enrolled in other studies, 3 refused by participants, and 1 for unspecified reasons. Ultimately, 162 patients were randomized, with 81 patients allocated to the TEAS group and 81 to the control group. All 81 patients in the TEAS group were included in the modified intention-to-treat analysis. One patient in the control group withdrew consent before anesthesia, leaving 80 patients included in the modified intention-to-treat analysis. As shown in Fig. 3 (Trial profile).

No TEAS-related adverse events (e.g., skin allergies) were observed throughout the study. Patients showed good compliance with TEAS treatment; the stimulation intensity in the postanaesthesia care unit ranged from 13.0 mA to 15.0 mA, which was 2–5 mA higher than that in the ward. Some patients in Group T experienced mild muscle twitching and did not require additional intervention.

Demographic and baseline characteristics

There were no statistically significant differences in demographic characteristics, American Society of Anaesthesiologists classification, body mass index, or tumour-node-metastasis (TNM) stage between the two groups (all $P > 0.05$; Table 2). Similarly, intraoperative and perioperative variables, including duration of anaesthesia and surgery; intraoperative medication dosages (midazolam, propofol, remifentanil, sufentanil, rocuronium); intraoperative fluid administration (crystalloids and artificial colloids); urine output; estimated blood loss; mean arterial pressure; heart rate (HR); and surgical location, were comparable between Group T and Group C (all $P > 0.05$; Table 3). These findings indicated that the two groups were well balanced at baseline, ensuring the reliability of the subsequent outcome comparisons.

Discussion

Our study investigated the use of TEAS as an adjunctive treatment for POGD in patients who underwent laparoscopic colorectal tumour resection. The results demonstrated that perioperative TEAS at CV12 and bilateral ST36, ST37, and ST39 shortened the time to first flatus and may have facilitated early recovery of gastrointestinal function after laparoscopic colorectal tumour resection. Furthermore, exploratory QoR-15 analyses suggested potential improvements in patient-reported recovery on postoperative day 3.

Acupuncture has long been recognized for its efficacy in promoting rapid postoperative rehabilitation, as demonstrated in numerous previous studies[17]. Traditionally, distal acupuncture has been widely employed in the rehabilitation of patients after abdominal surgery[18]; however, this approach is associated with concerns regarding surgical wound irritation, altered anatomical structures and organ positions, and potential infection risks during acupuncture manipulation. In recent years, accumulating evidence has indicated that combined stimulation of both abdominal and extremity acupoints yields superior improvements in abdominal pain and discomfort, with abdominal acupoint stimulation specifically shown to be more effective at alleviating abdominal pain severity[19].

Drawing on extensive clinical practice, the present study selected TEAS at bilateral ST36, ST37, ST39 (lower extremities) and CV12 (upper abdomen) for the intervention of POGD. TEAS, a novel noninvasive therapeutic modality that integrates acupoint stimulation with transcutaneous electrical nerve stimulation, shares similarities with traditional acupuncture and moxibustion while offering distinct advantages[20]. TEAS is safe, noninvasive, convenient to administer, and associated with fewer adverse effects—characteristics that have facilitated its increasing application in conventional medical settings[21]. Additionally, the selection of CV12, an unconventional incision site in laparoscopic colorectal tumour resection, not only simplifies the surgical procedure but also enhances operational manoeuvrability. From the perspective of clinical acupoint selection rationale, ST36, ST37, ST39, and CV12 are used on the basis of their established efficacy in promoting gastrointestinal motility and recovery. Mechanistically, these acupoints act through autonomic modulation, vagal pathway activation, anti-inflammatory effects, and attenuation of the postoperative stress response, thereby improving postoperative gastrointestinal function.

To ensure therapeutic efficacy, each patient in the TEAS group received at least 4 sessions of TEAS (30 minutes per session): once before anaesthesia induction and once daily for the first three postoperative days. The strengths of the present study include a high recruitment rate, high completion rate, and high patient satisfaction, which increase the reliability and generalizability of the results. Consistent with our findings, numerous previous studies have confirmed that TEAS can improve gastrointestinal function, patient comfort, and quality of life in postoperative patients. The multifaceted therapeutic mechanisms of TEAS include neuroregulation, improved blood circulation, endocrine regulation, immune modulation, and psychological relaxation; the synergistic effect of these mechanisms contributes to its efficacy in relieving pain, improving organ function, and promoting postoperative rehabilitation. For instance, EA at ST36 has been shown to alleviate visceral hypersensitivity in rats with ulcerative colitis by inhibiting enteric glial cell activity and reducing S100β release via the noradrenergic pathway[22], whereas TEAS at LI4, PC6, ST36, ST37, ST39, and SP6 has been demonstrated to increase postoperative serum protein levels and promote early recovery in patients with colorectal cancer[23].

Postoperative rehabilitation encompasses physical, psychological, social, and functional recovery of the body and is typically divided into three phases: early (first week), midterm (first month), and late (three months)[24]. Symptoms arising during the early and midterm phases can persist into the late phase, highlighting the critical importance of high-quality early postoperative rehabilitation for long-term

recovery. The recovery of intestinal function is a key determinant of early postoperative rehabilitation following laparoscopic colorectal tumour resection, and our findings confirm that TEAS effectively promotes early recovery in these patients, which is consistent with previous literature reports.

To comprehensively evaluate the effect of TEAS on postoperative recovery, we adopted the QoR-15 questionnaire, a feasible, reliable, simple, and highly acceptable patient-reported outcome measure[25]. The QoR-15 assesses postoperative recovery across five domains (pain, physical comfort, physical independence, psychological support, and emotional state), with each item scored from 0 (unfavourable) to 10 (favourable) and the total score ranging from 0 (no recovery) to 150 (complete recovery). It has been recommended as a measure of patient comfort in clinical trials by the Perioperative Medical Standardization Endpoint Initiative[26] and as a monitoring component during the immediate postoperative period by the American Society for Enhanced Rehabilitation[27]. Consistent with our hypothesis, patients in the TEAS group had significantly higher QoR-15 total scores on postoperative day 3 (but not on days 1 or 2), confirming the beneficial effect of TEAS on early postoperative recovery.

Beyond the observed effects of transcutaneous electrical acupoint stimulation (TEAS) on gastrointestinal function recovery, exploratory item-level analyses of the QoR-15 scale revealed several potential perioperative benefits. Since these analyses were performed without multiple comparison correction, all the findings should be considered preliminary trends rather than definitive conclusions. Collectively, the results indicated that perioperative TEAS may improve postoperative appetite and subjective sleep quality and alleviate postoperative pain and PONV, thereby facilitating overall rehabilitation and shortening hospital stay. The potential sleep-improving effect of TEAS was partially consistent with previous findings; standardized perioperative TEAS at HT7, PC6 and ST36 has been proven to relieve postoperative sleep disturbance in patients undergoing laparoscopic gastrointestinal tumour resection[28]. Postoperative sleep impairment is closely linked to surgical stress, anxiety and sympathetic hyperactivation[29]. Perioperative anxiety triggers hyperactivity of the hypothalamic–pituitary–adrenal axis and increases catecholamine release, whereas surgical trauma leads to excessive accumulation of reactive oxygen species and oxidative stress, which together disrupt sleep architecture. Meta-analyses have validated the efficacy of acupoint stimulation for insomnia-like symptoms, supporting TEAS as a promising nonpharmacological approach for improving postoperative sleep[30], although this outcome still needs further verification. This study also suggested a potential appetite-enhancing effect of TEAS, as the TEAS group achieved higher scores on the item “being able to enjoy food” on postoperative days 1 and 3. To date, no relevant studies have specifically reported this effect, which may be attributed to the combined actions of accelerated gastrointestinal motility, pain relief and reduced surgical stress, which improve dietary tolerance and promote early oral feeding. Unlike the conventional visual analogue scale for pain, the QoR-15 uses a reversed 10–0 scoring system, where higher scores indicate milder symptoms and better comfort. Higher scores for moderate and severe pain items in the TEAS group suggested reduced postoperative pain intensity, particularly severe pain, without additional analgesic consumption. Consistent with prior evidence, transcutaneous electrical nerve stimulation mainly relieves dynamic pain during activity rather than resting pain because of distinct neural mechanisms. Standardized TEAS intervention at PC6 and LI4 has been shown to reduce

postoperative pain, decrease opioid consumption and PONV incidence, and improve patient satisfaction after thoracoscopic surgery[31]. With reliable analgesic effects, high safety and few adverse events, TEAS is applicable to diverse surgical populations [32]. Given the lack of multiple comparison adjustments, all the exploratory trends regarding appetite, sleep and pain relief observed in this study should be interpreted with caution.

The clinical efficacy of TEAS is highly dependent on stimulation parameters, including stimulus intensity, frequency, duration, waveform, and acupoint compatibility. Optimized stimulation between the sensory threshold and pain threshold enables the induction of classic “de qi” sensations and rhythmic muscle contraction, which is essential for achieving optimal therapeutic effects. Given the variability in current TEAS protocols and the preliminary nature of the above exploratory item-level findings, standardized and individualized parameter settings should be established in future large-sample studies with rigorous multiple comparison correction to further validate and optimize the perioperative application of TEAS.

Limitations

This study has several limitations. First, the number of postrandomization exclusions and protocol deviations was greater than anticipated, which may have introduced attrition bias and limited the generalizability of the findings. Second, this was a single-center randomized trial with a relatively limited sample size. Third, only short-term postoperative outcomes were assessed, and long-term recovery and safety outcomes were not evaluated. Finally, the item-level QoR-15 analyses were exploratory and were not adjusted for multiple comparisons; therefore, these findings should be interpreted as hypothesis-generating.

Abbreviations

CAM complementary and alternative medicine

CI confidence intervals

HR heart rate

PONV postoperative nausea and vomiting

POGD postoperative gastrointestinal dysfunction

PPOI prolonged postoperative ileus

QoR quality of recovery

SAEs serious adverse events

TCM traditional Chinese medicine

TEAS transcutaneous electrical acupoint stimulation

TNM tumour-node-metastasis

Declarations

Ethics approval and consent to participate

This trial was approved by the Ethics Committee of Guang'anmen Hospital, China Academy of Chinese Medical Sciences (reference number: 2024-197-KY) and conducted in adherence to the Declaration of Helsinki. The study protocol was registered in the Chinese Clinical Trial Registry (ChiCTR2400090939). All patients were enrolled from Guang'anmen Hospital of China Academy of Chinese Medical Sciences and provided written informed consent before study participation.

Consent for publication

The authors declare that the manuscript has not been published and is not currently being considered for publication in another journal.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

F. C. Conceptualization, Data curation, Writing – original draft, Writing – review & editing; Y. C. Investigation, Project administration, Data curation; W. L. Data curation; Y. Q. Investigation, Data curation; C. J. Data curation; C. L. Data curation; C. L. Data curation; A. W. Conceptualization, Supervision; X. D. Conceptualization, Supervision, Funding acquisition.

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Not applicable.

Availability of data and materials

No datasets were generated or analysed during the current study. However, the data and materials are available from Feifei Chang upon reasonable request. Please contact Feifei Chang for further information regarding data availability

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Tables

Table 1
Blinding assessment of participants

Guessed as TEAS, n (%)	**Group T (n = 81)**	**Group C(n = 80)**	**Total (n = 161)**
	45 (55.56)	**38 (47.50)**	**83 (51.55)**
Guessed as sham TEAS, n (%)	36 (44.44)	42 (52.50)	78 (48.44)
Correct guess rate	55.60%	47.50%	51.60%
P	—	—	0.672
Data are presented as n(%).			

Table 2
Demographic and Baseline Variables

Age, yr	**Group T (n = 81)**	**Group C(n = 80)**	**P value**
	63.30 ± 11.19	**60.80 ± 10.81**	**0.152**
Male sex, n (%)	43(53.1)	48(60.0)	0.376
Body mass index, kg/m^2	24.31 ± 3.39	23.35 ± 3.41	0.074
Education,yr	8.2 ± 3.5	9.1 ± 2.3	0.054
TNM staging (n (%))			0.875
	32(39.50)	34(42.50)	
	38(46.90)	37(46.30)	
	11(13.60)	9(11.20)	
Preoperative comorbidities, n (%)			
Stroke	4(4.90)	6(7.50)	0.501
Hypertension	32(39.50)	24(30.00)	0.205
Coronary heart disease	8(9.90)	6(7.50)	0.593
Arrhythmia	5(6.20)	2(2.50)	0.253
Respiratory Disease§	5(6.20)	1(1.30)	0.099
Diabetes	8(9.90)	8(10.00)	0.979
Thyroid disease*	3(3.70)	4(5.00)	0.687
Liver dysfunction#	12(14.80)	16(20.00)	0.385
Renal dysfunctionΔ	10(12.30)	8(10.00)	0.637
Chronic smoking. n(%)‖	25(30.90)	28(35.00)	0.577
Alcoholism, n(%) **	15(18.50)	22(27.50)	0.363
ASA class, n(%)			0.697
	2(2.50)	4(5.00)	
	60(74.10)	58(72.50)	
	19(23.40)	18(22.50)	
Preoperative laboratory tests			
Hemoglobin, g/L	125.00 ± 24.82	131.04 ± 17.91	0.078

Age, yr	**Group T (n = 81)**	**Group C(n = 80)**	**P value**
	63.30 ± 11.19	**60.80 ± 10.81**	**0.152**
Leukocyte, $\times 10^9$/L	6.29 ± 1.72	6.82 ± 2.20	0.092
Albumin, g/L	40.41 ± 3.67	41.58 ± 4.86	0.086
Glucose, mmol/L	6.23 ± 1.73	6.12 ± 1.69	0.686
Data are presented as mean ± SD, n(%).			
§ Included chronic bronchitis, COPD(chronic obstructive pulmonary disease), asthma.			
*Included hyperthyroidism, hypothyroidism, nodular goiter, Hashimoto's thyroiditis.			
#Serum alanine and/or aspartate transaminase higher than five times the upper normal limit.			
ΔCreatinine concentration higher than 177 μmol/L.			
‖Smoking half a pack (10 cigarettes)/day for at least 1 year, either former or current smoker.			
** Daily intake of two or more alcoholic drinks, or weekly alcohol consumption equivalent to 150 mL pure alcohol.			
ASA, American Society of Anesthesiologists; TNM tumor-node-metastasis			

Table 3
Intra-and Postoperative Variables

Duration of anesthesia, min	**Group T (n = 81)**	**Group C(n = 80)**	**P value**
	314.14 ± 87.96	**330.39 ± 113.95**	**0.313**
Duration of surgery, min	275.86 ± 84.59	283.86 ± 110.60	0.607
Intraoperative medications			
Midazolam,mg	2.86 ± 0.61	2.87 ± 0.48	0.845
Propofol,mg	1707.85 ± 704.62	1732.34 ± 517.78	0.802
Remifentanil, μg	2960.00 ± 2985.24	3234.69 ± 1564.70	0.467
Sufentanil, μg	12.09 ± 3.96	11.38 ± 3.34	0.224
Rocuronium, mg	48.27 ± 11.24	46.17 ± 8.16	0.178
Intraoperative fluid,mL	1908.64 ± 607.91	2057.63 ± 535.46	0.101
Crystalloid,mL	1350.00 ± 550.45	1433.75 ± 416.49	0.278
Artificial colloid,mL	558.64 ± 164.85	570.13 ± 193.98	0.686
Intraoperative urine output,mL	469.38 ± 248.42	484.50 ± 270.72	0.712
Estimated blood loss,mL	48.27 ± 26.16	54.50 ± 28.15	0.148
Mean arterial pressure, mmHg$^{\Delta}$	103.63 ± 11.48	101.83 ± 9.48	0.281
Heart rate, beats/min$^{\Delta}$	75.40 ± 14.00	74.65 ± 12.37	0.715
Location of surgery, n(%)			0.617
Rectal cancer	41(50.60)	42(52.50)	
Left colon cancer	5(6.20)	8(10.00)	
Right colon cancer	15(18.50)	16(20.00)	
Sigmoid cancer	20(24.70)	14(17.50)	
Data are presented as mean ± SD, n(%).			
$^{\Delta}$Average value from the anesthetic induction to the end of surgery.			

Table 4
Recovery of Gastrointestinal Function

	Group T (n = 81)	Group C (n = 80)	mean difference (95%CI)	P value
Primary outcome				
Time to first flatus, h	55.51 ± 16.14	70.89 ± 10.89	-15.39(-19.67,-11.10)	< 0.001*
Secondary outcome				
Time to first bowel sound, h	16.78 ± 3.63	24.76 ± 5.04	-7.98(-9.35, -6.61)	< 0.001*
Time to first defecation, h	96.81 ± 18.41	109.33 ± 14.62	-12.52(-17.69, -7.34)	< 0.001*
Length of postoperative hospital stay, d	7.94 ± 1.72	10.85 ± 4.08	-2.91(-3.88,-1.94)	< 0.001*
The aggregate score of QoR-15 on postoperative day 1	91.84 ± 11.96	87.75 ± 15.79	4.09(-0.27,8.45)	0.066
The aggregate score of QoR-15 on postoperative day 2	99.56 ± 13.21	98.58 ± 14.19	0.98 (-3.28,5.25)	0.651
The aggregate score of QoR-15 on postoperative day 3	108.33 ± 11.34	103.90 ± 14.69	4.43(0.35,8.52)	0.034*
Data are presented as mean ± SD.				

Table 5
The scores of 15 items of postoperative QoR-15 questionnaire

Outcome	Postoperative Day 1			Postoperative Day 2			Postoperative Day 3		
	Group T (n = 81)	Group C (n = 80)	P value	Group T (n = 81)	Group C (n = 80)	P value	Group T (n = 81)	Group C (n = 80)	P value
Able to breathe easily	9.84 ± 0.64	9.78 ± 0.75	0.557	9.88 ± 0.43	9.95 ± 0.35	0.237	9.95 ± 0.31	9.88 ± 0.49	0.244
Able to enjoy food	3.98 ± 2.87	2.71 ± 3.38	0.011*	4.62 ± 2.82	4.75 ± 3.58	0.794	6.23 ± 3.05	4.74 ± 3.70	0.006*
Feeling rested	6.05 ± 1.98	5.59 ± 2.13	0.156	6.68 ± 1.39	6.84 ± 2.02	0.562	6.75 ± 1.38	7.24 ± 1.83	0.060
Have had a good sleep	5.35 ± 1.71	4.35 ± 2.24	0.002*	6.12 ± 1.48	5.49 ± 2.03	0.024*	6.60 ± 1.13	5.79 ± 2.05	0.002*
Able to look after personal toilet and hygiene unaided	1.75 ± 2.31	1.30 ± 2.31	0.216	3.73 ± 3.29	3.40 ± 2.88	0.497	4.05 ± 2.52	4.54 ± 3.20	0.284
Able to communicate with family or friends	7.77 ± 1.35	7.55 ± 2.10	0.441	8.30 ± 1.42	8.39 ± 1.58	0.699	8.69 ± 0.97	8.88 ± 1.32	0.316
Getting support from hospital doctors and nurses	5.78 ± 1.65	5.64 ± 1.98	0.618	6.38 ± 1.27	6.33 ± 1.50	0.792	6.63 ± 1.27	6.56 ± 1.78	0.783
Able to return to work or usual home activities	1.89 ± 1.48	1.64 ± 1.91	0.251	2.31 ± 1.82	2.41 ± 1.78	0.715	3.42 ± 1.88	3.21 ± 2.19	0.519
Feeling comfortable and in control	6.12 ± 1.68	6.68 ± 1.97	0.058	6.16 ± 1.21	6.30 ± 0.96	0.418	7.79 ± 1.29	7.44 ± 1.48	0.109
Having a feeling of general well-being	4.04 ± 1.27	4.31 ± 1.75	0.255	4.23 ± 2.06	4.61 ± 1.60	0.194	5.41 ± 1.23	5.08 ± 1.51	0.128

Data are presented as mean ± SD.

Outcome	Postoperative Day 1			Postoperative Day 2			Postoperative Day 3		
	Group T (n = 81)	Group C (n = 80)	P value	Group T (n = 81)	Group C (n = 80)	P value	Group T (n = 81)	Group C (n = 80)	P value
Moderate pain	6.63 ± 1.27	6.24 ± 1.84	0.119	7.11 ± 1.58	6.95 ± 1.43	0.501	8.30 ± 1.27	7.30 ± 1.35	< 0.001*
Severe pain	8.98 ± 1.16	8.66 ± 1.64	0.166	9.14 ± 0.88	9.44 ± 0.97	0.035*	9.49 ± 0.73	9.16 ± 0.93	0.013*
Nausea or vomiting	8.53 ± 1.01	8.88 ± 1.93	0.163	9.66 ± 0.711	8.94 ± 1.97	0.003*	9.78 ± 0.84	8.91 ± 1.58	< 0.001*
Feeling worried or anxious	7.52 ± 1.70	7.33 ± 1.93	0.501	7.54 ± 1.80	7.34 ± 1.97	0.490	7.43 ± 1.98	7.51 ± 1.73	0.784
Feeling sad or depressed	7.52 ± 1.73	7.33 ± 1.95	0.507	7.81 ± 1.89	7.45 ± 2.04	0.241	7.80 ± 1.24	7.68 ± 2.37	0.670
Data are presented as mean ± SD.									

Figures

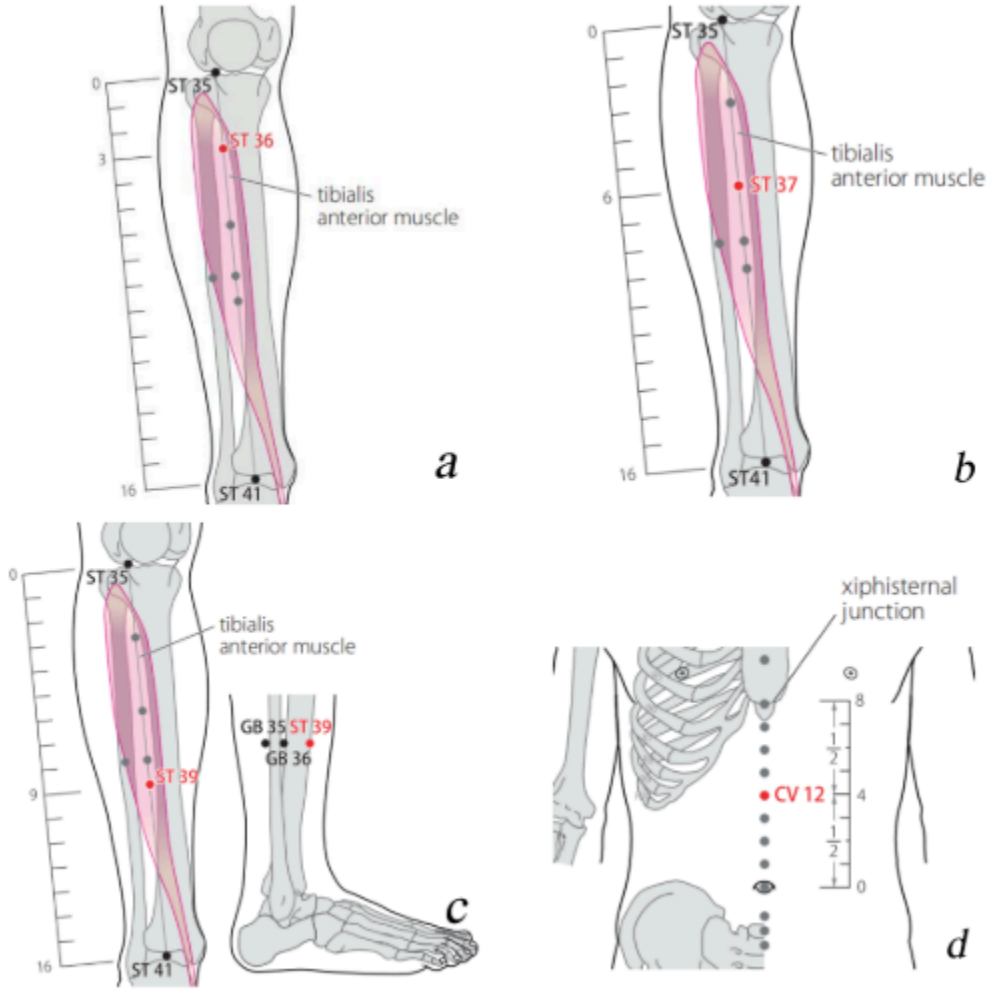


Figure 1

Location of Zusanli (ST36), Shangjuxu(ST37), Xiajuxu(ST39), Zhongwan(CV12)[1].

a.Zusanli (ST36), Stomach Meridian, on the anterior aspect of the leg. Located on the tibialis anterior muscle.

b.Shangjuxu(ST37), Stomach Meridian, on the anterior aspect of the leg. located on the tibialis anterior muscle.

c.Xiajuxu(ST39), Stomach Meridian, on the anterior aspect of the leg. located on the tibialis anterior muscle.

d.Zhongwan(CV12), Conception Vessel, on the upper abdomen, 4 cun superior to the center of the umbilicus, on the anterior median line. Located at the midpoint of the line connecting the xiphisternal junction and the center of the umbilicus.

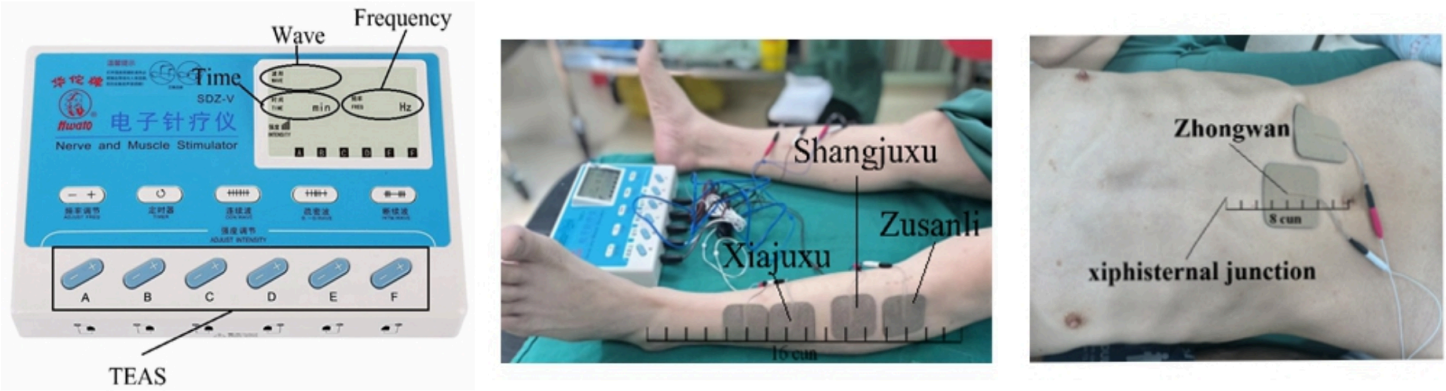


Figure 2

Instrument, Location of acupoints and electrodes.

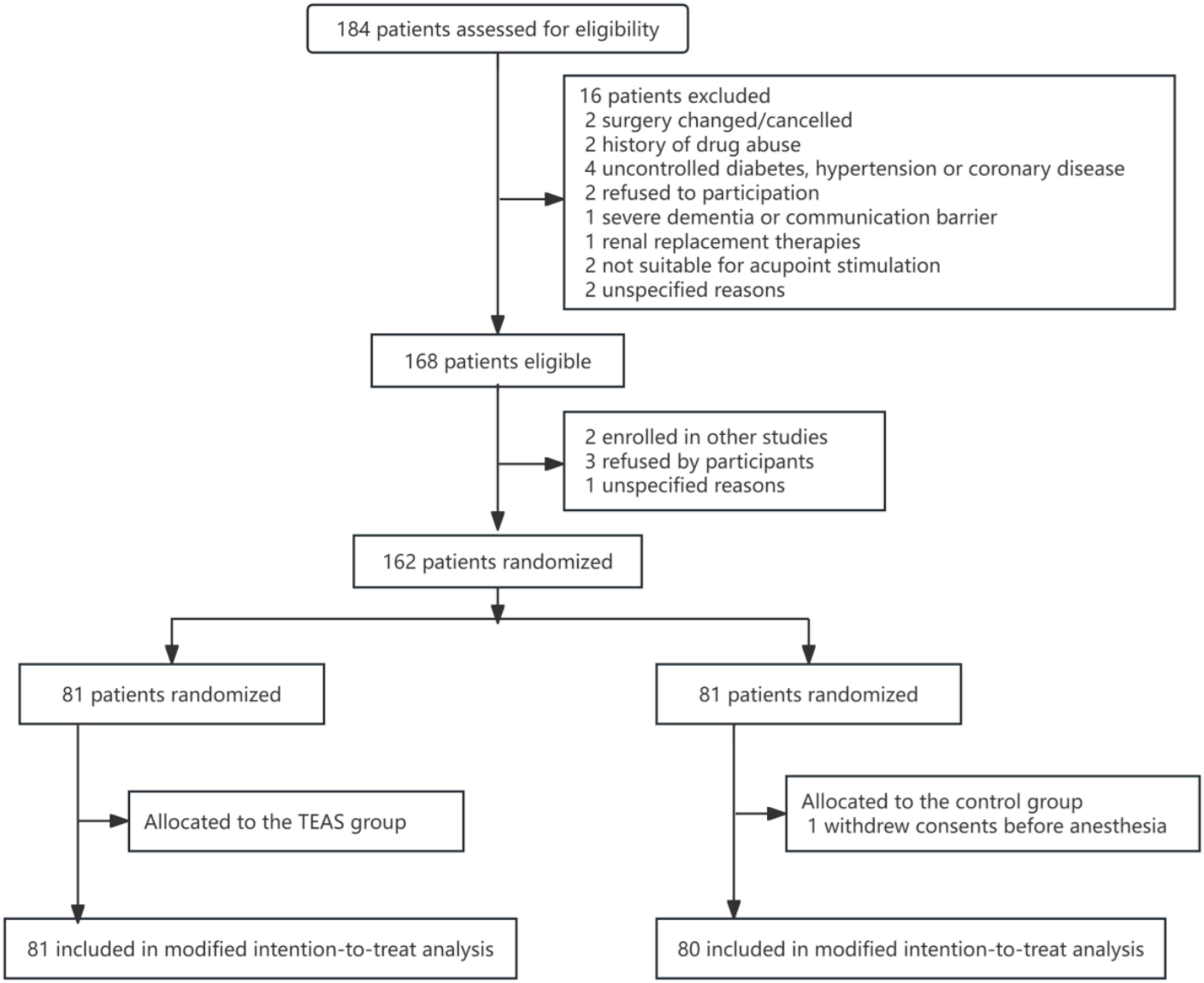


Figure 3

Trial profile. TEAS, transcutaneous electrical acupoint stimulation.

Supplementary Files

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