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Investigating the efficacy of electroacupuncture for postoperative ileus in patients with colorectal cancer: study protocol for a multicentre clinical trial with neuroimaging assessment

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ABSTRACT

Introduction Postoperative ileus (POI) is a prevalent complication following abdominal surgeries, significantly compromising patients' quality of life and imposing a socioeconomic burden. Electroacupuncture (EA), a widely used therapeutic approach in China, has shown promise as an effective intervention for POI. However, the neural mechanism underlying its therapeutic effects remains unclear. Thus, this study aims to evaluate the efficacy of EA treatment for POI and investigate its central mechanism by functional MRI (fMRI).

Methods and analysis This randomised controlled clinical trial will be conducted across three hospitals in China. A total of 50 eligible patients with colorectal cancer scheduled for elective laparoscopic surgery will be randomly assigned to either the EA or sham electroacupuncture (SA) group in a 1:1 ratio. All patients will undergo 5 sessions of 30 min EA or SA over 5 consecutive days post-surgery (once daily). Resting-state fMRI (rs-fMRI) scans will be performed at baseline and the end of treatment to examine brain functional changes related to EA treatment. The primary outcome is the time to first defecation. Secondary outcomes include the time to first flatus, ambulation, tolerability of semiliquid and solid food; length of postoperative hospital stay; severity of postoperative pain, abdominal distension and nausea; frequency of postoperative nausea and vomiting episodes; rate of readmission. Postoperative complications will be monitored and documented throughout the trial duration. Credibility and expectancy evaluation, along with blinding assessment, will be conducted after the first treatment session. Pearson/Spearman correlation analysis will be performed to determine the relationship between clinical variables and rs-fMRI metrics.

Ethics and dissemination This protocol has been approved by the ethics committees of Beijing University of Chinese Medicine (number 2024BZYLL0113), Cancer Hospital Chinese Academy of Medical Sciences (number 24/323-4603), Beijing Friendship Hospital Affiliated to Capital Medical University (number 2024-P2-081-01) and Beijing Chaoyang Huanxing Cancer Hospital (number 2024-011-02). Participants will sign the paper-based informed consent form before enrolment. The results will be disseminated through peer-reviewed publications.

Trial registration number ITMCTR2024000504.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This is a multicentre, randomised, participant-blinded, sham-controlled clinical trial.
⇒ Resting-state functional MRI will be used to observe the modulatory effects of electroacupuncture on brain function in patients with postoperative ileus.
⇒ Correlation analyses will be performed between neuroimaging metrics and gastrointestinal recovery parameters.
⇒ This study will recruit participants from three hospitals across China, which may limit the applicability to populations in other countries.
⇒ The inclusion of only elective laparoscopic surgery patients may limit the generalisability of the findings to those undergoing open or emergency procedures.

INTRODUCTION

Postoperative ileus (POI) is a common complication following abdominal surgery, characterised by abdominal pain, distension, defecation dysfunction, nausea and vomiting.[1 2] Compared with other abdominal surgeries, colorectal cancer surgery is more prone to postoperative gastrointestinal (GI) dysmotility, which significantly impairs patients' quality of life and imposes a substantial socioeconomic burden.[2]

Currently, non-pharmacological strategies such as gum chewing, nasogastric tube removal and early ambulation are routinely employed in the management of POI,[3 4] while alvimopan remains the only pharmacological agent approved by the US Food and Drug Administration specifically indicated for POI

owing to its selective antagonism of peripheral μ-opioid receptors.[5 6] However, the clinical application of these approaches is limited by inconsistent efficacy and potential cardiovascular risks.[7] Given these challenges, therapies targeting central regulatory mechanisms may present novel opportunities for improving GI dysfunction in POI.

Acupuncture has demonstrated the ability to modulate central neural pathways via somatic acupoint stimulation, thereby contributing to the regulation of GI dysmotility.[8] Recent evidence has highlighted its efficacy in facilitating GI functional recovery following abdominal surgery.[9–17] Multicentre randomised clinical trials conducted by our team further confirmed that electroacupuncture (EA), compared with sham electroacupuncture (SA) and standard care, significantly shortens the time to first flatus and defecation and reduces the incidence of prolonged POI in patients undergoing laparoscopic resection of colorectal cancer.[18 19] While the clinical benefits of EA in POI management have been preliminarily validated, its underlying central mechanisms remain to be elucidated.

The pathogenesis of POI involves vagal activation through neural circuits spanning the brainstem, hypothalamus, pons and medulla in response to surgical intervention.[20] Preclinical animal studies suggest that acupuncture modulates brain regions, alleviating POI-related symptoms[21]; however, these findings have yet to be validated in human subjects. Resting-state functional MRI (rs-fMRI), a non-invasive technique based on blood oxygen level-dependent signal fluctuations, has been widely employed to investigate acupuncture-induced brain function changes in GI disorders.[22–26] A systematic review reported that patients with functional dyspepsia exhibit functional abnormalities in brain regions such as the frontal cortex, insula, cingulate gyrus and hippocampus. These abnormalities are modulated by acupuncture and are associated with improvements in abdominal pain, distension, early satiety and overall quality of life.[27] Similarly, a neuroimaging study involving patients with irritable bowel syndrome demonstrated that acupuncture alleviates abdominal pain and defecation disorders by altering functional connectivity (FC) between the default mode network and the ventral attention network.[28] Collectively, these findings suggest that acupuncture may exert therapeutic effects through the modulation of aberrant brain activity and FC. However, existing research predominantly focuses on chronic GI diseases, with limited evidence available regarding postoperative GI dysmotility, such as POI.

Therefore, we have designed a randomised controlled clinical trial to evaluate the clinical efficacy of EA in the treatment of POI following laparoscopic colorectal cancer surgery. In addition, this study will investigate the underlying neuroimaging mechanisms of EA in alleviating POI by combining rs-fMRI techniques. It is expected to provide clinical evidence supporting the use of EA in managing postoperative GI functional disorders and to offer preliminary insights into its central mechanisms.

METHODS AND ANALYSIS

Study design

This is a multicentre, randomised, participant-blinded, controlled clinical study that will be conducted in three hospitals in China (Cancer Hospital Chinese Academy of Medical Sciences, Beijing Friendship Hospital Affiliated to Capital Medical University and Beijing Chaoyang Huanxing Cancer Hospital). This protocol (V.2.0 January 2024) has been approved by the ethics committees of Beijing University of Chinese Medicine (2024BZYLL0113) and the study sites mentioned above (24/323-4603; 2024-P2-081-01; 2024-011-02). This study is registered at the International Traditional Medicine Clinical Trial Registry (ITMCTR2024000504) on 29 September 2024. Figure 1 summarises the overall design of the trial. A total of 50 patients will be recruited and randomly assigned to EA group or SA group in a 1:1 ratio. The study protocol will be reported following the Consolidated Standards of Reporting Trials statements and the Standards for Reporting Interventions in Clinical Trials of Acupuncture. The study flow diagram is shown in figure 2 and the schedules for trial enrolment, interventions and assessments are illustrated in figure 3. Figures in this manuscript incorporate elements from BioGDP, PowerPoint SmartArt and Servier Medical Art, used under appropriate academic licences.[29]

Trial status

The study is currently in the recruitment phase, with the first participant enrolled on 8 November 2024. Recruitment is anticipated to be completed by 1 December 2025, and the results are expected to be published by 30 December 2026.

Participants

Patients diagnosed with colorectal cancer who are scheduled for elective laparoscopic surgery will be informed of the study. Patients who preliminarily meet the inclusion criteria, do not meet any exclusion criteria and express interest in the study will be considered potential participants. Potential subjects will provide written informed consent prior to surgery and undergo the first MRI scan. All patients will undergo postoperative screening to confirm their final eligibility for enrolment.

Inclusion criteria

1. Age between 45 and 65 years old.
2. Right handedness.
3. Diagnosed with colorectal cancer and scheduled for laparoscopic surgery.
4. American Society of Anesthesiologists grades I–III.
5. Undergo abdominal surgery for the first time.
6. Signed informed consent.

Exclusion criteria

1. Receive epidural anaesthesia.
2. Synchronise with organ resection.
3. Underwent open surgery or total colorectal resection.

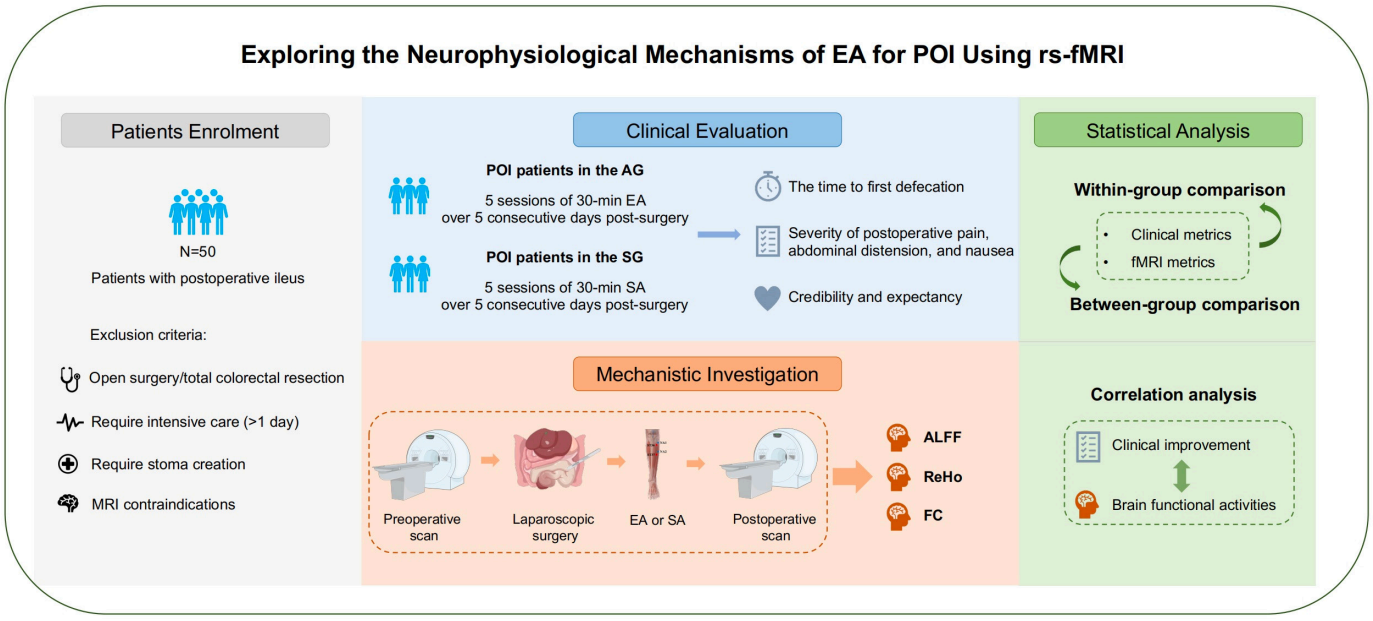

Figure 1 Study design and procedures. AG, electroacupuncture group; ALFF, amplitude of low-frequency fluctuation; EA, electroacupuncture; FC, functional connectivity; POI, postoperative ileus; ReHo, regional homogeneity; Rs-fMRI, resting-state functional MRI; SA, sham electroacupuncture; SG, sham electroacupuncture group.

4. Intraoperative and postoperative complications requiring long-term intensive care (>1 day).
5. Require stoma creation.
6. History of mental disorders or alcohol or drug abuse.
7. Received acupuncture treatment within 1 month prior to the study.
8. Implantable medical devices such as pacemakers.
9. Participated in other clinical studies.
10. MRI contraindications, such as cardiac pacemaker, nerve stimulator, artificial metal heart valve, metal joints or ferromagnetic foreign bodies, severe fever and epilepsy.

Randomisation and allocation concealment

Eligible postoperative participants will be randomly assigned to the EA group and the SA group in a ratio of 1:1 using stratified blocked randomisation. The randomisation sequence will be generated using Stata software by an independent statistician who does not participate in this study. Randomisation will be stratified among the three study sites, with random block size of four or six. The random allocation sequence will be maintained by an independent sequence custodian who is not involved in any other aspects of the study. This sequence will be kept strictly confidential. Once a participant is confirmed to meet all inclusion criteria and has signed the informed consent form, the study coordinator will notify the custodian. Prior to the first treatment session, the custodian will send the unique group assignment (eg, 'EA' or 'SA') to the acupuncturist by text message according to the predetermined sequence. Apart from the sequence custodian and the acupuncturist, all other parties—including participants, recruitment personnel, outcome assessors, data managers and statisticians—will remain blinded to the group allocations.

Blinding

All patients, outcome assessors, data statisticians, surgeons and fMRI scanners will be blinded to the group assignment, but the acupuncturists cannot be blinded owing to the intervention characteristics of acupuncture. To ensure successful blinding, the two types of EA devices used in this study were identical in appearance but labelled differently. The device used in the EA group functioned normally, whereas the device used in the SA group had internal wires cut, resulting in no electrical output. A blinding assessment will be conducted following the first treatment session by asking patients to guess which type of acupuncture they believe they received (EA or SA).

Interventions

All patients will receive five sessions of 30 min EA or SA over 5 consecutive days following surgery (once a day). The treatment will be operated at the patients' bedside. Acupuncturists at each study site hold a Chinese medicine practitioner licence issued by the Ministry of Health of the People's Republic of China and have at least 3 years of clinical experience. They will be trained in standardised operating procedures before this study. The acupuncturists will be instructed to minimise communication with patients to avoid breaking the blindness. Disposable stainless-steel needles (0.30×0.40 mm, Hwato, Suzhou, Jiangsu, China) will be used in all intervention processes. In addition, all enrolled patients will receive postoperative management in accordance with the Consensus

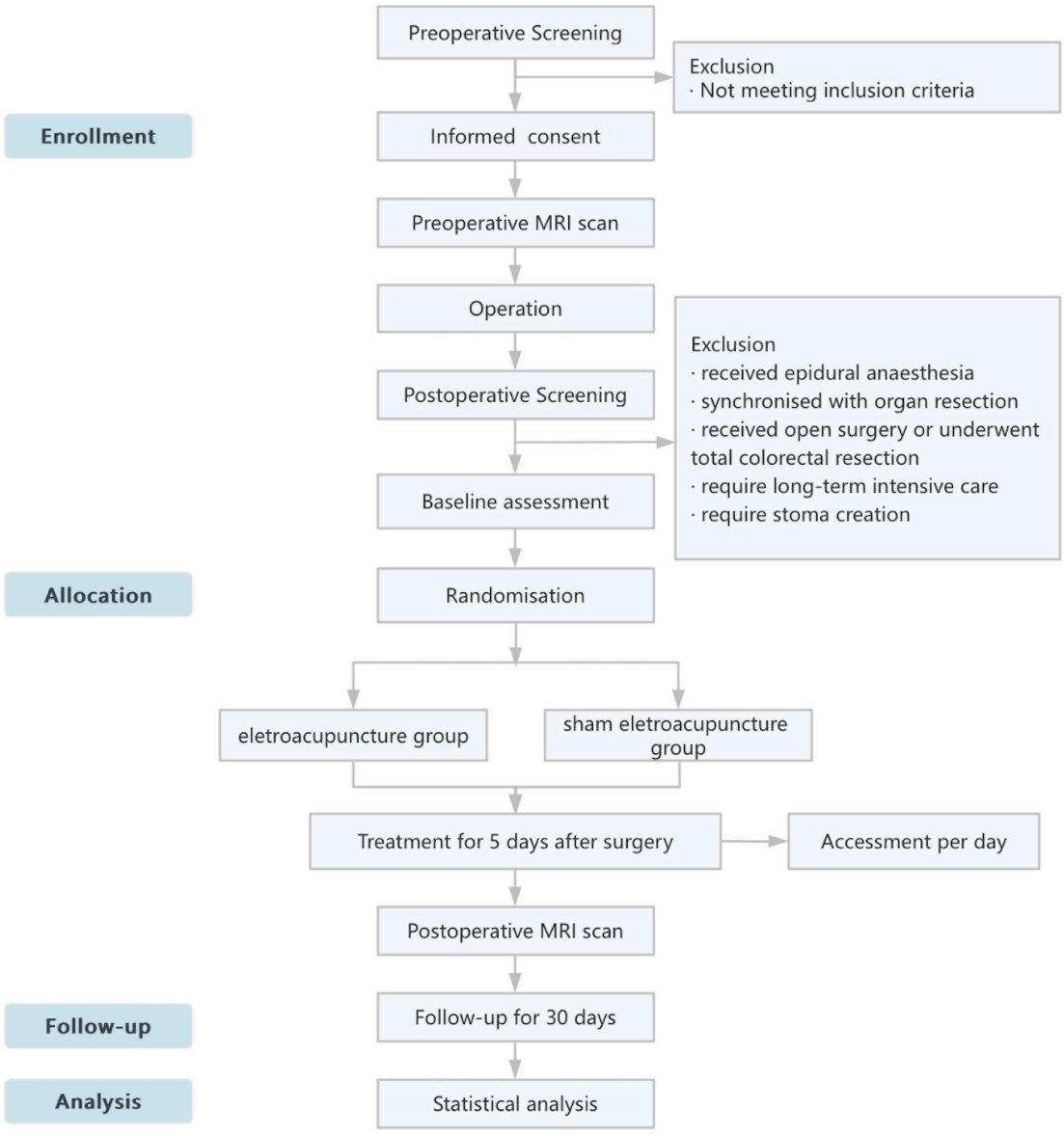

Figure 2 Study flow diagram.

and Guidelines on Enhanced Recovery After Surgery in China.

EA group

Based on the traditional meridian theory and previous clinical research conducted by our team,[30] the Zusanli (ST36, bilateral) and Shangjuxu (ST37, bilateral) acupoints will be selected for the EA group. The locations of the acupoints are presented in table 1 and figure 4, following the WHO Standard Acupuncture Locations. After penetrating into the skin, acupuncture manipulations will be performed to elicit the deqi sensation (a composite sensation characterised by aching, soreness, swelling, heaviness or numbness.[18 19 31] Subsequently, a pair of electrodes from an electric stimulator (FANGS-100, Acupoint Therapy Device, Hangzhou, Zhejiang, China) will be attached to the needles at Zusanli with a dilatational wave of 2/100 Hz. The electric current intensity will be adjusted according to the patients' tolerance.

SA group

Minimally invasive acupuncture manipulations (2–3 mm in depth) will be operated at non-acupoints (table 2 and figure 4) in the SA group. Needles will be inserted into skin and limited to a depth of 2–3 mm to avoid eliciting the deqi sensation. Similar electrodes to those used in the EA group will be attached to non-acupoint 1; however, no actual current output will be delivered.

Outcome measures

Primary outcome

The primary outcome is the time to first defecation, defined as the time of the first spontaneous bowel movement after surgery.[32 33] A difference of 12 hours in the time to first defecation is considered clinically meaningful.[34] Patients or carers will report the specific time at which it occurs to the assessors, who will then document it precisely to the nearest minute in the case report forms (CRFs).

	STUDY PERIOD								
	Enrolment	Allocation	Post-allocation						Close-out
TIMEPOINT	*Day-14*	Day0	*Day 1*	*Day 2*	*Day 3*	*Day 4*	*Day 5*	*Day 6*	*Day7-30*
ENROLMENT:									
Eligibility screen	X	X							
Informed consent	X								
Preoperative MRI scan	X								
Allocation		X							
Randomisation		X							
INTERVENTIONS:									
EA			←	—	—	—	→		
SA			←	—	—	—	→		
ASSESSMENTS:									
First defecation			Events were recorded as they occurred						
First flauts			Events were recorded as they occurred						
Postoperative nausea			X	X	X	X	X	X	Weekly
Abdominal distension			X	X	X	X	X	X	Weekly
Postoperative pain			X	X	X	X	X	X	Weekly
Postoperative vomiting			X	X	X	X	X	X	Weekly
Length of postoperative hospital stay			Events were recorded as they occurred						
First ambulation			Events were recorded as they occurred						
Tolerability of semiliquid/solid food			Events were recorded as they occurred						
Readmission rate									X
Postoperative MRI scan								X	
Expectation and Blinding assessment			X						
Complications of Surgery			Events were recorded as they occurred						
Adverse events			Events were recorded as they occurred						
Rescue medicine			Events were recorded as they occurred						

Figure 3 Schedule of trial enrolment, interventions and assessments. EA, electroacupuncture; SA, sham electroacupuncture.

Secondary outcomes

1. **Time to first flatus.** It is defined as the time of the first passage of flatus after surgery.[33] This outcome is dependent on patient self-perception and will be recorded in the same manner as the time to first defecation.
2. **Time to first ambulation.** This is defined as the duration from the end of surgery until the patient first gets out of bed and sustains ambulation for a minimum of 5 min.[9] The specific time will be recorded by carers to the nearest minute in the CRFs.
3. **Time to tolerability of semiliquid and solid food.** It is defined as the absence of nausea and vomiting within 4 hours after the consumption of semiliquid (eg, rice porridge, egg, soup, chicken custard) and solid food.[16 35] The time will be recorded by carers, reported to the outcome assessors and subsequently documented in the CRFs with precision to the nearest minute.
4. **Length of postoperative hospital stay.** The length of hospital stay will be calculated from the date of colorectal resection to the date of discharge. The discharge date will be recorded by the outcome assessor. Discharge readiness will be based on predefined clinical criteria, including stable organ function with independent mobility, adequate pain control with oral analgesics, tolerance of a semiliquid diet, satisfactory wound healing, absence of infection or other postop-

Table 1 Locations of the acupoints for the EA group

Acupoint	Location
Zusanli (ST36)	3 cun* directly below Dubi (ST35) and one finger breadth lateral to the anterior border of the tibia
Shangjuxu (ST37)	3 cun directly below Zusanli (ST36) and one finger breadth lateral to the anterior border of the tibia

*1 cun (≈20 mm) is defined as the width of the interphalangeal joint of the patient's thumb.
EA, electroacupuncture; ST, stomach.

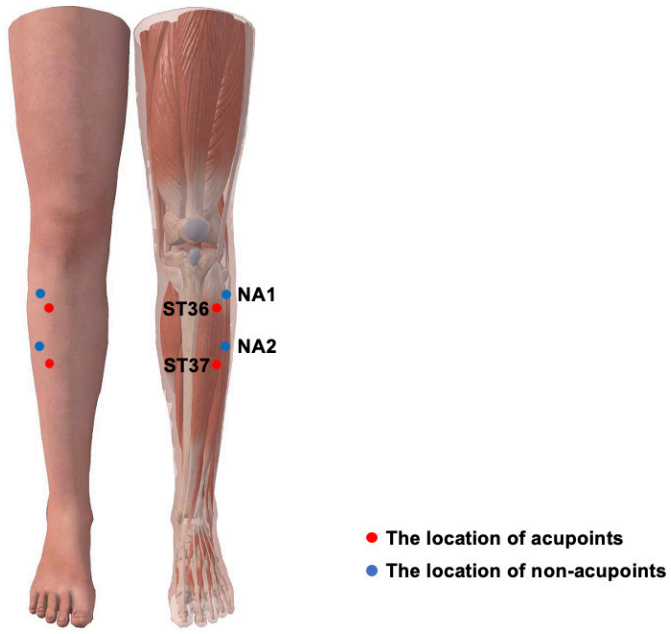

Figure 4 Locations of acupoints and non-acupoints. NA, non-acupoint.

erative complications, availability of appropriate home care, and the patient's consent to discharge.[36]

5. **Postoperative pain, abdominal distension, nausea and vomiting.** The severity of postoperative pain, abdominal distension and nausea will be evaluated, along with the number of nausea and vomiting episodes. Symptom severity will be assessed using the Numerical Rating Scale (NRS). The NRS is an 11-point scale (0-10) for self-reported pain intensity, where higher scores indicate more severe pain.[37] Nausea and vomiting episodes separated by more than 5 min will be recorded as two discrete events.[38] The assessment schedule is divided into two primary phases: a daily reporting phase from postoperative day 1 to 5 by the patients, followed by a weekly evaluation phase during the follow-up period (postoperative days 7 to 30). An additional assessment will be conducted by the assessors on the day of the postoperative imaging.
6. **Rate of readmission.** On postoperative day 30, a telephone follow-up will be performed by the researchers to assess whether patients have been readmitted due to surgery-related complications. The 30-day readmission rate will be defined as the proportion of patients who require readmission within 30 days after surgery.[39]
7. **Postoperative complications.** All postoperative complications occurring within 30 days after surgery will be recorded and graded according to the Clavien-Dindo classification system.[40]
8. **Blinding assessment.** After the first treatment session, a blinding assessment will be conducted by asking patients to indicate their acupuncture assignment (EA or SA).[41]
9. **Brain MRI.** fMRI metrics—Regional Homogeneity (ReHo, quantifying local neural synchrony), Amplitude of Low-Frequency Fluctuations (ALFF, reflecting spontaneous neural activity intensity), and FC (characterising inter-regional communication)—are secondary outcomes.[42–44] The validity of these metrics for investigating central mechanisms has been established in both GI disorders and acupuncture.[25 45–47]

Credibility and expectancy

The Credibility/Expectancy Questionnaire will be administered within 5 min following the first acupuncture session to evaluate patients' expectations.[48]

Safety evaluation and adverse events

All adverse events (AEs) related to acupuncture and MRI scan will be systematically documented by investigators. Once serious AEs occur, they will be reported to the principal investigator of the general centre and the Ethics Committee of the study site within 24 hours. No specific rescue medication will be prespecified in the study protocol. In the event of a clinical emergency or severe symptoms, the attending physician will determine and administer appropriate rescue therapy at their discretion based on standard medical care. All administrations of such medication will be meticulously documented in the CRF.

MRI data acquisition

The MRI scans will be conducted at presurgery and at the end of acupuncture treatment using a 3.0 Tesla scanner in the three study sites. All the participants were instructed to keep their eyes closed, remain awake and refrain from active thinking during scanning. Structural images will be acquired by 3D T1 BRAVO sequence: repetition time (TR)=7700/7000 milliseconds (ms), echo time (TE)=3.1/3.8 ms, flip angle=12°, slice thickness=1 mm, slice number=192, matrix=256×256. rs-fMRI data will be obtained via an echo planar imaging for 240 time points

Table 2 Locations of the non-acupoints for the SA group

Non-acupoint	Location
Non-acupoint (NA1)	In the middle of the Yanglingquan (GB34) and Zusanli (ST36) points, between the gallbladder and stomach meridian
Non-acupoint (NA2)	3 cun* below Yanglingquan (GB34), between the gallbladder and stomach meridian

*1 cun (≈20 mm) is defined as the width of the interphalangeal joint of the patient's thumb.
GB, gallbladder; NA, non-acupoint; SA, sham electroacupuncture; ST, stomach.

in the sequence: TR/TE=2000/30 ms, flip angle=90°, field of view=220 mm×220 mm, slice thickness=3.6 mm, slice number=32.

Data management and monitoring

The governance of the study data will include the principal investigator (C-ZL) and statistician, who will regularly monitor to ensure that all researchers involved in the study adhere to the proposed protocol. An annual progress meeting will be held mid-trial where the principal investigator can supervise the progress of recruitment and researchers can share advice on difficulties of study.

All study data will be assessed by outcome assessors and fully recorded in the CRFs. The research data will be input into Excel for storage. To ensure the accuracy of data entry, two researchers will independently enter the data, and any discrepancies will be resolved by tracing source data. Prior to the initiation of the trial, imaging scan parameters at all trial sites will be standardised to maximise consistency. Additionally, a professional technologist will assess the quality of each scan immediately after acquisition.

Participants' contact information and residential addresses will be securely recorded. Regular follow-up communications will be conducted to enhance protocol adherence while ensuring confidentiality.

Sample size

The primary clinical outcome is the time to first defecation. Based on the result of the previous study and clinical experience, the mean time to first defecation will be assumed to be 73.2 hours and 99.2 hours in the EA group and the SA group, respectively, with a SD of 30.1 hours. A total of 50 patients will be required to account for a 5% two-sided significance, 80% power and 10% drop rate, with 25 patients in each group. In terms of fMRI studies, a sample size of 20 participants may be sufficient to detect significant differences.[49–51] To account for potential data loss due to excessive head motion during scanning, we plan to recruit 25 patients in each group.

Statistical analysis

Clinical data analysis

SPSS software (V.20.0) will be used to conduct the statistical analyses of the clinical data. The primary analysis will be conducted according to the intention-to-treat (ITT) principle. The ITT population will include all participants who were randomly assigned to a treatment group and will be analysed according to their original allocation, regardless of the treatment actually received or any premature withdrawal from the study. Missing data for the primary outcome (time to first defecation) will be handled using multiple imputation based on the fully conditional specification method to generate 20 imputed datasets. Variables predictive of missingness will be included in the imputation model, and results will be combined using Rubin's rules. Secondary outcomes will be analysed using observed data only, without imputation of missing values.

The data analysts will be blinded to the patient group assignments. Normally distributed continuous variables will be presented as mean±SD, while non-normally distributed continuous variables will be reported as median and IQR. The comparisons between the EA group and SA group will be analysed using the independent samples t-test for normally distributed continuous variables and the Mann-Whitney U tests for non-normally distributed continuous variables, with the exception of postoperative hospital stay. As the length of postoperative hospital stay has typically right-skewed distribution, it will be analysed using a generalised linear model with a gamma link function. Categorical variables will be described as frequencies or percentages and will be compared between the two groups using the χ^2 test or Fisher's exact test. P values of less than 0.05 will be considered statistically significant for all analyses.

Neuroimaging data analysis

rs-fMRI data will be preprocessed using the DPABI toolbox implemented in MATLAB. Each functional image will undergo preprocessing, including the removal of the first 10 volumes, slice-timing correction, head motion correction, normalisation to the Montreal Neurological Institute space, and spatial smoothing with a 6 mm full-width at half maximum Gaussian kernel. Following preprocessing, the functional images will be resampled to a voxel size of $3 \times 3 \times 3\,mm^3$. The ALFF, ReHo, FC analysis will be performed on the preprocessed data of each group separately. Paired-sample t-tests will be conducted for within-group comparisons, while mixed effect models will be used to examine differences in brain region alterations between groups. Finally, Pearson/Spearman correlation analysis will be performed to determine the relationship between clinical data and fMRI imaging data.

Patient and public involvement

Patients and the public were not involved in the design, conduct, reporting or dissemination plans of this study.

Ethics and dissemination

The protocol was designed in accordance with the principles of the Declaration of Helsinki and approved by the ethics committees of Beijing University of Chinese Medicine (number 2024BZYLL0113), Cancer Hospital Chinese Academy of Medical Sciences (number 24/323-4603), Beijing Friendship Hospital Affiliated to Capital Medical University (number 2024-P2-081-01) and Beijing Chaoyang Huanxing Cancer Hospital (number 2024-011-02). Participants will be informed of the study protocol, potential benefits and risks before signing the paper-based informed consent form, allowing them to make a fully informed decision regarding their participation. The results will be disseminated through peer-reviewed publications. Important protocol amendments (eg, changes to eligibility criteria, interventions, or primary outcomes)

will be submitted to the Ethics Committee for prior approval. Any approved amendments will be updated in the public trial registry and promptly communicated to all investigators and site personnel. Participants will be informed of changes that may impact their willingness to continue participation. AEs related to trial participation will receive appropriate medical evaluation and treatment as required. Compensation for trial-related harm will be offered in accordance with institutional policies and applicable regulatory requirements. These arrangements will be clearly described in the informed consent form. No ancillary or post-trial interventions beyond standard care are planned.

DISCUSSION

POI, defined as a transient impairment of GI motility, is an inevitable complication following elective laparoscopic surgery for colorectal cancer.[2 52–54] The occurrence of POI is associated with delayed postoperative recovery, prolonged hospitalisation and increased healthcare expenditures.[54–58] Accumulating evidence highlights that EA may serve as a viable non-pharmacological strategy to enhance GI recovery after abdominal surgery.[14 59–62] Unlike conventional pharmacological treatments that primarily target intestinal inflammatory responses, preclinical studies have demonstrated that acupuncture can regulate postoperative GI motility through central mechanisms.[20 21] However, these effects have yet to be verified in clinical populations. The present study is the first clinical trial designed to evaluate the underlying cerebral mechanisms mediating its effects. Our findings may help bridge the gap between experimental research and clinical application and provide a neurobiological basis for the integration of acupuncture into postoperative care protocols.

Acupuncture has been extensively used in the management of GI disorders. According to traditional Chinese medicine theory, Zusanli (ST36) and Shangjuxu (ST37) are the most commonly selected acupoints for treating GI dysfunction.[17] Previous studies have found that stimulation of lower limb acupoints is more effective in promoting postoperative GI motility compared with abdominal acupoints.[18] Regarding EA parameters, a 2/100 Hz frequency has been demonstrated in the literature to be effective in alleviating postoperative pain,[63–65] suggesting its potential utility in perioperative settings. These pieces of evidence underscore the rationale for selecting specific acupoints and stimulation parameters in clinical applications of EA for POI. In terms of treatment duration, based on our team's previous research, the average time to the first postoperative defecation in patients receiving usual care was 99.36 hours.[18] Therefore, we will conduct a 5-day treatment protocol to ensure that all patients receive sufficient EA treatment. Time to first defecation is a commonly used indicator of postoperative GI recovery; hence, it was selected as the primary outcome measure. In addition, patients' subjective experiences of pain and abdominal distension will be assessed, along with the time to first intake of various types of food.[32]

rs-fMRI could identify spatially distributed networks with temporal synchronisation and characterise resting-state networks.[66] With regard to imaging data quality control, strict inclusion and exclusion criteria have been applied to ensure the reliability of the acquired data. Additionally, patients with excessive head motion or significant artefacts will be excluded during data analysis. Furthermore, given the multicentre nature of this study, we standardised the acquisition parameters with the assistance of professionals to reduce potential effects of MRI equipment variability on the study results. Currently, an increasing number of methods are being applied for the correction and analysis of multicentre data collection, which strengthens our confidence in conducting this multicentre clinical imaging study.[67–71]

This trial has several limitations. First, due to the inherent characteristics of acupuncture treatment, acupuncturists may not be blinded. Second, the SA group use minimally invasive acupuncture at non-acupoints, which may induce certain physiological effects, potentially underestimating the therapeutic efficacy of acupuncture. Third, we only include patients undergoing elective laparoscopic surgery, which may limit the generalisability of our findings to patients undergoing open or emergency surgery. However, this design ensures the homogeneity of the enrolled patients and minimises the impact of surgical type on imaging data. Fourth, although the sample size of 50 participants was sufficient to detect differences at the neuroimaging level, future studies with larger cohorts are warranted to validate our findings.

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Contributors All authors participated in this study. Conceptualisation: C-ZL, XW and N-NY; Methodology: Z-YW, XW and N-NY; Validation: Z-YW and X-YW; Investigation: Z-YW, WP, T-ZZ, JZ and W-WF; Resources: C-ZL, XW and N-NY; Data curation: J-FT, X-YW and LW; Writing–original draft: Z-YW, XW and N-NY; Writing–review and editing: Z-YW, XW and N-NY; Supervision: C-ZL, XW and N-NY; Project administration: XW and N-NY; Funding acquisition: C-ZL. N-NY is the guarantor.

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