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Original Article

Effect of electroacupuncture on internal carotid artery blood flow in patients undergoing laparoscopic gallbladder surgery: A randomized clinical trial

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ABSTRACT

Background: Little is known about the effect of electroacupuncture (EA) on cerebral blood flow. We investigated this question in patients undergoing laparoscopic cholecystectomy, hypothesizing that EA would increase cerebral blood flow during surgery.

Methods: Eighty-two patients undergoing laparoscopic cholecystectomy were randomly divided into receiving electroacupuncture and intravenous anesthesia (EA+IA) and receving intravenous anesthesia alone (IA). The patients in EA+IA were treated with EA at Baihui (GV 20), Shuigou (GV 26), unilateral Neiguan (PC 6) and unilateral Zusanli (ST 36) points 20 min before anesthesia until the end of the operation. The patients in IA received intravenous anesthesia alone. The internal carotid artery blood flow (Q), mean arterial pressure (MAP), end-tidal carbon dioxide pressure ($P_{ET}CO_2$) and heart rate (HR) were recorded respectively before anesthesia induction (T_1), 2 min after anesthesia induction (T_2), 1 min after pneumoperitoneum (T_3), 1 min after head-up tilt (T_4) and after anesthesia resuscitation (T_5).

Results: The internal carotid artery blood flow was significantly higher in EA+IA (mean [SD], T_3, 294.0 [89.6] ml min^{-1}; T_4, 303.8 [90.6] ml min^{-1}) than in IA (mean [SD], T_3, 246.4 [80.9] ml min^{-1}; T4, 253.5 [78.4] ml min^{-1}) at T_3 and T_4 ($P < 0.05$). There was no difference in blood flow between the two groups at T_2 and T_5. As compared with baseline (T_1), the internal carotid artery blood flow decreased at T_2-T_4 in two groups ($P < 0.05$). There were no differences in MAP, $P_{ET}CO_2$, and HR between the two groups.

Conclusion: Electroacupuncture intervention could reduce the decline of internal carotid artery blood flow in patients undergoing laparoscopic cholecystectomy.

Trial registration: ChiCTR: 2,100,041,761.

1. Introduction

Laparoscopic surgery has been widely used clinically due to its small trauma, wide field of vision, light pain, rapid recovery after surgery, short hospital stays and good abdominal cosmetic effect. Although artificial pneumoperitoneum during laparoscopic cholecystectomy is usually well-tolerated, the method alters the patient's cardiovascular and respiratory physiology challenging the control of cerebral blood flow.[1,2] General anesthesia, change of position, pneumoperitoneum may together lead to hemodynamic compromise[3,4] and may increase the risk of postoperative somnolence, delirium, delayed awakening, and postoperative cognitive dysfunction and other complications.[5]

During laparoscopic cholecystectomy, a large number of cardiopulmonary function changes due to anesthesia and mechanical ventilation may affect cerebral blood flow.[6,7] There is currently no effective means of monitoring cerebral blood flow, and previous studies have found that the changes in internal carotid artery blood flow are usually consistent with the changes in cerebral blood flow.[8–10] Electroacupuncture (EA) has been shown to increase cerebral blood flow, reduce ischemic infarction,[11] and EA pretreatment exerted a neuroprotective effect by previous clinical studies.[12] The vasoactive modulatory effect of EA at Dazhui (GV 14), Baihui (GV 20), and Shuigou (GV 26) acupoints increases perfusion on the affected side by releasing acetylcholine, leading to the release of nitric oxide.[13] EA can also decrease the expression of angiotensin

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II and its type 1 receptor, and thereby increases cerebral blood flow and vasodilation.[14] Therefore, we hypothesized that electroacupuncture could regulate cerebral blood flow in patients undergoing laparoscopic gallbladder surgery. In this current study, we aimed to investigate the changes in internal carotid artery blood flow in patients undergoing laparoscopic cholecystectomy by ultrasound continuous measurement of changes in internal carotid artery diameter and blood flow velocity, to evaluate the effect of electroacupuncture on changes in internal carotid artery blood flow in patients undergoing laparoscopic cholecystectomy.

2. Methods

2.1. Patients and setting

This study was approved by the Institutional Review Board of Yueyang Hospital of Integrated Traditional Chinese and Western Medicine, Shanghai University of Traditional Chinese Medicine (NO. 2020–066, August 21,2020). The study was conducted in accordance with the Declaration of Helsinki. The trial was registered prior to patient enrollment at https://www.chictr.org.cn/showproj.aspx?proj=119664 (ChiCTR 2,100,041,761, principal investigator: HU Lili, date of registration: Jan 4, 2021). Written informed consent was obtained from each participant. The inclusion criteria for patients who scheduled for laparoscopic cholecystectomy were as follows: (1) aged 18–75 years; (2) ASA status of I–II; (3) BMI 18–28 kg m^{-2}. Exclusion criteria were: (1) patients with known cerebrovascular disease, including cerebral infarction, cerebral hemorrhage, cerebrovascular stenosis, cerebral arteritis, etc.; (2) patients with severe liver and kidney function impairment (ALT, AST, BUN, Cr exceeding 1.5 times the normal value); (3) patients with previous central nervous system disorders; (4) patients who had undergone surgery along the route of meridian acupuncture; (5) patients with meridian skin infection; (6) patients who participated in other clinical trials within 4 weeks before enrollment; (7) other contraindications to electroacupuncture: pregnant women, pacemakers buried in the body, faintness, etc.

2.2. Randomization and masking

Study participants were randomized 1:1 into electroacupuncture group (EA+IA) and intravenous anesthesia group (IA) according to random digit table. Acupuncture points were covered with opaque sterile towels. Outcomes were assessed by trained investigators who were blinded to the treatment allocation. Other clinical staff, including surgeons, anesthesiologists, and ward staff, were unaware of the allocation.

2.3. Intervention

From 20 min before the induction of anesthesia to the end of surgery, EA was performed in patients in EA+IA at acupoints unilateral Neiguan (PC6), unilateral Zusanli (ST 36) and Baihui (GV 20), Shuigou (GV 26) by the same experienced acupuncturist . Sterile and disposable needles (size 0.40 × 25 mm, Suzhou Medical Supplies Factory, China) were inserted to a depth of 3–5 mm. The needles were manipulated until a *de qi* sensation was felt by the patient. The end of the needles was connected to Hua Tuo SDZ-III electronic needle therapy instrument (Suzhou Medical Supplies Factory). Parameters were set as disperse-dense with a frequency of 2 Hz/100 Hz, and the stimulation intensity was based on the patient's tolerance and comfort.

2.4. Anesthesia procedure

Upon arrival in the operating theatre, standard monitoring was applied: heart rate (HR), non-invasive blood pressure (NBP), pulse oxygen saturation (SpO_2), electrocardiograph (ECG), end-tidal carbon dioxide pressure ($P_{ET}CO_2$) and bispectral index (BIS) were routinely monitored. After the patient calmed down, the indicators were recorded as the basal level. Three-minute preoxygenation with 100 % oxygen preceded the induction phase in every patient. Anaesthesia was induced i.v. with propofol (3 ug ml^{-1}) and remifentanil (4 ng ml^{-1}) using a target-controlled infusion (TCI) system, cis-atracurium (0.15–0.2 mg kg^{-1}), and patients were orotracheally intubated 5 min later. Anaesthesia was maintained with TCI of propofol (2–2.5 ug ml^{-1}) and remifentanil (2–2.5 ng ml^{-1}). The depth of anaesthesia was monitored using BIS. Intensify analgesia with 1 to sufentanil (2 ug kg^{-1}, i.v.) before the start of surgery, as appropriate. Patients' lungs were mechanically ventilated in a volume-controlled mode with a tidal volume of 6–8 ml kg^{-1} body weight during the operation. The ventilatory frequency rate was set to 12–15 times min^{-1}. The ratio of inspiratory/expiratory was 1.0:2.0, inhalation oxygen concentration was 40 %, oxygen flow was 2 l min^{-1}, and $P_{ET}CO_2$ was maintained between 35 and 45 mmHg BIS was maintained at 40–60 and abdominal air pressure at 10–15 mmHg Intraoperative rehydration volume was 10 ml kg^{-1} h^{-1}. If mean arterial pressure (MAP) was lower than 20 % of the baseline, ephedrine 6 mg i.v. was administered. If the patient represented bradycardia (HR $\leq$ 50 times min^{-1}), atropine 0.5 mg i.v. was administered. Cardiovascular agonists were used up to once per patient. Metoclopramide 10 mg i.v. and ondansetron 4 mg i.v. were administered at the end of the procedure to prevent postoperative nausea and vomiting. Patients were extubated and transferred to the PACU when extubation criteria had been achieved.

2.5. Outcome measures

The primary outcome was the internal carotid artery blood flow. Measurements of mean internal carotid artery blood velocity were recorded for 10 to 14 cardiac cycles, 3 times in each of the following states: (1) before anesthesia induction (T_1), (2) 2 min after anesthesia induction (T_2), (3) 1 min after pneumoperitoneum (T_3), (4) 1 min after head-up tilt (T_4), (5) after anesthesia resuscitation (T_5). We measured the blood flow in the patient's neck using Wisonic Navi X high-grade digital color ultrasound, and the high-frequency line array ultrasound probe to determine the patient's right internal carotid artery diameter (D), peak systolic velocity (PS) and end-diastolic velocity (ED) . When measuring, the patient's head was deflected to the left. The linear array probe (8 MHz probe, insonation angle 60°) was evenly applied with an appropriate amount of coupling agent, and the probe was placed lightly about approximately 2 cm above the bifurcation of the common carotid artery to avoid turbulent flow. According to Poiseuille's law, the calculation formula of Q is as follows: $Q = ((PS + 2 * ED)/3) * \pi * (D^2/4) * HR$.[15,16] Secondary outcomes included, MAP, $P_{ET}CO_2$, HR at T_1, T_2, T_3, T_4, T_5 and extubation time. We recorded the presence of acupuncture adverse effects, such as needle sickness, retardation, bent needles, broken needles, etc.

2.6. Statistical analysis

In this study, we employed SPSS 23 software for data analysis. The quantitative data with normal distribution were expressed as mean and standard deviation (SD), and the quantitative data with skewed distribution were expressed as median and interquartile range (IQR). The qualitative data were presented as frequency count and proportion (ratio). In this study, Student's t-test, Mann-Whitney U test was applied to test the difference between two groups of quantitative data with normal or skewed distribution respectively, and Chi-square test was applied to test the difference between groups of qualitative data. Repeated measure ANOVA was conducted to judge the intergroup and intragroup differences for Q, HR, MAP and $P_{ET}CO_2$ over time. Figures were produced to show the change of Q, HR, MAP and $P_{ET}CO_2$ in different observation time points. In this study, two-tailed $P < 0.05$ was considered as statistically significant.

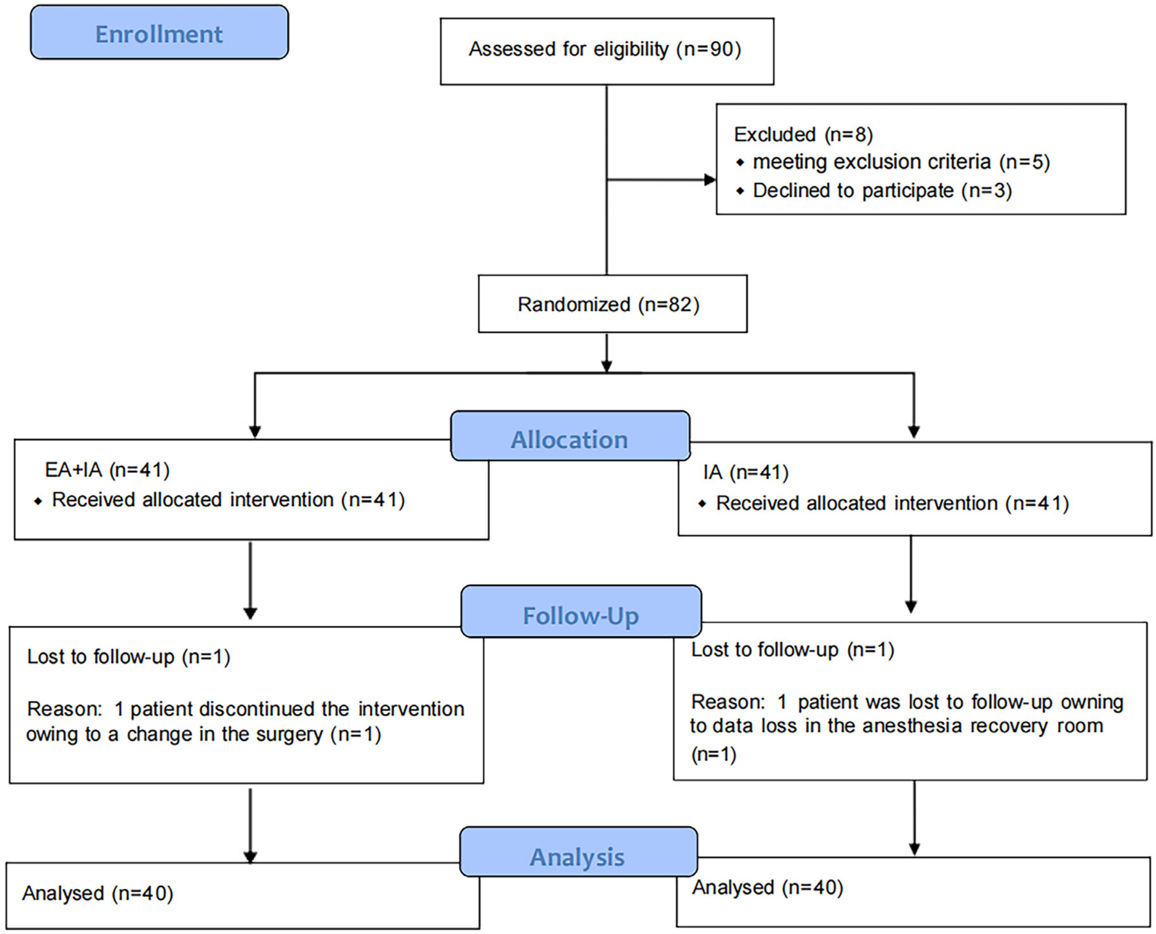

Fig. 1. Flowchart diagram of participants during the trial.

2.7. Sample size calculation

In our preliminary study, the mean value $u_1 = 200$ ml min^{-1} and standard deviation $\sigma_1 = 0.789$ of the internal carotid artery blood flow after the intervention of electroacupuncture were estimated ($n = 10$). According to previous reports,[17] the average value of internal carotid artery blood flow Under the dual action of anesthesia and pneumoperitoneum during laparoscopic cholecystectomy $u_2 = 178$ ml min^{-1}, the standard deviation $\sigma_2 = 30$. Using two degrees of freedom chi-square test with a significance alpha level of 0.05 ($\alpha = 0.05$), considering a dropout rate of 10 %, we defined a sample size of 88 participants.

3. Results

Ninety patients were screened for this study and eighty-two were eligible for enrollment. A patient discontinued the intervention owing to a change in the surgery in EA+IA. A patient was lost to follow-up owning to data loss in the anesthesia recovery room in IA (Fig. 1). Therefore, eighty patients were included in the study. The characteristics of patients such as age, gender, height, weight, BMI, and ASA status did not differ between the groups ($P > 0.05$) (Table 1).

The internal carotid artery blood flow was significantly higher in EA +IA than that in IA at 1 min after pneumoperitoneum and 1 min after head-up tilt ($P < 0.05$). There was no difference in blood flow between the two groups at 2 min after anesthesia induction and after anesthesia resuscitation. As compared with before anesthesia induction, the internal carotid artery blood flow decreased after 1 min head-up tilt in two groups ($P < 0.05$) and increased after anesthesia resuscitation in two groups ($P < 0.05$). There were no differences in MAP, $P_{ET}CO_2$, and HR between the two groups (Table 2).

The patient's extubation time was shorter in EA +IA compared with IA ($P < 0.05$) (Table 3). There was no significant difference in the duration of surgery among the two groups (Table 3).

We used repeated measures ANOVA to determine the effects of different groupings over time on Q, HR, MAP, and $P_{ET}CO_2$. There was no group × time interactions for Q, HR, MAP, and $P_{ET}CO_2$. We performed main effects test for the group factor and showed that there was a statistically significant main effect of the group factor on Q ($P < 0.05$), compared with IA, the changes of Q in EA +IA were more stable over time. The main effect for time on Q was found ($P < 0.05$). There was no significant difference in HR, MAP and $P_{ET}CO_2$ between the two groups (Fig. 2). No acupuncture side effect such as needle sickness, needle stasis and infection occurred in the perioperative period in both groups.

4. Discussion

The present study indicated EA intervention could reduce the decline of internal carotid artery blood flow in patients undergoing laparoscopic cholecystectomy. There were no differences in MAP, $P_{ET}CO_2$, and HR between the two groups.

EA intervention has been shown to increase cerebral perfusion and play a protective role in the brain.[18–20] The mechanisms underlying the EA-induced protection involve multiple factors in the brain and may be very complex. One mechanism of EA is via increasing perfusion by activating the intracranial cholinergic vasodilative system[18] and enhances the generation of NO and increases local circulation.[21] Previous acupuncture studies have mostly reported cerebral blood flow veloci-

Table 1
The demographic features of patients.

Variables	Total patients(n = 80)	EA+IA (n = 40)	IA (n = 40)	t/χ2	P
Age (years), mean (SD)	57.9 (11.4)	57.7 (12.3)	58.1 (10.6)	−0.40	2.559
Age (years), median (IQR)	61.00 (49.5, 66.5)	61.5 (49.0, 66.0)	59.0 (50.0, 67.5)	−0.11	0.916
Age group (years) n (%)				1.30	0.522
<50	20 (25.0)	12 (30.0)	8 (20.0)		
50–65	32 (40.0)	14 (35.0)	18 (45.0)		
>65	28 (35.0)	14 (35.0)	14 (35.0)		
gender, n (%)				1.25	0.263
Male	39 (48.8)	22 (55.0)	17 (42.5)		
Female	41 (51.2)	18 (45.0)	23 (57.5)		
Height (cm), mean (SD)	165.2 (7.2)	165.8 (6.6)	164.5 (7.7)	0.81	0.421
Weight (kg), mean (SD)	64.1 (8.6)	62.3 (7.1)	65.9 (9.5)	−1.973	0.052
BMI, n (%)				3.413	0.065
<24	50 (62.5)	29 (72.5)	21 (55.0)		
24–27.9	30 (37.5)	11 (27.5)	19 (37.5)		
ASA status				0.213	0.644
Class I	50 (62.5)	26 (65.0)	24 (60.0)		
Class II	30 (37.5)	14 (35.0)	16 (40.0)		

BMI: Body Mass Index.;EA: Electroacupuncture; IA: Intravenous anesthesia.; IQR: Interquartile range;SD: Standard deviation.

Table 2
The internal carotid artery blood flow condition after EA among patients undergo laparoscopic cholecystectomy.

Variables	Total patients (n = 80)	EA+IA (n = 40)	IA (n = 40)
Primary outcome			
Internal carotid artery blood flow (Q, ml min^{-1}), mean (SD)			
Before anesthesia induction (T_1)	367.5 (103.8)	346.4 (80.5)	388.5 (120.1)
2 min after anesthesia induction (T_2)	285.6 (90.9)	303.2 (90.4)	267.9 (89.1)
1 min after pneumoperitoneum (T_3)	270.2 (88.2)	294.0 (89.6)	246.4 (80.9) †
1 min after head-up tilt (T_4)	278.6 (87.9)	303.8 (90.6)	253.5 (78.4) †
after anesthesia resuscitation (T_5)	394.7 (132.9)	406.4 (132.9)	382.9 (133.5)
Difference between T_2 and T_1, median (IQR)	−73.3 (−118.9, −45.6)	−51.7 (−74.1, −25.4)	−106.9 (−169.7, −63.4) †,‡
Difference between Q T_3 and Q T_1, median (IQR)	−92.2 (−154.2, −39.3)	−60.2 (−101.0, −11.8)	−132.8 (−176.9, −88.2) †,‡
Difference between Q T_4 and Q T_1, median (IQR)	−82.3 (−146.8, −29.8)	−38.4 (−87.2, −16.5)	−140.8 (−169.1, −78.8) †,‡
Difference between Q T_5 and Q T_1, median (IQR)	11.7 (−16.4, 52.1)	32.7 (−3.9, 95.2)	0.6 (−38.8, 16.4) †,‡
Secondary outcomes			
Hear rate (rate min^{-1}), mean (SD)			
Before anesthesia induction T_1	69.5 (65.0, 78.0)	68.0 (62.5, 73.5)	72.5 (66.0, 79.5)
HR T_2(rate min^{-1})	60.0 (57.0, 64.0)	60.0 (57.0, 64.0)	60.5 (57.0, 65.5)
HR T_3(rate min^{-1})	62.0 (57.0, 65.0)	62.0 (59.5, 65.5)	60.5 (55.5, 65.0)
HR T_4(rate min^{-1})	62.0 (59.0, 65.0)	63.0 (60.0, 66.0)	61.0 (57.5, 64.0)
HR T_5(rate min^{-1})	69.0 (64.0, 76.5)	67.0 (62.5, 74.5)	70.0 (65.0, 77.0)
Mean arterial pressure (mmHg)			
Before anesthesia induction	90.0 (85.5, 97.0)	89.0 (83.5, 95.5)	92.0 (87.0, 99.0)
MAP T_2(mmHg)	75.0 (67.0, 82.5)	75.0 (67.0, 81.5)	73.5 (67.0, 84.0)
MAP T_3(mmHg)	84.0 (76.0, 97.0)	79.0 (73.5, 97.5)	86.0 (77.5, 97.0)
MAP T_4(mmHg)	90.0 (77.0, 100.0)	87.5 (76.0, 100.5)	90.0 (81.0, 96.0)
MAP T_5(mmHg)	90.5 (86.0, 95.5)	90.5 (85.0, 98.5)	90.5 (87.0, 95.0)
End-tidal carbon dioxide pressure ($P_{ET}CO_2$) (mmHg)			
Before anesthesia induction (T_1)	42.0 (40.0, 43.0)	42.0 (39.5, 43.5)	42.0 (40.0, 43.0)
$P_{ET}CO_2$ T_2(mmHg)	33.0 (31.0, 35.5)	33.0 (31.0, 36.0)	32.5 (30.5, 35.0)
$P_{ET}CO_2$ T_3(mmHg)	31.0 (30.0, 34.0)	31.0 (30.0, 34.5)	32.0 (30.0, 33.0)
$P_{ET}CO_2$ T_4(mmHg)	33.0 (32.0, 35.0)	33.5 (32.0, 36.0)	33.0 (31.0, 35.0)
$P_{ET}CO_2$ T5(mmHg)	41.0 (38.5, 43.0)	40.0 (37.0, 43.0)	42.0 (39.0, 45.0)

† , $P < 0.05$, EA + IA vs. IA;
‡ , $P < 0.05$, EA+IA vs. IA the adjustment of patients' age;EA: Electroacupuncture; IA: Intravenous anesthesia.; IQR: Interquartile range;SD: Standard deviation.

ties and ignored changes in cerebral vessel diameters,[22–24] and it has been shown that the internal carotid artery should not be regarded as a rigid vessel in studies of cerebral perfusion, and that changes in vessel diameters should also be taken into account.Both internal carotid artery blood flow velocity and internal carotid artery diameter were measured in this study. There were no significant differences in internal carotid artery diameter (D) and peak systolic velocity (PS) at 2 min after anesthesia induction, 1 min after pneumoperitoneum, 1 min after head-up tilt between the two groups. The end-diastolic velocity (ED) of the internal carotid artery (ICA) was significantly higher in EA+IA. It suggests that EA intervention may play a beneficial role in cerebral perfusion stabilization by regulating the end-diastolic velocity of the internal carotid artery. Few studies have been reported on the mechanism of carotid blood flow regulation by electroacupuncture, this requires further study.

The selection of acupuncture points was based on the results of previous series of studies.[20,25,26] In this study, we selected four acupoints, including Baihui, Shuigou, Neiguan, and Shusanli, which were common acupoints for regulating cerebral blood flow and protecting neurological functions.[27] The study confirmed that these four acupoints could regulate cerebral blood flow and regulating chemokines and various cell signal transduction pathways,and protect neurological functions.

Table 3
The operation related factors among patients undergoing laparoscopic cholecystectomy.

Variables	Total patients(n = 80)	EA+IA (n = 40)	IA (n = 40)	t/χ^2	P
Cardiovascular agonist frequency	8(10.0)	3(7.5)	5(12.5)	0.139	0.709
ephedrin	3(3.8)	1(2.5)	2(5.0)	0.000	>0.999
atropine	5(6.3)	2(5.0)	3(7.5)	0.000	>0.999
Operation time (h), mean (SD)	52.2 (8.3)	51.9 (9.3)	52.6 (7.4)	−0.37	0.709
median (IQR)	50.0 (45.0, 59.0)	50.0 (45.0, 58.5)	51.0 (46.5, 59.0)	−0.66	0.508
n (%)				0.00	1.000
<1 h	60 (75.0)	30 (75.0)	30 (75.0)		
≥1 h	20 (25.0)	10 (25.0)	10 (25.0)		
Extubation time (min)					
mean (SD) †	6.6 (3.8)	5.1 (3.1)	8.1 (3.8)	−3.90	0.000
median (IQR) †	6.0 (3.5, 10.0)	5.0 (3.0, 7.0)	9.0 (5.0, 10.5)	−3.51	0.000
n (%)				12.29	0.000
<10 min	58 (72.5)	36 (90.0)	22 (55.0)		
≥ 10 min	22 (27.5)	4 (10.0)	18 (45.0)		

† , P < 0.05, EA+IA vs. IA;EA: Electroacupuncture; IA: Intravenous anesthesia.; IQR: Interquartile range; SD: Standard deviation.

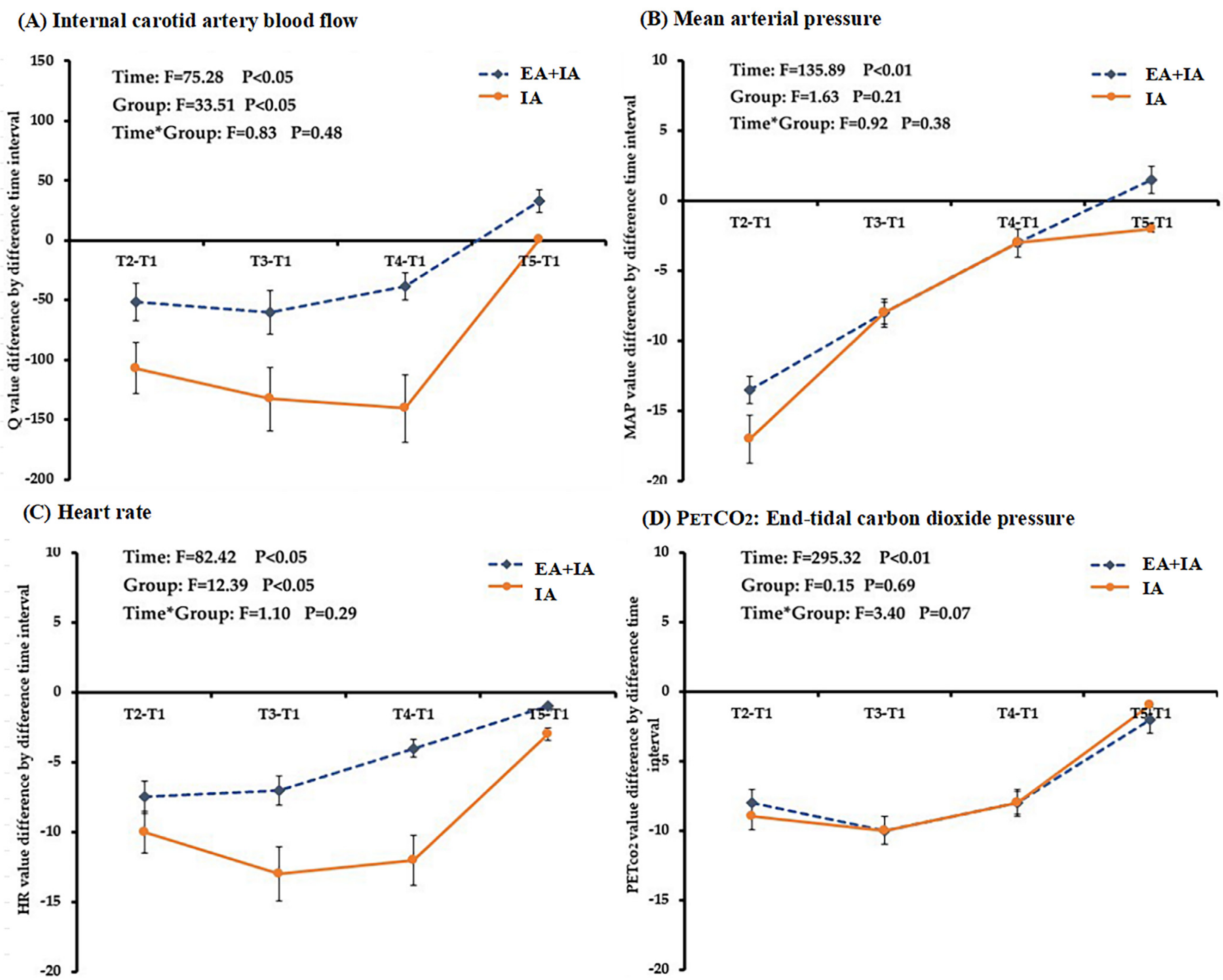

Fig. 2. Repeated measure ANOVA analysis of the differences between EA+IA and IA in difference time interval for Q value, HR, MAP and $P_{ET}CO_2$; HR: Heart rate; MAP: Mean arterial pressure; PETCO2: End-tidal carbon dioxide pressure; Q: The internal carotid artery blood flow.

When the frequency of electroacupuncture stimulation is 2 Hz/100 Hz alternating sparse-dense wave, it can release three kinds of substances such as enkephalin, endorphin, and dynorphin to reduce the use of anesthetic drugs,[28,29] which is widely used in clinical acupuncture anesthesia, and the sparse-dense wave of 2 Hz/100 Hz is also chosen in the present experiment. Previous literature on electroacupuncture stimulation intensity involves less and a limited range of options, the intensity is too large will lead to severe pain intolerable patients, so generally to the body to tolerate the maximum current is appropriate.

At 2 min after anesthesia induction, there was no difference in blood flow between the two groups. The difference between groups was only manifested at 1 min after pneumoperitoneum. It may be insufficient EA pretreatment time. Previous study have shown longer EA-pretreatment is relatively better to its protective effect of ischemic cerebral tissue.[30] Study explored the optimal duration of EA stimulation for protecting the brain against ischemic injury. The experiments were carried out in rats exposed to right middle cerebral artery occlusion (MCAO) for 60 min followed by 24 h reperfusion. The results showed that 30 min EA, starting at 5 min after the onset of MCAO (EA during MCAO) or 5 min after reperfusion (EA after MCAO), significantly reduced ischemic infarct volume, attenuated neurological deficits, and decreased death rate with a larger reduction of the ischemic infarction in the former group. Also, in group EA during MCAO, this protective benefit was positively proportional to the increase in the period of stimulation and increased protection in response to EA from 5- to 30-min stimulation.[25] Surprisingly, EA for 45 min did not show reduction in the neurological deficits or the infarct volume and instead demonstrated an increase in death rate in this group.[25] This suggest that the optimal duration of EA may be 30 min.

The results of this study suggest that for the decrease of internal carotid artery blood flow during laparoscopic cholecystectomy. Electroacupuncture can reduce the decrease of internal carotid artery blood flow at certain intraoperative stages, which may improve cerebrovascular autoregulation, regulate the level of neurotrophic factors associated with cerebral protection, and promote the rapid restoration of intracerebral environmental stability, thus exerting the cerebral protective effect of electroacupuncture. In future research, we will explore the mechanism of electroacupuncture regulating cerebral blood flow.

This study also has some limitations: $P_{ET}CO_2$ in the awake state could not be compared with values during anesthesia, pneumoperitoneum, and tilt, as the former was sampled from the humidifier filter connected to a facemask with high-flow oxygen whereas the latter were sampled from the filter connected to the endotracheal tube. The measurement of internal carotid artery flow may be influenced by the operator's habit. This is a single-center study with a small sample size the patients included are adults with a single disease type. A multi-center, large sample of clinical observational studies is still needed for further investigation.

During laparoscopic cholecystectomy, internal carotid artery blood flow declined with anesthesia and with pneumoperitoneum. EA at GV 20, GV 26, PC 6 and ST 36 (sparse wave, 2 Hz/100 Hz) could reduce the magnitude of the decrease in internal carotid artery blood flow at certain stages of the operation. EA pretreatment may slow down the dramatic intraoperative cerebral blood flow changes in patients undergoing laparoscopic cholecystectomy. EA may be an effective protective measure especially in fragile patients predisposed to adverse cerebrovascular events.

CRediT authorship contribution statement

Lili Hu: Methodology, Software, Validation, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration. **Yongyan Zhang:** Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Ying Li:** Writing – review & editing. **Ruiping Wang:** Investigation, Data curation. **Hua Xu:** Conceptualization, Funding acquisition.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

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Ethical statement

This research was reviewed and approved by the institutional review board of Yueyang Hospital of Integrated Traditional Chinese and Western Medicine, Shanghai University of Traditional Chinese Medicine (registration number 2020–066). Informed consent was obtained from all participants.

Data availability

The data that support the findings of this study are available from the corresponding authors.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.imr.2024.101097.

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