Research Article

BIOMEDICAL Journal of Scientific & Technical Research

ISSN: 2574 -1241

DOI: 10.26717/BJSTR.2025.61.009633

Efficacy of Electroacupuncture Analgesia for Acute Postoperative Pain After Abdominal Surgery in High Altitude: A Randomized Controlled Clinical Trial

Yajun Ding[1,3#], Wencheng Dai[1]*, Jiumai Ladan[2]*, Pengcuo Cairang[2], Jiahao Wang[2], Xingcun Zhang[2], Manlin Duan[3] and Hanzhong Cao[1]

[1]*Tumor Hospital Affiliated to Nantong University, Nantong Tumor Hospital, P.R. China*

[2]*Department of Anesthesiology, Guide County People's Hospital, Hainan Tibetan Autonomous Prefecture, P R China*

[3]*Department of Anesthesiology, Jinling Clinical Medical College, Nanjing University of Chinese Medicine, P R China*

[#]*These authors contributed equally to this work as first authors*

***Corresponding author:** Hanzhong Cao, 30 Tongyang North Road, Tongzhou District No.226361, Nantong, Jiangsu Province, China

ARTICLE INFO

Received: April 13, 2025

Published: April 30, 2025

Citation: Yajun Ding, Wencheng Dai, Jiumai Ladan, Pengcuo Cairang, Jiahao Wang, Xingcun Zhang, Manlin Duan and Hanzhong Cao. Efficacy of Electroacupuncture Analgesia for Acute Postoperative Pain After Abdominal Surgery in High Altitude: A Randomized Controlled Clinical Trial. Biomed J Sci & Tech Res 61(4)-2025. BJSTR. MS.ID.009633.

ABSTRACT

Background: Electroacupuncture is a non-pharmacological intervention that is widely considered to treat pain. However, the clinical efficacy of electroacupuncture analgesia for acute postoperative pain after abdominal surgery at high altitude was unclear.

Objective: The purpose of this study was to evaluate the efficacy and safety of electroacupuncture analgesia for acute pain after abdominal surgery in high altitude, and to investigate the effects and clinical significance of sufentanil intravenous controlled analgesia and electroacupuncture analgesia on serum expression levels of IL-6, PCT and CRP in patients.

Study Design: This study was a single-center, randomized, double-blind, drug-controlled clinical trial in a high-altitude hospital in northwest China.

Methods: Patients after abdominal surgery were randomly assigned to PCIA + shamEA and EA + shamPCIA group. In the PCIA + shamEA group, sufentanil was treated at 0.04 ug× Kg-1h-1 and sham EA, and EA + shamPCIA received EA at 2Hz / 100 Hz at GB34 and LR6. Patients in each group had two EA sessions or sham EA immediately and 24 hours after surgery. The primary outcome measures were resting and active VAS scores 2h, 4h, 8h, 12h, 24h and 48h and serum IL-6, PCT and CRP levels 48h (T0), immediate (before EA, T1) and 24h (T2) and 48h (T3). Secondary outcome measures included PONV score, OAA / S score, abdominal distension score at 2h, 4h, 8h, 12h, 24h and 48h after surgery; the incidence of respiratory depression within 48 hours after surgery, and the time of first exhaust and defecation.

Results: 59 patients undergoing abdominal surgery were randomized to PCIA + shamEA (n=24) and EA + shamPCIA (n=25) and included in the intention-to-treat analysis. Compared with the PCIA + shamEA group, the EA + shamPCIA group had lower activity pain scores at 2h than the PCIA + shamEA group ($P < 0.05$), and the resting and activity scores at 4h, 8h, 12h, 24h and 48h after the EA + shamPCIA group were significant compared with the PCIA + shamEA group ($P < 0.001$). Compared with T1, serum IL-6 level in T3 in PCIA + shamEA group was significant within the group ($P < 0.001$), and in T3 in EA + shamPCIA group ($P < 0.05$). Serum PCT expression levels in the EA + shamPCIA group,Compared with T1, the expression level of T2 and T3 was decreased, and the intragroup difference was significant ($P < 0.01$). Serum CRP levels in the PCIA + shamEA group decreased at T3 compared to T1, with significant differences within the groups ($P < 0.05$). Serum CRP levels in EA + shamPCIA in the group, T2 higher than T1, within-group differences were significant ($P < 0.001$), T3 higher than T2, within-group differences were significant ($P < 0.01$).

Conclusion: Electroacupuncture analgesia for acute pain after abdominal surgery in high altitude has better analgesia than sufentanil continuous intravenous analgesia, which can reduce the expression level of IL-6 and PCT, increase the expression level of CRP, inhibit inflammatory response, and relieve acute pain after abdominal surgery. Meanwhile, electroacupuncture analgesia can relieve postoperative nausea, vomiting and abdominal distension, shorten the time of the first exhaust and defecation, and have almost no adverse effects on the patient's consciousness and breathing.

Keywords: Electroacupuncture Analgesia; Abdominal Surgery; High Altitude; Acute Pain; Vas Score; IL-6; PCT; CRP

Introduction

Postoperative pain is an inevitable result of the surgical procedure. With the incision near the diaphragm and a dense network of nerves in the abdominal area, patients after abdominal surgery often have severe pain [1]. A study conducted in China showed that 58.7% of patients still reported moderate to severe pain within the first 24 h of the postoperative period, with abdominal surgery being the main type of surgery [2]. A survey conducted in Turkey showed that 37.3% of the subjects had moderate pain at 8 h after abdominal surgery and 35.7% had severe pain [3]. Improper management of postoperative pain can lead to immunosuppression, delayed wound healing, increased risk of postoperative infection, unfavorable to early ambulation, prolonged hospital stay, and increase the likelihood of Venous Thromboembolism VTE, thus reducing the quality of life of surgical patients after surgery [4].In the high altitude environment, due to the elevation of altitude, the partial pressure of oxygen in the air decreases, resulting in insufficient oxygen partial pressure of the gas inhaled by the body, the blood can not get sufficient oxygenation in the lungs, and the partial oxygen pressure of arterial blood drops, and hypoxemia occurs.Due to severe pain and other reasons, the reduced respiratory amplitude may further increase the risk of hypoxemia, and even threaten the life safety of patients because of ischemia and hypoxia of important organs. Therefore, the control of acute postoperative pain in patients undergoing abdominal surgery in high altitude and low oxygen environment remains a serious problem to be addressed. So far, the most common pain management methods in clinical practice are local anesthetics (such as ropivacaine) for controlled epidural analgesia (PCEA) or opioid (such as sufentanil) and opioid (oxycodone) combined with μ -receptor and κ -receptor for controlled intravenous analgesia (PCIA) [5].

Notably, Feng XX, et al. [6] found that oxycodone had better results in reducing postoperative visceral pain, maintaining sedation levels, reducing postoperative PONV and pruritus compared with sufentanil as one of the promising alternatives to PCIA for acute pain after abdominal surgery. However, its choice needs to consider many factors, such as the high cost of oxycodone and the risk of opioid abuse. Meanwhile, respiratory depression is one of the adverse reactions of opioids, aggravating the risk of postoperative hypoxemia in patients with high altitude and low oxygen environment. As a pharmacological alternative therapy for postoperative analgesia, manual acupuncture is effective for inflammatory and neuropathic pain [7], while electroacupuncture analgesia receives wide attention for its advantages of safety, effectiveness, low price, simple operation and easy to be accepted by patients [8]. As the main cause of infection and pain in the body, the levels of inflammatory factors to some extent reflect the changes of postoperative pain in the body. The correlation between postoperative analgesia and inflammatory response-related biological markers, including C-reactive protein (C-reactive protein, CRP), interleukin-6 (interleukin-6, IL-6), and procalcitonin (procalcitonin, PCT).

No studies on whether electroacupuncture analgesia could affect the expression levels of IL-6, CPR and PCT, and suppress inflammation and stress to reduce acute postoperative pain in patients undergoing abdominal surgery. "Yanglingquan" acupoint (GB34) and "Zhongdu" acupoint (LR6) are good acupoints in the treatment of abdominal pain and abdominal distension. According to the ancient traditional Chinese medicine "Lingshu meridians", acupuncture "yangLinquan" and "Zhongdu" can play the role of analgesia and promote gastrointestinal peristalsis, effectively relieve the symptoms of abdominal distension and abdominal pain, and promote postoperative defecation and exhaust. The efficacy and safety of electroacupuncture for GB34 and LR6 analgesia for postoperative acute abdominal pain at high altitude have not been reported in the literature. To reduce the potential short-and long-term negative effects, optimizing postoperative pain management is necessary. Clinical practice guidelines also emphasize that safe and effective pain management is a high priority to improve postoperative recovery [9]. Therefore, using electroacupuncture bilateral GB34 and LR6, we observed the effectiveness and safety of acute pain within 48 hours after abdominal surgery in high altitude, and discussed the effects and clinical significance of sufentanil intravenous controlled analgesia and electroacupuncture analgesia on serum IL-6, PCT and CRP.

Data and Methods

Study Design and Case Source

This study used a single-center, randomized, double-blind, drug-controlled clinical trial and was conducted in the anesthesiology department of our hospital from August 2024 to December 2024. The protocol was executed in accordance with the Declaration of Helsinki and approved by the hospital Ethics Review Board (permission number: 2024-070). All participants provided written informed consent before participation. We followed the ACURATE: guidelines for reporting sham controls in acupuncture trials [10].

Sample Size Estimation

This trial was a superiority test, and the sample size was estimated according to previous literature reports and preliminary clinical pretest results. Among them, postoperative electroacupuncture relieved postoperative pain by 90% efficiency (excluding adverse reactions such as respiratory depression, nausea and vomiting, drowsiness, and abdominal distension), postoperative control group relieved postoperative pain by 30% efficiency (excluding adverse reactions such as respiratory depression, nausea and vomiting, drowsiness, and abdominal distension), take the test level $\alpha = 0.05$, the test efficiency Power $(1- \beta) =0.80$, the sample size ratio of electroacupuncture group and control group is 1:1, through the formula can be calculated that the sample size of both groups was 24, and the total sample size was 48. The intervention was simple, short observation time, good patient compliance, an estimated shedding rate of 10%, and a total sample size of 54 patients.

Inclusion Criteria

Age 18-65 years, gender limitation, abdominal surgery patients under general anesthesia, and agreed to participate in this trial and live in the jurisdiction of Qinghai Province for at least 5 years.

Exclusion Criteria

Skin lesions in Zhongdu and Yanglingquan acupoints in patients, patients with severe arrhythmia and heart failure, have had preoperative deep vein thrombosis or severe swelling of the lower limbs, serious complications during treatment (e. g. coma, cardiac arrest, etc.),participated in other clinical trials in the last 2 weeks, with a long history of alcohol abuse, opioid addiction, or dependence, pregnant women, patients with chronic obstructive pulmonary disease, and patients with severe communication disorders.

Standards for Elimination, Stopping, and Shedding

The jects requested to withdraw during the trial, violates the trial protocol, and a serious adverse events occurred during the trial.

Randomization Method, Allocation Concealment, Blind Implementation

Random numbers were generated by SPSS21.0, and the 54 patients to be included were divided into control groups and electroacupuncture groups in a ratio of 1 : 1 according to the random block group method. The information of recording group and group processing method is printed into the opaque envelope with serial numbers 1~54 respectively, and is kept and distributed by special personnel. Patients who met the inclusion criteria were recruited and the envelope grouping protocol was followed before their first treatment. The trial used a double-blind design, and the patient, the anesthesiologist, the anesthesia nurse and the data statisticians did not know the grouping plan until the unblind.

Evaluating Indicator

The primary outcome measures were VAS scores and serum IL-6, PCT, CRP at 2h, 4h, 8h and 18 h, 24h (T0), 48h, T1), 24h (T2), 24 h and 48h (T3). Secondary outcome measures included PONV score, OAA / S score, abdominal distension score at 2h, 4h, 8h, 12h, 24h, and 48h after surgery; incidence of respiratory depression within 48h and time of the first exhaust bowel movement. When the patient was asleep, the assessors can determine the score of the relevant time point according to the patient's recall while awake.

Intervention Process and Data Acquisition

The intervention process and data acquisition time points are shown in Figure 1.

	Screening	intervention period					
	pre-operation	postoperation					
	48h	0h	2h	4h	8h	12h	24h	48h
Screen								
informed consent	•							
inclusion exclusion criteria	•							
randomized grouping	•							
Intervention								
PCIA+shamEA		•					•	
EA+shamPCIA		•					•	
Evaluation index								
VAS			•	•	•	•	•	•
PONV			•	•	•	•	•	•
respiratory depression occurs								•
OAA/S			•	•	•	•	•	•
time of first exhaust defecation								•
bloating score			•	•	•	•	•	•
IL-6	•	•					•	•
CRP	•	•					•	•
PCT	•	•					•	•

Note: PCIA: patient-controlled intravenous analgesia; EA: lectroacupuncture; VAS: visual analogue scale; PONV: postoperative nausea and vomiting; OAA/Observer's assessment of alertness/sedation; IL-6: interleukin-6; CRP: C-reactive protein PCT; procalcitonin.

Figure 1: Intervention process and data acquisition time.

Baseline Data Acquisition

Patient age, height, weight, body mass index, gender, ASA grade, surgical category, surgical method, operation time, medical history of hypertension, and medical history of diabetes mellitus.

Electroacupuncture and Analgesic Treatment Process

In the EA + shamPCIA group, bilateral "Yangling quan" point (GB34) and "Zhongdu" point (LR6) were taken for routine skin disinfection. The surgeon stood on the acupuncture side and held a 0.40×50mm disposable disinfection acupuncture needle on the right hand, about 35mm vertically into the skin. After getting gas (acid, swelling, anesthesia, sinking and other reactions at the acupuncture site), fix the acupuncture needle, connect SDZ-type electroacupuncture treatment instrument (Suzhou Medical Supplies Factory Co., LTD.), use density wave, pulse frequency was 2Hz / 100Hz, the intensity was based on the patient's tolerance (output power 0.3VA, 250 Ω load impedance), and release the needle after 0.5h of stimulation. The analgesia pump was connected to the peripheral venous tube and was carried out simultaneously with the acupuncture treatment. Only 100 ml of 0.9% sodium chloride solution was added to the analgesia pump, and the load, administration mode, parameter setting of the analgesic pump and the treatment measures for adverse reactions in the treatment were all the same as the control group. Sign the informed consent form and before the treatment, introduce them to relieve the patient's fear and tension. After the operation, the first treatment began after the patient was awake, and the second treatment began 24 hours after surgery. Each treatment was performed for 30min. For the control group, 1 inch above both "Yanglingquan" point and "Zhongdu" point (proximal heart end) was taken, and the fake electric needle was treated with a sleeve. Acupuncture needle only contact with patients skin actual and not into the skin, patients can feel acupuncture skin feeling after fixed needle, hua tuo brand SDZ-type treatment instrument, this group treatment instrument will output line in the machine, no current output, not the effect of electric stimulation, at the same time off the machine alarm setting, other operation with electric needle group. Sufentanil PCIA was also performed.

Sufentanil Protocol (PCIA)

Sufentanil citrate injection (Yichang Renfu Pharmaceutical Co., LTD., 1ml: 50 ug, 31A102011) 100 ug plus 0.9% sodium chloride solution diluted to 100ml injection analgesia pump (Kelun Pharmaceutical). The parameters of analgesia pump were set as: load dose 0.02 ug × kg-1, continuous maintenance amount 0.04 ug×kg-1h-1, automatic control dose 0.02 ug×kg-1, and locking time of 10min. After surgery, intravenous loading dose was immediately followed by analgesic pump for 2d. Patients with nausea and vomiting received intravenous azazazetron 10mg, serious adverse effects, respiratory rate <10 times / minute, PCIA, and naloxone if necessary.

Detection of The Biochemical Indicators

3 mL of venous blood was collected 48h (T0), before the procedure (T1), 24h (T2) and 48h (T3), 10% EDAT-Na 40ul aprotinin 40ul, centrifugation (3000 r/min, 10min), and stored in a-20 °C refrigerator for testing. Serum C-reactive protein (CRP), interleukin-6 (IL-6), and procalcitonin (PCT) were determined by enzyme-linked immunosorbent assay.

Statistical Method

Mapping and data were analyzed using SPSS21.0 and GraphPad Prism 9.5 software (GraphPad, Inc., CA, USA). In this trial, patient age, height, weight, body mass index, VAS score, time of first postoperative exhaust and defecation, and inflammatory factor level were all measured data. For measurement data, Shapiro-Wilk test, if the data follows normal distribution, mean ± standard deviation for statistical description of concentration and dispersion degree; without normal distribution, the median (upper and lower quartiles) (M, P25, P75)) for statistical description of concentration and dispersion degree, and the difference between groups using Mann-Whitney U test or Wilcoxon test, and Friedman test. In this trial, patient sex composition ratio, ASA grade, surgical category, surgical method, incidence of respiratory depression, history of combined hypertension and diabetes mellitus were expressed by frequency and percentage, using the χ 2 test of the four-grid table. In order to more accurately express the subjective perception of patient pain, the VAS scores were scored at 10 times the measured values and included in the statistical analysis. $P < 0.05$ was considered as a statistically significant difference.

Result

Patient and baseline characteristics

A total of 54 patients undergoing abdominal surgery were planned to perform analgesia after PCIA or EA, and 51 eligible patients were included and 3 patients were excluded for different reasons. Fifty-one patients were randomized to receive either PCIA + sham EA (n=25) or EA + shamPCIA (n=26) (Figure 2). Two patients were withdrawn from the study due to an altered surgical procedure (1 in EA + shamPCIA group and 1 in PCIA + shamEA group). Among the patients who completed the intervention, 24 patients in the PCIA + shamEA group and 25 patients in the EA + shamPCIA group, showed no significant difference in baseline characteristics between the two groups ($P > 0.05$) (Table 1). Notably, out of 49 patients, 2 laparotomy cases were in the EA + shamPCIA group (Table 2).

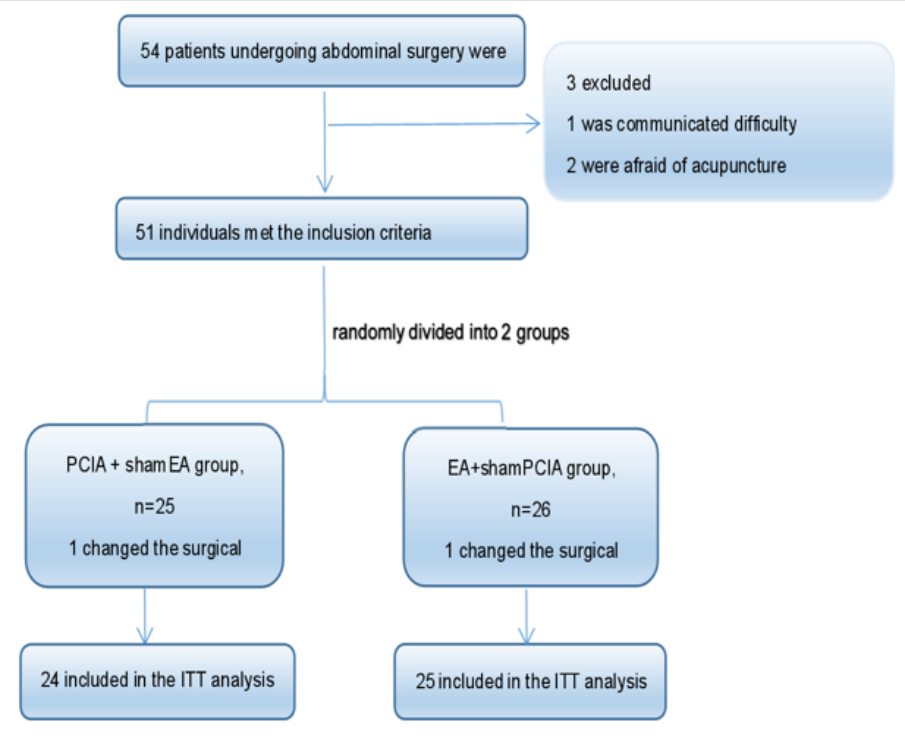

Figure 2: Study flowchart. EA: electroacupuncture; ITT: intention to treat; PCIA: patient-controlled intravenous analgesia.

Table 1: Baselin characteristics of patients.

	PCIA+shamEA(n=24)	EA+shamPCIA(n=25)	P Value
Age(year)mean±SD	42.5±12.1	45.6±12.1	0.381
Height(cm)mean±SD	163.3±7.1	16301±8.6	0.925
Weight(kg)mean±SD	67.3±12.6	63.4±13.7	0.311
Body mass index (kg/m^2) mean SD	25.1±3.7	23.7±3.5	0.173
Sex(M/F), n	7/17	7/18	0.928
ASA class (I/II), n	3/21	4/21	1.000
Type of operation			
hysterectomy, n (%)	4(80%)	1(20%)	0.321
Salpingectomy, n (%)	3(75%)	1(25%)	0.572
cholecystectomy, n (%)	12(42.9%)	16(57.1%)	0.322
Appendectomy, n (%)	5(41.7%)	7(58.3%)	0.560
Mode of operation			
Laparoscope, n (%)	24(100.0%)	23(92%)	0.490
No Laparoscope, n (%)	0.(0.0%)	2(8%)	
Operation time(min) M (P25, P75)	61(47.75,98.75)	63(44.86%)	0.575
Operation time ≥ 2h, n (%)	5(62.5%)	3(37.5%)	0.653
History of diabetes, n (%)	5(20.8%)	7(28.0%)	0.560
History of hypertension, n (%)	8(37.5%0	7(28%)	0.478

Table 2: Pain scores at 2 h, 4 h, 8 h, 12 h, 24 h,48 h Postoperatively.

	PCIA+shamEA (n=24)	EA+shamPCIA (n=25)	Z Value	P Value
2h postoperatively M (P25, P75)				
VAS(R)	0(0,0)	0(0,0)	1.372	0.170
VAS(A)	20(0,27,5)	0(0,15)	2.640	0.008
4h postoperatively M (P25, P75)				
VAS(R)	10(0,20)	0(0,0)	3.176	<0.001
VAS(A)	20(20,30)	0(0,20)	4.351	<0.001
8h postoperatively M (P25, P75)				
VAS(R)	10(0,20)	0(0,0)	4.591	<0.001
VAS(A)	30(20,30)	0(0,20)	4.949	<0.001
12h postoperatively M (P25, P75)				
VAS(R)	10(0,20)	0(0,0)	4.579	<0.001
VAS(A)	30(20,30)	0(0,20)	5.414	<0.001
24h postoperatively M (P25, P75)				
VAS(R)	15(2.5,20)	0(0,0)	4.847	<0.001
VAS(A)	30(20,30)	0(0,15)	5.805	<0.001
28h postoperatively M (P25, P75)				
VAS(R)	10(0,20)	0(0,0)	4.022	<0.001
VAS(A)	30(20,30)	0(0,5)	5.769	<0.001

Note: PCIA: patient-controlled intravenous analgesia; EA: electroacupuncture; VAS: visual analogue scale.

Electroacupuncture Analgesia Can Effectively Relieve Acute Pain After Abdominal Surgery

To explore the effectiveness of the two analgesia on acute postoperative pain after abdominal surgery by evaluating VAS scores at 2h, 4h, 8h, 12h, 24h and 48h after abdominal surgery.The results showed that compared with PCIA+shamEA group, the activity pain scores of EA+shamPCIA group were lower at 2 h after surgery than PCIA+shamEA group(P<0.05), and the rest and activity scores of EA+shamPCIA group were lower at 4h,8h,12h,24h and 48h after surgery. Compared with the PCIA + shamEA group, the differences in resting and activity scores at 4h, 8h, 12h, 24h, and 48h after surgery were significant (P <0.001) (Table 2), indicating that electroacupuncture analgesia can effectively relieve acute pain after abdominal surgery. It was noteworthy that the difference between the resting pain scores at 2h after surgery was not significant (P> 0.05) (Table 2), which may be related to the residual effects of intraoperative analgesia and sedative drugs.

Electroacupuncture Analgesia Can Reduce the Expression Level of Il-6 And Pct, Increase the Expression Level of CRP, Inhibit the Inflammatory Response, And Relieve the Acute Pain After Abdominal Surgery

Patients in both groups were measured 48h before surgery(T0), immediately after surgery(T1), 24h after surgery(T2), and 48h after surgery(T3).To explore the effect of electroacupuncture analgesia on perioperative inflammatory factors by measuring the expression levels of IL-6, CRP and PCT.The results showed that there was no significant difference in IL-6, CRP and PCT between the two groups (Figures 3a, 3d & 3g). The expression levels of IL-6, PCT, and CRP in the PCIA + shamEA group, TI and T0 no within-group differences were significant (P> 0.05, Figures 3b, 3e & 3h), and T2 and T0 no within-group differences were significant (P> 0.05, Figures 3b, 3e & 3h), indicated that postoperative analgesia with sufentanil did not have an effect on the expression levels of IL-6, PCT, and CRP within 24h after surgery in patients undergoing abdominal surgery. PCIA + shamEA group, T3 compared to T1, significant differences in IL-6 levels (Figure 3b, P <0.001), and there were significants in IL-6 expression levels between at T3 and T1(Figure 3c, P 0.05) in the EA+shamPCIA group. Note that there was a significant difference in IL-6 levels between the two points (T1 and T2) before and after the EA + shamPCIA group, but between the two points (T1, T2) before and after the PCIA + shamEA group, indicating that the electroacupuncture intervention could reduce the expression level of IL-6. The PCT expression level in the PCIA + shamEA group, T0 with T1, T1 with T2, and T1 with T3, None of the three time points was significant (Figure 3e, P>0.05), However, the PCT expression levels in the EA + shamPCIA group, In contrast to T1, The reduced expression levels at the T2 time point, Group differences were significant (Figure 3f, P<0.01), In contrast to T1, Reducreduced expression levels at time T3, Group differences were significant (Figure 3f, P<0.01), suggstrated that electroacupuncture intervention reduced the expression level of PCT, However, sufentanil analgesia had little effect on the expression level of perioperative PCT in patients undergoing abdominal surgery. CRP levels in the PCIA + shamEA group decreased the expression levels at the T3 point compared to the T1 (Figure 3h, P <0.05), while CRP levels in the EA + shamPCIA group increased significantly at the T2 and T3 points than T1, with significant differences within the group (Figure 3i, P <0.001, P <0.01), indicating that electroacupuncture analgesia can increase the expression level of CRP in patients, and that the two analgesic modes have opposite effects on the expression level of CRP.

DOI: 10.26717/BJSTR.2025.61.009633

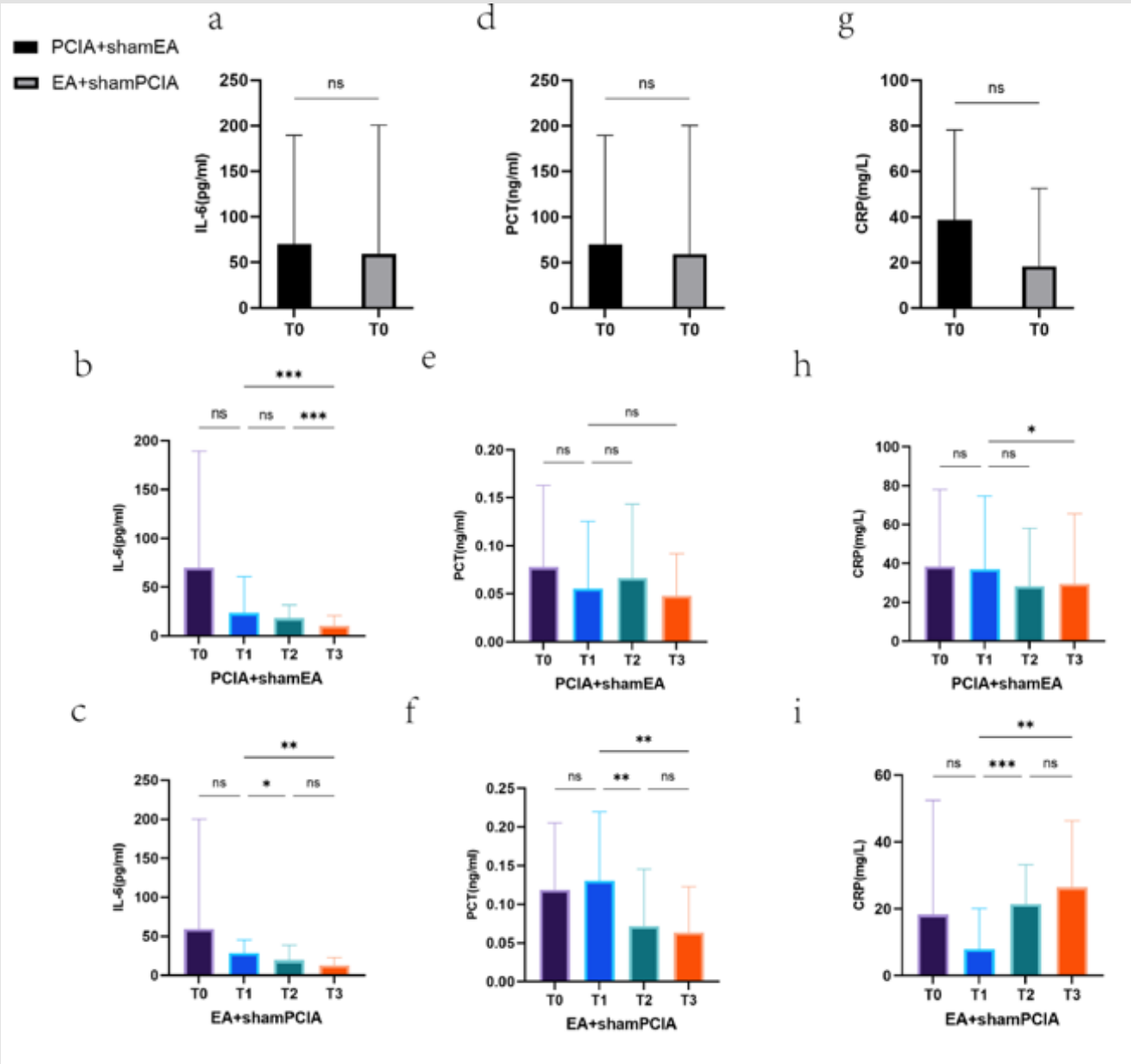

Figure 3: Effect of two analgesic methods on the expression levels of IL-6, CRP and PCT during the rioperative period of abdominal surgery.

a) IL-6 expression levels at 24h before surgery in both groups.

b) Perioperative IL-6 expression levels in the PCIA + shamEA group.

c) Perioperative IL-6 expression levels in the EA + shamPCTA group.

d) PCT expression levels at 24h before surgery in both groups.

e) Perioperative PCT expression levels in the PCIA + shamEA group.

f) Perioperative PCT expression levels in the EA + shamPCTA group.

g) CRP expression levels at 24h before surgery in both groups.

h) Perioperative CRP expression levels in the PCIA + shamEA group.

i) Perioperative CRP expression levels in the EA + shamPCTA group. PCIA+shamEA(n=24), EA+shamPCIA(n=25). Differences between groups were compared using the Wilcoxon test, and differences within groups were compared using the Friedman test. *P<0.05.**P<0.01.***P<0.001.

Electroacupuncture Analgesia Reduces Nausea and Vomiting, Increases the Degree of Consciousness, And Reduces the Incidence of Respiratory Depression

The safety of the two types of analgesia was investigated by evaluating the PONV score, OAA / S score at 2h, 4h, 8h, 12h, 24h and 48h after surgery.The results showed that compared with the PCIA+shamEA group, the EA+shamPCIA group had 2h, 4h, 8h, 12h, 24h and 48h PONV after surgery, the score difference was significant(Table 3, P<0.001), indicating that electroacupuncture analgesia can significantly reduce the occurrence of nausea and vomiting in patients. Compared with PCIA+shamEA group, theer were differences in 2h, 4h, 8h, 12h and 24h OAA/S scores in EA+shamPCIA group significance (Table 4, P<0.001). It was noteworthy that the difference in OAA / S score at 48 h remained significant (Table 4, P <0.05), It shows that the degree of consciousness in patients with electroacupuncture analgesia was better than that of sufentanil, and the advantage of electroacupuncture analgesia over consciousness was still evident at 48h after surgery. The difference in the incidence of respiratory depression within the first 48h was significant in the EA + shamPCIA group compared with the PCIA + shamEA group (Table 5, P <0.05), indicating that electroacupuncture analgesia could reduce the incidence of respiratory depression in patients.

Table 3: PONV scores at 2 h, 4 h, 8 h, 12 h, 24 h,48 h Postoperatively.

	PCIA+shamEA (n=24)	EA+shamPCIA (n=25)	Z Value	P Value
PONV score, M (P25, P75)				
2h after surgery	1(1,1)	0(0,0)	5.424	<0.001
4h after surgery	2(1,2)	0(0,0)	4.500	<0.001
8h after surgery	2(1,2)	0(0,0)	3.975	<0.001
12h after surgery	1(1,2)	0(0,0.5)	3.997	<0.001
24h after surgery	1(0.25,2)	0(0,0)	3.443	<0.001
48h after surgery	0.5(0,1)	0(0,0)	2.443	0.005

Note: Data are reported as the median (interquartile range).

PCIA: patient-controlled intravenous analgesia; EA: electroacupuncture; PONV: postoperative nausea and vomiting.

Table 4: OAA/S scores at 2 h, 4 h, 8 h, 12 h, 24 h,48 h Postoperatively.

	PCIA+shamEA(n=24)	EA+shamPCIA(n=25)	Z Value	P Value
OAA/S score, M (P25, P75)				
2h after surgery	4(3,4)	5(4,5)	4.106	<0.001
4h after surgery	4(3,4)	5(5,5)	5.933	<0.001
8h after surgery	4(4,4)	5(5,5)	5.463	<0.001
12h after surgery	4(4,4)	5(5,5)	5.202	<0.001
24h after surgery	4(4,5)	5(5,5)	4.767	<0.001
48h after surgery	4(4,4.75)	5(5,5)	5.028	<0.001

Note: Data are reported as the median (interquartile range).

PCIA: patient-controlled intravenous analgesia; EA: electroacupuncture; PONV: postoperative nausea and vomiting; OAA/S: observer's assessment of alertness/sedation.

Table 5: Incidence of respiratory depression.

group	Total(case)	respiratory depression	No respiratory depression	Chi-sqrare (X^2) test	
		[case (%)]	[case (%)]	Chi-sqrare	Pvalue
PCIA+shamEA	24	15(62.5%)	9(37.5%)	7.411	0.006
EA+shamPCIA	25	6(24.0%)	19(76.0%)		

Note: Data are reported as percentage.

PCIA: patient-controlled intravenous analgesia; EA: electroacupuncture.

Electroacupuncture Analgesia Shortens the Time of the First Postoperative Exhaust And Defecation, and Reduces the Abdominal Distension

We can compare the time of the first postoperative exhaust and defecation, and evaluate the scores of abdominal distension of the two groups.The results showed that the difference between EA + shamPCIA compared to the PCIA + shamEA group (Figure 4a, P <0.01), and first defecation in EA + shamPCIA compared to the PCIA + shamEA group (Figure 4b, P <0.01), indicating that electroacupuncture "yanglingquan" and "Zhongdu" can promote intestinal peristalsis and shorten the first defecation time after abdominal surgery. Compared with the PCIA + shamEA group, the difference in abdominal disten-

sion scores at 2h and 48h was significant (Table 6, P <0.05), and the difference in abdominal distension scores at 4h, 8h, 12h and 24h after surgery (Table 6, P <0.001), indicating that electroacupuncture analgesia could reduce abdominal distension after abdominal surgery.

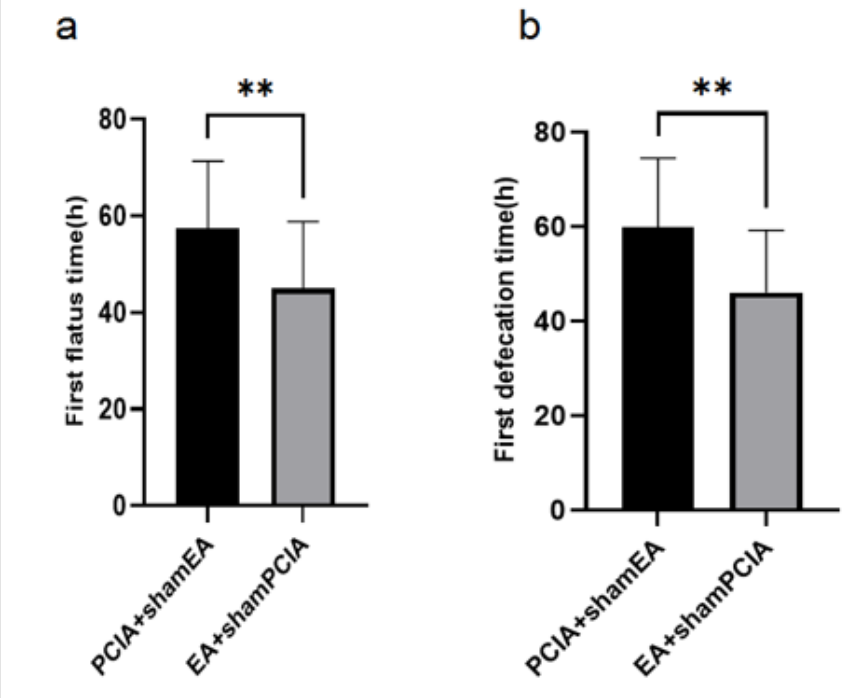

Figure 4: Effect of electroacupuncture analgesia on the time of first postoperative exhaust defecation in patients undergoing abdominal surgery. a) Time to the first postoperative discharge. b) the time of the first postoperative defecation. PCIA+shamEA (n=24), EA+shamPCIA(n=25). The Mann – Whitney U test, * * P <0.01.

Table 6: Bloating scores at 2 h, 4 h, 8 h, 12 h, 24 h,48 h Postoperatively.

	PCIA+shamEA(n=24)	EA+shamPCIA(n=25)	Z Value	P Value
Bloating score, M (P25, P75)				
2h after surgery	0(0,1)	0(0,0)	2.522	0.012
4h after surgery	1(1,2)	0(0,0)	4.153	<0.001
8h after surgery	2(1,2)	0(0,0)	5.189	<0.001
12h after surgery	2(1,2)	0(0,0)	5.299	<0.001
24h after surgery	1(0.25,1)	0(0,0)	4.171	<0.001
48h after surgery	0(0,1)	0(0,0)	1.972	0.049

Note: Data are reported as the median (interquartile range).

PCIA: patient-controlled intravenous analgesia; EA: electroacupuncture.

Discussion

In recent years, the much-concerned postoperative pain management has developed vigorously. However, acute postoperative pain is one of the most important challenges encountered by anesthesiologists, surgeons, and patients, and it may lead to atelectasis, prolonged hospital stay, sympathetic activation, and poor patient satisfaction [11].The multimodal analgesic regimen is currently the main protocol for controlling acute postoperative pain and achieves good analgesia, but the actual data show that almost half of the patients still report moderate to severe pain on the first postoperative day [12]. Despite undergoing PCIA after abdominal surgery, patients will still complain of vague, diffuse, poorly defined and defined visceral pain. It is noteworthy that even procedures considered "mild" with relatively limited tissue trauma may be associated with unexpectedly high postoperative pain intensity [13]. Although postoperative pain tends

to be gradually reduced, poorly controlled acute postoperative pain may persist for days to weeks, with adverse effects on recovery, length of stay, complications, and increased incidence of chronic pain [14]. The patients collected in this study mainly underwent laparoscopic hysterectomy, salpingectomy, cholecystectomy and appendectomy. Although the trauma is less severe than open surgery, they still face the risk of "mild" or "severe" pain within 48 hours after surgery, thus having adverse effects on the patients.

As mentioned above, high-altitude, low-oxygen environments can further aggravate this hazard. Pain is a complex process of electrical signal transmission. Electroacupuncture can adjust the biological electric energy state of the tissue in the pain site through the electrical characteristic structure unit (i. e. acupoints), and then play the analgesic effect. Electroacupuncture treatment of diseases is the result of the interaction between the external electric field and the electrical characteristics of the acupoint tissue [15]. When human tissues or organs undergo pathological changes, the homeostasis of cells is unbalanced, and electroacupuncture can regulate the imbalance of acupoint tissues, so as to play an analgesic effect. However, the traditional Chinese medicine believes that GB34 belongs to the foot Shaoyang gallbladder meridian, and LR6 belongs to the foot Que Yin liver meridian, which has the effect of slow and urgent pain relief and promoting intestinal peristalsis. In a randomized controlled study involving 1964 patients, Cohen, et al demonstrated that acupuncture was clinically better than medication in relieving acute pain in patients presenting with back pain and ankle sprain in an Australian emergency department [16]. Furthermore, a Chinese randomized controlled trial of 118 elderly people undergoing gastrointestinal tumor resection emphasized the positive analgesic effect and stability of acupuncture analgesia [17]. The results of this paper were consistent with the above results, and demonstrated that electroacupuncture stimulation of GB34 and LR6 can relieve acute pain after abdominal surgery, and the pain score was lower than that in the PCIA + shamEA group.

Meanwhile, it was worth noting that two patients in EA + shamPCIA group also obtained good analgesic effect. Continuous intravenous analgesia with sufentanil reduces the expression of IL-6 in the blood of patients after abdominal surgery and relieves the acute postoperative pain by reducing the local inflammatory response [18]. In a rat model of inflammatory pain induced by a full fu adjuvant (complete Freund's adjuvant, CFA), electroacupuncture stimulation of "huantiao" and "Yanglingquan" points can significantly reduce the expression of IL-6 in peripheral inflamed skin tissues, thus exerting an analgesic effect [19,20] found that electroacupuncture alleviated the inflammatory response by inhibiting the TLR 4 / MyD88 signaling pathway. As one of the anti-inflammatory factors, IL-6 is characterized by a rapid response, which was generally significantly increased within 1h-2h after surgery. Consistent with our results, we tested IL-6 levels before and 24 hours and 48 hours after electroacupuncture intervention, and found that IL-6 levels in both groups were significantly reduced at 48h after surgery, which may be related to the use of perioperative anti-inflammatory drugs, the removal of inflammatory infection factors, sufentanil drug itself and the causes of electroacupuncture analgesia. Notably, the difference in IL-6 levels between groups 24h after the intervention in the EA + shamPCIA group was significant ($P < 0.05$), but the difference in IL-6 levels in the PCIA group ($P > 0.05$), indicating that the IL-6 expression level was decreased on the first postoperative day, thus relieving acute postoperative inflammatory pain due to inflammatory infection in the early postoperative period.As one of the biological markers, PCT has a certain reference value in judging the postoperative infection and prognosis of patients after abdominal surgery [21].

Upon infection and inflammatory stimuli, monocytes and macrophages synthesize and release large amounts of PCT, while bacterial endotoxin suppresses the degradation of PCT, leading to a significant rise in serum PCT [22]. Our findings indicate that PCT levels significantly decreased at 24h and 48 h after abdominal surgery compared with before electroacupuncture intervention, suggesting that electroacupuncture intervention can suppress the expression level of PCT, thereby reducing inflammatory response and relieving acute pain after abdominal surgery. CRP is one of the most important inflammatory markers in the body, which is used in response to infections, tissue inflammation or other inflammatory stimuli and can be used to distinguish infections caused by bacteria and clinical viruses [23]. CRP is secreted by the liver, removing pathogenic microorganisms and damaged, necrotic and apoptotic tissue cells invading the body by activating complement and receptor-mediated means, increasing the defense ability of the body, so as to protect the body from serious damage. Our results showed that PCIA + shamEA group decreased at 24 hours compared to T1, but no significant difference between groups ($P > 0.05$), while EA + shamPCIA group showed higher CRP levels at 24 hours after surgery, compared with T1 ($P < 0.05$). Therefore, electroacupuncture intervention can improve the defense of postoperative patients against infection and reduce acute inflammatory pain caused by inflammatory infection.

Notably, CRP levels at 48 hours after surgery showed an opposite trend, with CRP expression significantly decreased in PCIA + shamEA group, significant compared with T1 ($P < 0.05$), and CRP expression significantly increasing in EA + shamEA group, compared to T1 ($P < 0.001$). This indicates that electroacupuncture intervention still protects the body against inflammatory infection through the anti-inflammatory effect of CRP. Continuous intravenous analgesia (PCIA) is the most widely used postoperative analgesia in clinical practice at this stage. It has definite effect and simple operation. It can be administered according to the individual needs of patients, reduce pain, surgical stress and complications as much as possible, and accelerate the rehabilitation process of patients [24]. Sufentanil is a derivative of fentanyl, whose analgesic effect is 5~10 times higher than that of fentanyl, with strong fat solubility, and has the advantages of quick

onset, good analgesic effect, and wide safety range. It is commonly used as anesthesia analgesia, anesthesia induction, anesthesia maintenance, and postoperative analgesia, which is widely used clinically [25]. However, sufentanil also has some side effects. Common side effects include respiratory depression, hypotension, nausea, vomiting, suppression of gastrointestinal peristalsis, etc. Serious side effects may include allergic reactions, cardiac arrhythmia, etc. The higher the drug dose is, the more severe the adverse reactions [26]. Sufentanil PCIA can cause the risk of opioid accumulation, thus producing the above side effects. Although it has good analgesic effect, its own side effects cannot be ignored. Importantly, the results show that electroacupuncture GB34 and LR6 acupoints for acute pain after abdominal surgery not only have better analgesia than sufentanil, but also can reduce nausea and vomiting after abdominal surgery, promote intestinal peristalsis, reduce abdominal distension, and shorten the time of first exhaust defecation after surgery.

Meanwhile, our results also showed that electroacupuncture stimulation of GB34 and LR6 had almost no adverse effects on the degree of consciousness and the respiration of patients after abdominal surgery, which may be related to the local stimulation effect of electroacupuncture only on acupoints. Although the efficacy and safety of electroacupuncture analgesia were clarified, the mechanism has not been further studied through animal experiments. In the future, the research team will study the mechanism in the future to clarify the mechanism of electroacupuncture analgesia on acute pain relief after abdominal surgery in high altitude and low oxygen environment. Meanwhile, as mentioned above, two of the study subjects had open surgery and achieved good electroacupuncture analgesic effect. However, since minimally invasive surgery is the main way of surgical treatment such as cholecystectomy in recent years, there is not enough clinical cases to prove the therapeutic effect of electroacupuncture analgesia for surgery with greater trauma. Furthermore, the trial was conducted in a single center, which may affect its generalizability. Xia JC, et al. [27] found that electricity also targeted chronic neuropathic pain such as sciatica. Therefore, a further multicenter study, including surgical patients with large trauma, is crucial to verify the effectiveness and safety of electroacupuncture analgesia.

We will expand the geographical scope of clinical cases in the future clinical study and the management of postoperative acute pain involving various surgeries, and observe the effectiveness and safety of electroacupuncture analgesia. In addition, the influence mechanism of electricity on the expression level of IL-6, PCT, and CRP during the perioperative period of abdominal surgery also needs to be verified by animal experiments. Electroacupuncture analgesia for acute postoperative pain after abdominal surgery at high altitude outperformed continuous intravenous analgesia with sufentanil, in addition, electroacupuncture stimulation of GB34 and LR6 in both lower limbs of patients was used for postoperative analgesia, which can reduce the expression level of IL-6 and PCT, increase the expression level of CRP, inhibit the inflammatory response, and relieve the acute pain after abdominal surgery. Meanwhile, electroacupuncture analgesia can relieve postoperative nausea, vomiting and abdominal distension, shorten the time of the first exhaust and defecation, and have almost no adverse effects on the patient's consciousness and breathing. Therefore, electroacupuncture analgesia can be used as a routine treatment for acute pain after abdominal surgery in high altitude areas.

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ISSN: 2574-1241

DOI: 10.26717/BJSTR.2025.61.009633

Hanzhong Cao. Biomed J Sci & Tech Res

Submission Link: https://biomedres.us/submit-manuscript.php