Urolithiasis
https://doi.org/10.1007/s00240-018-1056-8

ORIGINAL PAPER

Effect of transcutaneous electrical acupoint stimulation on postoperative analgesia after ureteroscopic lithotripsy: a randomized controlled trial

Qing Tu[1] · Jianhui Gan[1] · Jinlin Shi[1] · Hong Yu[1] · Shuangliang He[1] · Jian Zhang[2]

Received: 1 February 2018 / Accepted: 16 March 2018

Abstract

Transcutaneous electrical acupoint stimulation (TEAS) is an effective analgesic measure. We studied the analgesic effect of TEAS by applying it alone after ureteroscopic lithotripsy, rather than applying it as a supplementary analgesic measure. Participants ($n=120$) scheduled to undergo ureteroscopic holmium laser lithotripsy, were enrolled and randomly assigned into Group T (TEAS $n=60$) and Group C (Control, $n=60$). The participants in Group T were treated with TEAS for postoperative analgesia. TEAS were implemented on bilateral Shenyu (BL23) and Yinlingquan (SP9) at the time backward and the time at 4, 8, 12 h postoperatively. TEAS was re-implemented three times on the target acupoints for the next 2 days. When TEAS failed to meet the analgesic effect, the participants were given tramadol hydrochloride tablets of 100 mg. Participants of Group C were given tramadol hydrochloride tablets for postoperative analgesia. The primary outcome of VAS scores at the time backward (T_0), 4 h (T_1), 12 h (T_2), 24 h (T_3), 48 h (T_4) postoperatively and the amount of remedy for analgesic consumption within 48 h postoperatively were compared. The secondary outcome of adverse reactions and plasma concentrations of serotonin (5-HT) and substance P (SP) at T_0, T_1, T_2, T_3, T_4 were detected, respectively. The VAS scores at T_1, T_2, T_3, T_4 postoperatively in two groups were lower than T_0. Compared to group C, the VAS scores at T_1 (3.68 ± 0.68 vs. 4.79 ± 0.82, $P=0.01$), T_2 (2.64 ± 0.72 vs. 3.92 ± 0.88, $P=0.03$), T_3 (2.21 ± 0.88 vs. 3.38 ± 0.74, $P<0.01$) in Group T were lower, and total remedy of analgesic consumption was significantly lower (127.14 ± 28.46 vs. 415.27 ± 86.37, $P<0.01$) within 48 h postoperatively. The plasma concentrations of 5-HT in Group T was lower than Group C at T_1 (348.54 ± 138.49 vs. 418.69 ± 124.68, $P=0.03$), T_2 (324.28 ± 112.73 vs. 398.52 ± 114.53, $P<0.01$), T_4 (309.64 ± 129.09 vs. 388.46 ± 115.36, $P=0.04$) postoperatively and concentrations of SP at T_1 (59.38 ± 24.68 vs. 78.93 ± 26.32, $P<0.01$), T_2 (49.36 ± 25.55 vs. 66.49 ± 23.57, $P=0.02$), T_3 (42.19 ± 24.36 vs. 64.15 ± 28.16, $P=0.04$), T_4 (39.26 ± 19.88 vs. 54.64 ± 20.62, $P=0.02$) postoperatively were also lower than Group C. Meanwhile, the occurrences of vertigo (6.7 vs. 18.3%, $P<0.01$), nausea and vomiting (11.7 vs. 21.7%, $P<0.01$), constipation (10.0 vs. 20.0%, $P=0.03$) in Group T were also lower. Application of TEAS alone was associated with effective alleviation of postoperative pain, reduction of postoperative analgesics consumption, decrease of plasma concentration of algogenic substance and the incidence of adverse reactions after ureteroscopic lithotripsy.

Keywords Transcutaneous electrical acupoint stimulation · Ureteroscopic lithotripsy · Postoperative analgesia · Analgesic substance

Introduction

Urolithiasis is a kind of urinary tract diseases, the incidence of urinary calculi has been on rise markedly, there are many options for urologists to treat ureteral stones. It is proved that ureteroscopic holmium laser lithotripsy is a safe and effective procedure [1]. Which has the advantages of low complication rate and high postoperative satisfaction [2]. The importance of postoperative analgesia may be easily overlooked after this minimal and less invasive operation. In

✉ Jianhui Gan
ganjianhui666@163.com

[1] Department of Anesthesiology, Tangshan People's Hospital, North China University of Science and Technology, No. 65 Shengli Road, Tangshan 063000, Hebei, China

[2] Department of Anesthesiology, The Third People's Hospital of Chengdu, Southwest Jiao Tong University, Chendu 610000, China

Published online: 20 March 2018

fact, postoperative pain is one of the most common complications after lithotripsy, patients often suffer from the pain and need powerful opioids. For many years, surgeons and anesthesiologists have ordered liberal amounts of opioids to achieve optimal pain control for their patients. Unlike traditional perioperative pain care, the enhanced recovery after surgery (ERAS) pathways typically promoted to use a standardized multimodal analgesic regimen with non-opioid agents or techniques to minimize the consumption of perioperative opioid and to decrease opioid-related adverse effects. Opioids have high analgesic efficacy followed with many side effects (e.g., nausea, vomiting, sedation, ileus, pruritus, and respiratory depression). Statistical data showed that opioids resulted in 1 death approximately every 35 min [3]. Although less potent as opioids or non-steroidal anti-inflammatory drugs (NSAIDs), tramadol produces analgesia with a relatively lower risk of addiction, less constipation, minimal cardiovascular adverse effects, and minimal respiratory depression [4, 5]. Tramadol has been shown to provide effective analgesia for moderate postoperative pain [6]. In addition to the satisfactory level of pain control and less adverse reactions, which led to its frequent use in postoperative analgesia, compared to strong opioids [7–9]. Transcutaneous electrical acupoint stimulation (TEAS) is a new acupuncture therapy, combined the effect of transcutaneous electrical nerve stimulation (TENS) and acupoint therapy. Which has the similar analgesic effects of electroacupuncture [10]. Because of its non-invasive, easy to operate, high patient's acceptance and other advantages, TEAS is increasingly valued and affirmed by clinicians. TEAS may be an effective postoperative analgesia measure, however, related studies are relatively insufficient.

The main objective of the study was to explore the analgesic effects of TEAS used alone for postoperative analgesia, compared with the use of tramadol hydrochloride tablets after ureteroscopic lithotripsy.

Methods

Participants

The study was undertaken in accordance with the Declaration of Helsinki and the guidelines on good clinical practice. Approval of the regional research ethics committee was obtained. Our study had been approved by the Ethical Committee of Human Research of Tangshan People's Hospital & Tangshan Cancer Hospital (RMYY-YWLL-2017-1110). All patients enrolled in the study have signed informed consent. The study was a randomized, controlled trial. The sequence of postoperative analgesia TEAS (Group T) and oral tramadol hydrochloride tablets (Group C) was determined, randomization was stratified according to the time of admission in a block size of 10. Eligible participants were randomly assigned to receive either TEAS or oral tramadol hydrochloride tablets for postoperative analgesia via a central randomization system for clinical research using a 1:1 ratio. The random number list was generated by an independent statistician and block size was disclosed to other researchers. An independent, blinded statistician concealed the file of the generated random number table using a password and provided information regarding which group each participant was assigned to the clinical research coordinator (CRC). Researchers who assess outcome measures and those who perform data management and statistical analysis were blinded to each participant's allocation status. Outcome assessors were not allowed to have any conversations with participants regarding the treatment process. Each practitioner performed only one of the interventions to prevent any bias due to the deliberate interventions in the treatment. Practitioners were not involved in measuring the treatment outcomes.

Participants underwent ureteroscopic holmium laser lithotripsy were enrolled in our study. Eligibility criteria included participants aged between 18 and 70 years, with American Society of Anesthesiologists (ASA) physical status classification grade I or II. Eligible participants had sufficient cognitive function and language skills for the progress of the study. Exclusion criteria included the presence of a painful condition (e.g., inflammatory rheumatic disease, lumbar muscle degeneration, lumbar disc protrusion with low back pain, acute or chronic nephritis and pyelonephritis), major organ system disease, hypersensitivity to the study medications, participants fitted with pacemaker, participants with analgesic drug is being used or had a history of significant abuse of certain drugs. Those who had uncontrolled hypertension, diabetes, or malignancies, history of epilepsy, pregnancy and lactation or had childbearing potential, or participants enrolled in other clinical trials were also excluded.

Study design

Any sedative or anxiolytic medications was not administered preoperatively. Upon arrival in the operating room, a dedicated intravenous cannula was inserted by circuit nurse. Routine monitoring commenced, including temperature, ECG monitoring, oxygen saturation (SpO_2) and non-invasive blood pressure (NIBP). All patients were provided with 100% oxygen for 3 min before anesthesia induction. Anesthesia induction was implemented by experienced anesthesiologists with fentanyl (4 μg/kg), etomidate (0.4 mg/kg), *cis*-atracurium (0.15 mg/kg). All the patients received propofol and remifentanil controlled by the same closed-loop automated system during induction and maintenance of general anesthesia. Intermittent addition of *cis*-atracurium

to ensure the progress of the surgery. Discontinued all the anesthetics when the surgery terminated. All participants were transferred to the Post Anesthesia Care Unit (PACU) after surgery, escorted back to urological ward by anesthetic nurse after extubation.

For participants in Group T, acupoint electrical stimulation was implemented on bilateral Shenyu [BL23, located 1.5 cun (about 10 mm) outside the spinous process of the second lumbar vertebra] and SP9 (located at the beginning of the soleus muscle, between the posterior tibia border and gastrocnemius muscle) (Fig. 1). The HANS LH-202 electrical stimulator was used to provide electrical stimulation. After skin disinfection, electrode tabs were placed on bilateral BL23 and SP9, connected the output wire to electrode tabs, adjusted electrode intensity, set the intensity at the highest level if the patients could tolerate it. TEAS was carried out at the time backward and the time at 4, 8, 12 h postoperatively. Re-implement TEAS three times on the target acupoints (at 7 a.m., 11 a.m. and 15 p.m.) on the next 2 days. TEAS lasts for 30 min [11–13] with a dilatational wave with the frequency of 2/100 Hz. The intensity of the current ranges from 5 to 30 mA for TEAS (5–10 mA for upper limbs, 10–30 mA for lower limbs and trunk). The presence of de qi sensations was used to establish the efficacy of the acupoint stimulation. Participants in this group were also treated with oral placebo (the shape and color were similar to tramadol hydrochloride tablets), 100 mg, twice daily (8 a.m., 20 p.m.). When the TEAS failed to meet the analgesic effect (VAS > 3 points), the participant were given oral tramadol hydrochloride tablets of 100 mg (< 600 mg per 24 h). Participants in group C were treated with tramadol hydrochloride tablets for postoperative analgesia, 100 mg, twice daily (8 a.m., 20 p.m.). And electrode tabs were also placed on bilateral BL23 and SP9 just as participants in group T, but electrical stimulation was not implemented. When VAS scored more than 3 points, oral tramadol hydrochloride tablets of 100 mg was given to the participant for remedy analgesia (< 600 mg per 24 h).

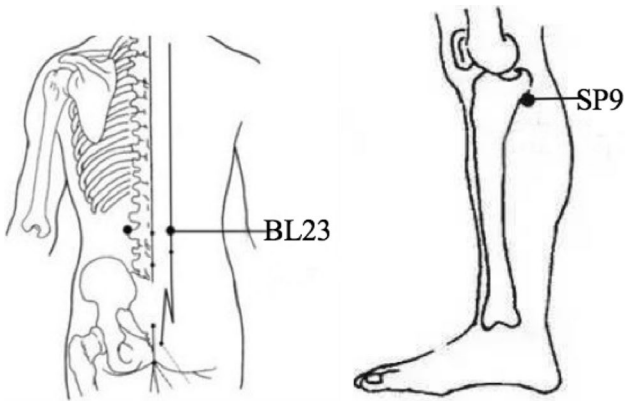


Fig. 1 Location of acupoints for the electrical stimulation. *BL23* Shenyu [located 1.5 cun (about 10 mm) outside the spinous process of the second lumbar vertebra], *SP9* Yinlingquan (located at the beginning of the soleus muscle, between the posterior tibial border and the gastrocnemius muscle)

The TEAS intervention was performed by our research nurses, who were qualified members of the research team, and then verified by two traditional Chinese medicine physicians. Throughout the trial, participants were treated separately to prevent communication and were discouraged from receiving any analgesic treatments except for our trials, participants receiving such treatments should be excluded.

Measurements

The primary outcome of the study was the VAS score and the total amount of analgesic consumption within 48 h postoperatively. We quantified the pain intensity using a simple 11-point VAS running from 0 (no distress) to 10 (unbearable distress). The VAS scores at the time back ward (T_0), 4 h (T_1), 12 h (T_2), 24 h (T_3), 48 h (T_4) postoperatively were detected and documented, respectively. This procedure was performed by the well-trained anesthetic nurse according to participants' pain intensity during anesthesia follow-up. The participants' pain level was recorded truthfully, any subjective inductive question formulations were prohibited during the procedure. Participants were given a Visual Analog Scale, respondent was asked to place a line perpendicular to the VAS line at the point that represents their pain intensity, the process was assisted by an anesthetic nurse. The amount of remedy analgesic consumption was recorded at every 24 h postoperatively. Total amount of remedy analgesic consumption was calculated at T_4. All the adverse reactions were documented throughout the trial.

The secondary outcomes were the incidence of adverse reactions and plasma concentrations of algogenic substance. Serotonin (5-HT) and substance P (SP) were selected as algogenic substance in the study. For all participants, venous blood samples of 3 ml were taken at T_0, T_1, T_2, T_3, T_4, respectively. The plasma concentrations of serotonin (5-HT) and substance P (SP) were detected by ELISA method.

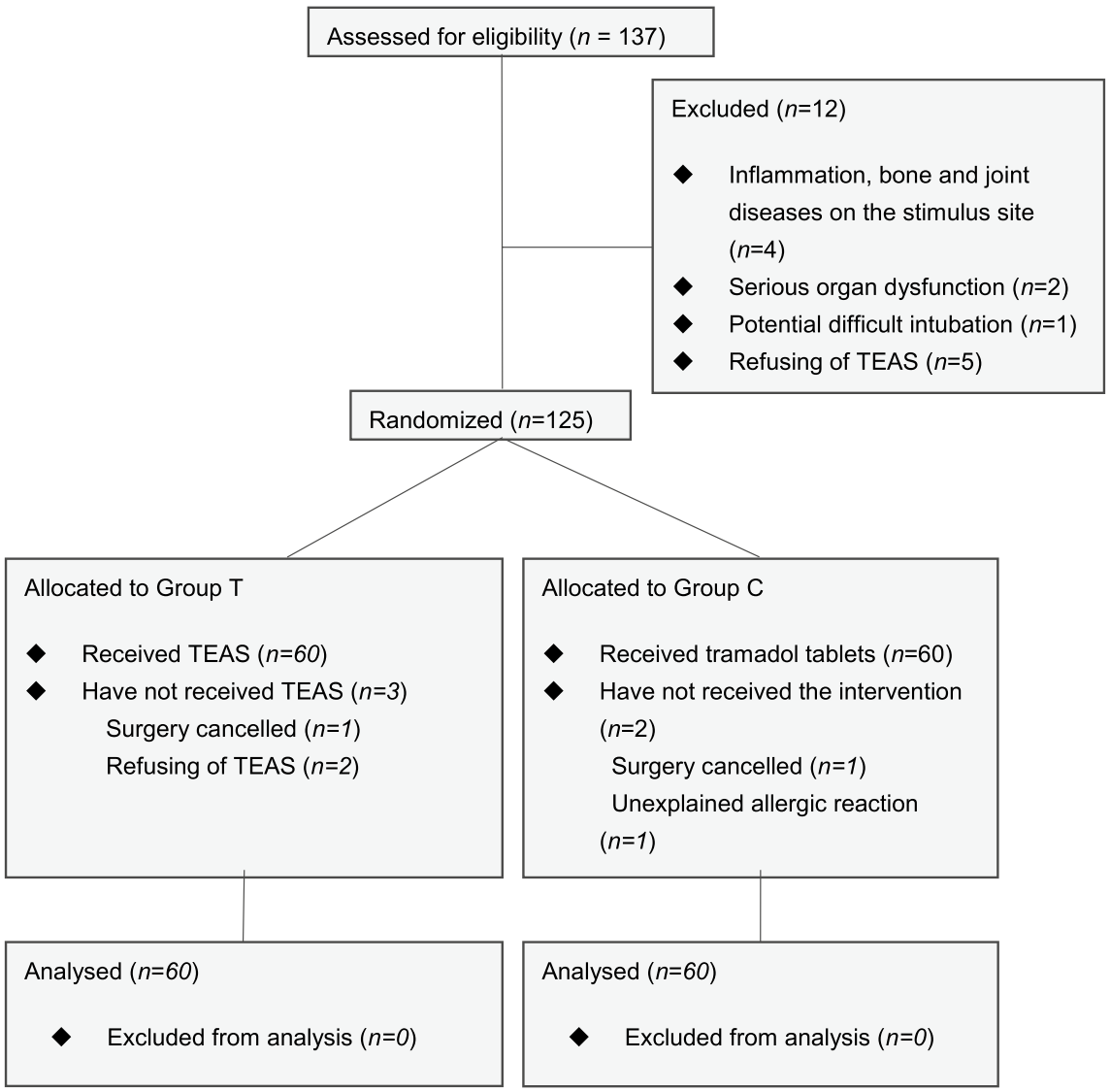
Statistics analysis

Data were processed using SPSS version 19.0 (SPSS Inc., Chicago, IL, USA). The values were expressed as mean ± SD or number of patients for all data. Differences between the two groups were analyzed by Student's *t* test. The Chi-square test was used to analyze the adverse event incidence rate between two groups. One-way ANOVA was used to analyze the difference between T_0 and the other time points. Repeated measurements were used to analyze the difference of the interaction effect between groups and time points. A value of $P < 0.05$ was considered statistically significant.

Results

Participants

We approached 137 participants who were selected to undergo ureteroscopic holmium laser lithotripsy in our teaching hospital. Seventeen participants (12.4%) were excluded because of exclusion criteria meeting and other reasons after consent. Four participants had Inflammation, bone and joint diseases on the stimulus site, two with serious organ dysfunction and one with potential difficult intubation. A case of surgery was cancelled in Group T, as well as in Group C. Two participants refused to receive TEAS postoperative in Group T and a participant in Group C had unexplained allergic reaction. Available data from 120 participants (87.6%) was obtained. Flow of participants randomized is shown in Fig. 2. Baseline characteristics were similar between two groups, no statistical significance between the demographic data of two groups (Table 1).



Abbreviations: TEAS, transcutaneous electrical acupoint stimulation.

Fig. 2 Flow of participants randomized to Group T or Group C. *TEAS* transcutaneous electrical acupoint stimulation

Table 1 Characteristics of participants at entry

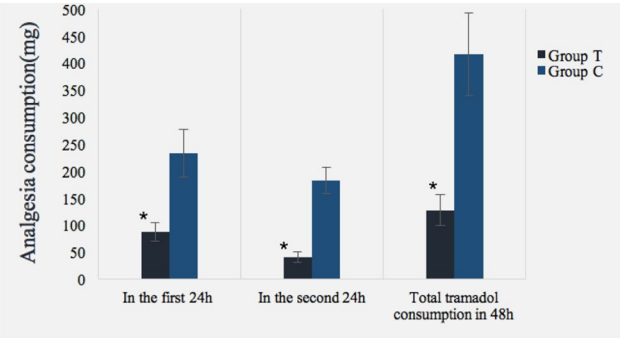
Characteristics	Group T ($n=60$)	Group C ($n=60$)	P value
Age (year)	64.32 ± 10.21	62.14 ± 11.34	0.59
Sex			0.43
Male	32	29	
Female	28	31	
Weight (kg)	59.45 ± 11.43	58.42 ± 11.92	0.51
ASA physical status			0.82
I	41	45	
II	19	15	
Stone position			0.97
Unilateral	50	48	
Bilateral	10	12	
Operation time (min)	134.21 ± 10.47	130.42 ± 12.38	0.65

Values are presented as mean ± SD or number of patients. *ASA* American Society of Anesthesiologists

VAS scores and remedy analgesics consumption within 48 h postoperatively

The VAS scores at T_1, T_2, T_3, T_4 of two groups were lower than T_0 ($P<0.05$). Compared to the group C, the VAS scores at T_1 (3.68 ± 0.68 vs. 4.79 ± 0.82, $P=0.01$), T_2 (2.64 ± 0.72 vs. 3.92 ± 0.88, $P=0.03$) and T_3 (2.21 ± 0.88 vs. 3.38 ± 0.74, $P<0.01$) in Group T were lower. Statistical differences did not exist at T_0 and T_4 between groups ($P>0.05$) (Table 2).

In addition, the remedy analgesics consumption in first (86.84 ± 16.44 mg vs. 232.68 ± 43.52 mg, $P<0.01$) and second 24 h (40.57 ± 9.82 mg vs. 182.59 ± 24.64 mg, $P=0.02$) postoperatively of participants in group T was strikingly lower than Group C. Total remedy analgesic consumption was also significantly lower (127.14 ± 28.46 vs. 415.27 ± 86.37, $P<0.01$) in 48 h postoperatively (Fig. 3) (the consumption of tramadol hydrochloride tablets was recorded as remedy consumption, extra amount to basic dosage of 200 mg).



Notes: Values are presented as mean ± SD; *P<0.05 vs. Group C.

Fig. 3 Comparison of remedy analgesic consumption between two groups ($n=60$). Values are presented as mean ± SD; *$P<0.05$ vs. Group C

Plasma concentrations of algogenic substances

The plasma concentration of 5-HT at T_1 (348.54 ± 138.49 vs. 418.69 ± 124.68, $P=0.03$), T_2 (324.28 ± 112.73 vs. 398.52 ± 114.53, $P<0.01$), T_4 (309.64 ± 129.09 vs. 388.46 ± 115.36, $P=0.04$) in Group T were lower than Group C ($P<0.05$). The plasma concentrations of SP at T_1 (59.38 ± 24.68 vs. 78.93 ± 26.32, $P<0.01$), T_2 (49.36 ± 25.55 vs. 66.49 ± 23.57, $P=0.02$), T_3 (42.19 ± 24.36 vs. 64.15 ± 28.16, $P=0.04$), T_4 (39.26 ± 19.88 vs. 54.64 ± 20.62, $P=0.02$) postoperatively were also lower (Table 3).

Occurrences of vertigo (6.7 vs. 18.3%, $P<0.01$), nausea and vomiting (11.7 vs. 21.7%, $P<0.01$), constipation (10.0 vs. 20.0%, $P=0.03$) in Group T were lower compared to Group C (Fig. 4).

Discussion

Urinary calculi is a common and frequently occurring disease in clinic, ureteroscopic holmium laser lithotripsy brings excellent clinical effects and has a wide range of clinical applications [14]. Opioids are widely used in postoperative analgesia, but adverse reactions associated with it can not be ignored. TEAS provides analgesic effect by stimulating

Table 2 Comparison of VAS scores within 48 h postoperatively between two groups ($n=60$)

Groups	T_0	T_1	T_2	T_3	T_4
Group T	5.32 ± 0.41	3.68 ± 0.68$^{\#}$	2.64 ± 0.72$^{\#}$	2.21 ± 0.88$^{\#}$	2.19 ± 0.43$^{\#}$
Group C	5.41 ± 0.35	4.79 ± 0.82$^{\#}$	3.92 ± 0.88$^{\#}$	3.38 ± 0.74$^{\#}$	2.47 ± 0.39$^{\#}$
t	1.35	2.78	2.16	3.79	0.63
P value	0.74	0.01*	0.03*	<0.01*	0.44

Values are presented as mean ± SD

VAS Visual Analog Scale

*$P<0.05$ vs. Group C

$^{\#}P<0.05$ vs. T_0

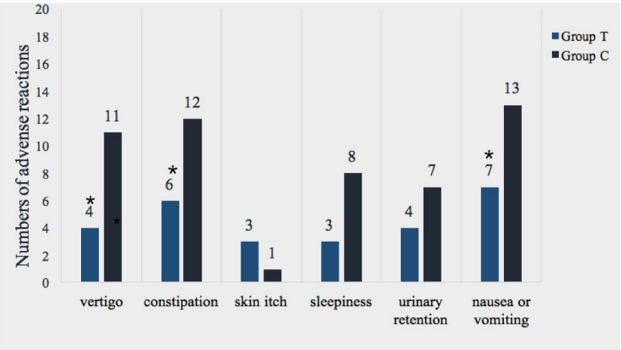
Table 3 Comparison of the levels of postoperative algogenic substances between two groups ($n=60$)

Tn	Plasma concentration of 5-HT (nmol/l)				Plasma concentration of SP (pg/ml)			
	Group T	Group C	*t*	*P* value	Group T	Group C	*t*	*P* value
T_0	442.43 ± 121.34	436.67 ± 118.72	0.84	0.73	78.74 ± 27.32	80.24 ± 30.21	0.94	0.53
T_1	348.54 ± 138.49	418.69 ± 124.68	4.16	0.03*	59.38 ± 24.68	78.93 ± 26.32	5.74	< 0.01*
T_2	324.28 ± 112.73	398.52 ± 114.53	2.53	< 0.01*	49.36 ± 25.55	66.49 ± 23.57	3.39	0.02*
T_3	351.15 ± 118.94	382.37 ± 104.21	0.63	0.27	42.19 ± 24.36	64.15 ± 28.16	4.63	0.04*
T_4	309.64 ± 129.09	388.46 ± 115.36	4.71	0.04*	39.26 ± 19.88	54.64 ± 20.62	2.17	0.02*

Values are presented as mean ± SD

5-HT serotonin, *SP* substance P

*$P < 0.05$ vs. Group C



Notes: Values are presented as mean ± SD; *$P<0.05$ vs. Group C.

Fig. 4 Comparison of adverse reactions between two groups ($n=60$). Values are presented as mean ± SD; *$P < 0.05$ vs. Group C

specific acupoints with certain frequency and intensity, it has the advantages of small irritation, strong operability and easy acceptance by patients. Feng et al. [15] found stimulation on target acupoints can effectively relieve the waist and abdomen pain, reduce the incidence of nausea and vomiting after abortion. While Huang et al. [16] suggested that The 2/100 Hz frequency of TEAS can reduce the opioid consumption, and the frequency of 100 Hz can reduce the incidence of postoperative nausea and vomiting in their study. Lin et al. also found that low-frequency stimulation induces analgesia through the release of β-endorphin, enkephalin, and orphanin, whereas high-frequency stimulation induces analgesia through the release of dynorphin [17]. A meta-analysis of 21 randomized-controlled trials (RCTs) revealed that analgesic consumption for postoperative pain is lower in patients who receive TENS than those received placebo [18]. In addition to reduce the consumption of perioperative opioid utilization, TEAS also helps to reduce the postoperative side effects and improve the quality of anesthesia recovery [19].

The analgesia effects of TEAS had been studied extensively in the last decades. However, the underlying mechanisms of TEAS are still remaining un-completely clear. TEAS adds an electrical stimulation pulse to target acupoints using electrodes placed on the surface of acupoints, instead of needles. TEAS activates nerve endings or fibers and generate action potentials [20–23]. The stimulation signals can be transmitted to spinal cord and brain, then the central nervous system (CNS) was stimulated to generate specific chemical mediators to induce relevant physiological effects, such as analgesia. It is generally accepted that the activation of sensory nerve terminals by either mechanical and/or electrical stimulation is transmitted to various critical pain regulatory centers in the spinal cord and brain to generate specific chemical mediators including endorphins. The descending pain modulator pathways are then activated, to induce an analgesic effect. For example, evidence showed that low-frequency (2 Hz) electrical stimulation promotes the production and release of encephalin in the CNS, while high-frequency (100 Hz) electrical stimulation promotes the production and release of dynorphins in the spinal cord [24]. However, we had a lot of considerations into the choice of the frequency and intensity of TEAS. Previous studies confirmed that 2, 100, and 2/100 Hz frequency of TEAS play an important role in pain relief. Ding Xiang et al. suggested that the high frequency (> 50 Hz) of TENS had significant effect on pain relief in knee osteoarthritis patients in comparison to the low frequency [25]. However, a meta-analysis of Bjordal et al. suggested that TENS of 85 Hz was the conventional frequency when implemented TENS in trials [26]. But no evidence revealed the optimal frequency of TEAS. However, a current research of Zhishun Liu et al. suggested that electroacupuncture stimulation lasted for 30 min with a continuous wave of 50 Hz resulted in less urine leakage for among women with stress urinary incontinence [26], but they have not supplied more evidence or materials about the frequency choice. On this issue, we consulted experts of traditional Chinese medicine in our hospital, and combined with our experience, a dilatational wave with the frequency of 2/100 Hz was selected, but maybe our choice was not the optimum. The optimal treatment and/or analgesia frequency of TEAS still needs to be justified.

Postoperative patients with upper ureteral calculi surgery, often accompanied with colic pain in the waist and

abdomen. In the viewpoint of traditional Chinese Medicine, stimulation on BL23 can be used in the treatment of kidney deficiency and urogenital system diseases. Acupuncture on BL23 may have effects of relax ureteral smooth muscle, relieve the mucosal edema caused by ureteral calculi, decrease pelvic pressure and the incidence of nausea and vomiting caused by colic pain of kidney stones. Zhang et al. suggested injection of flurphen mixture at BL 23 can significantly alleviate pain reaction in patients undergoing ESWL [27]. While Park et al. revealed that acupuncture point injection with placental extract at BL23 can substantially decrease the pain intensity in patients with knee osteoarthritis [28]. Studies confirmed that SP9 stimulation can also be used for the treatment of renal colic, the effect of renal colic relief was remarkable, and the effective rate of colic was 93.3% [29]. Which indicated that acupoint stimulation alone has a strong analgesic effect. Accordingly, BL23 and SP9 were selected as target acupoints for electrical stimulation of postoperative analgesia.

As a pain-inducing agent, 5-HT can result in hyperalgesia through a complex series of pain-causing mechanisms. Studies have shown that blocking the 5-HT's release or its activity can produce an effective analgesic effect [30]. A large amount of researches confirmed that SP is closely related to the occurrence and development of pain [31–33]. SP is a neuropeptide, widely distributed in the body, plays a major role in pain transmission. It can cause pain by delivering peripheral noxious stimulation to the dorsal horn of the spinal cord [34]. In the study, 5-HT and SP were selected for the concentration detection of algogenic substance.

In the study, the VAS scores at 4, 12 and 24 h after surgery were lower in patients with TEAS application postoperatively, the VAS score declined to less than 3 within 12 h postoperatively. However, the VAS scores were very close between two groups and statistical difference only existed at T_1, T_2 and T_3, but not existed at T_4. Our considerations may be related to the following factors. First, compared to other types of surgery, the pain intensity was relatively mild after ureteroscopic holmium laser lithotripsy, the baseline value of VAS score was small. Second, the pain caused after ureteroscopic holmium laser lithotripsy mainly originated from ureteral spasm associated with ureteral operations and local inflammation associated with the stone itself. With the recovery of ureteral spasm, the pain can be gradually alleviated. That was to say, the difference between analgesic measures can be narrowed as time goes by. But, it can not be concluded the analgesic effect of TEAS was not long. In a study, participants received four 20 min sessions (the first and second TEAS were performed the 4th and 6th h after surgery, the third and fourth were performed at 7 a.m. and 11 a.m. on the day after surgery) of electrical stimulation at chengshan (BL57) and erbai (EX-UE2) after hemorrhoidectomy showed a pain reduction for 2 consecutive days [35]. Third, it was possible that when the VAS score is less than 3 points, the patient's pain perception was not very smart, the effect of analgesic intervention was not very obvious.

The consumption of remedy analgesics in the first 24 h and second 24 h postoperatively was much less than participants with tramadol for postoperative analgesia. In addition, the total requirement of tramadol in 48 h postoperatively was significantly higher in Group C. Which suggested that TEAS has potent analgesic effects. The incidence of vertigo, nausea or vomiting and constipation in the Group T were lower than that in the Group C within 48 h postoperatively. Which suggested TEAS can effectively reduce the incidence of postoperative adverse reactions and improve the satisfaction of patients with perioperative treatments. The results of this study are similar to previous findings. The study also found that the plasma levels of 5-HT at 4, 12, 48 h postoperatively of patients in Group T were lower than patients in Group C. While at 4, 12, 24, and 48 h postoperatively, plasma concentrations of SP were lower. The results indicated that TEAS may inhibit the production of algogenic substances in the body, blocked the generation and conduction of pain to some extent.

Limitations

The study also has several limitations. First, the threat to internal validity could not be prevented because of the study design. Second, as both study groups comprised participants from the same hospital, our findings might not be generalizable to other hospitals, despite both groups being highly homogeneous. Third, it was necessary to set up a sham control group. When designing these experiments, we've considered setting up sham control group (electrode tabs were placed on bilateral BL23 and SP9 without electrical stimulation, and treated with oral placebo), 100 mg, twice daily. However, this practice has been questioned by our ethical committee. The participants' postoperative VAS scores in sham control group may be significantly higher than group T and C, and the treatment of remedy analgesic was lagging behind without any analgesic measures. Therefore, these participants may suffer more and may need a large amount of analgesic for pain relief, compared to participants in group T and C. In addition, the postoperative adverse reactions may increase, it was not conducive to postoperative recovery. Thus, more large simple size, double-blind multicenter randomized controlled trials (RCTs) are warranted to justify more evidence of the analgesic effects of TEAS. However, whether TEAS alone can alleviate more severe pain after other types of surgery, such as abdominal, chest, orthopedics surgery, etc., still need more evidence to justify it.

Conclusion

Poorly controlled postoperative pain may result in adverse events, prolong hospital stay, delay postoperative recovery, and affect the patient's experience with the health care system. The study demonstrated that TEAS can effectively alleviate the postoperative pain, reduce the consumption of postoperative analgesic drugs, decrease the plasma concentration of algogenic substance (5-HT and SP), and reduce the incidence of postoperative adverse reactions after ureteroscopic holmium laser lithotripsy. TEAS maybe an effective alternative measurement of postoperative analgesia compared to opioids and other non-opioid analgesics or for those patients with major organ and system diseases or those have presence of contraindications for opioid drugs. However, more detailed researches should be conducted to find more evidence of postoperative analgesia effects of TEAS.

Acknowledgements There were no acknowledgements in this study.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Research involving human participants All procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Li ZG, Zhao Y, Fan T, Hao L, Han CH, Zang GH (2016) Clinical effects of FURL and PCNL with holmium laser for the treatment of kidney stones. Exp Ther Med 12:3653–3657
2. Xu C, Song RJ, Jiang MJ, Qin C, Wang XL, Zhang W (2015) Flexible ureteroscopy with holmium laser lithotripsy: a new choice for intrarenal stone patients. Urol Int 94:93–98
3. Manchikanti L, Helm S, Fellows B, Janata JW, Pampati V, Grider JS, Boswell MV (2012) Opioid epidemic in the United States. Pain Physician 15:ES9-38
4. Radbruch L, Glaeske G, Grond S, Münchberg F, Scherbaum N, Storz E, Tholen K, Zagermann-Muncke P, Zieglgänsberger W, Hoffmann-Menzel H, Greve H, Cremer-Schaeffer P (2013) Topical review on the abuse and misuse potential of tramadol and tilidine in Germany. Subst Abus 34:313–320
5. Klotz U (2003) Tramadol—the impact of its pharmacokinetic and pharmacodynamic properties on the clinical management of pain. Arzneimittelforschung 53:681–687
6. Schnabel A, Reichl SU, Meyer-Frießem C, Zahn PK, Pogatzki-Zahn E (2015) Tramadol for postoperative pain treatment in children. Cochrane Database Syst Rev 18:CD009574
7. Cattabriga I, Pacini D, Lamazza G, Talarico F, Di Bartolomeo R, Grillone G, Bacchi-Reggiani L (2007) Intravenous paracetamol as adjunctive treatment for postoperative pain after cardiac surgery: a double blind randomized controlled trial. Eur J Cardiothorac Surg 32:527–531
8. Karanikolas M, Aretha D, Kiekkas P, Monantera G, Tsolakis I, Filos KS (2010) Case report. Intravenous fentanyl patient-controlled analgesia for perioperative treatment of neuropathic/ischaemic pain in haemodialysis patients: a case series. J Clin Pharm Ther 35:603–608
9. Unlugenc H, Vardar MA, Tetiker S (2008) A comparative study of the analgesic effect of patient-controlled morphine, pethidine, and tramadol for postoperative pain management after abdominal hysterectomy. Anesth Analg 106:309–312
10. Gao J, Li Y (2015) Multiple functions of transcutaneous electrical acupoint stimulation in peri-anesthesia period. Zhongguo Zhen Jiu 35:269–273
11. Research Group of Acupuncture Anesthesia, Peking Medical College (1973) Effect of acupuncture on the pain threshold of human skin. Chin Med J 3:151–157 **(Chinese)**
12. Wang JQ, Mao L, Han JS (1992) Comparison of the antinociceptive effects induced by electroacupuncture and transcutaneous electrical nerve stimulation in the rat. Int J Neurosci 65:117–129
13. Cheing GL, Tsui AY, Lo SK, Hui-Chan CW (2003) Optimal stimulation duration of tens in the management of osteoarthritic knee pain. J Rehabil Med 35:62–68
14. Scovell JM, Link RE (2014) A nephropleural fistula complicated by distal ureteral obstruction results in tension hydrothorax after percutaneous nephrostolithotomy. Urology 84:e28–e29
15. Feng X, Ye T, Wang Z, Chen X, Cong W, Chen Y, Chen P, Chen C, Shi B, Xie W (2016) Transcutaneous acupoint electrical stimulation pain management after surgical abortion: a cohort study. Int J Surg 30:104–108
16. Huang S, Peng W, Tian X, Liang H, Jia Z, Lo T, He M, Feng Y (2017) Effects of transcutaneous electrical acupoint stimulation at different frequencies on perioperative anesthetic dosage, recovery, complications, and prognosis in video-assisted thoracic surgical lobectomy: a randomized, double-blinded, placebo-controlled trial. J Anesth 31:58–65
17. Lin JG, Chen WL (2008) Acupuncture analgesia: a review of its mechanisms of actions. Am J Chin Med 36:635–645
18. Bjordal JM, Johnson MI, Ljunggreen AE (2003) Transcutaneous electrical nerve stimulation (TENS) can reduce postoperative analgesic consumption. A meta-analysis with assessment of optimal treatment parameters for postoperative pain. Eur J Pain 7:181–188
19. Wang H, Xie Y, Zhang Q, Xu N, Zhong H, Dong H, Liu L, Jiang T, Wang Q, Xiong L (2014) Transcutaneous electric acupoint stimulation reduces intra-operative remifentanil consumption and alleviates postoperative side-effects in patients undergoing sinusotomy: a prospective, randomized, placebo-controlled trial. Br J Anaesth 112:1075–1082
20. Han JS (2003) Acupuncture: neuropeptide release produced by electrical stimulation of different frequencies. Trends Neurosci 26:17–22
21. Kagitani F, Uchida S, Hotta H, Aikawa Y (2005) Manual acupuncture needle stimulation of the rat hindlimb activates groups I, II, III and IV single afferent nerve fibers in the dorsal spinal roots. Jpn J Physiol 55:149–155
22. Michikami D, Kamiya A, Kawada T, Inagaki M, Shishido T, Yamamoto K, Ariumi H, Iwase S, Sugenoya J, Sunagawa K, Sugimachi M (2006) Short-term electroacupuncture at Zusanli resets the arterial baroreflex neural arc toward lower sympathetic nerve activity. Am J Physiol Heart Circ Physiol 291:H318–H326
23. Zhao ZQ (2008) Neural mechanism underlying acupuncture analgesia. Prog Neurobiol 85:355–375

24. Han JS, Chen XH, Sun SL, Xu XJ, Yuan Y, Yan SC, Hao JX, Terenius L (1991) Effect of low- and high-frequency TENS on Met-enkephalin-Arg-Phe and dynorphin A immunoreactivity in human lumbar CSF. Pain 47:295–298
25. Ding X, Zhang Y, Deng ZH (2015) Transcutaneous electrical nerve stimulation for pain relief in knee osteoarthritis: a meta-analysis. Chin J Tissue Eng Res 19:1798–1804
26. Liu Z, Liu Y, Xu H et al (2017) Effect of electroacupuncture on urinary leakage among women with stress urinary incontinence: a randomized clinical trial. JAMA 317:2493–2501
27. Zhang S, Zhao Z, Li X, Wang J, Su X (2015) Impacts of the injection with flurphen mixture at Shenshu (BL 23) on hemodynamics and analgesia in patients with extracorporeal shock wave lithotripsy. Zhongguo Zhen Jiu 35:233–236
28. Park KM, Cho TH (2017) Therapeutic effect of acupuncture point injection with placental extract in knee osteoarthritis. J Integr Med 15:135–141
29. Luo SH (2009) Experience of treating 30 cases of biliary and renal colic by acupuncture of SP9. J Tradit Chin Med 24:179 **(Chinese)**
30. Florentino IF, Nascimento MV, Galdino PM, De Brito AF, Da Rocha FF, Tonussi CR, De Lima TC, De Paula JR, Costa EA (2013) Evaluation of analgesic and anti-inflammatory activities of *Hydrocotyle umbellata* L. Araliaceae (acaricoba) in mice. An Acad Bras Cienc 85:987–997
31. Avila EDD, Molon RSD, Camparis CM (2014) Relationship between levels of neuropeptide substance P in periodontal disease and chronic pain: a literature review. J Investig Clin Dent 5:91–97
32. Jarcho JM, Feier NA, Bert A, Labus JA, Lee M, Stains J, Ebrat B, Groman SM, Tillisch K, Brody AL, London ED, Mandelkern MA, Mayer EA (2013) Diminished neurokinin-1 receptor availability in patients with two forms of chronic visceral pain. Pain 154:987–996
33. Fearon AM, Twin J, Dahlstrom JE, Cook JL, Cormick W, Smith PN, Scott A (2014) Increased substance P expression in the trochanteric bursa of patients with greater trochanteric pain syndrome. Rheumatol Int 34:1441–1448
34. Muñoz M, Coveñas R (2014) Involvement of substance P and the NK-1 receptor in human pathology. Amino Acids 46:1727–1750
35. Yeh ML, Chung YC, Hsu LC, Hung SH (2017) Effect of transcutaneous acupoint electrical stimulation on post-hemorrhoidectomy-associated pain, anxiety, and heart rate variability. Clin Nurs Res 1:1054773816685745