

Clinical Studies

Effects of Intraoperative Electro-acupuncture on Healthy Dogs Undergoing Anesthesia for Elective Procedures: A Randomized, Controlled, Blinded Clinical Trial

Sarah Hammond

ABSTRACT

The objective of this study was to evaluate the efficacy of intraoperative electro-acupuncture (EAP) on duration of anesthetic recovery, immediate postoperative pain and isoflurane use in healthy dogs undergoing elective surgical procedures. Twenty-nine healthy dogs admitted for elective ovariohysterectomy or orchiectomy were enrolled and randomly assigned to either the EAP ($n = 14$) or control ($n = 15$) study groups. Subjects in the EAP Group were intubated and moved into the surgery suite. Acupuncture needles were then placed at LIV-13, ST-36 and GB-34 bilaterally with EAP started and maintained (at 20 Hz) for 20 minutes during the surgical procedure. Subjects in the Control Group did not receive any treatment after being moved into the surgery suite. Outcome data included time to extubation after the discontinuation of gas anesthesia, postoperative pain score (1 hour, 2 hours) and isoflurane concentration. The EAP Group had a significantly shorter anesthetic recovery time (mean $\pm$ SD = 5.93 $\pm$ 2.81 minutes) when compared to the Control Group (8.87 $\pm$ 2.75 minutes; $p = 0.007$). Mean postoperative pain scores were nonsignificantly lower with EAP treatment at 1 hour (1.5 $\pm$ 1.5, -25%) and 2 hours (1.82 $\pm$ 2.0, -22%) when compared to control means (2.0 $\pm$ 3.1 at 1 hour, 2.3 $\pm$ 3.4 at 2 hours). There was no statistical difference between groups for isoflurane use. The study concluded that performing intraoperative EAP could shorten the time between discontinuation of gas anesthesia to extubation in healthy dogs undergoing an elective surgical procedure. Larger scale trials are warranted to validate the findings of this study and other potential benefits such as improved analgesia.

Keywords: anesthesia, canine, castration, electro-acupuncture, neuter, orchiectomy, ovariohysterectomy, pain, traditional Chinese veterinary medicine

In small animal practice in the United States, the majority of privately owned pets (86%) undergo elective sterilization.¹ Although ovariohysterectomy (OVH) and orchiectomy are elective procedures requiring general anesthesia, postoperative care and pain management, they are performed so commonly as to be considered routine procedures in small animal clinics.² Anesthetic risk, however, is a major concern for veterinarians and staff, with length of patient anesthesia accounting for one of the highest risk factors.³⁻⁵

Currently, the American Animal Hospital Association (AAHA) standard of care guidelines for anesthesia and pain management focus on lowering the stress of handling and ensuring adequate pain control for all procedures, with particular attention to postoperative pain control.^{6,7} Standard of care for anesthesia includes careful monitoring of blood pressure, heart rate, expiratory CO₂ concentrations, oxygenation and electrocardiogram during the surgical procedure. It is recommended that the amount of inhalant anesthesia (i.e. isoflurane), should be adjusted to the lowest

possible dose to maintain proper level of anesthetic depth. Additionally, sedation and pain control should optimally include a multimodal approach where pharmaceuticals with different chemical structures/classes are synergistically used with tailoring of doses and medications to each patient and procedure.^{2,6,7} For example, hydromorphone, an opioid, and dexmedetomidine, an alpha-2 agonist, would be used to provide pain control and sedation as part of a multimodal preoperative surgical protocol. Ultimately, these guidelines stress the importance of considering the needs of the individual and selecting medications and surgical procedures to enhance surgical outcome for that patient.

Author Professional Degrees and Certifications: DVM, CVA, MS-TCVM, CVTP, CVCH, CVFT; **From:** Tidal Medicine, Gloucester, MA, USA; ***Address correspondence to** Dr. Sarah Hammond (doc@tidalmedicine.com).

In Chinese medicine theory, the substance *Qi* gives life. It permeates and influences all parts of the body and if *Qi* ceases, the vital activities of the body will also cease.⁸ As *Qi* flows through the body, it is concentrated along connecting pathways or Meridians containing a series of unique tissue locations (i.e. acupuncture points) which can be stimulated to promote *Qi* flow. Surgical procedures, which disrupt and manipulate tissues, block the normal flow of *Qi* along Meridians creating *Qi* Stagnation. This disease process results in pain, stiffness and organ dysfunction.⁸ Acupuncture therapy, through the stimulation of acupuncture points along the Meridians, improves *Qi* flow, resolving Stagnation and balancing the body's overall energy. The effects of acupuncture point stimulation can be intensified, or the duration lengthened by heating or electrically stimulating the needles placed into acupoints.⁹

The use of perioperative acupuncture therapy has several benefits to be considered. First, AAHA guidelines specifically list acupuncture as an appropriate intervention for pain management in soft tissue surgeries (as well as dental and orthopedic procedures). It provides another clinical tool to aide an integrated approach to a multimodal anesthetic plan and pain management. It benefits the entire patient by encouraging better *Qi* flow and minimizing surgically associated Stagnation. Additionally, there is a shrinking opioid supply in the United States due to the human health addiction crisis creating increasingly difficult access for veterinary practitioners. Additional therapies, such as acupuncture, can help reduce the requirement of opioid use in postoperative veterinary patients.¹⁰ Nonetheless, in the United States, practitioners unfamiliar with Chinese medicine may not understand/or have limited knowledge of how the use of even a few acupuncture points can improve their current patient care.

The aim of this study was to determine whether intraoperative electro-acupuncture (EAP) affects anesthesia monitoring parameters and immediate postoperative pain scores in healthy dogs undergoing elective surgical procedures. The acupoints chosen for this research were selected for effect on the patient, well known anatomic landmarks for clinicians and easy accessibility during the study surgical procedures: Stomach 36 (ST-36), Gall Bladder 34 (GB-34) and Liver 13 (LIV-13) (Figure 1). The first study acupuncture point, ST-36 (*Hou-san-li*), is a strong general *Qi* tonic point (also known as rear limb three-mile point). It is the master point for the abdomen with numerous investigations documenting its beneficial effects on intestinal motility. This acupuncture point was selected for its postsurgical potential to modify pain and Stagnation due to its well-known ability to move *Qi*.¹¹ The second study acupuncture point, GB-34 (*Yang-ling-quan*), is the master point for tendons and ligaments. This acupoint is also used for general pain relief.¹¹ The third acupoint, LIV-13 (*Zhang-men*), is the chief point for viscera, influential point for *Zang* organs, and has the ability to decrease abdominal pain.¹¹



Figure 1: Lateral view of a canine model demonstrating the location of acupuncture points Stomach 36 (ST-36), Gall Bladder 34 (GB-34) and Liver 13 (LIV-13).

Study objectives were to evaluate the efficacy of intraoperative EAP by assessing duration of anesthetic recovery, immediate postoperative pain and isoflurane use in healthy dogs undergoing ovariohysterectomy or orchiectomy. The study hypothesized that dogs undergoing these elective surgical procedures and receiving the proposed EAP treatment would have shorter recovery times following anesthesia, lower postoperative pain scores and reduced isoflurane use when compared to control subjects receiving no EAP treatment.

MATERIALS AND METHODS

Animals

The subject population for this study was healthy canine patients admitted for elective ovariohysterectomy or orchiectomy. Study subjects were recruited at a small animal private clinic located in Gloucester, Massachusetts, USA. All owners gave written consent for their animals to participate in the study. Inclusion criteria were 1) age between 0.5 and 2.5 years old; and 2) normal physical exam that included an American Society of Anesthesiologist Class I status, and normal preoperative conditions with complete blood count and clinical chemistry^a. Exclusion criteria included any dog that did not have a preoperative exam and bloodwork within normal limits at the time of anesthetic induction.

Study Design

Each qualified study subject was randomly assigned to 1 of the 2 study groups: Electro-acupuncture treatment (EAT) Group or Control Group. Randomization was conducted by using the estimated total number of subjects and an online software program^b to randomly assign numbers to the 2 study groups. Subjects were then marked

on admission to the hospital with a number in sequential order, which then correlated to the group their subject number had been placed in by the randomizer. Owners were not made aware if their pet was assigned to the Control Group or the EAT Group.

Anesthetic and Surgery Protocol

All animals were fasted from the evening before surgery with water allowed until 3 hours before their procedure. Each subject of both groups was given injectable premedication of dexmedetomidine^c (0.01mg/kg) and hydromorphone^d (0.1mg/kg) intravenously or intramuscularly, dependent on patient temperament. Once a subject was determined to be adequately sedated for cephalic catheterization, the subject was catheterized; propofol^e was administered intravenously at 4 mg/kg; and endotracheal intubation was performed. Subjects' anesthesia was maintained with isoflurane^f inhalant in 100% oxygen at 2L/minute oxygen at vaporizer settings of 1-2.5. Inhalant anesthesia was delivered through a rebreathing system with an isoflurane vaporizer. The isoflurane concentration was recorded every five minutes through the entire length of the surgery by the certified veterinary technician monitoring anesthesia. All subjects received intravenous (IV) lactated Ringer's solution throughout the procedure at 40ml/kg/hr. Adequate level of anesthesia was determined by palpebral reflex, jaw tone and kept at a similar level for all subjects.

Two veterinarians were responsible for performing the surgical procedures. Surgeons were of equal skill, and animals were randomized between surgeons. Surgeons were blinded to subject groups. For both OVH and orchiectomy procedures, animals were placed in dorsal recumbency. A 6-12 cm (dependent on animal size) ventral midline incision on the linea alba with a 3 clamp technique was used for all OVH procedures. A ventral midline prescrotal incision (2-3 cm) with a 2 clamp

technique was used for the orchiectomy procedure. The start and completion time of each study dog's surgery was recorded along with any adverse events if they occurred.

Electro-acupuncture Treatment Protocol

Subjects in the Control Group were moved into the surgery suite after endotracheal intubation and maintained on isoflurane in 100% oxygen at 2L/minute, followed by start of the surgical procedure. For subjects assigned to the EAT Group, once moved into the surgery suite, the author, certified in veterinary acupuncture, as well as a certified veterinary technician trained by the author, placed acupuncture needles^g (0.22x15 mm) at LIV-13, ST-36 and GB-34 bilaterally (Table 1). The acupoints were connected bilaterally with output wires connected to an acupunctoscope^h. Electrical stimulation at 20 Hz (F1-20Hz, F2-0Hz, continuous stimulation) with the intensity ranging between 1-5mA (determined by observation of muscle fasciculation) was started once all acupoints were connected. The acupuncturist adjusted the acupunctoscope to study protocol settings.

Directly following the start of EAP treatment, the surgical procedure was initiated. The EAT was performed and remained at the same settings during the entire surgical procedure, which lasted approximately 20 minutes. The veterinary technician, monitoring patient anesthesia, also made sure acupuncture needles remained fixed in place and adjusted/replaced any needle that moved or became dislodged at any point during the surgical procedure. Acupuncture needles were removed after discontinuation of isoflurane and before extubation so the veterinary technician monitoring post-extubation remained blinded to study groups. The veterinary technician monitoring anesthesia and acupuncture needles was a different person than the certified veterinary technician responsible for monitoring post-op outcome data parameters to maintain a blinded study.

Table 1: Acupoints used for EAT Group study dogs with the needle depth, anatomic location, indication and actions for each acupoint summarized¹¹

Acupoint	Approximate Needle Depth (inches)	Anatomic Location	Attributes, Indications and Actions
ST-36	0.12-0.2	On the craniolateral aspect of the pelvic limb, 3 <i>cun</i> distal to ST-35, 0.5 <i>cun</i> lateral to the cranial aspect of the tibial crest, in the belly of the cranial tibialis muscle	Master point for the GI tract and abdomen, <i>He-Sea</i> point (earth), horary point; nausea, vomiting, stomach pain, gastric ulcers, food Stasis, generalized weakness, constipation, diarrhea, general <i>Qi</i> tonic
GB-34	0.12-0.2	On the lateral side of the pelvic limb at the stifle, in a small depression cranial and distal to the head of fibula	<i>He-Sea</i> point (earth), Influential point for tendon and ligaments, ST and LIV <i>Qi</i> Stagnation, general pain relief, hypertension, vomiting
LIV-13	0.12-0.2	On the lateral thorax, at the distal end of the 12 th rib	Master point of the viscera, Influential point for <i>Zang</i> organs, alarm point for the Spleen, abdominal pain, diarrhea, abdominal mass, generalized muscle pain, agitation, anger

Postoperative Assessment

The time from discontinuation of gas anesthesia to extubation was recorded for each animal by a veterinary technician (blinded to study groups) monitoring anesthesia recovery. Postoperative pain scores were then measured at 1 hour post-extubation (time 1), and 2 hours post-extubation (time 2). This same technician (blinded to study group) was also responsible for observing dogs and recording pain scores. Pain scores were measured using the short form Glasgow composite pain scale.¹² This numeric scale was used to assess pain in six categories. It included 2 scoring observations for attitude while in the crate/kennel (e.g. ranging from quiet to screaming; range of ignoring incision to chewing at it). A third score was assigned for the dog's ability and ease to ambulate when taken out of the crate/kennel (if unable to ambulate, not scored). The fourth score was for reaction to light palpation of the surgical site, and 2 more scores were given for overall attitude (e.g. normal to depressed behavior, dog appears comfortable ranging to rigid with pain). The maximum composite score for these 6 scoring observations was 24. If an animal was unable to ambulate, therefore, unable to be scored for that observation, then the maximum score was 20. Rescue analgesic intervention was determined to be given for a score of 6/24 for ambulatory animals, or 5/20 if animals were not yet able to ambulate. A higher total score indicated higher patient pain level and higher requirement for analgesia in the patient.

Statistical Analysis

Three quantitative outcome measurements were collected from each subject to test the study hypothesis: 1) isoflurane concentration by vaporizer setting, recorded every 5 minutes throughout the procedure; 2) time from discontinuation of gas anesthesia to extubation (T_g); and 3) postoperative pain scores measured 1-hour post-extubation (time 1), and 2 hours post-extubation (time 2).

The study tested 3 sets of statistical hypotheses: 1) H_0 : the mean isoflurane concentration in the EAT Group is the same as that in the Control Group versus H_A : the mean isoflurane concentration in the EAT Group is lower than that in the Control Group; 2) H_0 : the mean T_g in the EAT Group is the same as that in the Control Group versus H_A : the mean T_g in the EAT Group is shorter than that in the Control Group; and 3) H_0 : the mean pain score in the EAT Group is the same as that in the Control Group vs. H_A : the mean pain score in the EAT Group is lower than that in the Control Group. The non-parametric Wilcoxon Rank Sum tests were used for all hypotheses which compared the means of continuous measurements between the 2 independent groups, without assuming normal distribution of the outcome assessment. For each of the tests, the H_0 was rejected when the resulting

p -value of the test was less than 0.05. A sample size of 24 subjects in each treatment group was planned to ensure a 90% power to reject the null hypothesis with a 0.05 significance level, anticipating that the EAT Group's mean outcome was superior with a difference that equals the overall standard deviation. All statistical analysis results and graphics were generated by statistical software R¹.

RESULTS

The study enrolled a total of 29 dogs for elective ovariohysterectomy or orchiectomy. The randomization procedure resulted in 14 dogs assigned to the EAT Group and the remaining 15 to the Control Group. The signalment data of the 2 study groups was not significantly different (Table 2). The EAT Group had 57.1% female versus the Control Group with 73.3% female ($p = 0.45$). Age and body weight of the EAT Group at study start was 9.8 ± 1.0 months and 18.1 ± 4 kilograms versus 8.6 ± 1.2 months ($p = 0.23$) and 19.1 ± 1.95 kilograms ($p = 0.47$) for the Control Group. Both groups included a variety (> 10) of canine breeds.

For each study subject, the time duration between the discontinuation of gas anesthesia and extubation was measured (Figure 2). The subjects in the EAT Group had shorter durations than those in the Control Group. The

Table 2: Group study animal signalment data with summary statistics

Group	Sex	Age (Mean $\pm$ SD)	Weight (Mean $\pm$ SD)
EAT Group (n = 14)	F = 57.1% M = 42.9%	9.8 $\pm$ 1.0 months	18.1 $\pm$ 4 (kg)
Control Group (n = 15)	F = 73.3% M = 26.7%	8.6 $\pm$ 1.2 months	19.1 $\pm$ 1.95 (kg)
EAT vs. Control p -value	$p = 0.45$	$p = 0.23$	$p = 0.47$

EAT = electro-acupuncture treatment

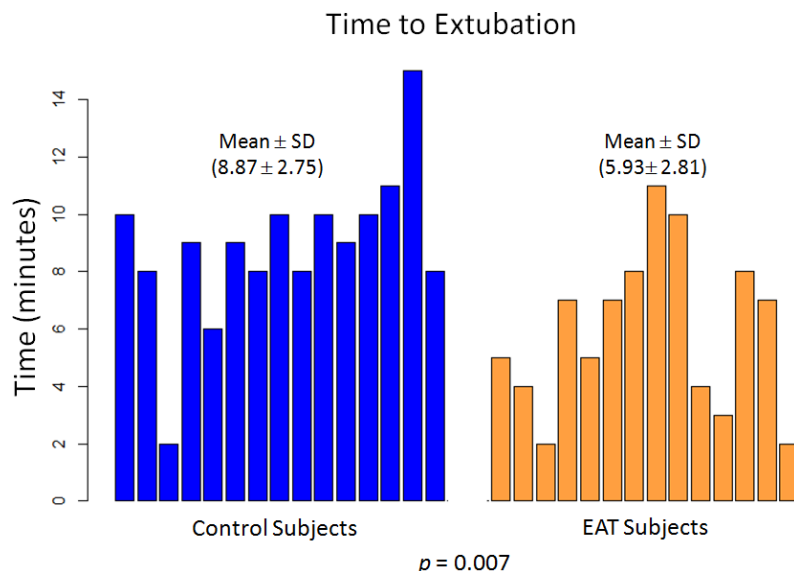


Figure 2: Time required to extubation for each subject

Mean±SD duration in the EAT Group was 5.93±2.81 minutes versus 8.87±2.75 minutes in the Control Group. Statistically, this difference was significant ($p = 0.007$), which concluded that subjects receiving EAT needed shorter times to be extubated.

The Mean±SD pain score at 1-hour post-extubation for the Control Group was 2.0±3.1 (includes all dogs) and 4.3±3.3 (excludes pain-free dogs). The mean pain score at 1-hour for the EAT Group was 1.5±1.5 (includes all dogs) and 2.33±1.2 (excludes pain-free dogs) which was a 25% and 46% score reduction, respectively when compared to Controls (Table 3). The group difference, however, was not large enough to reach statistical significance with or without inclusion of pain-free dogs ($p = 0.66$ and 0.38, respectively). It is worth noting that 3 subjects in the Control Group had pain scores of 7 or above, whereas all subjects' pain scores in the EAP Group were 4 or below (Figure 3).

The Mean±SD pain score at 2-hour post-extubation for the Control Group was 2.3±3.4 (includes all dogs) and 4.4±3.7 (excludes pain-free dogs). The Control Group had 1 dog that converted from pain-free (0 score) to expressing pain (score=5). All pain-free EAT dogs remained unchanged at 2 hours (Figure 4). The Mean±SD 2-hour pain score in the EAT Group was 1.8±2.0 (includes all dogs), which was a 22% pain score reduction compared to controls and 2.8±1.8 (excludes pain-free dogs), which was a 36% lower pain score (Table 3). Compared to the 1-hour scores, both groups had increased 2-hour pain scores. Similarly, the group difference was not statistically significant for subjects with or without pain ($p = 0.85$ and 0.51, respectively).

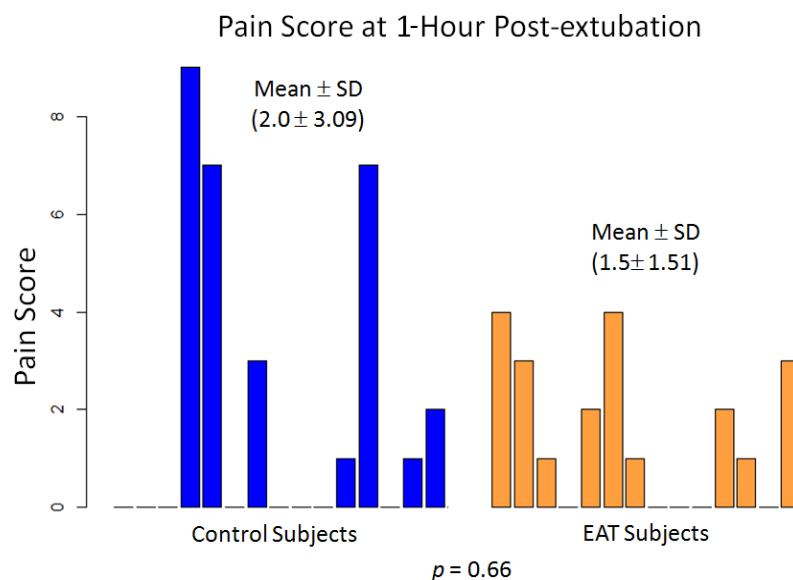


Figure 3: One-hour post-extubation pain score for each subject

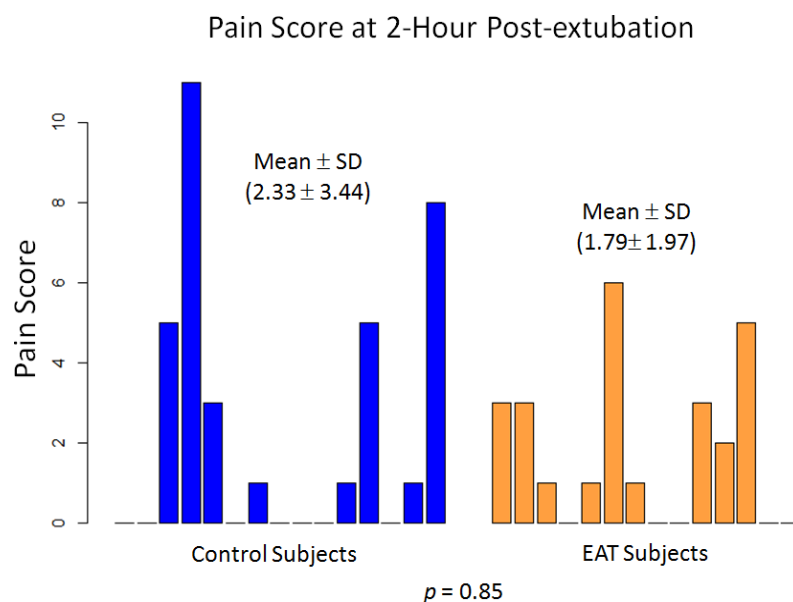


Figure 4: Two-hour post-extubation pain score for each subject

Table 3: Pain scores of control and electro-acupuncture treated (EAT) study dogs compared at 1 hour and 2 hours post surgery

Study Dogs	Controls 1-Hour Pain Score Mean±SD	EAT Dogs 1-Hour Pain Score Mean±SD	Controls 2-Hour Pain Score Mean±SD	EAT Dogs 2-Hour Pain Score Mean±SD
All Dogs in a Group	2.0±3.1	1.5±1.5 (25%) lower score	2.3±3.4	1.8±2.0 (22%) lower score
<i>p</i> -value	0.66		0.85	
Pain-free Dogs Excluded from Group Means	4.3±3.3	2.33±1.2 (46%) lower score	4.4±3.7	2.8±1.8 (36%) lower score
<i>p</i> -value	0.38		0.51	

The mean isoflurane concentration (recorded every 5 minutes throughout a surgical procedure) in the EAT Group was $1.67 \pm 0.31\%$, whereas the Control Group was $1.46 \pm 0.37\%$. Based on the Wilcoxon Rank Sum test, the difference between the groups was not statistically significant ($p = 0.081$) at the 0.05 level. Using the maximal isoflurane concentration data gave the same statistical conclusion (EAT $1.96 \pm 0.37\%$ vs. Control $1.70 \pm 0.41\%$; $p = 0.057$).

All subjects that were enrolled completed the study. There were no adverse events, including need for rescue analgesia, associated with either the experimental treatment (EAP) or controls during surgery and recovery. The unplanned reduction in group size for this study reduced the power of the statistical test to 72% under the same statistical considerations and assumptions.

DISCUSSION

A total of 29 healthy young dogs admitted for elective ovariohysterectomy or orchiectomy procedures were enrolled in this randomized, controlled, blinded clinical trial which investigated the effect of EAT on anesthetic recovery, postsurgical pain and isoflurane use during surgery. Findings for the study demonstrated a significantly shorter anesthetic recovery time for EAT dogs when compared to the Control Group ($p=0.007$). Additionally, mean postoperative pain scores were nonsignificantly lower for EAP treated dogs at 1 hour (-25%) and 2 hours (-22%) when compared to controls. There was no statistical difference between groups for isoflurane use.

Pain relief during surgery is mainly achieved using opioids (i.e. morphine) which are associated with undesirable side-effects such as delayed postoperative recovery, decreased level of consciousness and nausea/vomiting.¹³ Additionally, inhalation anesthetics are known for their dose-dependent cardiopulmonary adverse side-effects.¹⁴ In the past decades, there has been an increasing number of clinical trials evaluating the efficacy of EAP as a method supplementary to anesthesia and postoperative analgesia.¹³ In both humans and canines, perioperative acupuncture has been shown to reduce pain, nausea, analgesic requirements and can be an important part of a multimodal non-drug analgesia protocol.¹⁵⁻²⁰ Electro-acupuncture, in particular, can be of greater efficacy than dry needle technique as it produces a more prolonged intense stimulation.¹⁰ The effects are produced through modulation of the descending pain inhibitory system, including the opioidergic, adrenergic and serotonergic pathways in both the central and peripheral nervous systems.^{10,20,21} Electro-acupuncture administered at different frequencies (Hz) can promote varying release of these different neurotransmitters.^{10,21}

In the present study, the supplementary use of EAP with isoflurane during the surgical procedure in EAT dogs resulted in a statistically significant shortening of anesthetic recovery (time to extubation). To the author's knowledge, this is the first study to report this as

a statistically significant finding in dogs. There have been several studies in humans that have reported similar significant findings.^{13,22,23} One study looked at 80 patients undergoing thoracic lobectomy surgery. The study was designed to identify non-invasive, non-pharmacological adjunctive treatments that would improve perioperative analgesia and decrease postoperative surgical complications. The study was organized into 4 groups of patients which included no adjunct treatment (controls), and patients with various EAP frequency settings (2Hz/100Hz, 2Hz, 100Hz) administered before, during and after surgery. Study results demonstrated the alternating frequency of 2 Hz with 100 Hz provided significantly best analgesia, shortened time to extubation and lowest anesthetic use.²²⁻²⁷ Another study evaluated 80 human surgery patients undergoing craniotomy for supratentorial tumor resection. The study investigated the supplementary effect of EAP combined with 2% sevoflurane and its influence on sevoflurane concentration and speed of recovery. Patients were divided into control and those receiving EAP (2/100 Hz) on the same side as the craniotomy before anesthesia induction until end of surgery. The bi-spectral index was maintained between 40-50 (depth of anesthesia). Findings demonstrated significantly shortened time to extubation, reduced anesthetic use, with improved quality of anesthesia recovery (less nausea, vomiting, dysphoria) for EAP treated patients.²³

In addition to significantly shortened anesthetic recovery in the EAT group, there was a nonsignificant improvement in the 1-hour (-25%) and 2-hour (-35%) post-extubation pain relief. Similar to the present study, Gakiyal et al. reported mildly improved analgesia (less rescue drug needed) associated with perioperative EAP in their randomized controlled study.¹²⁻¹⁵ The trial included a total of 30 client-owned dogs having mastectomy procedures and randomly assigned to 3 groups: morphine group, EAP group (using ST-36, SP-6, GB-34, bilateral), and sham-EAP group ($n = 10$). Electrical stimulation was an alternating square wave at 2/200Hz. The study did not find significant difference in post surgery pain scores among groups, however, fewer subjects in the EAP Group (20%) required rescue analgesia compared to the other groups.

Wang et al. commented in their study discussion area about the variable postoperative analgesia results in studies investigating surgical patients receiving EAP treatment.¹³ They proposed several explanations which could apply to the present study: 1) the acupuncture technique may not have delivered sufficiently strong stimulation to produce a pronounced analgesic effect; 2) using a single frequency (i.e. 2Hz vs. 2Hz/100Hz) has a different effect on neurotransmitter release; 3) general anesthesia adjusted and monitored in a conventional way (heart rate, arterial pressure) adds unacceptable variability versus using a bispectral index (BIS) monitor maintained between 40 and 55 for all operations; and 4) combinations of acupoints can produce different effects (i.e. LI-4, PC-6, ST-36 are synergistic for analgesia).

Outcome data produced and analyzed for this study also included intraoperative isoflurane use in the EAT

dogs. Treatment with EAP during surgery did not reduce isoflurane use in these dogs. This was unexpected, as based on results from other investigations, the additional analgesia provided by perioperative use of dry needle or electro-acupuncture can significantly decrease anesthetic use.^{13,14,22-28} It has been demonstrated that morphine, by providing supplemental analgesia during surgery, can lower inhalant anesthetic use by as much 60%.⁸ Jeong demonstrated with EAP settings similar to the present study, significant lowering of minimal alveolar concentration of isoflurane in anesthetized dogs with EAP administered at 20Hz frequency for 30 minutes.^{3,9}

Different from the present study, however, is that no surgery was performed on Jeong's study dogs, therefore the pain level was negligible, especially compared to abdominal surgery in the present study. Analgesia provided by EAP can vary dependent on a number of conditions, such as acupoints selected, frequency settings (low versus high) and continuous versus intermittent (dense and disperse) stimulation. The lower frequency settings, as used in this study, release more enkephalins and β -endorphins which have slower onset but longer duration.²⁰ It has been recommended that to provide adequate EAP analgesia for abdominal surgery, it is necessary to have an adequate induction period of 30 to 40 minutes prior to the procedure.²⁹ The lack of significant isoflurane reduction may be associated with lack of an induction period in the present study. Additionally, it may have been better to use the dense-disperse frequency setting, as it releases a combination of endogenous opioids when set at a high and low frequency.

Limitations to this clinical study that may have been associated with inconsistent results included the use of varying dog breeds, body weights and age. It is likely that the subjects had different tolerances for pain and anesthesia that were not controlled for in this study. For example, premedications were administered by either intravenous or intramuscular routes due to patient temperament. This creates different drug pharmacokinetics in different patients which may affect anesthetic use in different individuals. This could be standardized in future studies. The acupuncture points selected for this study, LIV-13, ST-36 and GB-34, were chosen based on accessibility of location during surgery, and literature documenting a direct effect on the abdomen and/or viscera. In addition, these 3 points are associated with pain relief, and movement of *Qi*. By choosing these points, the treatment goal of electro-acupuncture was to directly affect pain associated with abdominal procedures (i.e. orchiectomy and ovariectomy). For example, the EAP treatment combination of ST-36 and GB-34 induced effective analgesia for an abdominal incision with a success rate of 89% in a study evaluating pain relief.¹⁴ Even with literature support, however, the acupoints selected for this study may not be the best ones to provide a significant effect on anesthetic parameters and postoperative pain under the experimental conditions of the present study.

Additional study limitations that may have affected results include combining 2 dissimilar surgical procedures and smaller sample size (n=14 for EAT, n=15 for controls). Ovariectomy procedures are open abdomen, while orchiectomy is an external procedure. Due to the difference in these procedures, pain experienced by subjects would be different, which could affect both anesthetic and analgesia outcome data. The number of dogs enrolled in the study was smaller than planned (n=24 for each group), for a desired 90% power to claim statistical significance (at a 0.05 level) when the group difference was at least as large as the data standard deviation. Under the same statistical considerations, the current sample size reduced the power to approximately 72% for concluding statistical significance which likely affected statistical significance for postoperative pain.

Further study is warranted in many regards to TCVM and general small animal practice. Recommendations for conduct of future studies would include reducing variables that likely affected this study such as breed, size and age differences; restrict investigation to 1 type of surgical procedure; and decrease variability in regulating depth of anesthesia. Suggestions for EAP protocol change might include adding an induction phase for optimal EAP analgesia prior to the start of surgery, the use of dense and disperse setting that includes low and high frequencies for production of a combination of endogenous opioids, and investigate additional acupoints that have demonstrated anesthetic sparing action such as LIV-3.

In conclusion, intraoperative EAP with settings of 20Hz for 20 minutes attached bilaterally to LIV-13, ST-36 and GB-34 on healthy dogs undergoing ovariectomy or orchiectomy resulted in a statistically significant shorter anesthetic recovery time. As veterinarians, it should always be an essential goal to minimize adverse effects associated with elective procedures and reduce discomfort for patients. The findings from this study suggest EAP treatment could improve the quality of anesthetic recovery for dogs and has potential to reduce postsurgical pain. Larger scale clinical trials are warranted to validate the findings of this study and explore other benefits associated with perioperative use of electro-acupuncture in small animal clinics.

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The author declares that there is no conflict of interest that could be perceived as prejudicing the impartiality of this paper and the author did not receive any specific grant funding from any organization in the public, commercial, or non-profit sectors.

FOOTNOTES

- ^a Vetstat Chem6, Abaxis North America, Union City, CA, USA
- ^b Research Randomizer (version 4.0) software; Urbanink G & Plous S; www.randomizer.org
- ^c Dexmedetomidine, Dechra Pharmaceuticals, Northwich, United Kingdom

- ^d Hydromorphone, Baxter International, Deerfield, IL, USA
^e Propofol, Zoetis Animal Health, Parsippany, NJ, USA
^f Isoflurane, Dechra Pharmaceuticals, Northwich, United Kingdom
^g DBC Spring Ten, Lhasa OMS-DongBang™ Corporation, Weymouth, MA, USA
^h Electro-acupuncture stimulator JM-3A, Wuxi Jiajian Medical Instrument, Inc., Wuxi, China
ⁱ R version 3.5.2. The R Foundation for Statistical Computing, Vienna, Austria (<http://www.R-project.org>)

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