Successful Practice of Electroacupuncture Analgesia in Equine Surgery

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Abstract
Electroacupuncture analgesia was used for surgery in horses and donkeys. A KWD-808 electrical stimulator was used to incrementally induce a dense, dispersed wave output at frequencies from 20 to 55 Hz, which was maintained at a frequency of 55 Hz, and to change the amplitude of the wave to the best grading number for the suggested operation in each animal. Induction of analgesia lasted for 20–30 minutes, and the effect of analgesia was maintained for 20–45 minutes depending on the type of surgery performed. The exhibited clinical signs, physical examination data, and the responses of all animals were used for evaluating the periods of analgesia. Although the majority of the cases (95%) had no response to strong surgical pain, they experienced significant increases in heart rates and respiratory rates during induction. The lack of pain, relaxed surgical procedures, reduced intraoperative bleeding, and improved healing without complications were all definite benefits of using electroacupuncture analgesia in surgery. Thus, this study has provided surgical evidence supporting the effectiveness of electroacupuncture analgesia, as well as confirming its reliability, in the field of equine anesthesia and surgery.
1. Introduction

Veterinary acupuncture was initially practiced in China and later spread to other Asian countries, such as Japan and Korea, about 1500 years ago. In the last 25–30 years, there has been a tremendous growth in animal acupuncture in Europe and the United States [1]. Many types of stimulations, including acupuncture, various peripheral electrical stimulations, vibrations, and electrical stimulations of specific areas in the brain, are able to produce analgesic effects [2]. They activate pathways from the brain to the spinal cord and inhibit incoming pain information in various layers of the dorsal horn of the spinal cord. These pathways involve many neurotransmitters, including serotonin, endogenous opiates, and norepinephrine [3]. Electroacupuncture has stronger effects than other types of acupuncture [4], and acupuncture analgesia has been produced using different types of stimulations at both acupuncture and nonacupuncture points [5]. Acupuncture has been proven to be effective for treating pain, geriatric diseases, and exercise-related diseases in horses [6], and results of neuroscience studies have provided a physiological basis for explaining how acupuncture works and how it stimulates the release of painkillers known as endorphins [7]. The acupoints are located throughout the body on meridians and are connected to each other. These points and nonacupuncture points [5]. Acupuncture has produced using different types of stimulations at both acupoints and nonacupuncture points [5]. Acupuncture has been proven to be effective for treating pain, geriatric diseases, and exercise-related diseases in horses [6], and results of neuroscience studies have provided a physiological basis for explaining how acupuncture works and how it stimulates the release of painkillers known as endorphins [7]. The acupoints are located throughout the body on meridians and are connected to each other. These points can be stimulated by various means in order to produce physiological functions to treat different diseases [8].

The current work was designed to prove the relevance of electroacupuncture analgesia in the field of equine surgery. The aim was to replace expensive anesthetic drugs with a simple analgesia technique that could maintain the animal’s normal physiology during surgery without pain and danger.

2. Materials and methods

The present investigation was carried out on 18 healthy experimental animals (10 stallions and 8 mares); their ages varied from 8 to 15 years, and their body weights ranged from 350 to 450 kg. These horses were cared for and managed during the 1-year study period in accordance with the guidelines of the Animal Ethics Committee of Veterinary Medicine, Cairo University (Cairo, Giza, Egypt). Electroacupuncture stimulation was used for seven clinical cases (2 foals, 1 gelding, 2 stallions and 2 donkeys) treated at our surgery clinic. Surgeries on the head and neck, the chest wall, the thigh, and the abdomen, as well as castration were performed on experimental animals. Each animal, whether clinical or experimental, had an independent acupoints plan. The selected acupoints were exposed to electroacupuncture stimulation throughout the duration of the surgery.

An acupuncture electrostimulator set (9 V; KWD-808 I Multi-Purpose Health Device) with a current frequency range of 1.2–55 Hz made in China. Acupuncture needles of different sizes (0.50 × 40 mm, 0.70 × 70 mm), and electric wires with terminal clips were used in this study. The electrostimulator was checked to ensure that the power was switched off. Needles were inserted at the selected acupoints at the appropriate angles and depths of insertion. The electroacupuncture stimulator, which produced a bipolar waveform (+, and −) electrodes were connected to the needles by electric wires with terminal clips. The power switch was turned on to establish a frequency of 20 Hz at the beginning, which took 10 minutes; the frequency was then changed gradually for the next 10–20 minutes to achieve a frequency of 55 Hz. Thereafter, for the maintenance of analgesia, the output with the 55-Hz frequency was sustained, and the amplitude of waves was changed to the required grade (from 1 to 10) of the outputs; the analgesic effect was maintained until the end of the surgery. The duration of analgesia varied (from 20 to 45 minutes) depending on the type of surgery performed.

The exhibited clinical signs, particularly after electroacupuncture induction and maintenance, were shivering, tremors, quidding, blinking of the eyelids, nystagmus, abnormal tongue movement, sweating, engorgement of facial blood vessels, muscle contraction, urination, and defecation. The body temperature (°C), mucus membrane color, respiratory rate (breaths/minute), heart rate (beats/minute), and capillary refill time were evaluated before electroacupuncture stimulation (control) and during induction and maintenance of analgesia.

Head and neck operations included cheek wound suturing (Fig. 1), neck wound suturing (Fig. 2), trephining (Fig. 3), and excision of the medial canthus sarcoid (Fig. 4). The acupoints used were bilateral and can be described as: Gui-Mu (facial nerve), Ting-Gong (auditory palace), Yan-Chi (rock pond), He-Xi (jaw stream) and Xia-Yi-Feng (lower wind (facial blood vessels), muscle contraction, urination, and defecation. The body temperature (°C), mucus membrane color, respiratory rate (breaths/minute), heart rate (beats/minute), and capillary refill time were evaluated before electroacupuncture stimulation (control) and during induction and maintenance of analgesia.

For the treatment of a lateral thoracic wound suturing, the acupoints Qiang-Feng (robbing wind) SI-9 and Qi-Jia (withers) between GV-13 and GV-14 were used and are demonstrated in Fig. 5. For the laparocolotomy, the acupoints Qi-Jia, Bai-Hui (hundred meetings), Wei-Gan (tail base), and Da-Kua (greater trochanter) were used as shown in Fig. 6. For thigh wound suturing, the acupoints Bai-Hui, Wei-Gan, Da-Kua, and Han-Gou (sweat groove) BL-37 were used. The procedures are displayed in Fig. 7.

For the treatment of a lateral abdominal hernia in a foal, the acupoints Bai-Hui, Wei-Gan, Da-Kua, Qiang-Feng, and Tian-Men (heavenly gate) GV-16 were used and are shown in Fig. 8. For the treatment of granulomatous swelling in the right side of the abdominal wall in a foal, the acupoints Qi-Jia, Bai-Hui, and Wei-Gan were used, with two thin needles inserted parallel to both sides of the operation site. These acupoints are shown in Fig. 9.

For the treatment of a long-standing fibroma at the right thoracic wall in a donkey, the acupoints Tian-Men, Qi-Jia, Bai-Hui, and Wei-Gan were used with two needles inserted at both ends of the operation site. In addition, the auricular acupoints Shen-Men (gate of mind), Fei-1, and Xiong (thorax point) were used. These procedures are illustrated in Fig. 10.

For the treatment of an obstructive urolith in the perineal urethra and rupture of the urinary bladder in a donkey, the acupoints Hou-Hai (caudal sea) GV-1, Han-Gou, Da-Kua, Wei-Gan, Bai-Hui, Qiang-Feng, and Tian-Men, with two thin needles inserted at the incision extremities of the urethrostomy site, were used. These procedures are shown in Fig. 11. For castration surgery, the acupoints Bai-Hui, Wei-
Gan, Da-Kua, Qiang-Feng, and Tian-Men, in addition to Duan-Xue (suspended pivot) GV-5, were used. These procedures are shown in Fig. 12.

After surgery, the power was switched off and the needles were removed. All data were collected and evaluated statistically using an ordinary analysis of variance with the GraphPad prism package program and the Student $t$ test [9] with the help of Office Excel package 2007.

3. Results

All the previously mentioned clinical signs were observed during electroacupuncture induction. On physical examination before performing the electroacupuncture stimulation, the experimental horses showed normal values. During induction, a few minutes following the start of stimulation, all horses showed signs of mild stress, including dilated pupils and significant increases in their heart rates [mean (M) ± standard error (SE): $63.166 ± 4.301$] and respiration rates (M ± SE: $24.333 ± 2.123$). They were still conscious and could eat or drink; in addition, their sight and hearing were normal. Pupillary dilation and salivation occurred in three experimental horses (approximately 17%), which indicated pain in the internal organs and was counteracted by increasing the frequency of the acupuncture analgesia stimulus. At the induction phase, the operation site was tested for analgesia using needle pricks. At first, full sensitivity to pain was present. After 10–15 minutes, the response to the stimulus

![Image](image1.png)

Figure 1 Cheek wound suturing: (A) deep cheek wound, (B) suturing procedures, (C) wound sutures, and (D) recovery of the horse from analgesia.

![Image](image2.png)

Figure 2 Neck wound suturing: (A) twitching of the horse, (B) deep neck wound, and (C) suturing procedures.
decreased. After 20–30 minutes, in 95% of the cases, the horses showed no response to strong pain stimuli in and around the operation site; at that time, the operation was begun. During maintenance, the ears in all horses were alert and moving. The horses voided variable amounts of urine, particularly at the end of surgery. During each surgery, a sufficient amount of manure was defecated by the animals as moist balls and not as dry or loose material. Insignificant increases in heart rates ($M \pm SE: 36.823 \pm 1.906$) and respiratory rates ($M \pm SE: 13.704 \pm 0.839$) were recorded during maintenance, as shown in Fig. 13.

At the time of induction, the horses showed a degree of discomfort or pain, which was substantiated by restlessness, defensive reactions, and struggling. The amplitude of the output was then reduced to a strong, but

**Figure 3**  Trephining steps: (A) circular skin incision, (B) exposed periosteum, (C) trephine of bone disc, and (D) exposed frontal sinus.

**Figure 4**  Excision of the medial canthus sarcoid: (A) sarcoid growth, (B) stimulated acupoints, (C) sarcoid excision with cauterization of bleeders, and (D) recovery after 1 month.
Figure 5  Suturing of a lateral thoracic wound: (A) stimulated acupoints, (B) induced skin wound, (C) sutured skin wound, and (D) wound sutures.

Figure 6  Laparocolotomy procedures: (A) stimulated acupoints, (B) incised skin in left flank, (C) completed laparotomy, (D) exteriorized small colon and colotomy, (E) closure of colon incision, and (F) closed abdominal wound.

Figure 7  Thigh wound suturing: (A) suturing of the tensor fasciae latae and (B) closure of skin wound.
acceptable, level so that it could be tolerated by the animal without any obvious discomfort. Excessive stimulation led to a reduction in the electroacupuncture analgesic effect and struggling. Severe muscular convulsions with rigidity, followed by conversions to a flaccid muscle, were observed at the end of this phase and throughout the maintenance period. During testing, skin nociceptors were present in four (approximately 22%) horses that underwent surgery, but their effects were eliminated using an injection of a local infiltration anesthesia (2% lidocaine) at the intended line of incision. The intraoperative bleeding was less than expected. The responses of experimental horses to electroacupuncture stimulation are summarized in Fig. 14; only one horse (approximately 6%) exhibited various degrees of discomfort manifested by restlessness and struggling.

All surgical and clinical cases exhibited excellent degrees of response to the induced electroacupuncture analgesia. Healing of surgical wounds in both experimental and clinical cases was adequate and without complications. The sutures were removed 10 days after the surgery.

4. Discussion

Various anesthetic regimens have been used for major and minor equine surgeries, but none has proven to support the physiological vitality of the animal or to have no side effects. Therefore, we directed our attention toward the use of electroacupuncture stimulation to produce surgical analgesia. The device for electrical stimulation, which is used for humans, in general, and used in the present study for the production of electroacupuncture analgesia, proved to be safe and adequate and prevented serious electrolytic lesions during surgery.

Electrical stimuli were induced through the acupuncture analgesia points in the peripheral sensory nerves to the spinal cord. The stimuli reached the midbrain through the

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**Figure 8** Herniorrhaphy procedures in a 1-year-old foal: (A) stimulated acupoints, (B) incised skin, (C) blunt dissection, (D) exposed jejunal loop, (E) closure of abdominal muscles and s/c, and (F) sutured skin subcutaneous tissue (s/c or subcutis).

**Figure 9** Excisions of granulomas in the right flank of a 2-year-old foal: (A) multiple granulomas, (B) incised skin, and (C) completed surgical excision.
ascending spinothalamic tracts. In the midbrain, the ascending signals caused release of endorphins, serotonin, and other neurotransmitters, which activated a descending inhibition mechanism and prevented the pain signals from the surgical area from reaching the cerebral cortex. The electroacupuncture analgesia enabled the surgeon to perform the surgery without any complications and discomfort for the animals. Before performing the surgery, the animals were properly restrained and acupuncture needles were inserted to the correct depths; output leads were not connected across the thorax to reduce the risk of cardiac arrest. The surgery was then performed in equines and other animals under electroacupuncture analgesia, which was the sole analgesic agent [10].

Electroacupuncture stimulation at 55 Hz had a long-lasting effect and produced analgesic effect for the aforementioned operations. In addition, the degree of analgesia diminished if the frequency was not changed every 20 minutes; this coincided with the results presented by Luna [11]. However, on pain testing, approximately 22% of the horses had suffered a stroke of the tissue forceps during skin suturing, which might have been due to the nociceptors that remained during acupuncture analgesia; injection of 2% lidocaine at the incised wound’s lips suppressed the effect of these nociceptors and facilitated suturing. When more acupoints were involved during acupuncture stimulation, there was a stronger analgesic effect [12].

Electroacupuncture causes release of β-endorphin and adrenocorticotropic hormone (ACTH) from the pituitary gland. ACTH induced the release of cortisol from the adrenal glands. The blood cortisol levels of the horses were significantly increased after 30 minutes of electroacupuncture treatment [13]. The release of endogenous opioids was consistent with acupuncture analgesia [12] and was potentiated by D-phenylalanine, which inhibited enkephalinase-mediated degradation of enkephalins and endorphins [14]. However, the opioid antagonist naloxone was able to reverse the effect of acupuncture analgesia in animals [15].

Activation of nociceptors increased the rate of glucose consumption in the superficial part of the dorsal horn of the spinal cord. Low-frequency electrical stimulation produced a relative decrease in the rate of glucose consumption.
However, morphine diminished this increase in glucose consumption and potentiated the analgesic effect [16].

Acupuncture analgesia induced its effect through neuronal mechanisms associated with the central nervous system [17,18], as well as through the mechanism of endogenous opiates and their receptors, such as endorphin, enkephalin, endomorphin, and dynorphin, which were reported to be frequency-dependent factors [19,20]. The De-Qi or De-Chi was distinguished by the cortex during acupuncture needling; thus, cortical involvement followed acupuncture stimulation [21,22].

Inflammation induced a state of hyperalgesia and, in turn, decreased the pain threshold. Acupuncture regulated this state of hyperalgesia and reduced the degree of pain. Acupuncture therapy was used not only to relieve pain but also to treat various medical conditions [23,24]. Injured neurons expressed more peptides (substance P, somatostatin, and calcitonin gene–related peptide) to induce neuronal plasticity, but with persistent inflammation, hyperalgesia was evolved [25]. Acupuncture had an anti-hyperalgesic effect in inflammatory animal models [26]. Electric stimulation of the peripheral nerve elicited an analgesic effect [27]. Intermittent electric stimulation was a valid way to prevent the occurrence of tolerance to acupuncture analgesia [28].

Serotonin (5-hydroxytryptamine) was an analgesic transmitter. The effect of serotonin was diminished after p-chlorophenylalanine (serotonin synthesis inhibitor) injection. Thus, serotonin levels increased in the spinal cord and enhanced electroacupuncture analgesia at 2 Hz [29]. The binding of serotonin to its receptor activated the inhibitory interneurons in the spinal cord, which contained enkephalin. Enkephalin and opioid receptors were thought to play important roles in inhibiting pain-sensation signals [18]. High-frequency electroacupuncture decreased the concentration of serotonin within the cortex, and therefore acted as a sedative [30]. The arcuate nucleus of the hypothalamus activated the periaqueductal gray mediated by

**Figure 11** Urethrostomy and abdominal catheterization in a 6-year-old donkey: (A) uroperitoneum on an ultrasonographic image, (B) stimulated acupoints, (C) surgery sites, and (D) the exteriorized urolith.

**Figure 12** Procedures for castration in 5- and 6-year-old stallions: (A) stimulated acupoints, (B) exposed testicles, and (C) completion of bilateral ablation of testicles.
β-endorphin. The activities of periaqueductal gray were fired by the actions of β-endorphin and enkephalin, but not by dynorphin in low-frequency electroacupuncture analgesia [31].

Analgesic effect was produced using various forms of stimuli, which activated pathways from the brain to the spinal cord and inhibited incoming pain information in various layers of the dorsal horn of the spinal cord [3]. The produced surgical analgesia was maximized in the first 1—2 hours subsequent to electroacupuncture stimulation and was indicative of neurohumoral mechanisms during the period of analgesia, as reported by Han [32].

The technical points necessary to achieve an acceptable analgesic effect in equine surgery were the manner of securing the horse; blindfold application; reduction of noise, movement, and excitement; and prevention of kicks using the Wei-Gan acupoints. The positive electrode was connected to collateral (auxiliary) acupoints, and the negative electrode was connected to the principle acupoints to adjust the electrical circuit at the operation site. However, in some operations when pain stimuli exceeded the analgesia, a pain response was manifested by the animals during incision and suturing of the skin or peritoneum. To solve this problem, the frequency or output voltage was changed to an acceptable level, which was normally sufficient to counteract the pain; however, sometimes a small amount of local anesthetic solution was sprayed on or injected into the surgery areas. The use of local infiltration at the intended line of incision was needed in less responsive horses (22% of the cases) to complete the surgery.

The choice of acupoints for acupuncture analgesia depended on the operation site and the experience of the veterinarian. Different acupoint combinations were effective, and no one combination was determined to be satisfactory by all the authors. Different combinations of acupoints have been used in various horse operations. Examples of acupoint combinations used in this work were Bai-Hui, Wei-Gan, Duan-Xue, and Tian-Men; these points were located on the midline from the first cervical to the last sacral vertebra. Points for abdominal and hind limb operations were the acupoints mentioned earlier along with Da-Kua. Points for chest operations were Qian-Feng, Qi-Jia, and Tian-Men, and other points on or near the spinal nerves supplying the operation site were added. In addition, two parincisional points were used in all horses operated under electroacupuncture stimulation. The long needles never impeded access to the operation site as they were placed apart from each end of the incision. Electroacupuncture stimulation at a frequency of 20—40 Hz was preferred at the start of operation, and the frequency was increased afterward. Auricular electroacupuncture was not helpful in producing the analgesic effect, as it did not result in increased endorphin levels in the animal’s plasma as reported by Pert et al [33].

This work has provided surgical proof for the relevance of electroacupuncture in the production of equine analgesia. Furthermore, it confirmed electroacupuncture as a suitable method to produce surgical analgesia in the field of equine anesthesia and surgery.

**Disclosure statement**

The authors declare that they have no conflicts of interest and no financial interests related to the material of this manuscript.

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**References**


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