Acupuncture and Pain Management

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There is a large and expanding body of scientific evidence supporting the use of acupuncture in pain management. In the last decade, our understanding of how the brain processes acupuncture analgesia has undergone considerable development. Profound studies on neural mechanisms underlying acupuncture analgesia have evolved rapidly and predominately focus on cellular and molecular substrate and functional brain imaging. The currently understood mechanisms of acupuncture analgesia are complex and involve direct and indirect neurohumoral effects that block pain perception, reduce the pain response, relieve muscle spasms, and reduce inflammation. The analgesic mechanisms of acupuncture involve the spinal cord grey matter, hypothalamic-pituitary axis, midbrain periaqueductal grey matter, medulla oblongata, limbic system, cerebral cortex, and autonomic nervous system. Electroacupuncture (EA) stimulation of these sites results in activation of descending pathways that inhibit pain through endogenous opioid, noradrenergic, and serotonergic systems. There are growing numbers of human trials supporting the use of acupuncture as an evidence-based practice for pain management in human medicine. There are many studies that support the efficacy of acupuncture for low back pain, neck pain, chronic idiopathic and migraine headaches, knee pain, shoulder pain, fibromyalgia, temporomandibular joint pain, and postoperative pain. Although the number of well-designed, controlled clinical research studies in veterinary medicine is lagging behind the number of studies in human medicine, much of the basic science research has been done in animals with neurophysiology that is more similar to veterinary patients than humans. Although there is research to support EA as an evidence-based practice for the control of back pain in horses, additional studies are needed in other clinical situations in veterinary medicine where pain management is required. Author’s address: PO Box 717, Clarksburg, NJ 08510-0717; e-mail: jdkennedydvm@msn.com. © 2011 AAEP.

1. Introduction

According to the World Health Organization (WHO), the effectiveness of acupuncture analgesia has been established in controlled clinical trials, and the use of acupuncture to control chronic pain is comparable with morphine without the risk of drug dependence and other adverse side effects. Acupuncture is an effective treatment for many types of pain, is well-tolerated by patients, and has a minimal likelihood of serious adverse effects. Modern and traditional acupuncture techniques have been shown to provide relief from low back pain, neck pain, chronic idiopathic or tension headaches, migraine headaches, knee pain, shoulder pain, fibromyalgia, temporomandibular joint pain, and postoperative pain. Acupuncture was more effective for chronic pain than placebos (sham acupuncture) based on the results of systematic reviews of pooled data from high-quality randomized controlled trials. For short-term outcomes (less than 6 mo), acupuncture was significantly superior to sham treatments for back pain, knee pain, and headache. For longer-term
outcomes (6–12 mo), acupuncture was significantly more effective for knee pain and tension-type headache but inconsistent for back pain (one meta-analysis was positive and one meta-analysis was inconclusive).

Acupuncture can effectively treat chronic pain of the locomotor system with restricted movements of the joints, because it not only alleviates pain but also reduces the muscle spasm that causes reduced mobility. Acupuncture can effectively reduce pain from cervical spondylitis and other causes of neck pain, peripheral arthritis of the shoulder, fibromyalgia, fasciitis, epicondylitis, low back conditions, sciatica, osteoarthritis, and radicular and pseudoradicular pain syndromes. In some cases, acupuncture integrated with conventional treatments was more effective than conventional treatments alone.

Although acupuncture may not reduce pain to the degree that some conventional treatments reduce pain, it is associated with a low incidence of serious adverse side effects. For example, acupuncture may not be as effective as corticosteroids for pain relief in some patients with rheumatoid arthritis, but chronic corticosteroid use may result in gastrointestinal ulceration, osteopenia, muscle loss, and other adverse effects. Acupuncture not only reduces pain and inflammation but has positive effects on the immune system, which directly benefits patients with rheumatoid arthritis, and less conventional medication may be needed.

2. Pain Pathways and Modulation

Pain may be classified as acute or chronic, adaptive or maladaptive, and neuropathic or nociceptive, and these types of pain have different underlying mechanisms. Neuropathic pain occurs from damage to the peripheral or central nervous system (PNS or CNS, respectively). Pain associated with activation of sensory (afferent) receptors (nociceptors) by mechanical, thermal, or chemical stimuli is considered nociceptive pain and will primarily be reviewed here. The pathways involved in nociceptive pain are also involved with the modulation of pain by acupuncture. Understanding PNS and CNS pain pathways is essential to understanding acupuncture analgesia. Terms associated with pain and pain modulation are defined in Table 1.

Table 1. Definitions of Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Neuropathic pain</td>
<td>Pain from damage to the nervous system</td>
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<tr>
<td>Nociceptive pain</td>
<td>Pain from stimulation of nociceptors</td>
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<tr>
<td>Nociceptors</td>
<td>Peripheral nerve endings in the skin, muscles, ligaments, joints, viscera, and other structures that initially respond to a painful stimulus</td>
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<tr>
<td>Nociception</td>
<td>Pain sense</td>
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<tr>
<td>Noxious</td>
<td>Mechanical, thermal, or chemical stimulus that alters nociceptors and causes pain</td>
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<tr>
<td>Analgesia</td>
<td>Reduced sensitivity to painful stimuli</td>
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<tr>
<td>Anti-nociception</td>
<td>Analgesia</td>
</tr>
<tr>
<td>Internuncial neuron</td>
<td>Neuron interposed between and connecting two other neurons</td>
</tr>
<tr>
<td>Inhibitory neurotransmitters</td>
<td>Inhibit receptors on neurons; examples are serotonin, GABA, norepinephrine, and epinephrine</td>
</tr>
<tr>
<td>Excitatory neurotransmitters</td>
<td>Activate receptors on neurons; examples are glutamate and aspartate</td>
</tr>
<tr>
<td>PAG</td>
<td>Periaqueductal grey matter that surrounds the cerebral aqueduct in the midbrain</td>
</tr>
<tr>
<td>Hyperalgesia</td>
<td>Increased sensitivity to pain</td>
</tr>
<tr>
<td>Allodynia</td>
<td>Non-noxious stimuli perceived as painful</td>
</tr>
<tr>
<td>Primary hyperalgesia</td>
<td>Hypersensitivity of the peripheral nociceptors</td>
</tr>
<tr>
<td>Secondary hyperalgesia</td>
<td>Central sensitization and hypersensitivity of CNS neurons associated with synaptic plasticity</td>
</tr>
<tr>
<td>Synaptic plasticity</td>
<td>Ability of the connection or synapse between two neurons to change in strength and responsiveness</td>
</tr>
<tr>
<td>Endorphins</td>
<td>Endogenous opioid polypeptide neurotransmitters that inhibit pain stimuli similar to morphine; includes β-endorphins, enkephalins, dynorphins, endomorphin-1, and endomorphin-2</td>
</tr>
<tr>
<td>Lower motor neurons</td>
<td>Neurons with cell bodies in the spinal cord whose axons form peripheral motor nerves and terminate in skeletal, cardiac, and smooth muscles</td>
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regions of the CNS for conscious perception. Pain signals are modified by substances released from cells at the site of pain, within the spinal cord grey matter, and by the concomitant stimulation of CNS inhibitory descending pathways from higher brain centers. The main neuroanatomic structures involved in the complex process of pain perception include the peripheral sensory receptors (nociceptors), afferent peripheral nerve fibers, dorsal horns of the spinal cord (body) or sensory nucleus of the trigeminal nerve (head), ascending pathways to the reticular formation in the medulla oblongata and midbrain, thalamus, hypothalamus, limbic system, and cerebral cortex as well as descending CNS pathways from all these sites.

Ascending Pathways
From a simplified functional neuroanatomic standpoint, the most direct pain pathways, like other sensory systems, can be basically viewed as a three neuron system: first-order, second-order, and third-order neurons (Fig. 1). Noxious (painful) mechanical, thermal, or chemical stimuli are detected by nociceptors (primarily free nerve endings) of somatic and visceral first-order afferent nerves. When a specific threshold of excitation is reached, electrical action potentials transmit along their peripheral processes to cell bodies in the dorsal root ganglia and then into the spinal cord, where they synapse on second-order neurons in the dorsal horn grey matter. Stimulated second-order neurons propagate electrical signals along their axons, forming ascending tracts in the spinal cord and brainstem that synapse on third-order neurons in the thalamus and other brain stem structures. The activated third-order neurons propagate electrical signals along their axons that terminate in the somatosensory cortex of the cerebrum as well as descending CNS pathways from all these sites.

For nociception from the head, electrical impulses of first-order neurons ascend in the trigeminal nerve (cranial nerve V) to cell bodies in the trigeminal ganglia and continue on to enter the brainstem and synapse with second-order neurons in the trigemi-
The first-order neurons that transmit pain and other sensations are classified according to their diameter, speed of conduction, function, and degree of myelination (Table 2). There are two classifications for these fibers, numerical and alphabetical, which can be confusing when reading the literature. The alphabetical Erlanger-Gasser classification will be used throughout this review. The Aδ and C fibers primarily conduct signals from nociceptive stimuli. Aδ fibers are myelinated, are rapidly conducting, and mainly sense pain from the skin, and C fibers are unmyelinated, are slowly conducting, and sense pain from skin, bone, viscera, and other structures (Table 2). If Aδ and C fibers are stimulated simultaneously, the pain experienced will come in two phases. The first phase will be sharp and localized and may be of short duration, because it is mediated by the faster-conducting Aδ fibers. The later phase is from the smaller and slower-conducting C fibers, and it will be dull and non-localized but last longer.

The second-order neuron cell bodies are located in one or more physiologically distinct layers (laminae) of the spinal cord dorsal horn grey matter (Table 2). There are six laminae in the dorsal horn (I-VI), three in the ventral horn (VII-IX), and an additional column of cells clustered around the central canal as Lamina X. The C fibers terminate mainly in Laminae I and II, where their axons secrete Substance P or Vasoactive Intestinal Polypeptide depending on whether they arise from somatic or visceral structures, respectively. The Aδ afferents terminate primarily in Laminae I, II, and V.

Axons of the second-order neurons of the spinal cord grey matter form two main ascending pathway systems that carry noception: the neo-spinothalamic pathway system and the paleo-spino-reticulo-diencephalic pathway system (Fig. 1 and Table 3). In Laminae I and V, where the majority of Aδ nerves terminate, second-order neurons immediately cross to the opposite side and form the neo-spinothalamic tract system in the anterolateral portion of the spinal cord. These neurons terminate on third-order neuron cell bodies in the ventral posterior lateral (VPL) nucleus of the thalamus and project to the somatosensory cortex (Fig. 1 and Table 3). The neo-spinothalamic system is direct, fast, and localizing and is the basic three-neuron system of discriminative pain.

The paleo-spino-reticulo-diencephalic pathways primarily originate from neurons in Laminae VII and VIII in the ventral horn of the spinal cord grey matter, with some input from Lamina V, and they connect to C fibers that terminate in Laminae I and II through internuncial neurons (Fig. 1 and Table 3). In Laminae I and II, the Aδ fibers are primarily afferents of the medulla oblongata, pons, and midbrain (Fig. 1). The second-order neurons, from the trigeminal sensory nuclei, ascend the brainstem to synapse with third-order neurons in the thalamus and other brainstem regions similar to second-order neurons from the body and viscera.

### Table 2. Sensory Peripheral Nerve Types and Their Function

<table>
<thead>
<tr>
<th>Fiber Type</th>
<th>Conduction Velocity (m/s)</th>
<th>Receptors</th>
<th>Sensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aα (Ia)</td>
<td>15–20</td>
<td>Muscle spindles</td>
<td>Proprioception</td>
</tr>
<tr>
<td>Aβ (II)</td>
<td>13–20</td>
<td>Golgi tendon organ</td>
<td>Proprioception</td>
</tr>
<tr>
<td>Aδ (III)</td>
<td>6–12</td>
<td>Muscle spindles and all cutaneous mechanoreceptors</td>
<td>Proprioception and touch</td>
</tr>
<tr>
<td>C (IV)</td>
<td>0.2–1.5</td>
<td>Free nerve endings</td>
<td>Touch, pain, and temperature</td>
</tr>
</tbody>
</table>

Medulla, medulla oblongata. *Unmyelinated; all other types have some myelin.
Most axons from neurons in Laminae VII and VIII cross to the opposite side in primates and form their pathways in the anterolateral portion of the spinal cord adjacent to the neo-spinothalamic pathways. They pass medially into the reticular formation (central core) of the brain stem and the medial intralaminar nuclei of the thalamus, and then, they project to the cingulate gyrus and frontal cortex (Table 2). 

In non-primates, some second-order neurons cross and others remain on the same side to form crossed and uncrossed spinothalamic pathways. The spinothalamic pathways in animals are interrupted by axons exiting and reentering after synapsing with other spinal cord neurons, forming diffuse, bilaterally represented multisynaptic pathways. Some second-order nociceptive neurons may also ascend to the thalamus and other brainstem regions through the dorsal column medial-lemniscal system, which mainly transmits proprioceptive information as well through multifunctional spinoreticular tracts and the fasciculus proprius.

The reticular formation (central core of the medulla oblongata,pons, and midbrain) contains bifurcating axons that project up through the paleo-spino- reticulo-diencephalic pathways to the diencephalon (thalamus and hypothalamus) and down through reticulospinal tracts to the spinal cord to influence muscle tone. Axons from the reticular formation that terminate in the hypothalamus also synapse with autonomic neurons, which descend to the medulla oblongata and spinal cord to affect autonomic lower motor neurons and alter vascular tone, heart rate, gastrointestinal function, and other visceral functions. Consequently, pain may cause autonomic signs of increased heart and respiratory rates, vasoconstriction, nausea, and vomiting.

Part of what makes the pain experience so complex and varied between individuals is the interpretation of pain by higher brain centers. The limbic system, which includes the hypothalamus, hippocampus, amygdala, and cingulate gyrus, is thought to control the motivational, behavioral, and emotional responses to pain. The pain stimulus projected to the frontal cortex is interpreted along with past experiences, mood, and current circumstances, and this combination influences the pain experience.

**Pain Modulation**

The normal neurophysiology of pain modulation is also important to review to better understand potential sites of acupuncture pain control. When a noxious stimulus is experienced, endogenous networks are activated that modulate pain at the peripheral nociceptors within tissues, in the dorsal horn grey matter of the spinal cord, in the network of relay stations between the dorsal horn and the cerebral cortex, and within the cerebral cortex (Fig. 2).

The first-order afferent fibers not only connect to second-order neurons for the ascending pain pathways but also send off branches that synapse with inhibitory internuncial neurons in the spinal cord grey matter. Considerable modulation of pain occurs at the dorsal horn grey matter, where inhibitory internuncial neurons secrete γ-aminobutyric acid (GABA) and other neurotransmitters that inhibit C fibers and reduce activation of second-order spinal cord nociceptive neurons. Larger-diameter afferent nerves, like Aβ and Aδ fibers, terminate on inhibitory internuncial neurons in the dorsal horn grey matter, which in turn, inhibit the nociceptive C fibers and reduce the amount of Substance P released (Fig. 2).

The ascending pathways of second-order nociceptive neurons give off branches that synapse with neurons at several sites in the brainstem that form descending pathways that inhibit pain. Neurons in the midbrain periaqueductal grey matter (PAG) send descending projections to the rostral ventromedial medulla and spinal cord dorsal horn, which form the primary neuroanatomical pathways mediating opioid-based analgesia (Fig. 2). Endorphins (β-endorphin, enkephalin, and dynorphin) are neurotransmitters released by neurons in response to painful stimuli and used internally to reduce pain. β-Endorphin is found primarily in the pituitary gland, but enkephalin and dynorphin are pro-

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**Table 3. Comparison of the Two Main Central Pain Pathway Systems**

<table>
<thead>
<tr>
<th></th>
<th>Neo-Spinothalamic System</th>
<th>Paleo-Spino-Reticulo-Diencephalic System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Origination</strong></td>
<td>Laminae I, IV, and V (stimulated by Aδ neurons)</td>
<td>Laminae I, IV, and V (stimulated by C neurons) connect through internuncial neurons to Laminae VII and VIII</td>
</tr>
<tr>
<td><strong>Transmission speed</strong></td>
<td>Direct fast</td>
<td>Indirect slow</td>
</tr>
<tr>
<td><strong>Subcortical targets</strong></td>
<td>None</td>
<td>Reticular formation, hypothalamus, and limbic system</td>
</tr>
<tr>
<td><strong>Thalamic nuclei</strong></td>
<td>Ventral posterior lateral</td>
<td>Intralaminar nuclei and other midline nuclei</td>
</tr>
<tr>
<td><strong>Cerebral cortex</strong></td>
<td>Parietal lobe (primary somatosensory cortex)</td>
<td>Cingulate gyrus, prefrontal cortex, and frontal lobe</td>
</tr>
<tr>
<td><strong>Pain type</strong></td>
<td>Sharp pain, discriminative pain, and pin-prick pain</td>
<td>Null pain, affective arousal components of pain, and tissue-damage pain</td>
</tr>
</tbody>
</table>
duced throughout the nervous system, including the dorsal grey matter of the brainstem and spinal cord. Enkephalinergic internuncial neurons are located on the border of Laminae I and II of the spinal cord grey matter and alter the responses of second-order nociceptive neurons located there. Endorphins interact with opioid receptors on neurons to reduce the intensity of pain. Opioid receptors are found in many areas of the brain, but they are especially concentrated in the PAG and dorsal horns of the spinal cord.

Serotoninergic descending inhibitory pathways are also suggested to be an important mechanism of analgesia (antinociception). Serotonin (5-hydroxytryptophan [5HT]) is a neurotransmitter, which inhibits pain transmission, leading to a decrease in perceived pain. Descending pathways from the midbrain PAG and locus coeruleus and raphe nuclei of the medulla oblongata are inhibitory to dorsal grey column nerves of the spinal cord, and some of the inhibition is mediated by serotonin (Fig. 2).6,7,9,10 The pain suppressing effect of antidepressants is probably because of their ability to enhance transmission down these pathways by blocking the uptake of 5HT.

Pathological Pain States
The peripheral terminals of C fibers become sensitized during tissue damage and subsequent inflammation by the release of bradykinin, serotonin,
potassium, adenosine 5’-triphosphate (ATP), prosta-
glandins, and leukotrienes from damaged tissue and
inflammatory cells. These sensitized C fibers se-
crete Substance P (a neuropeptide) and calcitonin
gene-related peptide, which have a vasodilatory ef-
fect on local blood vessels and stimulate additional
release of inflammatory mediators, further sensitiz-
ing the peripheral nociceptors. Sensitization lowers the threshold for activation, increases the magnitude and duration of activation, and results in peripheral (primary) hyperalgesia and allodynia (non-noxious stimuli being perceived as painful).

If there is massive or prolonged stimulation of C fibers, there is activation of N-methyl-D-aspartate (NMDA) receptors, which reduces the receptor threshold for activation of the dorsal horn neurons and spontaneous depolarization. This activation results in increased pain impulses ascending to higher levels in the brain. Chronic pain stimulation not only causes local and spinal cord hyper-

inflammation or other obvious ongoing tissue-dam-
ing processes, delay in onset after the precipitat-
ing injury, and abnormal or unpleasant sensations such as burning, searing, or deep, aching pain un-
resistant to conventional anti-inflammatory drugs. Persistent pain and sensitization can often lead to additional loss of function from reduced range of motion in joints and the mechanical effects of muscle shortening. Prolonged limitations of movement can result in disuse atrophy of muscles, which also limits mobility.

Pain not only originates from cutaneous struc-
tures but also arises from nociceptive receptors in muscles, tendons, and joints. Focal acute pain may be associated with muscle spasm and lactic acid accumulation and may result in muscle shortening. A major consequence of muscle shortening is the continuous, unremitting pull on the structures to which the muscle attaches. Muscle contraction that spans a joint can create pressure within the joint, abnormal patterns of motion, arthralgia (joint pain), injury, and finally, degenerative joint disease. The presence of muscle shortening also has deleterious effects on the tendons and ligaments. Unre-

lating muscle tension on these structures may be the precipitating factor in bicipital bursitis, epicon-
dylitis, hock and stifle degeneration, upper suspens-
ory pain, chondromalacia of the stifle joint, and other pathologic conditions that are frequently seen in veterinary practice. Continuous pressure on vertebral joint surfaces from muscle contractions causes vertebral facet degeneration, which may be a key factor in interspinous osteoarthrosis (spondylosis) or kissing spine conditions in the equine and other species.

Neuropathic pain is also common in humans and animals. Inflammation and primary damage to nerves alter their normal response to stimulation and modulation and can cause muscle spasm and shortening, which also amplify the pain. Nerve root inflammation from spondylo-
sis, intervertebral disk protrusion and other degenerative vertebral column changes causes spasm and shortening of paravertebral muscles that compress intervertebral discs and create a self-perpetuating cycle of contraction, inflammation, radiculopathy, and pain.

3. Mechanisms of Acupuncture Pain Control

Acupuncture is the stimulation of specific pre-deter-
dined points (acupoints) near the surface of the body, which produces a therapeutic effect by evoking homeostatic mechanisms within the nervous, im-
mune, endocrine, cardiovascular, and other body

systems to promote self-healing. Acupuncture stimulates small nerve endings and other structures around the acupoints, which result, in both local and distant changes within the body. Ancient traditional Chinese medical theories have explained the effects of acupuncture based on empirical obser-

vations and descriptions of naturally occurring phe-
nomena, and the underlying complex neurochemical mechanisms behind their observations have been explored in scientific studies for the past 50 yr.

Our understanding of how the brain processes acupuncture analgesia has undergone considerable development. Acupuncture analgesia is manifested only when the intricate feeling (soreness, numbness, heaviness, and distension) of acupuncture in patients occurs after acupuncture manipulation. Manual acupuncture (MA) is the insertion of an acupuncture needle into an acupoint followed by the twisting of the needle up and down by hand. In MA, all types of afferent fibers (Aβ, Aδ, and C) are activated. In electrical acupuncture (EA), a stimu-

lating current through the inserted needle is deliv-
ered to acupoints. Electrical current intense enough to excite Aβ and part of Aδ fibers can induce an analgesic effect. Acupuncture signals ascend mainly through the spinal ventrolateral funiculus to the brain. Many brain nuclei composing a complicated network are involved in processing acupuncture analgesia, including the nucleus raphe magnus (NRM), PAG, locus coeruleus, arcuate nucleus (Arc), pre-optic area, nucleus submedius, habenular nu-

cleus, accumens nucleus, caudate nucleus, septal

area, amygdale, etc. Acupuncture analgesia is es-
tenially a manifestation of integrative processes at different levels in the CNS between afferent im-

pulses from pain regions and impulses from acu-

points. In the last decade, profound studies on neural mechanisms underlying acupuncture analge-
sia predominately focus on cellular and molecular substrate and functional brain imaging and have
developed rapidly. Diverse signal molecules contribute to mediating acupuncture analgesia, such as opioid peptides (μ-, δ-, and κ-receptors), glutamate (NMDA and AMPA/KA receptors), 5HT, and cholecystokinin octapeptide (CCK-8). Among these molecules, the opioid peptides and their receptors in the Arc-PAG-NRM-spinal dorsal horn pathway play a pivotal role in mediating acupuncture analgesia. The release of opioid peptides evoked by electroacupuncture is frequency-dependent. EA at 2 and 100 Hz produces, respectively, releases of enkephalin and dynorphin in the spinal cord. CCK-8 antagonizes acupuncture analgesia. The individual differences of acupuncture analgesia are associated with inherited genetic factors and the density of CCK receptors. The brain regions associated with acupuncture analgesia identified in animal experiments were confirmed and further explored in the human brain by means of functional imaging. There are still many unanswered questions concerning the mechanisms of acupuncture analgesia, but there is no doubt that acupuncture produces effects at many different sites that result in analgesia.15,16

The analgesic effects of EA on brain function can be visualized using functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) scans.9 With a painful stimulus, the fMRI shows activation of areas in the cingulate cortex, thalamus, and other regions of the brain, but there is a significant decrease of activation in these areas after acupuncture. This finding suggests that acupuncture desensitizes or blocks pain at these levels.9 This finding may be associated with acupuncture modulation of pain at the dorsal horn grey matter and a reduction of ascending impulses along the spinothalamic pathway systems, or it may be associated with neurochemical alterations higher in the brainstem.

The currently understood mechanisms of acupuncture pain control are complex and involve direct and indirect neurochemical effects that block pain perception, reduce the pain response, relieve muscle spasm, and reduce inflammation. The acupuncture technique used affects the degree of pain control. In studies comparing EA with dry-needle acupuncture, EA produced greater brain changes on fMRI than dry needles and also elicited a better analgesic effect.15,16 In other studies, bilateral EA stimulation was superior to unilateral stimulation for analgesia, and unilateral stimulation had the most powerful analgesic effects on the contralateral side.17,18 EA is recommended over non-manipulated, dry-needle acupuncture for pain management and is used in most studies of acupuncture analgesia.15,19 fMRI data suggest that acupuncture needle stimulation at two different depths of needling, superficial and deep, does not elicit significantly different blood oxygen level-dependent (BOLD) responses.20

Analgesic effects of EA have been shown to occur in the spinal cord grey matter, hypothalamic-pituitary axis, midbrain PAG,pons, medulla oblongata, limbic system, cerebral cortex, and autonomic nervous system (Fig. 2). Changes in EA stimulation frequency can alter the site of antinociceptive activities, and the antinociceptive effects of EA in normal and hypersensitized painful humans and animals can be quite different.6,13 A striking feature of acupuncture-induced analgesia is its long-lasting effect, which has a delayed onset and gradually reaches a peak even after acupuncture needleling is terminated. A non-repeated, event-related (NRER) fMRI paradigm and control theory-based approach was adopted to capture the detailed temporal profile of neural responses induced by acupuncture.21 Neural activities at the different stages of acupuncture presented distinct temporal patterns in which consistently positive neural responses were found during the period of acupuncture needleling, whereas much more complex and dynamic activities were found during a post-acupuncture period. The amygdala and perigenual anterior cingulate cortex (pACC), exhibited increased activities during the needleling phase, which decreased gradually to reach a peak below the baseline. The PAG and hypothalamus presented saliently intermittent activations across the whole fMRI session. The overall findings indicate that acupuncture may engage differential temporal neural responses as a function of time in a wide range of brain networks.

A relatively new analysis method, functional connectivity fMRI (fcMRI), has great potential for studying continuous treatment modalities such as EA. Compared with sham acupuncture, EA can significantly reduce PAG activity when subsequently evoked by experimental pain. Findings indicate the intrinsic functional connectivity changes among key brain regions in the pain matrix and default mode network during genuine EA compared with sham EA.22

One of the earliest proposed mechanisms of EA pain control used the Melzack-Wall Gate Control Theory in which modulation of pain occurred through normal antinociceptive neuronal circuits in the spinal cord.6 Based on this theory, it was proposed that EA stimulates Aβ and Aδ nerve fibers (Table 1), which would transmit impulses to the spinal cord faster than C nerve fibers and engage synaptic sites on dorsal horn neurons. The later arriving pain signals from C fibers would have fewer sites on which to synapse, because the gates would be closed (synaptic sites are already occupied) (Fig. 2). Using this theory, EA was thought to induce a segmental spinal inhibition of nociceptive inputs and result in an immediate, short-term, non-opioid-mediated analgesia because of reduced release of Substance P from C fibers.6,9,23

The analgesic effects of EA are more complex than can be described using the Gate Control theory alone, because branches of Aδ and C fibers also
synapse with inhibitory internuncial neurons in the spinal cord grey matter, resulting in the release of inhibitory neurotransmitters that block incoming and outgoing pain impulses. EA of the Aβ fibers results in the stimulation of inhibitory enkephalinergic internuncial neurons in the outer part of Lamina II of the spinal cord that block C fiber pain impulses. Low-frequency EA at ST-36 significantly inhibited cold allodynia in a rat tail model of neuropathic pain through stimulation of GABA inhibitory interneuron systems in the spinal cord, whereas sham EA at a non-acupoint and dry-needle acupuncture at ST-36 were ineffective. The analgesic effects of EA have also been shown to be related to inhibition of the release of excitatory neurotransmitters (glutamate and aspartic acid), which normally transmit pain signals from the spinal cord to higher brain levels.

Activation of the NMDA subtype of glutamate receptors and subsequent nitric oxide (NO) production are important factors in central sensitization and the development of hyperalgesia. In a study of the role of NO in a carrageen-induced inflammation model, it was suggested that EA was a biochemical modulator in the spinal cord and prevented the activation of the NMDA receptors and central sensitization. The combination of EA with ketamine, an NMDA receptor antagonist, also enhanced the anti-hyperalgesic effect. In another rat neuropathic pain model study, EA stimulation decreased NO synthase expression in the L4–5 spinal cord and decreased mechanical allodynia secondary to nerve injury.

Other studies have shown the profound effect of EA on the hypothalamic-pituitary axis. The hypothalamic-pituitary axis not only produces the well-known neuroendocrine effects, but it is part of the central descending pain-inhibitory pathways involving endogenous opioids and most likely also plays a role in cholinergic anti-inflammatory mechanisms through the vagus nerve. EA has been shown to increase circulating β-endorphin in the blood, which is most likely associated with ascending afferent stimulation of the hypothalamus and release of these substances from the pituitary.

EA also activates neurons in the midbrain PAG region that stimulate the descending endogenous opioid inhibitory pathways to reduce pain (Fig. 2). Low-frequency EA (10–20 Hz) stimulates the release of β-endorphin, enkephalin, and endomorphin, which activates the μ- and δ-opioid receptors, and higher-frequency (100–200 Hz) EA stimulates dynorphin, which activates the κ-opioid receptors to produce analgesia. A mixture of frequencies (low-frequency stimulation for a period followed by high-frequency stimulation) is suggested to be most effective, because it stimulates all opioid receptors. In a carrageenan-induced arthritis pain model in rats, low-frequency EA pre-treatment had an antinociceptive effect against inflammatory pain through the μ-opioid receptor. EA of 10 Hz at ST-36 significantly improved the weight-bearing force, and this positive effect was abolished when a selective antagonist of the μ-opioid receptor was administered.

Central sensitization (secondary hyperalgesia) can be associated with tissue inflammation or peripheral nerve injury and is an important cause of persistent pain. Animal models of capsaicin-induced pain have well-defined peripheral and central sensitization components, and therefore, they are useful for studying the peripheral and central analgesic effects of acupuncture. In a recent study of the analgesic effects of EA on capsaicin-induced central sensitization, EA produced a stimulation pointspecific analgesic effect that was mediated by activating endogenous μ- and δ-opioid receptors in the spinal cord.

High-frequency EA (100–200 Hz) not only induces dynorphin release in the spinal cord but also increases the release of serotonin, epinephrine, and norepinephrine (inhibitory neurotransmitters), which inhibit pain signals. In another rat neuropathic pain model, studying pain modulation in the PAG region, EA completely abolished histamine and dopamine release, which is normally increased after a painful stimulus, and increased the release of norepinephrine in the PAG regions. EA is thought to also enhance the effects of descending serotonergic pain inhibition. EA has been shown to activate neurons containing serotonin, epinephrine, and norepinephrine in the nucleus raphe magnus and locus coeruleus of the medulla oblongata, which suppress pain and hyperalgesia through descending pathways to the spinal cord.

In a study of neuropathic pain in rats, changes of spinal synaptic plasticity were affected by EA. EA at a low frequency of 2 Hz at acupoints ST-36 and SP-6 reduced neuropathic pain and induced long-term depression of the C fiber-evoked potentials in a spinal nerve ligation model in rats.

Muscle contracture (non-voluntary muscle contraction) creates an energy crisis and pain in shortened muscles but can be relaxed by inserting needles into the corresponding acupoints to restore normal muscle physiology. Acupuncture can alleviate the pain, and it can allow the muscles to relax and the associated structures to return to normal patterns of motion. Intramuscular stimulation (IMS) is a modified version of acupuncture and is based on neuroanatomic principles. A basic tenet of IMS is that acupuncture points are usually situated close to motor points within muscles or at musculotendinous junctions. Points that are effective for treatment are at the same segmental level as the presenting clinical signs or the injury.
points usually coincide with palpable muscle bands that are tender to manual pressure. Tender points are distributed in a segmental fashion in muscles supplied by both dorsal and ventral nerve roots, indicating radiculopathy. Muscles with tender points are shortened from spasm and contracture. Symptoms and signs typically disappear when the tender and tight muscle bands are stimulated with acupuncture. Surface electromyography (EMG) can measure gross muscle fiber strength and show the fatigue and asymmetrical recruitment associated with myofascial pain syndromes. The typical myofascial pain patient has surface EMG evidence of one or more inhibited muscles. Evidence of fatigue shown by asymmetrical scalene muscle contractions and the increased activity of the muscles recorded on the EMG when an acupuncture needle is inserted can be shown. Another clinical example of the use of IMS is acupuncture of Ashi points for the treatment of piriformis muscle pain (piriformis syndrome). In a recent study of 80 cases of piriformis syndrome, one-half of the cases were randomly assigned to a group that received an inhibitory-needling acupuncture method on Ashi points, and the other one-half of the cases received a routine-needling acupuncture method at GB-30, BL-54, and GB-34. Both groups responded positively (92% in Ashi points inhibitory-needling group and 82.5% in transpositional acupuncture routine-needling group), but stimulating Ashi points produced a significantly better response than routine stimulation of transpositional acupoints (p < 0.05).36

The midbrain PAG region not only inhibits pain through the release of endogenous opioids but also causes changes in the heart and respiration rates and blood pressure associated with pain through the hypothalamus and autonomic nervous system. EA alters the effects of pain on visceral and blood vessels by its effects on the PAG and hypothalamic regions and descending pathways from these regions to the vagus nerves and parasympathetic and sympathetic spinal cord lower motor neurons. EA also induces local spinal cord segmental reflexes that affect vascular tone and other autonomic functions.6,13 EA affects the inflammatory reflex through the autonomic nervous system, regulates the immune system, and reduces inflammation-induced hyperalgesia. At 10 Hz, EA significantly reduced complete Freund’s adjuvant-induced hind paw edema and increased plasma levels of corticosterone, but it produced no noticeable signs of stress. At 10 Hz but not 100 Hz, EA suppresses inflammation by activating the hypothalamus-pituitary-adrenal axis (HPA) and the nervous system.37 Besides the mediation by different central structures, acupuncture may have direct effects on regulating peripherally the release of some inflammatory and pain mediators.38 It has been shown that EA significantly suppresses behavioral hyperalgesia in a rat model of persistent inflammatory pain by suppressing the spinal neurokinin-1 (NK-1) receptors and that NK-1/Substance P receptors play important roles in nociception and hyperalgesia at the spinal cord level.39 Electroacupuncture can effectively decrease the pro-inflammatory cytokine of interleukin-1 (IL-1) and IL-6, increase the inhibition cytokine of IL-4 and IL-10, and improve the internal environment of occurrence and progression of rheumatoid arthritis.40

Chronic pain syndromes often involve the autonomic nervous system, and persistent increased sympathetic tone causes regionalized hypothermia from vasoconstriction.41 Because these pain syndromes are not related to inflammation, they are unresponsive to anti-inflammatory medication. The types of pain experienced include hyperesthesia, burning, aching, throbbing, and allodynia. Thermal imaging provides objective, measurable evidence of the ability of acupuncture to restore normal blood flow through effects on autonomic regulation of vasomotor tone.41 Increased sciatic nerve blood flow measured in rats by laser Doppler flowmetry was observed with nerve root stimulation (100%) compared with lumbar muscle acupuncture (56.9%), suggesting that, in addition to its influence on the pain inhibitory system, acupuncture triggers a transient change in blood circulation.42

EA may also affect the motivational, behavioral, and emotional responses to pain through effects on the hypothalamic, limbic, and higher cortical regions.5,19 The effects of acupuncture to calm Shen and reduce anxiety are well-known, and anxiety and depression are factors in chronic pain. In a study of changes in cortical metabolites using fMRI in depressed and normal human patients, EA was shown to have a significant effect on brain neurochemistry compared with controls and EA positively affected depressed patients.44

Known variations in the response of individuals to acupuncture treatment complicates the evaluation of acupuncture for pain control.9 According to the work by Cho et al.,9 about 28% of humans are excellent responders, 64% are good and average responders, and 8% are weak or non-responders.9 In a pilot study of psychophysical pain responses in humans after dry-needle, EA, and sham treatments, all subjects receiving one of the acupuncture techniques had improved pain tolerance, but some responded better to EA, and others responded better to dry needles.44 The results of this study indicate the existence of both individual subject and acupuncture mode variability in the analgesic effects of acupuncture. This finding suggests that switching the acupuncture mode may be a treatment option for unresponsive patients.

4. Clinical Research on Acupuncture for Pain Control in Humans

A review of all the clinical research for pain control in humans is beyond the scope of this paper, but a few current studies that are applicable to veterinary medicine will be discussed here. Although clini-
cians have continued their respect and reverence for tradition in their training, they have also recognized the need for evidence-based medicine in their practice of acupuncture. The evidence base for acupuncture treatment in humans has changed. For example, in 2000, an article in Cochrane Database System Review stated that the evidence summarized in the systematic review did not indicate that acupuncture was effective for the treatment of back pain. In 2005, an updated systematic review of chronic low back pain research, within the framework of the Cochrane Database System Review collaboration, indicated that acupuncture was more effective for pain relief and functional improvement than no treatment or sham treatment.46

Immediate and sustained pain relief was observed in people with low back pain from lumbar spinal canal stenosis and herniated intervertebral discs who received EA at the nerve root compared with manual acupuncture. Acupoint electrical stimulation at the true acupoints, compared with placebo and sham groups, effectively reduced postoperative pain and analgesic usage in patients with spinal surgery receiving patient-controlled analgesia.47

A randomized, controlled trial was conducted in 255 human practices in Germany to assess quality of life, costs, and cost-effectiveness of acupuncture treatment plus routine care versus routine care alone in osteoarthritis patients. Four hundred eighty-nine patients with chronic pain caused by osteoarthritis of the knee or hip were evaluated for quality of life and costs at baseline and after 3 mo using health insurance funds data and standardized questionnaires. Patients receiving acupuncture had an improved quality of life but had significantly higher costs over the 3-mo treatment period compared with routine care alone. This increase in costs was primarily because of the cost of acupuncture. The study concluded, however, that acupuncture was an effective treatment strategy in patients with chronic osteoarthritis pain but might cost more than some conventional drugs.48

Moxibustion at San-yin-jiao (SP 6) can relieve uterine contraction pain and has no side effect to mother and infant; it is safe, effective, and a simple non-drug analgesia method. One hundred seventy-four cases of singleton pregnancy and cephalic presentation primipara were single-blinded and randomly divided into three groups: observation group (59 cases), placebo-treated group (57 cases), and control group (58 cases). The observation group was treated with moxibustion at San-yin-jiao (SP 6) for 30 min when the uterus cervix opening was 3 cm, the placebo-treated group was treated with moxibustion at no acupoint for 30 min, and the control group was treated with routine labor nursing; the uterine contraction pain and safety of the mother and infant were compared among the three groups. The uterine contraction pain was tested by the Visual Analogue Scale (VAS): the scores of VAS in the observation group were obviously decreased after 15 and 30 min moxibustion (both p < 0.05), there were no obvious changes of the VAS scores in the placebo-treated and control groups, and the scores of VAS in the observation group decreased much more obviously than the scores in the other two groups (all p < 0.05). The midwife rated the uterine contraction pain: after 30 min moxibustion, the effective rate of labor analgesia was 69.5% (41/59) in the observation group, which was higher than the rates of 45.6% (26/57) in the placebo-treated group and 43.1% (25/58) in the control group, with significant differences between them (both p < 0.05). The post-partum hemorrhage amount of the observation group was obviously lower than the amounts of the placebo-treated and control groups (both p < 0.05). The Apgar score of newborn was higher in the observation and placebo-treated groups than the control group (both p < 0.05).

Cancer pain can destroy the quality of life of humans and animals. Treatment with opioid analgesics has significant adverse effects, including inhibition of respiratory function, constipation, addiction, and tolerance that further decrease quality of life. EA may be used to reduce cancer pain. In a study of neuropathic cancer pain, sarcoma cells were inoculated around the sciatic nerves of mice. The presence of embedded cancer cells that induced mechanical allodynia was confirmed by MRI. EA treatment significantly prolonged paw withdrawal latency as well as shortened cumulative lifting duration compared with tumor control, suggesting reduced pain after EA.

In a review of five studies of 1,334 patients with chronic knee pain, acupuncture was found to be superior to sham acupuncture for pain reduction and improved function. The differences were still significant when patients were followed long term. Their conclusions were that adequate acupuncture treatment is superior to sham acupuncture and no treatment for improving pain and function in patients with chronic knee pain.

A systematic review and meta-analysis of randomized controlled trials of acupuncture for neck pain found that acupuncture was more effective than controls in the treatment of neck pain. A randomized controlled multicenter trial in Germany was performed in 14,161 patients with chronic neck pain (duration > 6 mo). Treatment with acupuncture added to routine care in patients with chronic neck pain was associated with improvements in pain and reduced disability compared with treatment with routine care alone.

Pain is a prevalent consequence of spinal cord injury that can persist for years after the injury and can have a significant impact on physical and emotional function and quality of life. In a review of several studies, acupuncture was as effective to treat neuropathic pain from spinal cord injury as anticonvulsant agents and tricyclic antidepressants.
The etiology of peripheral neuropathy (PN) often remains elusive, resulting in a lack of objective therapeutic strategies. Data suggest that there is a positive effect of acupuncture on PN of undefined etiology, which was measured by objective parameters. In a pilot study to evaluate the therapeutic effect of acupuncture on PN as measured by changes in nerve conduction and assessment of subjective symptoms, 192 consecutive patients with PN as diagnosed by nerve conduction studies (NCS) were evaluated over a period of 1 yr. Of the 47 patients who met the criteria for PN of undefined etiology, 21 patients received acupuncture therapy according to classical Chinese medicine, whereas 26 patients received the best medical care but no specific treatment for PN. Sixteen patients (76%) in the acupuncture group improved symptomatically and objectively as measured by NCS, whereas only four patients in the control group (15%) did. Three patients in the acupuncture group (14%) showed no change, and two patients showed aggravation (10%), whereas in the control group, seven patients showed no change (27%); additionally, in the control group, 15 patients showed aggravation (58%). Importantly, subjective improvement was fully correlated with improvement in NCS in both groups.

Acupuncture combined with rehabilitation therapy may improve motion recovery of impaired joints. Compared with rehabilitation therapy alone, EA combined with rehabilitation therapy can achieve a significant effect on the motion function recovery of the elbow joint after fracture repair. Acupuncture and exercise have a greater therapeutic effect compared with exercise on movement disorders of the shoulder joint after surgical repair of fracture of the humerus. Acupuncture combined with rehabilitation was superior to rehabilitation with improvement in NCS in both groups. EA and exercise may improve motion recovery of impaired joints.

In a report of the adverse effects of 32,000 acupuncture treatments, minor adverse events, defined as "any ill effect, no matter how small, that is unintended and non-therapeutic, even if not unexpected," resulted from 6.71% of treatments. Most common minor events were needle site bleeding (3.1%), needle site pain (1.1%), and aggravation of symptoms (0.96%), but 70% of symptoms subsequently improved. In a second report, 574 acupuncturists reported adverse effects of 34,000 acupuncture treatments. Minor adverse events occurred in 15% of cases; the most common events were aggravation of symptoms (2.8%), bruising (1.7%), needle pain (1.2%), and needle site bleeding (0.4%). Most (86%) aggravated symptoms improved, possibly indicating a healing crisis, which is a therapeutic process involving temporary exacerbation of existing symptoms that precedes improvement. These two studies reported no life-threatening events associated with acupuncture. The extent of actual risk of acupuncture treatment is difficult to quantify; however, there is a low but significant incidence of adverse events, usually minor, which includes needle pain, bruising, nausea or syncope (mild and transient), and aggravation of symptoms. A few case reports describe serious side effects such as pneumothorax, spinal cord injury, hepatitis, cellulitis, and trauma from broken or embedded needles. The serious adverse effects of acupuncture treatment reported in the literature may easily be prevented by straightforward precautions. Conditions that increase the risk of complications in acupuncture treatment in humans include hemophilia, advanced liver disease, anticoagulation therapy, diabetes, human immunodeficiency virus (HIV) infection, and other forms of immunosuppression, such as high-dose corticosteroid administration.

5. Clinical Research on Acupuncture for Pain Control in Animals

Currently, much of the practice of acupuncture in animals is based on the results of pilot research studies, case reports, and clinical experiences. Compared with human acupuncture, the clinical application of veterinary acupuncture is in the early stages of development as a science. On the basis of the findings of a systematic review performed in 2006, there is no compelling evidence to recommend or reject acupuncture for any condition in domestic animals. Some encouraging data do exist that warrant additional investigation in independent rigorous trials. There is a mixture of results in clinical trials of acupuncture for pain control in animals, but there are only a few high-quality research studies in animals that evaluate EA for pain control.
Analgesic effects from acupuncture have been observed in horses and other species. Acupuncture has been used clinically to treat lameness and chronic back pain, including fibromyalgia syndrome. There are several studies that measured the release of β-endorphin and cortisol during equine acupuncture. In one study, dry-needle acupuncture and EA provided cutaneous analgesia in horses without adverse cardiovascular and respiratory effects, and EA was more effective than dry-needle acupuncture for activating spinal cord release of β-endorphin into the CSF of horses.

Controlled clinical trials have shown significant improvement of thoracolumbar pain in horses using objective methods of pain evaluation. In a study of 15 horses with thoracolumbar pain, EA was compared with phenylbutazone and saline using thoracolumbar pain scores before and after treatment. Thoracolumbar pain scores were based on behaviors recorded on videotape and were evaluated and scored by a blinded, independent investigator. EA significantly lowered pain scores of horses with chronic thoracolumbar pain compared with phenylbutazone or saline. In a randomized, double-blind, controlled trial of 23 sport horses with back pain, objective measurements of pain threshold levels were obtained with a pressure algometer. Painful points (trigger points) were identified on each horse, and baseline pain threshold measurements were taken. EA was performed at GV-20 and GV-6 and bilaterally at BL-26, BL-54, BL-21, and BL-17 at a frequency of 20 Hz for 15 min and 80–120 Hz for 15 min. After five treatments, pressure-induced pain was significantly reduced at trigger points in the treatment group compared with the control group.

In another blinded, controlled study using an experimental model of lameness in the horse, the effects of EA were studied for pain control of the hoof sole. Lameness scores were assigned based on an established lameness scale with two independent evaluators; one evaluator assessed lameness by watching video only and was blinded to treatment. Lameness was evaluated before tightening the screw, after tightening the screw, after treatment with either EA, a 0.5% bupivacaine nerve block (positive control), or a saline nerve block (negative control), immediately after loosening the screw, and 95 min later. The EA caused a significant reduction in the lameness score compared with the saline nerve block (negative control) as well as a significant increase in plasma β-endorphin.

Equine myofascial trigger points can be identified and have similar objective signs and electrophysiological properties as those signs documented in human and rabbit skeletal muscle tissue. Four horses with chronic pain signs and impaired performance showed signs compatible with the diagnosis of myofascial trigger points in their brachiocephalic muscle (i.e., localized tender spots in a taut band of skeletal muscle that produced a local twitch response on palpation). Needle EMG activity and twitch responses were recorded at 25 positions at the trigger point and at a nearby control point during the course of each horse’s acupuncture treatment. All subjects showed objective signs of spontaneous electrical activity, spike activity, and local twitch responses at the myofascial trigger point sites within taut bands. The frequency of these signs was significantly greater at myofascial trigger points than control sites (p < 0.05).

EA can reduce visceral pain, regulate gastrointestinal motility, and improve regional blood flow in animal models. However, EA was not as effective as butorphanol in one rectal distention model, and bilateral EA at Guan-yuan-shu was ineffective in reducing the acute signs of discomfort induced by small intestinal distention in a clinical model. These results indicate the need for additional research in acupuncture for domestic animal visceral pain. EA at Nei-guan (PC-6) significantly inhibits the frequency of transient lower esophageal sphincter relaxations (TLESR) and the rate of common cavity during TLESR in cats. This effect seems to act on the brain stem and may be mediated through NO, CCK-A receptor, and μ-opioid receptors. Electroacupuncture with a high frequency at ST-36 enhances lower esophageal sphincter pressure (LES) as well as esophageal motility, whereas EA with a low frequency decreases LES. The effect of EA is acupoint-specific, and this effect seems to be mediated through gastrin, motilin, and vasoactive intestinal peptide.

Cardiac MRI (CMRI), an important tool in monitoring cardiovascular diseases, provides a reliable method to monitor the effects of electroacupuncture on the cardiovascular system. Ketamine/xylazine cocktail anesthesia caused a transient hypertension in the cats; EA inhibited this anesthetic-induced hypertension and shortened the post-anesthesia recovery time, countering the negative effects of anesthetics on cardiac physiology.

In a recent study of the use of EA for postoperative pain in intervertebral disc disease in dogs, the total dose of fentanyl administered during the first 12 h after surgery was significantly lower in the EA group than in the control group, but dosages of analgesics administered from 12 to 72 h after surgery did not differ between groups. Pain scores were significantly lower in the treatment group than in the control group 36 h after surgery but did not differ significantly between groups at any other time. The clinical efficacy of EA and acupuncture combined with medication for the treatment of thoracolumbar intervertebral disc herniation in dogs was compared with dogs treated with conventional medicines alone in paraplegic dogs with intact deep pain perception. Treatment efficacy was evaluated by postoperative neurologic function, ambulation, relapse, complication, and urinary function. The results suggest that a combination of electro-AP and AP with conventional medicine is more effective.
than conventional medicine alone in recovering ambulation, relieving back pain, and decreasing relapse. EA was more effective than decompressive surgery for recovery of ambulation and improvement in neurologic deficits in dogs with long-standing severe deficits attributable to thoracolumbar IVDD.97 The clinical success for dogs that underwent decompressive surgery and EA was intermediate.

In controlled, double-blind clinical trial of chronic hip pain from hip dysplasia in 78 dogs, the effect of gold bead implants in acupoints was compared with a sham treatment 2 wk, 3 mo, and 6 mo after treatment.98 The dogs with gold bead implants in acupoints had reduced pain and greater mobility compared with control dogs receiving the sham treatment.

EA may be combined with conventional anesthetic agents to reduce dose requirements for maintenance of anesthesia and improve cardiopulmonary function.99,100 In a study of goats, EA plus low-dose xylazine provided analgesia that was significantly better than EA or xylazine alone.99 Furthermore, EA plus xylazine administration at 0.1 mg/kg provided better analgesia than xylazine alone at 0.4 mg/kg.

As is the case for humans, few adverse side effects have been associated with acupuncture in animals. In a review of 1,292 acupuncture treatments that were performed on 221 animals (cats, cattle, dogs, and horses), adverse reactions to acupuncture needles totaled 4 of 12,274 needles or approximately 1 per 3,000 needles.100 Two of these reactions consisted of transient superficial edema of the skin, and because they did not require treatment, did not appear painful, and did not show other more serious signs, they were considered to be clinically trivial. There was one abscess, which resolved with antibiotic treatment, and one seizure event in a 7-yr-old spayed female Beagle that resolved without treatment and did not recur within a 7-mo follow-up period. Neither complication required hospitalization nor was life-threatening. There were 377 treatments of 74 horses using a total of 2,865 needles. A 10-yr-old Hanoverian gelding being treated for back pain and palmar heel pain of the left forelimb experienced a mild local swelling on the axial surfaces of heel bulbs on the treated foot for 1 wk after its treatment. Treatment was resumed, and 13-mm needles were placed in the extranavicular points; no additional adverse events were noted.

Although safe in most conditions, acupuncture should be used with caution in animals with debilitation, frailty, or febrile illness. Needles should not be inserted directly into skin infections, ulcers, tumors, or scar tissue. There is a traditional contraindication to acupuncture in the first trimester of pregnancy, and ST-12, ST-25, SP-6, BL-60, CV-1, CV-3 through CV-7, LI-4, and BL 67 are the transpositional acupoints typically avoided during pregnancy.101

Other than pain relief, acupuncture does not directly address any specific clinical sign but normalizes physiological homeostasis and promotes self-healing through normal endogenous pathways. Thus, acupuncture, in terms of its therapeutic mechanisms, is non-specific.9 As a physiological therapy, the efficacy of acupuncture depends on the pathology involved and the healing potential intrinsic to each patient. Therefore, acupuncture effectiveness varies from person to person and animal to animal.

In conclusion, there is a well-researched scientific basis for the mechanisms of acupuncture analgesia, the extent and depth of which continues to expand. As well, there are growing numbers of human trials supporting the use of acupuncture as an evidence-based practice for pain management in human medicine. Although the number of well-designed clinical studies in veterinary medicine is lagging behind human medicine, the basic science research has been done in species with neurophysiology more similar to non-primate animals than humans, and therefore, the scientific basis for the use of acupuncture in domestic animals is clear. Although there is research to support EA as an evidence-based practice for the management of back pain in horses, additional studies are needed in other clinical situations where analgesia is required. As contemporary conventional biomedical and laboratory research merges with the practical clinical experience of traditional Chinese medicine, it is reasonable to believe that the neurophysiologic mechanisms of actions of acupuncture will be further understood, and it will be shown to be an effective means of managing many different types of acute and chronic pain as well as other disorders.

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