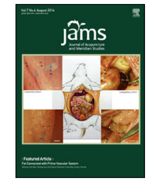
J Acupunct Meridian Stud 2014;7(4):190—193

Available online at www.sciencedirect.com

Journal of Acupuncture and Meridian Studies

journal homepage: www.jams-kpi.com



REVIEW ARTICLE

Effects and Mechanisms of Acupuncture Based on the Principle of Meridians

Wei Zhou [1,*], Peyman Benharash [2]

[1] *Department of Anesthesiology, University of California, Los Angeles, USA*
[2] *Division of Cardiothoracic Surgery, University of California, Los Angeles, USA*

Available online 24 June 2014

Received: Jan 24, 2014
Revised: Feb 25, 2014
Accepted: Feb 28, 2014

KEYWORDS
convergent input;
point specificity;
sensory nerve;
trigger point

Abstract
Acupuncture has been practiced in China for over 2000 years to treat a variety of diseases based on the "meridian theory" as described in the *Yellow Emperor's Classic of Internal Medicine*. To this date, the meridian theory continues to be an important guide for traditional Chinese medicine practitioners to diagnose and treat patients. Although the meridians have not been identified reliably as actual anatomical structures, they appear to serve as a road map to identify the location of various acupoints. Research has shown that acupoints overlie major neuronal bundles. The meridians extensively studied in the cardiovascular realm are the pericardial meridians (P) 5, 6, which overlie the deep median nerve. Meridians involved with gastrointestinal processes are (St) 36, 37, which overlie the deep peroneal nerve. Acupuncture needles, either manipulated manually or stimulated using a low current and frequency, have been documented to be a neurophysiological basis for modulating the activity of peripheral and central neural pathways. This review describes our current understanding of acupoints and meridians from a physiological aspect.

1. Introduction

Acupuncture is increasingly being used as a complementary therapeutic approach in the United States [1]. Manual acupuncture and its potent alternative, electroacupuncture (EA), have been used to treat a number of diseases in the Far East for centuries. However, many physicians who are trained in classic Western medicine are reluctant to recommend acupuncture, because its efficacy

* Corresponding author. David Geffen School of Medicine, 650 South Charles Young Drive 56-131 CHS, University of California, Los Angeles, CA 90095, USA.
E-mail: wzhou@mednet.ucla.edu (W. Zhou).

pISSN 2005-2901 eISSN 2093-8152
http://dx.doi.org/10.1016/j.jams.2014.02.007

remains controversial and the physiological mechanisms determining its actions are largely unknown. This review briefly describes the various anatomical and physiological investigations carried out in the last 50 years.

2. Meridian theory

The meridian theory was proposed based on empirical experience accrued over many decades. For example, ancient doctors found that for treating stomach aches, needling certain pulsing loci on the medial part of the lower leg was more effective than needling any other region in the body. They drew lines to connect these empiric points on the body, making a visible map of the 14 meridians, each of which correspond to various but specific organ systems.

Over the last century, researchers have tried to scientifically identify these meridians and acupoints on the body. Nakatani and Yamashita [2] reported that different areas of the body can have abnormally higher or lower conductivity, and that such abnormal conduction is very closely related to the meridian lines. These areas have been called "Ryodoraku channels," meaning *a good conduction line*. Other investigators have failed to replicate the observations made by Nakatani and Yamashita due to pressure artifacts from electrodes and the influence of sweat glands in the palm innervated by sympathetic nerves, which are sensitive to psychological inputs [3,4].

3. Anatomical structures of acupoints

In 1973, a group of Chinese researchers found that there were no unique structures under acupoints; if there was something, the researchers suggested that they must just be nerves and nerve endings [5]. Yu et al [6] studied the three-dimensional structure of Neiguan (PC-6) and found that normal tissues, including receptors and nerve endings, contribute to these acupoints, but that these tissues were not unique to these locations. Other researchers reported that in normal adults, vascular occlusion of the upper arm could not prevent the analgesic effect of acupuncture needling of a point on the hand [7]. Conversely, the infiltration of procaine, a local anesthetic, into the deep tissues around the point of acupuncture entirely abolished the analgesic effect, suggesting that nerves rather than humors were mediators of this response.

In 1978, Kline et al [8] reported that the electrical stimulation of the Zusanli acupoints elicited significant decreases in arterial blood pressure and heart rate when the tip of the needle was close to branches of the peroneal nerve. However, cutting the sciatic nerve or paralyzing the animal using succinylcholine or gallamine abolished these responses, whereas direct stimulation of the intact peroneal nerve continued to decrease arterial blood pressure and heart rate in paralyzed animals. Their results suggested that the responses to acupuncture were due to the activation of motor fibers that resulted in the contraction of muscles and subsequent excitation of muscles and/or joint receptors, which elicited an inhibitory reflex. They also demonstrated that there was no significant depressor effect if the acupuncture needle was inserted at a control point in close proximity to somatic nerves.

In 1984, Dung [9] listed the following anatomical structures found in the vicinity of acupoints: large peripheral nerves; nerves emerging from a deep to a more superficial location; cutaneous nerves emerging from deep fascia; nerves emerging from bone foramina; motor points of neuromuscular attachments; blood vessels in the vicinity of neuromuscular attachment; along a nerve that is composed of fibers of varying sizes; bifurcation points of the peripheral nerves; ligaments rich in nerve endings; and suture lines of the skull. These observations confirmed that there were no particular structures that were unique to acupoints. The prevalent finding that nerve bundles were involved in almost all such locations was also validated previously.

Additional details about the structures underneath the acupoints were described in some anatomical atlases of acupoints [10]. These details can be summarized as follows. Acupoints on the face and forehead region are located along the terminals or cutaneous branches of the trigeminal and facial nerves. They are either at the nerve trunks as they exit the foramina or at the tip of a terminal branch. Occasionally, they can be found at the anastomotic site of two different nerves or at the points at which a nerve branches bilaterally. In the external ear, there exists many lateral acupoints that can be used to treat different diseases, due to a heavy concentration of nerves stemming from the vagus, glossopharyngeus, and the combination branches of the facialis and occipitalis minor nerves. The medial ear also receives branches from the auriculotemporal, auricularis magnus, and occipital major nerves. This feature provides the anatomical basis on which acupuncture applied on the auricle could treat a multitude of visceral and somatic diseases.

On the trunk, typical spinal nerves have six cutaneous branches that reach the skin in the thorax and abdomen. Each of these branches corresponds to the splanchnic organs that are in the same or nearby spinal segments.

On the forearm and hand, acupoints are mostly related to the radial, median, and ulnar nerves, and are often used to treat diseases in their respective dermatomes as well as diseases on the head, face, and in the chest. The acupoints on the lower limbs are related to the sciatic and femoral nerves as well as their branches such as the peroneal and tibial nerves. Such locations are generally used to treat diseases of the lower limbs as well as those located within the abdomen or pelvis.

Using histological analysis, Croley [11] showed two-times as many papillae in the area of acupuncture points as non-acupoints. There was a high concentration of dermal papillae containing capillary loops with sympathetic nerve endings. Within the group of acupoints innervated by superficial somatic nerves, most fibers appear to be unmyelinated.

3.1. What kinds of nerve fibers are activated by acupuncture?

The essential correlate of analgesia by acupuncture has been known as "De-Qi sensation," a feeling of numbness, fullness, and sometimes soreness. Experimentally, however, intramuscular injection of procaine abolishes this feeling as well as the analgesic effect of acupuncture.

Japanese researchers reported that type II afferent nerves were sufficient for acupuncture analgesia in rats [12]. Pomeranz and Paley [13] recorded the afferent nerves from Hegu, and found that type II afferent nerves were sufficient to produce acupuncture analgesia in mice.

The selection of acupoints is crucial for the treatment of individual diseases. The fibers activated during acupuncture when treating a disease may be not the same as the ones involved in the analgesic effects of acupuncture [14]. For example, to treat cardiovascular diseases such as hypertension, coronary heart disease, angina pectoris, arrhythmias, and cardiac insufficiency, acupuncturists prefer to use Neiguan, Shenmen, Ximen, Zusanli, Sanyingjiao, Wuchi, Tai Chong, and occasionally, other auricular points. Deep somatic nerves innervate all these acupoints, and more myelinated fibers are involved. By contrast, to treat hypotension and shock, Renzhong, Chenjiang, and Shixuan are usually used. These acupoints, although sometimes located on the extremities but never near the organs, may represent the areas for referred pain. In the meridian theory, Neiguan is on the channels that go to the heart and has been shown to have projections to the same or nearby spinal segment (C6—T1). It is the sympathetic preganglionic neurons from the vicinity of the spinal cord that innervate the myocardium and coronary artery (T1—T5). Stimulation of these acupoints will send more afferent discharges to these neurons (directly at the spinal level, or activate the inhibitory system at the supraspinal level), inhibit the sympathetic output, decrease the cardiac oxygen demand and inhibit the myocardial ischemia, and thus relieve angina pain.

4. Pathophysiology of acupoints

Acupoints span different regions of the human body and have individual anatomic characteristics. All acupoints, however, have one element in common, that is, they are able to become sensitive, tender, or even painful when exposed to a pathologic process. To date, the mechanism of sensitization remains puzzling to scientists and clinicians. Recent research data and clinical observations related to muscle pain help to explain some of the characteristics of these acupoints more clearly.

4.1. Acupoints versus trigger points

Acupoints are defined based on neurologic connectivity, whereas trigger points are defined based on their myofascial locations [15]. A trigger point is classically defined as an exquisitely tender spot in the muscle, whereas an acupoint can be found anywhere in the body. The neurogenic definition suggests that acupoints may appear on any part of the body where there is a sensory nerve. Sensory nerves are distributed all over the body, indicating that acupoints may appear anywhere in the body, such as in the muscles, tendons, joints, at bone foramina, and in the suture lines of the skull. Approximately 70% of classic acupoints are also trigger points, because muscles constitute a large proportion of the human body. Acupuncture therapy and trigger point therapy are different by both definition and clinical practice.

Tender acupoints develop gradually as homeostasis declines. These tender acupoints, therefore, are defined as homeostatic acupoints. As a general rule, homeostatic acupoints develop symmetrically in the human body, because the distribution of peripheral nerves is bilaterally symmetrical. By contrast, most trigger points are activated directly by pain and are not necessarily symmetrical. Trigger points share some, but not all, characteristics of acupoints, meaning that trigger points have some inclusive but not exclusive parameters of acupoints. Acupoints share all the characteristics of trigger points, but all trigger points are not acupoints. Trigger points correspond to symptomatic acupoints in our integrative neuromuscular acupoints system.

One of the most important concepts of acupuncture is that acupoints are pathophysiologically dynamic entities. The degree of their sensitivity changes when homeostasis changes. Most acupoints show practically no sensitivity when the homeostasis is optimal, whereas they become tender under adverse conditions. Thus, the number of tender homeostatic acupoints may be a quantitative indicator of the health status of the body. Identification of more tender acupoints in the body indicates greater homeostatic imbalance. Once homeostasis declines, health deteriorates. The chain reaction is as follows: immune function is suppressed, self-healing capability is impaired, and different pathological disorders may develop. Patients with more tender acupoints in their bodies need more treatments than those with less tender acupoints.

An understanding of the physiology and pathophysiology of acupoints is important for clinical practice, because at the practical level such an understanding enables a practitioner to perform a quantitative acupuncture evaluation to obtain a reliable prognosis of acupuncture treatment, to predict how many treatment sessions will be needed, and to achieve maximal pain relief in over 90% of pain patients.

5. Convergent afferent inputs to neurons in the brain

The functional relationship between acupoints and splanchnic organs is related to the integrative function of the central nervous system (CNS) [16]. Acupoints have different effects depending on their connectivity to the effector organ through the CNS. The effectiveness of these acupoints may be due to the convergent inputs of these somatic areas and the related organs in the brain as well as the integrative function of the neurons of the brain [17].

Our group and others have extensively studied the cardiovascular effects of EA based on the meridian system. The central neuronal mechanisms of this reflex provide excellent insight into the science behind acupuncture, and therefore will be described briefly [16].

A previous study has demonstrated that cardiovascular neurons in the brain stem receive projections from the great splanchnic nerve and the median nerve. Stimulation at different acupoints causes different cardiovascular responses [18]. The EA at the pericardial meridian, overlying the median nerve (P 5—6) and the large intestine meridian, overlying the deep radial nerve (LI 10—11) are the most effective in reducing this reflex-induced hypertension. The EA at the large intestine and lung meridians, overlying branches of the median and the superficial radial nerve (LI 4—L7) and the stomach meridian, overlying the deep peroneal nerve (S 36—37) are less effective, whereas the EA at LI 6—7 and K1—B67 do not have any impact on blood pressure. These results thus indicate the importance of specific cardiovascular reflex responses to selective acupuncture point stimulation during EA, and suggest that differential input into the brain stem can, depending on the acupoints stimulated, inhibit cardiovascular and medullary sympathoexcitatory neuronal activity as one mechanism in the CNS.

LI4—L7 Hegu-Lique. Hegu: dorsal aspect of paw, between midpoints of first and second metacarpal bones and between first dorsal interosseous muscle and adductor pollicis of thumb.

Lique: radial side of forelimb proximal to accessory carpel pad between abductor pollicus longus and tendon of brachioradialis.

K1—B67 Youngquan-Zhiyin.

Youngquan: center of metatarsal pad of hindlimb.

Zhiyin: lateral side digit 5, above claw.

6. Summary

Acupuncture and the use of meridians have long been used to treat a variety of pathologic conditions. Recently, mechanistic discoveries of acupuncture have revealed that acupoints are rich in sensory nerve receptors. Acupoints become tender or painful, because their sensory nerve receptors are pathologically sensitized. This sensitized condition is a dynamic process that is triggered by altered homeostasis and returns to baseline after the insult is corrected. Although meridians were created based on empiric observations, scientific studies continue to shed light on the complex neurophysiologic mechanisms behind acupuncture.

The meridian theory only explained the spatial and functional relationship between the somatic part and the internal organs. To elucidate the intricate pathways that have an effect far from the acupoints, one must use the existing knowledge and techniques of physiology and neuroscience. Although we may be many years away from fully understanding the neurophysiological mechanisms of acupoints, we must keep the meridian theory in mind. Perhaps it is something we cannot understand with our present knowledge, however, if we dismiss it, we may lose some very important information.

Disclosure statement

The author affirms there are no conflicts of interest and the author has no financial interest related to the material of this manuscript.

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