J Acupunct Meridian Stud 2010;3(2):67–74

ELSEVIER

REVIEW ARTICLE

Defining Meridians: A Modern Basis of Understanding

John C. Longhurst*

Samueli Center for Integrative Medicine, Departments of Medicine, Physiology and Biophysics, Pharmacology and Biomedical Engineering, Schools of Medicine and Engineering, University of California, Irvine, USA

Received: Jan 29, 2010
Accepted: Mar 30, 2010

KEY WORDS:
acupoints;
acupuncture;
sensory nerves;
traditional oriental medicine

Abstract
Acupuncture, one of the primary methods of treatment in traditional Oriental medicine, is based on a system of meridians. Along the meridians lie acupuncture points or acupoints, which are stimulated by needling, pressure or heat to resolve a clinical problem. A number of methods have been used to identify meridians and to explain them anatomically. Thus, tendinomuscular structures, primo-vessels (Bonghan ducts), regions of increased temperature and low skin resistance have been suggested to represent meridians or as methods to identify them. However, none of these methods have met the criteria for a meridian, an entity that, when stimulated by acupuncture can result in clinical improvement. More recently, modern physiologists have put forward the "neural hypothesis" stating that the clinical influence of acupuncture is transmitted primarily through stimulation of sensory nerves that provide signals to the brain, which processes this information and then causes clinical changes associated with treatment. Although additional research is warranted to investigate the role of some of the structures identified, it seems clear that the peripheral and central nervous system can now be considered to be the most rational basis for defining meridians. The meridian maps and associated acupoints located along them are best viewed as road maps that can guide practitioners towards applying acupuncture to achieve optimal clinical results.

1. Introduction

Oriental medicine is well over 3000 years old since its earliest descriptions originated during the reign of the Yellow Emperor in 2697 BC in his Inner Classic (200 BC) [1]. In practice, oriental medicine includes both herbal remedies and acupuncture. Acupuncture is based on a meridional theory, which incorporates a system of channels through which vital energy, or *Qi*, flows. One of the earliest descriptions of meridians and acupuncture points (acupoints) as well as technical aspects of acupuncture and moxibustion was written by Hangfu Mi in 259–282 AD [1–3]. This book described 349 acupuncture points, or acupoints, which is more than the 160 contained in the Yellow Emperor's Inner Classic. Further description of acupuncture was provided in a text by Yang Jizhou (1520–1660) who mentioned 361 acupoints [1,2,4]. A French diplomatic scholar, George Soulié de Morant brought acupuncture to Europe in

*Corresponding author. Med Sci I, Room C240, School of Medicine, University of California, Irvine 92697-4075, USA.
E-mail: jcl@uci.edu

©2010 Korean Pharmacopuncture Institute

the early 1900s after serving in China [5]. He coined the terms meridian and energy.

Oriental medicine today is composed of a very diverse and complex set of practices, although common aspects to the practice exist throughout many Eastern cultures [6]. Traditional Chinese Medicine incorporates both *yin-yang* and the five elements theory, called *Wu Xing*. *Yin-yang* are mutually opposing forces, such as hot and cold, that are normally in balance with each other, i.e., homeostasis is present. Disease occurs when there is an excess or deficiency of either *yin* or *yang*. Our universe is composed of the five elements, including wood, fire, earth, metal and water, and these speak, in part, of the interaction between our body and the surrounding environment. Each of the 12 regular or principal meridians is associated with a Chinese organ, such as the heart, pericardium, lung, spleen, liver, kidney (the *yin* organs) and stomach, gallbladder, large and small intestine, urinary bladder and tri-heater or triple burner (the *yang* organs). The Chinese organs do not represent the organs that share the same anatomical names in Western science and medicine. The principal meridians are bilaterally symmetrical. There are also midline meridians as well as connecting channels or meridians that intersect the regular meridians [6].

2. Anatomy of Meridians

A number of anatomical structures have been proposed to describe meridians. For example, Helms [7] mentions tendinomuscular meridians, a system of superficial meridians located between the organism and the external environment. He also mentions principal meridians, lines that travel through muscles and nourish all tissues, as well as distinct meridians, which are located between the surface of the body and deep organs that nourish these organs. In addition, he mentions curious meridians that create connections between principal channels and serve as energy reservoirs. He cites no research verifying the existence of these meridians as physical entities.

Only relatively recently has there been an attempt to anatomically define acupoints (and meridians) [8]. A review of the available literature in 1984 by Chan [9] suggests that there is no specific substrate for acupuncture. He concluded that the most convincing argument for the effects of acupuncture come from the involvement of the nervous system. In his review Chan [9] cited studies of gross anatomical correlations, the primo vascular systems (Bonghan corpuscles and ducts), biophysical approaches, including the electrical properties (skin resistance) and the temperature of acupoints, as well as Japanese *Ryodoraku,* and physiological measurements. Physiological assessment included *The-Ch'i* or acupuncture sensations (see *deQi* below), receptor and sensory or afferent systems, specific versus non-specific acupuncture stimulation and pathological approaches, such as changes in skin resistance in pathological states, pain spots and trigger points.

3. The Primo Vascular Systems (Bonghan Corpuscles and Ducts)

The primo-nodes (Bonghan corpuscles) were originally identified in rabbits by a Korean physician, Kim Bong-Han in 1963 [10–12], although histological techniques were not revealed in his reports. The existence of these ducts are controversial, since Chinese scientists were unable to duplicate these data [9,13]. More recently, analysis of these ducts has been resurrected by Soh [14] and his colleauges, Ogay et al [15]. This system, composed of several networks, was traced and evaluated microscopically, and fluid from the ducts also was analyzed. These thread-like vessels are thought to be similar to blood and lymph capillaries, but are distinct in structure and some are located inside blood and lymph vessels. The conjecture that primo-vessels (Bonghan ducts) serve the role of meridians in acupuncture has not been proven [14].

4. Anatomical Structure of Acupoints

Acupuncture points located along meridians have been the subject of intense investigation with respect to their unique anatomical composition. According to Dung [16], acupoints include nerves of various types, blood vessels, ligaments rich in nerve endings and suture lines. Nerves seem to be the most common structure. Others have emphasized the high correlation with trigger points [17,18]. These are called *An Shi* points by Chinese practitioners and are often quite tender [19,20]. The abolition of pain and acupuncture analgesia by injection of local anesthetics into acupoints is probably the strongest evidence to suggest that neural innervation is required for the acupuncture response [21,22].

5. Imaging Studies

Labeling meridians with radioactive tracers, such as technetium, has led some to claim that this method provides anatomical evidence for their existence [23]. However, while there may be take-up of the radiotracer by acupuncture points, movement of the tracer is explained by transport along the venous system [24].

Thermogram infrared images have been taken in an attempt to show the response to acupuncture and to provide evidence for the existence of meridians [25]. According to this concept, meridians are made up of stable clusters of polarized water [26] that oscillate and transmit energy at the speeds of light and sound through meridians, with the energy of this transmission called *Qi*. Sometimes thermograms have been thought to actually show the pathway of a weakly luminescent meridian [27], but such demonstrations have been inconsistent between meridians. Furthermore, there is no physical proof that such oscillations occur, that they change with disease or that they actually represent meridians. There simply is no evidence for the existence of meridians based on this theory.

6. Skin Resistance

Electrodermal screening employing measurement of skin resistance has been used for some time to determine the location of meridians and as a guide for treatment [28–30]. Human skin has a resting potential across the epidermis that ranges between 20 and 90 mV [31]. It has been speculated that acupoints, by providing regions of low resistance, short circuit the high resistance imposed by the epidermis [32]. A preliminary unpublished study by Shu and Pomeranz [33], cited in a book in which Pomeranz contributed a chapter [32], claimed that acupuncture decreased local skin resistance for 1–2 days. The physiological meaning of this finding is, however, unclear. According to a recent article [34] the most compelling evidence for acupoints having low resistance compared to adjacent regions comes from Becker et al [35]. It is quite common to encounter instruments that ostensibly locate acupoints through measurement of skin resistance. Using these instruments, it is easy to find skin areas of low resistance that then are claimed to be acupoints [36]. In Japan, a Ryodoraku machine has been used to map out lines of high conductance that corresponded to Chinese meridians [9]. In Germany, a Voll machine has been used to identify a higher steady state capacitative resistance, which has been suggested to be diagnostic of acupoints [32]. Neither the Ryodoraku nor the Voll machines have been validated with a controlled study. In fact, although measurement of ear resistance has been claimed to correlate 72.5% of the time with Western diagnosis [37], a carefully controlled study by Melzack and Katz [38] found no consistent difference in conductance between acupoints and nearby non-acupoints in patients with chronic pain.

Studies in animals suggest that cutaneous electrical potentials (active spots) are different where sensory nerve endings are present [9]. The literature, however, is conflicting since there are many challenges and technical issues that have yet to be resolved [39]. For example, a recent study [34] was able to locate only a fraction of the acupoints using skin resistance or impedance. It is uncertain how active spots noted by some investigators relate to acupoints. Furthermore, the conclusion that active points are heavily innervated is clouded by the fact that sensory endings are present throughout the skin. Also, the contention that there are higher concentrations of acetylcholine and higher temperature at active spots has not been verified widely. Finally, it is important to acknowledge also that many technical factors can influence skin electrical resistance or impedance, which primarily stems from the stratum corneum, including the size of the electrode, the amount of pressure placed on the skin, the time of contact between the electrode and the skin and, importantly, the extent of skin moisture or sweat. Most references citing the validity of skin resistance are in poorly documented textbooks and low quality refereed journals. In fact, when acupoints are carefully mapped in healthy volunteers, inconsistent results suggest that measurement of skin resistance is an unreliable technique [40]. The inconsistency of acupoint location and the inability to identify meridians reliably by any anatomical method has led to the conclusion that neither acupoints nor meridians have a physical basis [41].

7. The Neural Hypothesis

Early studies in human volunteers showed that vascular occlusion of the arm does not alter the analgesic influence of acupuncture needling in the hand (Hegu, LI 4) or forearm [21]. Similarly local anesthetic blockade of cutaneous nerves in the forearm does not alter the influence of hand acupuncture. Conversely, infiltration of deep nerves around the acupuncture point impairs the acupuncture-related analgesic response. These studies have been replicated by the Research Group of Acupuncture Anesthesia, Peking Medical College [42] who demonstrated that injection of procaine into the Hegu acupuncture point prior to needling prevents the increase in pain threshold during iontophoresis of potassium when manual acupuncture is applied at this point on the hand. These investigators also found that needling of the affected side has no effect in patients with unilateral hemiplegia or paraplegia who are experiencing painful stimulation on the unaffected side. These studies have not addressed the possibilities that short-acting anesthetics may have acted locally or are transported to act at a more distant location. However, this early investigation strongly suggests that the nervous system is critical for the action of acupuncture on pain.

Acupuncture points commonly are located in clinical practice either through a site of pain or anatomically. Filshie and Cummings [43] have suggested that acupoints and their interconnections by meridians may have originated through the observation that trigger points or tender spots could be treated with acupuncture or acupressure, a hypothesis advanced by Melzack et al [18]. Filshie and Cummings [43] further suggest that the radicular pattern of the pain from trigger points may have led early practitioners to connect the points thus forming meridians. Despite claims by Melzack et al [18], trigger points do not precisely correlate with acupoints [44]. However, this conjecture leads to the notion that the sensation of pain and its radiation may have led to the early concept of meridians and perhaps *Qi*. During pain elicited by touching a tender or *An Shi* spot, there sometimes is radiation down a neural pathway, the radicular location described as a meridian, with the pain interpreted as a blockage of the normal flow of vital energy or *Qi* through the channel. Needling or pressure applied to the tender spot may have relieved the pain and the oriental medicine acupuncturist interpreted this as restoration of the normal circulation of *Qi*. Thus when practitioners stimulate acupoints they typically ask the patient if there is a sensation of *deQi*, interpreted as a feeling of heaviness, fullness, burning or even pain. Acupuncturists know that they will achieve an optimal response if *deQi* is achieved. The propagated sensation along a meridian during acupuncture has been stated to travel in a proximal to distal direction, which is the opposite direction of sensory nerve conduction [32]. However, it is well known that stimulation of nerves, including both sensory and motor nerves can occur both orthodromically and antidromically. Thus, the direction of the propagated sensation during acupuncture cannot be construed as a valid argument against the involvement of sensory nerves or the presence of a paresthesia during acupuncture stimulation. As such, all of these neurological sensations point towards a neural mechanism that underlies the clinical effect of acupuncture, at least with regard to the relief of pain.

8. Neural Pathways Activated by Acupuncture

As shown in Figure 1 [45], acupoints along many meridians are located over major neural pathways, e.g., P3–P8 over the median nerve, S37–S37 over the deep peroneal nerve, and LI 10–LI 11 over the deep radial nerve [45,46]. A number of studies support activation of somatic sensory nerves by acupuncture, particularly Group III afferents, which are finely myelinated. The fact that acupuncture causes mild discomfort but not frank pain (thought to be transmitted to the central nervous system by unmyelinated or Group IV fibers) led to the suggestion that the finely myelinated Group III sensory nerves were the predominant fiber type activated by acupuncture [44,47]. Early studies identified sensory nerve fiber types stimulated during acupuncture by recording the compound action potential [48]. Our studies [49], utilizing single unit recordings in cats, which can discriminate between finely myelinated (Group III) as well as unmyelinated (Group IV) somatic afferents have shown that low frequency (2–4 Hz), low intensity (2–4 mA) electroacupuncture (EA) applied at the Jianshi and Neiguan acupoints (P5 and P6) stimulates both groups of sensory endings in a ratio of approximately 70% myelinated to 30% unmyelinated afferents. These findings suggest that Group III afferents might be the predominant fiber type involved in this form of acupuncture. However, later experimental studies, in which Group IV fibers were eliminated by injection of capsaicin into neonatal rats, indicated that the Group IV afferents are essential for the ability of acupuncture to lower elevated blood pressure [50]. Thus both myelinated and unmyelinated somatic nerves are important for the action of acupuncture in lowering elevated blood pressure.

Recent studies in rats exploring the role of somatic sensory nerves in the EA-cardiovascular response have shown that low frequency EA is much more effective than high frequency EA, largely due to greater activation of somatic afferents with lower frequency of stimulation [51]. Furthermore, when carefully matched for frequency, manual and EA have a very similar influence in reducing elevated blood pressure, largely because they cause very similar degrees of activation of somatic sensory nerves [51]. All of these findings provide additional evidence suggesting that the peripheral nervous system is intimately involved with transmission of the responses to acupuncture stimulation, at least with respect to its effect on elevated blood pressure.

Studies in a number of animal species other than humans, including rats and cats (see above) [52,53], mice [54], horses [55] and rabbits [56,57] have shown that stimulation of acupoints along meridians produces analgesia, while stimulation of non-acupoints outside meridians (sham acupoints) that are not located over major neural pathways does not produce analgesia. Furthermore, lesioning the median and radial nerve but not the ulnar nerve appears to prevent acupuncture analgesia, further indicating that

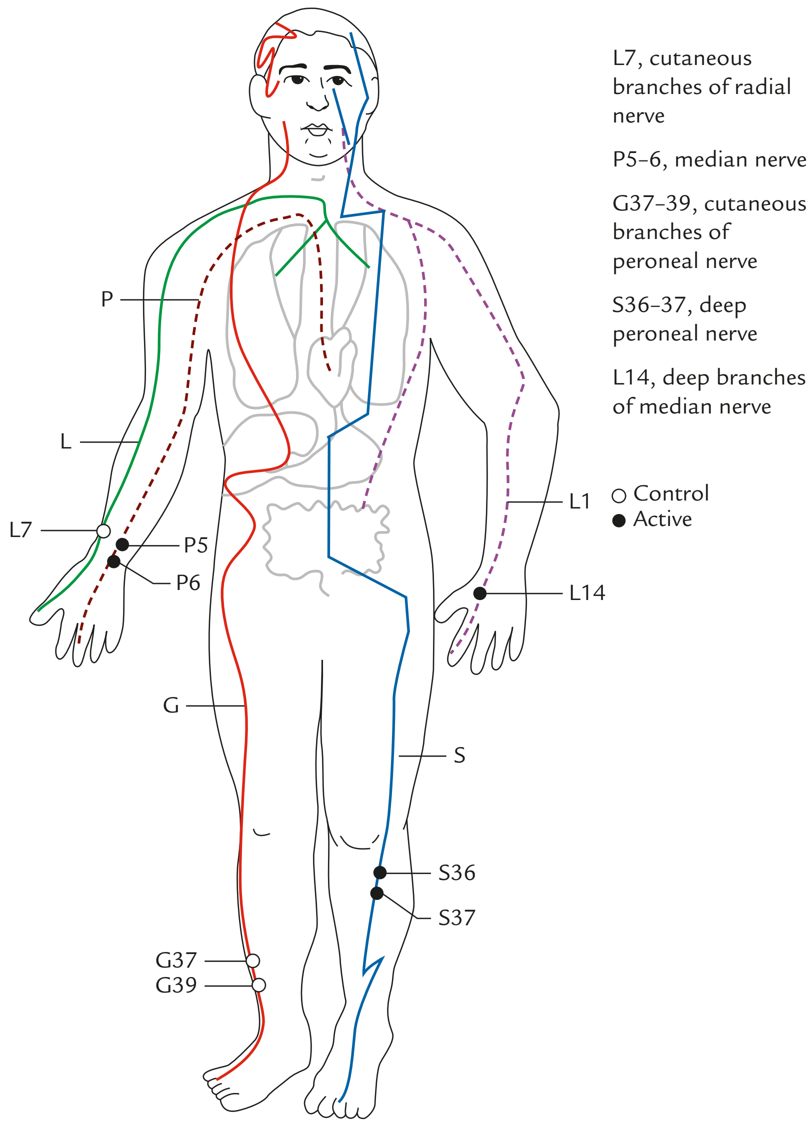

Figure 1 Diagram of meridians and acupuncture points (or acupoints) that have been studied with respect to the cardiovascular influence of electroacupuncture. The acupoints listed in this figure are shown on the right side in relation to the principal somatic nerve they overlie. The acupoints lying over deep nerves, e.g., P5 and P6, have a strong cardiovascular effect whereas those overlying more superficial (cutaneous) nerves have a weak or no cardiovascular influence. The close correspondence between acupoints and nerves supports the neural hypothesis to explain meridians. P=pericardial; L=lung; LI=large intestine; S=stomach; G=gallbladder meridian. This figure was adapted from Li and Longhurst [45].

some, but not other, nerves project to regions of the brain that process pain [58]. These observations are very similar to ours in rats and cats, showing that EA stimulation at acupoints located over deep nerves, including the radial and median nerve, but not superficial or cutaneous nerves like the superficial radial nerve, inhibit elevated blood pressure because deep nerves project more extensively to regions of the brainstem, such as the rostral ventrolateral medulla, concerned with regulation of sympathetic outflow and hence vascular tone [46,59]. Additionally, the action of acupuncture, for example in lowering elevated blood pressure also can be reversed by blocking neuronal activity or neurotransmitter action in a number of regions of the brain, including the ventral hypothalamus, mid-brain and medulla [60–66]. These well-controlled studies from several groups of investigators located in different academic institutions provide additional evidence to support the importance of the peripheral and central nervous systems in mediating meridian and acupoint specific effects during the use of acupuncture in the treatment of pain and elevated blood pressure.

9. Summary and Conclusions

Acupuncture and its various and more recent iterations, including EA, acupressure and moxibustion, are ancient forms of medical practice that have evolved over the last two to three thousand years. The concepts of meridians and acupoints along meridians originated empirically as practitioners sought to understand and explain the sensations evoked during stimulation that appeared to radiate down lines along extremities and the body torso. The movement of these sensations was given names, such as *Qi*, by the earliest Chinese practitioners, and since these sensations appeared to move along the body they were thought to represent a flow of energy. More recently, practitioners have tried to identify anatomical structures that represent meridians but, as of yet, structures such as tendinomuscular meridians and primo-vessels (Bonghan ducts) have not been shown to serve physiologically or clinically as meridians as originally proposed by early practitioners. Furthermore, there have been attempts to identify meridians using thermal or radioactive tracer imaging techniques. However, again these techniques have not proven to be reliable in their ability to identify meridians. Electrode measurements of skin resistance to identify acupoints along meridians likewise have been not proven to be a method capable of discriminating between acupoints and non-acupoints. The most recent and consistent observation has been the location of acupoints and meridians over larger mixed nerve bundles containing motor units, as well as sensory fibers, that project to regions in the central nervous system that regulate pain and blood pressure, i.e., conditions that appear to be influenced by acupuncture. Thus, we are left with the neural hypothesis as the seemingly most logical and consistent explanation for the action of acupuncture. In this view, meridians and their associated acupoints would be considered as simply road maps that help guide the practitioner where to stimulate to achieve the best clinical results. However, it is the stimulation of the underlying neural pathways that can account for the physiological effects and clinical responses to acupuncture in patients.

Despite the body of evidence supporting the neural hypothesis, there are a number of unanswered issues that still need to be addressed with respect to the concepts of meridians and acupoints. First, why are only some meridians and acupoints effective for treating certain conditions? Do differences between nerves and acupoints relate to the hard wiring of the system? That is, do some but not other nerves project to specific regions of the brain concerned with a physiological action, such as analgesia or blood pressure regulation? Second, what is known about meridians and acupoints that are not located over major neural pathways? How do they exert their clinical actions? Could they be working by stimulating a finer network of nerves or do they operate outside of the nervous system? Third, why do some patients, approximately 70%, respond to acupuncture while others do not, even when the appropriate meridian, acupoint and nerve are targeted during stimulation? Is this because there are opposing neurotransmitter systems in the central nervous system or is it because nervous system stimulation does not entirely explain the response to acupuncture? Fourth, if stimulation of underlying neural pathways is the physiological mechanism that explains how acupuncture works clinically, is it possible that many more (supplementary) acupoints located along the same meridian and neural pathway could effectively treat the clinical condition? If this is proven to be true, then particular acupoints may not be as specific as we currently consider them to be. Perhaps all we have to do is stimulate a neural pathway (meridian) at any point along it to achieve a good clinical response. Finally, acupuncture for some conditions seems to have a slow onset of action. Could this be because some other structure, perhaps slow transit down a small primo-vessel (Bonghan duct) may be participating in these delayed responses? Clearly the function of these structures has not been fully explored. For this reason, while the neural hypothesis explains perhaps the majority of the clinical action of acupuncture, I think it is best we accept that further studies are warranted to explore other potential systems that might serve the function of meridians and acupoints.

References

1. Ergil KV. China's traditional medicine. In: Micozzi MS, ed. *Fundamentals of complementary and alternative medicine*. New York, NY: Churchill Livingstone, 1996:185–223.
2. Guo Z. *China's Encyclopedia of the Medicine, A History of Medicine*. Shanghai: Science and Technology Publishers, 1987.
3. Huang F. *A-B Classic of Acupuncture and Moxibustion (Zhen Jiu Jia Yi Jing)*. Beijing: People's Health Publishers, 1956.
4. Yang J. *Great Compendium of Acupuncture and Moxibustion (Zhen Jiu Da Cheng)*. Beijing: People's Health Publishers, 1601.
5. Helms JM. *Acupuncture Energetics: A Clinical Approach for Physicians*. Berkeley, CA: Medical Acupuncture Publishers, 1995.
6. Birch S, Kaptchuk TJ. History, nature and current practice of acupuncture: an East Asian perspective. In: Ernst E, White A, eds. *Acupuncture: A Scientific Appraisal*. Oxford: Butterworth-Heinemann, 1999:11–30.
7. Helms JM. Medical Acupuncture. In: Jonas WB, Levin JS, eds. *Essentials of Complementary and Alternative Medicine*. Maryland: Lippincott Williams & Wilkins, 1999:340–54.
8. Mann F. *Reinventing Acupuncture: A New Concept of Ancient Medicine*, 2nd edition. Boston, MA: Butterworth-Heinemann, 2000.
9. Chan SH. What is being stimulated in acupuncture: evaluation of the existence of a specific substrate. *Neurosci Biobehav Rev* 1984;8:25–33.

10. Anonymous. A clinical study of ear-acupuncture and a preliminary explanation on its underlying mechanisms. *J Tradit Chin Med* 1959;10:32–6.
11. Han K. *On the Kyungrak System by Kim Bong Han*. Pyongyang: Kyungrak Research Institute, 1964.
12. Han K. A study of the anatomic substrate for the ching-lo system. *Acupunt Digest* 1966;1:3–11.
13. Li P. The anatomical and physiological rule of acupoints. In: Chueng L, Li P, Wong C eds. *Mechanism of Acupuncture Therapy and Clinical Case Studies*. New York: Taylor and Francis, 2001:34–43.
14. Soh K. Bonghan circulatory system as an extension of acupuncture meridians. *J Acupunct Meridian Stud* 2009;2:93–106.
15. Ogay V, Bae K, Kim K, Soh K. Comparison of the characteristic features of Bonghan ducts, blood and lymphatic capillaries. *J Acupunct Meridian Stud* 2009;2:107–17.
16. Dung H. Anatomical features contributing to the formation of acupuncture points. *Am J Acupunct* 1984;12:139–43.
17. Gunn C, Milbrandt W, Little A, Mason K. Dry needling of muscle motor points for chronic low-back pain: a randomized clinical trial with long-term follow-up. *Spine* 1980;5:279–91.
18. Melzack R, Stillwell D, Fox E. Trigger points and acupuncture points for pain: correlations and implications. *Pain* 1977;3:3–23.
19. Travell J, Rinzler S. The myofascial genesis of pain. *Postgrad Med* 1952;11:425–34.
20. Travell J, Simons D. *Myofascial Pain and Dysfunction: The Trigger Point Manual*. Baltimore: Lippincott Williams & Wilkins, 1992.
21. Chiang CY, Chang C. Peripheral afferent pathway for acupuncture analgesia. *Sci Sin B* 1973;16:210–7.
22. Pomeranz B, Paley D. Peripheral afferent pathway for acupuncture analgesia. *Exp Neurol* 1979;66:398–402.
23. Darras J, Alberede P, de Vernejoul P. Nuclear medicine investigation of transmission of acupuncture information. *Acupunct Med* 1993;11:22–8.
24. Wu C-C, Chen M, Lin C. Absorption of subcutaneous injection of Tc-99m pertechnetate via acupuncture points and non-acupuncture points. *Am J Chin Med* 1994;22:111–18.
25. Yin SY. *The Biophysics Basis for Acupuncture and Health*. Pasadena, CA: Dragon Eye Press, 2004.
26. Lo S, Geng X, Gann D. Evidence for the existence of stable-water-clusters at room temperature and normal pressure. *Physics Letter A* 2009;373:3872–76.
27. Lo Y. What are meridians? Can we see them? *Acupuncture Today* 2004;5(03). Available at: http://massagetoday.org/mpacms/at/article.php?id=28407 [Date accessed: May 15, 2010]
28. Nakatani, Y. On the nature of the acupuncture points and meridians. *J Japan Orient Med* 1953;3:39–49.
29. Voll R. Twenty years of electroacupuncture diagnosis in Germany. A progress report. *Am J Acupunct* 1975;3:7–17.
30. Reichmanis M, Marino A, Becker R. Electrical correlates of acupuncture points. *IEEE Trans Biomed Eng* 1975;22:533–35.
31. Barker A, Jaffe L, Vanable JJ. The glabrous epidermis of cavies contains a powerful battery. *Am J Physiol* 1982;242:R358–66.
32. Pomeranz B, Berman B. Scientific basis of acupuncture. In: Stux G, Berman B, Pomeranz B, eds. *Basics of Acupuncture*. New York: Springer-Verlag, 2003:7–86.
33. Shu R, Pomeranz B. Electrical impedance measurements of human skin at acupuncture points and changes produced by needling, 1994. [Unpublished data]
34. Colbert A, Larsen A, Chamberlin S, Decker C, Schiffke H, Gregory W, et al. A multichannel system for continuous measurements of skin resistance and capacitance at acupuncture points. *J Acupunct Meridian Stud* 2009;2:259–68.
35. Becker R, Reichmanis M, Marino A, Spadaro J. Electrophysiological correlates of acupuncture points and meridians. *Psychoenergetic Syst* 1976;1:105–12.
36. Ahn AC, Colbert A, Anderson B, Martinsen O, Hammerschlag R. Electrical properties of acupuncture points and meridians: a systematic review. *Bioelectromagnetics* 2008;29:245–56.
37. Oleson T, Kroening R, Bresler D. An experimental evaluation of auricular diagnosis: the somatotopic mapping or musculoskeletal pain at ear acupuncture points. *Pain* 1980;8:217–29.
38. Melzack R, Katz J. Auriculotherapy fails to relieve chronic pain. A controlled crossover study. *JAMA* 1984;251:1041–3.
39. Ahn AC, Martinsen O. Electrical characterization of acupuncture points: technical issues and challenges. *J Altern Complement Med* 2007;13:817–24.
40. Cho S, Chun S. The basal electrical skin resistance of acupuncture points in normal subjects. *Yonsei Med J* 1994;35:464–74.
41. Mann F. A new system of acupuncture. In: Filshie J, Hayhoe S, White A, eds. *Medical Acupuncture: A Western Scientific Approach*. New York, NY: Churchill Livingstone, 1998:61–6.
42. Research Group of Acupuncture Anesthesia, PMC. Effect of acupuncture on the pain threshold of human skin. *Chin Med J* 1973;3:151–7.
43. Filshie J, Cummings M. Western medical acupuncture. In: Ernst E, White A, eds. *Acupuncture: A Scientific Appraisal*. Oxford: Butterworth-Heinemann, 1999:31–59.
44. Birch S. Trigger point—acupuncture point correlations revisited. *J Altern Complement Med* 2003;9:91–103.
45. Li P, Longhurst JC. Neural mechanism of electroacupuncture's hypotensive effects. *Auton Neurosci* 2010. [In press]
46. Tjen-A-Looi SC, Li P, Longhurst JC. Medullary substrate and differential cardiovascular response during stimulation of specific acupoints. *Am J Physiol* 2004;287:R852–62.
47. Bowsher D. The physiology of acupuncture. *Acupunct Med* 1987;4:12–4.
48. Wang KM, Yao SM, Xian YL, Hou ZL. A study on the receptive field of acupoints and the relationship between characteristics of needling sensation and groups of afferent fibres. *Sci Sin B* 1985;28:963–71.
49. Li P, Pitsillides K, Rendig S, Pan H-L, Longhurst JC. Reversal of reflex-induced myocardial ischemia by median nerve stimulation: a feline model of electroacupuncture. *Circulation* 1998;97:1186–94.
50. Tjen-A-Looi S, Fu L-W, Zhou W, Longhurst JC. Role of unmyelinated fibers in electroacupuncture cardiovascular responses. *Auton Neurosci* 2005;118:43–50.
51. Zhou W, Fu LW, Tjen-A-Looi SC, Li P, Longhurst JC. Afferent mechanisms underlying stimulation modality-related modulation of acupuncture-related cardiovascular responses. *J Appl Physiol* 2005;98:872–80.
52. Chan SH, Fung SJ. Suppression of polysynaptic reflux by electro-acupuncture and a possible underlying presynaptic mechanism in the spinal cord of the cat. *Exp Neurol* 1975;48:336–42.
53. Fung SJ, Chan SH. Primary afferent depolarization evoked by electroacupuncture in the lumbar cord of the cat. *Exp Neurol* 1976; 52:168–76.
54. Pomeranz B, Chiu D. Naloxone blockade of acupuncture analgesia: endorphin implicated. *Life Sci* 1976;19:1757–62.
55. Cheng R, McKibbin L, Roy B, Pomeranz B. Electroacupuncture elevates blood cortisol levels in naive horses; sham treatment has no effect. *Int J Neurosci* 1980;10:95–7.
56. Fung K, Chow O, So S. Attenuation of exercise-induced asthma by acupuncture. *Lancet* 1986;2:1419–22.
57. Liao Y, Seto K, Saito H, Fujita M, Kawakami M. Effect of acupuncture on adrenocortical hormone production: I. Variation in the ability for adrenocortical hormone production in relation to the duration of acupuncture stimulation. *Am J Chin Med* 1979;7:362–71.

58. Toda I, Ichioka M. Electroacupuncture: relations between forelimb afferent impulses and suppression of jaw-opening reflex in the rat. *Exp Neurol* 1978;61:465–70.
59. Zhou W, Tjen-A-Looi S, Longhurst JC. Brain stem mechanisms underlying acupuncture modality-related modulation of cardiovascular responses in rats. *J Appl Physiol* 2005;99:851–60.
60. Li P, Tjen-A-Looi S, Longhurst JC. Rostral ventrolateral medullary opioid receptor subtypes in the inhibitory effect of electroacupuncture on reflex autonomic response in cats. *Auton Neurosci* 2001;89:38–47.
61. Tjen-A-Looi SC, Li P, Longhurst JC. Midbrain vlPAG inhibits rVLM cardiovascular sympathoexcitatory responses during acupuncture. *Am J Physiol* 2006;209:H2543–53.
62. Li P, Tjen-A-Looi S, Longhurst JC. Excitatory projections from arcuate nucleus to ventrolateral periaqueductal gray in electroacupuncture inhibition of cardiovascular reflexes. *Am J Physiol* 2006;209:H2535–42.
63. Zhou W, Fu L-W, Guo Z, Longhurst JC. Role of glutamate in rostral ventrolateral medulla in acupuncture-related modulation of visceral reflex sympathoexcitation. *Am J Physiol Heart Circ Physiol* 2007;292:H1868–75.
64. Tjen-A-Looi SC, Li P, Longhurst JC. Role of medullary GABA, opioids, and nociception in prolonged inhibition of cardiovascular sympathoexcitatory reflexes during electroacupuncture in cats. *Am J Physiol Heart Circ Physiol* 2007;293:H3627–35.
65. Li P, Tjen-A-Looi S, Guo Z, Fu L-W, Longhurst JC. Long-loop pathways in cardiovascular electroacupuncture responses. *J Appl Physiol* 2009;106:620–30.
66. Delfino R, Staimer N, Tjoa T, Gillen DL, Polidori A, Arhami M, et al. Air pollution exposures and circulating biomarkers of effects in a susceptible population: clues to potential causal component mixtures and mechanisms. *Environ Health Pespect* 2009;117:1232–8.