

The Biophysics of Acupuncture: Emerging Patterns From Selected Studies

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ABSTRACT

The underlying mechanisms of acupuncture and moxibustion are not self-evident, thus engendering considerable research interest. This article provides a glimpse of some of the pieces of the puzzle and draws some inferences from patterns that are emerging. Selected investigations of physical properties of points and channels, cellular effects of acupuncture, and physiologic effects are considered. Collectively, results point to some organizing principles that may give direction to future research.

Key Words: Biophysics, Acupuncture, Moxibustion

INTRODUCTION

FUNDAMENTALLY, ACUPUNCTURE AND moxibustion are physical stimuli. At the deepest level of understanding, the same could be said for all medical and surgical interventions, even pharmacologic ones. However, in one respect, acupuncture and moxibustion are unique. With a simple, usually mild, and very focal stimulus, profound local, distal, systemic, and, indeed, emotional and spiritual effects may result. In terms of modern Western science, this is a mystery and there are no cohesive theories yet that provide an explanation.

In his credo of 1930, Albert Einstein said, “The most beautiful emotion we can experience is the mysterious. It is the fundamental emotion that stands at the cradle of all true art and science.”¹ This sentiment is especially apropos to deepening the understanding and practice of an ancient healing tradition that is and always has been in a perpetual state of evolution.

In modern mathematics and physics, there are many examples of mysteries waiting to be solved, mysteries that have captured the imagination of the world’s greatest theoreticians. These mysteries include: fractals (seemingly, the mathematical basis for all shapes found in nature, whether plant, stone, cloud, mountain, seashell, or person);² Superstring Theory, a possible route for unifying all the

forces in nature, including gravity, but having the perplexing aspect of requiring a manifold of extra “compact” dimensions in addition to the usual 3 dimensions of space and 1 of time;^{3,4} dark matter and dark energy, accounting for higher than expected angular velocities observed for rotating galaxies and the totally unexpected finding that expansion of the universe is actually accelerating;^{4,5} The Planck Epoch, likely the quantum unit of time, having the implication that conditions during the first 10^{-42} seconds in the existence of our universe are cloaked by an impenetrable barrier thus disallowing any extrapolation from the present;⁵ and “quantum weirdness,” including wave-particle duality, tunneling, and entanglement.⁵⁻⁷ Because quantum weirdness pertains to the subsequent discussion, certain aspects should be explored in greater depth.

Quantum theory is a probabilistic description with intrinsic uncertainties. For example, the location of an orbital electron at a given time is represented as a probability density and simultaneous measurement of its position, and momentum is only possible to within a defined degree of uncertainty. Calculation of probability density for any particle is a function of a wave equation. Thus, in certain instances, depending on the experiment, a beam of electrons or even single electrons may demonstrate an interference pattern, consistent with wave behavior. In other instances, again depending on the experiment, a beam of electrons

may behave more like a stream of tiny marbles. This is called wave-particle duality.^{5,6}

Tunneling is another aspect of quantum weirdness that has to do with probability density. It is a way of materializing on the other side of a wall. We experience tunneling directly every time we use a cell phone, turn on the computer, or listen to the radio. It is the underlying principle for all semiconductor devices. Essentially, in electronic components such as transistors, solid-state diodes, or computer chips, an electron on the surface of a nonconducting thin film may, as a result of its wave equation, find itself on the other side, violating classical laws of electricity and magnetism.⁵

Entanglement is perhaps the most mysterious aspect of quantum weirdness. In certain circumstances, the wave functions of particles from quantized systems may become entangled and their physical properties forever linked, despite separation even to opposite ends of the universe. A simple example of entanglement is the Pauli Exclusion Principle as applied to the 2 electrons surrounding a helium nucleus. According to this exclusion principle, the 2 electrons may share the same quantized energy level but may not have the same quantized spin. The spins must be opposite. The interesting thing is that if you shear the 2 electrons from the nucleus, entanglement requires that they always have opposite spins, even if sent to diametric points billions of light-years apart. Furthermore, the information about any change in spin direction of one is immediately transmitted to the other, regardless of distance. There are other types of entanglement, such as with polarization of photons, but, in all cases, the relationship is apparently permanent. Entanglement has been posited as having importance in biological systems and is being explored as a means for transmitting information in quantum computing.⁵⁻⁷

Taking into consideration the many deeply mysterious and counterintuitive aspects of modern physics, are there connections to be made to the mystery of the mechanisms of acupuncture and moxibustion? In my view, *Qi* is a key link. Generally defined as a form of energy, I am not aware of a means of directly and quantifiably measuring *Qi* in the laboratory. Yet, the sensory experience of *Qi* is common. De *Qi*, propagation of needling sensation, and *Qi* Gong are examples. Also, according to classical theory, *Qi* has the ability to transform in a manner consistent with energy-matter equivalence and conservation of matter and energy.⁸ If one believes in dark matter and dark energy, there are very few conceptual differences in accepting *Qi* as a putative reality.

The vast majority of research in acupuncture and moxibustion has been clinical. However, a number of studies have examined basic science aspects. The 3 primary areas of investigation have included physical properties of points and channels, cellular effects, and physiologic effects. Illustrative articles cited herein were selected on the basis of (1) whether investigational goals and findings provided some inferences regarding signaling mechanisms and other

aspects of the physical basis of acupuncture and moxibustion; and (2) whether well-grounded methodologies were used. The literature contains many other worthwhile articles on the subjects covered; thus, the list of references should not be considered comprehensive.

PHYSICAL PROPERTIES OF ACUPUNCTURE POINTS AND CHANNELS

Many reports state that electrical conductance is increased in points and along channels. Reproducibility, however, has been an issue in this area. Some confounding factors include high impedance in the stratum corneum, ion shunting (as in sweat glands), and bioelectricity. Additionally, measurements are affected by the nature of the applied voltage (continuous, square-wave, sinusoidal, low-frequency, high-frequency, etc), moving charges (inductance), fixed charge reactance (capacitance), and the electrode-tissue interface. To attain valid data in future studies, careful attention should be given to experimental protocol.⁹⁻¹²

Optical properties of channels have been carefully investigated in a study involving transmission of visible light. Measurements were made using red laser light, amplitude modulated at 10 Hz collimated to a 2-mm beam, and applied orthogonally to the skin. Attenuation between source and detector points on the PC channel, calculated using the steady state reflectance method, were compared with nearby, equidistant source and detector points parallel to but off-channel. For each participant, the study was repeated at 3 different laser wavelengths. For all 3 wavelengths, attenuation was less in the channel direction than off-channel ($P < .01$).¹³

Transmission of infrared in channels has been an area of particular interest, owing in part to the efficacy of moxibustion. A sentinel study using infrared imaging techniques and moxa as a directed heat source at acupuncture points revealed a pattern of thermal gradients that is congruous with the classical pathways of the corresponding channels.¹⁴ In another study, infrared imaging demonstrated radiant tracks on the skin surface that corresponded with accepted channel locations; these thermal gradients varied with time.¹⁵

Migration of the radioisotope technetium 99 has been studied in relation to points and channels. In all cases, injection of the isotope into an acupuncture point resulted in migration along the associated channel, whereas injection into non-acupuncture points resulted in centrifugal, isotropic patterns of migration. Injection of a point and mechanical, electrical, or thermal stimulation of a different point on the same channel, either proximal or distal to the injected point, caused a transient, synchronized acceleration of the diffusion rate. Injection of a point and mechanical, electrical, or thermal stimulation of a point on the contralateral channel also resulted in a transient, synchronized accelera-

tion of the diffusion rate. Using a dual isotope imaging technique, isotope migration from acupuncture points was differentiated from vascular flow patterns. In a similar manner, flow via lymphatic vessels was also eliminated as the basis for migration. In a special case, it was found that injection of the point LI 18 resulted in migration across the midline of the face to the point LI 20, providing confirmation of the classical teaching regarding the course of the LI channel. Additional findings of this study were that application of a tourniquet blocks diffusion of isotope at the same point as blood flow; and that injection of a point without stimulation does not result in changes in granulocyte membrane potentials as measured by fluorometric methods, whereas stimulation of a point does result in changes.¹⁶

Proton-induced x-ray emission is a tool for determining the chemical composition of microscopic regions. In research performed in the physics department of Fudan University in Shanghai, China, this method was used to study acupuncture points in fresh human tissue specimens. Punctiform zones of very high concentrations of calcium were found. These calcium spikes were localized to the deeper levels in points and were associated with underlying connective tissue. In addition, high concentrations of phosphorus were noted with fixed calcium-phosphorus ratio of 2.19 by weight. These findings were not found in off-channel locations.¹⁷

Many have theorized that acupuncture channels are determined by connective tissue planes. The finding of calcium banks in acupuncture points that are physically juxtaposed with underlying connective tissue lends support to this hypothesis. In view of the findings noted with infrared imaging, another study done by the same group at Fudan University looked at infrared transmission in connective tissue. With an infrared source aligned parallel to collagen fibers, spectrophotometry revealed a window of enhanced transmission between 9 and 20 microns. Very low transmission was noted both below and above this wavelength range. Also, there was minimal transmission at all wavelengths when the source was aligned perpendicular to the collagen fibers.¹⁷

A third study at Fudan University (done by a different group) measured spectra for electromagnetic emissions from LI 4 (Hegu), PC 6 (Neiguan), and PC 8 (Laogong). In all cases, thermal emissions corresponded generally with the so-called black body spectrum that one might expect from any heat source. However, when the black body spectrum was subtracted from the measured spectra, 2 additional peaks were found at 2–2.5 microns and 15 microns. These peaks were not found for off-channel points.¹⁸

CELLULAR EFFECTS OF ACUPUNCTURE

Two major cellular effects have been documented with stimulation of acupuncture points: increased degranulation

ratios for mast cells in stimulated points^{19–21} and changes in granulocyte membrane potentials in the blood.¹⁶ More is written about the former than the latter, but both effects correlate with analgesia. Another finding pertains to the role of collagen fiber. In an animal study, when type I collagenase was injected to destroy collagen structure, analgesic effects were significantly attenuated as was mast cell degranulation.²²

Using whole cell patch clamp techniques on human mast cells, a transient receptor channel was identified that permits calcium ions to stream into the cytoplasm, resulting in degranulation. This receptor, TRPV2, is activated by both mechanical and thermal stress.^{23–25}

Granulocyte membrane potentials have been shown to be affected by both needle and laser stimulation of acupuncture points. Fluorometric studies were done on control and post-acupuncture blood samples taken from the same individual that demonstrated the change.¹⁶

PHYSIOLOGIC EFFECTS OF ACUPUNCTURE

There is evidence that acupuncture activates neurohumeral mechanisms, especially as it pertains to pain modulation. Electroacupuncture, using a square-wave stimulus, has been shown to result in release of dynorphin and enkephalins from the spinal cord and beta endorphins from the hypothalamus. The release of beta endorphins is dependent on the frequency of stimulation, occurring with lower frequencies (generally considered to be tonification frequencies), but not at higher frequencies (generally considered to be frequencies for moving Qi). In some instances, naloxone has been shown to block the analgesic effects of acupuncture.²⁶

In a recent series of studies done at the Research Institute for Acupuncture and Moxibustion of Anhui College of Chinese Medicine, Hefei, China, an animal model was used to study the effects of stimulation of HT 7 (Shenmen) on cardiac function and cardiac sympathetic nerve activity. In rabbits with chemically induced myocardial ischemia, ventricular function was improved and sympathetic nerve activity was simultaneously increased with stimulation of HT 7.²⁷ In another study by the same group (reported at the 2007 International Conference of the Society for Acupuncture Research), stimulation of HT 7 in rabbits with chemically induced cardiac arrhythmia resulted in a decrease in rhythm disturbance. If, however, the cardiac sympathetic nerve was severed, the effect was lost.

DISCUSSION

Acupuncture is associated with a wide range of effects. Underlying mechanisms, in most cases, are not self-evident. Certain inferences may be derived, however, and from these

inferences, a hint of unifying principles, most notably with respect to signaling mechanisms.

Despite difficulties with verification in the laboratory, it is widely believed in acupuncture circles, with some supporting data, that electrical conductance is increased in acupuncture points and along channels. If reproducible measurements ultimately confirm this impression, it is likely that electrical properties of connective tissue play a role.

Enhanced propagation of electromagnetic energy in both visible wavelengths and in the infrared range imply that this may be a mechanism of signaling. The particular role of infrared is inferred by the following: (1) thermal gradients that develop along associated channels when moxa is used at acupuncture points; (2) the finding of radiant tracks demonstrated by thermal gradient imaging; (3) the correspondence of radiant tracks with the classical course of channels; (4) the waveband filter property of connective tissue; (5) the finding of biophoton emission from acupuncture points with 2 peaks, both in the infrared range and 1 of which is in the center of the range of enhanced propagation; and (6) the directional aspect of infrared transmission by connective tissue, offering a possible explanation for how signaling might occur along connective tissue pathways that connect acupuncture points (i.e., the channels).

Migration of radioisotope along channels points to some molecular transport phenomenon, distinct from vascular or lymphatic flow. This may additionally be an aspect of signaling or it may also be the mechanism for activation of target receptors. Acceleration of migration with stimulation of acupuncture points implies coupling between molecular transport and point stimulation. Contralateral acceleration could be a manifestation of neurohumeral effects. The release of pain-modifying neuropeptides with electroacupuncture provides additional support for this hypothesis.

The unique finding of punctiform concentrations of calcium in acupuncture points leads one to suspect that stimulation initiates ion streaming. This is supported by the identification of the TRPV2 receptor on mast cell membranes, a receptor that permits calcium ion streaming into the cytoplasm with the ultimate result being degranulation, consistent with the discovery of high mast cell degranulation ratios after point stimulation. The collagenase study draws a connection between connective tissue, the zones of high calcium concentration, and what is happening with point stimulation. If the connective tissue substrate is removed, mast cell degranulation is decreased as is the analgesic effect.

Neural pathways for signaling are implied by the experimental finding that transection of the sympathetic cardiac nerve in an animal model blocks the effect of stimulation of HT 7 (Shenmen).

Thus, with regard to signaling, there is evidence to support all of the following mechanisms: nerve conduction, humeral releases, molecular transport, ion streaming, and

biophotons. Either this is a complex, multidimensional system or some observations are related to cause, and others to effect. Keeping in mind that signaling involves transmission of information, is there any basis for choosing the most fundamental aspect of signaling, and, if so, determining how it relates to other observed processes?

Points are distinguished by punctiform calcium banks that are physically connected with an underlying connective tissue substrate. Stimulation of a point may result in calcium ion streaming. A likely local effect is degranulation of mast cells. A neurohumeral cascade might be a consequence. However, this is not the probable mechanism for initiating distal or systemic effects. It would not explain, for example, long-lasting or permanent relief of pain nor would delayed onset of action fit this hypothesis.

There are contradictions to the neural pathway concept of signaling in acupuncture. One example is propagation of needling sensation along channels. Channels do not correspond with known neural pathways. Anytime the skin is needled, there is stimulation of cutaneous nerves, including perivascular plexuses of sympathetic nerves. However, this effect would apply to any point of skin stimulation and does not account for point specificity.

Molecular transport along channels is an interesting finding but experimentally, it is too slow to explain the immediate response that frequently happens with acupuncture. Also, by nature, molecular transport over a distance requires a significant energy source and no such energy source has been identified and, indeed, in the radioisotope study, there appears to be a limit as to how far the isotope migrates along channels.

In view of the existence of radiant tracks that correspond with channels, the waveband filter for infrared in connective tissue, and the discovery that biophotons are emitted from acupuncture points with a wavelength in the middle of the filter range, it is likely that this energy is a reflection of something profound. How might information thus be transmitted?

This is where quantum weirdness may be operant. As it happens, collagen fibers consist of tropocollagen molecules in a helical structure. There are gaps between the ends of the tropocollagen subunits that result in periodic variations in charge distribution and refractive index. This physical structure is conducive to cavity quantum electrodynamic effects, a possible explanation for spontaneous emission of entangled photons. These photons may actually be emitted as solitons, self-reinforcing, single-wave packets that propagate directionally along the connective tissue plane.¹⁷ As previously mentioned, this physical principle is being explored as a basis for quantum computing and may occur in biological systems.²⁸ It is a means for transmitting information. Though there is currently no way to prove it, one hypothesis might be that obtaining De Qi by stimulating an acupuncture point initiates excitement of the quantum electrodynamic cavity via disturbance of the calcium

bank and resultant ion streaming. Information contained in entangled solitons is then propagated via connective tissue pathways (the channels), and it is this information that is imparted at cellular and physiologic levels to cause observed effects.

CONCLUSIONS

A wealth of clinical data exists to show that acupuncture is effective. Moreover, each of us who practices acupuncture marvels at its *efficacy*, even though we are not fully able to explain it. This review attempts to illustrate that there is a body of knowledge that suggests, though does not prove, a physical basis for acupuncture. Rather than factual conclusions, we are left with questions. Will the solution be as exotic as entangled soliton emission from quantum electrodynamic cavities or will it be something else altogether? And what is our role in the continued evolution of both how we practice and how we understand acupuncture? Lastly, what is the peculiar resonance between the mind and physical reality that led to the discovery of this ancient healing art? That is perhaps the greatest mystery of all.

DISCLOSURE STATEMENT

No conflicting financial interests exist.

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