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Nonlinear Mathematical Model Explains how Acupuncture Works – Gender Differences in Acupuncture Response

By Prof. Maria Kuman

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Strictly as per the compliance and regulations of:

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I. Introduction

The nonlinear mathematical model offered here aims to explain what exactly happens when an acupuncture point on the surface of the skin is punctured with a needle. *Measurements of the skin conductivity revealed that the acupuncture points are ellipses about one inch long and a half-inch wide*. They are oriented with their long axes along lines called *acupuncture meridians* and separated [3] by distances of about 3/4 of an inch.

1/ Each acupuncture point has conductivity, which is 2-3 mA higher than the surrounding tissue [3,4]. This is because under each acupuncture point there is a dense set of nerve fibers without myelin cover, which are like wires without insulation (which explains why the *acupuncture points are more tender to the touch*). The higher conductivity of the acupuncture points [3,4,5] allows us to consider them in this mathematical model as neuronal pools.

The "pool" approximation means that the discrete systems of neurons are considered a continuum. Mathematically, this means replacement of the summation over the system of neurons with integration, which considerably simplifies the mathematical description of the acupuncture points.

Ref

3. Mann F, *Acupuncture - the Ancient Chinese Art of Healing*, Cambridge, 1971.

Author: PhD, Health and Happiness Books, 1414 Barcelona Dr., Knoxville, TN 37923, USA. e-mail: holisticare@mariakuman.com

2/ Also, since there is a dense set of thin blood vessels under each acupuncture point [3], the acupuncture points have a few tenths of a degree higher temperature [3] and higher oxygen consumption [2][3] than the surrounding tissue.

Thus, *neurologically* the acupuncture points are conducting ellipses imbedded in a semiconducting tissue. *Hematologically*, the acupuncture points are ellipses with higher temperature and oxygen consumption imbedded in a medium with lower temperature and oxygen consumption. In both cases the medium is inhomogeneous.

The propagation of waves in inhomogeneous media depends more on the topography of the inhomogeneous medium than on the kind of waves propagating in it - electric or temperature waves. Since the meridian topography is the same, should we consider the acupuncture points as neuronal or blood pools, mathematically they should be described by the same type nonlinear integral equations.

Shuiski [6] was the first to measure volt-ampere characteristics at the acupuncture points. He found that the acupuncture points have *hysteresis* type of behavior, while the surrounding tissue does not. Hysteresis type of volt-ampere characteristics means that at gradually increased voltage one electric current is measured, but when the voltage is gradually decreased another electric current is measured.

Thus, the electric response to the same strength of voltage is different depending on whether the voltage was increased or decreased. This is so because the voltage increase had induced long-range long-lasting correlations, which still exist when the voltage is decreased. *This makes history or initial conditions important, i.e. it matters what has happened to the system before the measurement.*

'*Hysteresis*' means '*delayed effect*' (hysteros=later), i.e. after the system has been influenced the first time, residual changes remained in it. Each inhomogeneous medium after a certain degree of inhomogeneity starts exhibiting hysteresis type of behavior [6] and the pulses and waves propagating in it become nonlinear [8]. Thus, each inhomogeneous media exhibits nonlinear properties and only nonlinear equations could describe it.

II. Nonlinear Mathematical Model

The conductivity of the acupuncture points is usually measured with different equipment specially designed for this purpose and with them their shape and size was found. *With these equipment, it was discovered that the acupuncture points that signal pathology (which are more painful to the touch) have electrical potential either higher or lower than that of adjacent acupuncture points. It was also found that with each acupuncture treatment the electric potential of these acupuncture points changes toward normal and their painfulness decreases.*

Let us consider each acupuncture meridian, which is a chain of conducting acupuncture points, as a chain of neuronal "pools" with higher conductivity. To describe mathematically a single acupuncture meridian, we will use the system theory [13] used for mathematical modeling of neuronal activity, which was developed for neuronal pools [9].

At the beginning for simplicity, let us assume that each acupuncture treatment stimulates only one neuron A making it to fire an impulse X_A. For simplicity, let the impulse X_A is a Dirac δ -function,

$$X_A(t) = \delta(t); \qquad -\infty < t < \infty \tag{1}$$

Ref

6. Shuiski V, Biophysical Aspects of Acupuncture, *VIII World Congress of Acupuncture*, Sofia, May 15-20, 1983.

and let this stimulus influences only one neuron B. The response of this neuron B to the stimulus X_A will be an electric potential $V_B(t)$ called generator potential (see [9]).

$$V_B(t) = V_{B0} + \int X_A(t')h_{BA}(t-t')\,dt' = V_{B0} + X_A @ h_{BA}(t), \quad (2)$$

Each acupuncture treatment can either excite and then $h_{BA} > 0$, or inhibit and then $h_{BA} < 0$, depending on the type of treatment and type of needles. According to the system theory [13], the response (generator) potential $V_B(t)$ to the stimulus X_A can be obtained from the convolution of the impulse X_A with response $h_{BA}(t)$

$$V_B(t) = V_{B0} + X_A @ h_{BA}(t) \quad (3)$$

The dependence of the generated potential $V_B(t)$ on the stimulus X_A should be nonlinear because: i) there are thresholds for activation of the synapses; ii) at large X_A the secretion of neurotransmitters would be exhausted; and iii) there is a postsynaptic saturation effect and the superposition of synaptic influences is not fully additive [9]. Hence, $V_B(t)$ should be represented by

$$V_B(t) = V_B(0) + S_{BA}(X_A) @ h_{BA}(t) \quad (4)$$

where $S_{BA}(X_A)$ is a nonlinear function of X_A that reflects the average generator potential S_{BA}, produced in cell B by the stimulus X_A.

Since each acupuncture treatment influences more than one neuron, we should replace X_A with X_{Aj} and consider each acupuncture point as a discrete set of n neurons, numbered j= 1,2,...,n. Let us assume that the answers to each of these neurons add up. Considering the interaction only between couples of neurons ij we can write the potential V_B as

$$V_B(t) = V_B(0) + \Sigma\, S_{BAj}(X_{Aj}) @ h_{BAj}(t) \quad (5)$$

Let us now consider each acupuncture point as a continuum of neurons or as a neuronal pool - the high concentration of nerve fibers without myelin cover in each acupuncture point allows us to do this. Then we can replace the summation in eqn. (5) with integration. As a result, eqn. (5) transforms into:

$$V_B(t) = V_{B0} + \int S_{BA}(X_A) @ h_{BA}(t)\,d\tau \quad (6)$$

Then each meridian becomes a one-dimensional chain R_i of neuronal pools s_i (the index i numbers the neuronal pools or the acupuncture points in the chain). The system theory [13] allows the effect of each acupuncture treatment to be presented either in potential representation or in frequency representation.

In potential representation (eqn. 6), the potential $v(s_i,t)$ of the treated acupuncture point is considered a basic variable. In frequency representation, the frequency $x(s_i,t)$ of the treated acupuncture point is considered a basic variable. The theory allows a transfer from potential to frequency representation and vice versa.
Through the following transformation

$$x(s_i,t) = T(s_i, v(s_i,t))$$

our equation (6) could be written in frequency representation

$$x(s_i, t) = T(s_i, v(s_i)) + \Sigma \int\int S_{BA}(s_i, s_j', v(s_j', t'))h(s_i, s_j', t')\,dt'\,ds_j'. \quad (7)$$

The needles, used for treatment of acupuncture points, generate electric potential (experimental fact [1]). Massage of the acupuncture points (acupressure) also generates

Ref

13. Varju D, *Systemtheorie*, Springer-Verlag, Heidelberg - NY, 1977.

electrical potential, because of the piezoelectric properties of the skin (electric potential resulting from rubbing of the skin).

In the cases of electro stimulation when the acupuncture point is stimulated with electric current or external potential V = E, eqn. (7) transform to eqn. (7')

$$x(s_i, t) = T(s_i, v(s_i)) + \Sigma \int S_{BA}(s_i, s_j', X(s_j', t')) @ h_{BA}(s_i, s_j', t')ds_j' + S(s_i, E(s_i, t)) @ h(s_i, t)) \quad (7')$$

The equivalent potential representation of eqn. (7') is:

$$v(s_i, t) = E + v_0 + \Sigma \iint U(s_i, s_j', v(s_j', t)) @ h(s_i, s_j, t)ds_j' \, dt' \quad (8)$$

Equation (8) is a reasonable approximation of the more general and more difficult model

$$V(t) = V_0 + \int K(X(t'), t, t') \, h(t - t')dt' \quad (9)$$

Our attention will be restricted to a special class of Kernel functions $K(s_i, s_j', t')$ allowing transformation of the integral equation into a partial differential equation of parabolic type. This type of equation has been studied extensively in the last two - three decades in various areas, such as ecology, nerve impulse theory, etc.

Let an acupuncture treatment at point s=0, at time t=0 creates an impulse shaped as Dirac function δ with strength a, which influences another acupuncture point, located at a distance s Є R at time t > 0. The direct influence is described by

$$h(s, t) = U(a)(1/2)(Dt)^{-1/2} \exp(-s^2/4Dt)\exp(-d't), \quad (10)$$

where U(a) > 0 means stimulation, U(a) < 0 - inhibition. D is a diffusion constant, d' - a constant of decrease of the signal with time.

If the mutual coupling of two points depends only on the distance between them |s - s'|, then

$$h(s, s', t) = h(|s - s'|, t); \quad U(s, s', v) = U(v); \quad (11)$$

By substituting (11) in (8) we get

$$w(s, t) = \int U(v(s, t)) @ h(|s-s'|, t-t')ds', \quad (12)$$

where w = v - E obeys *the parabolic equation*

$$w_t - d\, w - D\, w_{ss} = U(w + E). \quad (13)$$

This transfer integral -> differential equation is possible only at the special choice of h(s, t) described by (10). Is this choice suitable for an acupuncture theory?

According to formula (10), at a distance s from the origin of the signal (s=0), the response is maximal after time t = t max

$$0 = h/\, t = U(a)\,(1/2)(\pi D)^{-1/2}\, h(s, t)(-1/2t + s^2/4Dt^2 - d')$$

i.e.

$$t_{\text{max resp.}} = -1/4d' + ((1/4d')^2 + (1/4Dd')\, s^2)^{1/2}; \ (d' > 0);$$

or

$$t_{\text{max resp.}} = s^2/2D\,; \ (d' =/ 0); \quad (14)$$

Notes

In formula (14), the time response depends reciprocally on the diffusion constant D, i.e. the time response is shorter when the diffusion constant is larger. Since the processes in a child's body run faster, their constant of active diffusion D will be larger. Then formula (14) can explain an event observed in the acupuncture clinical practice: the cure of children is faster because their constant of active diffusion is larger.
At E = const., eqn. (13) transforms to:

$$v_t - D\, v_{ss} = U(v) - d'.\, v + I, \tag{15}$$

where I= d'.E. Therefore, d' describes the dissipation observed in a body tissue during the propagation of external input E=const.
By introducing the function

$$f(v) = U(v) - d'.\, v + I$$

we can write (15) in the form

$$v_t - Dv_{ss} = f(v) \tag{16}$$

known as *Fisher equation*. The equation has two types of solutions: stable (stationary) and unstable [10].

The stationary solutions of eqn. (16) v(s, t) = v(s) are determined by the ordinary differential equations

$$v''(s) + f(v(s)) = 0; \qquad -\infty \leq s \leq \infty \tag{17}$$

The unstable solutions of eqn. (16) correspond to a traveling front and can be written in the form

$$v(s, t) = u(s - ct) = u(z) \tag{17'}$$

$$u(\infty) = \lim\ u(z)$$

$$u(-\infty) = \lim\ u(z)$$

The two asymptotes of the function coincide with two of the stable (stationary) solutions (c - speed of the traveling front). If c > 0, the front travels to the right, if c ¡ 0 the front travels to the left, c=0 corresponds to a stationary wave.
The traveling front u is a solution of the ordinary differential equation

$$u'' + c\, u' + f(u) = 0, \tag{18}$$

which becomes eqn.(17) with substitution (17') and at

$$u(-\infty) = y_i; \qquad u(\infty) = y_j;$$

where y_i , y_j are different zeros of f.

Aronson and Weinberger in 1975 [11] have proved a theorem for a system of neurons: A sufficiently large local excitation can lead to a global excitation; a sufficiently large local depression can lead to a global depression.

This can explain how local excitation from local treatment (or inhibition when the treatment is done with a thick needle) can lead to a global excitation (or inhibition) of the processes in the whole body.

If we include self-inhibition [9] in our model, which has been proven to exist in nerve propagation and is included in all nerve-propension models, then instead of traveling fronts, we will have as solutions traveling pulses.
Equation (16) then becomes

Ref
10. Fisher B, A Neuron Field Theory: Mathematical Approaches to the Problem of Large Numbers of Interacting Cells, *Bull. Math. Biol.*, 1973; 38: 253-267.

$$v(s, t) = \int [U(v(s, t) - w(s, t)) @ h(| s-s'|, t-t')]ds' + E; \tag{19}$$

where

$$w (s, t) = v(s, t) @ h(t) = \int v(s, t) h(t - t') dt';$$

$$h (t - t') = b \exp (-d_2 (t - t')); \quad b > 0; \; d_2 > 0.$$

Differentiating (19) we get

$$v_t - D v_{ss} = f(v) - w; \quad w_t (t) = b v - d_2 w. \tag{20}$$

Equation (20) is identical with the *Fitzhugh - Nagumo equation, which is simplification of the Hodgkin - Huxley model for nerve pulse propagation* [9]. The unstable solution of (20) is a traveling pulse, which can be represented in two-coordinate vector form

$$(v(s,t), w(s,t)) = (u (s - ct), g(s - ct)) = Z (z) \tag{21}$$

It is time now to take into consideration the natural DC potentials at rest V_N, which exist between the upper and lower body and determine the direction of the acupuncture meridians. When the arms are up, the acupuncture meridians run downward on the outer side of arms, legs, and on the back and they run upward on the inner side of arms, legs, and the chest and abdomen.

Without these natural DC potentials at rest that determine the direction of the acupuncture meridians, the pulses created during acupuncture treatment of point j would run with the same speed in both directions of the meridian. The DC potentials at rest make the electric pulses run in the direction of the meridian.

When acupuncture point is treated with a needle, some patients feel the electric current running in the direction of the meridian (especially during rotation of the needle). Based on their sensation, they can tell in which direction the meridians run. Prof. Zhu experimentally measured these traveling electric pulses [1].

Whenever the equation (20) has solutions traveling electrical pulses, it has solutions traveling waves. The nonlinear equations have more than one solution and all solutions need to be considered on an equal basis. This gives to the traveling waves equal right of existence with the traveling electric pulse.

The *traveling-wave solutions* are described by a function

$$Z(z) = Z (k s - t), \tag{22}$$

where k is the wave number ($k = 2 \pi / \lambda$), λ - the wavelength, and the speed of wave propagation is $c = \omega /k$.

The traveling waves, also called *wave trains*, can be represented as two component vectors

$$Z(z) = (v (s, t), w (s, t)) = (v (z), w(z)). \tag{23}$$

In this representation eqn. (20) can be written as

$$k^2 D u'' + u' + f(u) = g(z) \tag{24}$$

$$u - g(z) d = -b u$$

In the case of nerve propagation, the existence of wave trains has been proved by Conley, Hasting and Carpenter [12] independently. Numerical calculations showed that

Ref

1. Zhu Z X, *Biophysical Approaches in Acupuncture*, Conference in Budapest, 1985.

there are two types of waves with frequencies ν and ν' (with wave numbers k and k') propagating with different speeds c (slow) and c' (fast).

The train-waves, predicted by our mathematical model, must be running from the treated acupuncture point in the direction of the meridian. This was first reported at the 8th World Congress of Acupuncture. The Hungarians showed interest and a year later they proved experimentally that waves do propagate along the meridian [2]. However, more detailed experiments are necessary to prove that both slow and fast waves are present.

Ref

2. Eory A, *International Acupuncture Congress*, Bratislava, February 1985; see also: *Acupuncture and Electro-Therapeutic Research (Int. J.)* 1984; 9: 217-223.

III. Auto-Waves

The offered here nonlinear mathematical model also allows us to explain the following fact known to every acupuncturist: treatment of distant points of the acupuncture meridian has maximal effect on the organ. It has never been explained before, but it can find its natural explanation in the frames of this model, if we think of the waves propagating along the acupuncture meridian as auto-waves.

Auto-wave means that the wave generated at each acupuncture treatment moves in the direction of the meridian and when it meets the next acupuncture point, it makes it a new center of wave propagation. This could happen only if the distances between the acupuncture points are such that the echo - reflected waves from the second point annihilate the forwarding signal from the first point, but enhance the signal from the second point.

In this way, the wave center moves in the direction of the meridian and the further it goes from the initial point, the larger the amplitude of the signal becomes. This explains why the more distant is the treated acupuncture point of each acupuncture meridian, the stronger is the effect on the organ represented by this meridian.

If waves are involved in each acupuncture treatment, this means that the acupuncture works through the waves of our nonlinear electromagnetic field (NEMF), which is located in the Subconscious and from the Subconscious rules and regulates the functioning of all the organs and everything else in the body.

Our fast response is done through the waves of this NEMF. If we don't have conscious awareness of the existence of this NEMF, it is because when our life is threatened and we need to respond fast to survive, we don't want to be bothered with information about the functioning of our organs.

The waves of this NEMF are the basis of our Quantum Computer, which operates in the Subconscious, and from the Subconscious rules and regulates everything in the body. If acupuncture works through waves, it influences the regulatory work of our Quantum Computer.

IV. Gender Differences in Acupuncture Response

Ancient acupuncture books say that the acupuncture meridians are like rivers, but along them runs energy instead of water. In the way the rivers flow into sea, the acupuncture meridians flow into 6 spinning seas. They are called chakras in Hindu sources because "chakra" means "spinning wheel" in Sanskrit [15].

Each of these chakras is related to a gland of internal secretion secreting hormones into the blood stream. If so, these spinning energy centers, called chakras, rule our endocrine system, the balance of which determines our physical and mental health. Since the chakras spin in opposite directions in males and females, the acupuncture meridians are expected to run in opposite direction in males and females.

If so, there will be a difference in the response of males and females to acupuncture. Indeed, ancient texts recommend: when treating females with acupuncture to use points on the left hand because the effect on the organ will be stronger; when treating males with acupuncture to use points on the right hand because the effect on the organ will be stronger [15].

Also, ancient texts when speaking about pulse diagnosis claim that the best way to diagnose a woman is to measure the pulse on her left hand, while the best way to diagnose a man is to measure the pulse on his right hand. This is because the pulse on the left woman's hand is stronger and the pulse on the right man's hand is stronger [15].

There is also a difference left – right in the strength of our eyes. For women the left eye is stronger, for men the right eye is stronger. The difference is about ¼ of diopter, but it is always present [15]. The cited book of the author [15] contains a lot more interesting facts including the offered here mathematical model.

V. Conclusion

Let us summarize. The nonlinear mathematical model offered here was able to explain many of the bizarre features observed in the clinical acupuncture practice: i) why the treatment of distant acupuncture points has maximal effect on the organ, ii) why for children the cure is faster, and iii) why some patients feel electric current is running from the treated acupuncture point in the direction of the acupuncture meridian.

The nonlinear mathematical model describing one acupuncture meridian, being nonlinear, has two types of solutions - electric pulse and electromagnetic wave. Based on this, *each acupuncture treatment is expected to generate electric impulse and electromagnetic wave. They will both run from the treated acupuncture point in the direction of the acupuncture meridian.*

The Chinese Prof. Zhu [1] already experimentally measured *electric pulses running from the treated acupuncture point in the direction of the acupuncture meridian*. This is also consistent with clinical observations - some patients do sense the electric pulse generated at the treated acupuncture point and propagating in the direction of the acupuncture meridian.

The Hungarian scientist Dr. A. Eory [2] confirmed the theoretically predicted by us waves. This was the first attempt to measure *traveling waves running from the treated acupuncture point in direction of the acupuncture meridian*. He found that waves do run in the direction of the acupuncture meridians all the time, but when an acupuncture point of the acupuncture meridian is treated with a needle, a wave is generated which modifies the constantly running wave.

However, more detailed measurements are necessary to determine the speeds of propagation of these waves. *The model predicts two types of traveling waves*, called slow and fast wave trains. Obviously, two types of waves (slow and fast) are generated at each acupuncture treatment. They propagate along the acupuncture meridian, where the conductivity is higher, and they propagate in the direction of the meridian determined by the DC potential gradient of the body at rest.

We shouldn't finish this article without emphasizing again the fact that if acupuncture works through waves, this means that the acupuncture works through the waves of our nonlinear electromagnetic field (NEMF), which is located in the

Ref

15. Kuman M, Modern Aspects of Ancient Acupuncture, Health and Happiness Books, 1997.

Notes

Subconscious. From the Subconscious, it rules and regulates the functioning of all the organs and everything else in the body and determines our physical and mental health.

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