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ELECTROPHYSIOLOGICAL CORRELATES OF ACUPUNCTURE POINTS AND MERIDIANS†

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Electrical correlates have been established for a portion of the acupuncture system and indicate that it does have an objective basis in reality. Thus far, the data are supportive to the theory of the action of the acupuncture technique as influencing a primitive data transmission and control system.

INTRODUCTION

The therapeutic technique of acupuncture has no known basis in fact; neither the points nor meridians have any neuroanatomical relationship and the simple insertion of a needle unaccompanied by any chemical agent appears to be of trivial significance. We reject the philosophical, vitalistic explanations of Yang and Yin, but have been unable to provide any adequate explanation based upon our current scientific knowledge. In this situation, logic dictates two conclusions: either acupuncture has no basis in biological fact and its effects can be ascribed solely to suggestion, or it is real, but it acts via a heretofore undescribed physiological mechanism.

For the past 15 years, our laboratory has been concerned with the factors that initiate and control healing mechanisms. During that time we have slowly accumulated evidence for the existence of such a previously unknown mechanism, until today we believe we can describe a complete control system functioning in concert with, but separate from the nervous system. This has proven to be a powerful theoretical tool that is applicable to many poorly understood biological phenomena including acupuncture.

At the outset of our studies, we applied two specific disciplines which may require some explanation: cybernetics or control system theory and solid state physics. The former arose as a distinct discipline from the application of early studies of computer technology on the way the human central nervous system functioned. For our purposes, only a few concepts are important:

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most, such as feedback control, are well known. One will require some explanation.

It is common in control systems for highly energetic processes (ones involving large power inputs or outputs) to be controlled by signals of low energy content. To apply this biologically, the healing of a major wound requires large amounts of metabolic energy expressed as cellular activity. Such healing, whether it is a highly competent process such as limb regeneration in a salamander, or the less competent scarification and epithelization in the human, is extremely well controlled. It is initiated only in response to injury, it is appropriate in morphology and extent to the injury and it ceases when repair is complete. While there was ample evidence that the central nervous system was involved in the healing process, it was also evident that its normal mode of functioning, the action potential, was not involved. We reasoned that a control signal had to be present, but of a more primitive type than the action potential. The action potential transmits data in a fashion comparable to a digital type computer and is capable of handling large volumes of data at high speed.

It is inconceivable that in the evolutionary process the earliest living things possessed a system of such sophistication. Yet it would be likewise inconceivable that they lacked a mechanism informing them when an injury had been incurred and controlling the subsequent necessary repair process. If we may draw an analogy from the development of computer technology, the analog computer antedated the digital type, transmitting data by the continuous passage of direct current with information contained in parameters such as polarity, magnitude or specific low frequency wave forms. Such a system is not capable of high speed, high capacity operation, but can function very precisely to control a few variables. In his analysis of the human central nervous system, John von Neuman (1958), one of the pioneers in cybernetics, concluded that such a system must be the basic substratum for the digital action potential system. We therefore postulated that direct current signals, such as the current of injury, may be the overt local expression of such a system, even though they are of small magnitude.

While direct current (DC) potentials had long been described and correlated with a variety of biological functions, notably by Burr and Northrup (1955), the explanations for the origin and distribution of the potentials verged on the vitalistic and were not acceptable to science. The only mechanisms for the production of potentials that were acceptable involved the well known membrane potential resulting from specific ionic distribution which could not produce organized potential patterns at the gross anatomical level. It appeared to us that the proposal of Szent-Györgyi (1960) that solid state mechanisms could play a role in living materials had merit as an alternative explanation for the generation and transmission of DC potentials. Solid state refers to specific electronic properties resulting from highly organized crystalline materials and includes such phenomena as semiconductivity, piezoelectricity, etc. In such processes, current is carried by electrons or "holes" (defects in the crystal lattice assumed to carry positive charge). While the current carriers have high mobility, the current capacity is low and such materials are limited to small currents. The highly organized state of cells and tissues revealed by electron microscopy appeared to make them fully capable of possessing such properties as semiconductivity.

Furthermore, since such organization is the "sine qua non" of life, it has been postulated that complex organized macromolecular assemblies were the original living materials (Hinton and Blum, 1965). Semiconductive properties would provide them with an inherent, analog type data transmission and control system for signaling injury and effecting repair. Such a system would have an additional property of interest. The high mobility of the charge carriers makes them particularly susceptible to external electrical and magnetic fields and changes in these fields will produce corresponding perturbations in the DC potentials in a semiconducting lattice. It has been reported that magnetic field reversals in the past were accompanied by major biological events (Hays and Updyke, 1967), and such a semiconduction system would provide an effective environmental linkage mechanism in this case.

Working within these concepts of semiconduction-based electronic analog control systems as biological regulators for healing mechanisms, we have been able to describe a primitive data transmission and control system, antedating and basic to the central nervous system. This system has been related to several physiological processes such as: the pattern of DC potentials exhibited by living organisms both grossly (Becker, 1960) and within the central nervous system (Becker, Bachman, and Slaughter, 1962), growth and healing processes of several types (Becker, 1963), and levels of consciousness such as hypnosis (Friedman, Becker, and Bachman, 1962) and anesthesia (Becker, 1962). It has been shown to have some of the characteristics of semiconductivity (Becker, 1961) and to be perturbable in a functionally important fashion by magnetic fields (Becker, 1966) and electrostatic fields (Becker, 1972). The prime function of the system is that of sensing injury and effecting repair and our latest data indicate that the DC electronic signals of the system are generated and distributed by the perineural cells (Becker, 1974).

While our evidence at present linking the perineural cells to the DC control system is limited to the Schwann cells and to the output or repair portion of the control system, the pervasive nature of the perineural cells and their structure as a continuous network involving the Schwann cells peripherally and the satellite and glia cells centrally enables us to postulate a complete analog system with peripheral transmission lines and central integrating areas. There is considerable data on the electrical activity of the glia cells that is substantive to this hypothesis (Tasaki and Chang, 1958).

While we have been primarily interested in the output or control portion of the control system loop with the intent of securing some positive control over growth processes (Becker and Spadaro, 1972), we have, over the past year, begun analysis of the input portion of the system, that which indicates that damage or injury has been received. Since classical neurophysiology has been unable to provide any coherent general theory to account for the sensation of pain which accompanies such injury, it would appear appropriate to postulate that the DC analog system is at least in part responsible for pain sensation and that it is that portion of the input system signalling injury that reaches the higher integrating center that we perceive as pain.

If, as we postulate, pain transmission is one of the functions of the DC electronic data transmission system in the perineural cells, then certain engineering principles must be applied. The transmission of DC signals via actual current flow over transmission lines is subject to cable constants. These are the factors of resistance, capacitance, and inductance which combine to reduce the signal magnitude with increasing transmission distance. In engineering practice, this is overcome by inserting into the line at intervals, operational or "booster" amplifiers to restore signal strength and maintain intelligibility over distance. Since our data indicate that the operational signal levels of the biological DC system are in the millivolt and nanoampere ranges, one can predict the need for structures functioning as operational amplifiers along the channels of DC transmission. This analysis leads one to consider the acupuncture meridians as DC communication channels and the points as sites of operational amplifier location. Considering the low signal levels employed by the system, it would seem quite reasonable to postulate a significant perturbation in either the signal itself or the system's signal transmission capability by the insertion of a metallic needle; particularly into the immediate vicinity of an operational amplifier. Further, the application of low levels of externally generated electricity, either DC or pulsed DC, would be correspondingly more effective.

Some electrical correlates of acupuncture points have been reported. Several authors have measured lower skin resistance over acupuncture points (Saita, 1973; Tiller, 1973), although most recently, this has been ascribed to pressure artifact from the measuring electrode (Noodergraaf and Silage, 1973). If we are correct, the points should show lower resistance and higher conductance than non-point areas of skin and both resistance and conductance factors should show an organised field pattern around the point. Furthermore, such data, if accurately collected without artifact, should be analyzable by statistical methods to determine its significance. Such data, if positive, would provide objective evidence for the existence of acupuncture points as real entities. More important, however, would be the DC electrical characteristics of the system. The points should be discrete sources of direct current. They may demonstrate a polarity indicative of the direction of signal transmission and when instrumented in series, the points should demonstrate propagation of a signal and permit measurement of such parameters as signal characteristics and transmission time.

This concept offers an opportunity to objectively assay the system of acupuncture meridians and points in a scientific fashion within the framework of a viable theory. Such analysis has been in progress for the past year and our results indicate that approximately half of the acupuncture points studied exist as real, measurable entities with electrical characteristics as predicted by our theory.

METHODS

Probes. A probe was designed to rapidly scan a 50 cm length of a meridian in a fashion obviating the pressure artifact. This probe was used for resistance and conductance measurements and details are shown in Figure 1.

FIGURE 1 Meridian scanning probe: the teflon body is constructed in two parts with a flexible joint between the two and a metal insert to furnish weight in the distal portion. The electrode proper is a stainless steel wheel on a stainless steel spindle with low friction between it and the teflon. This probe design permits constant pressure and no drag between the skin and the wheel contact.

A different probe was constructed for the measurement of the resistance/conductance field around points previously determined to be valid, real electrical entities. Measurements were made rapidly with a scanning switch from 36 stainless steel electrodes in a precise grid pattern. The conductance values at each point were transcribed to a corresponding graphic grid. The details are illustrated in Figure 2.

Measurement circuit. A Wheatstone bridge was used as a constant DC voltage source for continuous measurement of skin conductance (the reciprocal of skin resistance). The output of the circuit was a direct reading of skin conductance and was displayed on a strip chart recorder. For each scan along a section of a meridian, a continuous chart record of conductance was obtained. In the case of the conductance field pattern, the value of the conductance at each electrode was registered on the chart and later translated back into the original grid pattern of the electrodes. DC measurements were made with silver-silver chloride liquid junction electrodes as previously described (Becker and Murray, 1970) with the potential measured by a Keithley 602 electrometer, or with the probe head of the Monroe electrostatic voltmeter.

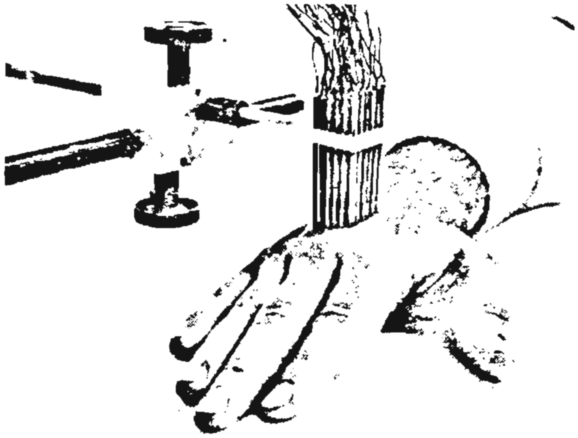

FIGURE 2 Multi-point probe for measurement of conductance field around acupuncture points. The points are located anatomically and verified by the meridian scanning probe. The center of the multi-point probe is lowered over the point and the conductance read off from each single electrode in rapid succession. Each electrode is of stainless steel and slides freely in a vertical direction in the teflon holder. Contact is made by the weight of each individual electrode.

Techniques. A total of seven volunteer subjects were used, three males and four females, ranging in age from 24 to 32 years. The acupuncture meridians and points on the forearm were located by reference to the standard charts (Mann, 1971) and by anatomical reference points. Those portions of the large intestine (Li) and pericardium (P) meridians which lay between the finger tips and the elbow were used. A line was drawn on the skin with a felt tip pen about 5 mm. away from and parallel to the meridian under study. The points were indicated along this line and numbered in accordance with the standard charts. The skin was cleansed with 70 per cent alcohol and slightly moistened with tap water before each determination to ensure uniform conductivity. A total of ten separate conductance scans were made of each meridian on each subject. In addition to the established meridians, a scan line was chosen of approximately the same length over an area devoid of meridian lines and acupuncture points.

A total of ten scans for each subject was taken over this line using identical techniques. These latter data were used as a control for the actual meridian evaluation. In each subject, the areas to be scanned were examined for cuts, abrasions and pigmented moles and such lesions were avoided. The conductance data obtained were statistically analyzed in a fashion designed to normalize individual variations in absolute magnitudes. The percent change in conductance, H, at an acupuncture point was defined as:

$$H = \left(\frac{C_{max} - C_{min}}{C_{min}}\right) \times 100\%$$

where C_{max} is the maximum conductance recorded at the point and C_{min} is the average of the conductances at the two adjacent minima. The mean H at each acupuncture point and the mean H for all peaks on the background non-meridian trace were computed for all subjects and trials and the statistical significance between H and $H_{background}$ was determined by a t-test for each point.

Using the same subjects, points previously determined to be valid by the conductance scan technique were evaluated for conductance field pattern using the multipoint probe. All valid points have not been done at this writing due to the time consuming nature of this technique and a computer program for this data analysis is now being set up.

DC measurements were made using both methods on selected valid points. An artifact of note was observed: major DC voltages can be recorded for several hours after conductance or resistance measurements have been made with point electrodes and voltages in excess of three volts. Presumably the DC voltages in this case arose from the current of injury due to the damage induced by the current passing through the small electrode. This artifact was avoided in our studies by using voltages lower than three volts and making conductance determinations as rapidly as possible.

RESULTS

Conductance scans. The raw data revealed by conductance scans were very suggestive of conductance maxima at many of the presumed acupuncture points. Marked individual differences in magnitude were observed betwen subjects, but repeated scans on individual subjects were highly reproducible (Figure 3). Generally, in all subjects, peaks were noted for points 2, 4, 5 and 7 on the Li meridian and 3, 4, 7 and 8 on the P meridian. The background trace over the non-meridian line was quite variable from individual to individual and did not show any consistent pattern.

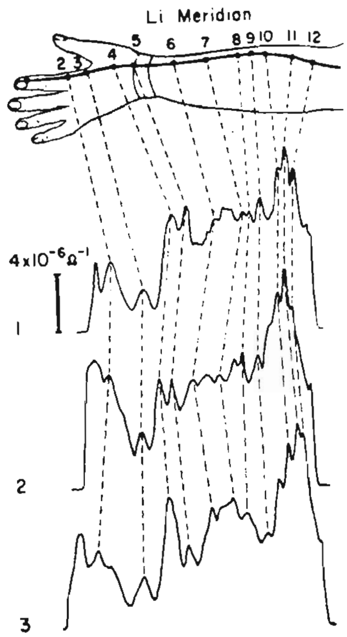

FIGURE 3 Three separate scans made by the meridian scanning probe in succession from the Li meridian of one subject. The meridian line and points are indicated and the dotted lines connect each point to corresponding areas on the scans. Note the reproducibility of the scan pattern. The length of each scan is slightly different due to differences in the speed with which the experimenter moves the probe.

Statistical analysis showed that points 2, 3, 4, 5, 7, 8, 9, 10, 11 and 12 on the Li meridian and points 3, 4, 7 and 8 on the P meridian had conductance maxima significant to the 0.05 level or better from the pooled data (Figure 4). However, as previously noted, all of these points were not found on all subjects. On an individual basis, points Li 2, 4, 5 and 7 and P 3, 4, 7 and 8 were found to be statistically significant in all subjects.

Conductance field plots. Complete conductance field plots for points Li 4 and T4 have been determined. Remarkably precise and extremely well organized field plots have been found in all instances. The plot shape was generally ovoid with

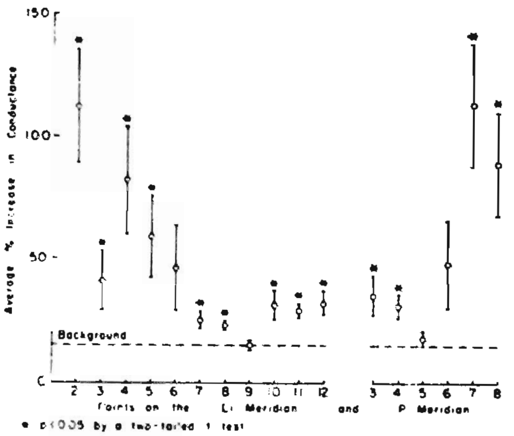

FIGURE 4 Chart of the data determined by meridian scan method from the Li and P meridian of seven subjects. Each subject was scanned ten times and the data pooled. Each point on both meridians is indicated with means and extremes of measurement. Non-meridian scans were made on each subject, also ten times and the data pooled. The average of this non-meridian scan is indicated as the background line. The acupuncture points marked with an asterisk demonstrate overall statistical significance compared to the non-meridian scan.

the long axis roughly parallel to the meridian line (Figure 5). Where the meridian line changed direction, such as at point T4, the field plot showed a definite lobe along the changed meridian line (Figure 6).

DC potentials. As expected, determinations of the DC potentials of acupuncture points were the most difficult of all the measurements made. The electrostatic voltmeter, while theoretically an ideal tool for such determinations, was found to be unsuitable in actual practice. Reproducible results could not be obtained due to difficulties with maintaining a constant probe to skin surface distance and to artifacts produced by hairs entering the sensing part of the probe head.

The standard liquid junction silver-silver chloride electrodes were found to be usable and yielded reproducible but low voltage data. Several points on both the Li and P have been studied. Readings taken at centimeter intervals along the meridian and at right angles to it at point positions have shown that compared to its immediate surroundings, the point demonstrates a localized positive shift in potential. The magnitude of this shift

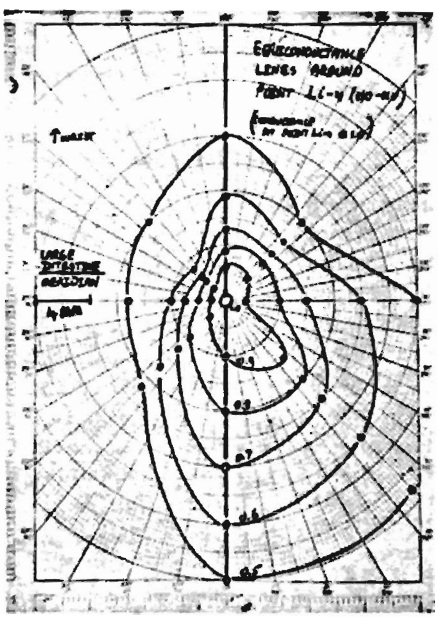

FIGURE 5 Conductance field plot around point Li4. The plot is overall ovoid in shape with the long axis along the Li meridian. The lines of equal conductance are concentric about the point itself and complete without crossings. The overall organization suggests the presence of some discrete structure at the center of the plot with specific conductance properties

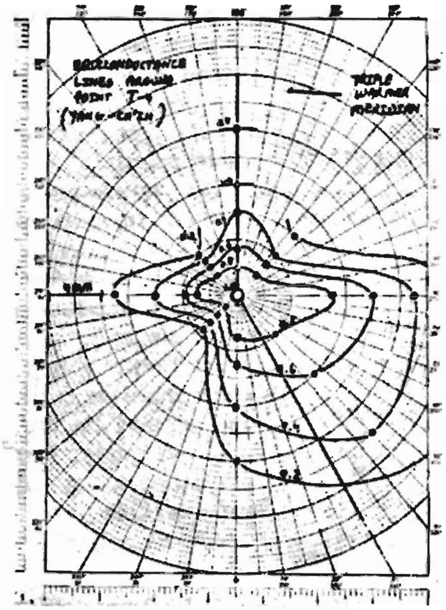

FIGURE 6 Conductance field plot around point T4. At this point the T meridian is purported to change direction by approximately 30°. The plot demonstrates the expected skew in the changed direction, although it would indicate a deviation of almost 45° off of the original axis. The significance of the small lobe extending to the left on the plot is not presently known.

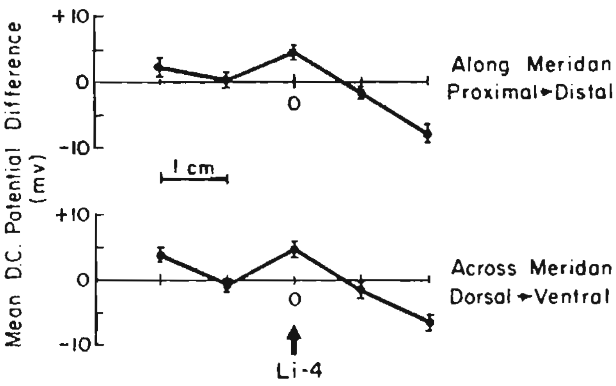

FIGURE 7 Direct current potentials measured along the meridian (top trace) and at right angles to the meridian (bottom trace) at point Li4. The point itself is significantly more positive than the remainder of the trace.

averages about 5 mV compared to regions 1 and 2 cm. away from the point (Figure 7). There also appeared to be an overall proximo-distal negative gradient along meridian lines. This was not unexpected in view of our previous measurements of the gross pattern of skin potentials on the human (Becker, Bachman, and Friedman, 1962). In addition, there appears to be a dorsi-ventral negative gradient on the extremities, although confirmation of this will require measurement of several more meridian lines. A short period cyclic fluctuation in total overall DC potentials at and in the immediate vicinity of acupuncture points was noted. The cycle time averaged 15 minutes and while previous determinations on the gross DC potentials had demonstrated typical circadian rates of fluctuation, such short period cycles were not noted until measurements were made directly over acupuncture points in this study. The DC data gathered so far must be viewed as preliminary in nature and studies are ongoing on both the spatial and temporal fluctuations of the DC potentials associated with the acupuncture meridians and points.

DISCUSSION

It appears entirely reasonable to conclude that portions of the system of acupuncture meridians and points have an objective basis in reality. Approximately 50 percent of the points on those portions of the Li and P meridians measured demonstrated statistically significant conductance maxima when compared to non-meridian portions of the skin. Furthermore, the field plots of the equi-conductance lines around the valid points measured can only be interpreted to indicate that a discrete structure with highly specific electrical properties exists, superficially located at or near to the center of the field plot and coinciding with the classical acupuncture point.

The failure to find rigorous statistical proof for all of the points is probably the result of the empirical nature of acupuncture with some of the designated points spurious in reality. Alternatively, it may be that these points do actually exist, but have less well defined electrical properties.

While conductance measurements may be used in this fashion to determine the existence of some electrical entity co-extant with the acupuncture meridians and points, they do not indicate the functional capabilities of the latter. It is encouraging that our preliminary survey of the DC potentials of the acupuncture points is compatible with our thesis. Much further work remains to be done on the electrical correlates of acupuncture and the DC potentials would seem to be a fruitful area to pursue.

CONCLUSIONS

Electrical correlates have been established for a portion of the acupuncture system and indicate that it does have an objective basis in reality. Thus far, the data are supportive to our general theory of the action of the acupuncture technique as influencing a primitive data transmission and control system.

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