What Do Electrodermal Diagnostic Acupuncture Instruments Really Measure

William A. Tiller
Professor, Department of Materials Science and Engineering
Stanford University
Stanford, California 94305-2205

Abstract: What do electrodermal diagnostic acupuncture instruments really measure? How do they differ from one another? Can one really expect to make experiments on the skin and say something meaningful about the condition of specific internal organs? Is there any evidence that such measurements do provide an early warning system of body pathology? The purpose of this paper is to provide some answers to these questions by relating some of the history of large electrode studies, followed by a brief discussion of the Schimmel commercial device that utilizes some of this basic information and, 2) relating some of the history of the small electrode studies on acupuncture points which led to the Nakatani, Voll and Motoyama commercial devices. This is followed by a brief discussion of some experimental data and theoretical speculation concerning possible connections between specific skin points and specific internal organs. Finally, one example of early detection of cancer using the Nakatani device is identified.

IT IS WELL KNOWN that the costs of U.S. health services currently amount to approximately one billion dollars per day. We also know that U.S. medical care costs have risen from 5 percent of the Gross National Product (GNP) in 1960 to 10.5 percent in 1984 and are still rising. Because of this, many feel that fundamental reform of the U.S. Health Care System is long overdue and that immediate action on this issue must become a national priority.

At this time, electrodermal diagnostic and treatment instruments appear to hold significant promise for lowering health care costs by providing a faster and cheaper method of diagnosis with an earlier warning system of impending problems before they fully manifest at the chemical level.[1] Although this cannot be fully evaluated at this time, a number of important ancillary questions can be raised and answered: (1) What do these devices really measure? (2) How do they differ from one another? (3) Can one really expect to make experiments on the skin and say something meaningful about the condition of specific internal organs? (4) Is there any evidence that such measurements do provide an early warning system of body pathology?

The purpose of the present paper is to provide partial answers to these questions by (i) relating some of the history of large electrode studies followed by a brief discussion of the Schimmel commercial device that utilizes some of this basic information and, (ii) relating some history of the small electrode studies on acupuncture points which led to the Nakatani, Voll and Motoyama commercial devices. This will be followed by a brief discussion of some experimental data and theoretical speculation concerning possible connections between specific skin points and specific internal organs. Finally, one example of early detection of cancer using the Nakatani device will be identified.[2]

Large Electrode Studies

The electrodermal studies of the early decades of this century involved the use of a very large indifferent electrode ($\sim 10^2$ cm^2) and a large ($\sim$ 1-2 cm^2) movable electrode placed at different locations of the skin while a voltage was applied between them. The studies led to the invention of the EEG, ECG and EMG and, by the late 1930's, the conventionally accepted schematic picture of the skin was that shown in Fig. 1; i.e., a three-layer structure of dermis (lowest resistivity, highest fluidity), epidermis (medium resistivity and fluidity) and stratum corneum (highest resistivity, lowest fluidity). The electrical equivalent circuit of the skin was thought to be that of Fig. 2 with constant parameters R_1 (dermis) and R_2,C (epidermis plus stratum corneum). It was well known that the application of a small D.C. voltage to such a circuit leads to the transient current decay shown in Fig. 3 with a time constant $\sim$ 10-100 seconds.

In the early 1940's, Rosendahl[3,4] published three important findings: (1) using a D.C. voltage < 2 volts, a polarity effect such as shown in Fig. 4 was observed in the skin resistance. This was recently postulated to be due to to ion transport through selectively permeable membranes[5] (cation permeable) wherein the skin membranes pass positive ions more easily than they pass negative ions. Thus, a positive potential applied to the skin would cause + ions to leave the stratum corneum and epidermis for the dermis so the skin resistance should increase with time. A negative applied potential should lead to the reverse condition. (2) Electrolyte moistening of the skin for $\sim$ 30 minutes led to a lowering of the skin resistance by about an order of magnitude. We expect such a phenomenon to occur as a result of the diffusion of + ions from the surface fluid into the stratum corneum. (3) After (2), the application of a D.C. voltage > 2 volts led to a further decrease of the skin resistance by about an order of magnitude. This occurs because of the dissociation of H_2O in the stratum corneum and epidermis into $H^+ + OH^-$ ions[3,4] which leads to an enhanced ion content and thus an enhanced conductivity.

In subsequent years, many others refined the picture further.[5] In the mid 1970's, Nagel and Tiller performed a frequency-dependent study of skin resistance, plotting the real and imaginary mathematical parts of the skin impedance (Cole-Cole plots), and realized that the electrical equivalent circuit of the skin was not like that shown in Fig. 2 but was like that shown in Fig. 5.[5] The skin exhibits a low frequency (time constant $\sim$ 10-100 secs.) and a high frequency (time constant $\sim$ 1-10 μsec.) circuit in series. Further, the circuit parameters are not completely constant but contain diffusional admittances Z_I and Z_{II} that are time dependent. Kume and Ohzu,[7] using bipolar pulses in a pain study, observed the high frequency circuit component with a time constant $\sim$ 5 μsec., as illustrated in Fig. 6.

In the Schimmel segment electrograph device,[5] the electrode arrangement shown in Fig. 7 indicates that the total resistance measured will be the sum of that for an anodic plus a cathodic current. Because, of the permselectivity, the anodic current effect will dominate and the sum of the two resistance values will increase with time. Using the bipolar voltage pulse indicated in Fig. 8, the response current was measured for the three possible cases—(a) normal body function, (b) subnormal body function and (c) hyper body function (see Fig. 9). The useful information here is in (i) the average amplitude of the current pulse which is inversely proportional to the sum of the two skin resistance values and (ii) the decay slope of the current curve which depends on both the degree of permselectivity of the cell membranes in the skin and the skin conductivity (inverse of resistance).[5] At this point the connection between these skin measurements and the functioning of internal organs is not obvious.

Small Electrode Studies

In this section, we are concerned with electrodes $\sim$ 1-2 mm in area. In 1950 Nakatani,[6] using a 12 volt D.C. voltage source, detected a number of high conductance points and lines on the skin. He called these lines "Ryodoraku" and his measuring device a "neurometer." He noted the remarkable posi-

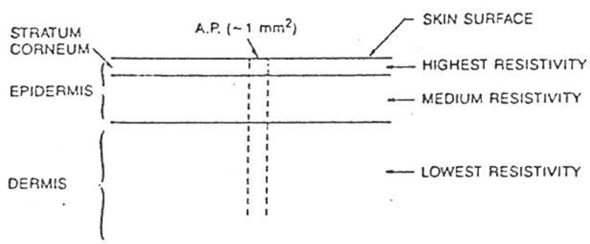

Fig. 1.

Schematic illustration of skin structure in cross-section.

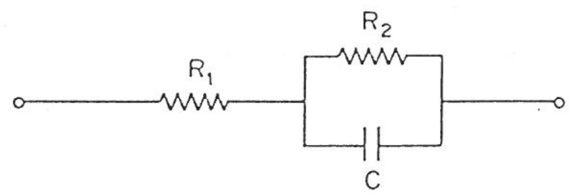

Fig. 2.

The simplest frequency-independent electrical equivalent circuit for the skin.

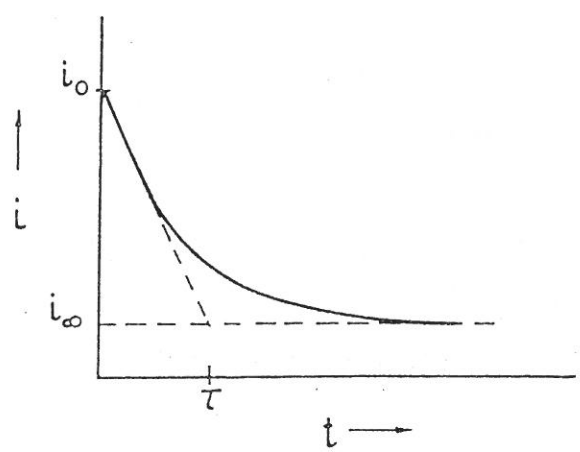

Fig. 3.

Current waveform arising from the application of a constant D.C. voltage to the circuit of Fig. 2.

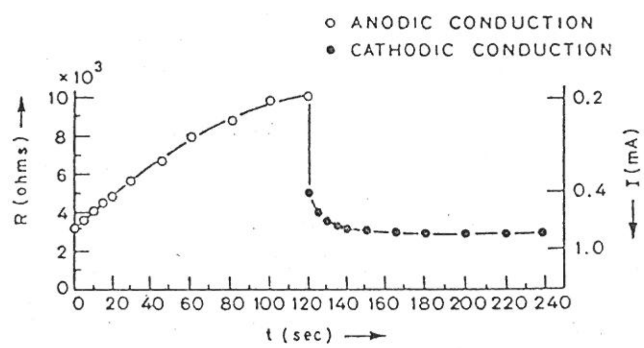

Fig. 4.

Time dependence of the electrical resistance, R, of the skin for a 2-volt applied D.C. potential (7 cm^2 of skin moistened for 20 min. with saturated KCl solution. (Courtesy of T. Rosendal).

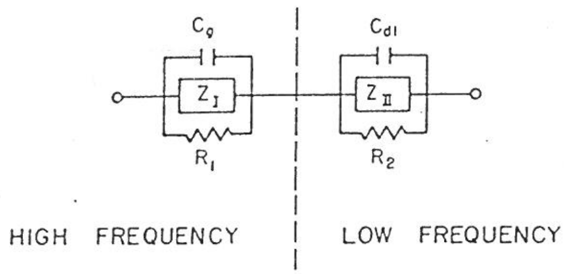

Fig. 5.
Electrical equivalent circuit generated from skin measurements using D.C. conductance techniques and complex plane analysis.

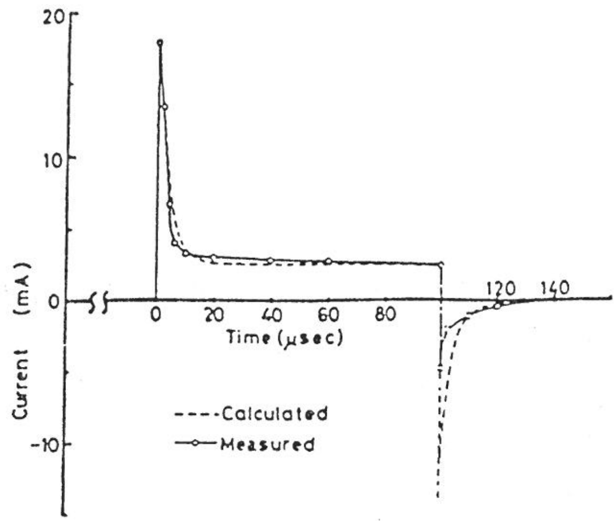

Fig. 6.
Stimulus current corresponding to a constant voltage pulse applied to the skin through a concentric electrode.

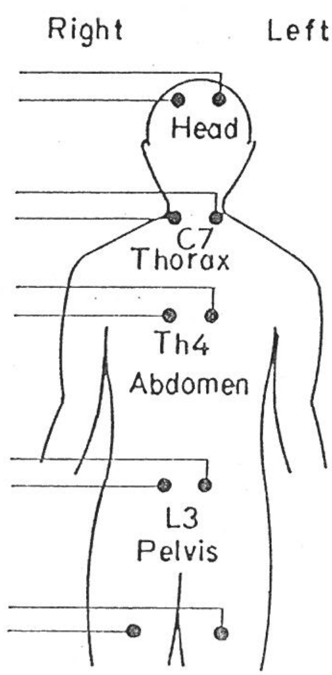

Fig. 7.
Body placement of electrodes in the Segment Electrograph. technique.

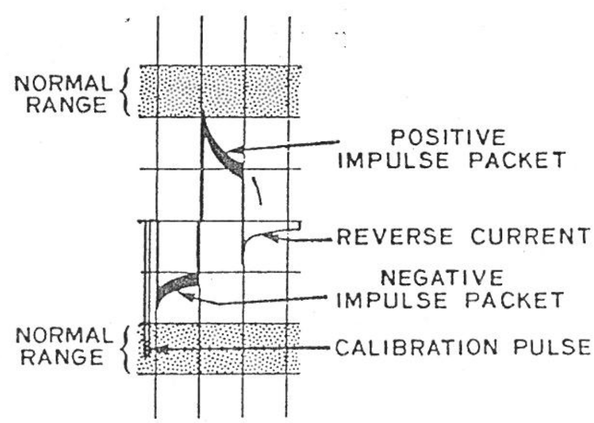

Fig. 8.
Illustration of bipolar electrical pulse cycle.

tion correspondence between these points and the acupuncture points on the classical charts. He used a bilateral measurement (left and right sides of the body with the same type point) and indentified the degree of pathology with the difference in the current flow between the left and right points.[5] Since his voltage was greater than 2 volts, most of this current was generated by the electrolytic dissociation phenomenon mentioned earlier. Thus, the operating principle of his device is probably based on the relative ease of electrolytic dissociation on the two sides of the body.

Many other people verified and substantiated the Nakatani findings,[6] among them Becker and his associates who also showed that the skin electrical potential was more positive at acupuncture points than for the surrounding tissue.[8] This is exactly what one would expect if the conductivity is higher at the acupuncture points than for the surrounding tissue. Diffusion of positive ions from the stratum corneum tissue to the surface will be greater for the acupuncture point regions than for the surrounding regions because the ion content is greater at the acupuncture points.

The Voll Dermatron commercial instrument utilizes a large hand-held electrode and a small moving electrode, as illustrated in Fig. 10, with a positive voltage of less than 2 volts magnitude and operates in the low frequency domain.[5] The meter registers both the skin conductivity value (initial maximum reading) and some information on the permselectivity value of the membranes via the "indicator drop," which is the reduction of the meter reading with time. This, of course, is just the anodic current polarization effect shown in Fig. 4. With exactly the same degree of membrane permselectivity, we expect that a low skin conductivity (high skin resistance) will give rise to a slow indicator drop because either the ion content is low or the ion mobility is low, while a high skin conductivity will give rise to a fast indicator drop for the same reason.[5]

The Motoyama AMI commercial instrument[5] utilizes multiple fixed electrodes rather than the moving electrode technique. The 28 acupuncture point electrodes are placed at the ends of the meridians on the hands and feet, as illustrated in Fig. 11. This technique samples the high frequency domain of information space and measures the four parameters, BP, AP, TC and IQ defined in Fig. 12.[6] Motoyama conducted various experiments to show that the origin of the skin polarization in this short time domain was at the basal membrane illustrated in Fig. 13. The relevant conductivities involved are for the dermis and epidermis rather than for the stratum corneum, while the capacitance is associated with charge storage across the basal membrane interface.

The simplest combination of a high frequency and a low frequency process in skin would be a constant parameter circuit like that shown in Fig. 14. The application of a constant voltage to such a circuit would lead to an overall current flow picture such as illustrated in Fig. 15. Of course, in real skin, the time-varying parameter effect, such as illustrated by Fig. 5, is needed to accurately portray the response current behavior. However, the functioning of the simpler circuit of Fig. 14 is easier to comprehend. There, the initial current (BP) is due to ion flow in the dermis until charging of the basal membrane has reduced it to AP which is just the initial current for the low frequency circuit that drops further via slow charging due to ion transport through the stratum corneum.

Comparing the moving electrode technique with the fixed multiple electrode technique introduces a new factor for consideration. This is the human interaction factor involvement in the measurement. With the moving electrode system, the operator unconsciously (or consciously) interacts with the measurement of an acupuncture point (via the electrode/skin contact angle or contact pressure, etc.). This effect is much reduced in the fixed, multiple electrode technique, although even that method may not be completely free of subjective influences. This is to be expected as we develop instruments for detecting more and more subtle body energies; i.e., the results will be less and less objective unless special pains are taken to refine the design of the experiment. Such experiments will be more easily influenced mentally by the patient, doctor or outside source.

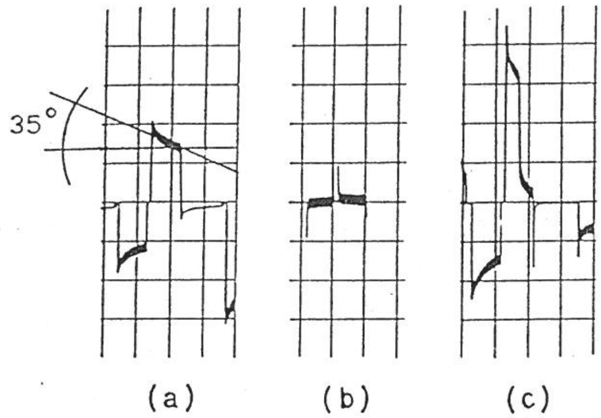

Fig. 9.

Illustration of the general types of current trace resulting from the stimulation voltage wave: (a) normal body function, (b) sub-normal body function and (c) hyper body function.

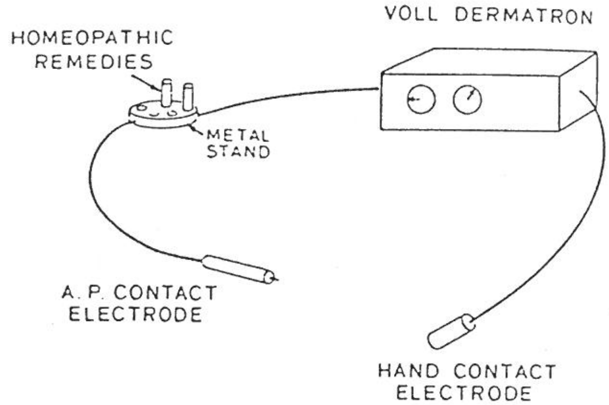

Fig. 10.

Schematic illustration of the Voll Dermatron with electrodes.

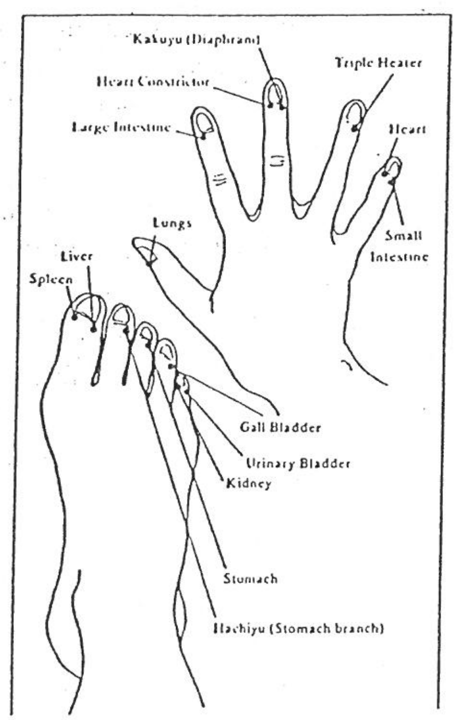

Fig. 11.

Multiple electrode arrangement in the Motoyama technique.

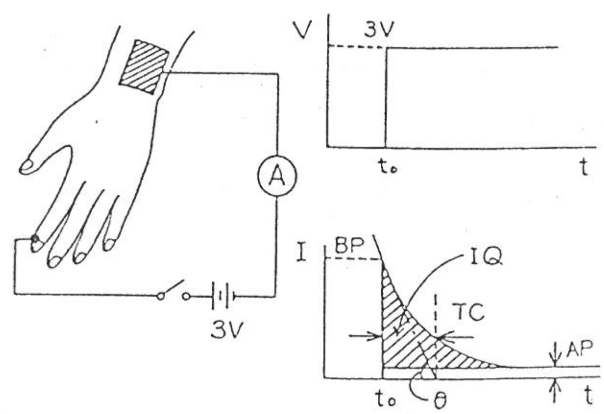

Fig. 12.

Response current waveform for a single measurement in the Motoyama multiple electrode technique.

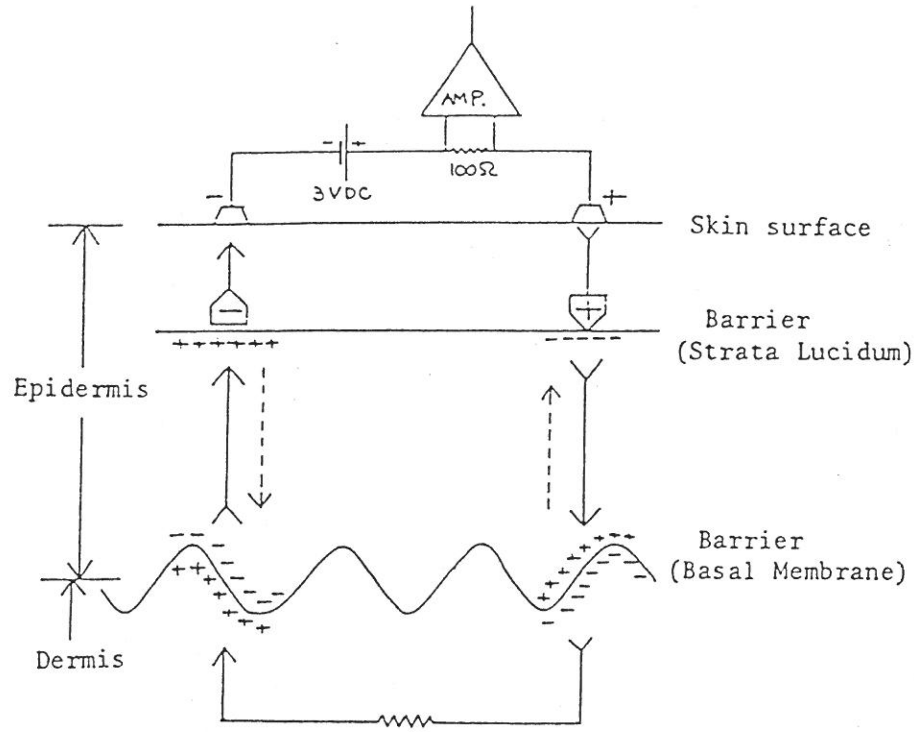

Fig. 13.
Generalized diagram of the ionic accumulations at the basal membrane during the short time measurements.

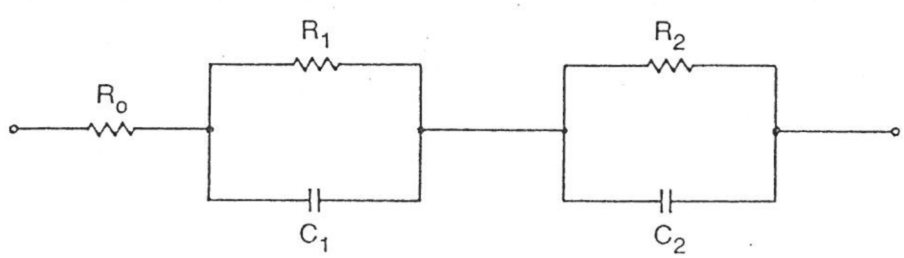

Fig. 14.
Simplest electrical equivalent circuit with frequency independent paramaters exhibiting both high frequency and low frequency behavior.

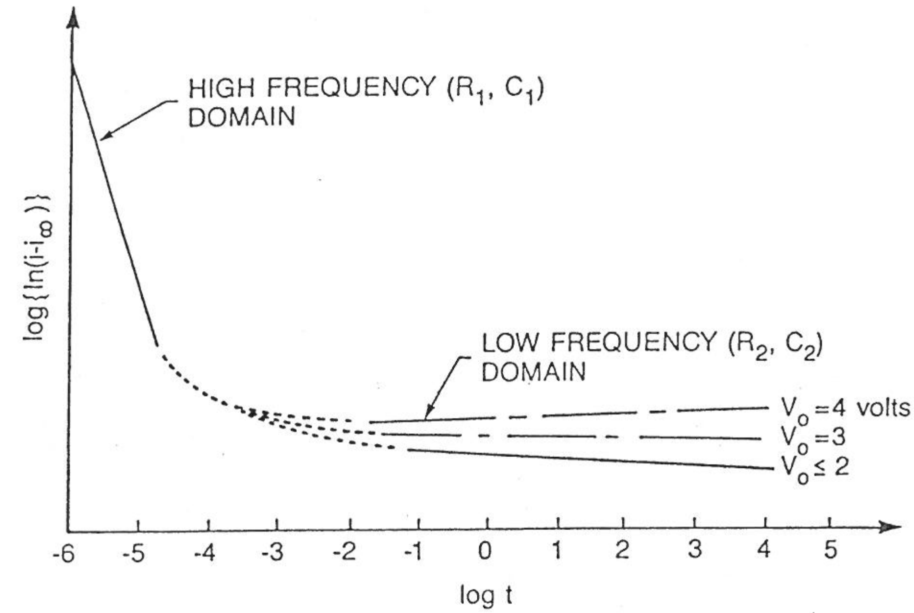

Fig. 15.
Schematic representation of the current response when a constant voltage is applied to the circuit of Fig. 14.

Skin/Inner Organ Linkage

Rosenblatt[9] investigated the linkage between the heart and specific heart acupuncture points using a biofeedback technique. He found that a significant correlation ($p = 0.01$) occurred between heart rate and the conductivity of special points:[6] as the heart rate was increased or decreased (via biofeedback), the conductivity of the special acupuncture points also increased or decreased, respectively, while the conductivity of acupuncture points not on the heart meridian remained constant and the conductivity of normal skin near the special acupuncture points remained constant. Conversely, as the conductivity of the special acupuncture points was increased or decreased (via biofeedback), the heart rate was observed to increase or decrease, respectively.

From a theoretical modeling basis, one expects that cooperative cellular oscillations in an organ will lead to the generation of electromagnetic radiation in a broad frequency band from above the infrared to the KHz range. If meridians are indeed present as a type of conductance channel in the body, then electromagnetic radiation waves of the appropriate wavelength from this generated organ spectrum will be guided away from the organ en virons and out to the skin through specific acupuncture points. Because the dimension of the meridian channel is expected to be a fraction of a millimeter, the guided electromagnetic radiation waves will be in the microwave portion of the spectrum. Such a guided microwave beam will have an added value in the modeling because it is expected to enhance the ionization of the bound water states at the membrane surface of the stratum corneum. It is just such an ionizing process that we need to cause the acupuncture point to be of higher conductance than the surrounding tissue.[5,6]

Early Warning Cancer Detection

Kobayashi[2] used a Nakatani neurometer and found simultaneous abnormalities in the bilateral readings of six specific meridians identified as the "signature of cancer." These were the pericardium, heart, triple heater, spleen-pancreas, kidney and gall bladder meridians. He divides cancer into seven stages b: weight: cancer-free, microgram (μ), small milligram (M_1), large milligram (M_2) and gram level or clinical cancer (early gram, G_1, median gram, G_2, and terminal gram, G_3). He observed a statistically significant difference between the μ-gram cancer and the non-cancer groups ($p < 0.001$). He also found a significant difference between M_1-level cancer and the non-cancer group ($p < 0.1$). In general, he found his electrodermal technique to be an effective early warning system for cancer detection.

Conclusions

1. There are several effective electrodermal techniques in use and we understand both how they work and what they actually measure.
2. There does appear to be some experimental support and a possible theoretical model for connectivity between the organs and their specific acupuncture points.
3. There does appear to be important differences between the moving electrode modality of skin measurement and the fixed, multiple electrode modality of skin measurement.
4. We are just at the beginning of this technology and it is likely that new devices in this area will appear during the next decade and be orders of magnitude more precise and effective than those reported on here.
5. It does seem possible that such electrodermal acupuncture devices can significantly reduce health care costs.

References

1. Tiller, W.A.: Toward a Future Medicine Based on Controlled Energy Fields. *Phoenix*, 1 (1), 5-16, 1977.
2. Kobayashi, T.: Early Diagnosis of Microcancer by Cancer Check of Related Acupuncture Meridian. *Amer. J. Acupuncture*, 13, 63-68, 1985.
3. Rosendal, T.: Studies on the Conductivity Properties of Human Skin to Direct Current. *Acta Physiol. Scand.*, 5, 130-151, 1943.
4. Rosendal, T.: Further Studies on the Conducting Properties of Human Skin to Direct and Alternating Current. *Acta Physiol. Scand.*, 8, 183-202, 1944; and 9, 39-49, 1945.
5. Tiller, W.A.: Explanation of Electrodermal Diagnostic and Treatment Instruments, Part I: The Electrical Behavior of Human Skin. *J. Holistic Medicine*, 4 (2), 105-127, 1982.
6. Tiller, W.A.: On the Evolution of Electrodermal Diagnostic Treatment Instruments (to be published).
7. Kume, Y., Ohzu, H.: Electrocutaneous Stimulation for Information Transmission, I: Optimum Waveform Eliciting Stable Sensation Without Discomfort. *Acup. & Electrother. Res. Int'l J.*, 5, 57-81, 1980.
8. Becker, R., Reichmanis, M., Marino, A.: Electrophysiological Correlates of Acupuncture Points and Meridians. *Psychoenergetic Systems*, 1, 105, 1976.
9. Rosenblatt, S.L.: The Electrodermal Characteristics of Acupuncture Points. *Amer. J. Acupuncture*, 10, 131-137, 1982.

Acupuncture in Medicine

May 1998

A Statistical Comparison of Repeatability in Three Commonly Used Bioelectronic Devices:

- Kirlian Photography
- the Segmental Electrogram
- and the AMI of Motoyama

Julian Jessel-Kenyon MD
Lucia Pfeiffer MD
Martin Brenton

This paper is based on a presentation at the 4th Annual Conference of the International Society for the Study of Subtle Energy and Energy Medicine held in June 1994 at Boulder, Colorado, USA

Summary

This paper describes the results of measurements made on 30 patients, tested at the same time of day on consecutive days, with each of three commonly used bioelectronic diagnostic devices. The repeatability of these measurements was compared statistically using a method known as the coefficient of variation. The most repeatable technique was the AMI of Motoyama. Kirlian photography and the segmental electrogram showed widely varying results, which casts doubt upon their validity as bioelectronic investigational devices.

Key words

AMI of Motoyama, Bioelectronic devices, Kirlian photography, Repeatability, Segmental electrogram.

Address for correspondence:
Dr Julian Jessel-Kenyon
The Centre for the Study of
Complementary Medicine

51 Bedford Place,
Southampton, SO15 2DT, U.K.

Acupuncture in Medicine is the Journal
of the British Medical Acupuncture Society

Return to the
The Contents Page

Search the Web Site

You may purchase single copies of back numbers of the Journal, or take out a subscription.
BMAS, 12 Marbury House, Higher Whitley, Warrington, WA4 4JA
Tel 01925 730727 Fax 01925 730492
E-mail: Admin@medical-acupuncture.org.uk