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In vivo dc and ac measurements at acupuncture points in healthy and unhealthy people

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Summary
Objectives: The aim of this work was to compare in vivo measurements of direct current (dc) and alternating current (ac) obtained from acupuncture points in Ukrainian and Mexican residents.
Methods: Measurements were made using the method of Voll. The participants were 43 healthy Ukrainian and 71 healthy Mexican residents aged between 20 and 30 years, as well as 24 Mexican patients with a clinical diagnosis of rheumatoid arthritis and 14 patients with a clinical diagnosis of allergy.
Results: The results showed that dc measurements are not directly applicable to different populations. Thus, the dc resistance of the acupuncture points in the Mexican participants was 4—5 times larger than in the Ukrainians. In contrast, the capacitance of the two groups did not differ by more than 25%.
Conclusions: Impedance measurements from acupuncture points can be used as an efficient and prompt non-invasive method for diagnostic purposes.

Introduction

Electrical resistance at acupuncture points (APs) is normally smaller than that of the surrounding skin. Based on this, a few methods have been proposed to measure the direct current (dc) electrical resistance of the APs for diagnostic purposes.[1—3] Amongst these methods, one of the most popular is that developed by Voll,[1,2] in which it is suggested that the dc resistance of the APs reflects the condition of the associated organs or systems, and could thus be used to diagnose and monitor a patient's health. This method is known as electroacupuncture by Voll (EAV). In several countries (Germany, USA, Russia, for example), devices for measuring

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the dc resistance of the APs for diagnostic purposes are commercially available.

In devices that operate based on Voll's method, the resistance read-out is in relative units on a scale of 0—100; this scale can be converted into resistance using the calibration curves for the device (correlation between relative units and the values for dc resistance). According to Voll's calibration, readings from 50 to 65 (or resistance between 53 and 95 kΩ) are normal; readings above 65 (or resistance less than 53 kΩ) indicate inflammation, and readings below 50 (or higher than 95 kΩ) indicate degeneration in the organs associated with the measured point.[4,5] Voll's method proposes that the results of measurement do not depend on age, sex or colour of skin, and that it can be directly applicable to different populations. But it is well known from the literature (see for example 6—9) that total and segmental impedance measurements of the human body (as a rule such measurements are taken at relatively high frequency of 50 or 100 kHz with electrodes placed on the wrist and ankle or another part of the body) differ in different ethnic populations. The values for impedance depend on many factors, such as age, environment, race, differences in body build among ethnic groups and body water distribution.[6—11] So, it is likely that the same difference will be observed in dc and low-frequency measurements from the APs in different ethnic groups.

The electrical characteristics of the APs have also been extensively studied using alternating current (ac) impedance measurements.[12—17] These publications report that the capacitance of the APs is larger and the resistance smaller than that of the surrounding skin. But these studies have investigated the electrical properties of APs in healthy people, and according to Voll's methodology these properties depend on the condition of the specific internal organs they are connected to. For that reason, one would expect that the impedance measurements of the APs must depend on the condition of the internal organs they are connected to as well.

On reviewing the literature available to us, we have concluded that the electrical properties of the APs have not been sufficiently studied to understand, for instance, the influence of a person's place of residence and of illness. Moreover, any comparison of results obtained using dc and ac measurements is difficult because in all the investigations the measurements have been carried out using different techniques and different measuring conditions, such as frequencies, materials and geometry of contacts.

The aim of this work was to compare in vivo dc and ac impedance measurements obtained in APs connected with healthy organs in Ukrainian and Mexican residents. We also studied the electrical characteristics of the APs connected with unhealthy organs in Mexican residents as well as the skin around these points.

Methods

The general method of measurements described by Voll, as well as his system of APs[1,2,5] constitutes the basis of our study. All measurements (dc and ac) were carried out at room temperature (20—25 °C) using two brass electrodes. One of them is a cylinder with a diameter of 30 mm, which the patient holds in one hand; the second, the active point electrode, with a diameter of 3 mm, is placed on the AP or on the skin (at a distance of 5—10 mm from the AP)[14] with approximately the same pressing force of about 3 N (for this purpose a spring-loaded active electrode was made, which allowed control of the pressing force). Before the measurements, the skin was wiped with ethanol to prevent sweat influencing the results. To improve electrical contact, the point electrode was wetted with bi-distilled water. So, the only difference between Voll's method (see for example1,2,4,5) and ours was the use of a spring in the active electrode, which allowed us to obtain reproducible results.[14]

We must emphasize that in the present investigation we used the standard Voll's method and not the classical skin bioimpedance measurements in which special electrodes are used to decrease polarization effects. Moreover, it has been reported that the values for skin conductance strongly depend on the electrode materials used.[17] For that reason, we used brass electrodes and the same type of Voll's device to examine both the Ukrainian and the Mexican residents.

One set of dc measurements was made, using a commercially available Voll's device (Mini Expert; Imedis Ltd.) and two brass electrodes, on seven control measuring points[1] located in the fingers [on the meridians (see Fig. 1): large intestine (point 1), nerval degeneration vessel (point 2), circulation (point 3), allergy degeneration vessel (point 4), triple warmer (point 5), organ degeneration vessel (point 6) and small intestine (point 7)]. The calibration curves (correlation between relative units and the values for dc resistance) of the two Mini Expert devices used in the range of 35—100 relative units for measurements in Ukraine and Mexico were very similar, and they differed by no more than a few percent from those obtained using the K + F-Diatherapunteur device produced in Germany (this device is the basis for all EAV instruments[3]).

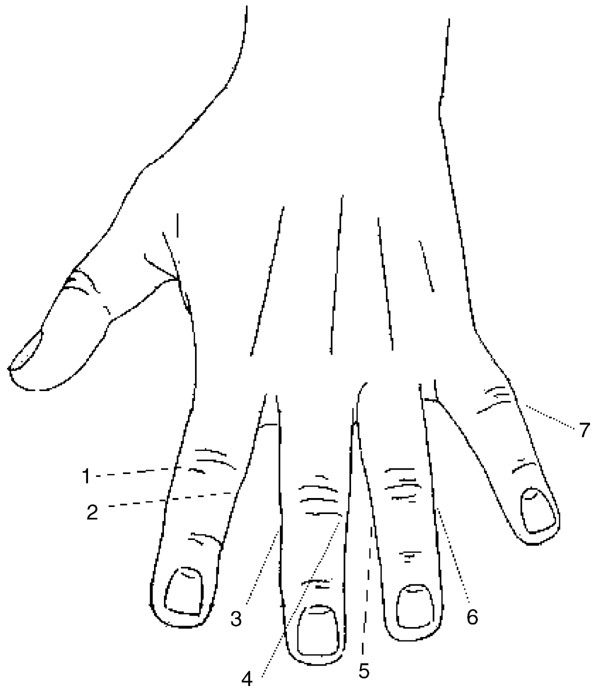

Figure 1 Position of acupuncture points measured in healthy persons.

However, in the range from 0 to 30 relative units, the difference in readings between the Mini Expert and the K + F-Diatherapunteur is up to 30%, which is why we considered only the results from healthy Ukrainian and Mexican participants with readings above 35 relative units.

Another set of measurements (ac capacitance and ac resistance at a fixed frequency of 180 Hz) was carried out at the same APs using a phasemeter in Ukraine and an impedance analyser in Mexico, with a signal amplitude of 100 mV in both cases. This frequency was chosen because the difference between the impedance of the APs and surrounding skin is large enough to allow an optimal signal-to-noise ratio.[14,15] Before any measurement, both devices were tested with standard resistors and capacitors in parallel; the readings at 180 Hz did not differ by more than 1—1.5%.

The dc and ac (at a fixed frequency of 180 Hz) measurements were carried out on 43 healthy Ukrainians aged between 20 and 30 years (mean age 27.4 years; S.D. 4.8 years) and on 71 healthy Mexicans in the same age range (mean 26.2 years; S.D. 3 years), using the same electrodes. We used groups of participants of approximately the same age because it has been reported[11] that impedance measurements from the human body at frequencies of 50 kHz depend on age.

The third set of ac impedance measurements on the APs and surrounding human skin, in a group of Mexicans with specific diseases, was carried out with a Schlumberger Technologies 1260 impedance gain-phase analyser in the frequency range of 3 Hz to 1 MHz (with an amplitude of 100 mV) and the same brass electrodes. These measurements were made on patients with the following clinical diagnoses:

- 24 patients with rheumatoid arthritis (confirmed by blood tests); measurements were done on the APs located at the meridian of the articular degeneration vessel, which according to Voll's methodology is connected with this disease;
- 14 patients with allergy (confirmed by standard allergy tests); measurements were done on the APs located at the meridian of the allergy degeneration vessel.

In order to compare the electrical characteristics of the APs connected with the pathological internal organs, we made additional measurements on another APs connected with healthy organs on the same participant. Also, dc measurements were carried out using the commercially available Voll's device on the same points.

Results

Measurements on healthy persons

The results for dc measurements using the Voll's device and ac measurements at a fixed frequency of 180 Hz on healthy Ukrainians and Mexicans are shown in Table 1. dc and ac resistance in the low-frequency range for the two populations differed by about four to five times, while the low-frequency capacitance only differed by approximately 25%. One of the hypothetical explanations for such large differences in dc resistance between the two populations is the difference in skin colour. Impedance tends to be much higher for darker skin,[18] perhaps because the stratum corneum is denser and has more cell layers.[19] To check this hypothesis we made additional impedance measurements in three groups of Mexicans with different skin coloration. Fig. 2 shows the mean values for the real (Z') and imaginary (Z'') parts of impedance as a function of frequency for 15 people with white, 38 with dark, and 18 with very dark skin. The results show that with the method described here the impedance measurements on Mexican residents with different skin coloration were basically the same. The difference between the means of the real part of impedance did not exceed 13, 2 and 0.6% at frequencies of 180 Hz, 50 and 100 kHz, respectively. Therefore, skin colour cannot be used to explain

Table 1 dc and ac (at 180 Hz) measurements in healthy Ukrainian and Mexican residents.

	Device reading (r.u.)	S.D. (device reading)	dc resistance (kΩ)	ac resistance at 180 Hz (kΩ)	S.D. (resistance)	ac capacitance at 180 Hz (nF)	S.D. (capacitance)
Ukrainian	72.3	4.64	38.1	22	3.41	12.47	3.43
Mexican	42.3	8.92	122.3	105.4	17.21	8.97	2.14

The columns 'device reading' and 'S.D. (device reading)' present the mean and S.D. of measurements, in relative units (r.u.). In the column 'dc resistance', the r.u. have been transformed using the calibration curve of the device in the scale of dc resistance. Columns 'ac resistance', 'ac capacitance', 'S.D. (resistance)' and 'S.D. (capacitance) show the means for resistance, capacitance and their S.D. at 180 Hz, respectively.

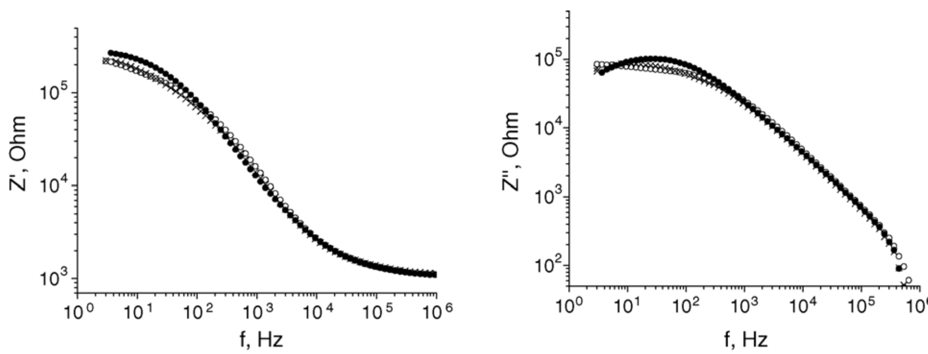

Figure 2 Means for the real (Z′) and imaginary (Z″) parts of the impedance as a function of frequency, measured in vivo on acupuncture points (APs) of 15 healthy Mexican residents with white skin (○), 38 people with dark skin (×) and on 18 people with very dark skin (●).

the large difference in resistance observed in the Ukrainian and Mexican populations.

Measurements on unhealthy persons

The points connected with unhealthy organs were selected using Voll's methodology. That is, the locations of the points connected with healthy organs were chosen using dc measurements, and if readings from the APs were in the range of 37—47 relative units, it was concluded (according to the results previously obtained in healthy Mexicans) that the organs connected to these points were healthy. Results for dc measurements obtained on 24 patients with rheumatoid arthritis and 14 patients with allergy are shown in Table 2. dc readings obtained at points connected with healthy organs were little different from those obtained in healthy young Mexicans (see Table 1). However, the value of these readings according to Voll's classification indicates degeneration of the organs associated with the points measured. Furthermore, the readings obtained in these patients with a clinical diagnosis of rheumatoid arthritis and allergy (63.1 and 60.7 relative units) indicate a normal status according to Voll's methodology.

Table 2 dc measurements in the Mexican residents with clinical diagnoses of rheumatoid arthritis and allergy.

	Device reading (r.u.), healthy APs	S.D. healthy APs	dc resistance (kΩ), healthy APs	Device reading (r.u.), pathological APs	S.D. pathological APs	dc resistance (kΩ), pathological APs
Rheumatoid arthritis	42.4	7.9	122	63.1	6.6	61.9
Allergy	45.8	4.3	112.7	60.7	3.7	67.5

The 'device reading' and S.D. columns show, in relative units (r.u.), the means and S.D. of measurements. In the 'dc resistance' column, the r.u. have been transformed into dc resistance, using the calibration curve obtained for the device. The columns named as 'healthy APs' suggest that the measurements have been carried out on acupuncture points connected with healthy organs and those named 'pathological APs' on points connected with pathological organs.

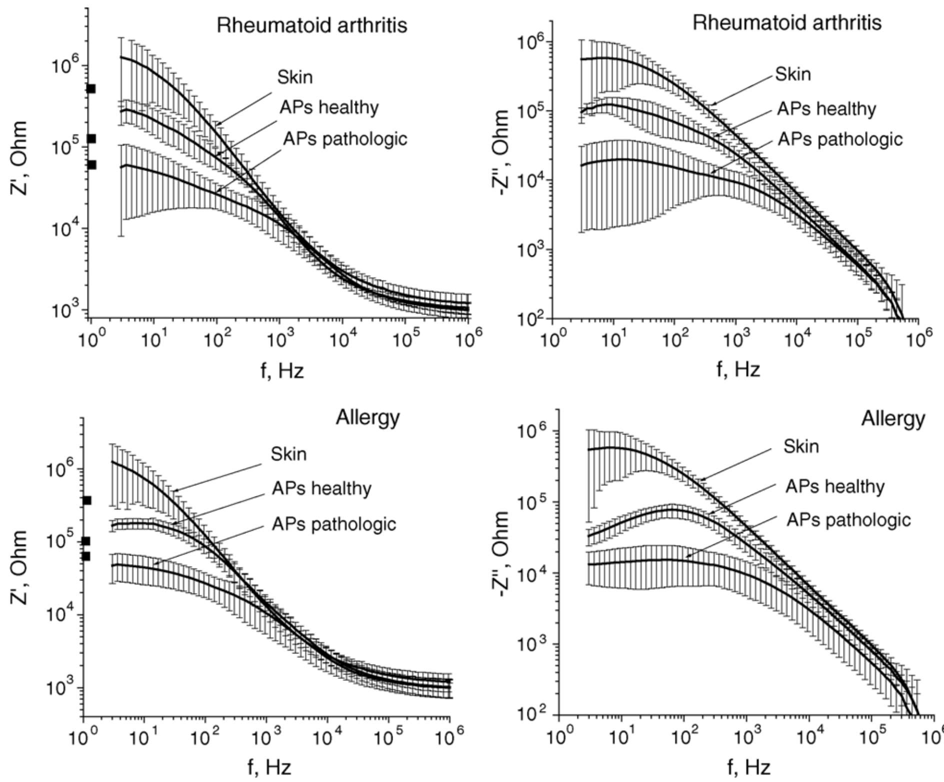

Figure 3 Means for the real (Z′) and imaginary (Z″) parts of the impedance as a function of frequency, measured in vivo on the skin, on the acupuncture points (APs) connected with healthy organs and those APs connected with pathological organs. The vertical lines indicate the S.D.

Fig. 3 shows the means for the real (Z′) and imaginary (Z″) parts of impedance as a function of frequency, measured in vivo on skin, on APs connected with healthy organs and on APs connected with pathological organs in the same participants. These results show that in the frequency range of 3—1000 Hz, the real and imaginary parts of the impedance for APs of organs with some disease are smaller than the real and imaginary parts of the skin impedance.

Fig. 4 shows the ratio of the mean impedance for the real Z′ (Sk) and imaginary parts Z″ (Sk) of skin to that measured on the APs connected with healthy and pathological organs [Z′ (AP) and Z″ (AP)]. For frequencies of approximately 10^3 Hz or higher, the difference between the real parts of the impedance in the skin and APs practically disappears, whereas a noticeable difference between the imaginary parts of the impedance in the skin and APs is present in all frequency ranges.

dc measurements on the same participant using Voll's device also showed a difference between the resistance measured on the skin and on the APs connected with healthy and pathological organs (mean resistance is shown as black squares in Fig. 3), but this difference is not as large as in the ac measurements.

Discussion

The results of this investigation show that Voll's method (or more precisely, the calibration correlation used in the devices) is not directly applicable to populations from different parts of the world. According to Voll's classification, the means of the readings obtained in healthy Ukrainians of 72.3 relative units (Table 1) indicate the beginning of inflammation of the organ associated with the point tested; the readings obtained from healthy residents of Mexico (42.3 relative units) also indicate degeneration in the organs associated with the points. Furthermore, readings obtained in patients with clinical diagnosis of rheumatoid arthritis and allergy (63.1 and 60.7 relative units; Table 2) indicate a normal status for these patients. From another point of view the dc measurements indicate differences in dc resistance at points connected with healthy and pathological organs. Therefore, it is probable that the calibration dependence of Voll's devices differs for different populations.

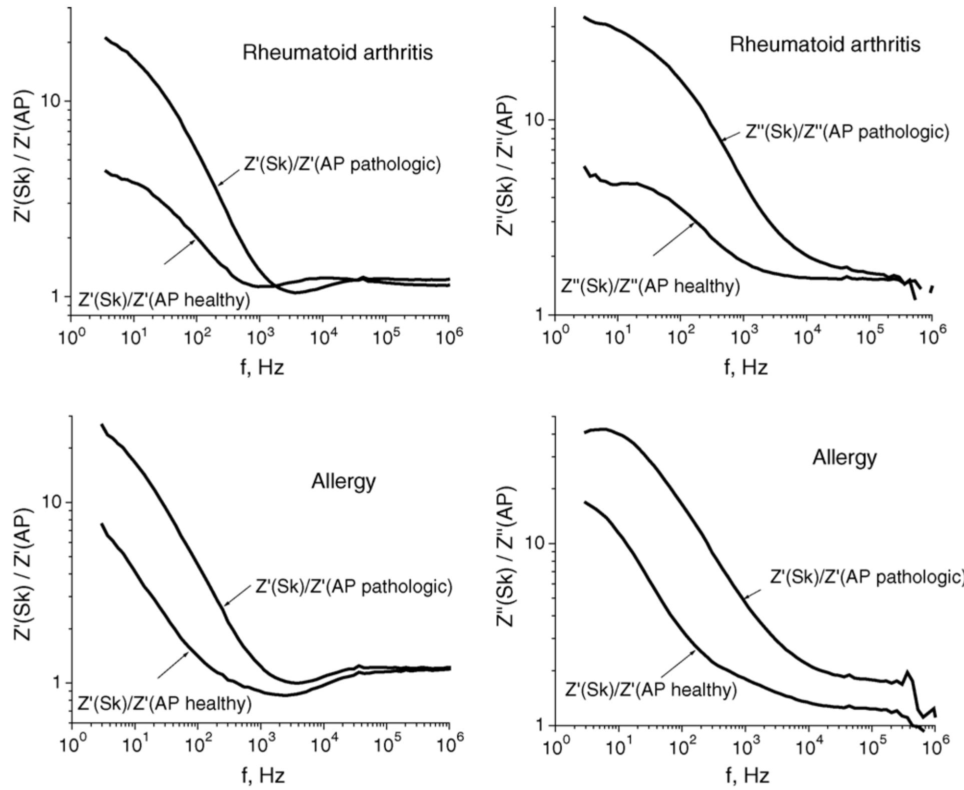

Figure 4 Ratio of the means for the real Z' (Sk) and imaginary parts Z'' (Sk) of the impedance for skin to the corresponding values measured on acupuncture points (APs) connected with healthy and pathological organs. The measurements are shown as a function of frequency.

We believe that this is the first report of impedance measurements at APs of different populations, so we can only compare our results with those published for bioimpedance (impedance measurements in different parts of the body) in various ethnic populations. Bioimpedance measurements taken with one electrode at the right wrist and the other at the right ankle at a frequency 50 kHz in non-Hispanic white, non-Hispanic black and Mexican American people living in USA show that the real parts of impedance in these three groups (age range between 20 and 30 years) do not differ by more than 1.5% for men and 0.8% for women.[11] This result correlates well with those obtained in the APs of our three groups of Mexicans with different skin coloration (difference of 2% at 50 kHz), suggesting that race and skin colour do not greatly influence impedance in populations from neighbouring areas.

In contrast, it has been reported that body impedance measurements on different ethnic populations with different places of residence show significant differences.[6,8] For example, differences in arm impedance at 100 kHz between Indian and Malay populations are about 8.7% for males and 5.6% for females.[6] From Fig. 2, we estimate that the mean of the real part of the AP impedance at 180 Hz is about 35 times larger than at 100 kHz. A rough estimation gives a difference in impedance of 2.5 times between the two populations at a frequency of 180 Hz, which correlates well with our results (4.8 times between Ukrainians and Mexicans).

We have not been able to find an adequate explanation of these facts. It has been suggested that differences in body impedance have some correlation with body water distribution across different ethnic groups and body builds.[8–10] Thus, when the ratio of extracellular water to total body water changes, then a change in the resistivity of extracellular fluids compared with intracellular fluids[8] occurs, this being probably the most impotent factor influencing the difference in dc resistance of two different populations. Some results indicating the dependence of body impedance on the water distribution in the measurements have been reported previously.[21]

Another explanation might concern differences in ambient temperature in Ukraine and Mexico. Impedance values are reportedly lower when body temperature is higher.[20] Moreover, the effect of environment is said to be stronger than the effect of race in these measurements.[7] Body composition and body impedance depend on environmental factors, fat content, bone mineral density, average food intake and dietary composition.[7] All these factors could be responsible for differences in the values of the real part of the body impedance of different populations, and also for variations in the impedance and dc resistance of APs, and may lead to systematic biases, which is why the calibration dependence used in Voll's devices must be different for different populations.

It is known that dc only passes through extracellular fluids, owing to the capacitance properties of the cell membrane. Difference in extracellular milieux (especially in the stratum corneum, which has 40% water), environment, temperature etc. may be responsible for the differences in the resistance (or real parts of impedance) measured in our Mexican and Ukrainian populations. In addition, the non-conductive lipophilic membranes of the stratum corneum[18] determine approximately the same capacitance properties of skin in both populations. Nevertheless, this is only one possible explanation of our results, which need further analysis. But independently of the proposed explanation, the dc and low-frequency resistance of the APs must (according bioimpedance measurements reported in the literature) depend on the place of residence.

In addition, low-frequency capacitance in the two populations did not differ by more than 25% and the imaginary part of the APs impedance was different from that of normal skin and very sensitive to pathological changes in the body (see Fig. 3). Based on the above results, we propose that the reactive component of the impedance measurement might be used as a relevant criterion for basic diagnosis. This criterion is independent of place of birth and/or residence.

Conclusions

Our data show that impedance measured in vivo in different regions of the human body depends on the person's condition. Specifically, these characteristics for APs connected with pathological organs are significantly different than those observed for APs connected with healthy organs and for the surrounding skin.

The results obtained on healthy people in Mexican and Ukrainian populations show that resistance measurements are more sensitive to the place of residence than capacitance measurements.

Acknowledgment

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