Coupling IR Thermography and BIA to analyse body reaction after one acupuncture session

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Abstract. Coupling both thermography and bio-Impedance, some biophysical acupuncture mechanisms are statically studied on a small population of 18 subjects. Results show that a possible way of understanding acupuncture, in an electrical way, should be to consider ionic flux redistribution between vascular and extra cell compartments. This is a two steps mechanism. The first one is starting with needles insertion and the second one is lasting with more intensity after removing them from skin.
Key words: Bio-Impedance, I.R. thermography, acupuncture, cell membrane.

1. Introduction
In previous studies, we have noticed that the phase angle, captured by single-frequency four-electrode bioelectrical impedancemeter, varies as high as 0.2° during one acupuncture session [1]. Coupling thermography and BIA, the current investigation attempts to understand phase angle variation mechanisms based on physiology.

2. Material and Method
2.1.Material
IR thermography is captured by a thermal Inframetrics camera, model 525, 8 bits resolution [2].
Bioimpedancemeter is model BIA 2000 S, from Data-Input (Frankfurt, Germany) [3].
We use Gel electrodes, model Red Dot, (3M), compatible with BIA 2000 S [4, 5].
Image processing is done by Matlab software [6].

2.2.Method
The study group consists of 18 patients (32 ±16 years, 56% female) suffering different kinds of pathologies. Group control (healthy and without needle) includes 10 people (54±5 years, 40% female).
After a detailed explanation of the purposes and the protocol of the experiment, all subjects signed an informed consent. Thermal and bioimpedance analysis take place in the morning, at the same hour, patient with empty stomach [7]. The protocol begins with a fifteen minute rest for each patient, lying in supine position, in close metabolism test conditions, in accordance with the recommendations chart provided by the manufacturer. Data acquisition bases are double and done three times. Both techniques surround a single ten minutes acupuncture session based on three needled zones (acupuncture points) according to symptomatology and Chinese rules of acupuncture, but never done in the thermal region of interest (ROI), to avoid direct segmental spinal cord reflex.
In this way, local vasomotricity change will not be related to segmental arc reflex but reflects more integrative brain reflex. ROI is selected, too, not to interfere in acupuncture session.
Four gel electrodes are settled on the posterior face of right hand and on the anterior region of the right foot. Skin electrodes remain stuck, during the protocol. Thermography is used upon the anterior region of the right foot (metatarsus), from skin between the two gel electrodes, before and after a single acupuncture session. Then, a single-frequency four-electrode bioimpedance test is performed (resistance and reactance). The last coupled data acquisition is collected ten minutes after the needles are removed.

ROI is partitioned into three equal surfaces, where the pixels are standardized and averaged to transform qualitative data into quantitative ones. These three partitions are as follows: close to injection electrode, central and close the reception electrode. Phase angle improves by 0.2º each time after acupuncture session.

Three distinct periods seem relevant: before (period 1), after a ten minute acupuncture session (period 2) and finally, ten minutes after removing needles (period 3).

3. Results

Simple statistical and correlation analysis are done between thermal data base (reflecting change in local vasomotricity) and bioimpedance analysis results (only reactance and resistance standing for cell membrane) for each time of this three periods protocol. Thermal and BIA changes are explored according to error percentage method [(Initial value - final value)/ Initial value]. To conclude, relationship between thermal and BIA data base is established according to correlation study process.

3.1. Correlation analysis between starting point and immediately after a ten minutes acupuncture session.

3.1.1. Simple Statistical analysis. For ten subjects over the whole population, vasomotricity just shows a 2% change. Speaking about BIA, table 1 shows percentage of changes for both, resistance, reactance, phase angle $\alpha$.

| Statistical Parameters | % Variation of Resistance | % Variation of Reactance | % Variation of $\alpha$ |
|------------------------|---------------------------|--------------------------|------------------------|
| Maximum                | a) 2.73                   | b) 1.2                   | a) 4.69                |
|                        | a) 2.4                     | b) 2.4                   | a) 2.92                |
| Minimum                | a) -0.52                  | b) -0.3                  | a) -2.04               |
|                        | a) -3.7                    | b) -3.7                  | a) -2.25               |
| Average                | a) 0.62                   | b) 0.3                   | a) 1.60                |
|                        | a) 0.3                     | b) 0.3                   | a) 0.59                |
| Standard deviation     | a) 0.77                   | b) 0.005                 | a) 1.66                |
|                        | a) 0.02                    | b) 0.02                  | a) 1.12                |

3.1.2. Correlation between changes in vasomotricity in the three foot zones and BIA values. (Table 2)

| Thermal zones          | Resistance | Reactance |
|------------------------|------------|-----------|
| Injection zone         | -0.84      | -0.53     |
| Central zone           | -0.60      | -0.44     |
| Voltage zone           | -0.32      | -0.32     |

During acupuncture session, vasomotricity is better correlated with resistance than reactance, for zone close to injection current electrode. Following the same procedure, we analyze what is happening after removing the three needles from skin insertion.
3.2. Correlation analysis immediately after acupuncture and after 10 minutes of rest (needles out of skin)

3.2.1. Simple Statistical analysis. For the whole population minus one people, vasomotricity change is homogeneous. From BIA, results are quite different. Table 3 shows percentage of changes for both, resistance and reactance.

Table 3. Percentage of variation of BIA values. Period 2 versus Period 3.

| Statistical Parameters | % Variation of Resistance | % Variation of Reactance | % Variation of $\alpha$ |
|------------------------|---------------------------|--------------------------|-------------------------|
| Maximum                | 5.14                      | 4.69                     | 2.87                    |
| Minimum                | -0.34                     | 0.00                     | -1.35                   |
| Average                | 1.40                      | 2.70                     | 1.09                    |
| Standard deviation     | 1.11                      | 1.37                     | 1.10                    |

Even without needles insertion, we notice that electrical tissue properties still changing.

3.2.2 Correlation between changes in vasomotricity of the three ROI versus BIA values. (Table 4)

Table 2. Coefficient correlation between thermography of the three rectangular zones and BIA values (Resistance and Reactance).

| Thermal zones        | Resistance | Reactance |
|----------------------|------------|-----------|
| Injection zone       | -0.21      | -0.20     |
| Central zone         | -0.00      | -0.19     |
| Voltage zone         | -0.06      | -0.34     |

After removing needles, we cannot observe any relationship between vasomotricity and electrical changes in tissue. We have to consider changes in electrical tissue properties (table 3) to cell membrane ionic flows, as no vascular change is noticed from previous state.

4. Interpretation

Changes in resistance are due to ionic flow in the extra cellular matrix. Reactance relies on spherical capacitor effect of cell membrane so transmembrane ionic flow. During acupuncture session both mechanisms (blood flow and electrical properties of tissue) are correlated. After removing needles, electrical mechanisms are dissociated from thermal data, that means with blood flow. Both modifications (resistance and reactance) involve ionic flow. The first one is related to vasomotricity as thermal change is noticed with respect to previous vascular state. Second one seems to be more correlated with ionic membrane transfer as previously extracellular matrix has been modified, in an electrical sense, by needle nociceptive actions on central nervous system. Removing needle seems to have left new dynamics in ionic flow balance. No more vasomotricity dominance, physiologically speaking. From now starts the next step: transmembrane ionic equilibrium to reach a new balance regarding electrolytes distribution, at a cellular level. This step is triggered by the local electrical charges concentration. So acupuncture mechanisms seem to be, at least, a two steps physiological process in a schematic way of biophysics thought. First, acupuncture process is modifying extracellular matrix by changing blood flow pattern, thanks to the local needles insertion (central nervous system integration based on nociceptive message with autonomic nervous system response). Then, after removing the stimuli (needles), begins the second auto-regulated phenomenon. This time, electrical changes occur at cellular level. High concentration ionic charges, present in extra-cellular compartment, modify transmembrane equilibrium, increasing in that way, the capacitive properties of the cells.
5. Conclusion
The study group consists of 18 patients (32 ±16 years, 56% female) suffering different kinds of pathologies. To understand better acupuncture mechanisms on both physics and physiological basis, coupled IR thermal (Inframetrics model 525, Usa) and bioimpedancemetry (BIA, model 200-s, Data-input, Germany) are monitoring changes in the physiological process, after a unique three needling acupuncture session.

The protocol begins with a fifteen minute rest for each patient, lying in supine position, in close metabolism test conditions, in accordance with the recommendations chart provided by the manufacturer. Data acquisition bases are double and done three times. Both techniques surround a single ten minutes acupuncture session based on three needled zones (acupuncture points) according to symptomatology and Chinese rules of acupuncture, but never done in the thermal region of interest (ROI). Thermography is the first of two tests providing quantifiable data. Thermography is used upon the anterior region of the right foot (metatarsus), from skin between the two gel electrodes, before and after a single acupuncture session. Then, a single-frequency four-electrode bioimpedance test is performed (resistance and reactance). The last coupled data acquisition is collected ten minutes after the needles are removed. Phase angle improves by 0.2º each time after acupuncture session.

The results from the correlation between thermal and bioimpedance data show that a possible method of understanding acupuncture, from an electrical point of view, could be to first analyse ionic flux redistribution in tissues from the vascular system and then ionic change on both side of cellular membrane. This is a two-step mechanism, the first starting with the insertion of the needles (vasomotricity versus resistance) and the second (reactance) taking place after the removal of said needles from the skin due to local ionic cell membrane redistribution, as phase angle changes.

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