Characterisation of human skin impedance at acupuncture point PC4 Ximen and pericardium meridian using the four-electrode method

Shima Rezaei,¹ Ali Khorsand,² Jamshid Jamali³

ABSTRACT

Introduction Traditional Chinese medicine offers several theories to explain the mechanism of acupuncture. One of these theories proposes that acupuncture points and meridians have unique electrical properties and their electrical skin impedance is lower than surrounding areas. The aim of this study was to evaluate the differences in electrical skin impedance between PC4 and the pericardium meridian compared with the surrounding areas.

Methods Eighteen healthy subjects (10 women) were recruited to participate in the study. An impedance meter based on the four-electrode technique was designed specifically for the study. Twenty-five points were marked on the skin: one on the point PC4, four others on the pericardium meridian and 20 points around it. The electrical impedance of each point was measured with the four-electrode device.

Results The mean electrical skin impedance at PC4 was significantly different from the 20 of the surrounding points but not significantly different from the four adjacent points. The mean skin impedance of the five points over the pericardium meridian was significantly different from that of parallel rows of points using repeated measures analysis of variance (p<0.001).

Conclusion Within the possible limits of this measurement technique, skin impedance along the pericardium meridian is lower than surrounding areas, supporting the idea of different properties of the pericardium meridian compared with the control areas. Evidence on skin impedance at PC4 is inconclusive and further studies are needed.

INTRODUCTION

An important concept in traditional Chinese medicine is Qi which is believed to flow through channels called meridians. Acupuncture points are located along these meridians. Stimulating these points is believed to affect the quality and quantity of Qi flow and thus affect body systems. Although acupuncture points and meridians are basic issues of Chinese medicine, there is not yet a complete explanation for this system.

Traditional Chinese medicine offers several theories to explain the mechanism of acupuncture. One of these theories proposes that acupuncture points and meridians have unique electrical properties and their electrical skin impedance is lower than surrounding areas.¹⁻⁴ Many devices have been developed to locate the right acupuncture points and to diagnose the diseases based upon this theory.

This phenomenon was reported independently by different scientists in the 1950s.⁵⁻⁷ Although many investigators have tried to find the relationship between acupuncture and electrical properties of the skin, a review article by Ahn et al in 2008 showed that, among 320 articles referring to electrical resistant and acupuncture points, only 18 met the criteria for further evaluation. These authors concluded that there is not enough evidence to prove conclusively that acupuncture points or meridians are electrically distinguishable and more research was recommended.⁸ The most important problem in many studies is the control of confounding factors such as environmental disturbances, physiological factors and other factors related to the device including electrode size, angle of electrode, electrode application pressure, skin moisture, electrode contact and abrasion of the stratum corneum.⁹ To obtain valid measurements, these factors should be controlled as much as possible. Most devices used for electrical skin impedance have two electrodes, one of which is pressed manually against the skin by the examiner.¹⁰⁻¹² Variation in pressure and angle could significantly influence the results. There is a need for further development of devices to measure electrical skin impedance. An impedance device based on the four-electrode technique was designed specifically for this study. A similar method has been used previously,¹³⁻¹⁶ but this device was designed with some significant modifications.

The aim of this study was to evaluate differences in electrical skin impedance between the acupuncture point PC4 Ximen and surrounding area and also the pericardium meridian with control lines using the designed device.
MATERIALS AND METHODS

Participants
Eighteen subjects (10 women) were recruited to participate in the study. Participants were chosen from students of Beijing University of Chinese Medicine. Subjects were excluded if they were under 18, pregnant or had any scar on the skin of interest for our study. The mean±SD age of the subjects was 25±7 years.

Setting and procedures
Testing was performed in the research centre at the acupuncture department of Beijing University of Chinese Medicine from July to August 2010. The environment was controlled for temperature, relative air humidity, body temperature, skin humidity, electromagnetic devices and noise. The temperature was set at 22–24°C and humidity at 30–40%. Humidity was controlled by air conditioner and evaporation humidifier and was measured by hygrometer during the study. The study was approved by the Medical Ethics Committee of Beijing University of Chinese Medicine and volunteers gave written informed consent.

Instruments
An impedance meter model LRM30-R based on the four-electrode technique was designed and made specifically for this study at Peking University, Beijing, China. The impedance meter outputs a regulated alternating (AC) 5 kHz sinusoidal current of variable amplitude (set to 30 μA) between two outer electrodes (the justification for using 5 kHz is detailed in the online supplement). AC was used to avoid saturation of the electrode surfaces from build-up of free ions (electrolysis). Prior to initiation of the study, rigorous evaluation of the instrument was performed in vitro and in vivo. For calibration, a standard 100Ω resistance was used. In addition, the calibration process was performed automatically each time the device was turned on, as shown in figure 1. More details can be found elsewhere.

As schematically shown in figure 2, the specific arrangement of the skin electrodes ensures it measures only the impedance of the small subcutaneous region lying just below the current electrode PI. This property is a result of the densely populated current lines along with equipotent lines in that region, which in turn is a result of the special sequence of electrodes—that is, PV–PI–Pvr–Pir (PV, PI, PVR and PIR represent the voltage, current, voltage reference and current reference electrode plates, respectively). Note that in order to make the measured region as small as possible, the electrode PV is not at the ‘normal’ position PV but outside PI.

Specifically, in the present study the diameter of each of the three electrodes PV, PI and PVR was 5 mm, while PIR was much larger and placed outside PVR but far from it. The PV–PI and PI–PVR distances L1 (length) and L2...
were 8 and 12 mm, respectively. These dimensions were slightly smaller than their counterpart in the equipment used by Yang and Zhang. The probe takes only 3 s to collect the electrical impedance. The schematic diagram of the system is given in figure 1. Note that, for simplicity, only the N-th probe is shown. An advantage of such a system is that it can be used to monitor the impedance almost continuously. A digital screen on the device displays the measured impedance values in ohms (Ω). The data were then imported to a laptop computer via a serial cable. The device was connected to a PC (Dell Inspiron mini10 laptop, Dell, Windows XP Operating System) through a serial port, then automatically entered into Microsoft Excel for analysis. The electrode type was Ag/AgCl. We immersed the electrodes in the electrolyte before each measurement. The reference lead was installed on the left leg. The instrument was calibrated on a daily basis. We used a square plastic foil of 5×5 cm. Each side of the foil was divided into five equal intervals and 25 points were marked and punched on this plastic foil square, referred to as A1 to E25. The central point (C3) was placed on PC4 which was located by two expert acupuncturists. The first author identified the acupuncture point under the supervision of an acupuncturist with >10 years of experience. The supervisor acupuncturist’s opinion was used for any disagreements. Acupuncture points were located using written guidelines which are based on anatomical landmarks and proportional measurements and acupuncture charts available in a textbook of traditional Chinese medicine acupuncture.

The plastic foil was fixed on the skin in a way to have horizontal lines (A–E) parallel to wrist and vertical lines (1–5) parallel to the radius. These 25 points were marked...
The probe was fixed on each point by non-sensitising adhesive tape using a standard blood pressure cuff with a pressure of 15 mm Hg for each point. The investigator started the measurements one row at a time (from A1 to E1, and then the second row B2 to E2, and so on), placing PI on the measurement site. In some of the points evaluated, PV may actually end up over PC4. However this was not important for impedance measurement since the PI was actually measuring the impedance.

Electrical skin impedance measurements were performed in a single-blind setting. An investigator who was trained to work with this device put the probe on each point and fixed it on the skin. The computer screen was out of sight of the investigator.

For each volunteer an assistant who was not involved in data analysis recorded the data with an identification number. Because each point had an identification number, the person who recorded the data did not know which data belonged to the corresponding area on the skin. The analyser was also blind with regard to the data.

**Statistical analysis**

Statistical analysis was performed with Minitab and SPSS V.11. To study the difference between points we used paired sample t tests and for meridians repeated measures analysis of variance.

**RESULTS**

In this study the electrical skin impedance of 25 points for each of the 18 volunteers were measured. The electrical skin impedance of C5 (mean±SD 39.83±7.18) was the lowest and of E3 (50.07±12.52) was the highest. Mean electrical skin impedance was 45.79±12.10. Repeated measures analysis of variance (ANOVA) showed that mean electrical skin impedance of C3 was significantly different from all other points except for C3–C4, C3–C5, C3–D5 and C3–B4.

As shown in table 1, the lowest mean electrical skin impedance belonged to C5, not C3. Although this point belongs to the pericardium meridian, it was expected that C3 (PC4) would have the lowest electrical skin impedance. One reason for this unexpected result could be improper positioning of PC4. However, this is unlikely since two experienced acupuncturists located the point. Also, a trend of decreasing electrical skin impedance was noted on the other lines from proximal to distal. This could be explained by a gradation in the thickness of cutaneous and subcutaneous tissues from proximal to distal parts. Our result is consistent with the concept that acupuncture points have some special properties.

We also found differences in the electrical properties of the pericardium meridian compared with adjacent lines. Others have found similar results. For example, Ahn et al inserted four gold-plated needles along a straight line to be used as electrodes. A parallel series of four control needles were placed 0.8 cm medial to the meridian needles as the control area. They found that skin impedance along the pericardium meridian was lower than the control area: ‘at the pericardium location, mean tissue impedance was significantly lower at meridian segments (70.4±5.7 Ω) compared with control segments (75.0±5.9 Ω) (p=0.0003)’.15

Zhang et al,15 Reichmanis2 18 and Hu et al19 have supported this claim. However, Martinsen et al20 found no evidence in support of this concept.

We can claim that the meridians have some special electrical properties and the points which are on the meridians also significantly differ from surrounding points, although it seems that all points on the meridian have similar

**DISCUSSION**

Our results can be considered in two sections. First, the comparison of one point with the surrounding area, then the comparison of the meridian with parallel lines.

We found that electrical skin impedance of the PC4 was significantly different from the surrounding area except for C4, C5, D5, B4. We note that two of these points belong to the pericardium meridian and the other two points were adjacent.

There are many possible explanations for these findings. On one hand, this gradient is consistent with the concept of meridians in that pericardium meridian was lower than the control area. On the other hand, this result could be explained by a gradation in the thickness of cutaneous and subcutaneous tissues from proximal to distal parts. Our result is consistent with the concept that acupuncture points have some special properties.

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**Table 1** Electrical impedance of PC4 (located as C3) and surrounding area

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49.96</td>
<td>47.93</td>
<td>44.23</td>
<td>46.61</td>
<td>47.70</td>
</tr>
<tr>
<td>2</td>
<td>49.18</td>
<td>45.48</td>
<td>43.93</td>
<td>46.68</td>
<td>50.03</td>
</tr>
<tr>
<td>3</td>
<td>46.80</td>
<td>43.41</td>
<td>41.04</td>
<td>43.66</td>
<td>50.07</td>
</tr>
<tr>
<td>4</td>
<td>46.68</td>
<td>42.22</td>
<td>40.33</td>
<td>45.34</td>
<td>49.46</td>
</tr>
<tr>
<td>5</td>
<td>45.50</td>
<td>42.94</td>
<td>39.83</td>
<td>43.76</td>
<td>49.35</td>
</tr>
<tr>
<td>Total</td>
<td>47.62</td>
<td>44.39</td>
<td>41.87</td>
<td>45.74</td>
<td>49.32</td>
</tr>
</tbody>
</table>

Numbers in parentheses are SDs.
Summary points

- Skin impedance at acupuncture points is used as a basis for treatment.
- We used a new device to reduce measurement errors.
- Impedance was reduced over the pericardium meridian.

properties. Zhang et al suggested that the reduced electrical impedance in the meridians could be due to larger amounts of interstitial fluid.\(^\text{15}\)

To minimise the sources of bias, blinding in our study was strict and none of the differences between points and lines can be attributed to the prior knowledge of the investigators or analysts.

Compared with previous studies which investigated the electrical properties of acupuncture points and meridians, our measurement methods have some advantages. We used a four-electrode method to measure skin impedance whereas most previous studies used a two-electrode method for measuring the voltage between the two electrodes.\(^\text{1–7 18 21}\) However, Ahn et al commented that this method can cause significant fluctuation of voltage between the two electrodes due to variable contact impedance between electrodes and tissue.\(^\text{13}\)

The four-electrode technique used in this study is widely used to measure electrical resistance/impedance of skin and tissue.\(^\text{13–16}\) This method minimises error due to fluctuation in voltage and electrode contact impedance. Studies using the four-electrode technique to evaluate the bioelectric properties of acupuncture meridians found lower impedance.\(^\text{12 14}\)

Limitations of the study

It should be mentioned that the four-electrode technique has some inherent technical limitations which are beyond the scope of our article to explain. More information can be found in an article by Grimnes et al.\(^\text{22}\) Lung and heart meridians are close to the pericardium meridian. In some cases there is a possibility that our control points were located actually on the abovementioned meridians. This can be considered as a limitation of our study. Finally, impedance measurements do not contain phase information and thus cannot account for why impedance is reduced at some points (low impedance or high capacitance). This can be considered as a limitation of our study.

CONCLUSION

We found skin impedance along the pericardium meridian to be lower than the surrounding area, supporting the idea of different properties of the pericardium meridian compared with control areas. Evidence on skin impedance at PC4 is inconclusive and further studies are needed.

REFERENCES

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