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RESEARCH ARTICLE

The Distribution of Transcutaneous CO_2 Emission and Correlation With the Points Along the Pericardium Meridian

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Abstract
This study aimed to understand energy metabolism distribution along the pericardium meridian and verify the correlation between the body surface (points), and classic meridian theory. A highly sensitive CO_2 instrument was used to measure the transcutaneous CO_2 emission at 13 points along the pericardium meridian line (12 points on the line and one point beyond the line) and 13 control points beside them. Results showed that the distribution of transcutaneous CO_2 emission is highly related to the position on the body. Transcutaneous CO_2 emission is significantly higher at P7 and P3, than the control points beside them. The points along the meridian and the points beside them were clustered with relative distance by SAS statistics software. Two distance matrixes were then obtained. The correlation coefficients between the points along the line and between the control points were calculated. The results showed that the 13th point beyond the line was far from the 12 points on the line (distance, 0.24), while acupoints on the line clustered earlier when compared with the non-acupoints. The average correlation coefficients among the acupoints was 0.65 which was significantly higher than 0.56, among the non-acupoints. No such characteristics were found among the control points. It was concluded that there is a strong correlativity of energy metabolism activity between the body surfaces along the meridian, and an even stronger correlativity between the acupoints on the meridian.

1. Introduction

In classic meridian theory, meridians were discovered according to the phenomenon in which some body surfaces appear specifically related during acupuncture. The correlations between the body surfaces gradually became the acupoints and meridians. Such ancient law needs to be understood with scientific data in the present age. To obtain this data, a quantitative index which reflects physiological activity in loci should be used.

Transcutaneous CO_2 Emission (TCE) is the tiny amounts of carbon dioxide emitted from skin I, also called skin respiration in some early papers [1,2].

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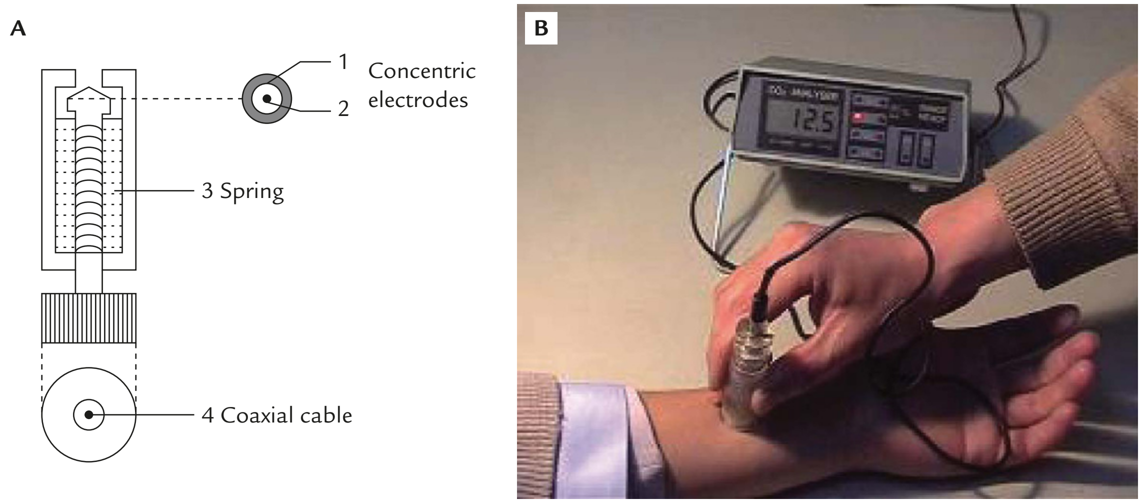

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3\downarrow + H_2O$$

Figure 1 CO_2 probe structure (A) and the measuring technique (B).

This small amount of CO_2, which is very difficult to measure, is related to the energy metabolism in local skin and also the tissue under the skin. In 1976, a highly sensitive CO_2 detector was invented by a Hungarian, F. William. The probe used to measure CO_2 from skin is small and easily operated (the hole is 7 mm in diameter, see Figure 1). A membrane of $Ca(OH)_2$ is made when putting the electrodes into the $Ca(OH)_2$ solution and pulling back. The probe is quickly placed on human skin with suitable pressure to isolate air that has entered the hole. The initial CO_2 from the air is consumed by waiting until the resistance increases to a certain value. The increasing of resistance in the membrane at a certain time is measured as $Ca(OH)_2$ will change to $CaCO_3$ and deposit. The rate of change positively relates with the rate of CO_2 released from skin which, in turn, reflects the energy metabolism of local tissue.

In 1984, William's student Eory, who owned an acupuncture clinic, tried the machine on a human body. He measured the TCE on P8 (Laogong) and found a higher TCE on the acupoint than the surrounding control area [1]. He also measured the changes of TCE along the Lung meridian during acupuncture and found that there was a wave change of TCE along the line [2]. From 1992, we began to study the relationship between TCE and meridians using a series of experiments. The results showed that some acupoints or points on meridians have relatively higher TCE [3]. The TCE increased proximally along the pericardium meridian during acupuncturing P6 (Neiguan) and recovered quicker on the meridian than outside the meridian [4]. The TCE correlated with the metabolism of tissue, the absorption of CO_2 by the circulatory system, the permeability of skin and the volume of extracellular fluid in the tissue [5]. The experiments implied that the TCE can provide significant physiological information and is related to Qi and blood, as described in Traditional Chinese Medicine. Therefore, the ancient law of correlativity of body surfaces may be able to be proven by measuring TCE and calculating the correlativity using cluster analysis.

2. Materials and Methods

A highly sensitive CO_2 instrument (FREWIL-QF, China) was used to measure the TCE on 13 points along the pericardium meridian (12 points on the meridian and one point beyond it, group A) and 13 control points outside the meridian (group B; Figure 2). The positions, point name and standard acupuncture nomenclature (SAN) of group A are shown in Table 1.

Room temperature was kept between 22 and 25°C. Twenty two healthy volunteers (14 males and eight females, with an average of 38) participated in this study. The subjects were asked to lie on a bed and relax for about 5 minutes. The pericardium meridian was determined using the percussion active point (PAP) method [6] combined with classic acupoint location. All the measured points were marked with a colored pen after referring to a standard acupuncture chart. The distance of the 13^{th} point was 2 cm beyond P1 (Tianquan) at the lengthen line of the meridian. The 13 control points (group B) were alternatively beside (about 1 cm away) the 13 points of group A. All the points were measured three times and the average values were calculated. The room CO_2 level was also monitored to keep a low level (less than 0.05%) which was controlled by ventilation. The correlative coefficient (CC)

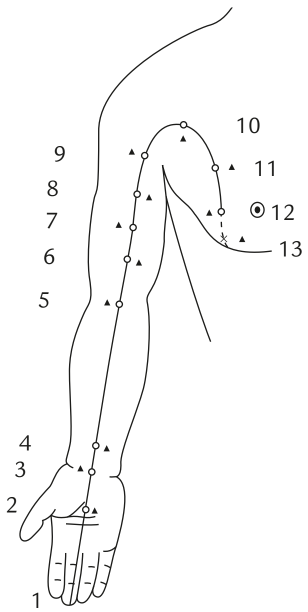

Figure 2 Position of measured points along the pericardium meridian, ○ are the points on the meridian, ▲ are the points beside the meridian. × is a point beyond the meridian.

between the 13 points along the meridian line (Group A, including the point beyond the meridian) and the 13 control points outside the meridian (Group B) were calculated respectively to produce two CC matrixes. SAS statistic software was used to cluster the matrixes in which the CC(r) were replaced by the correlative distance ($d=1-r$) in the cluster tree. Wilcoxon Rank Sums test was used to compare the two mean coefficients to obtain $p<0.05$.

3. Results

The average values at these points are shown in Table 2.

At point 3, which is P7 (Daling), referred to as a source point and point 5, which is P3 (Quze), referred to as a sea point, the TCE was significantly higher than the control points. The correlative coefficient between the two groups is 0.95. The distribution of TCE on the meridian and control points is shown on Figure 2.

The cluster results of the two groups using an average linkage method are shown in Figures 3 and 4.

From the cluster of group A, we could see that the 13th point beyond the meridian was obviously further than points on the meridian. It clustered last. The distance between CL2 and the 13th point was 0.24. In group A, the acupoints seem to be closer than non-acupoints. For instance, the 4th point (P6 Neiguan), 8th point (P2 Tianquan), and 5th

Table 1 The positions, point name and standard acupuncture nomenclature (SAN)

Point number	1	2	3	4	5	6	7	8	9	10	11	12	13
Name or position	Zhong-chong	Laogong	Daling	Neiguan	Quze	Between P3 and P2	Between P3 and P2	Tianquan	Between P2 and P1	Between P2 and P1	Between P2 and P1	Tianchi	2 cm beyond the meridian
SAN	P9	P8	P7	P6	P3	Non-acupoint	Non-acupoint	P2	Non-acupoint	Non-acupoint	Non-acupoint	P1	Non-meridian point

Table 2 The average values at 13 control points

Levels	1	2	3	4	5	6	7	8	9	10	11	12	13
Group A	8.1±3.4	10.3±4.3	8.8±4.0	8.2±3.8	9.2±3.5	8.0±3.0	8.2±3.8	8.4±2.9	11.3±1.9	10.9±4.5	11.6±4.6	11.7±3.9	11.4±3.7
Group B	8.6±3.7	10.0±4.1	8.0±3.8	8.9±4.6	8.5±3.4	8.3±3.0	8.0±3.1	8.1±3.1	11.0±0.6	10.5±4.3	11.4±4.0	11.0±4.9	10.7±5.2
Difference	−0.5±1.6	0.3±1.5	0.9±1.3*	−0.7±2.3	0.8±2.1**	−0.3±1.3	0.1±1.9	0.3±1.6	0.3±2.0	0.4±3.1	0.3±1.3	0.7±3.1	0.7±2.6

Comparing group A with group B. $^*p<0.05$, $^{**}p<0.005$.

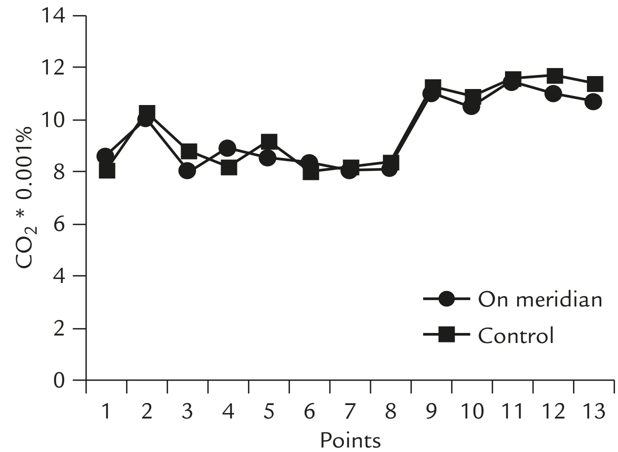

Figure 3 The distribution of TCE on the meridian and control points.

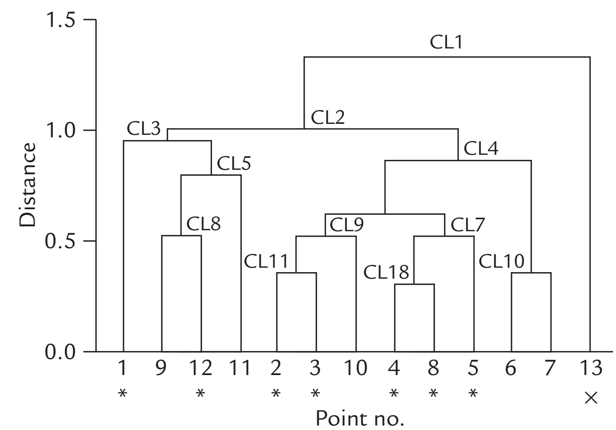

Figure 4 Cluster tree shown by correlative distance between the points of group A. * are the acupoints and × is the point on lengthen line of P meridian.

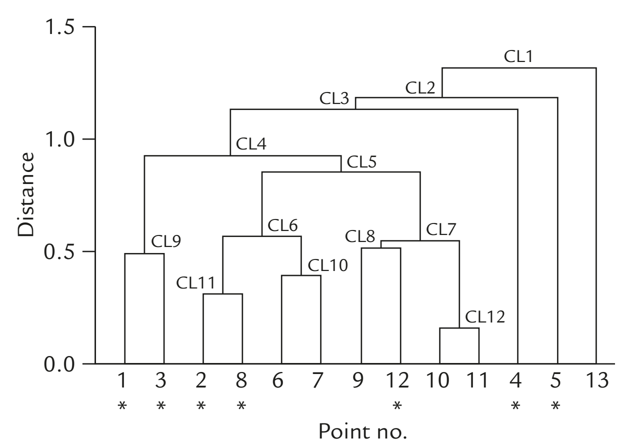

Figure 5 Cluster tree shown by correlative distance between the points of group B. * are the control points beside the acupoints.

point (P3 Quze) were clustered in the 8th cluster (CL8). The 6th cluster (CL6) had six points, including five acupoints. The mean CC between acupoints was 0.65, but only 0.56 between non-acupoints. The rank sums test was used to examine the difference because of the non normal distribution. The result showed significant difference ($p<0.05$). In group B, although the 13th point still clustered last, the distance between CL2 and the 13th point was only 0.1. The average CC between the points beside the acupoints and between the points beside the non-acupoints were 0.58 and 0.60 respectively, which was not a significant difference.

4. Discussion

According to the classic theory, Qi flows along channels and becomes rich at several main points. Result showed that TCE was higher on a source and sea point than the control points beside the meridian. The distribution of TCM is also gradually higher with the points close to the position of lung. This positioning may influence the TCE due to a higher concentration of CO_2 in the lung. The high correlativity between the points on meridian and control points imply that the TCE is highly related to the position on the body.

The meridian line may have two meanings. One is the channel in which Qi and blood flow. The propagated sensation can also move along the channel whenever some points are stimulated. The other meaning is that the acupoints on the line belong to the meridian. Usually the acupoints have similar treatment functions and may have a certain correlation. We have now revealed the correlation by calculating CC between these points. At first, we assumed that the pericardium meridian would lengthen beyond P1 and that the 13th point had similar correlation with other points on the meridian. But results showed that only the points on the pericardium meridian had stronger correlation and the 13th point beyond P1 was far from other points. This result proved that the end point of the pericardium meridian was P1 which corresponded to traditional meridian theory.

The high correlation of TCE along the meridian may illustrate that the metabolism on the meridian has similar changes or relationships. The acupoints on the meridian have even stronger correlation than the non-acupoints. These results illustrated that the acupoints on the meridian may be a group of special points which are strongly associated with each other. These associations may exist not only in one meridian. Other TCE research has found that the left and right source acupoints on the same meridian have very strong correlativity, with a mean CC of 0.814 [7]. Also, the correlativity between the source points in exterior and internal meridians and between the source points on the meridian with the same name are also strong. The mean CC was 0.65 and 0.514, respectively, which was significantly higher than the mean CC of 0.379 between normal source acupoints. These results proved that a complicated connection in meridian and collateral network existed on the human body. The rule of treating certain acupoints according to the meridian system can be understood by our studies.

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